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**Building Organizations
with
Information Technology**

**Opportunities and Constraints
in the Search for
New Organizational Forms**

by
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“Man is not the sum of what he has already, but rather the sum of what he does not yet have, of what he could have.”

Jean-Paul Sartre, *Temporalité*, in *Situations* (1947-49)

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Preface

"Sometimes a scream is better than a thesis."
Emerson, *Journals*, 1836

Apart from secret diaries, texts are usually written to be read by someone else. Writing is therefore basically an act of communication, although I also tend to agree with Mintzberg when he says (in the preface to his *The Structuring of Organizations*), "I write first of all for myself. That is how I learn." Noting the ample number of published titles from his hand, however, I feel safe to conclude that he too has at least a secondary purpose in writing: he wants someone else to profit from what he has learned.

This brings up the question of who the reader is—or, indeed, if there will be any readers at all, as the sad fact about doctoral dissertations is that they often come uncomfortably close to the secret diary, with the reviewing committee, the examiners, and maybe a few friends as the only serious readers.

With all the time, effort, and forgone consulting assignments invested in this dissertation, the thought that it should end up as nothing but a dust collector in a few Norwegian university libraries has been too much to bear. I have therefore kept up the hope of a wider circulation and have composed the text with that goal in mind.

Who, then, would the prospective reader be? Sometimes, the answer is easy: you simply write for the scientific community in your own field, or you write for the practitioners, the ones who actually work in and around organizations. If so, you have few problems choosing the presentation form. You know what you can assume to be known, you can use professional jargon, and you generally tie your arguments to the reigning paradigm of the field. If you are writing for people outside your field, the problems are more severe; now you have to be careful to explain and elaborate on your arguments, and you have to find the right level of simplification.

Writing this dissertation, however, I find myself in a still worse predicament. By choosing a cross-disciplinary subject, I end up writing for two quite different scientific communities, with little common ground—organization theorists and information systems people—and run the risk of estranging all parties involved. In addition to the danger of breaching scientific community tenets comes the fact

that the explanations needed for one group may bore the living daylight out of the other. Moreover, I know a fair number of professionals outside the scientific community who I hope will be interested as well, and whom I genuinely want to reach.

Clearly, there is no panacea that can resolve this dilemma, and I have had to make a number of choices. The central decision has been to stick to my academic background as an organization sociologist and make the organization perspective the dominating one. It has nevertheless been impossible to avoid a certain dose of computerese, and I have tried to explain as I go along. A summary of the history of computing, useful for those who do not know or care about computers (as background information when reading Chapter 8), has been included in Appendix B. For the benefit of those who belong to the computer systems community, a brief overview of the many-faceted field of organization theory has been included in Appendix A. If you know little about organization theory, it may be useful to read it before you embark on Chapters 2 and 3.

In composing a text like the present one, however, one is also presented with constraints on creativity, as the ground rules for scientific discourse are heavily biased toward the analytical, literate mindset. The text must appear as a structured, coherent, and linear presentation of facts and ideas. The ideas presented should be consistent with each other, and the whole presentation must be sufficiently clear and unequivocal to let the reader understand it without having to pose a lot of questions to the author. Diligent use of Occam's Razor is recommended: keep your arguments clear, and eliminate everything that is not needed for your main purpose. Or, as Lee Gremillion advised me after reading an early draft of part of this thesis, quoting what he claimed was an old saying in the United States, "Tell them what you're going to say, say it, and then tell them what you said."

There are good reasons for those rules, but they conflict with the nature of the subject itself, where themes, problems, and solutions are all intertwined, and almost any explanation seems to presuppose the result of a discussion that has to come later. It is tempting to quote from Mintzberg's (1979) preface again, where he laments:

Linearity is what makes all writing so difficult. This book contains about 175,000 words laid end to end in a single linear sequence. But the world is not linear, especially the world of organization structuring. It intermingles all kinds of complex flows—parallel, circular, reciprocal.

The same kind of frustration is vented by Herbert A. Simon in the introduction to his landmark *Administrative Behavior*, but as a practical rationalist, he also knows that this conflict cannot be resolved by just throwing the traditional rules overboard. Consequently, he devises the necessary compromise (Simon 1976, p. x):

Anyone who tries to write a book soon learns that there is a fundamental incompatibility between the simple linear sequence of words that he has to set down and the complex web of his thoughts. To meet this difficulty, he combs out his thoughts as best he can into long strands and ties them together in as orderly a manner as possible. While preserving the most important relations in the pattern of his ideas, he sacrifices others.

The conflict is still an unhappy one, however, which I hope technology and the computerate mindset will relieve in the future. Nevertheless, with a conscious eye on the expectations of the readers, the conventions laid down for academic publications, and the limits of the paper paradigm, I have (although somewhat grudgingly) yielded to the thesis format and made an attempt to control the associations that cropped up as I wrote. However, I have not suppressed them completely. If I did, I would not have been honest, and by not presenting what I think are intriguing thoughts and possibilities related to the subject matter of this thesis, I might have deprived the reader of associations, insights, and new ideas. In addition, such a suppression would have made the dissertation too frustrating and boring to write; it is the small, inspired sparks that spring from the associative cortex thinking through a subject as thoroughly as one does only when writing about it that makes the whole thing endurable—at least for me. Not to let at least some of them survive the final pruning would just have been unbearable. So please bear with me if you think I am straying somewhat from the subject: I will soon return.

This brings me to the subject of readability. Personally, I do not believe that the academic value of a text is inversely correlated with its legibility. I hate to struggle through a book where I lose the thread or find that my concentration lapses several times on each page. Even though this is a doctoral dissertation, therefore, I have strived to create a narrative that is both pleasant to read and easy to follow. You will be the judge of my success, but know at least that I tried.

This is also one of the reasons I have tried to use examples to illustrate the properties of computers and information technology in general—in addition to the obvious purpose of substantiating theoretical arguments. Many of them are actual systems that are or have been in operation; but because my main point is to say something about not just what has been done already, but also what should be possible, I cannot stop there. To illustrate and explain what I see as the potential of information technology, and its fundamental strengths and weaknesses, I have also used imagined examples or thought models of systems that are possible but not yet realized.

This immediately raises an important question about which level of technology those models should assume. To allow only existing products as bases for speculation would be unduly restrictive when the pace of development is as fast as it demonstrably is in the IT industry (this dissertation alone has resided on three generations of computer systems and has been edited with the help of three different word processing programs in a total of seven versions). Any conclusion would then be overtaken by new developments before the document left the printer. On the other side, speculations based on potential technological capabilities fifty years from now would not be very interesting either, since a) we do not have the foggiest idea of what that technology will look like and what its capabilities will be and b) it would be of no use for those who would like to do something about their organizations today or in the coming decade, since the capabilities assumed might not be available within the span of their entire careers.

I have tried to hit the middle of the road in this matter. In Chapter 8, *Information Technology Development Trends*, I have given an overview of what I see as the most important probable technological developments during the next ten

years (1996–2006) and the capabilities that computer-based systems are likely to attain in this period (and sometimes a few years beyond that). We know that most mainstream products today were at the laboratory or prototype stage ten years ago, and it is not unreasonable to assume that most of the mainstream products that will be available at the turn of the century can be seen in today's laboratories. There are, of course, always surprises, but as an industry matures the number of surprises and completely new product classes tends to diminish.

In addition, for some of the most fundamental parts of computer systems, such as microprocessors, memory, and mass storage, we have had great stability in the pace of development for several decades; the present level of chip complexity was in fact predicted fairly accurately by Gordon Moore in 1964 (Noyce 1977). He overshot the target by less than a factor of 10, which is not bad at all when you bear in mind that the number of components per chip today is more than *one million times higher* than it was in 1964. We therefore have every reason to believe that the established trends will continue for the next ten years as well, since, as far as we can see, the continued improvement can be attained just by refining existing technology; no new breakthroughs are needed.

I have therefore based my thought models and my discussion of the fundamental capabilities of computer-based systems and the way they alter the preconditions for organizing on the developments outlined in Chapter 8, and have not assumed a level of technology higher than what I believe will become commercially available (and affordable) in the course of the next ten years.

Finally, some words on ambition. When you start to write a dissertation on your most cherished subject, your ambitions are naturally very high. You may acknowledge that your prospective new insights will probably not turn the world over, but you expect at least to rock it a little. As you plod along, your early ambitions (stated or not) come back to haunt you, as you can see no illuminating light in the darkness ahead, no ingenious insight—in fact, nothing new beyond what you wrote in your project proposal—nothing at all to amaze your friends and colleagues. And, worse, nothing to justify the grant money you burn while you work. Therefore, when you start writing, you naturally want to include all the good ideas that come along, you want to write the dissertation to end all dissertation efforts—to write your collected works in one fell swoop. You reign in only when you have entangled yourself in a discomfoting number of loose threads that threaten to tie you to the keyboard for ever.

Then comes the moment of truth, when you realize that you are about to make (you hope) a modest contribution to a part of the field of interest. My ambition as I write this preface is to contribute to the understanding of the connection between organization and technology in general, and in particular to explain what kind of organizational advances we may make with the computer as a tool. I also think it has been a very worthwhile effort to extend an established body of organization theory to accommodate possibilities opened up by new technology.

Acknowledgments

“Gratitude is the poor man’s payment.”
English proverb

The impetus behind this project was my desire to be able to say something sensible about the interrelationship of information technology and organization, a desire born under circumstances I shall describe in the Introduction. However, without the funding generously supplied by a number of organizations, I would not have been able to embark on this endeavor. I am therefore very grateful to the then Royal Norwegian Council for Technical and Scientific Research (now a part of the Research Council of Norway) for their bold support, which enabled me to attract support also from the the County of Akershus, Elkem Aluminium ANS, the Ministry of Government Administration, the Norwegian National Bank, Norsk Data A/S (later taken over by Siemens Nixdorf), and Norsk Hydro A/S. Norsk Data and the County of Akershus supported the participation of Akershus Central Hospital. In each of these organizations, there are many people who have helped with this project, and I feel grateful to them all. Without their support, this effort could never have succeeded. I would also like to thank my employer during the first half of the project, Avenir A/S, for their understanding when the project started to slip behind schedule. Finally, I would like to express my gratitude to my partners in Pharos DA, who generously provided me with the necessary overdraft facilities when my income dwindled during the intensive last year and a half of writing.

When I started to explore the possibilities for this project, I received crucial support from four persons. First of all I must thank Marie Haavardtun, then managing director of Avenir, who strongly encouraged me to go on and was very helpful in providing contacts with possible sponsors. Tron Espeli, who was secretary of the governing committee for the Research Council’s program “Man, Computer, and Work Environment,” went out of his way to help me structure the project to meet the Research Council’s requirements. Prof. Sverre Lysgaard at the Department of Sociology at the University of Oslo volunteered without hesitation to review my work—as he did more than a decade earlier when I wrote my master’s thesis. Finally, my colleague Peter Hidas both urged me on and volunteered to act as my mentor toward the Research Council.

Sadly, both Sverre Lysgaard and Marie Haavardtun died before the dissertation was finished, and before I could present them with the final results of their generous support. Their premature deaths were a blow to all of us who knew them and regarded them as friends.

Also, Prof. Erling S. Andersen (the Norwegian School of Management, Oslo), Prof. Per Morten Schiefloe (The Norwegian University of Science and Technology, Trondheim), Ass. Prof. Pål Sørgaard (University of Oslo), Prof. Kjell Grønhaug, and Prof. Leif B. Methlie (both of the Norwegian School of Economics and Business Administration, Bergen), Åge Borg Andersen, and Otto Stabenfeldt (both old colleagues from Avenir), Eivind Jahren (Ministry of Government Administration), and Kamar Singh (GE Aircraft Engines) gave of their valuable time to read and comment on my last draft.

However, during the writing process, two people have rendered more help and support than others, and without any formal obligation to do so.

First of all, I would like to thank Lee Gremillion for all his support and encouragement over the last six years. Lee and I first met when I called on him in Boston early in 1990 following an article in *Datamation* on rapid prototyping, where a project that Lee managed was highlighted. Together with two colleagues, I contacted him to hear more about his experiences, and Lee, in his characteristically forthcoming and friendly way, freely shared his hard-won knowledge with the strangers from a small country far away. Later that year, he came over to Norway as the main speaker at a conference that Avenir organized in Oslo on the same subject. When he heard about my doctoral work, he expressed interest and offered to read my drafts and comment on them. Since then he has been my main reviewer, and whenever I sent something over, his comments returned with a promptness worthy of a rather more profitable client. With his doctorate from Harvard University, his background from academic appointments at Harvard, Indiana University, and Boston University School of Business, and his experience as a partner in Price Waterhouse in Boston, his advice and criticism has been invaluable to me. He has also been an inexhaustible source of encouragement, which has helped greatly in pulling me through the deep troughs that invariably occur in such projects.

The second person I would like to single out is Ass. Prof. Gunnar Christensen at the Norwegian School of Economics and Business Administration in Bergen. We met during work on the Norwegian government's 1992–95 plan for developing the use of information technology in Norwegian industry, and afterward on one of the projects under that plan. I immediately seized upon the chance of recruiting Gunnar as an informal reviewer, and, by and by, he quietly accepted the role as sounding board. Patiently, he responded to my questions, offered suggestions, and listened to my occasional tales of frustration. During the final year, he also read and commented on the complete text, and thus effectively assumed the role Prof. Sverre Lysgaard had before his death. As one of the few researchers in Norway who is equally well versed in organization theory and computer-based systems, Gunnar has been of great help. Of special importance was his assistance during and after my decision to stand for the doctorate in Bergen rather than at my alma mater in Oslo. His help with the formalities as well as with access to the other people there who had to look at my work was vital for the final success of my efforts.

There are, of course, others to thank as well. Jan Heim (then at the Norwegian Computing Center) read my first drafts on our cognitive capacities and offered very valuable advice, and Prof. Ivar Lie (University of Oslo) also helped with valuable information for this chapter. Prof. Tjerk Huppel (University of Groningen) found time to receive me and offer advice, and Ass. Prof. Jan Brage Gundersen (University of Oslo) helped me with some of my philosophical excursions. My colleagues in Avenir and in Pharos have also been both helpful and supportive, prodding me on with their interest. I would especially like to thank Dag Solberg for his interest and suggestions. Dag is certainly one of the most experienced practitioners in the field of modeling in Norway, and he is also theoretically better versed in the subject than many academic specialists. His comments have been very useful.

Lastly, I want to thank my family for enduring the hardships with me. I have read many such statements of gratitude toward a family through the years, and until a few years ago I viewed them as perhaps little more than a social reflex. Now I know better. To have one of the parents strained by dissertation work year after year, often working both evenings and weekends, is an experience most families could well do without. I am very grateful that you put up with me, supporting me even through the nth delay. I hope I shall never test your love and tolerance in this way again.

I A Platform for the Investigation

In this part, my purpose is to build the foundation for the main analytic thrust of the dissertation. In Chapter 1, *Introduction*, I explain how I was prodded to initiate the project—how my curiosity for the organizational potential of information technology was aroused to the point where I felt I had to do something about it. I also delineate the project's point of departure and the approach chosen for the analysis: to use the basic human preconditions for organizing as a starting point, and investigate how they are enhanced by technology—first by pre-computer technology and then by information technology itself.

In Chapter 2, *Organization and Tools—the Human Advantages*, I set out to establish the (in my view) crucial link between organization and technology and explain the concept *space of constructible organizations*. The chapter ends with a delineation of the scope of the analysis.

In Chapter 3, *The Basic Preconditions for Organizing*, I discuss the subject of organization, especially how organizations are defined and what their basic elements of structuring are. The structural configurations of Henry Mintzberg (1979) are adopted as the main framework for the analysis. The discussion concludes that coordination is the linchpin of all organization, and a taxonomy of coordinating mechanisms (based on Mintzberg's definitions) is proposed. The chapter ends with the definition of what I see as the basic human preconditions for organizing, which will serve as the foundation for my main analysis.

1 Introduction

“A man’s behavior is the index of the man, and his discourse is the index of his understanding.”

Ali Ibn-Abi-Talib, *Sentences*, seventh century

Prods That Kindled Curiosity

This is a treatise on how the inherent properties of computer-based systems fundamentally alter some of the basic human preconditions for organizing and for work in organizations, and thus open up the possibilities for new organizational arrangements. It has been my intention to reach an understanding of *what* those basic preconditions are, and *how* they are alleviated by information technology, in order to be able to outline—on the basis of general organization theory—how organizations that *really* exploit the technology might look like and function. Although I do not succumb to the folly of thinking I have found the definitive answer, I do believe I have developed an interesting line of argument that may help to elucidate the intimate relationships between information technology and organization. I also hope that my narrative will be of interest both to scientists and to the practitioners of the difficult art of management.

As I write this, a research effort that has absorbed more time than I like to think of and has lasted more years than I like to keep track of (and displaced more billable assignments than I like to add up) is finally drawing to an end. Like many such efforts (probably most), it was inspired by a combination of professional interests, curiosity, and unexpected incidents that served to put a question before me in a way that made me want to search for an answer. As a prelude to the dissertation, and to provide the best possible understanding of what I set out to do, I would like to describe briefly the circumstances that led me to embark on this journey back in 1986.

Scenting a Revolution

An organization sociologist by training, I wanted to work with organization development when I graduated from the University of Oslo in 1977. Fairly soon I became convinced that the rapid spread of computer systems would be the most important driving force for organizational change in the decades to come, and in

1980 I joined a computer consulting firm that wanted to complement its computer-related services with assistance in organization development. That proved to be an uphill battle, however. Customers viewed organizational matters either as something quite irrelevant to their data processing needs or as a trivial detail they could take care of themselves. Even the obvious need for dedicated personnel for user support and restructuring of routines was usually denied.

At about the same time, there were growing complaints about the missing benefits of investments in computer systems. The expected return on investments did not seem to materialize. Widely published analyses showed zero or even negative productivity growth in the office sector, in spite of heavy investments in information technology. It was a stark contrast to the continuous improvement in manufacturing. The complaints were an international phenomenon, and some of the arguments are summed up by Strassman (1985, pp. 151–165).

Whether the complaints were valid was not altogether clear, however. As practitioners, my colleagues and I were often puzzled by the analyses, because our everyday experience indicated that the majority of computer projects paid for themselves within reasonable time. Of course there were always projects that went wrong, and a good number where the profitability was questionable, but according to our experience, they were definitely outnumbered by the successes, at least when it came to structured data processing, such as accounting, inventory control, records management and claims processing. As for more unstructured applications, such as general office support, the record was much less clear. Indeed, in the mid-1980s, when the data processing societies in the Nordic countries made a survey to locate successful and demonstrably profitable office automation installations, they reportedly found none! The DP societies had planned a public campaign on the benefits of computing and wanted to use the success stories as cases. As you may well understand, the campaign was canceled.

These allegations about lacking productivity were both bewildering and hard to swallow. Like most technocrats, computer people were and are generally very optimistic on behalf of their technology, and their common credo was that computers enhance productivity and open new vistas of unexplored opportunities—be it in business, in education, or in local and central government. Their conviction was born out of their enthusiasm for the machines they worked with—their raw power, the elegance of their logic, the richness and flexibility of their software, and the incredible pace of their development. I have shared much of this enthusiasm, although I have become more cautious lately—feeling a need to put some distance between myself and the exuberance of the more unrestrained enthusiasts, whose imagination and excitement have now been fired to the point of meltdown by the exploding success of Internet and the notion of a Wired World.

It later turned out that many of the reports fueling complaints about missing productivity were built on macroeconomic statistical analyses with doubtful relevance to the subject in question (Panko 1985). However, most people tended to accept them at that time—and it could at least not be denied that even successful projects frequently experienced considerable implementation problems (they often still do). Even accepting that computers *did* increase productivity, therefore, one could justly ask why they did not increase it even *more*, and why there always seemed to be so much trouble involved.

An Organization Connection?

Apart from the often obvious effects of the lack of training and support, a mismatch between organization and technology seemed like a possible explanation to me. After all, the technology was new and unexplored, whereas our models for organization and our ways of working seemed old and entrenched. Time and again, we saw that the introduction of computers just involved an “electrification” of existing routines; even on-line systems tended to mimic paper files and manual work. Frequently, adjoining routines were not modified to take account of changes in the workflow. For instance, an executive of the Norwegian metals producer Elkem¹ told me that the underlying routines for data capture and registration of accounting information were not changed when the company headquarters made the transition to computerized accounting (a batch-oriented accounting system) in 1972/73. He also said that the control of the accounts and the finances grew worse when the new system was introduced. With the old bookkeeping machines, status could be checked at any time just by looking at the cards; with the new system, ad hoc listings between the monthly reports had to be specially ordered, cost extra, and were therefore seldom produced.

This is an apt illustration of one of the basic dualities in human nature: that we are both naturally curious and competitive, inclined to experiment and explore the ramifications of new insights, *and* (simultaneously) heavily influenced and constrained by the awesome power and perseverance of habits and established patterns of thinking. Throw in our very limited mental ability to handle complex problems and foresee consequences where many parameters vary simultaneously, and you have a good explanation for why we almost always change our work and organizations step by step, in small increments.

The consequence of these very basic human traits was that, while we eagerly sought to exploit a new and potentially revolutionary set of tools (computer-based systems), we still built our organizations and arranged our work as if little has happened since the invention of the quill pen. The result was, by all probability, a basic mismatch between organization and technology—a mismatch that not only prevented the full realization of the technology’s potential, but that, from time to time, actually created problems that reduced the overall efficiency compared with the situation before the computers were introduced.

Some Questions Come to Nag Me

This organization hypothesis was exciting for an “old” sociologist, and spurred by this realization, I started stressing the importance of organization and user support both in computer magazine articles I wrote as well as in talks I gave to audiences that consisted both of users and computer professionals. At the same time, the subject was gradually becoming more in vogue, at least in the data processing community. (The users, although more willing to accept the theory “in theory,” continued to resist the idea that they should squander their IS money in practice by using it for anything other than hardware and software.)

¹ One of the larger Norwegian industrial companies, with aluminum, ferroalloys, silicon metal, and equipment for environmental protection as main products. Elkem is one of the sponsors of this research project.

One of the most intriguing statements one could make at the time (it still is!) was that a widespread adoption of advanced computer systems would make it possible to build new organization structures, more efficient and flexible than the ones we were used to. This was always a sure hit, especially with the more well-groomed professional audiences, all members of the chip-chip-hurrah community. From time to time, however, a few uninitiated participants would have the temerity to ask "how" or "what kind of structures," instantly creating that special kind of embarrassed silence experienced in sacred (or political) congregations when newcomers ask "stupid" questions about central dogmas.

Such questions also tended to create a slight panic in the speaker, who time and again had to fall back on the well-worn examples of American Hospital Supply Corporation and American Airlines (and, fortunately, a couple of credible local cases). However, they did not quite seem to fit the bill. The companies in question had undoubtedly changed some aspect of the way they did business, and with notable success, but the systems' organizational impacts were questionable, apart from eliminating a number of positions associated with the old routines.

In fact, most of the success stories that circulated in the business at the time seemed to deal with intrinsically very simple applications, based on the computer's outstanding capabilities in handling large registers with mostly numerical data. As soon as you left these simple and highly structured applications, the success stories thinned out and became more and more difficult to validate.

Often I ended up saying that the ways and means here were not quite clear yet, as we were all in the forefront of a development that was just taking off, and that, consequently, the new structures and ways of working had yet to emerge. It was hardly a satisfying answer for the audience, and definitely not a satisfying experience for me—all the more so because I really believed that the possibilities were genuine. I was in dire need of a qualified answer, since I really wanted to be able to say something about "how" and "what kind of structures." That was when (in 1986) I started to formulate (and obtain funding for!) a research project to look into the matter—a project that started in earnest in 1988, has experienced some pauses along the way, but has stayed alive to produce the dissertation you are about to read. I now believe that I have an answer—perhaps not *the* answer, but a reasonably logical and coherent set of explanations about what kind of organizational structures that may indeed evolve as we gradually master the new tools provided by the digital computer. I also believe that I can say sensible things about what kinds of organizations will be able to benefit the most.

And, by the way, the doubts about productivity have since largely been dispelled. The definitive public breakthrough of the new view of computers as universal tools of change and improvements in efficiency could be read off the front page of *Business Week* on June 14, 1993. Under the tabloid-sized heading "The Information Payoff," the special report on computerized productivity increases was heralded with the following:

U.S. business spent \$1 trillion on information technology in the last decade—but showed little gain in efficiency. Now, productivity is finally bursting out, thanks to better software and a reorganization of work itself.

The Point of Departure

A Quest for Practical Directions

My viewpoint is a practical one. I have been working as a consultant since 1980, and my clients always expect practical advice that will produce concrete improvements in their organizations. That is what they pay to get, and that is what I strive to provide. The basic goal for my research was therefore to be able to offer my clients better advice and perhaps also help others who needed to understand how their organizations could really come to grips with this new and exciting technology. The basic questions I wanted to answer were no more and no less than those I had encountered during my talks:

- ◆ What will the organizations look like that really take advantage of the full power of information technology?
- ◆ How should they be structured?
- ◆ How will they function?
- ◆ What will be their benefits and drawbacks?
- ◆ Are the opportunities the same across the board, or do they vary among organizations of different kinds?

If I could answer these questions, I felt I would also be in a much better position to help my clients both to take advantage of contemporary systems and to stake out the road ahead—since I would then be able to tell if their particular organizations could benefit from intensive use of information technology, what they would need to do in order to exploit it, and (just as important) how they could *not* exploit it.

However, I found no one who could answer these questions—at least not in a convincing manner. As far as I could ascertain, the research done was largely of a local and empirical nature, investigating the current best practices practice in existing organizations and analyzing the actual impact of their systems—or, rather, the way those organizations had exploited them. I could find few explanations of a more general nature, and none at all that in a coherent and comprehensive way could make clear why information technology seemed to facilitate some organizational innovations and not others. Nor could I find any real attempts to bridge the gulf between these new technology-based developments and the more established body of organization theory. In fact, most organization theorists seemed to be either uninterested or simply unaware of the developments that were taking place.

Quite frankly, I felt at a loss. I felt that I did not understand this field at all, even if I new quite a lot about the reported successes and failures at that time. I remained hard pressed if challenged to judge the potential benefits particular organizations could reap, or point out exactly where in those organizations the greatest potentials were buried.

Actually, I believe most executives (and even consultants!) often feel that way even today. Inundated by a steady stream of success stories reported both in the

trade press and in the general media, it remains difficult for them to know which of the many alleged roads to success are most appropriate for their own particular organizations. It is my experience that they often feel bewildered, wondering why it is so difficult to see the opportunities and to achieve the same kind of successes at home. Sometimes they may even doubt if all those much-heralded opportunities are really *real*. After all, people in other organizations cannot simply be that much more ingenious? Or they may wonder if perhaps the opportunities are quite disparate in different kinds of organizations—and, if so, how they can find out which ones apply to their own. Most likely, there are also possibilities within reach now or in the near future that no one has thought about yet. Is it possible to speculate sensibly about such matters at all?

Found Missing: A Theory of Computer-Based Organization

Sometimes one ends up looking for an answer in seemingly unlikely quarters. One may perhaps think that answers to practical problems are best sought by accumulating experience, but, in this case, I soon concluded that we most of all lacked an adequate body of theory that could help us analyze experience and advance our understanding of the deeper relationships between information technology and organization. This scarcity of theory has also been noted by others; as late as three years ago a call for such theories was issued in an editorial essay in *Organization Science* titled "Where Are the Theories for the 'New' Organizational Forms?" (Daft and Lewin 1993).

The link here is really quite straightforward. It is my deep conviction that without adequate theory, questions like the ones posed above simply cannot be credibly answered. Without theory to help us interpret our experiences, we will not be able to understand much about what is going on and why, let alone chart a viable course into the future and sense potentials unrealized so far. In order to provide the kind of practical, effective advice I wanted to be able to give my clients, then, factual knowledge and experience is not enough. To obtain a sound understanding of a particular field, experience, factual knowledge and theory are *all* mandatory. Sometimes an unconscious, everyday theory-in-use (Argyris 1980) may suffice, but for the large, complex organizations of our age, explicit scientific theories are necessary as well.

As JoAnne Yates says, summing up her very interesting work on the development of methods and technology for management control and communication in American industry between 1850 and 1920 (Yates 1989, pp. 274–275, my italics):

Perhaps the most obvious implications concern communication and information technology. James R. Beniger has recently argued that the "Control Revolution" that began in the late nineteenth century contained the seeds of today's information society. Certainly, there are some parallels between the revolution in office technology of the 1880–1920 period and the revolution of the last twenty-five years. Recent innovations in computers and telecommunications have been so spectacular that contemporary commentators tend to focus solely on the technology, seeing it as the driving force causing changes in other parts of the organization. The case studies in this book, however, illustrate some of the problems with simple technological determinism. Technologies were adopted, not necessarily when they were invented, but often when a *shift or*

advance in managerial theory led managers to see an application for them. Moreover, technologies were often adopted simply to facilitate existing managerial methods; potentially more powerful applications, such as the use of the telegraph for railroad dispatching, were ignored for long periods. *The technology alone was not enough—the vision to use it in new ways was needed as well.* A related implication for contemporary issues concerns both communication technology and geographical dispersion. Just as the telegraph once opened up possibilities for wider domestic markets and more scattered production facilities to companies such as Scovill and Du Pont, worldwide telecommunications systems are now doing the same for international markets. The historical cases suggest, however, that the real potential of these networks cannot be realized through a simple extension of existing patterns of communication. *Real gains await innovative thinking about underlying managerial issues.*

Therefore, when we encounter a new and uncharted territory like the interplay between computers and organizations, “nothing will be so practical as the development of a good new theory,” as Daft and Lewin (1993) note (with due reference to Kurt Lewin²). As Yates attests, the future can seldom be forecasted by extrapolation, and to envisage potential new arrangements, it does not suffice to make empirical investigations of the current best practice. Without theory, we cannot distinguish between the significant and the insignificant, we cannot easily perceive causal relationships, and we cannot predict likely outcomes in new situations. Even today we are in the infancy of computer use, and no one would seriously propose that our results so far fathom the technology’s potential or contain the complete blueprint for any future best practice.

So, first of all, I felt an acute need for a theoretical foundation for the study of information technology and organization. Equally important, this foundation should not be built in isolation, but should relate directly to the established body of organization theory. It is very unlikely that the introduction of a new technology alone (albeit a powerful one) should alter the basic principles of human interaction beyond recognition, and by segregating the study of computers and organization from the rich body of organization research, we are bound to forgo major insights and take on a crippling burden of parallel research. In a field where there are many different and partly competing theoretical approaches, it is also of significant scientific interest to test established theory by systematically applying it to new problems.

To me, this is also a matter of practical concern; a large part of today’s managers know a lot about organization theory and feel quite at home with the main lines of argument. Linking a theory of information technology and organization to one of these traditions will make it much easier for them to relate to it, to understand it, and to use it for their own purposes.

The task I set myself, therefore, was to develop a theoretical basis for understanding the interplay between information technology and organization. I wanted to base the analysis on core social science tenets, and to carry it out as far as possible within an established framework of organization theory. Existing

² Another, older Lewin. Daft and Lewin here refer to the article “The Research Center for Group Dynamics at Massachusetts Institute of Technology” by Kurt Lewin, appearing in *Sociometry*, 1945 (vol. 8), pp. 126–135.

empirical material, as documented by other researchers, would serve as illustrations and indications of the validity of the theoretical conclusions. In particular, I wanted to focus on organization structuring and design.

It was the unmannerly but very practical questions about the nature of the promised new organizations that sent me searching for an answer, then—and it was the lack of satisfactory answers that inspired the theoretical investigation leading to this dissertation. Hopefully, it will be both readable and useful for practitioners and academics alike.

Attacking the Problem

How I should go about the task I had set for myself was not self-evident. However, to answer the questions posed above, I needed to do two things: I had to obtain an understanding of the relationship between technology and organization in general, and I had to understand just what it was that information technology contributed over and above earlier technology. With these realizations as guideposts, I worked out a design as outlined below.

Of course, although the basic concept was decided before the work was started in earnest, it has inevitably been modified and refined as the work proceeded—both in order to strengthen the basis for the later steps and in order to create a reasonably coherent account of my work for others to read. The narrative that follows, with its seven major steps, is therefore somewhat more structured and linear than the actual process behind it, even if the basic approach has been the same throughout my work. I will state the reasons for the choices described below more thoroughly in Chapter 3.

Step One: The Basic Preconditions for Human Organizing

My basic notion has remained unchanged throughout the project: that our use of technology—any technology—has its roots in our desire to overcome limitations in our natural, physiologically defined capabilities, and that this also applies to the construction of organizations. To gain an understanding of how we might exploit information technology in organizations, I therefore first had to determine our most important limitations with respect to organization building, and how they constrain us in establishing and maintaining organizations.

During the review process, I have had objections to this perspective. One line of argument emphasizes that the human is a creature with amazing talents, and it seems somewhat misconceived to focus on its shortcomings. The other argues that humans are what they are, they experience the world through their bodies, and, as they cannot transcend their given capabilities, it is meaningless to say that they are constrained by their own nature.

I disagree with both of these lines of argument. Both our bodies and our minds do have very real limitations, which we can experience and sense every day if we care to notice, and, since time immemorial, humanity has dreamt of going beyond these limits, as we know from myths and sagas from cultures all over the world. The story of Icarus is a typical example, proving that we have dreamt of flying for thousands of years before we actually accomplished it. Jules Verne wrote about travels to the moon and under the sea long before they could possibly be realized,

and modern “myths” such as the stories about Superman continue to express this yearning to transcend our mortal shortcomings. Many of the conceptions of magic and sorcery can also be interpreted as a longing for powers beyond the scope of the normal body; is not levitation considered one of the pinnacles of achievement in Mahareshi’s transcendental meditation movement? Even the major religions of this world have as their central theme the final transcendence of our earthly shortcomings.

If we did not constantly strive to transcend our capabilities, if we did not have a vision of reaching beyond our present grasp, we would not seek new knowledge and continue to invent new tools all the time. As Sartre says in his *Situations* (“Temporalité,” v. 1), a quote I decided to use as a motto for this dissertation, “Man is not the sum of what he has already, but rather the sum of what he does not yet have, of what he could have.”

Step Two: The Range of Organizations Built on Our Basic Capabilities Alone

To learn the fundamental facts about how our abilities and choice of organization structures are related, it was necessary to look into the range of organizations built on these basic capabilities alone, as well as the methods invented to cope without significant tools. Evidence here may be drawn both from history and from the anthropological research of our own century.

Step Three: The Nature of Pre-Digital Technology

The next important step was to look into the use of technology, which has from a very early stage been an extremely important aspect of human life and culture. Some of the tools that were developed have had very significant impacts on the possible scope for organization. In order to be able to isolate the possible contributions of information technology, it was therefore necessary to look into the most important of the pre-computer technologies and investigate how they helped us overcome some of our basic limitations.

Step Four: The Organizational Impact of Pre-Computer Tools

To follow the chosen path of analysis, I then had to assess the main organizational impacts of the new tools from the development of writing onward. Some of the potentials created by the expanding inventory of tools were fairly early exploited; some laid dormant. In fact, it was not until the advent of the Industrial Revolution that the potentials were explored to any depth, and it was not until our own century that we came up against the limits of pre-computer tools. An understanding of the nature of those limits is an important prerequisite to understanding IT’s potential contributions.

Step Five: The Basic Properties of IT

The properties of computer-based systems had to be analyzed in some depth to ensure that all important aspects of the technology were covered. In many ways, this meant shooting at a moving target, as the technology is still developing very rapidly. I have tried both to describe the properties of the technology as it stands today and to establish the main trends of development for the next ten years as a basis for analyzing its potential for organizational innovation.

Step Six: The New, IT-Based Preconditions for Organizing

At this point, it should finally be possible to establish what the new preconditions for organizing are like and how they differ from the preconditions provided by earlier technology. I will try to show how, where and why information technology can be used to reshape organizations.

Step Seven: The Potential for Organizational Change

On the basis of the analysis of the IT-based preconditions for organizing, it should at last be possible to fathom the potential they offer for new patterns of organization, and for making organizations both more effective and more efficient. It should also be possible to say something about what they will require from us, and how it will be to work there.

A Key to Parts and Chapters

As indicated in the Preface, I have tried to write a narrative that is easy to follow and pleasant to read. However, even with the best intentions on my side, readers may at places be confronted with leaps of thought that remain invisible to one who has been steeped in this material for years. Using the seven steps outlined above as a background, I will therefore say a few words about how each part and each chapter fits into the scheme.

Part I: A Platform for the Investigation

In Part I, my purpose is to build the foundation for the analysis itself. In the *Introduction*, I have explained how I was prodded to initiate the project—how my curiosity about computers and organization was aroused to the point where I felt I had to do something about it. I have also delineated my approach: to use the basic human preconditions for organizing as a starting point and investigate how they are enhanced by technology—first by pre-computer technology and then by information technology itself.

In *Organization and Tools—The Human Advantages*, I set out to establish the crucial link between organization and technology and explain the concept *space of constructible organizations*, ending with a delineation of the scope of my analysis.

In *The Basic Preconditions for Organizing*, I discuss the subject of organization, especially how organizations are defined and what their basic elements of structuring are. The goal is to identify a suitable framework from the body of organization theory on which I could base my own analysis. Mintzberg's structural configurations are adopted as the main framework, and the discussion concludes that coordination is the linchpin of organization. A taxonomy of coordinating mechanisms, based on Mintzberg, is proposed. The chapter ends with a definition of the basic human preconditions for organizing, which are to serve as the foundation for the analysis of technology use. This completes the first of the seven steps outlined above.

Part II: Individual Capacity and Organization before the Computer

In Part II, my purpose is to analyze the contributions of pre-computer technology. *Confined by Physiology* begins by looking at the six basic human preconditions in more detail. I also discuss important traditional methods for alleviating or circumventing some of these constraints.

In *The Dawn of Organization*, I explore the problems of organization building in societies without significant tools for organizational purposes, and try to determine the extent of the space of constructible organizations in such societies. The analysis focuses on the methods and techniques used to build and maintain preliterate organizations. The analysis corroborates the conclusion that coordination is the essence of organization, and ends with what I see as the basic principles of preliterate organization. This concludes step two in my ladder of analysis.

In *The Power of Technology*, I discuss the nature of tools and the way the most important pre-computer technologies have alleviated our original constraints, gradually allowing for extensions of the space of constructible organizations. The single, most important innovation was undoubtedly the art of writing, and the great impact writing has had on our mental capacities is explored. Next, I discuss the communications revolution of the nineteenth century, and the chapter (and step three in my analysis) ends with some thoughts on complexity and the nature of automation.

In *The Modern Organization*, I try to assess the relationship between the development of pre-computer tools and the emergence of the modern organization. I conclude that the new forms of organization, especially the Machine Bureaucracy, were based on a new and vastly more efficient concept of coordination: the transition from direct to indirect supervision through standardization of work processes in the form of explicit routines and automation. I also propose that the emergence of the modern organization involved another breakthrough: the emergence of the explicit conceptual model and the concomitant explicit design of organizations. The chapter ends with a short discussion of the effect of culture on organizational forms. This is step four in the analytical ladder.

Part III: IT and the Preconditions for Organizing

With the platform for analyzing the impact of information technology finally in place, I start out in *Information Technology Development Trends* by assessing the state of the art of the technology and the likely achievements in basic performance improvements during the next decade (step five in the analysis). In *The Impact of IT on Individual Capabilities*, I proceed to analyze how information technology can improve the capabilities of the individual beyond the contributions of earlier technology. This constitutes step six in my initial outline and will form the foundation for the subsequent analysis of possible new organization forms and practices.

While working on this part, I felt it necessary to balance a fairly technocentric analysis in Chapter 9, and emphasize that human nature is not exclusively defined by logic and reason. In Chapter 10, *Emotional Barriers and Defenses*, I therefore discuss how our emotional side may put a spoke in the best technological wheel.

Part IV: Extending the Space of Constructible Organizations

In *The Individual and the Group* I begin a prelude to the kernel by analyzing the possibilities that information technology provides on the individual and group level. This is necessary both because they represent the primordial elements of organization as well as the fundamental building blocks of larger organizations, and because there are a number of application types (among them some of the most hyped ones) that apply foremost to these levels.

Then I move on to the core of the matter: the larger organizational context and the tools and potentials that apply to the organization as a whole. First I look at *Routines and Automation*, which in my view will continue to represent an extremely important contribution to the development of modern societies, allowing enormous increases in productivity—something that will also have a number of interesting side effects. Computer-based automation also includes automatic routines at various levels, which is a very important prerequisite for two later themes. One of them, *Coordination by Default*, is about how databases can contribute to the age-old problem of coordinating work, both improving on existing arrangements as well as providing new ones. The second I have called *Comprehension and Control*; it is about how information technology can improve our understanding and control of both our work and our organizations by making information more accessible and even enabling the procurement of information that was previously unavailable. This has clear implications for organization structure and the way organizations can be run.

At the end of each of these three chapters, I discuss the possible extensions that information technology may offer to the space of constructible organizations.

Part V: Models and Configurations

I then close in on the final target in Part V. First, in *Toward the Model-Driven Organization*, I discuss what it really means to build organizations with information technology: That computer programs become ever more prominent parts of the organizational fabric, and therefore also become part of the very patterns of actions that constitute organizations. Next, I return to the conceptual model: With the introduction of computers and computer programming the model and modeling activities have become very explicit, and they are becoming extremely important within the computerate paradigm. In my view, active models will make up the central element in most organizations in the future.

Finally, in *The New Organizations*, I discuss if and how the extensions to the space of constructible organizations combine to modify Mintzberg's configurations, and I find three significant new variants: the *Joystick Organization*, an entrepreneur's dream evolving from the Simple Structure; the *Flexible Bureaucracy*, a formidable fighter growing from the Machine Bureaucracy, and the *Interactive Adhocracy*, an Adhocracy where system-mediated communication allows true mutual adjustment to work in much larger settings than before. I end by proposing two altogether new configurations: the *Meta-Organization*, a closely coupled group of separate organizations, and the *Organized Cloud*, which challenges our notions of what an organization really is.

Some Central Terms

Throughout this dissertation, there will be copious use of a number of terms related to the technology. Some of them, such as “processor,” “memory,” “disk,” and “program” have fairly clear meanings. Others, such as “information technology” and “computer-based systems,” are a bit fuzzier around the edges. All of them, however, are in daily use throughout both the industry and the research community, and I have found it fruitless to try to establish my own “local” definitions for the purpose of this document. That would only make it harder to read, and it would probably introduce more confusion rather than preventing it. For those who are in doubt, however, I would like to explain my understanding of three of the fuzzier terms.

By *information technology* I denote all the technologies that today depend on digital, electronic processing—which broadly means computing in all its nuances, from industrial automation to word processing, as well as telecommunications. The transmission and processing of sound and pictures are included, insofar as it is digital. Traditional broadcasting is thus not generally included. Telephones are, even though they are still mainly analog—switching is now largely done by computerized switches, and the use of telephones, telephone lines, and fax emulations are increasingly integrated with the use of computers in office environments.

By *computer-based systems* I generally mean systems where computers have a more recognizable role, such as administrative systems and production control systems. Industrial automation on a larger scale, such as process control and automated production lines, are also included, but single machines, such as computer-controlled lathes or milling machines are not.

A *computer* is understood to be a combination of a processor, primary memory and a secondary storage device. It does not necessarily refer to a PC, server, mini, or mainframe, although all of these are, of course, included in the definition.

2 Organization and Tools— the Human Advantages

“Man is a tool-using animal ... Without tools he is nothing, with tools he is all.”

Thomas Carlyle, *Sartor Resartus*, 1833–34.

A Crucial Link

The basic notion behind this dissertation is that technology has been a very important factor in the emergence, development, and design of organizations throughout history, and that changes in organization-relevant technology will spur changes in the structure and functioning of organizations as well. Why do I believe this?

Apart from the commonsense assumption that telephones and computers must matter, and convincing empirical evidence that railroads and the telegraph did so in the past (Chandler 1977, Beniger 1986), there are also theoretically well-founded reasons for believing so, and I would like to elaborate a little on this theme before proceeding to identify which of our abilities and limitations are most relevant for our organizing efforts.

The discussion that follows to some degree presupposes a knowledge of some of the main approaches to organization theory. Those who are not familiar with the subject and the theorists, terms, and ideas discussed in the following sections will find a summary that may prove helpful in Appendix A, highlighting some of the milestones in the development of organizational theory most relevant to the discussion. It is partly based on Scott (1987), with some emissions and additions. It is, admittedly, somewhat biased toward my prime interest in this dissertation: organizational structure, the interaction between organization and technology, and the theories most relevant to this. I have no intention of presenting a balanced condensation of the history of organization theory.

To Be Human Is to Be Organized ...

Everything we know about ourselves tells us that organizing is a fundamental part of human life;—for as long as we know, humans have organized themselves in order to accomplish tasks that are not within the reach of single individuals. All that archeology and anthropology have discovered supports this; humans are and have always been social animals, and the isolated individual is an anomaly. Organization may well be rudimentary, as in the small bands of hunter/gatherers believed to constitute the primordial form of human society, but they nevertheless have a social structure and a basal role diversification, and a number of the hunter/gatherers we know of from historic (and present) times in fact have quite sophisticated social structures. Some of the oldest texts known, such as the Epic of Gilgamesh (believed to have been written down as early as in the beginning of the second millennium B.C.), contain descriptions of elaborate social organization. In the opening verse in the Epic of Gilgamesh alone, there are mentions of the king, of nobles, of warriors, and the concept “shepherd of the people/city” (Sandars 1964, p. 60):

Gilgamesh went abroad in the world, but he met with none who could withstand his arms till he returned to Uruk. But the men of Uruk muttered in their houses, “Gilgamesh sounds the tocsin for his amusement, his arrogance has no bounds by day or night. No son is left with his father, for Gilgamesh takes them all; yet the king should be a shepherd to his people. His lust leaves no virgin to her lover, neither the warriors daughter nor the wife of the noble; yet this is the shepherd of the city, wise, comely, and resolute.”

The Bible even contains concrete directions—and reasons—for organizing (King James version¹, Exodus 18:13–23):

And it came to pass on the morrow, that Moses sat to judge the people: and the people stood by Moses from the morning unto the evening.

And when Moses' father in law saw all that he did to the people, he said, What is this thing that thou doest to the people? why sittest thou thyself alone, and all the people stand by thee from morning unto even?

And Moses said unto his father in law, Because the people come unto me to enquire of God:

When they have a matter, they come unto me; and I judge between one and another, and I do make them know the statutes of God, and his laws.

And Moses' father in law said unto him, The thing that thou doest is not good.

Thou wilt surely wear away, both thou, and this people that is with thee: for this thing is too heavy for thee; thou art not able to perform it thyself alone.

Hearken now unto my voice, I will give thee counsel, and God shall be with thee: Be thou for the people to God-ward, that thou mayest bring the causes unto God:

And thou shalt teach them ordinances and laws, and shalt shew them the way wherein they must walk, and the work that they must do.

Moreover thou shalt provide out of all the people able men, such as fear God, men of truth, hating covetousness; and place such over them, to be rulers of thousands, and rulers of hundreds, rulers of fifties, and rulers of tens:

¹ CD-ROM edition by Andromeda Interactive, 1995.

And let them judge the people at all seasons: and it shall be, that every great matter they shall bring unto thee, but every small matter they shall judge: so shall it be easier for thyself, and they shall bear the burden with thee.

If thou shalt do this thing, and God command thee so, then thou shalt be able to endure, and all this people shall also go to their place in peace.

Moses' father in law saw that the task Moses had taken upon himself was too big for one man. To resolve the situation, he devised a method in the form of an organizational structure to share the work among many, leaving Moses only with the most important cases.

Implicit in these examples lies another, decisive factor: Not only are humans born as organizers, they accumulate their experience and increase their collective skill from generation to generation. For even if every innovation must spring forth from an individual mind, it is (if successful) rapidly absorbed into the collective consciousness of the inventor's society, and may even spread beyond to other societies if there is sufficient contact between them.

Even if the pinnacles of individual creativity throughout history are impressive, then, it is as a collective phenomenon, as a meta-mind stretching through time and space, spanning thousands of generations, that the human intellect really shines. And the basis for this is our ability to organize—our ability to congregate in groups, tribes, and societies where knowledge and skills can accumulate and be transferred to new generations, who, in their turn, can develop them further. Although individual contributions are recognizable, they are indeed impossible to separate from the collective consciousness of humanity. As Boulding says, discussing the levels of theoretical discourse for systems theory (1956, p. 8, italics in original):

The next level is the 'human' level, that is of the individual human being considered as a system. In addition to all, or nearly all, of the characteristics of animal systems man possesses self consciousness, which is something different from mere awareness. His image, besides being much more complex than that even of the higher animals, has a self-reflexive quality—he not only knows, but he knows that he knows. This property is probably bound up with the phenomenon of language and symbolism. It is the capacity for speech—the ability to produce, absorb, and interpret *symbols*, as opposed to mere signs as the warning cry of an animal—which most clearly marks man off from his humbler brethren. Man is distinguished from the animals also by a much more elaborate image of time and relationship; man is probably the only organization that knows that it dies, that contemplates in its behavior a whole life span. Man exists not only in time and space but in history, and his behavior is profoundly affected by his view of the time process in which he stands.

Because of the vital importance for the individual man of symbolic images and behavior based on them it is not easy to separate clearly the level of the individual human organism from the next level, that of social organizations. In spite of the occasional stories of feral children raised by animals, man isolated from his fellows is practically unknown. So essential is the symbolic image in human behavior that one suspects that a truly isolated man would not be 'human' in the usually accepted sense, though he would be potentially human.

To become masters of the Earth, we had to organize, and so we have done—in modern civilizations, the inventory of organizations is large and extremely

diverse; they are a part of everyday life for nearly every human, and only the hermit escapes daily contact with them.

... and to Use Tools

Humans are not the only organizers in the animal kingdom, however, although undoubtedly they are the most accomplished. An even more distinguishing characteristic is our ability to make tools, particularly the way in which we use the process of collective accumulation of knowledge and experience to develop ever better tools, tools with increasing power and complexity.

Our array of tools and methods have grown large and diverse, and we apply them—or at least try to apply them—wherever we come up against challenges that go beyond our bare physical and mental powers. It is hardly possible to imagine that the realm of organizing should be exempted from this; the only possible reason would be that our abilities for organizing had no bounds, and that we never experienced any gap between them and our ambitions.

While this may hold true for our Lord, we—as mere humans—must rather content ourselves with the fact that the unaided human is an animal with definite physical and mental limitations, restricting the amount of work or the amount of information any single individual can cope with. As March and Simon say (1958, p. 11):

This, then, is the general picture of the human organism that we will use to analyze organizational behavior. It is a picture of a choosing, decision-making, problem-solving organism that can do only one or a few things at a time, and that can attend to only a small part of the information recorded in its memory and presented by the environment.

Not only do we have limitations that can only be (partly) overcome by organization, but those very limitations even restrict the nature and size of the organizations we are able to build.

To organize on the scale necessary for the conquest of the Earth, we had to go beyond the of social organization in the family, group and village, which built directly on our innate abilities. We had to develop tools and methods for building larger and more effective organizations, as we have done for so many other ends. The electronic computer is no more than the newest of these tools, although it may prove to be the most powerful of them all so far.

The Point of Leverage

Earlier, I underlined how our success as a species derives from the powerful interplay between individual creativity on the one side and collective actions and accumulation of knowledge on the other. This field of force is evident in the theories of organization as well, but there has been a tendency to simplify the picture, by downplaying either the role of the individual, the role of the environment, or both. I feel distinctly uncomfortable with this—perhaps because my career as a consultant has awarded me with practical experience with a fairly large number of organizations. In every one of them, I think, I have seen the

crucial role of both the individuals that make them up and the environment they work in.

Organizations Are Constructed

Theories are by their very nature always simplifications of reality, not least when the subject is human behavior in and around organizations—and the reason is not only differences in contingencies such as history, cultural settings, ages, and power structures. It is easy to lose sight of the simple fact that organizations are not physical entities acting and behaving on their own, but *derived* entities—wholes that are constituted through the actions of the individual human beings that make them up. Those humans have their own peculiar characteristics, dreams, objectives, and preferences, and the character of the organization, its successes and failures, is the result of an interplay both between those individuals and between them and other individuals outside the organization itself.

My experience therefore supports most of the basic views of Silverman, Weick, Berger and Luckmann, the social constructivists, and some (ontological) postmodernists such as Clegg. Organizations are constituted through the daily actions of their members and of the people they deal with in the environment, directly or indirectly. Organizations do not act; it is the people constituting them who act. Even single individuals can be of decisive importance in shaping the fate of very large organizations. The spectacular rise of ITT, for instance, is probably attributable to Harold Geneen (and, arguably, so is its fall), and the growth of IBM up to around 1950 was no doubt to a large degree a result of the vision, ruthlessness, and willpower of Thomas Watson, Sr. Further, IBM's phenomenal success as a computer company in the following four decades was not the result of an inevitable development, but primarily a consequence of the stubborn effort displayed by Tom Watson (son of Thomas). Keenly interested in the new machines, he defied his father's skepticism and, together with a small team of corporate mavericks, managed to develop and produce first the 701, IBM's first digital computer, and then the remarkably successful 650—all against strong, persistent opposition from IBM's planning department, who could not see any need for machines more powerful than the company's existing punched card equipment (Augarten 1984).

There is also no doubt that Henry Ford was the driving force behind the ascendancy of Ford Motors, or that (in Norway) there would have been no Norsk Hydro (or even Elkem) without Sam Eyde's vision, tenacity, and unsurpassed energy.

Even in the absence of such singular entrepreneurs, two organizations that are formally very similar—for instance, two Norwegian municipal administrations of the same size and in the same part of the country—can be very different in how they work, how efficient they are, what their main problems are, and how receptive they are to change. Many of the dissimilarities can simply be traced back to the differences between the actual persons working in the two organizations, especially the differences between their most significant members (which usually include not only managers and local trade union representatives, but also strong personalities with informal influence over others). Even persons who no longer work in the organization may cast long shadows, clearly visible in the daily

proceedings—both as symbols of unity (or discord) and through their legacies in the form of policies and procedures.

When organization members act, however, they will of course be influenced—often heavily—by the interpretations of meaning that their roles in the organization imbue them with. They act within a set of frames² (Goffman 1974) that to a large degree incarnate the collective interpretations of both other organization members and important persons and collectives outside the organization. Persons with important roles in an organization are therefore often perceived as acting for the organization, and the organization as “acting” through those persons. Clegg’s concept of *modes of rationality* also fits neatly into this framework. Acting within their local frames, agents will use the means available and allowable to construct their organizations in a way that meets their purposes. Since frames will be different in different parts of the world, and even within different local regions in the same society, modes of rationality will also differ, and no single organizational solution will achieve total domination—although solutions that are successful in certain settings may inspire actors elsewhere to adopt certain aspects of them that are compatible with the local conditions. Wholesale transplantations may also be tried, but are sure to run into trouble.

Over time, there will of course be recurring patterns of action in organizations, certain actions will acquire a commonly understood meaning, and expectations about the durability of certain patterns of action will grow. These sets of expectations will be quite resilient; organizations can retain a remarkable degree of stability even with a high turnover of people, and can endure great stress without breaking. They can also continue to cling to life through year after year of unsuccessful operation (Meyer and Zucker 1989). Even when an organization is economically and legally dissolved, as after a bankruptcy, it happens—not infrequently—that a number of the people who constituted that organization will reconstitute themselves as a new organization with roughly the same purpose and many of the habits of the old one. The ingrained resistance to any change of routines and ways of working in almost any organization is another manifestation of the strength of recurring patterns of action.

But They Are also Systems

However, organizations also clearly exhibit systemic properties. A defining characteristic of a system is that it is more than the sum of its parts (Bertalanffy 1973). That is, if we study the individual cells that make up a fox, we cannot deduce the full nature or the behavior of the fox. By dissecting the fox, we destroy

² A *frame* is a scheme of interpretation that makes it possible for us to interpret, organize, and make sense of particular events and actions. Frames are therefore also expressions of the generally accepted norms in the social domains where they are valid. The same event may have very different interpretations in different frames. For instance, crying in a funeral is generally positively regarded and readily understood, while laughing would meet with strong resentment. In a meeting with old friends, however, laughter would be the normal thing, and crying would be met with puzzlement and concerned questions about the reasons. In a ceremony such as the opening of a new session in parliament, both laughter and crying would be regarded as improper. We all recognize a very large number of frames. Some are more or less universal, many are common to most people within a particular society, and many are local.

it and lose sight of its systemic properties. The same is true for social systems: if we only study people acting in a social void, we cannot understand cooperation. If we only receive a description of isolated, single acts carried out by the members of an organization, we cannot comprehend its structure and dynamics—and, just as important, neither can we understand the single acts, because their meaning, the frames they are conceived in (and by which they must be interpreted), contain such systemic information.

When people engage in the kind of partly regulated and partly bounded interaction that occurs in organizations, their interaction (interlocked behavior, in Weick's [1979] terms)—and hence the organization itself—therefore acquires a systemic character: actions are directed toward others, who interpret them in terms of their own frames and act in response to that. People thus receive feedback on their own actions and may modify them according to their own interpretations of this feedback.

Even people who are not intended targets of a particular action may choose to interpret it as something that concerns them, and act accordingly, with ramifications not only for the original actor but for others in the organization as well. The universe of actions that constitute an organization is therefore dynamic, with patterns of actions and reactions reverberating through it, over time creating the recurring patterns of action mentioned above. We then have a system that exhibits both stability and dynamism. It shows stability in the sense that it is a recognizable social entity with roughly defined roles and a relatively predictable behavior. It is dynamic in the sense that its constituting members will change and that they over time will come up with new actions and establish new patterns of action.

Since the organization members all have relations with people in the organization's environment, and indeed its business transactions are built upon such contact, all organizations are also open systems. Changes in the outside relations, in the problems and opportunities they represent, will provide major impetuses for internal changes. Organizations where the members, especially the leading members, are not able to interpret important changes in the environment in an adequate way, or do not respond to them, will soon be in trouble, which testifies to the fact that the stability of open systems is a precarious stability: it requires continuous effort to maintain. This is, by the way, in accord with Ashby's law of requisite variety (Ashby 1956), which says that to survive, a system must contain within itself greater variety than the variety it is confronted with by its environment³.

If organizations are systems, then, it follows that they have characteristics that arise from their systemic nature, and not from the actions of any single individual. This is a salient point—and a point of controversy for at least some action theorists, as Silverman (1970) notes. For if organizations are constituted only

³Humans are so successful as biological systems because they are extremely flexible with respect to food, organization, and tool use. Insects and bacteria flourish because of their prodigious breeding capacity, which allows a very rapid proliferation of successful genetic combinations or mutants. Humans, insects and bacteria thus all possess a large capacity for rapid variation. Most large animals do not: an example is the koala, whose numbers dwindle in step with the diminishment of the Australian eucalyptus forests.

through the actions of their individual members, there seems to be no room for characteristics that are not traceable to one or a number of individuals.

I think this paradox is resolved when we take a closer look at the nature of systems—both systems in general and the peculiar class of systems that we call organizations. Systems are composed of parts, and real systems⁴—such as foxes and organizations—can be physically divided into their constituent parts. However, the systems are not defined only as the sum of their parts, but also (and indeed primarily) through the *interrelations* of these parts.

This means that the systems characteristics of organizations emanate first and foremost from the *interactions* of their members. Of course, they have to be manifested through concrete actions by concrete people, but since the conception of every significant action in the organization is influenced (to some degree) by the complex interactions and the established expectations within the organization or toward people in its environment (often both), the systems characteristics emerge *as a quality of the individual actions themselves*.

And Contingencies Matter

If organizations are systems, then, their systems characteristics become important. What are the recurring patterns of action like? Are they different from organization to organization, or are there similarities? Maybe some internal and environmental conditions are important?

This is leading toward the questions posed by contingency theory, and I see no reason to back away from them, since I think there are regularities in the systems characteristics of organizations, even if no two organizations are completely alike—just as most people have two arms and two legs despite their individual differences, and most small children giggle when tickled, no matter what culture or nationality they belong to. Galbraith (1977) addressed this question (Is there a general theory relevant to a specific organization?) in the introduction to his book *Organization Design* (p. 7–9). His conclusion, based on interpretations of empirical studies, was that 50% to 75% of the variance in organizations could be accounted for by general theoretical propositions, leaving the rest to specific factors peculiar to the individual organizations. This means that no organization can be understood apart from its history, its particular setting, and the particular individuals who dominate it, but neither is any organization isolated from more general relationships.

One can probably differ in opinion on how much of the variance can be explained by general propositions—that proportion will vary, among other things, according to the cultural homogeneity of the sample—but there is, in my view, ample evidence that there is indeed a mix. Therefore, we have no choice but to approach the analysis of organizations on several levels: that of the individual actor, that of the single system, and that of the system in its environment. Important insights can be gained on either level; they are all significant for organization design and organization change, and all are relevant for my present purpose.

I would also like to repeat here the gist of some of the statements I make toward the end of the summary in Appendix A. The fact that a lot of the variation

⁴ There are also conceptual systems, such as logic and mathematics (Bertalanffy 1973).

in actual organizations is due to individual factors that are unpredictable on a theoretical level does not mean that organizations have no regularities at all. The view that any perspective is as valid as any other, or that theory “cannot be evaluated by its capacity to predict” and thus gains its only value “by the way it figures in ongoing patterns of relationships” (Gergen 1992, p. 210) borders dangerously on theoretical anomie and seems to exclude the possibility of conscious design and organizational development.

To me, it is proof enough that experience demonstrably improves people's ability to understand organizations and to operate inside them. People who have worked their way through a number of organizations develop a “feeling” for organization that makes it possible for them to understand the nature and peculiarities of a new exemplar both faster and better than others. Talent for understanding human affairs also helps, and seasoned practitioners can become very adept in organizational coaching even without formal training or knowledge about organization theory. If organizations had nothing in common, if there were no basic rules that applied to how people behave in them, it would be simply impossible to learn from experience in this way; you would be back to square one every time you encountered a new specimen. The mere existence of theories-in-use (Argyris 1980) implies regularities and common traits in organizations that can be made the subject of explicit theories as well.

The Space of Constructible Organizations

The problem posed in the introduction, which was the starting point of my research efforts, was the apparently innocent question of what organizations based on innovative use of information technology would look like. An effort to answer that question cannot, as stated earlier, build only on empirical evidence of past and present achievements, since we are only beginning to learn how to use computers. Rather, we must try to map out the space of possible organizational arrangements after the introduction of computers. We can now outline this problem more precisely.

As acknowledged above, organizations are shaped by a great number of factors. Not only the traditional contingencies apply. Clegg (1990), for example, drawing on a large, cross-cultural selection of studies, presents a convincing case for the way cultural, technical, economic, and other contingency factors can influence people to assemble their organizations in innumerable ways—and still operate them successfully, both domestically and when exposed to international competition. In addition comes the fact that organizations are constructed by real humans, exhibiting great variation in their dispositions and goals.

Building on this, we can say that the space of possible organizational solutions in any particular situation is determined by the *local mix* of relevant contingency factors at that point in space and time, including the normal range of individual characteristics of the members of that society, as well as their local social norms and arrangements. We can call this space the *local space* of possible organizations. Acknowledging our inborn limitations as humans, we can also safely conclude that there must be some absolute limits to what we can achieve, defined jointly by our biological nature and the capability of the available tools. These limits define what we might call an absolute space of all possible organizational solutions.

However, this absolute space is not constant, nor is it entirely defined by nature. I will therefore avoid the term “absolute space” and replace it with three concepts that reflect the mixed nature of humans: on the one side, we are biological creatures with a set of biologically defined characteristics, like other animals; on the other side, we have an extreme social and cultural plasticity and creativity, providing a potential for development that is utterly different and superior to that for any other creature on Earth; but even so, there are things we do not do, even if we could actually accomplish them.

The first of these concepts I will call the *primal space* of organizations. It is defined by man’s biological characteristics and basic psychological and social needs—the possible organizations of the human animal, if you like. The second one I will call the *space of constructible organizations*. It represents the expanded organizational space made possible by the tools, methods, and social practices developed by man to relieve the limiting constraints of the primal space. The constructible space encompasses all existing local spaces. In fact, it is equal to the sum of all local spaces.

While the primal space is by and large constant (changed only by biological evolution), the constructible space is changing all the time. Generally, it also expands, since new technologies and the evolution of methods and customary practice tend to increase the number of alternatives. Of course, developments in social and moral attitudes will over time render some customary arrangements unacceptable (such as slavery and serfdom in our parts of the world), but such curtailments have so far not remotely matched the increases in variation. The arrow has thus pointed largely in one direction, and only a major loss of technological, methodological, or social capability through a global catastrophe could possibly lead to a significant contraction in the constructible space.

The third concept is the *technical space* of organizations, which is defined solely by what should be possible given humanity’s physiological capabilities extended by the existing technology and methods, thus excluding psychological, social, and cultural constraints. It will, of course, be larger than the constructible space, since it is always possible to imagine physically feasible organizational solutions that will not be psychologically feasible or socially acceptable in any actual situation, and thus impossible to realize within any local space.

My prime interest is the constructible space and how it is extended by information technology. However, as a step on the road, it is necessary also to try to outline the primal space, and the way the constructible space has grown with the development of tools and methods. Since many people in the computer business also show tendencies to equate the technical space with the constructible space, in blithe ignorance of the social and psychological needs and preferences of normal humans, it will also be necessary at various points to discuss some of the main differences between the two.

Defining the Boundaries of Constructible Space

What, then, defines the boundary of the constructible space? Obviously, the number of factors is large, and an exhaustive analysis is probably impossible. Analytically, at least, we can discern four broad classes of factors, hinted at above, which are the most significant:

- ♦ **Biological characteristics:** Obviously, we cannot build organizations that presuppose telepathy, unlimited human memory, or the ability to engage in five conversations simultaneously or to run at the speed of five hundred miles per hour. We have some definite physiological constraints that limit what we can do.
- ♦ **Psychological characteristics:** As humans, we have a psychological makeup that limits what we can accomplish and tolerate in daily life. The limits here are quite fuzzy; they vary strongly with the circumstances. For instance, people can endure much higher strain in a crisis (such as a war or disaster) than in a normal work situation. Also, organizations are not infrequently set up in such a way that some jobs have quite harmful psychological (and in turn even physical) effects on the incumbents. The constructible space is therefore not limited just by what is harmful, but by what is generally recognized as either harmful enough to impair the organization, or as too harmful to be acceptable. Indeed, much of the substance in the work of the labor unions since their inception has been to reduce the acceptable range of harmful working conditions.
- ♦ **Social and cultural factors:** This class comprises social organization (including family systems), culture (including knowledge, norms, and laws), and social institutions in the fields of religion, economy, and politics. It is obviously of great importance to the definition of the constructible space. A special case here is the sphere of illegal organizations, like the Mafia and other agencies of organized crime, and organizations that defy commonly accepted norms, such as organizations of various kinds of dropouts. Insofar as they are fairly stable, de facto elements of most societies, they must clearly be viewed as being inside the constructible space: in fact, it is easy to show how they comply with the local mix of contingency factors in their particular sub-culture, and thereby define a viable local space. Borderline cases will be organizations such as the extermination camps of Hitler's Germany, the gulags of Stalin's Soviet Union, and the concentration camps of other, lesser perpetrators, which may be defined either as temporary, freak outgrowths of the constructible space or as a genuine part of the constructible space to which access is (fortunately!) normally hindered.
- ♦ **Available tools and methods:** Analytically, tools and methods can be viewed as two different classes of factors. However, they are so often intertwined that it seems more appropriate to group them together: writing is not possible without writing materials, nor is accounting; lateral filing requires special equipment; and so on. Sometimes it is also difficult to draw the line between a method

and a social practice in association with a tool: the clock is certainly a tool for timekeeping, but is the practice of reliably reporting to work at a particular time every day (so necessary for certain organizational forms) a method or a social practice? Perhaps it is both—a basic instance of a method for coordination that has become an ingrained part of the social fabric of industrialized societies.

The example of the concentration camp underlines an interesting feature of constructible space: As one moves toward its boundaries, it becomes more and more difficult to actually construct and maintain an intended organization—sometimes because it pushes the limits of generally accepted norms, sometimes because it verges on exceeding the tolerances of human psychology or physiology, and sometimes because it stretches technology toward its limits.

If we were modern social physicists, then, we might endeavor to create field equations for the constructible space—and discover that there is a Great Attractor at its center, perhaps in the form of the rationalized myths of our societies (Meyer and Rowan 1977), which shape the organizations we build unless we consciously (and at the price of a considerable effort) go in another direction. Now, social physics is an antiquated approach, and field equations are hardly viable tools in the social sciences—but as a metaphor, they can be useful. All local spaces will have their own set of attractors in the form of traditionally preferred organizational forms, and it will always take vision, boldness, and energy to go against tradition and construct something new.

For an organizational form to fall within the constructible space, it is, of course, not a requirement that every particular instance of that form survives. It is, for instance, perfectly possible to set up a new organization in a market where the competition is too tough for most newcomers to make it; indeed, this happens regularly in open, market-oriented economies, as entrepreneurs often overestimate their chances and end up in bankruptcy. The point is that it is possible to set up that kind of organization at all. Environmental factors such as the number of existing firms in a market or the profitability of a certain line of business is therefore not a factor in defining the constructible space.

The Scope of This Investigation

The object of this investigation is to understand how and why information technology extends the boundaries of the space of constructible organizations. Obviously, it is impossible to discuss all possible permutations; to make a significant contribution without overextending my undertaking, I will have to concentrate on what I believe are the most important factors involved.

Our Biological Characteristics

As indicated above, I consider the first class of factors, our physiological characteristics, to be the most basic determinants of the size and shape of the constructible space. These constraints can also be assumed to be constant on the timescale of interest to us here. Proper training can improve individual performance, but our basic capabilities have probably remained basically

unchanged for tens of thousands of years. It is these that represent the iron constraints that put absolute limits on human achievements. It is also these constraints that we have most eagerly attacked with the help of technology and methods—not only because they are so unyielding in nature, but also because they are the ones that are most open to amendment by such means. I will therefore discuss these constraints in considerable detail, and base most of my analysis on them and the way they are alleviated by technology.

Our Psychological Characteristics

The basic situation is probably much the same for the second class of factors, our psychological characteristics. That is, they have been constant for a very long period of time. However, they are a lot more pliable than our biological capabilities, at least in the way they manifest themselves. The limits for the amount of aggression or compassion that can be expressed, for instance, or the amount of psychological stress a person can endure, are to a considerable degree determined by social and cultural factors. We do not find this kind of variation in talking speed or in the number of items that can be held simultaneously in short-term memory.

Since our psychological attributes seem to be both less limiting to our organizing abilities and less amendable by technology, they have received scant attention in the development of computer-based systems. The exceptions are, of course, the user interface, which has received much notice over the last ten to fifteen years, as well as methods and strategies for introducing computer-based systems in organizations. The crucial importance of the introduction process has received increasing attention as systems have become more complex and comprehensive, and as evidence has grown on the problems that come from poorly planned system introductions.

Both of these factors as well as the size and vigorousness of the market for computer games and gimmicks such as cartoon-like screen savers, “eyes” that follow the cursor around, and so on, suggest that emotions and other nonrational parts of our psyche may be more important in our interactions with technology than normally recognized by computer professionals. Although the subject is somewhat elusive, I have found it difficult to leave it out altogether, especially since I believe emotions play a very important part in deciding the viability of a number of computer applications, not least in the “groupware” category. I have therefore included discussions on the role of emotions in several of my analyses.

Social and Cultural Factors

Social and cultural factors are, of course, even more malleable than our psychological characteristics, as we can see from the great variation found among the societies in the world today and in historic times. Their influence on the size and shape of the local constructible space is great but so varied that it constitutes a vast field of study in itself, challenging not only the discipline of sociology but almost all of the social sciences. This makes it impossible for me to incorporate social and cultural factors into my analyses—other than as examples to throw light on particular problems—with one very important exception: the tools and methods we use and have used to construct our organizations.

Of course, this does not mean that the present analysis is culturally neutral. Although I have strived toward a dissociation from my particular social and cultural background, I readily acknowledge the fact that a complete neutral stance is simply not possible for any human. My analysis will therefore obviously be most appropriate for the Western industrialized sphere. However, I also believe that humans have enough basic traits in common to make the analysis valid, to a large extent, even in other cultural settings.

Tools and Methods

Tools and methods are both creations of the human mind, and as such they are wholly constructed expressions of both knowledge and social values. A computer is indeed a cultural manifestation, and a mighty one at that.

Tools and methods also represent the most pliant class of factors with bearing on the space of constructible organizations, and is by far the class subject to the most rapid development. For the last several hundred years at least, the development of tools and methods have arguably outpaced all other patterns of change in human society, and the speed is not getting lower.

As I noted above, tools and methods can be roughly separated analytically, but in practice they are intimately connected and often intertwined, and will more often than not have to be discussed as combined phenomena.

This brings us back to an implication that was raised in the discussion on biological characteristics: it is, of course, a central question just *how* new tools and methods make their undisputed contributions to changes in social and cultural conditions (which include organizations). However, if we believe that the basis for the construction of the social fabric (and of organizations) is the individual actions of the members of that society, *it follows from our conclusions above that the direct influence of tools and methods must come from the way they change and enlarge the realm of possibilities for individual actions. And such changes must spring mainly from enhancements of our basic, physiologically defined capabilities.*

The main analytical thrust in this dissertation will therefore remain **the augmentation of our natural, biological constraints by technological means (including both tools and methods), and what kinds of extensions to the space of constructible organizations these augmentations will allow.** To get started, then, we must first decide which of our abilities (or constraints) are most important to our ability to organize.

3 The Basic Preconditions for Organizing

"I am certainly convinced that it is one of the greatest impulses of mankind to arrive at something higher than a natural state."

James Baldwin, "The Male Prison," in *Nobody Knows My Name*, 1961

The Essence of Organization

I have stated that organizations, in my view, are constructed; like any other kind of social system, they are constituted through the actions and interactions of their members, both between themselves and with people in an organization's environment. I also said that the systems characteristics of organizations emanate precisely from these interactions and manifest themselves as a quality of the individual actions themselves. By enhancing the abilities and capacities of the individual organizational members, then, the use of tools will tend to alter the systems characteristics of the organization as well.

Further, the most important systems effects must be those that arise from the types of recurring patterns of actions most common to organizations: the actions that aim to carry out their basic functions, and thus constitute what we may call their structure. To discover the main enabling qualities of new tools, we must therefore identify the human abilities and constraints that are most important to those basic functions. For this purpose, I will mainly use Mintzberg (1979), Galbraith (1977), and Nadler and Tushman (1988). I use Mintzberg because his models sum up the work of numerous others (and also offer a number of concepts that will be very useful later on), Galbraith because it is perhaps the most quoted work on organization design, and Nadler and Tushman because they expand and elaborate on Galbraith on a number of issues.

Defining Organization

What, then, constitutes the essence of organization? What are the basic features and functions of organizations? When sifting through the literature on organization theory, one is struck by the fact that although nearly everyone

complains about how difficult it is to define “organization,” they still tend to end up stressing largely the same central features. At least this holds true for theorists in what we may call (for want of a better term) the systems or contingency tradition, and for people with consulting or management experience.

Henry Mintzberg goes right to the core in the first pages of his book *The Structuring of Organizations* (1979) with his illustrative story about the potter Ms. Raku, who started out making pottery in her basement. She did everything herself, just like any ancient craftswoman—wedged the clay, formed the pots, tooled them, prepared and applied the glaze, and fired the pots in the kiln. She then marketed and sold the pots to craft shops. Everything went smoothly; there were no problems—except that demand outstripped supply.

Ms. Raku then hired an assistant who was eager to learn pottery, and everything still went without hassle, even though Ms. Raku now had to divide the work. The assistant wedged the clay and prepared the glazes, and Ms. Raku did the rest—since the shops wanted pottery made by *her*. It required some coordination, but since they were only two, and worked in a small studio, it posed no problem.

Before long, however, Ms. Raku was again outselling the production capacity. More assistants were needed and, even with three new people, coordination could be conducted informally. But as still more assistants were added, Ms. Raku faced more serious problems. There were simply too many people to coordinate everything informally and without plans, and, besides, Ms. Raku was now mostly away from the studio, spending time with her growing number of customers. The time had come for the first assistant to become studio manager and full-time supervisor.

Ms. Raku’s ambitions were limitless, and the company continued to grow, branching out into new product lines (even clay bricks) and new customer groups. Eventually, she was the proud president and owner of the large, divisionalized company Ceramico, with her office located on the fifty-fifth story of Pottery Tower. Ms. Raku and her company had traversed the history of human organization in a couple of feverish decades.

Mintzberg concludes this introduction (p. 2, italics and boldface in the original) by making the following observation:

Every organized human activity—from the making of pots to the placing of a man on the moon—gives rise to two fundamental and opposing requirements: the *division of labor* into various tasks to be performed and the *coordination* of these tasks to accomplish the activity. **The structure of an organization can be defined simply as the sum total of the ways in which it divides its labor into distinct tasks and then achieves coordination among them.**

Jay R. Galbraith (1977), for his part, starts out with an intuitive definition of what constitutes organization (p. 2):

As a beginning, it can be said that organization is that “something” which distinguishes any collection of 50 individuals in Kennedy International Airport from the 50 individuals comprising a football team in the National Football League.

After an example dealing with spontaneous organization in the wake of such disasters as hurricanes, floods, and earthquakes, quoting Thompson (1967) he concludes (p. 3):

We can say that organizations are (1) composed of people and groups of people (2) in order to achieve some shared purpose (3) through a division of labor (4) integrated by information-based decision processes (5) continuously through time.

These definitions are what Scott (1987) would term rational systems definitions of organizations: they do not include either the informal communication and conflicting interests of the natural systems definition, or the relation to the environment of the open systems tradition. Both informal aspects of organizations and relations with the environment are also vital parts of action and constructivist perspectives. However, all the authors quoted here are aware of both aspects and discuss them in their books. We shall return to these subjects, but first we shall explore the main structuring features of organizations—not least because there is reason to suspect that the human abilities that are most important to them will also be the central ones for actions involved in both the informal side of organizations and their connections with the environment.

The Need for Information

According to Galbraith, an organization must have a domain for its activity, and it must have a set of objectives and goals. There is great variation as to how consistent and explicit domains, objectives, and goals are, but it is difficult to envisage an organization completely without any kind of consciousness about a common domain and some common objectives; we would then really be confronting something that was more akin to the accidental collection of fifty people in Kennedy International Airport. Next, an organization must have what Galbraith calls an *organizing mode*—a way of decomposing work into subtasks and a way of coordinating them for the completion of the whole task. It must then have a way of integrating individuals into the organization—of selecting and training people and of rewarding them so they stay and actually do what the organization requires. And it must (to be successful) strike a balance between these three elements so that they harmonize internally as well as with the challenges of the environment.

Again, we see the stress on the division of labor and the coordination of work as a central problem for any organization. Galbraith further postulates a close correlation between task uncertainty and the amount of information decision makers must process in order to achieve a given level of performance, and he also maintains that the required level of information processing will have a decisive influence on organization structure. In other words, the amount of uncertainty determines the amount of control and coordinative activities that will be needed, which again translates into certain required levels of information processing. He therefore ends up with an *information processing model of organization* as the basis for his design framework.

Nadler and Tushman (1988), building on Galbraith (1977), elaborate this further in their "Information-Processing Model for Organizational Design." They

argue that “the fundamental function of organizational arrangements is to process information,” and that the main determinant for organizational structure is the information processing requirements of the tasks the organization is there to take care of. Their three basic propositions are (1988, pp. 55–62):

1. *“Different tasks pose different information-processing requirements.”*
Tasks vary in:
 - their predictability
 - the degree to which they are environmentally impacted
 - the degree of interdependence of the task elements
2. *“Different organization designs provide different types of information-processing capacity.”*
The main organizational elements are:
 - the grouping of work functions, positions, and individuals
 - the structural linking (the formal connections between different groups)
 - the management and operational processes (such as information systems, control systems, goals, meetings, and reward systems)
3. *“Organization effectiveness will be greatest when the information-processing capacities of the structure match, or fit, the information-processing requirements of the task.”*

All the views referred to above are in close accordance with general systems theory, which claims to be a general theory of organization in physical, biological and social systems, and which has had substantial influence on organization theory for the last three to four decades. Drawing on the writings of people such as W. Ross Ashby (1962), Kenneth Boulding (1956), Walter Buckley (1967), and Ludwig von Bertalanffy (1973), we can conclude that general systems theory defines organization mainly in terms of communication. As Buckley says (1967, p. 82):

It should be of particular interest to us that the modern systems theorist links closely the generalized concept of organization to that of information and communication, because—as we have seen—the socio-cultural system is to be viewed as a set of elements linked almost entirely by way of the intercommunication of information (in the broad sense) rather than being energy- or substance-linked as are physical or organismic systems.

James G. March and Herbert A. Simon, in their *Organizations* (1958), note in the first page of the book that organizations are “empirical phenomena, and the world has an uncomfortable way of not permitting itself to be fitted into clean classifications,” and that their purpose (in the book) did not require an “exact distinction between an ‘organization’ and a ‘non-organization’.” However, they also stress the high degree of coordination in organization behavior (p. 4, italics in original):

A biological analogy is apt here, if we do not take it literally or too seriously. Organizations are assemblages of interacting human beings and they are the largest assemblages in our society that have anything resembling a central coordinative system. Let us grant that these coordinative systems are not developed nearly to the extent of the central nervous system in higher biological organisms—that organizations are more earthworm than ape. Nevertheless, the high specificity of structure and coordination within organizations—as contrasted with the diffuse and variable relations *among* organizations and among unorganized individuals—marks off the individual organization as a sociological unit comparable in significance to the individual organism in biology.

In his foreword to the third edition of *Administrative Behavior*, however, Simon ventures further and offers a definition (1976, p. xvii, italics in original):

In the pages of this book, the term *organization* refers to the complex pattern of communication and relationships in a group of human beings. This pattern provides to each member of the group much of the information and many of the assumptions, goals, and attitudes that enter into his decisions, and provides him also with a set of stable and comprehensible expectations as to what the other members of the group are doing and how they will react to what he says and does. The sociologist calls this pattern a “role system;” to most of us it is known as an “organization.”

Since Simon views the organization mainly as a decision-making system, coordination and control for him become synonymous with communication of decision premises and decisions. Elsewhere in the book, he further emphasizes the importance of communication as “essential to the more complex forms of cooperative behavior” (1976, p. 106), and he is very clear about the need for stable, predictable cooperative patterns and communication channels if an organization is to operate efficiently.

Basic Elements in Organization Structuring

Most writers, then, seem to agree on the basic features of organizations: the *division of labor*, the concomitant *need for coordination*, and the fundamental requirements for *information processing* and *communication* that the coordination needs give rise to. Information processing and communication are also pivotal for the ceaseless adaptation to the environment to which organizations must commit themselves in order to survive.

The Division of Labor and Structuring of Work

The division of a greater, common task into smaller ones that are suitable for single persons is the defining feature of purposeful organizations. In principle, there are two ways of dividing work: Everyone can do the same, miniature version of the total task, as when fifty persons go together to clean up a beach and all collect litter in their own plastic bags, or the total task can be divided into specialized subtasks.

Practically all purposeful organizations belong to the latter category, simply because there are extremely few of them that have tasks so simple that it is

possible for every organization member to do exactly the same thing. Once the overall task is divided into more or less specialized jobs, it becomes a challenge to structure those jobs by grouping them (and thereby the people who execute them) in a way that ensures both that the organization's mission is accomplished and that the efficiency of the operation is sufficient to ensure the survival of the organization.

Grouping Tasks

Tasks can be grouped in many ways, and grouping is a very important determinant for organizational performance. Grouping is necessary to establish a system of coordination and supervision, of resource sharing, and of performance measurement (Mintzberg 1979). The basis for grouping can be either activity, output, or customer. These three categories can be further decomposed, and Nadler and Tushman provide a good classification (1988, p. 68), which is also in rough accordance with Mintzberg (1979).

Grouping by activity

- By function As when the different steps in a production process are organized as separate departments.
- By work process As when different processes are organized as departments, e.g., when a printing shop has one department for offset and another for letterpress.
- By knowledge/skills/discipline As in universities and many research institutes.
- By time As in shift work.

Grouping by output

- By product As when a dairy has separate departments for the production of cheese, milk, and other milk products, such as yogurt.
- By service As when a consulting company has separate departments for management consulting, telecommunications, and programming.
- By project As when engineering companies set up separate project organizations.

Grouping by user/customer

- By market segment As when telephone companies have separate organizations for handling businesses and residential customers.
- By user/customer need As when there are separate departments to handle low-volume and high-volume buyers.
- By geography As when markets are divided into regions, each served by different organizational units.

Most often, different bases for grouping are used at different levels in the organization. For instance, top management may be grouped according to

function (marketing, finance, production, etc.), the middle level according to market or product (or both), and production according to process or function. The reason is, of course, that different criteria for grouping may apply at the various levels. Mintzberg counts four such criteria, all related to important interdependencies (1979, pp. 115–124): work-flow interdependencies, process interdependencies, scale interdependencies, and social interdependencies.

- ♦ **Work-flow interdependencies:** To Mintzberg, this category embraces all kinds of interdependencies between separate tasks or stages in a functionally specialized organization. Mintzberg, Galbraith, and Nadler and Tushman agree with Thompson (1967) that there are three basic kinds of work-flow interdependencies: Units exhibit *pooled interdependence* when they operate independently but share scarce resources, they have *sequential interdependence* when they pass work from one to the other through a chain, and they exhibit *reciprocal interdependence* when there are loop-backs in the production cycle, so that a product may go back to earlier stages or even back and forth several times. An example here could be a person who is rushed to the hospital after a car accident, going to the intensive care unit, from there to x-ray, back to intensive care, to surgery, to postoperative, back again to intensive care, maybe to surgery for a second time, and so on. Evidently, the coordination needs are smallest for an organization with pooled interdependence and greatest for one with reciprocal interdependence.
- ♦ **Process interdependencies** (interdependencies within specialized functions): *Process* here denotes the separate work processes that together comprise the work flow, such as machining and welding in an engineering workshop or damage assessment and claims processing in insurance. The interdependencies here usually relate to skill and knowledge, which are easier to develop in groups, where experts can assist and learn from each other. Process interdependencies may be particularly strong in highly professional work (as in hospitals, universities, and R&D organizations). In casework, grouping experts together will make it easier to achieve consistency in judgment and decisions.
- ♦ **Scale interdependencies:** Scale considerations are sometimes important. It is usually not economical for each department in a company to have its own cafeteria, for instance, and maintenance crews may be set up to service a whole factory or even several factories to achieve enough volume to keep an adequate staff.
- ♦ **Social interdependencies:** Grouping should allow at least a minimum of social interaction, to avoid boredom and fulfill social needs. In addition, it is always advantageous (and even critical sometimes) to pay heed to strong, personal antipathies and sympathies.

When organizations are drawn between conflicting criteria, as they often are, they must either choose the one they deem most important or, if the conflict is too pronounced, try to accommodate it by creating various kinds of matrix organizations. The most common conflict is between product/market and function/process, but in many industries there is also conflict between product and market considerations. A common solution is then to have one array of managers with responsibility for one set of considerations, and a second array for the other set. There are even examples of three-dimensional matrixes, with functional, product-, and market-oriented axes (Mintzberg 1979).

Coordination

Information Processing and Communication

Grouping is in itself the primary instrument for coordination. Usually, we (quite intuitively) try to group together those functions that seem to have the most immediate interdependencies. The reason is, of course, that physical proximity allows richer communication, and, generally, the richer the communication, the closer, swifter, and more flexible the coordination. The primary group, where coordination is effected through informal communication and where feedback is immediate, is the building block of all organizations. Today we tend to call this primary group a team, especially if the group members are on a more or less equal footing with respect to decisions.

However, while informal communication may be quite sufficient for the coordination of individual activities within the primary group, it cannot support the necessary coordination within and between the larger units in the organization. To accomplish this, the organization has to communicate and process large amounts of information across groups and units. To quote Galbraith (1977, p. 41), "The organization design problem is to create mechanisms by which an integrated pattern of behavior is obtained across all the interdependent groups."

According to Mintzberg, there are three main flows of information involved in coordination in any regulated system such as a purposeful organization (1979, pp. 37–46):

- The information part of the operating work flow

The operating work flow is the flow of work through the producing part of the organization, what Mintzberg calls the "operating core." In manufacturing firms, the work flow itself is mainly material; in a service organization it is often information in the form of documents. Along with these objects under transformation, there is also an accompanying flow of pertinent information, such as work documents and time sheets, and even oral instructions and ad hoc information.

- The flow of control information and decisions

The main bulk of information associated with coordination falls in this category. Information about actual performance and problems flows upward in the hierarchy; directions and plans move in the opposite direction.

- The flow of staff information

Most organizations larger than a handful of people have some kind of staff functions, and larger organizations may have sizable staffs. The staffs typically have a large number of contacts with the line, both institutionalized and ad hoc, involving exchanges of information. It is usually operating data that flow toward the staff, with professional advice or plans and programming coming back (in a bureaucracy, the actual manuals containing the detailed regulations for work and decisions is usually a staff product).

All of these flows have to be taken care of in order to make an organization function properly, and this is where we hit the main challenge of organized work. Indeed, all the authors reviewed here view communication and information processing as the main bottlenecks for organized activities, although perhaps Galbraith expresses it most clearly. To him, information processing is therefore the focus of design, and he believes that organizations will seek to reduce the need for information processing as much as possible. In addition to the effects of grouping, they will preplan as far as the environment allows, and only maintain the flexibility that is needed to cope with the variations the environment forces upon them. If they can, they will in fact try to influence their environment to make it more stable, and if their competitive situation allows it, they may create slack resources in order to tolerate lower internal performance.

If this is not sufficient, an organization will have to increase its information processing capacity in order to cope. According to Galbraith, two main alternatives are open: to improve its vertical information processing capacity (this is where Galbraith sees an important role for computers), or to create lateral relations. Since the processing capacity of the hierarchy is bound to be quite limited, the development of lateral relations is seen as the main remedy (we shall return to this a little later).

Coordinating Mechanisms

If a group is sufficiently small, coordination can occur naturally through informal communication between the group members. That is the secret of the small team's flexibility. In Mintzberg's example of the growing pottery business of Ms. Raku, coordination was addressed in the first phase. Ms. Raku and her first few assistants divided the work among themselves, and easily coordinated their activities because they were all in the same room: each one could see what the others did, and most of their conversations were group-oriented and included all the workers. They were all constantly updated on the activities and immediate intentions of all the others. Mintzberg (1979) terms this basic coordinating mechanism *mutual adjustment*.

However, mutual adjustment through informal communication demands a high volume of communication. Ideally, every member of the group must communicate with every other member—or, at least, all the members must listen in on the group's shared dialogue, and contribute the relevant information about their own actions and needs. Obviously, when the group expands, the required volume of communication rapidly saturates human communication capacity, and coordination through mutual adjustment breaks down, just as Ms. Raku

discovered when plant hangers started to take the wrong color and people began tripping over pots stacked on the floor.

At that point, someone must take the lead (either through appointment or common consent) and start planning and directing the work of the others. At its simplest, this takes the form of *direct supervision* (Mintzberg 1979). That is what Ms. Raku resorted to when mutual adjustment ceased to work. She named one of her assistants studio manager, and divided her own time among planning, supervision, and customer relations.

Even direct supervision in its basic form breaks down fairly rapidly, however; there is a definite limit to how many workers one person can continuously direct and coordinate. The actual number depends on the nature of the work, but even with the simplest and most undifferentiated work there cannot be more than a few tens at the most.

However, direct supervision can be extended through delegation: the original leader can appoint a number of people to supervise a group each, and concentrate on supervising these subordinate leaders. In turn, they may again appoint leaders of still more groups, and so on. Theoretically, there is no limit to the size of such a hierarchy, but it is evident that if there is to be any lateral coordination at all, it must be achieved chiefly by channeling information and decisions up and down the formal hierarchy: to reach a decision involving two groups at the bottom, the matter must be taken up through the organization to the first common leader. In such an organization, the strain on individual communication capacities therefore increases toward the top, which is the only point where the communication lines to and from all the groups meet.

To avoid communication saturation, the need for coordination must therefore be reduced. Two avenues for action are open: the lower layers of the organization may be regrouped to create self-contained organizational entities that require a minimum of coordination, or the activities may be standardized in some way to reduce the need for supervision.

The first solution is what we normally understand as divisionalization. Corporate headquarters will normally not meddle in the internal workings in a division, as long as it produces the expected profit and its plans are palatable. From the vantage point of the headquarters, the complexity of day-to-day business is hidden, encapsulated within the division; communication takes the form of results, plans, and budget proposals upward, and of appraisals, budgets, and directions for planning downward.

Standardization can take three forms (Mintzberg 1979): Standardization of work, standardization of outputs, and standardization of skills. Actually, divisionalization usually implies *standardization of output*: as noted above, corporate headquarters is primarily interested in a division's profit, not its internal workings. Even the work of individuals can be supervised in this way, as when factories employ piecework rates combined with standards for product quality, or as when Ms. Raku tells the clay wedger only to deliver the clay in four-pound lumps, not how to wedge.

Standardization of work involves a direct specification of how work is to be done. It usually presupposes fairly extensive planning, to ensure that interdependent tasks are carried out in such a way that the necessary coordination between them is automatically ensured. A successful implementation of work

standardization will therefore eliminate a considerable volume of supervision, and allow for a much higher ratio of productive to supervisory work in an organization. The use of standardization of work as the main coordinating mechanism is the defining characteristic of a bureaucratic organization. Ms. Raku resorted to standardization of work when she hired a work study analyst to organize her first production lines. Mintzberg's standardization of work corresponds to Galbraith's preplanning.

Another approach is to build on *standardization of skills*. This is what vocational and professional training is all about. On all levels, from bricklayer to brain surgeon, the educational process equips craftspeople and professionals with a professionally certified set of solutions to common tasks, ready to be activated. When Ms. Raku expanded, she hired assistants from the local pottery school, and they could immediately go about their work in her pottery studio without further instructions. In a hospital, a quite complex organization, very complex work is routinely carried out, coordinated mainly by the medical personnel's internalized work directions, provided through their education.

Usually, an organization does not depend on only one coordinating mechanism; several or all will be used at some point and on some level. But often the organization has a defining mechanism that will serve as a basis for the main part of the work and contribute heavily to organization's character.

In Mintzberg's view (1979), there is a logical progression from mutual adjustment through direct supervision to standardization as the organization grows in size. He also postulates that if the environment becomes too variable for standardized solutions, the organization will try to revert to some sort of adaptation of mutual adjustment at critical points. During military campaigns, for instance, the high command coordinates the different services by mutual adjustment. That is what war rooms are all about: when the heads of the services gather at one facility and ultimately in one room, it is to achieve the speed and richness in communication and the flexibility in action that only face-to-face consultations and deliberations can provide. In crisis, an organization may also revert to a larger measure of direct supervision.

Lateral Linkages

To Mintzberg, Galbraith, and Nadler and Tushman, grouping and the use of the appropriate coordinating mechanisms represent the basic solutions to the problem of coordinating separate tasks in an organization. However, none of these solutions is perfect, and every organization of some size will always struggle to coordinate. The main bottlenecks are invariably the limited capacity for communication and information processing.

It was the inadequate capacity of the informal communication pattern in Ms. Raku's pottery studio that eventually led to an organization based first on direct supervision (with a hefty dose of standardization of skills), and it was the (later) saturation of the studio manager's information processing capacity that led to a shift to a main reliance on standardization of work, supported by standardization of skills and direct supervision. After divisionalization, Ms. Raku relied on standardization of output (mainly profit) to control her divisions, probably because direct supervision of the now giant Ceramico Inc. would require prodigious information flows and a superhuman processing capacity.

As we noted above, Galbraith's alternative when the information processing capacity of the organizational hierarchy becomes saturated is the development of lateral relations. Both Mintzberg (1979) and Nadler and Tushman (1988) follow Galbraith closely here. The organizational hierarchy is easily overloaded when the attempt is made to coordinate the activities of different units by communicating through the formal structure. The prescription is the use of what Mintzberg calls *liaison devices* and what Nadler and Tushman call *structural linking*. They all endorse Galbraith's continuum of liaison devices and propose a minor simplification by dividing it into four basic types, ascending from *liaison individuals* (persons with a special responsibility to inspire cross-unit coordination by informing about certain aspects of their units' activities), via *cross-unit committees or task forces* (with the same purpose, but with more comprehensive participation), *integrating managers or departments* (similar to liaison individuals and cross-unit groups, but with a stronger mandate and more clearly defined responsibility), to the full *matrix organization*, where there are two (sometimes even three) intersecting chains of command.

Mintzberg also argues that the organization's planning and control systems represent lateral linkages, especially action plans (Mintzberg 1979, pp. 153–154, italics in original):

... by its imposition of specific decisions, action planning turns out to be a less than pure form of standardizing outputs; more exactly, it falls between that and standardizing work processes. This point can be expressed in terms of a continuum of increasingly tight regulation, as follows:

- *Performance control* imposes general performance standards over a period of time, with no reference to specific actions
- *Action planning* imposes specific decisions and actions to be carried out at specific points in time
- *Behavior formalization* imposes the means by which decisions and actions are to be carried out . . .

Action planning emerges as the means by which the nonroutine decisions and actions of an entire organization, typically structured on a functional basis, can be designed as an integrated system. All of this is accomplished in advance, on the drawing board so to speak. Behavior formalization designs the organization as an integrated system, too, but only for its routine activities. Action planning is its counterpart for the nonroutine activities, for the changes. It specifies who will do what, when, and where, so that the change will take place as desired.

Centralization/Decentralization

Another aspect of the struggle to coordinate is the question of centralization versus decentralization. If our capacity to communicate and process information were limitless, organizations could be totally centralized, with all decisions made by one brain, knowing all and directing everyone. Since this is impossible, no organization can be said to be totally centralized; however despotic the top manager, the majority of decisions will nevertheless be made by his or her underlings, although they will obviously try to cater to the boss's tastes.

Decentralization, then, is a means to reduce the information processing requirements in the organizational hierarchy by spreading the processing

throughout the organization—to engage more brains, so to speak. That also reduces the amount of information that has to be communicated up and down the hierarchy. According to Mintzberg (1979), there are two dimensions: vertical decentralization and horizontal decentralization. In addition, there is a third use of the term, which has really nothing to do with decentralization of decision making power: the physical dispersal of services.

Vertical decentralization is what most people think of when they use the term. It is concerned with the delegation of decisionmaking power down the line of authority in an organization. For instance, market-oriented organizations will usually grant enough decisionmaking power to their customer interface to fulfill their customer's everyday requirements and solve their most common problems. An example is the bank clerk who can grant small loans and credits, and the branch manager who may grant larger loans. Divisionalization represents an expression of such decentralization in a larger setting. The goal is obviously to have matters settled as close to the point of origin as possible, where information is richest and the information processing capacity greatest.

Horizontal decentralization denotes the delegation of decisionmaking power away from the line of authority altogether. It may take several forms, and is often informal. One variety is the conscious delegation of decisionmaking power to experts in the matters concerned. Another is the informal power sharing a manager may enter into with his immediate staff and even selected individuals at different levels and in different departments throughout the organization. In organizations relying heavily on planning and standardization of work, a lot of de facto power can be exercised by the professionals who carry out the planning and devise the methods and rules the rest of the organization has to follow. In organizations that live in turbulent environments, a corresponding power will migrate to those who are expert in understanding the changes and forecasting the necessary adaptation in the products.

A simple physical distribution of services does not necessarily imply any decentralization of power. It is quite conceivable, for instance, that you can run a network of bank branch offices and still have all loan applications sent to a central office for processing; indeed, that was what most banks did before the advent of computers and remote terminals. The penalty, however, usually is a bottleneck in the main office and poor service to customers.

Adapting to the Environment

Every organization has an environment; that is, it exists in a social, political, and technical context, and generally has a multitude of formal and informal relationships with both organizations and persons. These relationships may span the gamut from the Internal Revenue Service to customers to the families of employees. To survive, the organization must be able to adapt to or resist changes in the environment to a sufficient degree to keep the necessary resources flowing. Most theory centers on adaptation, but resistance is a surprisingly common strategy and not infrequently constitutes the first line of defense when changes threaten. A notable example from recent Norwegian history is the mobilization of farmers and large parts of the food processing industry against Norwegian membership in the EU, which would imply considerable changes in these

industries' environments. Officially, the management of the national dairy cooperative *Norske Meierier* (which has a *de facto* monopoly on most dairy products in Norway) refused even to think about what they would have to do if Norway became a member. However, as documents leaked to the press showed, they had secretly been drawing up contingency plans for development in case the referendum should turn out a "yes" majority. Contrary to official policy, then, they were in fact ready for adaptation should the resistance strategy fail.

Resistance, however, is an alternative only in situations where the organization or its friends or allies can influence matters. Also, the environment is more than changes in markets or subsidies; it is, for instance, also a matter of the kind of business one is pursuing and the nature of the customers or clients. To contingency theory, almost everything outside the organization is subsumed under the label "environment." To quote Mintzberg (1979, p. 267):

So environment comprises virtually everything outside the organization—its "technology" (i.e., the knowledge base it must draw upon), the nature of its products, customers and competitors, its geographical setting, the economic, political and even meteorological climate in which it must operate, and so on.

Nevertheless, Mintzberg (1979) boils the main dimensions down to four:

Stable–dynamic

An organization's environment can range from stable to dynamic. For instance, even if prices fluctuate due to periodic imbalances in supply and demand, newsprint production is a fairly stable business, with planning horizons of several tens of years. Commodity trading, on the other hand, can be extremely dynamic, with huge fluctuations in prices over short periods of time, fluctuations that are often unpredictable because they may be caused by wars, fires, accidents, natural catastrophes, or surprising weather conditions. Decisions about taking or leaving positions must often be taken in a matter of hours or even minutes and seconds. It is precisely the amount of unpredictability that defines the level of dynamism and tests an organization's ability to respond—not expected variations. Newsprint producers, for instance, are used to cyclical developments in prices; they plan for them and are generally not surprised when they come.

Simple–complex

The simple–complex dichotomy is also easy to understand. A local savings bank has a quite simple environment, with few and well-known products and a well-defined set of customers. An oil company prospecting and producing oil in the North Sea, on the other hand, must master very complex technology while prospecting, during development, and throughout the period of operation. In addition, it must handle complex relationships with political authorities, powerful customers and competitors, and (increasingly) environmental activists. It is the required sophistication of the required knowledge about markets, products, technology, and so on that defines the level of complexity. The level of experienced complexity can be reduced by routinization and accumulation of knowledge, however: according to Mintzberg, car manufacturers face relatively simple environments by virtue of their great experience and knowledge about their products and production processes.

Integrated-diversified (market)

An organization has a highly integrated market when it has few products and customers—like shipowners specializing in large-volume, intercontinental car transport. Market diversity arises from a broad range of customers, products, or geographical areas. Market diversity affects the diversity of tasks, and thereby structure.

Munificence-hostility

Finally, environments may be friendly and generous, as they generally are for organizations that are able monopolize coveted products—like the International Olympic Committee (IOC)—or they may be more or less hostile, with cutthroat competition as in today's PC business. The ultimate in hostile environment is, of course, experienced by an army in war. This dimension resembles the stable-dynamic dichotomy, in that hostile environments most often are dynamic. Mintzberg nevertheless thinks it merits separate treatment.

The environment, says Mintzberg, is not of interest in itself, but only because it has specific impacts on organizations. The interesting thing is how an organization copes with the environment. He presents five hypotheses about the relations between environment and organizational structure (1979, pp. 270-85):

1. **"The more dynamic the environment, the more organic the structure."** If the environment is stable, an organization can easily shield its operating core and standardize its operations. This will allow a highly structured organization—a bureaucracy. In a rapidly changing environment, the organization must also be able to change in a hurry—resulting in much less structure and less standardization of tasks. Persistently changing environments will drive organizational structure toward organic states (coordination by mutual adjustment) despite pressure in the other direction from other factors such as size and technical system.
2. **"The more complex the environment, the more decentralized the structure."** Complex environments mean that no single person or group of persons can have all the knowledge required for the organization's operations. Management will therefore have to decentralize responsibility. Standardization efforts tend toward standardization of skills, not of work, in which case professionals will often have large autonomy (as in hospitals and universities).
3. **"The more diversified the organization's markets, the greater the propensity to split into market-based units (given favorable economies of scale)."** Diversity in markets means that it takes many people to accumulate the necessary knowledge and maintain customer contacts, and organizations must therefore create a corresponding diversity and decentralization on their own part to manage. The main impediment is an organization's dependence on an operating core or another important function that is not easily split.

4. **“Extreme hostility in its environment drives any organization to centralize its structure temporarily.”** This can be explained in terms of coordinating mechanisms. Direct supervision is the fastest, since only one brain (or a few) is involved. A crisis may thus force centralization in spite of both complexity and diversification in markets. However, if the crisis is not overcome, leaving the organization to revert to the necessary structure for its day-to-day affairs, it may simply go under.
5. **“Disparities in the environment encourage the organization to decentralize selectively to differentiated work constellations.”** Environments are seldom uniform, and organizations usually need a number of responses. Newspapers are clear examples: the editorial staff is usually fairly organic in structure, in order to handle constantly changing priorities due to the unpredictability of events in the world outside. The printing works, however, is organized as an industrial operation (a bureaucracy), in order to deliver the reliability and cost-effectiveness that is demanded in the daily printing of specified numbers of newspapers within very narrow deadlines. Also, different vantage points in the organization can present different environments. While filling station managers representing different oil companies may compete furiously throughout the marketplace, oil company executives may cooperate closely in the planning of oil pipelines and in influencing government tax policies.

According to Mintzberg, four basic types of environments emerge from this discussion, each requiring a basic coordinating mechanism. They can be put into a two-by-two table (Table 3-1).

	<i>Stable</i>	<i>Dynamic</i>
<i>Complex</i>	Decentralized Bureaucratic (standardization of skills)	Decentralized Organic (mutual adjustment)
<i>Simple</i>	Centralized Bureaucratic (standardization of work processes)	Centralized Organic (direct supervision)

Table 3-1: The four basic organizational environments and their typical organization forms. (Reproduced from Mintzberg 1979, p. 286.)

The Basic Structural Configurations

In his further quest for clarity, Mintzberg came up with his famous set of five basic structural configurations, describing the five main organization types. The configurations are named the *Simple Structure*, the *Machine Bureaucracy*, the *Professional Bureaucracy*, the *Divisionalized Form*, and the *Adhocracy*. Their most important characteristics are outlined in Table 3-2.

Configuration	Main Coordinating Mechanism	Main Design Parameters	Main Contingency Factors
Simple Structure <i>Examples:</i> <i>Startups, populist political parties with strong leaders</i>	Direct supervision, in principle directly by autocratic top manager.	Centralization and organic structure. Little specialization, little formalization.	Young, small, non-sophisticated technical system, simple, dynamic environment (possibly hostile), or strong power needs of top manager.
Machine Bureaucracy <i>Examples:</i> <i>Airlines, insurance companies, mass-producing factories</i>	Standardization of work processes by rules and regulations produced by professionals in the technostructure.*)	Behavior formalization, vertical and horizontal job specialization, usually functional grouping, large operating unit size, vertical centralization and limited horizontal decentralization, action planning.	Old, large, regulating technical system, (as in a mass-producing factory or transaction-processing clerical organization), simple, stable environment, technocratic control.
Professional Bureaucracy <i>Examples:</i> <i>Hospitals, large consultancy firms</i>	Standardization of skills through education in external institutions (like universities). The professionals (who are the producers) hold much power.	Professional training, horizontal job specialization, vertical and horizontal decentralization.	Complex, stable environment, non-regulating technical system, professional operator control.
Divisionalized Form <i>Examples:</i> <i>Large companies, especially in manufacturing.</i>	Standardization (control) of financial and market-related outputs—like profit rates, sales growth and return on investment.	Market-based grouping, performance control systems, limited vertical decentralization. Often bureaucracy within divisions.	Old, very large, diversified markets, relatively simple and stable environment. Technical system divisible, otherwise similar to machine bureaucracy.
Adhocracy <i>Examples:</i> <i>Creative organizations like R&D organizations, innovative consultancy and advertising firms.</i>	Mutual adjustment, with much informal communication. Project oriented. Experts have much informal power.	Liaison devices, organic structure, selective decentralization, horizontal job specialization, training (large percentage of professionals/experts). Functional and market grouping concurrently.	Young, often fairly small, complex and dynamic environment, sophisticated and often automated technical system.

*) Mintzberg makes a distinction between the *technostructure* and the *support staff*. The technostructure is the professional part of the staff, where you find the analysts who standardize and plan the work that the others are doing as well as monitor and analyze the environment. The support staff comprises the housekeeping functions, like payroll, mailroom and cafeteria. Mintzberg also includes legal departments and R&D under this heading (support staff).

Table 3-2: Main characteristics of Mintzberg's five basic structural configurations. (Adapted from Mintzberg 1979.)

Mintzberg later (1989) added another two configurations,¹ the *Missionary Organization* and the *Political Organization*, which are not so much complete configurations as images of organizations kept together by strong common norms or pulled apart by strong conflict, respectively.

Mintzberg also acknowledges that most organizations today are mixtures of configurations. He therefore now also represents them as forces acting on organizations. Circumstances decide which one of the forces will exert the strongest pull and shape organizational structure. For our discussions later, both the pure types and the concept of pulls will be useful.

Coordination: The Linchpin of Organization

As a one-sentence conclusion of the discussion so far, I think a passage from Mintzberg's definition of organization quoted earlier is perfectly suited (1979, p. 2): "*Every organized human activity—from the making of pots to the placing of a man on the moon—gives rise to two fundamental and opposing requirements: the division of labor into various tasks to be performed and the coordination of these tasks to accomplish the activity.*"

Despite the great latitude of today's organization theories and the enormous breadth of variation in actual organizations, it seems evident that organizations also have some basic problems in common. These common problems in turn give rise to a set of basic structural features, with a limited set of main forms.

First of all, organizations above a certain small size (a few individuals) have a **division of labor**, since any single individual has a definite ceiling on his or her work capacity, be it physical or mental work. Single tasks must be made small enough to be fit for single persons. When you thus divide work among several people, it means that coordination between those tasks can no longer be effected within one brain, as when one person does everything. This sounds like a rather trivial conclusion (indeed a tautology), but the implications are far-reaching, because coordination of more than a handful of people involves most of what we know as organization.

Coordination among several individuals in turn implies **communication**, which may be either **routine** (proceduralized) or **ad hoc**. Without information flowing about what everybody should do and how they progress, coordination is impossible. Next, information about what is happening both inside the organization and in its environment must be **collected and distributed**, and the organization will also need to **process information** of this kind.

Communication and information processing also imply that the organization will need to establish some sort of an **organizational memory**—which in modern times usually means files and archives of different kinds, in addition to the vital information organization members carry around in their heads. (In preliterate times, people had to carry *all* the information around in their heads—a very constraining demand, as we shall see later.)

Further, there must be **accepted mechanisms for reaching decisions** on all levels, which also means that there will be a **power structure** of some kind (even in

¹ He has also changed the name of two of the configurations: the Simple Structure has been renamed the *Entrepreneurial Organization*, and the Adhocracy is now called the *Innovative Organization*. I use the original names here, since they are the most widely known.

a small, egalitarian group, some people will usually have more influence on decisions than others). Finally, to secure permanence, the organization must fulfill a number of other conditions, which we have not discussed so far. If it is a normal public or private organization, it will have to reward its members in some ways, and provide the necessary tools, premises, and amenities for their work and well-being.

In my view, these needs are as objective as anything in social science can be, and *coordination* emerges as the linchpin of organization. Before we go on, I therefore think it is necessary to take a second look at the subject, and I also think it will be useful to establish a taxonomy of coordinating mechanisms (Figure 3-1), which we can refer to during subsequent discussions.

A Taxonomy of Coordinating Mechanisms

In the discussion earlier in this chapter, I adopted Mintzberg's (1979) classification of coordinating mechanisms. As we noted, he defines three main mechanisms, one of which has three subforms:

- ♦ Mutual adjustment
- ♦ Direct supervision
- ♦ Standardization:
 - of work
 - of skills
 - of output

Mintzberg also argues that these mechanisms create a continuum as one moves from simple to more complex work. Mutual adjustment gives way to direct supervision, which in turn must yield to standardization of some kind. However, if the level of complexity (especially combined with a high rate of change) rises even further, it will saturate the adaptive capacity of standardized coordination. Mintzberg then postulates a return to mutual adjustment as the only coordination mechanism that can handle really complex work with a lot of problem solving. However, it is clear (although he does not point it out specifically) that this is mutual adjustment on another level than in the small group working in Ms. Raku's workshop. His example is NASA's Apollo project, which was extremely large and complicated, and where the adjustments probably took place in a "representative" system based on professional competence. He also sees a similar role for direct supervision, which may become the answer when an organization (or indeed a nation) in crisis appoints a manager with more or less dictatorial power.

If we take a closer look at these coordinating mechanisms, we see that they fall into two main classes: *the real-time ones* ("coordination by feedback," a term borrowed from March and Simon 1958), where coordination is continually adjusted as people observe the effects of their own and other people's actions, and *the programmed ones* ("coordination by program"), where coordination is effected through instructions or plans ("programs") generated beforehand. Both main types have two main variants (see Figure 3-1).

Real-Time Mechanisms

The real-time mechanisms are *mutual adjustment* and *direct supervision*, which are the same ones that Mintzberg defined.

With *mutual adjustment*, coordination is achieved by a continuous exchange of information among those who participate in the work. It is the coordinating mechanism best suited for complex problem-solving work with little standardization. In its pure form, there is no single person who continually directs or supervises the work, and it is therefore necessary for all organization members to have a sufficient understanding of their goal, the overall design of the work and how their different tasks fit together. They must also be sufficiently motivated to do their part voluntarily. Mutual adjustment is an inherently egalitarian coordinating mechanism, best suited for settings where people are on a fairly equal footing. It is impossible to extend it to organizations larger than the small group without compromises. Large organizations that need the creative potential of this coordinating mechanism therefore often employ hierarchical project organizations, where teams are represented by trusted members on one or more levels of coordinating committees.

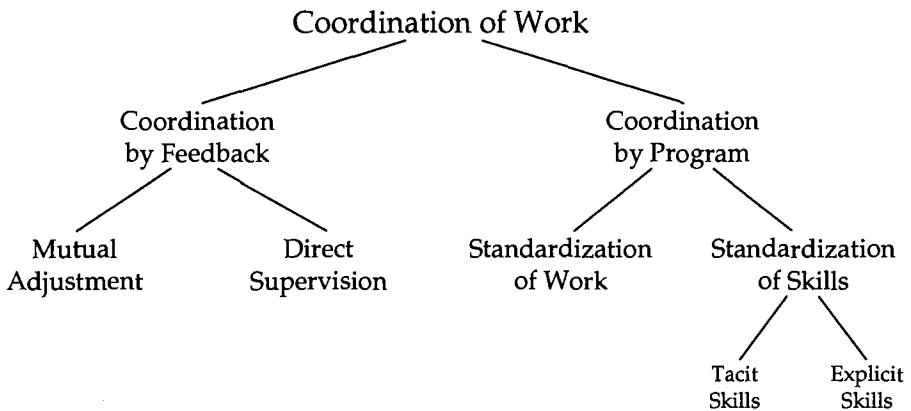


Figure 3-1: A taxonomy of coordinating mechanisms.

The reason mutual adjustment breaks down so quickly as a pure form is, of course, because it in principle requires everyone to communicate with everyone else. As the number of participants increases, the number of possible information links multiplies: with five people, there are 10 links; with ten people, 45 links; and with twenty people, 190 links.² To use terms from network theory (Lincoln 1982): to employ mutual adjustment as the prime coordinating mechanism, a network must be very dense—and, since our communication abilities are limited, that means they will also have to be small. In large organizations, real mutual adjustment can take place only inside organizational units small enough to allow

² The formula is $n \cdot (n-1) / 2$, where n is the number of members in the group.

all-to-all communication, or between similarly small groups of managers or group representatives, acting on behalf of their departments or groups. It is thus possible to achieve a sort of layered mutual adjustment, but only with strong elements of hierarchy and bureaucratic control.

Direct supervision is quite different from mutual adjustment, since it requires one person to direct the others, tell them what to do (even how to do it), and monitor their actions during execution. While mutual adjustment requires all participants to know (and accept) the goals and task designs, direct supervision in principle requires only one person to know the goals, the overall design, and how tasks are meant to fit together. It is also inherently hierarchic, and therefore easily extendible through delegation of authority.

Programmed Mechanisms

Mintzberg lists three coordinating mechanisms based on standardization: *standardization of work*, *standardization of skills*, and *standardization of output*. In my view, only the two first of these are proper coordinating mechanisms, in the sense that they are used to coordinate the work of organization members in order to achieve particular patterns of action in an organization. Standardization of output, on the other hand, does not involve any coordination of people or work at all, only a prescription for a certain output—usually in the terms of form of profit, although even total sales, or tons, or pieces of whatever one produces may be used. It is therefore of little interest in discussing the potential organizational ramifications of computer-based systems, even if it may represent a useful method for controlling the profitability of large and far-flung corporations.

I will therefore include only two basic *programmed* coordinating mechanisms, standardization of work and standardization of skills.

With *standardization of work*, as Mintzberg describes it, coordination is achieved by specifying beforehand and in some (often considerable) detail how work is to be done. It is best suited for fairly simple work where tasks do not change very often, and can then be very efficient. Most large organizations use standardization of work extensively, especially Machine Bureaucracies.

While standardization of work may be said to represent the special program, developed for a specific collection of tasks in a specific organization, *standardization of skills* represents the general program—an education designed to enable one to tackle cooperation of a specific kind, unrelated to a particular organizational setting. I propose here that there are two kinds of standardized skills. For the set *tacit skills* I borrow part of the name from Polanyi's tacit knowledge; it is also related to Argyris's (1980) theories-in-use. It comprises the kind of internalized skills that are seldom or never made explicit, and which we may not even be aware of as distinct skills. The prototype of such skill sets is the standard social skills everyone learns during childhood and adolescence, which makes it possible to function as a normal member of society and perform the expected roles in everyday interaction.

The other set, *explicit skills*, includes the skills that are taught in schools or during apprenticeship, and which serve not only to teach the candidate a set of concrete skills, but usually also a code of professional conduct and a notion of the accepted level of quality. In larger organizations, this coordinating mechanism is best suited to fairly routinized but complex work (as in the medical professions).

Not only does this kind of education serve to standardize work processes on a professional basis, it also contains elements that are designed to enable coordination both within the profession and with colleagues from other, relevant professions. Mintzberg's example (1979) is the medical professions: the cooperation between the various specialists both among doctors and nurses during an operation is largely regulated by procedures learned during their education, and are usually not specific to a particular hospital. In fact, my own contacts with personnel at Akershus Central Hospital³ strongly indicate that the main stumbling block for organizational development there was the combination of standardized professional procedures and high staff turnover (common in large Norwegian hospitals), which made it excessively demanding to introduce and maintain procedures different from those at other Norwegian hospitals.

The Basic Preconditions for Organizing

With the discussion in this chapter in mind, which of our abilities have significant bearing on our capability for organizing ourselves? Clearly, our capacity for *physical action* is pivotal; our limitations here is the reason we need to organize in the first place (apart from strictly social purposes). Further, as noted above, all cooperation presupposes *communication*, and our bottlenecks in this area are, of course, extremely important. Then there is our ability to *accumulate and retrieve information* and our capacity for *information processing*—what our brain can actually accomplish with the information it is fed. Finally, to carry on cooperation through time, the *reliability* of organization members also becomes an important issue.

Translating these five concepts into actual human faculties or properties, there seem to be six areas where we quickly run into limits restricting organization building:

1. **Capacity for work:** Obviously, both our need for organizations and their nature are strongly dependent on the nature and amount of work that we can carry out, on how much a single individual can accomplish. Although our capacity for physical work is of obvious importance, our special interest is in the limitations we have with respect to mental work.
2. **Memory performance:** The basis for any intellectual activity, and so important for the accumulation of knowledge and for the management of complex relationships, both the storage capacity and the retrieval capabilities of our long-term memory is of vital importance. So are the limitations of our short-term working memory.
3. **Information processing capability:** Closely related to the question of work capacity, our ability for reasoning, problem solving, and

³ Sentralsykehuset i Akershus—one of the sponsoring organizations.

decision making is directly related to the amount of complexity we can handle.

4. **Communication bandwidth:** This is the first of communication's two aspects. The amount of information we can absorb and disseminate per unit of time is of obvious importance.
5. **Communication range:** This is the second aspect of communication. How far and how fast we can communicate is also central, as are the possibilities of communicating not only over distance, but through time.
6. **Emotions:** The five properties above are derived from the rational activities in organizations. However, we are not entirely—maybe not even principally—rational beings. As the action, constructivist, and postmodern approaches to organization (among others) point out, emotions play a decisive part in our daily lives both within and outside organizations. We all have our secret aspirations, phobias, likes, and dislikes, and we all have to live with our basic, primate instincts and psychological makeup.

Some may find it strange to include emotions in the small number of basic human properties that are most important for organizing, especially when my expressed purpose is to analyze the interplay between organization and information technology. However, my purpose at this stage is not to single out the human faculties that will be most influenced by the use of information technology; rather, it is to decide which ones are the most important for the construction and maintenance of organizations—and I believe that emotions are extremely important, for the spirit that can develop in organizations, for the conflicts they harbor, and for their reliability as logical “machines.” I also believe that emotions (used here as a collective term for the nonrational part of the human mind) and the social relations they foster have extremely important impacts on the use of technology, and often determine if a specific application will be successful or not—quite independent of its “rational” merits. My discussion of emotions will therefore differ from the way I treat the five other faculties listed above: the discussion will focus not so much on how emotions are “enhanced” or “improved” by information technology, but on how emotions will impact its possible use and thus influence the general development both of the technology itself and of IT-based organization.

It is difficult to ascertain which of these abilities or properties are most important, both in man's almost mythical “natural state” and in contemporary, industrialized society. It may even be meaningless to rank them, since they are so intertwined in real life. Most of the limitations we encounter can fortunately be ameliorated by tools (but to a varying degree), and through our history as a species we have amended our shortcomings in gradually more advanced and powerful ways. Both by material technology and with the help of techniques and methods of various kinds, we have considerably increased our organizing abilities. Those shortcomings that respond most readily to amplification by

material means easily attract the most interest, of course, especially in a technologically mesmerized society like our own.

Information technology represents nothing more and nothing less than a new chapter in this history. It promises, however, to become an extremely important chapter, which we will be busy writing for a long time to come. In keeping with contingency theory, we may say that IT modifies and extends the technology contingency factor. This may seem innocent enough, but, in my opinion, computer-based systems modify this factor substantially—and in the process extend it from a matter primarily of the operating core to an important contingency factor not only for the rest of the organization, but for its exchanges with the environment as well. Through this, it may open up possibilities for new structural configurations (Mintzberg 1979) and provide the basis for significant shifts in the fit between common configurations and the different kinds of business or task structures they can efficiently support.

II Individual Capacity and Organization Before the Computer

In this part, my purpose is to establish a platform for the analysis of the possible contributions of information technology to the space of constructible organizations. I begin Chapter 4, *Confined by Physiology*, by looking at the six basic human preconditions or constraints (as listed at the end of Chapter 3) in more detail. I also discuss two of the most important methods we have always used to alleviate or circumvent some of these constraints (in addition to simplification), namely, imitation and the creation of mental sets.

In Chapter 5, *The Dawn of Organization*, I explore the problems of organization building in societies without significant tools for organizational purposes and try to determine the extent of the space of constructible organizations in such societies. The analysis is based on historical records and anthropological evidence from primitive societies, and focuses on the methods and techniques used to build and maintain organizations. The analysis corroborates the conclusion from Chapter 3 that coordination is the essence of organization, and it concludes with the basic principles of preliterate organization.

In Chapter 6, *The Power of Technology*, I discuss the nature of tools and the way the most important pre-computer technologies have alleviated our original constraints (preconditions for organizing), gradually allowing for extensions of the space of constructible organizations. The single most important innovation was undoubtedly the art of writing.

Finally, in Chapter 7, *The Modern Organization*, I try to assess the relationship between the development of these tools and the emergence of the modern organization. I conclude that the new forms of organization, especially the Machine Bureaucracy, were based on a new concept of coordination: the standardization of work processes in the form of explicit routines and automation. This allows a transition from direct to indirect supervision, which is vastly more efficient. However, I also propose that the emergence of the modern organization involved another breakthrough: the emergence of the explicit conceptual model

and the concomitant explicit design of essential parts of the patterns of action that constitute organizations. This opened the door for conscious improvements and a rational approach to organization, as opposed to the traditional approach of oral societies and societies with a weak literate foundation. I end the chapter with a short discussion of the effect of culture on organizational forms, and the possibility of claiming any significant common ground in organization structure.

4 Confined by Physiology

“Man is a mind betrayed, not served, by his organs.”
Edmond & Jules de Goncourt, *Journal*, 1861

The six areas listed at the end of Chapter 3 are all about restrictions ultimately rooted in our physiology. The limits to our capacity for physical work are the most obvious, but even the others reflect our biological capabilities at varying levels. Our capacity for communication, for instance, relies both on the physical bandwidth of our senses (chiefly the eyes and the ears), the strength and nature of our voice (relying on sound waves), the physical characteristics of our mouth and vocal chords, and the brain’s capability for information processing. Processing, in turn, is dependent on extremely complex processes in the brain, of which we presently have very limited understanding. The same is true with our emotions, desires, and drives, and the irrationality they often give rise to. To understand the nature of organizations and the way tools empower us, we must therefore have a basic understanding of our fundamental capabilities and—most important—our limitations as biological creatures.

One Thing at a Time

As any traffic authority can confirm, the operation of radios, stereo players, and cellular phones while driving increases the likelihood of accidents. The reason is that we have to split our attention between driving and pushing buttons or turning knobs. Even if driving is a more or less automatic activity for most of us, the operation of a radio or telephone attenuates the attention directed toward the road sufficiently to slow down our responses to unexpected events on the road. In dense city traffic, where distances between cars are small and the required reaction times often short, the danger is especially high.

The fact is that we are quite single-minded animals, both with regard to physical action and intellectual activity. There are very definite limits to what we can consciously perceive and do in parallel. To achieve good control of any complex physical activity, for instance, we need to practice again and again until the control of movements is *automatized* (Ellis and Hunt 1989) and our conscious

processing capability is relieved from the burden of coordination. That is why we need so much practice as children to walk and run with reasonable control. As grown-ups, we confront the same process again when learning to drive a car or to master new sports. Our conscious system is simply not able to handle the coordination of many muscle groups in real time. To achieve perfection in sports that require complex movements combined with high precision (like gymnastics), extreme amounts of drill are necessary—many hours every day, years on end.

It is fairly easy to understand some of the limits for parallel physical activity—in the end, we only have two arms and two legs. However, our possibilities for actual coordination of muscles seem to be restricted by the same basic mechanisms that limit our mental activities. Generally, activities (both physical and mental) that require our full attention preclude the possibility of doing something else simultaneously (Ellis and Hunt 1989, Barber 1988): we cannot carry on two conversations at once, or read a book *and* ponder a complicated problem at the same time.

On the other hand, it is possible to be engaged in one conversation and still keep “an ear” on a conversation close by. You can split your attention if you reduce concentration on the main task (Ellis and Hunt 1989). It is a common experience in the proverbial cocktail party: if you are engaged in a trivial conversation with someone, you will tend to notice the contents of the conversations around you, scanning for something more interesting. However, if the conversation you are engaged in is sufficiently absorbing, you will not notice anything other people say, except (possibly) if someone mentions your name. If the discussion becomes sufficiently heated, people will probably have to yell at you to redirect your attention.

Serious work, then, requires almost all of our attention and blocks other activities. If we are interrupted or attention drifts (shifts to a daydream or the recollection and pondering of a piece of news read in the morning paper), activity comes to a halt. The only exceptions are activities that are automatized to such a degree that we do not need to allocate much attention to them. If less common situations or problems occur, however, even normally automatized activities will absorb our full attention until a normal situation is restored. As Barber (1988, p. 113) notes, a bus driver and a passenger chatting with each other will let the conversation lapse if an unexpected thing happens or the traffic suddenly gets worse, in order to let the driver devote his full attention on the task of controlling the bus.

Since there is no way of getting around the attention barrier (except for tasks that lend themselves to automatization), our work acquires a serial nature. When faced with more than one task, we have to attend to one at a time. We often do not complete it at once, but break off, do something else, and then return. In fact, this is the normal mode of work in most offices. It may sometimes look like we do many things at once, but a closer look reveals that we are only switching back and forth—allocating slices of time to each task, as Mintzberg found managers do all the time (Mintzberg 1989).

Perhaps some of the fastest switchers are currency traders, as they (apparently) simultaneously talk into several telephones, operate a computer terminal, and read messages scrolling over the news screen. They are all young and work in a frenzy for a few years, until they can take it no more; the level of concentration

they have to maintain to master such rapid switching and to keep trace of important events outside their main activity at any one time, without losing vital information and without mixing up their different ongoing exchanges, is simply exhausting.

Some of the same strain is experienced by air traffic controllers. They are probably not switching as rapidly as the currency traders, but then they are dealing with lives, not money. They also have more parameters to look after. Air traffic controllers in busy areas probably come close to the limit for human conscious control, and even when highly experienced, and (probably) with a level of automatization as high as this kind of mental work can allow, they are occasionally simply overloaded—sometimes with disastrous effects. Barber (1988) cites the evidence of an actual accident in the Zagreb area in September 1976 (p. 101):

It was nearly two minutes before the DC-9 first communicated with the upper-sector controller, following the instruction to change to the upper-sector radio frequency. Meanwhile, the controller for that sector had been working without his assistant, having in effect been responsible for two jobs for some minutes. Moreover there were eleven aircraft in his sector, he was in radio communication with four other overflying aircraft, and he took part in a telephone conversation with Belgrade regarding two others. In that short interval he transmitted eight messages and received eleven. The task facing him seems to a lay observer to have been an unenviable one, and it is apparent from the working practices for air-traffic control (cf. Sperandio 1978¹) that this is not a mistaken impression. Indeed the inquiry board were clear in their view that he had been subject to overloading. (He was subsequently prosecuted, held partly responsible for the accident, and was jailed.)

Our capacity for conscious action is thus limited by the serial nature of our mind. Taking on more than one main task, we have to switch between them. As additional work is piled upon us, we cannot compress our workload in time by doing several tasks in parallel; we have to increase the time available for work each day, thereby taking time away from eating, sleeping, family life, and socializing. This is a merciless fact, learned the hard way every day by millions of people in rich and poor countries alike. Even for sleepless workaholics with limitless energy, there is a definite ceiling to the amount of work they can carry out. Taking our fairly modest physical strength into account as well, it comes as no surprise that most human endeavors require cooperation, and the amount of work or level of complexity does not have to be large before organization is necessary.

It is also interesting to note that today fewer and fewer jobs lend themselves to automatization.² A hundred years ago, most jobs were manual and the great majority of them could be highly automatized. They did not command great mental effort once they were learned. Today, manual work is being taken over not only by "classical" machines, but also by highly sophisticated, computer-

¹ Reference in original. The article is: Sperandio, J.C. (1978): "The Regulation of Working Methods as a Function of Workload Among Air Traffic Controllers," *Ergonomics* 21:193–202.

² We are here still talking about automatization in its cognitive sense—the ability to automatically execute a task as a result of extensive practicing (repetition). It must not be confused with automation—the act of replacing human labor or mental efforts with machines.

controlled machines. Simple mental work is assumed by computers. A large proportion of the jobs that eventually remain will involve more advanced mental efforts, and allow only limited (cognitive) automatization. Jobs that really put a strain on our mental capacity will probably also increase in number. This could mean that we are entering an age where people with above-average mental skill and ability to handle complex workloads will constantly be in short supply, while people with below-average capabilities will have severe problems in finding a job at all.

Another notable effect of our limited span of attention is our strong tendency to decouple separate activities. Since activities are time-sliced, and we tend to change our frame of reference when we change activity, we are in fact able to engage in activities that are not only overlapping but even contradictory, and without noticing it or experiencing conflict. One day we may protest to local authorities about the inadequate public funding for the day-care center our children attend or about the lack of room in the local nursing home for our old and sick parents. A week later, we may be found at a political rally denouncing big government and calling for lower taxes. One day we may scold our children for pilfering sugar or raisins from the cupboard; the next day we may bring home a couple of pencils and a notepad from the office for private use because it is so "convenient." We are thus able to maintain different, decoupled standards for behavior in different situations, because we never handle them in parallel. These examples are obvious ones, but we daily maintain scores of more obscure incompatibilities in both our working and private lives.

Memory

Memory lies at the very base of our nature as intelligent beings. Without memory, without any retained experiences or patterns to which we could compare sensory signals, we could not live. This is aptly reflected in archaic Greek mythology: Mnemosyne, the goddess of Memory, was no less than the child of Earth and Heaven (Gaea and Uranus), and the mother of the nine muses. Our memory is both wonderful, fascinating, and frustrating. It is also a very complex phenomenon. As John Cohen says in his *The Lineaments of Mind* (1980, p. 85),

Of all the powers of the mind that robot-makers (including those occupied with artificial intelligence) are most eager to come to terms with, is that of memory. Here lie the darkest secrets. In spite of the combined efforts of psychologists, neuro-physiologists, biochemists, mathematicians, and computer scientists, the mystery of memory remains.

Or, as Mishkin and Appenzeller put it in the introduction to their article "The Anatomy of Memory" (1987):

Within the small volume of the human brain there is a system of memory powerful enough to capture the image of a face in a single encounter, ample enough to store the experiences of a lifetime and so versatile that the memory of a scene can summon associated recollections of sights, sounds, smells, tastes, tactile sensations and emotions.

Memory is indeed many-faceted; several areas of the brain are involved, and there is obviously a fair amount of specialization between them (Mishkin and Appenzeller 1987, Geschwind 1979). There are also various theories about how memory is structured logically, and whether different parts of memory functions according to different principles (Ellis and Hunt 1989). For our purpose, the distinctions here are not so important, and we can leave that discussion alone. The main divisions from a “user” standpoint are between the sensory registers, short-term memory, and long-term memory.

Sensory registers are simply buffer memories that store the raw data pouring in from our sensing organs for the very brief time (a few tenths of a second) it takes for our attention to select them for further processing and to transfer the result of the pattern recognition process to short-term memory for interpretation. Information *not* selected (by far the vast majority of it) is lost when the information in the sensory registers decays or is “overwritten” by new data. Even if we often find it irritating that information is lost in this way, as Weick remarks (1979, p. 208), this is in reality a good thing. It is precisely the process of selection and interpretation that allows us to sense and function at all; otherwise, we would be permanently overwhelmed by unstructured information both from our senses and from our memory (our attention directs the selection process in remembering as well).

The short-term memory is the workbench of our active consciousness. There has been much theorizing about the similarities and differences between short-term and long-term memory, but the current view is that short-term memory is not so much a separate memory system as a workspace for information selected for transfer from the sensory registers, as well as for information retrieved from long-term memory when we want to use it in an active thinking process. For this reason, it is often termed *working memory* (Anderson 1990, Ellis and Hunt 1989). It can retain both sensory impressions (such as sights and sounds), numbers, words, concepts, and ideas. This working memory has a very limited capacity; laboratory experiments suggest that the normal range for humans is between five and nine elements or “chunks,” with seven the average. It is thus probably not a coincidence that the number 7 is sacred or prominent in religious conceptions in many cultures.

The “chunks” can be of any kind, size, and complexity, however—from single letters or numbers, to complex concepts (like “democracy”) or objects (like “passenger airplane”). The very fact that we perceive them as chunks implies that we see them as organized entities, conceptually or physically, with certain main, defining properties that blend into a single representation in working memory.

The contents of working memory must be constantly rehearsed to be maintained for more than a few seconds. (Experiments indicate that, on the average, it takes us only 18 seconds to forget 90% of the contents in working memory if rehearsal is prevented.) However, with rehearsal, our access to its contents is fast and reliable, due to its high level of activation. We are able to compare, juggle and manipulate the items maintained in working memory.

Long-term memory, on the other hand, retains information for an indefinite period of time, once it is encoded. Indeed, most current theories assume that encoded memories do not decay, and that forgetting is just failure to retrieve (Ellis and Hunt 1989). There are a number of different explanations for why retrieval

may fail. It has been claimed that we can recall even trivial childhood incidents under hypnosis, and experiments with electrical stimulation of points in the brain's temporal lobes have elicited forgotten childhood memories (Penfield, referred in Anderson 1990). It is, however, difficult to verify the correctness of such "provoked" memories, and they are generally not accepted as proof that we retain all memories.

The general structure of long-term memory and the nature of the encoding process have yet to be fully explained. There are several (partly competing) theories, and much we do not understand. However, encoding information in memory seem to involve organization of separate elements of information into meaningful groups or categories as well as elaboration—relating the information to items already in memory. The attachment of meaning to the information to be remembered is also very important.

There are likewise a number of theories about recall, building on different views of the organization of memory. We know, however, that we can remember things directly, recall the wanted item with the help of a cue, or slowly work our way toward the right information following chains of memories or associative paths in memory, uncovering new cues as we go along. Sometimes, we may even have to leave the conscious process alone for a while, to allow the wanted item to "drift" to the surface. Memories below a certain threshold seem to be impossible to recall under normal conditions, but experiments indicate that they are still present—number/noun pairs once learnt but apparently forgotten seem to be easier to learn and remember later than totally new pairs (Anderson 1990).

While our understanding of the architecture and functioning of memory is still very limited, there is no doubt that we store an enormous amount of information in our brains. Much to our chagrin, however, we seem to have limited control over what we can recall. Not only is it very often difficult or even impossible to remember the items we need, but what little we do recall is quite likely to be incomplete or even distorted, especially when it comes to details.

As indicated above, facts are not only selected, interpreted and accorded meaning during recording, but are subject to later selections, interpretations, and changes in a subtle interplay with other memories, as well as with preconceptions, desires, and hopes, as Piaget's stick experiments with children suggest (Hofer 1981).³ It is not only the future that is unpredictable and open to conjecture; so indeed is the past. Anyone doubting this is referred to the daily affairs in our courthouses, where the dominating activity is the painstaking review of human explanations (spelling out the retrievable content of memories) and physical evidence in order to establish plausible descriptions of past events. And it is precisely the fickleness of human memory that leads us to grant greater credibility to documents and pictures than to human explanations, even when there is no reason to suspect intentional misrepresentations. As Cohen (1980, p. 85) remarks

³ Children of ages three to six were shown six sticks of varying length, sorted by length, and asked to draw the sticks as they remembered them both one week and six months later. It turned out that the drawings six months later were more accurate, being rearranged by the major changes (connected to maturation) in cognitive processes that had taken place during those six months. The oldest children now drew correct pictures, and the younger ones had changed their errors in correspondence with their increased age.

describing the archaic Greek view of memory, "The hidden things of the past, no less than the future, have to be wrested from the gods. Recollection, therefore, becomes a species of retrospective prophecy."

In addition to the fuzziness that often mars our memory and makes us doubtful as to what actually took place or what the details of a conversation really were, our memory may also let us down in a more deceptive way: there may be errors in what we think is a clear and unequivocal memory. Sometimes we may even "remember" events that never happened, or remember as our own experience something told us by another. When it comes to early childhood experiences, for instance, it is often difficult to separate what we actually remember from what we have been told by parents, older siblings, or others. Our brain has no error detection and correction mechanisms that can alert us to such erroneous memories, once they are established.

The knowledge that any one person can absorb, remember, and, most important, *recall and use* is thus limited, and with only our unaided memory at hand, we are therefore severely restricted when it comes to organization building; our memory deficiencies restrict the size of organization that can be run. It is difficult to keep tabs on large numbers of people, and the accumulation, transfer, and dissemination of knowledge is cumbersome. Moreover, information is continually subject to deterioration both in individual memories and during communication. There is thus a definite limit on the amount of information that can be held, both individually and collectively, and there is also the nagging question of how much one can trust information stored in human memory. The lack of permanent records precludes the accumulation of knowledge above a certain, rather basic level; social relationships spanning great distances are difficult to maintain, and trade is generally restricted to low-volume, direct barter.

No wonder, then, that organization in nonliterate societies tends to be fairly small scale (by our standards) and mainly tied to family relations—by far the strongest, most important, and stable social framework of societies past and present. Even personal connections outside the family line tend to be couched in family terms: for the aborigines of the Cape York Peninsula in Australia, for instance, trading partners in neighboring tribes were classified as ritual brothers (Sharp 1952). The relationship was considered so close to a real brotherhood that one of the men was always defined as elder and one as younger, with the "elder" brother having a perpetual advantage over the "younger" in the trading relationship, because a younger brother by custom had to show deference to an older one. Similar practices can also be found elsewhere in the world, for instance among the Lapps of Northern Scandinavia (Pehrson 1964).⁴

In this connection, it is noteworthy that some of the most successful nonliterate, expansionist peoples have been those with the most extensive family systems. The Bantus of Africa, for instance, had to their advantage a notion about a common forefather, implying that all Bantus are related. They also kept tabs on their lineage several generations back. If threatened, a Bantu could summon the assistance of his entire family line, down to the point where it merged with his opponent's. If the opponent was not Bantu, then he could call upon all Bantus.

⁴ Pehrson also refers to other research by Ishino, Mintz, and Wolf confirming ritual kinship as a significant characteristic of more complex nonindustrial societies.

This enabled the Bantu tribes to amass superior forces in all instances when opposed by more fragmented tribes.⁵ In just a few hundred years, they swept southward from the North of Africa, eradicating weaker tribes in their way. Today, the large majority of the African population south of the Arab territories belongs to the Bantu group.

Information Processing

Although we cannot handle more than one serious information processing task at a time; at least that process can be multidimensional—but only within narrow bounds, as our working memory is quickly saturated. There is a definite limit to how many variables or aspects of a particular subject we are able to juggle at the same time. To picture the relationship between cost, sales volume, price, and profit is barely possible, as long as the factors are stable and the relationship between them linear. If cost is production cost, however, with a nonlinear relationship to volume and time from order to delivery, and if the cost and effect of marketing and sales must be taken into account, as well as the size of different orders and the consequences of rebate schemes, then the conscious mind quickly bows out; the number of variables exceeds the amount we can keep in our working memory, and they are simply not simultaneously available for processing.

The consequence is that we are not able to “see” all the different relationships and the effects of their mutual dependencies in one “picture.” To work around our mental limits, we tend to use time, ponder parts of the problem separately, structure it in subsets that can be treated as single elements, and so on. Sometimes, such long-time “submersion” in a complex problem alone allows us to organize it sufficiently to get an overall grasp on it and see a solution, but if the problem is complex enough, we need to commit intermediate thoughts and analyses to paper, use other tools (like computers!), or resolve the matter by dividing the task among several people.

Elements in Problem Solving

However, that is only part of the problem. In addition to the limits to our sheer processing capacity, there are many other constraints involved in problem solving as well. To examine them a little closer, we can use a three-stage model for problem solving proposed by Ellis and Hunt (1989, p. 219): understanding the problem, generating hypotheses about solutions, and testing and evaluating solutions. Since Ellis and Hunt refer mainly to laboratory experiments, they omit one stage that is very important in real-life situations, especially in organizations: the procurement of sufficient information. For real-life problem solving, we can therefore propose the following stages (stages 2 to 4 are adapted from Ellis and Hunt 1989, p. 219):

⁵The Bantu extended lineage conception was not a multipurpose structure, however; it was limited strictly to conflict management. A man could not call upon his extended family line to clear land, tend animals, or build dwellings. The customary rights and obligations in such matters were limited to the local group and the most immediate family.

1. Procuring of information
2. Understanding the problem
3. Generating hypotheses about solutions and selecting among the alternative hypotheses
4. Testing and evaluating the solutions

As Ellis and Hunt emphasize, even if we logically go through the stages in the order mentioned, and sometimes do so in practice, most problem solving is an iterative activity, where we cycle through the different stages and even jump back and forth between them.

Procuring Information

Getting at the necessary information is simple in the laboratory setting, where the experimenter furnishes you with the setup for the experiment. In real life, it is much more complicated. Often, we do not even know exactly what kind of information we need, and if and when we find out, it too often turns out that we cannot get at it (or part of it), either because such information does not exist, because no one has collected it, because it is technically or economically unavailable (such as aggregate information from a huge manual archive), or simply because those who have it will not divulge it.

In organizations, procuring the information needed for decisions is one of the main activities, and there are entire departments devoted to such work—for instance, the accounting department, whose sole purpose it is to keep track of the economical performance of the organization and present this information to the decision makers. Market analysts are occupied with collecting information about the outside world, production planners try to provide information about expected production schedules for both sales and management, and so on. We all know how crucial it is to have the really relevant information available when we are deciding something, and how important it is that the information be of high quality—that it gives a correct representation of the facts. We also know how often the information we have seems both insufficient and of doubtful quality.

An additional problem is, of course, that since we almost always have a simplified (and sometimes quite wrong) perception of the problem itself and the causal relationships involved in it, we often procure the wrong information set, and we also generally tend to believe that the information we have is better and more complete than it in fact is. Elementary cognitive errors, such as misinterpretation of sensory impressions or other people's behavior (including oral and written communication) may compound the problem.

Understanding the Problem

As Ellis and Hunt emphasize, "Before a problem can be solved, it must first be understood." Before we can start to seek out a solution, we must have a sufficiently clear picture of the problem. Research shows that an adequate mental representation of the problem is very important to finding a good solution, or even finding a solution at all (Ellis and Hunt 1989, Anderson 1990).

An example of the disastrous effects of an inadequate problem representation (and the concomitant success of a better one) can be found in the German attack on France in 1939. The French military perceived the defense of France to be a matter of repelling an attack over land coming from German territory, and felt quite safe behind the formidable Maginot line. The Germans, however, included both airborne troops and a detour through neutral Belgium in their representation of the inverse problem—how to *attack* France. We know the outcome, and each one of us is undoubtedly able to find similar (if less momentous) examples from our own experience.

Understanding the nature of a problem may also involve understanding its causes. They are not always obvious, they are not necessarily objective in the sense that they seem the same regardless of perspective, and they are certainly not always unitary. When management rationalists Kepner and Tregoe (1965, p. 17) maintain,

Here it should be pointed out that every problem has only one real cause. It may be a single event that produces the unwanted effect, or it may be a combination of events and conditions operating as if they constituted a single event.

they display an attitude that may be valid for simple engineering problems, but not for the complexities of human life. Consider, for example, the editorial by Garrett Hardin in *Science* referred to by Weick (1979, p. 68), with the title "Nobody Ever Dies of Overpopulation." It treats the catastrophe that occurred when East Bengal (now Bangladesh) was hit by a cyclone in November 1970, and 500,000 people living on the low islands in the river delta were killed. A similar catastrophe hit in April 1991, with about 150,000 dead. Now, we may ask: What caused the death of these unfortunate people? Was it the cyclone, an unpredictable, natural disaster? Was it the lack of dikes that could keep the water out? Or the lack of cyclone-safe shelters? Or was it perhaps the fact (as Hardin argues) that overpopulation has forced people to live in places where even an ordinary storm constitutes a grave danger? And is it possible to devise a single best solution to ensure that such a catastrophe does not repeat itself in the future? True, this is an exceedingly large and complicated matter, but when humans are involved, there are always ambiguities and complications.

By choosing perspective, or problem representation, then, we also decide which information is relevant and what kind of causes will be allowed for consideration. By choosing evaluation criteria, we decide what kind of solutions will be considered "best."⁶

Generating Hypotheses About Solutions

When we have acquired at least a tentative understanding of the problem space and have constructed a preliminary problem representation, we start the hunt for a solution, employing one of two main strategies. In some instances,

⁶Our blaming the storm can also be interpreted as a classic instance of the decoupling mentioned earlier: The actual catastrophe belongs to one mindset, one set of references, and the problem of overpopulation to another. We attend to them at different times, and we do not connect them with one another.

especially when solving technical problems (involved in, for instance, the construction or computer programs), we will use an *algorithmic* strategy, which consists of a set of rules or procedures that *ensures* a solution. In everyday life, however, most problems do not have algorithmic solutions, and we have to use a *heuristic* strategy. The term *heuristic* comes from the Greek word for finding or discovering (*eurisko*) and designates a “commonsense,” “rule-of-thumb” approach, a problem solving method that works and is used in practice, regardless of whether we know why it works; indeed, we may not care to know at all.

To illustrate the difference, Ellis and Hunt (1989, p. 220) use the example of locating a friend with the name J. Smith in a large city, where there are 41 J. Smiths listed in the telephone directory. An example of an algorithmic strategy for solving this problem is to start at the top and call all J. Smiths in consecutive order until the right one is found. Provided our J. Smith is listed, and is at home from time to time, this method is sure to work if we just keep on calling until we find him. Normally, such a strategy will not appeal to us, however, since it is time-consuming, expensive, and potentially embarrassing (some of the other J. Smiths may not like our inquisitive call). It is much more likely that we will make an educated guess about where in the city our man is likely to live and/or what kind of occupation he is likely to have (if listed). This way, we can considerably reduce the number of people we need to call (if our guesses are about right, which they often are in everyday life).

There are, of course, many variations of these strategies, and solutions often include both algorithmic and heuristic elements—such as when we use heuristics to reduce the number of J. Smiths we call, but then call our selections in consecutive order. Some of the more well-known heuristic methods (Ellis and Hunt 1989, Anderson 1990) are the *generate-test method* (which more or less equals what in everyday life we call trial and error), the *means-ends analysis* (first determine the desired end result and then consider the means by which it can be reached), the *working backward* method (estimating what the solution ought to look like and then working backward to the current problem state), the *difference reduction* method (stepwise reduction of the difference between the problem state and the goal state), and *problem solving by analogy* (using the structure of a known solution for a problem to guide the solution of another one). The last method is one of our prime methods for problem solving in everyday life.

Regardless of the strategy, the solutions we generate depend on more than our problem definition and the available, immediately relevant information. Background knowledge and past experience are clearly also very important; a problem that is unsolvable for most people may belong to the routine repertoire of a specialist with experience from a large number of similar problems. Values are always of substantial importance, both during problem definition (as shown above) and in searching for a solution. A liberal left-winger and a Christian fundamentalist would almost certainly have very different problem definitions if their teen-age daughters became pregnant without being married, and would quite likely arrive at different solutions—such as an abortion for the liberal, and a hurried marriage for the fundamentalist.

Another very significant determinant for the generation and selection of solutions is what we know or believe about their consequences—both their direct bearing on the problem and their side effects. The calculation and evaluation of

consequences also involve risk assessment, which becomes more important the riskier a solution is.

Testing and Evaluating the Solutions

That brings us to the last stage in problem solving, which involves choosing the actual solution to be executed—a simple step as long as the problem and the possible solutions are well understood, and the criteria for judgment are clear. If price is the only criterion, for instance, it is simple to choose among the alternatives for a transatlantic flight presented by a travel agent. Unfortunately, however, the situation is seldom so simple except for simple and fairly inconsequential decisions. Important decisions tend to be complex and may involve both ambiguous problem definitions and solutions that are difficult to compare. They may also have consequences and benefits that are contested, or the criteria for judging the possible solutions may be unclear or have unclear priorities (or even both). And, of course, once a particular solution is chosen, it remains to be executed, and we all know from our everyday experience that much can go wrong in that process as well—and that execution even may lapse or be actively sabotaged.

From Maximizing to Satisficing: Accepting Simplification

The picture that shines through this short discussion is not exactly that of a supremely rational being, analyzing all relevant facts, choosing the best among all possible solutions, and carrying it out flawlessly. And there are even many more cognitive pitfalls in the various stages of problem solving, especially when we operate under uncertainty (see, for instance, Kahneman, Slovic, and Tversky 1982). It is indeed *simply impossible* for humans to find the one best solution (given that such a solution exists in theory, which it often does not) for anything but the very simplest problems.

With what we now know, it seems preposterous even to suggest it. However, we need only go back fifty years to find this illusion widely accepted as fact, upheld both by the economists' image of "economic man" and by the "rational manager" of the management theorists. These concepts did not receive any real dents until the publication of Herbert A. Simon's *Administrative Behavior* in 1947 (see Appendix A), and even if they are now academically discredited, they linger on in the simpler parts of the management realm and flavor many an offering from the more archaic breeds of consultants.

Viewed in retrospect, it is almost unbelievable that the systematized common sense presented in *Administrative Behavior* could be so sensational, and even result in a Nobel Prize in economics. That it in fact *was* groundbreaking at the time, in terms of both economic and organization theory, is perhaps more than anything else a proof of how far we humans are able to theorize ourselves away from reality. As such, it is perhaps nothing more or less than another chapter in the never-ending story of clashes between utopians and theoretical purists on the one hand, and pragmatists and empiricists on the other. And, as we pragmatists know, in the fuzzy, murky world of human behavior, the utopians and purists always come out with a bloody nose in the end (like Marx and Lenin just did), battered by a rude reality not behaving according to their theories. To quote

Simon from his introduction to the third edition of *Administrative Behavior* (1976, pp. xxvi–xxvii):

. . . the economists attribute to economic man a preposterously omniscient rationality. Economic man has a complete and consistent system of preferences that allows him always to choose among the alternatives open to him; he is always completely aware of what these alternatives are; there are no limits on the complexity of the computations he can perform in order to determine which alternatives are best; probability calculations are neither frightening nor mysterious to him. Within the past generation, in its extension to competitive game situations and to decision making under uncertainty, this body of theory has reached a state of Thomistic refinement having great intellectual and esthetic appeal but little discernible relation to the actual or possible behavior of flesh-and-blood human beings.

Simon's great, commonsense realization was that man operates with limited information and wits in an exceedingly complex world, and *perforce* has to simplify, to operate with a bounded rationality, to *satisfice*—not maximize (1976, p. xxviii, italics in original): “Administrative theory is peculiarly the theory of intended and bounded rationality—of the behavior of human beings who *satisfice* because they have not the wits to *maximize*.” As a contrast to economic man, Simon defines *administrative man* (1976, pp. xxix–xxx, italics in original):

Administrative man recognizes that the world he perceives is a drastically simplified model of the buzzing, blooming confusion that constitutes the real world. He is content with this gross simplification because he believes that the real world is mostly empty—that most of the facts of the real world have no great relevance to any particular situation he is facing and that most significant chains of causes and consequences are short and simple. Hence, he is content to leave out of account those aspects of reality—and that means *most* aspects—that appear irrelevant at a given time. He makes his choices using a simple picture of the situation that takes into account just a few of the factors that he regards as the most relevant and crucial.

What is the significance of these two characteristics of administrative man? First, because he *satisfices* rather than *maximizes*, administrative man can make his choices without first examining all possible behavior alternatives and without ascertaining that these *are* in fact all the alternatives. Second, because he treats the world as rather empty and ignores the intrrelatedness of all things (so stupefying to thought and action), administrative man can make his decisions with relative simple rules of thumb that do not make impossible demands upon his capacity for thought.

Simplification, here proclaimed as one of the defining characteristics of administrative man, is indeed our most common weapon against complexity, and is used also when tools and organizational measures are brought into service. We simplify our models of the world simply because rich models are too complicated to handle—and convince ourselves (and others) that there are actually just one or two or three factors that “really count.” Research on judgment under uncertainty is rife with examples of how we make our judgments on the basis of information that is superficial, the most readily available, or easiest to think of, and how we are deceived by our intuitive interpretations of our immediate impressions of reality, even when we have solid theoretical and factual knowledge to guide us toward more correct solutions (Kahneman, Slovic, and Tversky 1982; Rachlin 1989).

We also have a strong tendency to let concrete, immediate urges and experiences displace or overrule abstract knowledge about later, possible consequences—such as continuing to smoke even while acknowledging that it may lead to cancer at a later date, or driving our car very fast when late for an appointment, even though we know it increases the likelihood of a dangerous accident, with consequences that would be way out of proportion to the importance of the appointment in question.

Even if we in many instances claim that we have to simplify because we have insufficient information (which is often correct), we nevertheless, as Simon also noted, tend to use even *less* information than we in fact have. Research has shown that people's models of the world tend to be much simpler than they could be, given the information they actually possess (Brunsson 1985).

Simplification is usually a combination of a conscious process (consciously choosing some variables over others) and an unconscious or intuitive one (just regarding some variables as "naturally" important or unimportant). The criteria in both cases can be questionable; for instance, it is not uncommon to have an overrepresentation of computable variables in organizational decision processes. Computable variables are convenient to handle and have the added advantage of appearing to be very objective and accurate, even when they are not (such as market forecasts five years ahead reported to the tenth of a percent).

In real life, then, we do tend to pick some facts, some variables, and disregard the rest. To be able choose the right variables, those that are really the most important ones, we require considerable experience with the problem domain. Normally, we are quite good at it, but if we enter a new field of work or knowledge, or suddenly have to live in a country with a very different culture, we need a period of adjustment, until we internalize the essentials of the new setting.

As noted above, Simon's view of administrative man as satisficing rather than maximizing delivered the first real blow to the glossy picture of the manager as the supremely rational being presiding over tidy, rational organizations. Another strong blow was delivered by Henry Mintzberg (1973). Mintzberg's study of what managers actually did found that the old picture of the manager as a reflective, systematic planner was utterly false. According to Mintzberg, managers are interrupt-driven, are strongly oriented to action, and dislike reflective activities. They prefer oral to written communication, and work chiefly through formal and informal meetings and telephone conversations. In addition to the simplification such informal work habits imply, another interesting way of thinking is suggested, which came to occupy more and more of Mintzberg's attention: unconscious processing and intuition.

Unconscious Processing and Intuition

In pursuing this line of thought, Mintzberg involved himself in a strong (but friendly) controversy with Simon, who holds that even if man's rationality is bounded, we still talk about conscious rationality, and not about obscure sub-conscious processes. Simon also contends that human thinking is made up of programmed sequences, sufficiently similar to computer programs that computers can be used to describe and simulate human thinking (Simon 1977).

The notion of unconscious processing and intuition is indeed interesting but still controversial. It may amount to the next step in the “derationalization” of decision-making that Simon started, and certainly deserves a discussion at this point.

As noted above, our conscious mind becomes bogged down fairly quickly as variables are added or as the relationships between them are made more complex. Our working memory does not suffice. Experience suggests, however, that subconscious thought processes can integrate and weigh a larger number of variables. A number of sayings and proverbs allude to this—we talk about “sleeping on a problem,” about “problem gestation,” about “digesting” information or dramatic experiences, and so on. Most of us have, for instance, probably experienced the anguish of having to face pivotal decisions about our lives or careers, and we know that we do not rely entirely on rational analysis in such circumstances. We “ruminate” on the decision until we have an answer that feels right “in our stomachs.” As Hofer remarks (1981, p. 68),

It is sobering to realize how much of behavior regulation can take place without consciousness, and in fact does so in our daily lives. Perceiving and reacting do not have to be conscious to be effective, nor does learning or the formation of concepts. Even the mental processes for simple judgment—for example, which of two objects held in our two hands is heavier—are not conscious; the answer just pops into consciousness.

Incubation effects (more rapid problem solving after a period of thinking of something else) have been demonstrated experimentally (Anderson 1990)—especially for problems requiring *sudden insight* to solve (such as the problems presented in books or magazine columns on recreational problems and riddles). Subjects who had a break for some hours after studying the problem for a little while, and then resumed, had a higher percentage of success than those who did not have a break. Ellis and Hunt (1989) recommend such breaks to evoke the incubation effect as practical advice for problem solving, in spite of the fact that we do not thus far have a satisfactory explanation of why it works.

Many scientists have reported similar personal experiences when working with and suddenly solving particularly intriguing and hard problems—problems they may have struggled with for long periods of time. According to Anderson, the French mathematician Poincaré reports numerous instances. Kekule von Stradonitz’s discovery of the molecular structure of benzene (which had puzzled chemists for many years) is another example, perhaps the most famous: He was dozing off, half-dreaming about strings of dancing carbon atoms. Suddenly one of the strings snaked back on itself, forming a ring—at which point he woke up with a jolt, the benzene ring clear in his head (Asimov 1975). More examples are provided by Goldberg (1989).

In his annual hour with the Nobel Laureates on Swedish TV, the host, Bengt Feldreich, always ends the program by asking the participants if they believe in intuition—and the majority of them invariably do, citing their own experiences with that sudden flash of insight. They all agree that it feeds upon years and years of experience and knowledge accumulation, but that the problem-solving process is only partly a conscious one—it is the sudden culmination of a combination of conscious work and an inscrutable, subconscious process beyond inspection.

This is in harmony with the views of most of the people who write about intuition, whether they think, like Simon (1989), that intuition is essentially a conscious recognition of established patterns, or, like Rowan (1989), that it is knowledge gained without rational thought: they all agree that intuition does not come totally out of the blue. Rather, it requires a solid foundation of factual knowledge and experience.

As a process not controlled by the conscious self, subconscious processing is of course subject to influence from all kind of facts, judgments, conjectures, desires, and other emotions that our mind harbors. Nevertheless, the intuitive insights that arise time and again from the depths of our mind are often worth more than weeks and months of "rational," conscious analyses. Indeed, as Simon (1989) notes, analysis is often an activity that experts carry out only to check the validity of solutions found almost instantly through intuition. In his now famous article "Planning on the Left Side, Managing on the Right" (1976), Mintzberg describes how such processes and their outcomes in fact seem more important for managers than conscious, rational analyses—even though managers and management consultants usually hold forth the banner of rationality both as an ideal and as a description of their way of working.

The more complicated the problem is, the more likely it is that the solution will not be found through rational analysis, but through "weighing," "digestion," and "sleeping on it"—mediated through informal discussions with people who also have "thick" information on the subject. The interest for intuition as a management device has since then spread, and is now definitely on the increase (Agor 1989), and new evidence is steadily surfacing. Weiss (1990), for instance, reports how rigorous quantitative studies of psychiatric patients under therapy prove the existence of unconscious processing, and concludes (p. 81):

It seems that the cognitive capacities of the unconscious mind have been underappreciated and that human beings can unconsciously carry out many intellectual tasks, including developing and executing plans for reaching certain goals.

Nowhere in the organizational world is the dependence on subconscious processes so apparent as in choosing main strategies for an organization. As Mintzberg states (Mintzberg 1987), the deftest player in any market is usually someone with an intimate knowledge of it, acquired through first hand experience. He or she has an intuitive feeling of what the strategy should be like. And, indeed, one of the saddest sights of this world is a large organization trying to plan a new strategy by strictly rational means. Such an exercise usually involves large numbers of people, all busy prolonging present trends into the future in a purportedly meaningful way, and in the end producing something that is with 99% probability dead on arrival. A common explanation for AT&T's miserable failure in attempting to enter the computer business in the last half of the 1980s, for instance, was that no one in the management had a "feel" for the special characteristics of the computer market.

One may argue that they did not know the market, and the answer is both yes and no—they no doubt had the information available in reports, memos, and presentations. But, they had not *internalized* that knowledge—they had not been

able to *digest* and *integrate* it, as only a submersion over quite a long time can bring about. Therefore, they did not have any *gut feeling* about the matter and could not come up with a vision or *sense of direction*.⁷ Strategy needs vision, and vision is not obtained through calculations—not even in business.

Of course, intuition may be wrong, just like rational analysis. Even subconscious integration needs valid observations of the world to work with, and if vital facts pass unknown, no amount of inspiration can make up for it. It becomes particularly dangerous when combined with the process of groupthink, and can then keep a set of beliefs about the world alive in a group of people long after it has ceased to be true. The self-reinforcing nature of the groupthink process acts as an effective barrier against “unpleasant” facts and easily leads to decisions out of touch with the real world. A relative of groupthink, the *set effect*, has been demonstrated repeatedly in simple experiments (Anderson 1990). They show that experience with a certain solution to a class of problems inhibits problem solving in situations demanding another solution.

Moreover, as noted earlier, the (always simplified) models on which we base our understanding of the world are often too simple or even quite wrong, and we generally tend to have too much confidence in them (Brunsson 1985). Russo and Schoemaker (1990) argue that people also often overestimate their knowledge of basic facts. Intuition is moreover easily influenced by our own feelings, hopes, and wishes. Its roots in the subconscious, its integrating powers, are thus both the source of its strengths and of its weaknesses.

Intuition can no doubt be powerful for finding solutions to complicated problems, and it is something we constantly rely on for making up our mind when rational analysis is insufficient. Intuition is not, however, a viable tool for reliable execution and coordination of the everyday chores that also fill our lives (not the least our working lives). There, we have to rely on our limited, but still powerful conscious mind. Where the complexity exceeds our powers, we must simplify, decompose, and distribute the task in question.

The Delays of Deliberation

The time we need to reach a decision can vary enormously. If it is a question of a minor, recurring problem, we usually have the answer on hand, and a decision can be made in fractions of a second. If the problem at hand is totally new, of major importance, and involving a lot of parameters, we will often need to cycle repeatedly through the different stages of the problem-solving process.

This can in itself be rather time consuming. Because of our limitations in juggling many parameters or considering several possibilities in parallel, we need to go through many iterations pondering the problem, trying out different paths to a solution and thinking about the possible consequences. We may need to obtain additional information, or we may need to consult with others, but even without these even more time consuming procedures, having all pertinent information, it can take us a long time to reach a decision.

⁷Note how all these common life expressions about problem solving and direction finding allude not to the conscious mind, but to instincts and the autonomous nervous system (which, among other things, runs our bowels for us).

A further reason for this is that we often do not trust our conscious reasoning alone. As noted above, we like to obtain a “gut feeling” pointing in the same direction as our rationally derived answer. In other words, we feel a need to bring our unconscious, integrating abilities into play. We talk about “sleeping on it,” “digesting the information,” and the like. The metaphors we employ all connote subconscious phenomena, and the process we are trying to describe is the same as the one we discussed above when talking about intuition: the ability to unconsciously weigh and interrelate a larger number of parameters than we can consciously handle, and then arrive at a solution that is reasonably consistent with both our previous experiences, our present knowledge, and our basic values and goals.

These limitations clearly restrict the number and magnitude of the decisions that any one individual can handle, thereby constraining our freedom of organizing. They are of course compounded by our limited ability to absorb information (treated earlier), and are especially important as limitations for the centralization of control: In essence, you can only have first-hand control where you can decide yourself—decisions delegated mean control surrendered, even if you try to uphold control by orders, rules, regulations, or law. This is a basic dilemma known to every entrepreneur—expansion means losing the total control you have as owner/manager of a tiny start-up.

Our Communication Bottleneck

Human beings have many senses registering information about both the world around us as well as our own states. Ordinarily, we count five, but there are many more: We sense temperatures, air pressures, acceleration, and the positions of our limbs, to mention a few. Our senses are capable of receiving and processing an astounding amount of information—just the combination of the eye and the visual cortex has a raw processing power that still outstrips modern supercomputers. In computing terms, our visual system processes raw data at the rate of hundreds of megabytes⁸ per second. Moreover, our additional ability to quickly scan the picture the cortex presents us with, and pick out and classify its important features in real time, is nothing short of an information-processing miracle. Simultaneously, our brain can also receive and digest information about the states of the muscles in the body, and coordinate their movements in real time with immense precision. It is only when we try to build walking, self-guiding robots that the prodigious information-processing capacities of the brain are really driven home to us. The day when a two-legged robot can compete with human downhill skiers in the Hahnenkam competition in Kitzbühl’s notorious “Die Streif” track is indeed far off (but not entirely unthinkable—such a day may come).

However, the communication that builds organizations is first and foremost verbal. It is the spoken and written word. But our rate of acquiring and disseminating verbal information is painstakingly slow compared to our

⁸ One byte is the amount of digital information needed to represent one character. A megabyte is one million bytes (characters). For a more elaborate explanation, see Appendix B, “A Brief History of Computer Systems.”

processing of pictures. The raw processing power of the aural system is probably less than one thousandth of the visual by digital measures, and when we count not the entire range of sound impressions (like in a rich orchestral piece), but only the information contained in speech, it is even only a small fraction of that again. Of course, if we take into account the information contained in voice volume and inflection (which is frequently as important as the actual words), the amount of processed information in digital terms is similar to the interpretation of music.

Normal speech (and thereby listening) happens at a net rate of about 150 words per minute, not counting pauses for thinking, groping for words, etc. Very fast talk approaches 250 words per minute, but by then both speaker and listener will begin to experience problems. Sustained speaking for longer periods of time (for instance, a lecture) probably averages around 100 words per minute.

Reading is faster, but not so much—at least for factual prose. Most of us level off around 300 to 400 words per minute even when really concentrated and absorbed by what we read (like when devouring a really exciting novel). Taking into account our normal lapses in concentration when reading factual prose (with no plot or drama to capture our primate mind), it is difficult to average much more than 100 words per minute for longer periods of time (several hours). Assuming that the average word has 6 characters, that amounts to 10 characters or bytes per second (or 0.00001 megabytes). Even accomplished speed readers cannot go much beyond 1000–1500 words per minute (about 100–150 bytes per second, or 0.00010–0.00015 megabytes), and research indicates moreover that such reading is not very effective—it resembles most of all “skimming,” giving an overview of the text without a concern for detail (Barber 1988).

Writing is the slowest means of verbal communication. Quite apart from the slow and excruciating process of formulating the text, the physical writing process itself is a plodding activity. Until voice-recognition technology has developed to the point where a machine can reliably take rapid dictation and render it into text, the typewriter and the computer keyboard are the fastest devices we have available. An experienced (but autodidactic) 3–5 finger typist like myself typically enters text at around 25–30 words per minute, not counting error correction. An extremely fast touch typist can exceed 125, about the rate of normal speech.

The immense difference in speed between picture processing and verbal communication is the main reason for the efficiency of graphical presentation of data. Presenting data as pictures and graphs taps the enormous bandwidth of our visual system, and makes it possible to absorb both quantitative information and the interrelations between variables much faster and more accurately than through text and numbers. There is much research going on along these lines, not least for military applications. For fighter pilots being guided toward enemy aircraft or around enemy defenses, it will, for instance, be much easier to have the changing direction and altitude merged graphically into a curving tunnel on a screen (and then proceed to fly “through the tunnel”) than to be presented with numerical data and compass bearings.

Another proof of the value of visual representation is given by experiments performed by cognitive psychologists representing the same logical problems in geometrical form (Venn diagrams) and in verbal form. When the problems are geometrically represented, people’s decisions conform much better to the laws of deductive logic than when they are described verbally (Rachlin 1989).

The extremely narrow bandwidth of verbal communication places serious limits to the achievable levels of organizational coordination and control. Every minute, large amounts of information are created or received in any organization, and to be acted upon much of it needs to be aggregated, processed, communicated, and presented. Much must also be stored for future reference. As the rates above indicate, such work is very labor-intensive—and, for economic reasons alone, it must be kept within certain limits. The result is that only a fraction of the received information is ever processed, only part of the processed information reaches the people who need it, and they again will only acquaint themselves with a selection of what they actually receive.

The results are familiar for all who work in organizations: Decisions are made on shaky foundations, changes in the environment go unnoticed or are acted upon too late, coordination is often inadequate, there is much duplication of efforts, and different parts of the same organization may even be working against each other without realizing it. To this we must add the universal tendency for goal displacement, whereby subunits act more according to their own immediate needs and interests than in conformity with overall organizational goals. Goal displacement is not only a question of information deficiencies, but also of inadequate awareness of the overall consequences of local actions.

While we as individuals, then, can drive our cars through teeming city traffic effortlessly and with perfect control, the organizations we belong to are destined to blunder along, always bumping into obstacles and other organizations, always fighting to coordinate their various parts, always striving to pass along vital information to those who need it, and always trying to figure out where they in fact are, where they are going, and what state they are really in. The coordination problems rising from the constraints on our basic communication abilities constitute a basic problem in all human organizations above a certain size, and this is one of the most iron-clad constraints on operational effectiveness and efficiency.

As Mintzberg notes in his introduction to *The Structuring of Organizations* (1979), coordination is effortless only as long as the number of people that must coordinate their actions remains well below ten, and it is handled through continuous and informal communication. At that level, coordination is hardly noticed as a separate task—it just comes naturally. As soon as the number of people climbs into double digits and beyond, coordination and control becomes the most pressing operational problem, and a wide array of tools and techniques are brought to bear on it—schemes for division of labor, organizational structures, delegation of authority, coordination meetings, reporting, accounting, and so on. *Almost all of the planning, supervisory, and administrative work carried out in an organization is an expression of the continuous fight to stay in control of events and coordinate the various parts of the organization and its interaction with the environment.*

Since most of the tools and techniques necessary for the coordination of large organizations require abilities to record and communicate information that is far beyond the capacity of human memory, they are not available to oral societies—another reason why social and commercial organization in oral societies level out at a much smaller scale than in literate societies.

The Constraints of Space and Time

Parents who have tried in vain to call in children playing outside have no problem appreciating the fact that the unaided human voice has its limits. A conversation is difficult to keep going if the distance exceeds several meters, and even a primal scream does not go far on a day with normal wind and background noise. People living in mountainous terrain, like the Swiss and a few others, have devised rudimentary “languages” or code systems consisting of patterns of high-pitched tones or whistles that bear from hill to hill or across ravines, but even under exceptional conditions, their range is limited to a few kilometers. Our basic communication abilities thus allow for only local communication, mostly with one or a few persons at a time. Without special surroundings, such as an amphitheater (which has very favorable acoustic properties⁹), even a Stentor or a British sergeant major would have trouble addressing more than a few hundred people at a time.

Our vision does make it possible for us to receive information over great distances when there are no obstacles—after all, the naked eye can see stars trillions of kilometers away—but our means of replying are not on the same level. Some of the earliest techniques for communication tried to remedy this, by using visual aids—such as the smoke signals of the American Indians and the beacons of the Vikings—that can be seen from great distance.¹⁰ Their aural counterparts are the “talking drums” of certain African tribes.

Time is an even more merciless enemy of communication than space. Writers sometimes contend that one of their characters “left his/her words hanging in the air,” but apart from this strictly literary storage mechanism, all unaided human communication must take place in real time. Once a word is uttered or a gesture performed it is also a thing of the past, and it may be remembered, distorted, disputed, or completely forgotten.

The fact that unaided human information exchange can only take place locally and in real time puts severe constraints on the possibilities for building and sustaining large organizations. The only means of communication over distance is then the dispatch of messengers, and the messengers have to rely on their memory to ensure that the message reaches its destination uncorrupted. The use of messengers also brings in the question of authenticity: When you speak to someone in person, you know immediately that the message is authentic. When you have to rely on messengers, you never know if the messenger intentionally or unintentionally is misrepresenting the words of his master. As Eriksen (1987) shows, history is rife with examples of messengers having decisive influence on

⁹ The amphitheater is actually a very advanced acoustic device. The ancient Greeks built many, and even in the largest, which lies in Epidaurus and can seat 22,000 people, the actors on the stage can be heard by everyone in the audience without any artificial amplification. The theater is still in use.

¹⁰ More sophisticated systems were devised as communication needs became more pressing. In the century before the telegraph was invented, several European nations built national systems of semaphore lines, where messages were sent from tower to tower not by flags but by means of large, movable mechanical arms that could be seen from far away. The capacity was very limited, however, and served only urgent official purposes—mainly of a military nature.

historic events. The delay or liquidation of messengers can also have profound consequences. And when the messenger has to spend not only hours or days, but may be weeks and months on the road to reach his destination, events unknown to him could already have changed everything by the time the information is presented to the receiver.

We must remember at this point that physical travel has been very slow up to the middle of the nineteenth century, especially over land. In the year 1800, for instance, it took six weeks to go from New York to Chicago (Chandler 1977). Until the advent of large, swift sailing vessels, transport of cargo was also expensive and time consuming. Land transport remained slow and costly until the railroad revolution in the middle of the nineteenth century. Throughout most of our recorded history, therefore, long-distance trade has concentrated on high-value items, such as metals, spices, fur, and silk.

The strains on the communication system were prominent in every major empire in history, and large works were undertaken to speed the passage of messages. The Roman roads are well-known,¹¹ the Incas built roads as well, and the Mongols under Genghis Khan built a vast system of posting stations, where the Khan's express messengers could change horses on their breakneck journeys to and from the Khan's command posts. Communication technology has thus for a long time been a key factor in our ability to extend our organizations beyond the local community.

A striking example of the importance of enhancing our natural communication apparatus was forced upon us by the attack on Iraq by the allied forces on 17 January 1991. It opened with a massive air strike against radar installations, command and control centers, and communication lines. The rationale was that, if the Iraqi military leaders could be left with only their eyes, ears, and mouth, orders for counterattack could not be given, information about the allied attacks and their effects could not be collected, and even consultation between different command centers would be impossible. A modern army and air force with only the real-time, local communication capabilities of the unaided human are instantly reduced to a fraction of their theoretical strength, even without any other material or human loss. The subsequent development of the war and the total collapse of the Iraqi army proved this point well.

Wishing, Wanting, and Feeling

However sophisticated we have become, however much we hide behind our machines, our natural sciences, and our rational facades, we are still beings of flesh and blood, with complex minds, full of instincts, ambitions, hopes, fears, and desires. Some of our emotions are raw and basic, others refined and even noble, but the mixture is volatile and always prone to produce unpredictable effects. Our secret inner lives can be pretty wild and untamed. As the zoologist Desmond Morris noted in the introduction to his widely popular book *The Naked Ape* (1967, p. 9),

¹¹ The roads of the Roman empire had a very high quality, and main roads were paved with stone. The road system had a total length of more than 300,000 kilometers.

. . . in becoming so erudite, Homo Sapiens has remained a naked ape nevertheless; in acquiring lofty new motives, he has lost none of the earthy old ones. This is frequently a cause of some embarrassment to him, but his old impulses have been with him for millions of years, his new ones only a few thousand at the most—and there is no hope of quickly shrugging off the accumulated genetic legacy of his whole evolutionary past.¹²

Although each one of us (presuming a minimum of honesty) can confirm this through simple introspection, the importance—or even the mere existence—of emotions has to a large degree been ignored in the literature on organization, surfacing mostly in discussions of motivation, work satisfaction and stress (as noted by Hochschild in the preface to Fineman 1993). When you first notice this, it is a bit puzzling—when you reflect upon it, it starts to look like a very serious defect in organization theory and an embarrassment to organization theorists. As Fineman explains in the two first paragraphs of his introduction to *Emotion in Organizations* (1993, p. 1),

A book about feelings should not seem strange to anyone who has worked in an organization. It should not seem odd to those who have tried to organize others, or have been subjected to management efforts. Emotions are within the texture of organizing. They are intrinsic to social order and disorder, working structures, conflict, influence, conformity, posturing, gender, sexuality and politics. They are products of socialization and manipulation. They work mistily within the human psyche, as well as obviously in the daily ephemera of organizational life.

Although we might know this, it seems to be uncomfortable knowledge. Writers on organization have successfully “written out” emotions, to the extent that it is often impossible to detect their existence. A scan of the indexes of recent texts on organizational behaviour reveals no direct entries under “feelings” or “emotions.” We teach and preach on organizational life and management, usually acknowledging that our subject matter can be a bit messy—because people are not like machines. But at the same time we fail to square up to the essential emotionality of organizational processes, much of which is, and is likely to remain, unmanaged.

This preoccupation with the rational side of organizing seems even stranger when you contemplate that there is indeed a vast literature on human emotions and their significance in social life. Not only can we look to the discipline of psychology; the study of history is also rife with examples of how emotions have decided or heavily influenced the outcome of social and political conflicts with far-reaching consequences. Going still further, we can draw upon the literature of the world, or indeed the total body of art produced throughout human history, as a powerful witness to the sway that emotions hold over human actions.

¹² Interestingly enough, today, we tend to describe this our emotional self as our “human” aspect—as opposed to our logical faculties, which we tend to perceive as machine-like: hence the contemporary fascination for the impulsive, emotional, expressionist personality, capable of loving and hating with equal intensity. People ruled by logic and reason are frequently depicted as cold and indifferent to other people’s sufferings. This represents a turnabout from the time of the ancients, who looked at our emotions and instincts as something generally despicable that resembled animal nature, hailing reason and logic as our virtuous, “human” aspect – that part in us most resembling God.

As a contrast to the modern classics in the field of organization theory, which treat emotions either cursorily or not at all, it is tempting to make a diversion 2400 years back through history to Plato's three books *The Republic*, *The Statesman*, and *The Laws*, arguably the first books on organization ever written. In them we find that control of emotions, especially destructive emotions, is a central theme in the struggle to achieve justice—a view formed under the influence of Socrates and the political events during the first 30 years of Plato's life.

Growing up during the Peloponnesian War and the concomitant decline of Athens,¹³ Plato quickly became disillusioned with politics and the politicians of his time, who did not even remotely approach the standards he thought necessary for good government. He turned down several requests from friends and relatives to take part in government in the years following the defeat at the hands of Sparta (404 B.C.), and his repudiation of the Athenian leadership became particularly strong after the execution of Socrates, his mentor, in 399 B.C.

He concluded that no one could rule justly without an understanding of what justice really was; in other words, the ruler must be so thoroughly trained in philosophy and so advanced in his thinking that he would be totally governed by reason, unmoved by all kinds of desires, always working for the best of his subjects and never serving his own interests. This view was first presented in *Gorgias*, but received its full expression first in *The Republic* (where the philosophers are appointed rulers) and later in *The Statesman* (where rule is effected partly by law and partly by philosopher-statesmen) and *The Laws* (where an almost immutable set of laws is set to provide the rule that fickle human nature cannot).

A passage from *The Laws* serves to illustrate Plato's conclusions, in which the Athenian (the book's main character and presenter of Plato's views) says:¹⁴

Cronus¹⁵ was of course aware that human nature, as we've explained, is never able to take complete control of all human affairs without being filled with arrogance and injustice. Bearing this in mind, he appointed kings and rulers for our states; they were not men, but beings of a superior and more divine order—spirits. We act on the same principle nowadays in dealing with our flocks of sheep and herds of other domesticated animals: we don't put cattle in charge of cattle or goats in charge of goats, but control them ourselves, because we are a superior species. So Cronus too, who was well-disposed to man, did the same: he placed us in the care of the spirits, a superior order of beings, who were to look after our interests—an easy enough task for them, and a tremendous boon to us, because the result of their attentions was peace, respect for others, good laws, justice in full measure, and a state of happiness and harmony among the races of the world. The story has a moral for us even today, and there is a lot of truth in it: where the ruler of a state is not a god but a mortal, people have no

¹³ Plato was born in 427 B.C., just two years after the death of Pericles. The death of this remarkable statesman marked the end of the golden age of Athens, when she dominated the Delian League and her democratic leaders were also men of philosophical merit.

¹⁴ The traditional method of reference to Plato's works is by the page numbers in the edition by Stephanus (1578). The quoted paragraph is from pages 713–14, the passage on the Age of Cronus in book four. The translation is by Trevor J. Saunders, and was published by Penguin Books in 1970.

¹⁵ One of the Titans, son of Uranus and Gaea (Heaven and Earth), father of Zeus and several of the other gods.

respite from toil and misfortune. The lesson is that we should make every effort to imitate the life men are said to have led under Cronus; we should run our public and our private life, our homes and our cities, in obedience to what little spark of immortality lies in us, and dignify these edicts of reason with the name of "law." But take an individual man, or an oligarchy, or even a democracy, that lusts in its heart for pleasure and demands to have its fill of everything it wants—the perpetually unsatisfied victim of an evil greed that attacks it like the plague—well, as we said just now, if a power like that controls the state or an individual and rides roughshod over the laws, it's impossible to escape disaster.

Plato, then, who was much more uncompromising in his fervor for reason and logic as the governing principles for organizing than the modern classics of organization theory ever were, at the same time fully realized that it was the emotional side of human nature that was his worst enemy, and devoted large parts of his works to discussions of how the unwanted part of those emotions could either be eradicated, suppressed, or controlled. He certainly also realized (at least as he grew older) that his goals were utopian, and that the best one could do in practice was to enlighten prospective politicians as much as possible, hoping that this would moderate their behavior when in office. At least, that was one of the practical functions of his Academy, which attracted students from throughout the Greek world.

Indeed, as Fineman suggests, the time is long overdue for bringing the subject of emotion (back) into the discussion of organization, though the scope of this text does not permit a detailed discussion of the subject. However, I believe it is too important to leave out altogether, and all the more so because its importance seems to be grossly underestimated in the debate on the use of information technology in organizational settings. I will therefore include those aspects of emotions that I think are the most important in the following discussions.

As Flam (1993) points out, our emotional self is constantly interfering with the rational and normative parts of our mind.¹⁶ Fear, for instance, which is the subject of Flam's discussion, can cause an individual to rationally plan and perform actions that are in direct conflict with the normative self, and pride can cause an individual to obey the normative self even if it means death, thus overriding rational deliberations. As we all know, love and desire can also have devastating effects on rational behavior.

In a small hunter/gatherer band, our most probable "natural" state, the strong influence of the emotional self poses few organizational problems. On the contrary, organization in such a band is indeed structured around affectionate relationships, as well as real and ritual family relationships, myths, and religious conceptions—and emotions constitute a large part of the glue of such relationships. Emotions here ensure the stability and predictability of both structures and lines of authority, and can thus be said to constitute a fundamental human organizational tool.

¹⁶ Flam herself contrasts this trichotomy with Etzioni's (1988) merger of norms and emotions. However, the division of the human consciousness into a rational, a normative and an emotional part is an old and established way of conceptually dividing human consciousness into partly conflicting selves. For instance, it roughly corresponds to Freud's *ego*, *superego*, and *id*.

That this basic mechanism is still very important can be seen from the fact that family ties continue to be of great importance in most societies of the world, both in private organizations (businesses) and in politics. Even in modern democracies, family ties continue to have considerable significance. Another class of emotional bonds, friendship ties, is also very important, and in the headlines of newspapers and newscasts we are constantly reminded of the immense power of tribal (ethnic) identification—both for the better (national unity in crisis or celebration) and for the worse (racial discrimination, war and ethnic cleansing).

As a tool for organization, emotions are definitely most appropriate in the small group—such as the hunter/gatherer band, where it probably awarded an evolutionary advantage. In larger organizations, however, emotions may give rise to problems such as factionalism, when loyalties and interests defined locally clash with those defined on higher levels or elsewhere in the organization.

Emotions also make us less reliable in many ways, and harder to predict. They often bend our memory, shift our focus of attention, create interpersonal tensions, give rise to tactical behavior and generally mess up our performance as organization members. Organizations become not only rational means to legitimate ends, but also, as Morgan (1986) shows, arenas for display of ambition, pursuit of individual goals and fights for control. They become instruments of domination and vehicles for status. Some of the most extreme demonstrations of this phenomenon are presented by the takeover kings of our modern market economies. Driving their aggressive manipulations are the same desires, ambition, and thirst for power and status that drove Genghis Khan, Alexander the Great and Harold the Fair-haired. Some of the modern warriors are no less ruthless than their ancient brothers-in-arms either, if judged relative to the accepted standards for chieftain conduct in their respective epochs and societies.

However, it is perfectly in line with the dual edge of our emotions that they sometimes make people extraordinarily reliable, as in times of war or other great danger, where, as already indicated, social bonding and emotional ties can induce people to remarkable selflessness and courage even in the face of torture and death.

Coping With Reality

So, as naked animals, we have our limits. We have nevertheless been able to survive and prosper in a complex world even without our present sophisticated tools. Indeed, we still have to trust our basic capabilities for many of our activities. How do we cope with the complexities of life, with the avalanches of information of all kinds (both through raw sensing and through symbol interpretation) that hit us every minute? What about the innumerable large and small decisions we have to make every day?¹⁷ Why are we not permanently bogged down in decisions?

¹⁷ If you think you are not deciding anything, think twice. Decisions are not only a question of determining which product to bet your company's future on, or what to do about that foreign subsidiary. It is also figuring out which bus to take to work, what to eat for dinner, what to wear, whom to greet (and how), and so on. We usually do not think about such mundane events as decisions, because they are performed more or less automatically—but decisions they are.

In his main work, "Reflections on the Revolution in France" (first published in 1790), Edmund Burke¹⁸ made the following observations (1986, p. 183):

You see, Sir, that in this enlightened age I am bold enough to confess, that we are generally men of untaught feelings; that instead of casting away all our old prejudices,¹⁹ we cherish them to a very considerable degree, and, to take more shame on ourselves, we cherish them because they are prejudices; and the longer they have lasted, the more generally they have prevailed, the more we cherish them. We are afraid to put men to live and trade each on his own private stock of reason; because we suspect that this stock in each man is small, and that the individuals would do better to avail themselves of the general bank and capital of nations, and of ages. Many of our men of speculation, instead of exploding general prejudices, employ their sagacity to discover the latent wisdom which prevails in them. If they find what they seek, and seldom they fail, they think it more wise to continue the prejudice, with the reason involved, than to cast away the coat of prejudice, and to leave nothing but the naked reason; because prejudice, with its reason, has a motive to give action to that reason, and an affection which will give it permanence. Prejudice is of ready application in the emergency; it previously engages the mind in a steady course of wisdom and virtue, and does not leave man hesitating in the moment of decision, skeptical, puzzled, and unresolved. Prejudice renders a man's virtue his habit; and not a series of unconnected acts. Through just prejudice, his duty becomes a part of his nature.

Burke's observation here is twofold: His first point is that man will do well to heed the accumulated experiences of his predecessors, which are manifested in society's common institutions, laws, rules and tradition. They embody more experience and knowledge about the nature of men than any single person can ever hope to possess. To put it into a modern wording, they contain not only our explicit knowledge about man, but also the citizens' tacit knowledge (Polanyi 1967) and what Argyris (1980) terms *theories-in-use*, acquired through generations of experience. Just as important, the prejudices even embrace relationships that are still deeper hidden and unknown to any man, as they have slowly evolved through countless, practical trials and modifications, in constant interplay with the exceedingly complex interrelationships of a large-scale society unfolding through time.

¹⁸ Edmund Burke is without doubt the foremost of conservative British political thinkers through history, and arguably one of the founding fathers of that particular brand of European conservatism that combines democratic traditions with a program of piecemeal reform and social responsibility. His main work, *Reflections on the Revolution in France*, is both a persuasive statement of that philosophy and a brilliant analysis of the pitfalls of revolution. Both the French revolution itself and the communist takeovers of our own century have proved the main points of his analysis beyond any reasonable doubt.

¹⁹ The word prejudice is here not to be taken in its modern, derogatory meaning. To Burke, a prejudice is an internalized pattern for action resting on experience, as opposed to theoretical ideas for action building on speculation. A prejudice is to Burke more akin to the modern sociological concepts of *norms*, *theories-in-use* and *tacit knowledge*. It is also important to note that a Burkean prejudice is nothing like Plato's concept of a law in *The Laws*. It is not immutable; it is not something that is going to reach a final, perfect state sometime in the future. A prejudice is always amenable to change; it is evolving, continually absorbing the lessons of history and everyday experience.

His second point is that it is exactly our prejudices (with their contained action prescriptions) that allow us to act at all, or at least to act swiftly and without expending precious time and energy. If we had to analyze every new situation, every new challenge from scratch, we would be left in constant bewilderment—our brain would simply experience permanent overload. Interestingly, this a good description of our two most prominent strategies for coping: imitation and the compilation of mental sets.

Imitation

Imitation is the most obvious of the two. It lies at the very base of human learning and has been discovered to occur even in infants only a few days old (Hofer 1981). The socialization process is nothing but a transfer and subsequent internalization of standard procedures and norms for everyday life in society. The standards are not immutable, but they normally show great resilience against sudden change. Much of what our great-grandparents considered proper conduct is still endorsed by the great majority. By accepting established norms, we can relieve ourselves of an enormous amount of decision-making—we greet another person without thinking about how to do it, we do our shopping without fussing about how to behave toward staff and fellow shoppers, we automatically behave differently in a funeral than during a rock concert, we know how to conduct meetings in our local resident's association, and so on.

In organizations, we learn the local 'mores as we go, internalizing their traditional way of conducting business. The importance many people accord to this organizational socialization can be judged from the fact that numerous organizations have adopted a practice of only recruiting managers internally—thereby avoiding the potentially disruptive consequences of putting people with deviant norms in positions of power. The downside of this approach is the risk of groupthink and blindness to alternatives, which can be very dangerous—especially in rapidly changing environments.

Organization structures themselves are, as Stinchcombe (1965) convincingly argues, almost always imitations—most often of previously established organizations in the same line of business. Burke would have nodded his approval to people who, on starting a new business, copy organizational structure and business conduct from existing, successful operations. Very often, the founders of a new company have extensive experience from other organizations in the same business, and it is of course a lot more convenient just to roll out something one knows will work and is familiar with, than to use a lot of time and energy constructing something new and untried. Your financial backers may not approve it, either. On the other hand, you can also (as always in human affairs) find examples of the opposite: experienced people breaking out from a traditional operation to start a competing organization with a novel organizational approach as their main weapon.

In the same paper, Stinchcombe furthermore points out the conditioning effects of the prevailing social structure, which affects all contemporary organizations to a considerable degree. According to Meyer and Rowan (1977), organizations also tend to inherit formal structure from their society's institutional

myths—often resulting in a formal structure that is out of step with the actual, day-to-day work procedures.

Imitation is a very economic way of building an inventory of responses to common problems and events, and it allows knowledge to both accumulate and spread.

Mental Sets

To a newborn baby, the world must be a bewildering chaos of light, patterns, and sounds. Although it can already recognize some sounds heard before birth (especially the heartbeat of its mother), it has few possibilities of understanding what it senses—it has no established pattern “library” to relate its impressions to. Before it can recognize objects and sounds, it must build such a library, synthesizing similar, concrete, perceived patterns into generalized object classes, which can then provide the templates needed to recognize a particular instance of the class and ascribe the proper rules of behavior to it. It is exactly the class concept that allows us to recognize a particular car as a car, even if it is a model we have not seen before. We also know that we cannot count on it to stop on a dime—we expect it to have inherited the general properties of its class, of which a certain, approximate inertia and braking power are among the most important for pedestrians and drivers alike. The classes, their properties, and their relations to each other must be extracted from what we see and experience, and then stored in memory to allow later use. As Cohen notes (1980, p. 116), “If we are to be able to apprehend the world around us, this apprehension must be guided and shaped by our cumulative store of experience. In short, memory may be said to be the organ of perception.”

Similarly Hofer (1981, p. 134), when relating how even newborn babies learn to couple a bell signal with the availability of milk, and turn their heads toward the rubber nipple that slides into reach as the bell is sounded, remarks:

Lacking a preadapted reflex solution to the task posed by the experimenter in the example above, infants’ adaptive capacities must be fourfold. They must have some mechanism that will allow them to select the relevant stimuli from among all the sensory information coming into the brain—a sensory processing plan. They also must have a set of actions that are appropriate to this stimulus—a strategy. Both sensory and action plans must be stored and available for future use. They must have a mechanism for comparing the outcome of their efforts with some optimum state, and for revising the selection of sensory and/or action strategies if that comparison detects a discrepancy.

A little later (p. 138–39) he notes:

The idea is that within the newborn’s capabilities, as described above, lie all the building blocks for the mind as we know it. The sensory plan by which certain information is selected, together with the related action pattern, may be referred to as a *schema*. The human infant begins with some simple preadapted schemas, which I have described. Experiences like those studied in the laboratory experiment of Hein on early visual-motor coordination of kittens, may be supposed to enlarge the number and sharpen the details of such schemas by biological processes similar to those described in previous chapters. The essence of such processes is to form *inner representations* of the outside world and to make “predictions” as to the outcome of actions directed at that world. Both the

inner representations and the predicted outcomes are repeatedly modified when discrepancies are detected between the selected schema and the perceived outcome.

The speed with which the child advances in its early synthesizing efforts, its establishment of *schemas*, is a proof of the very powerful pattern recognition and integrating faculties of the brain. As the basic, physical patterns are synthesized, a child must also build the even more subtle models of the objects' properties, their normal behavior, the settings in which they occur, the relations between different objects, and so on. When it slowly realizes its own position as a separate entity with a certain freedom of action, this exhilarating fact must be integrated with its views of the outside world. It must start to build its own implicit theories of action—its own theories-in-use.

As we advance from the concrete, physical level to the abstract and symbolic, the synthesizing process becomes more and more demanding. It takes many years to build an adequate set of schemas for understanding human behavior and the proper responses in different situations, and quite a number of people seem to have problems ever acquiring a suitable understanding of the intricacies of human interaction. Likewise, establishing an adequate understanding of a branch of science is no easy matter, and beyond the reach of many people.

You get a renewed taste of this basic experience every time you enter a new field of knowledge: You are not able to judge what is important and what is not, or see what constitutes quality and what is more doubtful. You have to "get your bearings" first, to develop a "map of the terrain," a "feeling for the subject," so that you can judge and remember by relating to things you already know. To give you an example from the data processing world—my own field of the last eleven years: If you visit the annual CeBIT fair in Hannover without any prior knowledge of computers, you will probably end up in the enormous Münchener Halle or one of the other watering holes very quickly. In 1996 there were 6,300 exhibitors displaying their wares in more than twenty large exhibition halls (some of them multi-storied), and every year the fair is bigger than the previous. You will rapidly get completely lost in a numbing multitude of computers and software products that look very much alike, and return more confused than you entered. But, on the other hand, if you have a thorough knowledge of the field, the Hannover Fair presents an unparalleled opportunity to survey the state of the art and get a feeling for the priorities of the major vendors. With your bank of knowledge as a frame of reference, you are able to scan the booths and quickly pick out the new, the interesting, and the revolutionary. You can relate your observations to their context, and learn a lot where the novice only experiences chaos.

As we grow older, we build up an extremely rich complex of schemas covering the different aspects of the world and our lives, from the most minute details to a general world view. The schemas can relate to objects, persons, animals, acts, sensations, symbols, and so on, or combinations thereof. They tend to be organized in clusters, covering the totality of common situations. If we follow Goffman's (1959, 1970) analysis of human interaction and accept his metaphor of the theatrical performance, it seems natural to label these amalgamations of schemas as *mental sets*. A mental set defines the totality of the situation we confront and tells us what kind of objects, persons, acts, etc. are likely to occur,

and which types of actions and responses that are appropriate on our part. It thereby guides our perception and decision processes, provides us with an arsenal of preconceived solutions, and makes it generally possible for us to scan and evaluate the avalanches of information constantly bombarding our senses, and react to it in real time.

Sets can exist on different levels. At home, one set is activated, covering our domestic activities. Engage in political or philosophical debate, and a more sweeping set may be invoked, called ideology. Join in scientific research, and you will soon discover the reigning set of that science—what Kuhn called its *paradigm* (1969). And while much of our set building is original, in the sense that we synthesize our own sets on the basis of original experiences, we also co-opt (imitate) sets or parts of sets built by others. That is especially true for the more abstract, symbolic sets—for instance, ideologies and scientific paradigms. As a student, only the foolishly self-confident or the true genius will dare to deviate from the basic set (paradigm) agreed on by the canons of the science in question.

The Constraints of Sets

Our mental sets are powerful and indispensable. Set building is a very efficient way of coping with reality, and we could literally not survive a day without them. But, like all simplifications (and they are indeed simplifications of reality), they are also constraining, because we tend not to perceive events or objects that fall outside our sets (or, if we perceive them after all, we are inclined to judge them irrelevant). Our thoughts and actions tend to occur inside the set and consider it given, as in the experiments with the set effect mentioned earlier. In real life, breaking out of the set requires considerable energy, and will often be felt as disturbing and threatening. Thomas Kuhn (1970) has convincingly demonstrated this effect in the realm of science, but it is just as true in other spheres of action. Business history is full of companies going bankrupt because reality was changing, whereas the managers' mental sets were not, with the consequence that new, crucial developments were overlooked. You may as well talk of business paradigms as scientific ones.

Consider for instance the example of the Swiss watchmakers: Their paradigm was built around mechanical clockworks. They strived to become better precision mechanics. Unconsciously, they assumed that watches were in their essence mechanical devices. Accordingly, when a superior technology for timekeeping came along, they did not recognize it: Electronics was not their business; it was not part of their paradigm. The customers thought otherwise, though, and electronic watches almost wiped out the entire Swiss watch industry. Their business was cut by two thirds in just a few years. Now the Japanese dominate.

The electronic revolution in timekeeping also tore the timekeeping function away from watches altogether, and we got timekeeping pens, calculators, and radios—even coffee machines! The victorious paradigm of the Japanese watchmakers, however, was strictly a technological one—it did not contain the notion of a watch as a piece of apparel that happened to measure time. It took a shell-shocked Swiss to think of that, which shows that when a paradigm first breaks down, radical change is again possible (indeed, for people who feel stifled by the old paradigm, its collapse is often experienced as a liberation). Combining

the knowledge that people always like to dress smart with the low price of electronic watches, the stricken Swiss watch industry spawned the Swatch, and the ever-changing collection of funny, colorful watches soon swept the world.

It is also noteworthy that IBM almost did not enter the computer business, at least not as early as they did. According to Cuthbert C. Hurd, then a coworker of Tom Watson, son of the legendary Watson Sr. and champion of the computer cause within IBM, IBM's planning department in 1950 vigorously opposed going into computers (Augarten 1984). "Because they could not imagine classes of problems different from those already treated by punched-card equipment," Hurd wrote, the planning department "told me throughout 1950 that no computer could ever be marketed at a price of more than \$1000 per month."

At about the same time, Watson Sr. is credited for saying that "the United States will never need more than twelve computers." Eventually, IBM delivered eighteen of its first computers, the 701, at a cost of \$15,000 per month, and most of them to private corporations! Even after this remarkable success, the planning department kept repeating their "You can never sell a machine that rents for more than \$1000 per month," now modified by the extension "except to scientists." They kept on resisting the construction of the 650 all the way to its release in July 1953, when it was an instant hit at around \$3,500 a month. Fifteen hundred machines were manufactured altogether before the 650 was phased out in 1969.

You may also speak of national or societal mental sets and paradigms. The Yir Yoront (which will be discussed in the next chapter) present a striking example of this. Their paradigm denied them the use of the bark canoe, and when artifacts and people not defined in the paradigm became too many and too conspicuous to ignore, the paradigm itself collapsed. The tribal society collapsed with it, as the Yir Yoront were not able to construct a new paradigm and a new array of mental sets in time to save their social fabric from unraveling. A contemporary example is the development in the newly liberated countries of Eastern Europe, where the communist paradigm has been officially discarded. The common mental sets created by this paradigm linger on, however, and are still the main obstacles for turning the economy around. Typically, those countries that fare best are those that experienced a period with a modern capitalist economy before they were occupied, and where capitalist/liberalist mental sets therefore still exist in the population.

As the communist sets slowly disintegrate under pressure of the new realities, chaos is threatening, as it is extremely difficult to build new sets shared by all in such a short time, even when there are obvious (and indeed identified) models to be found elsewhere in Europe. Most epochal of all, the paradigm of the Soviet Union as a strong, centralized empire has broken down—not only the paradigm of communist party leadership, but the very concept of the union.

The breakup of empires is a risky business, and both revolutions and wars as well as other dramatic upheavals show us that we are not masters of the complex. Unintended consequences proliferate and surprises abound. That is the basis for Burke's fondness for prejudices—they represent integrated knowledge, tested through centuries of unforeseeable incidences. We know they work in their proper settings; therefore, they provide us with much needed stability and predictability in human affairs. That is their strength but also their weakness, since stabilization also means a bias toward the status quo.

5 The Dawn of Organization

“My notion is, I said, that a state comes into existence because no individual is self-sufficing; we all have many needs.”
Socrates, in Plato, *The Republic*, c. 380 B.C.

Evolving from the Primate Stage

As a naked animal, then, man is in many ways constrained in his organizational abilities, even if he far outperforms any other animal. He cannot process important matters in parallel, has a limited memory, and there are many important constraints on his capacity for problem solving. His communicative capabilities are restricted by narrow bandwidth and short range, and his more basic, primate nature poses many obstacles to the rational behavior required for large-scale organizing, especially when taking place outside the domain of the family or the local band.

What kind of organization did man then build in his “natural”¹ state? To answer that question, we can either look to the studies of contemporary primitive societies, or we can consult historic evidence—or, preferably, both. There are a couple of problems, however.

First, if one wants to study preliterate organization, one confronts the same main problem as when studying preliterate history—there are simply no firsthand accounts available, because all written material must by definition be secondhand renderings of knowledge passed on from an oral tradition. What we do have preserved are myths and legends, such as folk tales, religious myths, and epics (e.g. the *Iliad* and the *Odyssey*).

But all is not lost. Although we know that myths are not accounts of historical facts, and legends are notoriously unreliable in details, both myth and legend

¹ The quotation marks around the word *natural* are quite intentional—as it is highly debatable what the natural state of contemporary man really is. It is quite interesting that people today always seem to think that modern urban life is unnatural for humans, and that only the most primitive of societies can be said to be in close accord with human nature. However, if we applied the same standards of judgment to humans that we use for animals, that is, determining what is natural from observation of unrestrained, actual behavior, our conclusions would, as Morris (1967) argues, be entirely different.

preserve important background information about the societies that created them. As Shotwell says about legends (1961, p. 48–49),

Their study belongs to the field of folk lore, a field in which scientific methods have as yet made little progress. But history may sometimes find in it at least a general guidance in matters otherwise unrecoverable. The incidental mention of natural objects helps to throw light upon the character of the civilization which produced the legend. For instance, the tales of early Rome point to a farming community. In like manner, the very absence of mention is sometimes just as significant. None of these same early Roman legends points to the sea. The story of Aeneas's wanderings came in after Greek civilization had penetrated Italy. It was obviously manufactured after the Romans knew about Greece and appreciated Homer enough to wish to trace their ancestry to the fields of Troy. We know that this was the case because there are no primitive traditions that correspond to it.

It is highly unlikely that myths and legends will operate with basic social and organizational patterns that are totally different from those of the societies that produced them, and archeological evidence can further corroborate the evidence contained in the myths and legends.

The myths and legends that have made it into writing, however, are largely the creations of the most advanced societies—those that made the transition to literacy. They therefore probably reflect social organization at a fairly mature stage. To gain insight into the conditions of man before what we call civilization, to grope for the very beginnings of human society, we are, as Wilson (1988) remarks, invariably drawn toward the simplest societies we know—the contemporary hunter/gatherer societies of the third world. This has its own problems, since the primitive societies that have survived to be studied in our own time may not be representative of man's prehistoric past. As Morris says, taking on traditional anthropology (1967, p. 10),

What it did not tell us was anything about the typical behaviour of typical naked apes. This can only be done by examining the common behaviour patterns that are shared by all the ordinary, successful members of the major cultures—the mainstream specimens who together represent the vast majority. Biologically, this is the only sound approach. Against this, the old-style anthropologist would have argued that his technologically simple tribal groups are nearer the heart of the matter than the members of advanced civilizations. I submit that this is not so. The simple tribal groups that are living today are not primitive, they are stultified. Truly primitive tribes have not existed for thousands of years. The naked ape is essentially an exploratory species and any society that has failed to advance has in some sense failed, "gone wrong." Something has happened to hold it back, something that is working against the natural tendencies of the species to explore and investigate the world around it. The characteristics that the earlier anthropologists studied in these tribes may well be the very features that have interfered with the progress of the groups concerned. It is therefore dangerous to use this information as the basis for any general scheme of our behaviour as species.

However, everything we know about prehistoric man suggests he was a hunter/gatherer, and even if parts of the culture or environments of contemporary tribes have served to hold back their development, it is highly probable that they have enough in common with our (and their) distant ancestors

that we can learn a lot about the conditions of prehistoric man by studying them. It is the closest we can get.

Present-Day Hunter/Gatherers

According to Wilson (1988), hunter/gatherer societies—at least those of the twentieth century—are extremely simple and small scale. The bands are small, consisting normally of 25 to 50 people, and they have no permanent place of residence. Neither do they recognize exclusive territories or formal boundaries. Although bands normally move within a geographically restricted region,² the regions overlap, without this giving rise to territorial conflicts. There is nevertheless a definite association between the people and the territory, but it centers around features of the landscape rather than the stretches of land between them. Paths, tracks, water holes, and sacred sites are the landmarks of the hunter/gatherer bands, and these serve them as base points for mapping their relative positions as they move about.

Because they are constantly on the move, they have no permanent settlements—they erect temporary camps that may last only a few days or weeks. Shelters normally take little more than an hour to construct, and in some cases they even live around the fire in the open. They live in very close physical proximity to each other, with almost no privacy as we know it. Not surprisingly, conflict management and control are well developed in these societies—conflict is disruptive and must be avoided. If things get too tense, the exit option is always there—it is perfectly legitimate to leave the band and join another.

This relaxed attitude to group membership seems to permeate hunter/gatherer society. Contrary to conventional theory, which placed great importance on kinship bonds as the major structuring force in the bands, modern research (according to Wilson) seems to bear out that hunter/gatherers have very flexible and fluid relations. Kinship ties are weak, even between parents and children. Pandam children, for instance, are free to leave their parents after the age of about six. Marital relations change, and people frequently change dwelling for what seem to be just desires and whims. The strongest criterion seems to be personal affection and feeling of friendliness, and kinship ties have significance only as far as they are reinforced by affection and physical proximity. Even for people in the same band, kin is generally not reckoned beyond the second degree of collaterals. At the third degree, people start to forget kinship ties. However, kinship still seems to be the most basic structuring mechanism. It can easily be overridden by affection, but in most hunter/gatherer societies, it always exists as an independent factor (the Pandam appear to be at the extreme end of the kinship importance continuum).

Above all, however, the hunter/gatherers seem to value independence—it is encouraged in children from the start. Dependence on others is looked down upon. The ideal is that everyone should be independent and self-sufficient. Sharing of food is nevertheless ubiquitous, especially the meat of larger animals. The bands are extremely egalitarian, and any attempt on the hunter's side (after

² The region can be quite large, however, and the population density in hunter/gatherer areas is very low—typically 0.5 to 10 persons per 100 square kilometers.

killing big game) to boast about his skill is immediately put down by the others. Great care is also taken to avoid recognizing the lucky hunter as a benefactor, as someone to whom the rest should owe favors.

It follows from the fluidity of group membership and personal relations as well as the independence ideal that the hunter/gatherer bands have no real central authority structure. There is no chief in our meaning of the word, and the social order is upheld mainly through consensus and group pressures. People breaking the consensus are more or less ostracized—they are in reality forced to comply or leave the group.

As Wilson describes it, the structure of hunter/gatherer society is minimal, and it shows a definite resemblance to the roving bands of our relatives among the primates. (Indeed, some of the apes have a clearer central authority, in the form of a dominant male.) There is a degree of organization—common tasks are undertaken, food is shared—but on a very small scale, and based mainly on direct personal relationships reinforced by affection. The size and scope of organization is limited by the extremely low overall population density in hunter/gatherer territories, by the small size of the bands, and by man's intrinsic physical limitations. There are, however, hunter/gatherers that have developed more advanced social structures—for instance, the aborigines of Australia.

The Yir Yoront and Their Neighbors

When Europeans first encountered them, the aborigines had been living undisturbed for perhaps as long as 30,000–40,000 years and had developed a richer culture and more elaborate organization than most of their remaining "colleagues" on other continents. But, even if they were more advanced socially than the Pandam, Naiken, Hadza, !Kung, and others described by Wilson, they were still distinctly "primitive" and without any trace of sedentism.

As Lauriston Sharp (1952³) described them, they lived a roving life in fairly small bands. They had domesticated the dog, but no animal that served as a source of food. They did not know metals, and even their stone tools were primitive compared to the refined flint implements of the mature stone age cultures of ancient Europe. Living in a tropical climate, with few means of food conservation, foraging was their dominant activity.

Their social organization was closely associated with their religious concepts and their perception of the world. Aboriginal belief divided time into two great epochs—the first a distant and sacred past, populated with mythical ancestors, and the second a new and more prosaic order comprising the present. The mythology held that everyone and everything present had a corresponding archetype in the mythical epoch, and that everything that happened today was just a reenactment of the actions originally carried out by the mythical ancestors. A man was a member of a particular clan (the Yir Yoront were divided into two dozen clans) because his alter ego among the ancestors was so, his name was the

³ Sharp's paper is about the Yir Yoront and their neighboring groups on the Cape York Peninsula in Queensland, Australia, in the 1930s. It has inspired several comments about the important interplay of technology, culture, and organization, for instance Peter S. DeLisi, "Lessons from the Steel Axe: Culture, Technology, and Organizational Change," *Sloan Management Review*, 3, 1990, pp. 83–93.

same as the ancestor's, he performed the same duties, married a certain woman from a certain clan because his ancestor had done likewise, and so on. His position in his community and relations to everyone else was clearly defined by his mythical ancestor's relation to the ancestors of the others, and was acted out both in rituals and in everyday life.

These relationships even transcended the local group, because of ritual and trade relationships between groups. In northeastern Australia, the most important items of trade were stone axe heads, coming from quarries in the south, and spears made from the barbed spines of stingrays, originating from the coast-dwelling groups in the north. This string of trade relationships may have extended up to a thousand kilometers, involving a large number of separate communities. The trade relationships between pairs of persons from different communities were defined within the ancestral system in kinship terms, although no actual kinship was involved. Trade was carried out mainly during the great ritual celebrations in the dry season, which often attracted hundreds of people.

The aborigines had no conception of a future different from the present—their view of history was circular rather than linear. They believed that nothing new ever happened, that their total universe of people, actions, and artifacts was defined and laid down in the sacred epoch. No new actions or artifacts were in their view possible. Certain beings, artifacts, places, and actions in the mythical world and the corresponding persons, animals, artifacts, places, and actions in the present world also made up the thousands of different totems of their totemic religion,⁴ all associated with a particular clan, and all having their prescribed places in the different rites and religious ceremonies. Thus, aboriginal life was regulated by an exceptionally strong combination of world view, religion, heredity, and tradition. Surplus time was used not for exploration or accumulation of food or artifacts, but primarily for sleep. In many ways this society was oppressive, leaving little room for entrepreneurship and exploration as we know it (except, probably, the right to leave the group and join another), but at the same time it provided a stable social system where actions and events were predictable and justified, and where an individual could trust others and experience the dignity that comes with a life in adherence to prescribed norms and rules of conduct.⁵ The resilience of this system and the importance ascribed to it can best be illustrated by the following two examples.

⁴ The totems could include not only natural or cultural beings, things, or phenomena as animals, huts, spears, the sun, stars and daybreak, but also actions such as swimming, vomiting, and fighting. Ghosts, babies, corpses, milk, blood, lips, and loins were also totems. And although individual members of the classes of totems might disappear or be destroyed, the class itself was ever present and thus indestructible, much like Plato's conception of ideas (versus their temporal representations in the everyday world).

⁵ For most people, such social stability is a very important part of the foundation for a satisfying life—the insecurity of an undefined social situation will lead to stress. This is perhaps the main reason for the attractiveness of large bureaucracies or the peacetime military: These organizations closely define both your role, your tasks, and your expected behavior. If you follow the rules, you are safe, and your dignity is conserved or even enhanced. In war, however, this system breaks down in the military, and quite different personalities are attracted to the service and making quick careers: the risktakers, the creative, and the vigorous.

In 1864, it was recorded that a party of cattlemen had been attacked by aboriginals while driving a small herd from southern Queensland to the north tip of the Cape York Peninsula. The attack took place at Mitchell River, where the Yir Yoront were studied 70 years later. At least 30 aboriginals were killed by the cattlemen's firearms before they withdrew. One would expect that such a surprising and tragic event should live in Yir Yoront memory for generations afterward, and become a focus of tales of heroism and magic. Yet when the anthropologists arrived (70 years later), not a trace of the event could be found in any of the stories containing the history of the group. It was as if a collective suppression of the fact had taken place because it did not fit in their view of the world: None of the mythical ancestors had ever been attacked by white men and killed in scores by firearms.

The other interesting example (briefly mentioned in the previous chapter) is the fact that the Yir Yoront did not use any form of boat or raft, while their neighbors 70 kilometers to the North made and used bark canoes. During their constant swimming in rivers, creeks, and tidal inlets, the Yir Yoront never used any other craft than a light wood log, to which they would cling as we would to a life buoy. This way, they were constantly exposed to crocodiles, sharks, stingrays, and poisonous jellyfish, and could only fish from beaches and river banks. They knew perfectly well that their neighbors used canoes, and they knew the relevant materials, which were readily available. But they also knew, they explained, that their mythical ancestors never built or used canoes, and that was the reason why they themselves lacked it. They assumed that the canoe was a part of the ancestral universe of their neighbors and regarded it therefore natural for them to have it.

For the Yir Yoront to adopt the use of the canoe, then, would not only require learning new skills (which would be relatively easy), but would demand a substantial change in their model of the world. It was thus blocked, in spite of the considerable evolutionary pressure that must have existed in favor of adopting the canoe as a daily tool. It is tempting to interpret this in the light of Morris's comments and the concept of mental sets described in the previous chapter: The Yir Yoront had developed a religious/cultural paradigm and an accompanying mental set that blunted curiosity and blocked any development in knowledge and technology. They had locked themselves into an evolutionary dead end compared with the mainstream of humanity.

We may similarly question the extremely weak structures of the hunter/gatherer societies described by Wilson. Maybe it is their seeming aversion to social control and obligations—which is a necessary complement to more permanent, close cooperation—that explains why they have remained at the hunter/gatherer stage.

Domesticated Humans

Ancient tribes similar to the Yir Yoront did not by any means exhaust the basic human potential, however—the evolutive process continued, and man settled down. Even if the hunter/gatherer society is mankind's starting point, the overwhelming majority of men have been living in permanent settlements for the last 10,000–15,000 years. Historically, this has been the natural way of life for all important civilizations. When inquiring into the roots of human organization, we

must therefore include some reflections on the changes wrought by sedentism—which we know fairly well both from archeological evidence⁶ and the study of simple sedentary people from our own century.

When humans became sedentary, two important things happened. First, they began to build more sturdy dwellings, and second, the concept of property was extended. At the outset, it was not necessarily a question of individual property or the ownership of land or animals—many of the earliest known settlements were situated by the seashores or along lakes and rivers, and their inhabitants probably relied on fishing. But the village itself, at least, became the property of the community, as well as the increasing number of personal and family belongings such as tools and household utensils. Later, when horticulture, agriculture and domesticated animals became the economic basis for most societies, the rights to tillable land, herds, grazing areas, and tools became not merely important, but crucial for survival. Humans became fiercely territorial, defending what he had, and often engaging in war to seize new land.

When rights to land became established, kinship took on an important new dimension. The fluid arrangements of the hunter/gatherer bands were simply not adequate anymore, since kinship regulated the access to land—collective or individual. Land rights were inherited on the basis of kinship and village affiliation, and the exit option was not so easily available anymore—individuals could not simply leave their native village and expect to become a full member of another one. Leadership became more pronounced, either in the form of chiefs or councils.

There were (and are) many variations, however. The status of chief may be inherited, or a chief may be chosen. Councils may consist of family heads, elders, or combinations thereof. There is even evidence that the same societies may oscillate between the two forms, which Leach (1970) reports as a likely explanation for the existence of two parallel systems of authority among the Kachins of highland Burma: Some villages were hereditary chiefdoms; some were ruled by councils of family heads. According to Leach, the evidence suggests that chiefs who stretch their powers too far could be deposed and supplanted by a council, and that a strong natural leader eventually emerging in a council in his turn could succeed in establishing a new hereditary chiefdom.

This new importance of kinship gave sedentary communities a much more permanent and substantial structure than hunter/gatherer society, a structure that was further elaborated and strengthened in the societies that were systematically able to produce a food surplus—as a result of abundant natural resources, irrigation engineering, or both. Surplus production of food made room for craftsmen, merchants, religious specialists, and ruling classes, and made large construction projects possible—some of which (like the extensive irrigation projects of the ancient civilizations in the Middle East) increased the fertility of the land further and thus contributed to the development of even larger and more complex societies.

⁶ Almost by definition, hunter/gatherer people without permanent dwellings leave no trace for posterity. Archaeology deals almost exclusively with sedentary cultures or with semisedentary nomads, who may live part of the year in permanent villages.

Surpluses invariably lead to social stratification, an uneven distribution of property, and a more stable social structure. Again, we can turn to Leach (1970) for evidence: the Kachins, with their structural instability, lived in the hills in the highlands, more or less at the subsistence level. The hills were quite steep, and fertility and arable land were limited. The villages could produce little or no surplus; there was simply no economic room for a class of landowners.

In the valleys, on the other hand, the conditions for agriculture were much better. The people living there, the Shan, had a more sophisticated culture (they were, among other things, Buddhists) and a stable social structure, forming feudal⁷ states based on hereditary positions tied to the ownership of land.

The new structured society imposed a much wider set of rights and obligations on people and developed a rich set of rituals and routines to enforce them. Unlike in hunter/gatherer society, routine is a hallmark of the sedentary community. Most of the day is spent doing programmed tasks that are necessary to fulfill one's obligations toward others or tending the land and animals that are the basis for one's subsistence. The social and political structure is thus cast in a stable pattern of actions that is constantly enacted and becomes thoroughly ingrained in people's minds. Periodical religious or other feasts and rituals contribute to this and give the status quo a more solemn blessing. Often, a period of religious training followed by initiation rituals becomes a part of the upbringing for all children.

When the development of human society reached this stage, technology and techniques had already started to make a difference. Domestication of the horse in many societies and the emergence of ships improved communication, and buildings were used not only for shelter, but also to encode information—especially information of a ritual character and with a bearing on the social structure. Mankind was approaching its first real technological revolution, the invention of writing—to which we shall return in Chapter 6.

The rest is, literally speaking, history.

Theory for Simple Organization

Most organization theorists are not very interested in simple organizations, in exploring the primal space of organizations. That is perhaps not so surprising, since organization theory as a discipline sprang from the problems experienced in building and running the complex organizations that arose in the late nineteenth century and grew to prominence in our own. Small-scale societies and simple organization have by and large been left to anthropology.

Another reason is probably the distinction that early theorists made between formal and social organization set up by the classical theorists. Organizational theory was restricted to the former—the latter, especially the family, was seen as something quite different. To me, this distinction is artificial. Organization lies at the bottom of human existence, and the repertory of behaviors that formed our

⁷ There are some nuances in how different people use the term "feudal." The most restrictive reserve the term for the political system of the kingdoms of medieval Europe, others think (as I) that it is meaningful to extend the term to cover all hierarchical political systems where lineage and control of land are the main structuring elements.

societies from the earliest is are the same that underlies the more advanced formal organizations of the modern era—even if they have evolved considerably, and have come to depend in large part on tools not available to humans in the “natural” state. Even today, when formal organizations, voluntary organizations, and family life all have different “frames” (Goffman 1974), we are not able to separate them fully. Experiences and prescriptions from one frame tend to spill over into the others, and our situation in one of these domains always interacts with our situation in the others.

One of the few theorists who does discuss simple organizations is Henry Mintzberg (1979). His classification of organizations (see Table 3-2, page 58) contains two forms that encompass small, simple organizations: The Simple Structure and the Adhocracy.

Of these, the Simple Structure is the intuitive small-scale organization with a strong leader, often charismatic and entrepreneurial, leading the organization through direct supervision effected through informal contact with its members (Mintzberg 1979, p. 306, bold type from original):

The Simple Structure is characterized, above all, by what it is not—elaborated. Typically, it has little or no technostucture,⁸ few support staffers, a loose division of labor, minimal differentiation among its units, and a small managerial hierarchy. Little of its behavior is formalized, and it makes minimal use of planning, training, and the liaison devices. It is, above all, organic. In a sense, Simple Structure is nonstructure: it avoids using all the formal devices of structure, and it minimizes its dependence on staff specialists. The latter are typically hired on contract when needed, rather than encompassed permanently within the organization.

Mintzberg gives the Simple Structure a much wider span, however—it ranges from the small entrepreneurial start-up, where everyone works in the same little room (which he calls the *simplest structure*), to the large, autocratic organization run by the iron-willed founder/owner. It also includes Thompson’s (1967) *synthetic organizations*, ad hoc organizations set up to handle unexpected crises, such as natural disasters, and headed by strong leaders with comprehensive authority.

It is thus clear that many of the organizations falling into the Simple Structure category (the large ones) are anything but simple in administrative terms, and that they require sophisticated, technology-based infrastructures (such as paper-based archives and telegraph lines) to function. Prime examples are the large American trusts of the late nineteenth century, which Mintzberg classifies as Simple Structures because of their total dominance by single owners/entrepreneurs.

The Simple Structure, on a sufficiently small scale, has probably always been an extremely common organizational structure in human societies, as indicated by the foregoing discussion. This conclusion is also supported by recorded myths and legends. From the matriarchal queens of neolithic Europe⁹ to the matriarch or

⁸ For a definition of *technostucture*, see note to Table 3-2 on page 58.

⁹ In neolithic Europe the normal configuration seems to have been the *matriarchate* (Graves 1955). This configuration existed before the concept of fatherhood had been introduced into religious thought, and the matriarchs probably built their rule and goddess-like position on the basis of the female fertility. The ruling matriarch took a new ceremonial king as husband every

patriarch with her/his family, to the chief and his tribe, to the master craftsman with his apprentices, the Simple Structure abounds.

But, as indicated earlier, other structures have also existed from time immemorial—from groups of cooperating hunters, all on an equal footing, coordinating themselves by mutual adjustment, to more or less democratic villages and tribes with a council of elders or family heads as the supreme authority. The extremely simple bands of the Pandam, for instance, do not have sufficient leadership to qualify as Simple Structures. They can only be described as very loose Adhocracies. The more democratic variety of Kachin villages are a sort of a mixture, with family heads (Simple Structure) forming a governing council (Adhocracy).

With the term *Adhocracy*, Mintzberg mainly denotes innovative organizations with a high content of professionals and experts (Mintzberg 1979, pp. 432–33, bold type from original):

In Adhocracy, we have a fifth distinct structural configuration: highly organic structure, with little formalization of behavior; high horizontal job specialization based on formal training; a tendency to group the specialists in functional units for housekeeping purposes but to deploy them in small market-based project teams to do their work; a reliance on the liaison devices to encourage mutual adjustment—the key coordinating mechanism—within and between these teams; and selective decentralization to and within these teams, which are located at various places in the organization and involve various mixtures of line managers and staff and operating experts.

To innovate means to break away from established patterns. So the innovative organization cannot rely on any form of standardization for coordination. In other words, it must avoid all the trappings of bureaucratic structure, notably sharp divisions of labor, extensive unit differentiation, highly formalized behaviors, and an emphasis on planning and control systems.

This connotation is natural in the modern world of formal organizations. But the basic structural properties of the Adhocracy are found in the small, egalitarian human group, where problems are solved as they crop up, decisions are made by consensus, and coordination is taken care of by mutual adjustment—just like in the hunter/gatherer societies described by Wilson (1988). When society develops and grows beyond the limits of the mutually coordinating band, especially when it becomes sedentary, the Adhocracy evolves into the form seen in the Kachin villages, where the basic structure is the family, but where authority on the societal level is still created by mutual adjustment—now through the institution of the council. Following Mintzberg's terminology, we might well call this second-order form of the Adhocracy a *Councilcracy*.

If a strong natural leader emerges in a Councilcracy, it may change to a Simple Structure, but there may also be strong norms that inhibit such transformations (as in our own societies) or effect a return to Councilcracy when the leader dies, is deposed, or otherwise discredited.

spring, only to have him ritually killed and sacrificed at the end of the year—in periods, there may have been even two such cycles every year (from spring to late summer, and from late summer to the end of the year). As fatherhood was introduced as a concept and the men improved their status, the time the king lived was extended, the ritual killing was replaced with a mock sacrifice, and, finally, the king supplanted the matriarchal queen as the supreme leader.

Looking at the anthropological and historical evidence there is much to suggest that those two configurations—the Simple Structure and the Adhocracy—are the two basic organizational configurations of the human race.

In their simplest forms, they are also clean representations of two of the fundamental solutions to the problem of coordination (see Figure 3-1 on page 61): the Simple Structure achieves coordination by empowering one person to direct the others, and the Adhocracy by letting all the group members know what the others are doing at all times, thereby allowing each one to continually adjust his or her behavior accordingly.

That the basic forms of organization are differentiated on the basis of their approach to coordination only serves to underscore the observation by Mintzberg (1979) quoted in Chapter 3, that any organized activity “gives rise to two fundamental and opposing requirements: the **division of labor** into various tasks to be performed and the **coordination** of these tasks to accomplish the activity.”

The two other basic coordinating mechanisms delineated in Chapter 3, standardization of work and standardization of skills, did not give rise to separate organizational forms in preliterate societies, but they were obviously operative in rudimentary forms. As long as there have been humans, there must have been tacit knowledge and routinized ways of executing recurring tasks—indeed, as noted in Chapter 5, this is perhaps our main trick for surviving in an information-rich world with limited cognitive capacities.

If we look closer at the Simple Structure and the Adhocracy and their strategy for coordination, another striking difference also emerges. In the Simple Structure, it is sufficient that *one* person—namely, the leader directing the others—knows the goal of the activities and how all the different tasks are interrelated, since he can direct all the others according to his own plan. Coordination in the Simple Structure is focused on *directing work* and does not require that people are equally competent or informed (indeed, most leaders in such organizations will prefer that they are not).

The Adhocracy, on the other hand, requires not only that everyone in the group knows the goal, but also that they agree on it, have a common understanding of it, and are in reasonable agreement on the means. If not, their self-administered actions will simply not fit together. We may therefore say that coordination in the Adhocracy is focused on *sharing information*, and it requires that the participants are on the whole *equally competent* to act on that information.

Enlarging a Simple Structure is fairly straightforward, in the sense that there are means that are a part of an age-old human repertoire of social roles: if the organization becomes too large for the leader to oversee, he or she can *delegate authority* to trusted persons who are inferior in status and have clear loyalties. Insofar as such persons can be seen as direct extensions of the leader’s own person and authority, the capacity for direction and control can be substantially increased, whereas the line of command is kept unequivocally intact. We shall soon see how that was done in preliterate societies.

The Adhocracy, on the other hand, is much more difficult to extend. In an organization where everyone communicates directly with everyone else, the number of links increases very rapidly, according to the formula $n \cdot (n-1) / 2$, where n is the number of members in the group. With 30 people, for instance, there are 435 links—obviously far too many to be viable. Even if there are mechanisms in

such groups that normally reduce the necessary number of links well below the theoretical maximum, the members' communication capacity rapidly becomes saturated as the group grows.

All answers to this problem must compromise on the basic form to a much larger degree than for the Simple Structure. Because the only possible answer is to divide the growing group into subgroups, the all-to-all communication and direct, mutual adjustment is irretrievably lost. Even if direct mutual adjustment is preserved within the groups, coordination between them can be achieved only through group representatives. The method of representation then becomes an important parameter. The basic Councilcracy solved this by combining the Simple Structure of the patriarchal family with the Adhocracy of the council. The Greek city states evolved it into a combination of the town meeting and representative democracy (where, however, only proper citizens—free men who owned land—could vote), a tradition further elaborated to create our own modern representative democracies.

Adhocracy has not been a favored form of organization in more elaborate societies up through the ages. The reasons are probably mixed: in addition to the scaling problem, which is serious enough, the Adhocracy's democratic form could not survive in the more authoritarian cultures that have dominated every large and sophisticated society until quite recently.

The Problems of Organization Building in Preliterate Society

There are three questions that seem especially interesting regarding organization in illiterate or semiliterate societies (societies where the art of writing is known, but where so few are skilled in it that most activities and organization building have to be conducted without its help): what are the domains of the organizations we find, how are they structured, and what happens when they hit the upper limits of human memory, communication, and information processing—when they become too complex to handle by mutual adjustment or by direct supervision (the commands of a single person)? How does a kingdom grow larger than the number of persons the king and his immediate helpers can oversee?

The Organization Domains and Their Structuring

The domains of organization in illiterate societies are few. The first and most basic domain is the family, then we have the society's authority structure—whether the boundary of the society is the village, the tribe or the state. In more advanced societies, there may also be specific religious domains with separate organizing, and even small organizational domains of a craft or commercial nature.

Some readers may balk at the idea of calling a family an organization. We are used to reserving that concept for formal organizations (see, for instance, the discussion in Silverman 1970). However, I think this distinction is artificial. The formal organization, be it business or governmental, is a fairly new phenomenon. In preliterate society, the family was no doubt the main structuring element of society—indeed, even in Western societies, it kept this position until quite recently. In Taiwan, which has built a modern economy while retaining traditional

Chinese values, the family can still be regarded as the main structuring element of ownership in business (Hamilton and Biggart 1988).

There are several reasons for this. First, the family was not only an informal group bound together by affection; it was a structure with very formal and material purposes: to uphold rights to land (or condemn to serfdom), and to channel political power. Rights to land were almost the sole source of economic and political power until trade became so abundant that a rich merchant class emerged. Often, however, citizenship continued to be tied to the rights to land. As Nash says about the control of land in primitive and peasant societies (1966, p. 34):

The chief capital goods in primitive and peasant societies are land and men. Tools, machines, terraces, livestock, and other improvements in productive resources are controlled in a manner derived from the conventions of controlling and allocating land and human beings. In most societies land tenure is merely the geographical expression of social structure. Land is allocated through the operation of kinship, inheritance, and marriage, not through conveyance, contract, sale, or other more strictly economic modes of transfer. In fact, use of a word like tenure obscures the sorts of rights peasants and primitives tend to have in land. Since the rights are reflections of a person's or social unit's place in the social structure, they are not rights to property in the same sense as tenure in the law and economies of the Western world. Part of being a member in the tribe or the community, in the family or the lineage, in the clan or the phratry is to have access to specified pieces of land. Shifts in social position—by age, by marriage, by succession, by death, by inheritance—all occasion shifts in rights to the land.

Second, the family structure was already there—an important feature in illiterate society, where the burden of retaining administrative information was formidable: everything had to be remembered by someone, and, preferably, by a number of people, should claims be contested. Family relationships were widely known and easily remembered and were therefore a convenient infrastructure for other purposes. Third, loyalty could best be counted upon from members of one's family, where both affective and economic ties were present. And, of course, let us not forget that ancient humans in all probability had the same kind of affectionate feelings for their family, especially their offspring, that we have. In a society without the social and judicial safety nets of modern industrialized nations, it is quite natural for people to protect and support their nearest and dearest first.

Circumventing the Barrier of Cognitive Capacity

The rule by family head, chief, or council is adequate as long as the family, tribe, or city is below a certain critical size. This critical size is not possible to determine in any exact way, because it varies according to contextual circumstances (geographical extent of domain, fertility of land, hostility of neighbors, etc.). However, as our assessment of man's cognitive capacities indicates, the critical size cannot be very large and was probably transcended long before the invention of writing gave man an adequate instrument for large-scale administration.

The barrier must have proved a formidable one, and most prehistoric societies were probably small-scale structures, just like a large number of the primitive societies studied by anthropologists in our own time. The old Norse religious

myths, for instance, tell us that all the gods, *æsene* (the Aesir), lived together in Åsgard, with Odin as their chief, and even if they all had their separate duties, there is no mention of a larger hierarchy based on territory.

But, somehow and sometime, such hierarchies emerged, and we can find evidence of this also in the myths. The Pelasgian version of the Greek creation myth, for instance, says (Graves 1960, p. 27):

Next, the goddess¹⁰ created the seven planetary powers, setting a Titan and a Titaness over each. Theia and Hyperion for the Sun; Phoebe and Atlas for the Moon; Dione and Crius for the planet Mars; Metis and Coeus for the planet Mercury; Themis and Eurymedon for the planet Jupiter; Tethys and Oceanus for Venus; Rhea and Cronus for the planet Saturn.

And, in the very old Mesopotamian epic of Gilgamesh, believed to be written down 1500 years earlier than the Iliad and the Odyssey (Sandars 1964), we can read about Ishtar, Queen of Heaven, the goddess of love, fertility, and war, trying to persuade Gilgamesh to become her husband (p. 83):

When you enter our house in the fragrance of cedar-wood, threshold and throne will kiss your feet. Kings, rulers, and princes will bow down before you; they shall bring you tribute from the mountains and the plain.

Both passages indicate arrangements of a feudal character, where a ruler delegates power to subordinate chiefs or lords to rule separate parts of the kingdom. Even the myths of the Aztecs tell about how the supreme god, Omeyocán, divided the heavens into different regions and created a god to head each of them (Beals 1970). Further evidence of the general nature of this arrangement can be found in anthropological studies. If we return for a moment to the Kachins of Burma, a village was often part of a group of villages, and the local chiefs were subordinate to one supreme chief. The valley Shans, on their part, had a social structure that was even more distinctly feudal, where the local nobles were subordinate to higher lords and finally to the king himself.

In Africa, such structures were quite common in the kingdoms that existed when Europeans colonized the continent (Lloyd 1965). There were variations in the mechanisms by which the King appointed his subordinate chiefs, and the ruling class might be closed or open for upward migration from commoners, but the main principle was a division of responsibility by means of geography. Historic variations on the feudal structure have been the common political frameworks throughout the world, and these were probably developed to their most stringent and elaborate form in the kingdoms of medieval Europe.

The beauty of such a system—from a cognitive point of view—lies in the extreme economy it offers with respect to information processing, communication, and memorizing. Based on land rights and family lineage, it contains its own structuring information; information that is constantly enacted in everyday life and thereby reinforced in everyone's memory. By delegating to his vassals total

¹⁰ Euronyme, the Goddess of All Things, the first goddess to arise from Chaos, who, in the form of a dove, laid the Universal Egg. From the egg sprang the earth, the universe, and everything that exists.

authority over their fiefdoms and the people who live there, the king effectively encapsulates the information required to run the fiefdoms and shields himself from it. He now only has to worry about the loyalty of his vassals (often no small worry, unfortunately), the size of their tributes and their contributions to his army. The number of people with whom he must deal is drastically reduced. The king normally does not interfere in the way his vassals run their affairs, as long as they are sufficiently competent, loyal to him, and not so cruel or unreasonable to the people as to inspire massive uprisings.

It is thus a system that can exist without the help of writing, and, from an information processing point of view, there is no theoretical limit to the size of states built on these principles. However, we know of few large nonliterate states, and only one really large one: the Inca state overthrown by Pizarro in 1533. After extensive conquests in the two centuries preceding the Spanish invasion, it covered what is now Peru, as well as parts of Bolivia and Chile, an area of approximately one million square kilometers—about twice the size of France, or nearly one third the size of India. The total population of this empire was about 4 million.

The Incas' state organization was of a feudal type, and their expansion came almost exclusively in the coastal areas and in the hills where sedentary farming dependent on irrigation had already produced a society with feudal organization resembling their own. There they could rule through the established structure, through the old leaders, if they agreed to submit to Inca rule (which they often did). The Inca king (or the Inca, as he was called) supplied the vanquished lord with a new first wife from his own lineage and accepted one of his daughters into his harem in return. In such a way, the local lord was tied into the dynastic kinship system (Murra 1986). Note this prime importance of lineage as a structuring element: When such links were absent, they had to be at least formally established to foster loyalty and reestablish the customary congruence between lineage and political power.

However, even if the Incas were not literate, they had a system for numeric records, called the *quipu*, to help them. It consisted of a bundle of knotted threads, where threads and knots of different colors had different values. It was primarily used for taxation, but as the empire expanded and the king's needs for soldiers, food and other goods and services came up against the limits of feudal organization, the *quipu's* decimal organization started to be used also for organization purposes. Murra (1986) notes that, in the last years before the Spanish conquest, the Incas seemed to try out new local subdivisions based on numbers rather than on lineage and ethnic origin.

It is also very interesting to note that up to that point, the Incas had not managed to conquer and hold on to areas adjoining their empire—where people were not fully sedentary, but lived in semipermanent villages. Where the social organization stopped at the village level, and the villages themselves moved about,¹¹ the information economy of the feudal structure was not available and the task became too complex.

¹¹ Such as the southern grassland and plains of Chile, the dry savanna and forests of the Gran Chaco, and the tropical rain forest in the upper Amazonas.

If there were other preliterate states of the same magnitude, knowledge of them has not survived to be written down. Judging from the empires we do know, we can only conclude that very large states seem easier to build and control when the rulers have access to a literate class of administrators—a conclusion that seems perfectly plausible. Maybe the Incas represent the extreme accomplishment in organization building for an oral culture. Judging from the great importance that the *kipu* had for their administration, we may even view them as a borderline case—not truly oral anymore, but not quite literate either. If left alone for another century, they might well have developed their own script as an answer to their pressing administrative challenges.

The Feudal Type Organization

The feudal system builds upon the rule of one, on the concepts of the family head and the chief. Because there is a hierarchy in the family (father-son, mother-daughter), this concept lends itself readily to build a hierarchical social structure as well. More democratic systems had no such blueprint to follow, and, anyway, it goes against the grain of democratic assemblies to delegate power upward. It is thus no accident that societies with a more democratic type of government have been less prone to build empires than autocratic states. When a Greek city-state founded a colony, for instance, it was at no point supposed that the new city should obey the authorities of the mother city (Kitto 1951). It was certainly considered distasteful to enter into conflict with the mother city, and her citizens usually enjoyed certain privileges when visiting, but the new city was by all parties considered politically independent from day one. Another indication of this can be found in the reluctance of the the citizens of most EU-countries to move toward further political integration in the European Union.

From this perspective, it is also noteworthy that when countries in Europe managed to sustain colonial empires even when they themselves became democracies, they did so by basing their rule on ideas of racist and cultural supremacy. As soon as those concepts crumbled through moral debate and reflection in the ruling countries, the empires also disintegrated. The last example is the current collapse of the Russian empire. Built by the feudal and imperialist czars, it was upheld and even extended by the Communist Party, which (though democratic on paper) ruled on the basis of their own supremacist ideology: the theory that only the party cadres were politically conscious and could understand the true interests of the people. By demolishing that ideology, the Soviet leadership destroyed the ideological basis for the union, and the republics and regions were bound to claim sovereignty.

How does the hierarchy of the feudal-type state fit into modern organization theory? It has certainly evolved from the Simple Structure, but it no longer belongs to that category. On the surface, it may seem, it is just a case of the universal hierarchical form, found today in military organizations and in the large bureaucracies of government and private business. However, there are in fact significant differences. Modern bureaucracies rely on advanced administrative technology, primarily the art of writing and its associated tools. They are specialist oriented, with each level and department having definite responsibilities that fit together in a complex task structure. Work flows through it in an orderly fashion,

according to centrally administered plans and rules for execution. There are large flows of information both vertically and horizontally.

The original feudal hierarchies did not have the instrument of a written language at their disposal. They were not specialist oriented; on the contrary, the parts of a feudal state (on the same level) are by definition similar to each other. Communication, both vertically and horizontally, was kept to a minimum. The whole point of the feudal structure was precisely to simplify complexity as much as possible, so that the unaided human mind could handle it—it was to *abolish*, as far as possible, the need for coordination in the first place.

If we can compare it to a modern form of organization, it must be what Mintzberg (1979) terms the *Divisionalized Form*. A division, in the original sense of the word, is a more or less self-contained part of the organization, with a broad objective (usually to serve a particular market) and a minimum interface with corporate management—ideally limited to general goals, budgets, and profit goals downward, and status information (mostly in the form of financial reports) upward. As Mintzberg says (1979, p. 381, boldface in the original),

Most important, the **Divisionalized Form** relies on the market basis for **grouping units at the top of the middle line**. Divisions are created according to markets served and are then given control over the operating functions required to serve these markets. Thus, in [Figure 20-1¹²] a typical organigram for a divisionalized manufacturing firm, each division contains its own purchasing, engineering, manufacturing, and marketing activities. **This dispersal (and duplication) of the operating functions minimizes the interdependence between divisions, so that each can operate as a quasi-autonomous entity, free of the need to coordinate with the others.** To use Weick's [1976¹³] term, the system is "loosely coupled"—"tied together either weakly or infrequently or slowly or with minimal interdependence" (p. 5). This, in turn, allows a large number of divisions to be grouped under the headquarters—in other words, **the span of control at the strategic apex of the Divisionalized Form can be rather wide.**

This structural arrangement naturally leads to pronounced decentralization from the headquarters: each division is delegated the powers needed to make the decisions concerning its own operations. **But the decentralization called for in the Divisionalized Form is highly circumscribed: not necessarily more than a delegation from the few managers at the headquarters to the few more managers who run the divisions. In other words, the Divisionalized Form calls for decentralization of the parallel, limited vertical variety.**

He continues by discussing coordination (1979, p. 382–3, bold type and italics from the original):

Were the headquarters to delegate *all* of its power to the division managers, it would cease to exist, and each division would, in fact, emerge as an independent organization. So some form of control or coordination is required between headquarters and the divisions. The question then becomes: how can the headquarters maintain control while allowing each division sufficient autonomy to manage its own operations? And the answer lies in one specific

¹² Refers to generic organigram for a divisionalized manufacturing company reproduced on p. 382 in Mintzberg 1979.

¹³ Karl E. Weick: "Educational Organizations as Loosely Coupled Systems," *Administrative Science Quarterly*, 1976, pp. 1–19.

design parameter: the performance control system. In general, the headquarters allows the divisions close to full autonomy to make their own decisions, and then monitors the results of these decisions. This monitoring is done after the fact, in specific quantitative terms, in the case of the business corporations by measures of profit, sales growth, and return on investment . . . By the use of these systems, headquarters maintains control in the face of divisional autonomy. So the prime coordinating mechanism in the Divisionalized Form is the standardization of outputs, and a key design parameter, the performance control system.

The key elements here, from our point of view, are the *separate objectives* of the divisions, the *duplication of operating functions* across them, their resultant *quasiautonomy* and *elimination of the need for interdivisional coordination*. Real coordination is not necessary, as evidenced by the use of *standardization of output*, which, as we concluded in Chapter 3, is not a proper coordinating mechanism, but a prescription of a certain performance.

The goal of this method of organizing is obviously to *limit the need for information flows across division boundaries* and thus obtain a *wide span of control* for top management. Viewed in this perspective, the Divisionalized Form is only the modern commercial version of a primordial *Feudal Form* of organization, which developed out of the need to build large organizational structures with minimal requirements for memorizing, information processing, and communication. In the Feudal Form, the subunits were fully independent from each other, answering only to the higher level, they had their own administrative apparatus, and their objectives, although usually similar, were separate in the sense that they did not depend on each other or require any coordination with other units on the same level. Finally, control was maintained through the use of established standards of output (with the size of the tribute or taxes and the number of men for the army as the most important) supplemented by the occasional royal command.

Except for the disagreement of the status of standardization of output as a coordinating mechanism, this is in no way in conflict with Mintzberg's definition. On the contrary, he says that (1979, p. 381)

It is not a complete structure from the strategic apex to the operating core, but rather a structure superimposed on others. That is, each division has its own structure.

He goes on to say that the Divisionalized Form tends to draw its divisions toward the Machine Bureaucracy configuration, but that it is not a necessary condition, since the focus of the Divisionalized Form configuration is on the structural relationships between the headquarters and the divisions.

Military Organization

Military organization is an interesting chapter in itself, and one that has undergone radical changes that are not (even today) fully acknowledged in the code of command.

At first, the military organization was only a mirror image of the feudal state, reflecting the same substitution of group for territory as contained in God's advice to Moses for organizing the Exodus (see page 29). There was little differentiation among the soldiers, and they were commanded by their feudal lords. The

hierarchy was thus structured after the civil society, but, as the civil structure was fashioned to minimize information processing and communication, it also served the needs of war well: during the complexity of battle, communication is extremely difficult, and the need for it must be reduced as much as possible.

The feudal army was thus also very similar to the Divisionalized Form, with one important exemption: The King now needed to coordinate the actions of his subordinate lords, and he needed to do so in as close to real time as circumstances would allow. In this respect, we may say that the feudal nation in war reverts partly to the Simple Structure by strengthening central coordination as much as possible. In preliterate society, however, it is not feasible to revert fully to the Simple Structure with a large army, as the administrative load on the central command in that case would quickly overwhelm its capacities. The modern, specialist, bureaucratic armed force with its abundance of communications equipment and its great capacity for detailed planning is therefore closer to Mintzberg's definition of the Simple Structure than the army of Genghis Khan was.

The small differentiation between soldiers that persisted up through history, even into our own century, also meant that an officer could successfully command almost any military unit, and it was from such a structure that the military code of command grew, whereby any officer had authority over all personnel below him in rank, regardless of unit. It was probably Frederick the Great of Prussia who really established this principle, through the standardized, elaborate training he mandated for all his soldiers.

Today, this tradition is rapidly becoming meaningless. The specialization in a modern armed force is just as extensive as in a modern corporation, and the notion of universal authority in war today makes no more sense than it would in industry—such as authorizing a vice president of finance in a manufacturing company to issue direct orders to a foreman on the shop floor about the way he should run his robotized paint line. In theory, the unity in military command is still in force, but, in practice, the sensible officer will always yield to the specialist knowledge of a subordinate.

The Basic Principles of Preliterate Organization

We have now explored what was defined as the primal space of organizations in Chapter 2. Before the art of writing permanently changed the premises for human reflection and human society, central planning and minute, standardized directives were not available as organizational tools. Preliterate societies had to use solutions with much greater information economy, structures that could rely on human memory alone, and that required an absolute minimum of communication between the levels in the hierarchy. The basic forms relied either on the rule of one or on a form of rule by consensus or council. For larger structures, where one ruler or one council could not manage the complexity, the iron constraints on human memory, communication, and information-processing capabilities forced a reliance on two principles: the *delegation of authority* and the *encapsulation of information*. We shall return to these principles later, because they play interesting and crucial roles in today's organizations as well.

6 The Power of Technology

“It must be confessed that the inventors of the mechanical arts have been much more useful to men than the inventors of syllogisms.”

Voltaire, “Philosophy,” in *Philosophical Dictionary*, 1764

The Nature of Tools

In many ways, this dissertation represents an inquiry into the nature and use of tools. Before continuing, I would therefore like to reflect for a moment upon the nature of tools—the implements we have invented and used to make ourselves what we are.

A tool is most often conceived of as something extraneous to humans—indeed, in the case of new and revolutionary tools, sometimes even as alien and threatening. When talking about the natural state of humans, most people in modern societies seem to envisage a primordial hunter/gatherer society, where man lives in peace with himself and nature—something like Rousseau’s “noble savage.” There seems to be a peculiar reluctance to acknowledge tools as something intrinsically human, something to be proud of as an expression of our most extraordinary attributes, that which really sets us apart from the rest of the animal kingdom: our intellect.

However, tools do not develop themselves or spring spontaneously from a lump of raw material—they are not ordained by fate. Rather, they are conceived, designed, and crafted by humans; they are socially and culturally dependent *constructions*, and they represent a material expression of culture and knowledge (Bijker and Law 1992). Tools remain an intrinsic and natural part of man and his development, an expression of the human mind.

Hunter/gatherer society may well represent humanity in its primordial, natural state, as a primate among other primates—differentiating itself mainly by hairlessness, control of fire, and a somewhat extended set of tools. However, hunter/gatherer societies ceased to be typical representatives of our species thousands of years ago, and those that survived may represent no more than the longest surviving dead ends of cultural evolution.

As Morris (1967) argues, judged from an evolutionary point of view,¹ the most successful human societies today are the modern industrialized societies of Europe, Asia and North America. It is also evident that the driving force in human development and competition is no longer biological evolution, but cultural evolution—which has probably been the case for at least the last 20,000 years.² As Berger and Luckmann says (1967, pp. 65–66, italics in original),

Man occupies a peculiar position in the animal kingdom. Unlike the other higher mammals, he has no species-specific environment, no environment firmly structured by his own instinctual organization. There is no man-world in the sense that one may speak of a dog-world or a horse-world . . . Man's instinctual organization may be described as underdeveloped, compared with that of the other higher mammals. Man does have drives, of course. But these drives are highly unspecialized and undirected. This means that the human organism is capable of applying its constitutionally given equipment to a very wide and, in addition, constantly variable and varying range of activities. This peculiarity of the human organism is grounded in its ontogenetic development. Indeed, if one looks at the matter in terms of organismic development, it is possible to say that the foetal period in the human being extends through about the first year after birth. Important organismic developments, which in the animal are completed in the mother's body, take place in the human infant after its separation from the womb. At this time, however, the human infant is not only *in* the outside world, but interrelating with it in a number of complex ways.

The human organism is thus still developing biologically while already standing in a relationship to its environment. In other words, the process of becoming man takes place in an interrelationship with an environment. This statement gains significance if one reflects that this environment is both a natural and a human one. That is, the developing human being not only interrelates with a particular natural environment, but with a specific cultural and social order, which is mediated to him by the significant others who have charge of him. Not only is the survival of the human infant dependent upon certain social arrangements, the direction of his organismic development is socially determined. From the moment of birth, man's organismic development, and indeed a large part of his biological being as such, are subjected to continuing socially determined interference.

Relatedly, it is interesting to note how the ecologists Robert Boyd and Peter J. Richardson (1985) argue that cultural evolution has many traits in common with

¹ In an evolutionary view, we are not concerned with morality. Many people today would hold the hunter/gatherers as our moral superiors, as they live nonobtrusive lives in harmony with their natural habitats. (I do not subscribe to such a view.) From the evolutionary standpoint, however, we must simply conclude (from observation) that the industrialized societies are the most successful. They are unquestionably the most powerful societies on Earth. In the course of their development, they have physically overrun and almost eradicated other societies they encountered, like the Indians of North and South America and the aborigines of Australia, and they have been stopped from doing the same elsewhere mainly by their own evolving moral consciousness. Today, almost all other societies do their best to become more like them. The culture of the Western industrialized countries is therefore overwhelmingly successful in terms of diffusion and adoption.

² According to Wilson (1988, p. 59), the first permanent settlements (which marked a break with the primordial hunter/gatherer existence) seem to have become widespread just 15,000 to 20,000 years ago. The first settlements started the new era of culturally based evolution, the one that really set us apart from other animals.

biological evolution and follows many of the same laws—a fact that should perhaps not surprise us too much, given the basically systemic character of both spheres.

If we accept that the physical and biological properties of the modern human and the prehistoric human are not very different, there must be solely cultural reasons for the differences between hunter/gatherers and the modern industrialized societies—including the immense differences in size and scope of their organization. The basic preconditions must have been considerably augmented by knowledge, techniques and technology in the course of the last millennia.

The improvements have been spectacular, and have totally transformed humans from intelligent apes, outwardly not that much different from their primate cousins, to beings with a knowledge and power that set them utterly apart from all other animals. In a mere blink of an eye on the evolutionary timescale, we have progressed from a position as unobtrusive members of the fauna, predators among many others and definitely no serious threat for any other species, to a position as the total masters of the earth and most other animals. The only large animals on earth that we tolerate in large numbers besides ourselves are the ones we keep for food or pets, or preserve for hunting or recreation. Within the next 100 years, we can even expect to transcend our inception as earthbound animals, and take up permanent residence on at least the Moon and Mars.³ I may not live to see the first human born on another planet, but my children or grandchildren probably will.

The basis of all this is twofold: On one hand we have our knowledge and our methods for thinking and working, on the other we have our tools—the material instruments we use to transform the face of the Earth, turn out all our artifacts, and support all our work and our constant quest for knowledge.

The developments of knowledge and methods on one side, and of tools on the other, are of course not separate processes. On the contrary, they are intimately linked—even more so than we normally recognize. Our intellect is not something that is suspended in a pristine, spiritual capsule; it is the very instrument that has brought us to where we are. It has been and still is developed in our ongoing interaction with nature and other humans.

The basic nature of this iterative, recursive process is aptly illustrated by Rachlin (1989, pp. 248–49) when he describes the opening sequence of a film about Picasso. Picasso is filmed painting, but the camera is set up to take single pictures about every other minute, compressing about a week's work into a few minutes.

³ A word to the skeptic: research has already started on *Terraforming*, as the process of making other planets habitable is termed. The prime target is of course Mars, which has a convenient size, geology, and distance from the sun. (Mars's diameter is about 50% of the Earth's, its gravity 38%, and the escape velocity 46%. That means that the leakage from an artificially created atmosphere on Mars will be manageable.) Venus seems more difficult today but is also a possible object in the very long run, being more like the earth in size and gravity (diameter 95% of the earth's, gravity 90%). The scale of the research is so far very modest, but since most of the research done on the earth's ecological system is relevant for terraforming, the knowledge accumulation in this futuristic field is actually much more substantial than one should think. Terraforming will of course be a very long-term project, but it will be preceded (and carried out) by colonies built within pressurized enclosures.

The picture starts with a few bold lines, but what follows is a constant metamorphosis, as Picasso tries one approach after the other: "A fish becomes a chicken. A bird becomes a woman. He keeps on working." After the week has passed, Picasso finally says, "Now I know what I was trying to do," and starts again—almost from scratch. Clegg, discussing the technical aspects of factory production, is on to the same phenomenon (1990, pp. 186–87):

Technique is not simply a commodity to be bought, but a vital aspect of organization. This is clear in the sense that applied technique includes the human organization or system that sets equipment to work. Equally importantly the concept includes the physical integration of a new piece of equipment into a production process and its subsequent refinement and modification at the hands of the technically skilled workforce. Many manufacturers have come to grief on the belief that technical solutions can be bought pre-packaged. This is to ignore, precisely, that in operation these are always socio-technical solutions. What is at issue is precisely the "cultural" context in which these solutions have to work. Studies have shown that equipment users rather than makers develop major process innovations (thus stealing a march on their competitors) and that small, imperceptible "everyday rationalizations" account for the lion's share of productivity gains in an ongoing manufacturing business.

This is the basic human approach to discovery and innovation—to act, to try out, and then gradually modify until it is "right." In fact, this process is so basic that it is even reflected in the physical development of the brain: Experiments have shown that animals growing up in a complex and changing environment attain larger brains with more interconnections than similar animals growing up in extremely simple and stable environments (Hofer 1981). And it is important to note that this difference occurs only when the animals are allowed to engage in sensorimotor interaction with the environment, that is, merely living in a cage in a complex environment does not foster brain development; the animal must be able to move freely around, interacting directly with it, physically experiencing the changes and the complexity.

Our tools thus constitute our minds' projection into the physical world; they allow our minds to engage the complex world on a much grander scale and in a much more sophisticated way than our unaided hands and feet. The feedback our minds receive is correspondingly advanced, and it drives our thinking and investigations toward ever higher levels. The mind creates the tool; the tool allows us to do new things and shows us new constraints, thus posing new challenges and riddles to solve—both technological, scientific, and moral.

As we shall see in a moment, this is even true of the art of writing. The invention of writing (I include here both letters and numerals) was really a watershed in the human saga, and still the most momentous one. It represented an enormously powerful combination of method and tools. In an iterative process, taking place over several centuries, man's first script evolved as merchants and officials in Mesopotamia struggled to keep tabs on their growing businesses and taxation systems. The alphabet and the pen then provided the mind with tools vastly more powerful than any other before them, and, both consciously and unconsciously, we entered into a symbiosis that simply had to change the way our

mind operated, just as the development of the steam engine more than 2000 years later forever changed our material approach to the world.

This represents the essence of human progress—the concept of iteration, the endless number of small steps, some erratic, some successful, but always spawning new insights, new ideas, new experiments, and still new experiences. The history of human development is therefore also the history of man's tools, and probably much more so than historians generally recognize.

It is easy to see this mechanism at work in the sciences. Astronomy, for instance, was clearly stagnating when Galileo set the stage for new growth through creating the first astronomical telescope in 1609. The revolutionary initial discoveries led to the construction of larger instruments to gather more light and resolve even finer detail, a process that is still underway. Each new generation of telescopes has revealed new and startling facts and has led to new theoretical developments in astronomy, cosmology, and physics. The theories in their turn have called for new observations to test new hypotheses, frequently outside the capacity of existing instruments, spurring a new round in the spiral of tool development.

Another prominent example is Pasteur, who could not have developed his theories about bacteria without the microscope, which, on the basis of its new importance, was subsequently quickly developed to the limits of the resolving power of visible light. Further developments led to the electron microscope and later to the scanning tunneling microscope, which can resolve—and manipulate—individual atoms.

Nuclear physics on its part rests heavily on the giant particle accelerators, the king of which is at the moment (and probably for many years to come) the Large Electron-Positron Collider of the CERN laboratories near Geneva. It has a diameter of 27 kilometers and is located in a tunnel 4 meters across, running from 50 to 150 meters below ground. One of the newest and most exiting disciplines of science, chaos theory, was not even discovered at all until that paramount tool, the digital computer, came into use.

In the engineering world, we can point to Thomas Newcomen's steam engine as an example. Its limits became the starting point for James Watt's improvements, subsequently leading to Richard Trevithick's high-pressure machine, the first really modern steam engine.⁴ Likewise, radio broadcasting could not have been developed until Marconi had shown that electric signals could indeed propagate through air and even empty space. Shackleton's, Bardeen's and Brattain's crude transistor was a necessary stepping stone for integrated circuits. As the race to shrink the circuit continues, light is no longer sufficient for etching the ever thinner lines on silicon chips, spurring the development of compact synchrotrons

⁴ It is interesting to note that James Watt himself was eminently aware of the fact that the output of a steam engine of a given size could be increased many times over by increasing the steam pressure (Watt's engines were low-pressure machines). However, he considered the risk for explosion to be too high and held back development through his patents as long as he could. The high-pressure engine was thus not realized until after his patents ran out in 1800, and then only by somebody else.

(the synchrotron itself being a tool developed for research in nuclear physics) emanating the soft X-rays needed for resolving details as small as 0.1 micron.⁵

In business, the co-evolution of modern communications and modern industrial and retailing organizations from about 1850 is one of the paramount examples. In Norway (as the histories of Norsk Hydro and Elkem show) one man's quest for synthetic saltpeter and another man's failure in building an electrical cannon led to the invention of an electric arc furnace for the manufacture of nitrogen oxide, spurring a large-scale development of hydroelectric power, which in turn created the basis for a vigorous metals industry. Today, both the fertilizer and metals industries in Norway are world-class, and among the leaders in their fields.

Indeed, even the lofty subject of moral philosophy is more closely related to our tools and material advances than generally acknowledged. Our ideas about war, for instance, have changed considerably the last 100 years, as we have developed modern weapons of mass destruction *and* experienced their effects. Nuclear weapons in particular have spurred new developments in our conceptions about war as a political instrument. Before World War I, war, even between major nations, was much more readily accepted as a legitimate extension of politics.

Even more obvious is the recent debate over the ethical implications of changing the genetic composition of bacteria, plants, animals, or even human beings. Before we actually had the tools and knowledge necessary to do it, it was not on the agenda at all. Philosophers of previous centuries were not even aware of the possibility. The case is the same with modern ecological considerations—before human activities actually started to interfere seriously with nature, the question was not even raised.

The question of contraception is typical for the gradual adaptation of moral attitudes to new capabilities. Mainstream ethical positions have changed gradually, almost in step with the diffusion of contraceptives. When family planning through the use of contraceptives was first raised as an issue in Western countries, it created strong, morally and religiously based reactions. Today, only the conservative part of the Catholic church and a few other very orthodox Christian fringe movements are against it, and it seems safe to predict that even the Catholic church will give up its resistance at some point in the future—indeed, with a less orthodox pope than the present one, it might have done so already—especially considering the rising specter of AIDS.

Thus, our tools are our destiny, for better or worse. To paraphrase William Ralph Inge⁶, man may never succeed in becoming lord of himself—there will always come a new tool, a new capability, a new insight that will tax our ethics and invite questionable actions. And we can never deal with it before the fact.

⁵ 1 micron is a millionth of a meter. The wavelength of ordinary light ranges from 0.39 micron (extreme violet) to 0.78 micron (extreme red), X-rays from 0.00001 to 0.01 micron. The term "soft X-rays" denotes the longer wavelengths.

⁶ "For better or worse, man is the tool-using animal, and as such he has become the lord of creation. When he is lord also of himself, he will deserve his self-chosen title of *homo sapiens*." William Ralph Inge, "The Dilemma of Civilization," in *Outspoken Essays: Second Series* (1922).

As artifacts of our minds, tools also have their own aesthetics. It is no coincidence that many people collect watches, cameras, knives, and guns. The aesthetic appeal of a tool does not only lie in its immediate appearance—although they may also be true works of art. The beauty of a tool is really rooted in the way it fits with the task. Even humble instruments such as an old screwdriver, a well-worn hammer, or an aged sewing machine appeal to us. The enormous fascination with the American Patriot rocket during the war against Iraq did not rest in its sleek appearance, but in the uncanny speed and precision it displayed when it seemingly knocked out incoming Scud missiles.⁷ What people really loved was not that canister of metal, but the intellectual feat of designing and manufacturing it and actually making it work—a triumph of craft, creativity, and knowledge.

If the reader judges it immoral to associate such feelings with weapons, I can agree on logical, left-brain terms. However, it is a fact that our right brain has much fewer qualms about such matters and will not easily accept repression—especially in moments of stress. Experience tells us, moreover, that instruments of death have always had a sinister appeal to humans, the deeper reasons of which I shall leave to another discipline than sociology to explain.

The Breakthroughs

The development of our tools as well as our knowledge and conception of work has gone through many stages. There may be several ways of classifying them and, conceivably, some disagreement as to their relative importance. For our purposes three breakthroughs stand out:

1. The invention of writing
2. The Industrial Revolution, with its sweeping developments:
 - abundant energy and mechanized production
 - new means of communication, from railroads to telephony
 - mass literacy, cheap printing, and the knowledge explosion
3. The invention of the digital electronic computer

In this chapter, we shall look at the first two; the third must wait until Chapter 8.

The Externalization of Memory—from Orality to Literacy

Oral Society

According to Eriksen (1987), Cicero, in his *De Oratore*, tells a story about the famous poet and orator Simonides, who was having a meal with a number of friends. The building they were in suddenly collapsed, but just before the roof

⁷ After the war, considerable doubt was expressed as to whether the Patriots actually succeeded in downing any Scuds at all. However, the public's fascination with the missiles at the time when everyone believed they did so was real enough, proving the point regardless of the actual results.

caved in, Simonides was rescued and brought outside by the gods Castor and Pollux. All the others were crushed to death under the tumbling stones. Simonides, the only survivor, could tell exactly who had been present, because he recalled just where they had been seated at the table. Therefore, he was able to help the men clearing up the place afterward. He then realized that much could be remembered if one located *pictures at places* in memory.

That was purportedly the wellspring of the classical mnemonic techniques so widely used from antiquity to the renaissance.⁸ However, it is reasonable to suspect that mnemonics did not originate with Simonides, who lived from 556 to 468 B.C. The Greeks had then just started down the road to literacy, after the full Greek alphabet was developed from the Phoenician sometime around 700 B.C. (Havelock 1986). There is therefore all reason to believe that Simonides was very well acquainted with the full set of mnemonic techniques of an oral society, since the adaptation of writing was slow and probably met considerable resistance. An inscription from the sixth century B.C. mentions the civic office of *mnemones* (literally, "remembrancers")—people entrusted with the task of remembering important public information, such as rulings, precedents, and other events worthy of chronicling. In fact, it was probably not until late in the fifth century B.C. that letters were being taught to children in Greek schools on a regular basis—the first direct account of it was given by Plato early in the fourth century B.C. (Havelock 1986).

The office of *mnemones* also serves to illustrate the iron-clad constraints of oral society. Keeping records of key public information required the dedication of many people's memories. Remembering must have put a severe burden on the minds of everyone engaged in activities beyond mere subsistence. Just memorizing the minutes of day-to-day affairs can be challenging enough—affairs such as kinship relations, property rights, trade agreements, debts, and obligations. As indicated in Chapter 5, from this perspective one can interpret feudal systems not only as power relationships, but also as mnemonic systems, which structurally defined and thereby fixed in communal memory large sets of rights and obligations.

Even more important than the temporary remembrance of the minutes of everyday affairs is the preservation of the body of information needed to survive in a particular environment, and its transfer to new generations. Nonliteral societies above the basic subsistence level of the simplest hunter/gatherers must have techniques for this, and they devote considerable time, effort, and ingenuity to keep the communal memory from fading. The information is often encoded in myths and religious conceptions—adding pictures, stories, and emotions, and thus making it easier to remember. Alternatively, it may be kept alive by rituals and ceremonies, with their role playing and drama. The Yir Yoront are a prominent example of this. Indeed, the rich pantheon of the aboriginal sacred epoch can from this perspective be interpreted as a mnemonic device, where the mythical

⁸ The technique centers on building up a permanent mental picture of a house with a number of rooms, and a permanent route through all the rooms. For each occasion, the rooms can then be "filled" with objects or events that serves to recall a part of the speech. The most advanced orators must have maintained such houses with hundreds of rooms, since they could remember long speeches word by word.

landscape, figures, and events serve to visualize and thereby fix in memory the elaborate structure of aboriginal society.

But the effects on the mind were more profound than we normally think, thoroughly conditioned as we are to the literate mindset. In fact, only during the past few decades have we become conscious about the magnitude of the difference between the oral and the literate mind. This awareness really started in the 1920s with Milman Parry's new theories about Homer's epic poems the *Iliad* and the *Odyssey*, but his theory was slow in being accepted. More widespread understanding only entered mainstream discourse through the groundbreaking works of Walter J. Ong (esp., 1982) and Eric Havelock (esp., 1986).

What characterizes the oral mindset? First of all, people in oral cultures are predominantly operational and concrete in their thinking. They think in terms of physical objects, actions, and events. Interpretations of things are always tied to their context of events and actions. A striking illustration of this is provided by A. R. Luria (see Ong 1982). Luria made extensive studies of illiterate, literate, and partly literate people in Uzbekistan and Kirghizia in 1931–32. He administered questionnaires and conducted interviews and experiments to gain insights in the differences in cognition between literate and illiterate (oral) people. In one of his experiments, he showed his subjects drawings of geometrical objects, such as circles and rectangles. The illiterate peasants would invariably identify them as representations of objects they knew—plates, buckets, mirrors, doors—never as abstract categories. Students from the same communities (under training to become teachers), on the other hand, immediately identified them by their abstract classifications. Likewise, when asked to eliminate one of the four objects *hammer, saw, log, hatchet*, that did not belong in the group, the fully literate subjects would immediately eliminate the log (which did not belong to the abstract class *tools*), whereas the illiterates would protest, saying that all the objects belonged together. Both the hammer, the saw, and the hatchet belonged to the *situation of working with logs*, which was their frame of reference. Ong refers to a particular peasant, who, when pressed, eliminated the hatchet, because "it doesn't do as good a job as a saw" (p. 51). Asked to explain what a tree is, a respondent answered: "Why should I? Everyone knows what a tree is, they don't need me telling them." The abstract definition of a class of objects named "trees" was simply not part of the oral mindset.

To us, this concrete, contextual orientation seems backward and even childish—a patronizing view that is a product of our particularly literate bias. That we compare oral people to children is not surprising, since young children are in fact themselves oral people, living in a partly oral community (with other children). The process of acquiring a capacity for abstract thinking and symbol manipulation, which we normally regard as part of the natural maturing process of the child and the young adult, in reality represents a forced, culturally determined transition from an oral to a literate mindset, a transition that everyone in a modern society has to go through in order to become a fully functional member of that society.

The action- and context-centered state of the oral mind is easier to understand if we consider the nature of the spoken word and the way it differs from the written word. The written word is an unchanging thing; it has an existence of its own, and reading and writing it is something one does in isolation—if not

physically isolated, at least mentally so. It is normally not part of a collective experience. The spoken word, on the other hand, is an event—it happens when spoken and heard; immediately disappears and lingers on only as a fleeting trace in the memories of the people present. It is also a social event, since an exchange of words requires at least two people. Talking is action; it happens in a social context. There is a world of difference between 300 people gathered in the village fête grounds to hear a visiting bard relate the latest news of the king's exploits, and 300 students sitting in a large reading room, all of them absorbed by their own particular book.

To be remembered, the spoken word must also be forceful; it must tie meaning to actions and events that are easy to remember. To aid memorization, rhyme and rhythm is often added. The bard in an oral society is not primarily an entertainer (although he is also that): He is even more a living memory bank, storing both the chronicles of important events *and* the social code of moral and conduct, all embedded in the stories that make up his repertory. His memory, however, is neither infallible nor incorruptible; he subtly edits his songs to suit the audience, especially people of power and riches. Oral memory is therefore unstable, and accounts of past events are often changed to suit the present.⁹

Because the volume of information that can be kept in memory is limited (at least the volume that can be willfully retrieved), accumulation of knowledge in our sense of the term is not possible. New information is only added at the peril of losing some of the old. And since much of the memorized information (such as knowledge about crafts, materials, plants, animals, and natural conditions) is vital to the survival of society, an oral society will be hesitant to add new information and will stick to tradition, to proven knowledge. Since knowledge and experience accumulate only in the relatively few people who survive to old age, oral societies normally hold their old members in great respect. Remember that knowledge in oral society exists only as living memories, and if those who know something die before they have transferred their knowledge to others, *that knowledge is irretrievably lost.*

Old people in oral societies are like our libraries—they act as repositories for society's accumulated knowledge. It is probably no coincidence that old people love to tell the same stories again and again, and that small children are equally enthralled by the hundredth repetition of a favorite tale. It is not unreasonable to

⁹ The myths of the Yir Yoront also had some of this flexibility, although only in details, and Ong (1982) provides further examples of the flexibility of religious doctrines in oral societies. It is interesting to reflect upon this in view of the preposterous resistance that the Catholic church has put up against contraceptives, especially in the face of AIDS: the church is tied down by the fact that its holy doctrines are written down and not mutable. Most of the resistance is probably based on the passage about Onan in the first book of Moses. Onan (by force of custom) had to marry the widow of his older brother, but faced the problem that if this union resulted in a son, that boy (and not Onan) would become the brother's lawful heir. So, Onan practiced *coitus interruptus* in his new marriage, and for this, the Lord made him die. Conceivably, in an oral tradition, the story of Onan would have been modified to allow for contraception when need pressed itself upon society. Mainstream Protestants and other liberal Christians have solved this and similar problems by abandoning literal interpretation of the scriptures in favor of a symbolic approach. Christian fundamentalists, however, remain prisoners of the fixed scripture, and they will become increasingly outmoded as the world changes and our knowledge grows.

claim that these complementary characteristics of children and old people constitute an important evolutionary advantage for oral societies, and that natural selection has favored families with this trait.¹⁰

So in spite of Cicero's acknowledgment of Simonides as the father of mnemonics, we can safely conclude that the tradition was much older. It was kept alive, though, by both the Greek and the Romans, even as literacy developed. There are even accounts of the recording and teaching of mnemonics, indicating that it was losing its stature as common knowledge and everyday tool. The literate intelligentsia of Cicero's time used the techniques mainly for remembering their numbingly long speeches—Cicero himself could speak for hours on end with memory as his only support. To use a written manuscript as a mental crutch was simply considered a disgrace and a sure sign of an inferior intellect. Our present acceptance of the written manuscript is a fairly recent phenomenon, and yet another proof of the thoroughly literate consciousness permeating our culture.

Architecture as a Mnemonic Device

As we have already seen, the life of nomadic hunter/gatherers did not lend itself to really elaborate social structures, and it was fairly well served by unaided memory. The number of people living together was small, and the number of artifacts they could carry with them was very limited. Their societies had to remain simple. Sedentary life brought great changes, however. As Wilson states (1988, p. 58),

Although the extent and depth to which the house is cited as a key vehicle of symbolic and systematic thought by ethnographers of domesticated societies varies, it is clear that the house and the village plan provide people the world over with an instrument, and a model, for conceiving the world in a complex, comprehensive way. The house and the village are not only an order constructed of walls, boundaries, and fences; they also serve as smaller scale reproductions of the structure of the universe. They do this because the house and village are geometric constructions and can therefore represent relationships irrespective of scale and the nature of the parts . . . The adoption of the house as the permanent context of social and economic life also marks a major development in cosmological thinking. Open societies¹¹ have available to them as tools for thought language and such features as the natural environment as animals, landmarks, topographies, and the like. But their artifacts are limited by the need for portability, and their nomadism restricts the range of communication of their art somewhat. With settlement comes a proliferation of material culture, and with the house is made available what has proved to be the most powerful practical symbol until the invention of writing. In many domesticated societies the house is appropriated to mediate and synthesize the natural symbols of both the body and the landscape. At the same time it provides the environment and the context for social life. The adoption of

¹⁰ In this connection, it is also interesting to note the speculations by deBeer, mentioned in Anderson (1990), on the reasons for the extraordinarily long time a human needs to reach adult stature – about 15 years, or around one-fifth of a normal life span; deBeer argues that the reason for the slow physical development of human offspring (lagging far behind that of the brain, which is almost complete at the age of 5) is the evolutionary advantage of prolonged dependency on the parents, guaranteeing that the children do not leave before they have had time to acquire all the knowledge necessary to become a competent adult.

¹¹ Such as the hunter/gatherers.

the house and the village also ushers in a development of the structure of social life, the elaboration of thinking about the structure of the world, and the strengthening of the links between the two.

In addition to the physical characteristics of the house itself, the larger numbers of people living in one place, and the combination of commonality and privacy that a village with houses permits, another extremely important structuring factor discussed in Chapter 5 enters the picture: land becomes property—either individual property or group property—and rights to land are inherited. Clearly, persons or groups possessing more or better quality land than others will be at an advantage and will be able to establish a superior position. The village itself, then, and later the town, the city, and the nation, by its structuring of space and by turning land into property, created a rich and evolving set of anchoring points for social organization and stratification. Great engineering works (especially watering systems) allowed for even more intensive agriculture and larger cities, and technology proper became an important factor in the development of human organizations.¹²

Wilson cites many examples of how ancient architecture encoded the reigning world view and thus supported social order and tradition, and there is little doubt that the form of both private houses and public buildings and monuments served as a memory bank for common values and organizational systems. By learning to live in a private house and participate in the rituals and functions associated with public buildings and monuments, a child would also learn the basics about the reigning social organization and its own place within it.

Both Wilson and Eriksen quote Yates (1966) when discussing this—Wilson on her interpretation of both the Roman temple and the Elizabethan theater as representing the *fabrica mundi*, Eriksen on her theory of the meaning embedded in the construction of the great cathedrals. She perceives the cathedrals as modeled on classical mnemonic theory, functioning as enormous tableaux of memory, with numerous niches and room dividers, with carvings, friezes, pictures and sculptures creating and furnishing the many “rooms” required to hold and display the entire common memory of Christianity. We might add that even modern churches, in all their stark simpleness, often contain works of art depicting central themes in the Christian heritage.

But the tradition of encoding organization and the social order in buildings is kept alive on a much broader scale than this, and it is not limited to spectacular projects such as the presidential palaces built by Nicolae Ceaucescu or the sultan of Brunei. Parliaments in democratic countries invariably reside in buildings of prestige at the very center of the capital;¹³ banks and industry erect pompous

¹² The architectural and construction technology of the ancient civilizations is impressive even today. Everybody knows about the pyramids, but there are other examples. For instance, 18 canals with fresh water went into Nineveh in Mesopotamia in the second millennium B.C., the one best known was 20 meters broad and 80 kilometers long. It was built in only 15 months. Asphalt and bricks were used on the bottom, and in difficult passages the asphalt was covered with a foot of concrete, lined with stone tiles (Dahl, 1984).

¹³ Interestingly, the Swedish parliament, in a fit of northern European rationalism, in 1971 moved out of its cramped building in the historical central part of Stockholm to a new and supremely functional structure in a more commercial district. The new building was very well suited to its purpose, but the representatives discovered (to their own astonishment) that they

headquarters signaling their economic power; and hotels, the new cathedrals of the international elites, today represent the most daring and opulent architecture in the Western world.

Inside buildings, you will also find a lot of encoded information, not least in office buildings. You are seldom in doubt about the relative rank of people you meet in their own offices. In the new building of the Norwegian national bank, for instance, a rigidly symmetrical design restricts some of the uses of space often employed in signifying organizational hierarchies. As you get closer to the governor's quarters, however, the wall lining suddenly changes from white synthetic materials to rich wood panels, and the floor shifts from carpets to dark wood. When you finally enter the governor's office, you are in no doubt about the occupant's position. The zeal for such visual incarnations of power varies from organization to organization, but in quite a few you will find that the size and floor allocation of a person's office are better indicators of his or her real rank and standing than the position in the formal organization plan.

The Art of Writing and the Development of the Literate Mind

An Administrative Technology

It is the art of writing, however, that represents the most fundamental, single technological breakthrough in the history of organizations¹⁴—at least until now, when the ripening information technology may be able to equal or (given enough time) even eclipse it. We may not normally think of writing as a technology, but that is only because we are so used to it—it has become second nature to us, a complement to speech. Plato, who lived during the crucial transition from an oral to a literate society in Greece, thought otherwise—he considered writing an external, alien technology, just as many people today characterize the computer (Ong 1986). Writing was and is an artificial activity; its product is material (although with an immaterial message content), and to produce it, one needs tools (chisels, styli, pens, brushes, inkwells) and materials (stone surfaces, clay, papyrus, parchment, paper, ink).

So writing is not only a technology, it is a formidable technology. It gave humans the power of absolute reminiscence and of communication across time and space without loss of content or accuracy. Writing made it possible to make private records for business and personal use and to make public records about property rights, taxation, and various compulsory services. Indeed, all evidence suggests that the first known script, the cuneiform of Mesopotamia (about 3500

resented it – the symbolic value of its address, together with its businesslike modernity, collided headlong with the parliament's perception of its own position. It really signified that the parliament was not so important anymore, and that the power now resided in the cabinet and its departments, still located in its traditional quarters in the area the parliament had left. After 12 frustrating years in "exile," the Parliament rectified the situation by moving back to its old building in the geographical center of power, now refurbished and extended through passages into adjoining buildings.

¹⁴ For man as a species, it may be argued that the most fundamental event, that which allowed us to ascend to the mammalian throne, was the invention of language itself (Ross 1991). However, to me that is a little bit like claiming that the basement is more important than the castle built on top of it, just because it comes first. The genesis of language is anyway too remote and too obscure for our purposes.

B.C.), developed directly out of a need for economic records in the growing economy of what may be termed the world's first states—for private business, for public administration, and even for the economic side of the religious establishment (Goody 1986). The first use for writing in the temples of Mesopotamia was demonstrably not for recording religious material, but for temple administration. Writing, then, was first a tool for administration, and the information recorded was administrative. Discourse, recording of poetry, and recording of religious and scientific material all came later.

The enormous significance of the written record comes not only from the fact that it preserves information for indefinite time, relieves the mind, and makes it possible to accumulate much more information. Even more important for the development of organizations is the fact that it represents an *external memory*, accessible by a large number of persons—in fact, by any person so authorized. An *active file* of written records therefore allows many people to base their work on the same information, and an update made by one person is immediately available to the others and applies directly to their decisions. The revolutionary new integrity of information inherent in the active file of written records provides even an *implicit coordination* of the people who work with it—because of their common basis of information, they are now able to act with considerable consistency without ever talking to each other. Since this information will not disappear with the bearer, it also means that both private and public administration can survive even sudden and unexpected changes in personnel.

Through its gift of permanent records, writing made it possible to build much larger and more complex organizations (both public and private, even spanning continents and oceans) and maintain them for long periods of time. The formal explication of rights, obligations, laws, and treaties added the necessary strength to relationships outside the bonds of immediate kinship and friendship. As Goody says (1986, p. 175),

Directly or indirectly writing enters into the way we define “a religion” and “the law” (as distinct from religion and “custom”). At a different level, it enters into the way we define bureaucratic polities and a complex economy, one of which would be meaningless without the office and the file, and the other without elaborate methods of accounting for the profit and the loss, of raising credit and organizing investment, and of carrying out productive and mercantile activities by some development of the partnership or firm, organizational forms that are significantly dependent on the use of writing. Hence we find an association between money-lending, banking and literacy throughout human history.

This is not to claim that oral societies do not possess analogous institutions. The arrangements of a group of brothers, or a husband and wife, working together on the farm or in some craft activity bears a close resemblance to a partnership or to a family firm. What the introduction of writing helps to do, however, is to make the implicit explicit, and in so doing to extend the possibilities of social action, sometimes by bringing out tacit contradictions and thus leading to new resolutions (and probably new contradictions), but also by creating more precise types of transaction and relationship, even between trusted kin, that give these partnerships the strength to endure in more complex, more “anonymous” circumstances.

Even if the example of the Incas (discussed in Chapter 5) proves that it is possible to build large states and organizations without the help of writing, it also seems that writing makes it easier. The great Arab and Asian empires, the Roman empire, the Roman church, and the Roman army were created and maintained by literate cultures, with their written codes and files, their reports and orders unequivocally committed to parchment, paper, or tablets. Even if Genghis Khan, the warrior of warriors, conquered his great empire by the sword and the horse, in the end had to rely on the literate Chinese bureaucracy to maintain and run his vast empire.

We also know that in Northern Europe the riches, power, and reach of the Hanseatic League increased many times over when writing was introduced as an instrument of business, allowing the merchants to direct their increasingly diverse and far-flung trading activities from their home bases, instead of traveling with their ships to manage the trading directly (Buckmann 1991). Wherever it was employed, writing also served to homogenize language and establish national or cultural identities, especially in the cultures that adopted phonetic writing.¹⁵

The Importance of Numerals

But the revolution did not only encompass letters—numerals, numeracy, and the development of systems and techniques for calculation have in many ways been just as important as writing, although they usually receive less attention (maybe because nearly all historians are men of letters rather than men of numbers!). The work with numbers is a crucial aspect of our economic and scientific development.

The progress was very slow as long as Roman numerals were the only instruments for working with numbers. The Arab numerals and notation we use today (which are really Indian, and which did not become widely used in the Arab world until about 1000 A.D.) arrived in Europe around 1200 A.D., but took several hundred years to become really accepted. It met with much resistance—one of the arguments was that accounts kept with the new system were easier to forge, and in Florence, as late as 1299, a person could be fined for doing his accounts in the new system (Eriksen 1987). The system nevertheless became popular with merchants, the fledgling bankers, and the money changers, since they appreciated its flexibility and efficiency much more than the theologically dominated scientists of the day.

When Roman notation was finally superseded throughout Europe in the course of the sixteenth century, development came rapidly, both in mathematical theory and mechanical tools. The crowning achievement for calculating techniques was the invention of logarithms, by the Scottish baron of Merchiston, John Napier (his *Mirifici Logarithmorum Canonis* was published in 1614), and mechanical calculators¹⁶ were also invented to relieve people from the drudgery of

¹⁵ Ideographic and pictographic writing systems, such as Chinese, allow a multitude of spoken languages to coexist within the same literary sphere. Even today, China has a large number of different languages and dialects that are very different and not mutually understandable.

¹⁶ The first mechanical calculator was built by the German Wilhelm Schickard, not, as commonly believed, by Blaise Pascal (Augarten 1984). Schickard built his machine in 1623, the year Pascal was born.

calculation. The new developments made it possible to carry out much more computing-intensive tasks than before.

Calculations remained very labor-intensive, though, and continued to be a serious bottleneck both in engineering and science, even if mechanical calculators were considerably refined in the last half of the nineteenth century and the first half of the twentieth. It was only when they were superseded by the advent of the electronic digital computer that this constraint on most scientific and engineering work was really eliminated.

A New Mold for the Mind

When writing first appeared as a technology, its use spread from the economic sphere to the recording of religious material; to the accumulation of knowledge; the creation of more widespread, detailed, and lasting systems of law; and to immortalizing verbal art and historic accounts such as poems, songs, and plays. The cultural heritage could suddenly grow out of the tight bonds put on it by the constraints of memory, and the collection of scrolls and books in libraries provided the learned with troves of information quite unlike anything before in history.

As the art of writing liberated the mind from the task of remembering a numbing load of existing information, it also set the mind free to work on contemporary problems. The invention on writing therefore had profound effects on man's mind and the way he thought about things, effects that were just as important as the more immediate economic and political consequences outlined above. To quote Ong (1982, p. 78), "More than any other single invention, writing has transformed human consciousness." Or, as Havelock states (1986, p. 100),

To suppose that after a million years, vision employed on a physical artifact—a piece of writing—could suddenly replace the biologically programmed habit of responding to acoustic messages, that is, that reading could replace hearing, automatically and easily, without profound and artificial adjustments of the human organism, is to fly in the face of the evolutionary lesson.

By eliminating memory as the prime storage for information, writing also eliminated the need for oral mnemonics. The strong, heroic personalities of oral narratives, the narrative itself; the bonding between pieces of information and descriptions of actions or concrete properties; the rhymes, the rhythm, and the redundancy¹⁷ of oral accounts became superfluous in the written text. Writing did not need to draw on the emotions to amplify its contents and make it more vivid; it did not need to exploit the oldest and best trodden paths in our primate memory. A written text was its own memory: It was always there for reference, both during reading (if one needed to refresh an earlier paragraph) and later. The transition to the new paradigm for information presentation that writing gave rise to did not happen at once—even in the Middle Ages, manuscripts show vestiges of the oral tradition. But it was then mostly reduced to a matter of style, as the

¹⁷ One of the techniques of enhancing the memorization of oral narratives is to repeat the most crucial information many times over during the presentation, with slightly different words. Such redundancy, or *copia*, has always been one of the main tools of rhetoric.

literate consciousness had already become dominant among the tiny educated class.

Both Ong and Havelock argue that the transition in Greece was the first full-fledged transition, and the reason they give is the peculiar nature of the Greek alphabet: It was the first alphabet to include both vowels *and* isolated consonants, and so both give an exact representation of any native word, as well as an acceptable rendition of any word from a foreign language.¹⁸ It was also much easier to learn than any earlier script.

Be that as it may (Goody and others would disagree with Ong and Havelock here), the main point for our purpose is that the surviving texts from the classic period in Greece provide an illustrative example of the transition from an oral to a literate state of mind. After the first spurts to record oral material, such as the *Iliad* and the *Odyssey*, the Greek mind slowly started to explore the new tool. Its expressions became less and less epic, more and more analytic. Language became separated from man, it acquired an independent existence, and Greek philosophers started to exploit and study the analytic and epistemological properties of the language itself, reaching an apex with the syllogisms of Aristotle—the foundation of modern logic. Even Socrates (470–399 B.C.) demonstrated an analytic approach that was clearly marked by a developing literacy (Havelock 1986), although he did not himself write anything, and his dialogues retained an oral unaffectedness right through Plato's writing.

It is noteworthy that Socrates did not write down his thoughts himself, although he lived more than two hundred years after the invention of the Greek alphabet, and that we had to wait for Plato (427–347 B.C.) to write "the first extensive and coherent body of speculative thought in the history of mankind," to quote Havelock (1986, p. 111). Plato himself struggled with the transition: Despite his distinctly literate, analytical discourse, he laid out his text in the form of dialogues; he extolled the virtues of the dialogue as the supreme pedagogical instrument but banned the poets from his city-state in the *Republic*, because they appealed to the emotions alone and not to reason (Ong 1982, p. 80). Plato's pupil Aristotle (384–322 B.C.) brought the transition to its conclusion in his lucid, analytical prose and his foundations for formal logic.

The difference between the oral and the literate form of expression and thought is perhaps easier to grasp through an example. Ong (1982, p. 37) presents a well-known passage from the bible, as it is rendered in the Douay version from 1610, and in the New American Bible from 1970. The Douay version was produced in a culture that still had a massive oral residue, and it kept its style fairly close to the Hebrew original, in its turn passing on much of the oral tradition of its originators. It uses a simple, direct language, drawn from a limited vocabulary, starting with a simple statement and adding the other elements with connecting

¹⁸ The very first alphabet, the Semitic (1500 B.C.), and all its descendants until the creation of the Greek version, contained only consonants and required the reader to fill in the vowels on the basis of context. Pictographic systems such as Chinese are extremely difficult to learn, and they remain an elitist instrument. Syllabic systems such as the modern Japanese Katakana consist of syllables and cannot represent words with multiple consonants – which works for Japanese, but makes it difficult to represent foreign words. Since the number of syllables is much greater than the number of phonemes, a syllabic system is also much more complicated and cumbersome than an alphabet.

"ands." We can almost "hear" the text—it is perfect for reading aloud. The modern translation in the New American Bible, on the other hand, is thoroughly conditioned to our literate tradition. It uses a much more indirect, complex, and analytical style, adds a more pronounced chronology, and obviously draws on a richer vocabulary.

The Douay version:

In the beginning God created heaven and earth. And the earth was void and empty, and darkness was upon the face of the deep; and the spirit of God moved over the waters. And God said: Be light made. And light was made. And God saw the light that it was good; and he divided the light from the darkness. And he called the light Day, and the darkness Night; and there was evening and morning one day.

The New American Bible version:

In the beginning, when God created the heavens and the earth, the earth was a formless wasteland, and darkness covered the abyss, while a mighty wind swept over the waters. Then God said, "Let there be light," and there was light. God saw how good the light was. God then separated the light from the darkness. God called the light "day" and the darkness he called "night." Thus evening came, and morning followed—the first day.

After Aristotle, the literate program was firmly established: the analytic approach, the linear account, the concise prose, and the context-free language (the language separated from its author and the collective listening experience). Free from the oral mind's constant load of memorization of precious private and collective information, the literate mind could allow itself to collect new knowledge, to compare new with old, and to speculate about new theories. It could also develop far richer vocabularies than an oral culture—with ten, twenty, up to a hundred times more words!¹⁹ With writing as a tool, an infallible, extended working memory, it could tackle much more complex problems than the oral mind, present them for a larger audience, preserve them for posterity, and start to accumulate knowledge in an unprecedented way. A truly literate society therefore tends to be much more oriented toward new things than toward tradition, and is much more prone to invent and develop. Since old people are no longer needed as repositories of knowledge, and much of their knowledge is rendered obsolete by the development anyway, a literate society does not revere its elders the same way that an oral society does.

Printing and Mass Literacy

The invention of printing, on the other hand, did not have much direct effect on our possibilities for organization building. For instance, it did not affect the way most administrative records (both public and private) were kept—tax registers and general ledgers still had to be entered by hand. Correspondence was

¹⁹ Oral languages can consist of as little as 5000 words. A rich literary language such as English now has maybe as many as 1.5 million (Ong 1982). Comprehensive English dictionaries contain several hundred thousand words.

also still a manual affair. However, for society the consequences were momentous. The development of printing greatly amplified the effects of writing, mainly through its revolutionary effect on the dissemination and accumulation of knowledge. Thereby, it also had profound consequences for traditional structures of authority, both in society in general, and in some of its most central organizations—especially the Church.

When most people were illiterate, knowledge resided in a few persons and handwritten books and was not generally available. It could be—and was—controlled by the hierarchies controlling the books and the people who knew them. The Church was strong and unified because the priests were the only source of the scriptures, as they read from the bible or preached over texts during services. The Church thereby effectively controlled the publicly available interpretations of the Holy Writ. Dissenting interpretations could be suppressed by denying the person(s) in question access to the pulpit, or simply by disposing of them. Any writings they might leave after them would be too expensive to distribute in numbers.

Gutenberg's revolution meant that the written word for the first time escaped control and became a mass medium. Indeed, the production of books represents the first real mass production of identical products, preceding the Industrial Revolution by more than 200 years. By printing a book, one could reach a much greater audience than by any other method. There is little doubt that the success of the Reformation rests squarely on the printing press and Luther's understanding of its power. The Reformation and the printing business fed each other. According to Eriksen, 40 titles were printed in Germany in the year 1500, 111 in 1519. In 1523 the number was 498, of which an impressive one-third originated from Luther himself. All in all, 418 had to do with the Reformation! Not bad, considering only six years had passed since Luther nailed his ninety-five theses to the church door in Wittenberg.

So the Holy Scriptures were finally on the loose, and regardless of how much the Church deplored the new situation, it could not reverse it. It tried to control the dissemination of unwanted books by banning and burning them, but the *Index Librorum Prohibitorum*, intended to suppress dissent, functioned more as a medium for advertising than anything else. Records show that a place on the index was the best guarantee for commercial success—and Eriksen concludes that no Papal institution has contributed more to the promotion of science and general enlightenment (1987, p. 115). The paramount religious authority of the Church had received a deathblow, and it was clear that all monolithic political and scientific authority was in similar peril.

The printing press revolutionized society by two mutually reinforcing attacks. First, the printed book served as a medium for accumulation and dissemination of knowledge—scientific, political and, otherwise. To quote Eriksen, "About 1500 a green student could have access to the same learning that one had to travel from place to place one's whole life to find in the twelfth century" (1987, p. 83, my translation). Scientific treatises were suddenly available throughout the learned community (and even outside it) simultaneously and did not have to circulate in a small number of handwritten copies. Second, the sudden availability of (relatively) cheap books greatly increased the rate of literacy and pulled European societies through the transition from a dominantly oral culture and mindset to a literate

one. Analytic and abstract thinking became dominant in large segments of the society, notably the growing bourgeoisie, sweeping aside the Church's insistence on tradition and religious mysticism and preparing the ground for a widespread acceptance of empiricism and practical engineering.

As scientific discoveries and theories now spread much faster, the pace of scientific progress increased tremendously. Practical people (the engineers of their day) published directions for crafts and industrial processes, and the guilds began to lose their power. Innovation was stimulated, and new ideas spread rapidly. It is safe to say that the immense economic and intellectual developments of the centuries that followed would not have been possible without printing and the unprecedented accumulation of knowledge it allowed. It is equally true that the development of democracy owes a great deal to the dissemination of printed scientific and political knowledge first to the bourgeoisie and then to the whole population.

The printing press also led to a further normalization of language and homogenization of national cultures. The later development of mass-distributed newspapers served to develop an even stronger sense of national unity and consciousness through the definition of national news and thereby the agenda for national concerns.

Organization of Records

As noted earlier, writing as a technology was most probably created to keep administrative records. The unique and changing content of both private and public records made handwriting a very good instrument, and the cheap mass-reproduction brought on by the invention of printing made little difference for the running of large and small organizations—however much it contributed to the development of science, politics, and the society in general. Meanwhile, there were innovations in record keeping as well. There is scant documentation to be found on such mundane matters, but we can at least establish that elaborate systems for filing eventually came into existence, with cards, folders, filing cabinets, and Rolodexes. Vertical filing was in its time seen as a substantial step forward, as noted by Yates and Benjamin (1991). They quote Cope²⁰ (Yates and Benjamin 1991, p. 76) as follows:

It will already have become evident that it is impossible to sever the problem of finding a good practicable filing system from the whole problem of business organization.

Such technology is still selling, even if the volume is considerably lower than it was 40 years ago. The most monumental contraptions were the motorized filing cabinets, with storage bins in pater noster fashion and a height of several meters. The most modern offshoot of this traditional filing technology is the microfilm reader, which greatly reduces the space needed. In principle, however, it is just another filing cabinet.

²⁰ Cope, E. A.: *Filing Systems: Their Principles and Their Application to Modern Office Requirements*. London, Sir Isaac Pitman and Sons, 1913, page 14.

Cross-referencing and indexing systems were also invented along the way to help locate and retrieve recorded information. Information recording, storage, and retrieval nevertheless continued to be a very labor-intensive activity, and inventions such as the typewriter could not change that to any great extent. The strain developing in large record-keeping organizations (e.g., insurance companies, banks, and various public institutions) in the 1940s and 1950s bears witness to that.

But the crowning invention of precomputer record keeping was of course the punch card reader. The idea of punch cards as information carriers probably originated in the textile industry, where the Frenchman Joseph-Marie Jacquard in 1801 invented a large automatic loom for weaving tapestries and similar textiles. It was controlled by punch cards, strung together in long bands.²¹ The British calculator pioneer Charles Babbage learned about the loom and adapted the use of punch cards for his Analytical Engine—which unfortunately was never finished.²²

It was Herman Hollerith, the son of a German immigrant to the United States, who put the punch card to practical use in record-keeping. His machines (with electrical sensors registering the holes) were first used in the American 1890 census, where they were a great success. They allowed for far more advanced statistics than manual methods, including filtering and cross-tabulation, and, when the information first was registered on cards, delivered the required information in a fraction of the time manual methods would have demanded. In a test arranged by the Census Office before the 1890 census, Hollerith's machines tabulated data ten times as fast as the two fastest manual methods. Even punching the cards went significantly faster than the manual registration (Augarten 1984). The reason for the success was twofold: both the mechanization itself and the new and much more stringent structuring of the records that became necessary to use the machines (Yates and Benjamin 1991).

Both public institutions and large private companies—notably in the service and utility sectors (where the customer bases were large)—invested in the new machines to ease the burden on their record-keeping departments. There is little doubt that punch card equipment represented a significant step forward, because it was the first invention that allowed mechanization of record keeping—the “industrialization” of an old handicraft. These systems also had many of the same properties as the first computer-based systems—indeed, for three decades, punch cards (based on the Hollerith cards) were one of the chief storage media for digital electronic computers.

²¹ The jacquard loom itself was based on an earlier, less efficient loom invented by another Frenchman, but it was Jacquard's design that succeeded and revolutionized the French textile business. To demonstrate the loom's capabilities, Jacquard programmed a loom to weave a portrait of himself in black and white silk. The program needed 10,000 cards! (Augarten, 1984.)

²² Babbage's life was the tragedy of a genius too far ahead of his times and lacking the practical savvy to push through ambitious projects that stretched the limits of available technology. His designs for mechanical calculators were extremely advanced for his time, but due to personal conflicts and financial and mechanical difficulties, none of them were ever completed. Under the auspices of the Science Museum in London, however, a number of enthusiasts are now slowly building Babbage's “Analytical Engine,” and enough of it has already been completed to prove that the design was indeed sound, and that the machine actually works.

In 1911 Hollerith's Tabulating Machine Company merged with three other companies to create the Computing-Tabulating-Recording Company (CTR), which was eventually restructured and, in 1924, renamed IBM.

The Communications Revolution

The other great field of organization-relevant innovation is the field of communication. When memory was externalized and in principle no longer limited, communication quickly became the bottleneck for organization building. Communication has two aspects, both of which are important: physical transportation of people and goods, and communication of information. Both have been very important, and, for a long time, they were (with very few exceptions) one and the same. Before writing came into use, the only way to send information (with the exceptions mentioned in Chapter 5) was to send a person, a messenger. The advent of the written message made it possible to do without him, but the message itself was still a physical object and had to be transported. Even though writing may have increased accuracy, it did not necessarily increase communication speed. For some of the very oldest texts, engraved on rocks and large slabs of stone, the reader in fact had to come to the text rather than the opposite.

Clay tablets were more handy, though, and we know that both the Egyptians and the Assyrians of northern Iraq were running regular courier services as early as about 2000 B.C. (James and Thorpe 1994). In the nineteenth century B.C., the Assyrians had a dependable postal system operating between their homeland and trading bases abroad. Excavations of one of their merchants' colonies, at Kültepe in Turkey, uncovered a mass of correspondence, accounts and legal documents. The letters were small clay tablets, complete with clay envelopes inscribed with the name and address of the recipient. The service was even reliable enough for people to send money along with their letters. Chinese postal systems are known from around 1000 B.C.

The development of papyrus paper and parchment made transport easier, and increased speed was sought by employing homing pigeons and horse riders. In Egypt pigeons were used as early as the twelfth century B.C., and regular, fast horse transport from about 500 B.C. Cyrus the Great (550–530 B.C.), who built the almost 2600 kilometer Royal Road from Sardis to Susa, also organized a regular courier service with postal stations at regular intervals, and with relay riders carrying the messages around the clock. The whole distance was covered in a mere nine days. A similar service, but much more extensive, was organized by the Mongols in China after the conquest by Genghis Khan. Marco Polo reported that Kublai Khan (A.D. 1260–1294) had 10,000 postal stations, with 300,000 horses employed on a regular basis (James and Thorpe 1994).

The great costs and extraordinary efforts involved in organizing these early communication systems only serve to underline the vital importance that communication has for large-scale organizations. Both Cyrus the Great and the Mongol khans no doubt viewed their courier services as vital for keeping grip on their empires, and they probably built on bitter experience.

However, none of these systems (with the possible exception of the early Assyrian system) had the capacity to serve as an infrastructure for mainstream organization building, and the beginnings of the first really comprehensive, public mail service only took place in Europe millennia later. France was first in 1576, followed by England in 1590 and Denmark in 1624. International postal cooperation was not institutionalized until 1874, when the world organization of post offices was founded. Before that (with the exceptions noted above), one had to rely on merchants, shipmasters, pilgrims, or other travelers if one was not wealthy enough to send one's own messenger.

Communications improved only at a very slow pace up through the millennia. The Romans and Incas built extensive road networks, and sailing vessels underwent a more or less continuous improvement. The improvements were nevertheless not revolutionary, even if they were considerable. The great clippers of the tea trade were very swift compared to their predecessors, but they still needed weeks to cross the great oceans. To cut travel time from, say, three months to six weeks was not enough to significantly change the basic constraints of organization building. International operations (the few there were) still had to operate like the Roman emperor when he sent forth his governors: Choose a reliable, sensible person, give him general instructions, and pray he can tackle the problems challenging him on his own—since reports on critical events could not reach the headquarters until long after the matter was settled.

Such was the relationship between shipowner and shipmaster as well—the shipmaster had a general direction about the ports he should visit and the business he should seek, but once he had left, he had the authority to do whatever he thought served the interests of the owner best—to negotiate the local terms of trade and change his itinerary if need be. In those days, the position of an ambassador was very important—if it took him three months to pose a question to his king, president, or cabinet and receive an answer, he was very much left to act on his own judgments. In times of crisis, that could mean acting on behalf of his country with almost the same power and authority as the ruler himself.

Eriksen (1987, p. 133) describes the fate of the Russian fleet in the Russian-Japanese war in 1905, where the Tsar sent his navy from St. Petersburg halfway around the globe to Japan, to counter Japanese actions in the east. When it finally arrived, after months of sailing, the conditions of the war had totally changed—but the commander of the fleet did not know anything about it, since he had not been in contact with the Russian high command after he left. His fleet was crushed by the Japanese in the Strait of Tsushima. It was in fact an attempt at organization on a geographical scale that could not be supported by the means of communication then available.

The Railroads and the Telegraph: The First Communication Revolutions

If the Russian admiral had visited a number of ports on his way around the globe, though, he might have been able to receive tidings and even new orders from home. Because the 1830s produced the first real communications revolutions in historic time:—the railroad and the telegraph.

The railroad got started first—it was officially “invented” when Stephenson built “The Rocket” in 1829 (even if it has older roots²³). The railroad revolutionized both travel and the transportation of goods. It is indeed a sobering experience for an IT buff of today to read about the development of the railroads in the middle of the nineteenth century. We like to think that we live in an age of unprecedented technological change, and that never before in history have such great changes taken place in such a short time. In a way, we are right—the pace of technological development is both breathtaking and unprecedented. However, the societal changes in the Western countries brought about by the combined technological developments the last 50 years are hardly as great as those wrought by the developments of the railroads alone in the years from 1840 to 1890.

Consider the development of railroads in England: It “happened” almost overnight. In 1836 about twenty short lines were in operation, most of them concentrated in the Liverpool/Manchester and Newcastle/Middlesborough areas. The longest single line of rail was about 50 kilometers. In 1848, only 12 years later, the whole of England was covered with a surprisingly fine-meshed net of lines, connecting all major towns and scores of smaller ones. During the busiest year of “the railway mania” (as it was called), 1845, Parliament endorsed 623 new railroad projects, and more than 3000 kilometers of rail were laid that year alone (Dahl 1982).

In less than 20 years the diligences were eliminated, the canal companies thrown from prosperity into financial difficulties, and travel times drastically reduced. Suddenly, small country towns that had been living a life in placid isolation were only hours away from the nearest big city, and most of Great Britain was abruptly brought within one day’s travel from London.

In the United States, where distances were far greater and the pace of development was even more furious (even if it came a little later), the effect must have been even more revolutionary: In 1840 there were 4500 kilometers of rail; in 1870, 85,000 kilometers; and in 1890, 263,000 (Beniger 1986). That gives an average construction of 8900 kilometers per year from 1870 to 1890! This is quite an impressive figure, especially when one takes into account that America’s population in 1890 was only twice that of England’s—or 62.6 million. In 1840 it had been only 17.1 million, about the same as England.

Although U.S. railroad construction did not start in earnest until the 1840s, the first transcontinental link was opened in 1862. Within the span of 20 years, travel time from New York to Chicago was reduced from three weeks to three days (Chandler 1977). Not only did trains capture the passenger traffic; the transportation of goods soon followed. Indeed, the first rail line laid down by Stephenson (in 1830) was built mainly to transport coal and cotton between Liverpool and Manchester.

²³ The railroad was not the invention of one man; rather, it developed slowly over about two centuries—starting with horse-drawn carts on wooden rails in the sixteenth century. The rails were gradually iron-clad, then produced exclusively in iron. But it was the development of the steam engine that really made the difference. The first steam locomotive was built by Richard Trevithick in 1804, and Stephenson himself built his first in 1814. “The Rocket,” however, was the first locomotive with the power and fuel economy to make the railroad practical.

The telegraph spread just as rapidly. After its invention in practical form in 1835, it fanned out through the world with impressive speed. In 1851 the first subsea cable was laid between Dover and Calais; the first transatlantic cable (between Ireland and North America) came in 1866. Within a few decades, national telegraph networks were linked all over the world, and messages could be sped around the globe almost instantly. Semaphores, beacons, and drums notwithstanding, this was the first time in history that communication of information was truly separated from the transport of a physical message, and could take place reliably and routinely over long distances. In 1876 the telephone was invented, allowing people to speak to each other in real time irrespective of location. The invention of radio in 1896 increased the flexibility and range of telecommunications even further.

The first industry to profit from this double communications revolution was the newspaper industry, as the newspaper in the second half of the nineteenth century made the transition from a fairly exclusive phenomenon to a mass product. But the telegraph also had impact on business and proved especially important for the growing railroad companies, if for no other reason because of safety considerations (Chandler 1977, Beniger 1986). Most lines were only single-track, and the movements of trains in both directions had to be closely coordinated. It was also necessary to monitor railroad cars traversing the different networks to offer point-to-point transport of goods without reloading.

The telegraph was not fast or flexible enough to have really decisive influence on business, however. It was the telephone that really changed things. After its invention in 1876, it spread rapidly, especially in the United States, and it no doubt played a very important role in the growth of the great, national enterprises. Numerous effects of the telephone have been noted, many of them commented on by Pool in his assessment of forecasts on the use and effects of the telephone (1983).

One of the first major effects noted was that the telephone encouraged the physical separation of plant and office. Until then, it had been common to house the office in a building adjacent to the plant itself, to ensure good communication between administration and production. The telephone allowed the office functions not immediately connected to production to move to the central part of the cities, closer to customers and finance institutions. By making the physical separation of different parts of the enterprise more feasible, the telephone in fact supported both centralization *and* decentralization: On one hand, it gave central management much greater opportunity for direct control over geographically dispersed units; on the other, it was precisely the contact provided by the telephone that convinced managers that they could locate major business units far away from the main office, and put greater emphasis on proximity to major markets or sources of workers, energy, or raw material.

The telephone also had great effect on the speed of many types of transactions, from banking to the ordering of goods—especially perishable goods. Pool cites a 1906 article in *Scientific American* on "The Sociological Effects of the Telephone," describing how oyster barge men were put out of business because restaurateurs could phone their orders directly to the oyster planters. "In general," Pool notes, "the greatest business use of the telephone has been in finance, commerce and where complex logistical coordination is required." Even the railroads, after much

hesitation, converted from the telegraph to the telephone for train operation. As Pool goes on to say (1983, p. 68),

It permits coordination of pieces of that complex clockwork which is the economic system. It is used millions of times a day to control production, shipping, recording, and selling. It permits the operation of a complex division of labor. All of that was recognized from early on.

With the new transportation infrastructure for information, goods, and people in place, it suddenly became feasible to build efficient distribution networks, to trade reliably over great distances, and to exert a degree of control over branches and subsidiaries in locations that had been impossible up until then. Again, the railroad companies themselves were at the forefront of the development. A number of early accidents because of insufficient control of trains on single-track lines, and the ensuing public outcries, forced the railroad companies to shore up their organizations by defining responsibilities and improving coordination. The rapidly increasing administrative load also demanded a much better structured approach. In a few hectic decades the American railroad companies grew to become the largest private enterprises in the world, and they remained so until they were overtaken by the new, integrated manufacturing companies around the turn of the century. In retrospect, it is evident that the telegraph and later the telephone went a long way toward easing the constraints on organizations spanning great distances, and the improved physical transport the railroads offered took care of much of what was left.

Among the predictions recorded by Pool, some are more notable than others. One prediction in particular should have a familiar ring for proponents of electronic mail: that the telephone would reduce travel. This was attributed both to the use of normal telephone calls and to telephone conferencing—the simultaneous connection of several people. It is interesting to note that telephone conferences were easy to set up in the first decades of telephone service because of the flexibility of the manual operators. When automatic exchanges took over, conferences became all but impossible and did not become a viable service again until recently, when computer-based switches were introduced. Then, as now, it was difficult to discern any reduction in travel as a result of improved telecommunications,²⁴ but it is of course impossible to say what the volume of travel would have been without them.

The telephone has obviously made group work easier, has probably made a number of meetings unnecessary, and has made it possible to organize work groups without co-location of the members. Experience tells us, however, that it cannot totally replace face-to-face meetings. The telephone is very useful for questions, informal discussion, and general conversation between two persons, but most people experience telephone meetings as awkward and rate them as clearly inferior to “real” meetings. Reports about regular use of telephone conferencing almost invariably involve small, close-knit groups of people who have been working together for a long time and know each other well. The most

²⁴ Although (according to Pool) there was an article in *Telephony* in 1901, claiming a visible effect on railroad traffic.

common exceptions are training and sales conferences, which more have the character of broadcasting (Johansen 1988).

The videophone, or "picturephone" as it was originally called, was envisioned as the next step in telephony, and it has prematurely been predicted at regular intervals. It was expected to reduce travel significantly. Pool quotes a 1914 article in *Scientific American* in which it was argued that something soon had to be done to check the congestion of the city, and that the fundamental difficulty seemed to be the necessity for close proximity when transacting business. The telephone and the picturephone were expected to change that. For the last 30 years, conference television has been an available instrument in a number of countries, but it has met with limited enthusiasm. The main reason may be the high cost or poor quality involved²⁵—but people also feel that it is "artificial" (Johansen 1988). Even here, the most successful use has been in training and sales, where the broadcast aspect is strong.

The telephone even eliminated jobs—most notably, the position as messenger boy. This was far from inconsequential: there were considerable numbers of messenger boys employed in every large city, giving many a poor family a welcome extra income. The advent of the telephone left them bereft of their jobs, but, on the brighter side, it therefore allowed them to stay in school.

From the beginnings of the railroads and the telegraph in the 1830s (with the addition of the telephone from 1876 on), it took 70 to 80 years to really explore and apply the main changes those technologies brought to the preconditions for organizing, and still a few more decades to perfect the new practices and reap the full benefits. In the same way, we are today still groping to really understand and exploit the new possibilities opened up by the rapid development of the computer and its related technologies.

Of course, the communications revolution did not stop with the telephone and the railroads. The development of steam and motor ships speeded up sea travel; the automobile gave the individual the freedom of unrestricted, rapid personal transport; and the airplane gradually achieved primacy in the long-haul market, shrinking travel time to a small fraction of what even the swiftest train could offer. The telephone became ubiquitous; the telegraph was supplanted by telex; and radio provided even ships, airplanes, and remote communities with the benefits of direct, real-time communication. The printing press has been supplemented by radio and TV broadcasting, records, and video—a development with its own societal repercussions, which, however interesting, cannot be treated here. The combined effects of these developments were quite significant. Indeed, it was possible to run large, international organizations as very tight shops, with strong control exercised from a central headquarters for many decades before the computer became emerged as a widespread and significant tool. Harold Geneen, for instance, did not need computers to keep his 20-year iron grip on ITT—jet

²⁵ At the time of writing (fall 1997), the cheapest option available for videoconferencing between Oslo and New York is a 128 kilobit connection, which, however, is only able to provide a slow-scan connection. The price (including studio) is about \$150 per hour. The best option is a 768 kilobit connection at about \$800 per hour, which will provide reasonably good resolution as well as an adequate scan rate.

planes, telephones, and mammoth management meetings were quite sufficient (Schoenberg 1985).

Today, cellular radio technology severs the last physical and geographical bonds of technology-mediated communication, at last giving us the capacity to communicate freely without spatial restrictions. In a couple of decades, it will be possible to reach and talk to almost any person in the industrialized part of the world without even knowing where that person is—as long as he or she has switched on the receiver and thus signified his or her availability.

It is irresistible to end this discussion of the telephone with two other quotations related by Pool, showing how established mental sets can prevent otherwise knowledgeable persons from perceiving and understanding the portents of a new technology. In 1879 Sir William Preece, then the chief engineer of the British Post Office, told a special committee of the House of Commons that the telephone had little future in Britain, even if it seemed to be a success in the United States (Pool 1983, p. 65):

There are conditions in America which necessitate the use of such instruments more than here. Here we have a superabundance of messengers . . . The absence of servants has compelled Americans to adopt communication systems.

This was three years after the invention of the telephone and one year after the switchboard was introduced. It was also one year after Alexander Graham Bell wrote the following to a group of British investors (Pool 1983, p. 21):

At the present time we have a perfect network of gas pipes and water pipes throughout our large cities. We have main pipes laid under streets communicating by side pipes with the various dwellings, enabling the members to draw their supplies of gas and water from a common source.

In a similar manner it is conceivable that cables of telephone wires would be laid under ground, or suspended overhead, communicating by branch wires with private dwellings, counting houses, shops, manufactories, etc., uniting them through the main cable with a central office where the wire could be connected as desired, establishing direct communication between any two places in the city. Such a plan as this, though impracticable at the present moment, will, I firmly believe, be the outcome of the introduction of the telephone to the public. Not only so, but I believe in the future wires will unite the head offices of telephone companies in different cities, and a man in one part of the country may communicate by word of mouth with another in a distant place.

The Bandwidth Problem

The revolutions brought about by the externalization of memory and the development of communication technology has not had any parallel when it comes to our interface with the real world. Yes, we can now instantly connect to and talk with a person sitting halfway around the globe, but our information exchange can still not exceed 250 words per minute—in fact, because of the slight deterioration that always follows transmissions through the telephone, we cannot even talk as fast as when sitting in the same room. True, we may now watch events taking place on other continents on TV in full color and in real time, but we

cannot absorb the televised information any faster than information reaching the eye directly. The slow speed at which we can absorb and output information continues to be a source of frustration, and it remains an iron-clad constraint on our organizing abilities.

Much energy has been expended through the centuries trying to alleviate this problem. We are still trying to cope with this shortcoming: from the perspiring student poring over his books the last weeks before the exam to the distressed CEO spending even Saturday and Sunday reading reports, memos, and magazines, desperately trying to catch up with the information constantly pouring down on him. Speed reading has been in vogue from time to time, but it has failed to gain widespread acceptance.²⁶ Much more important are the different means for preprocessing information, concentrating it, and making it easier to absorb.

The first remedy is **selection**—ferreting out the most relevant pieces of information. It is typically a demand placed by managers on their subordinates. Many top-level managers set a limit of one or two pages on memos, contending that what cannot be presented on one page is not worth knowing. Selection is also standard procedure in the news media. The problem with selection is that, to obtain a good result, the selector(s) must know just what is relevant for their masters/customers, which they of course do not. Managers are normally aware of this, and seek out alternative information sources as well. Nevertheless, we all have to depend on others doing selections for us, and we never know in which way they are biased—and too frequently, we are not concerned. Only professional investigators and researchers routinely question the reliability and completeness of the information they receive.

The next countermeasure against information overload is **concentration**—presenting the information in as compact a form as possible. The copywriters in large newspapers are infamous for this—reducing the well-polished prose of a proud journalist to a few close-cropped sentences. Television news and advertising are also arenas for extreme compactness. American television in particular seems to favor brevity and concentration above almost everything else—as if the price per second of advertising has left an indelible mark in the mind of everyone who works for these networks.

Concentration is not only achieved through expert editing and economy in words, however. Numbers are more readable if presented in a systematic layout such as a table, and the information they contain is even more accessible if presented as graphics. The brain's capacity for pattern recognition and visual processing is massive, and any information that can be presented in pictorial form will be grasped much quicker than if given in verbal form. Graphics is therefore an important and growing application area for computers, especially in engineering and the natural sciences, where equations and numerical relationships are so important. We must conclude, however, that our capacity for absorbing

²⁶ One can speculate on the reasons for this. It may be the training required, but if the benefits were as great as its proponents claim, the training should not deter anyone. I suspect that the main reason is that the real barrier against fast reading does not rest with inefficient eye movements, but with the mental concentration needed to actually absorb what the eyes see. We can all notice the enormous differences in reading speed we have when reading a really exciting novel and a really boring report. From my own experience, at least, I know the difference can be greater than 10:1.

information has not been dramatically enhanced, and lags far behind the huge increase in our storage and communication abilities.

When it comes to information dissemination, the picture is mixed. In face-to-face communication, our capacity has not increased. If we extend the concept to letters, typewriters (and later, word processing computers) have marginally increased our rate of output, but it is nothing to brag about. Our capacity has increased beyond all measure, however, when it comes to one-to-many communication. The printing press, radio, television, records and tape of various kinds have totally revolutionized the human capacity for addressing others. Of course, it is an intrinsic property of the concept of mass media that channels are not open to everyone—but in principle (at least in an open society) they are open to *anyone*. The powerful nature of the mass media's communication capacity is reflected in the exertions made by totalitarian regimes to control them, and in political parties' efforts to use them.

For organizations, the new media mainly allow for easier communication from organization leaders to the members and for more efficient information distribution to customers or other organizations in the environment. Even fairly small organizations have their internal circulars, and larger organizations often have internal newspapers or magazines. Mailing lists are kept for many purposes, and almost all commercial (and many public) organizations advertise. Indeed, mass media advertising is one of the prerequisites for the formation of large companies building their business on national or international brand names. By dramatically enhancing our capacity for one-to-many communication, mass media technology has also significantly enhanced our possibilities for organizing and sustaining large organizations.

Still Processing One Problem at a Time

Our inability to handle more than one conscious thought process at a time has of course not been modified by technology. However, the art of writing makes it possible to extend time slicing considerably and thus get a much better hold on complex matters. When intermediate results are committed to paper, we can leave the subject, do something else for a while, and then return to pick up where we left. The externalized memory is not totally infallible: Even if the written information itself does not change, our interpretation at two separate points in time may differ somewhat—but it is sufficiently precise to allow us to keep many more parallel processes going than a person in an oral culture can, and with much higher precision. Being literate thus helps us to extend our scope of interest and action considerably.

Automatic machines have also become extremely important. By isolating the essential patterns of action in the production process and literally forging them in steel, we have multiplied our actions by building machines that mimic them—and have thus become able to produce goods in unprecedented volumes.

Expanding the Limits of Complexity

As noted in Chapter 4, the working memory is not able to hold the many variables of a complex problem at once—it has a very limited capacity. The mind itself has not changed perceptibly, but once again the art of writing has proved to be a formidable technology. Literacy both spawned the analytic mind and ushered in the quest for new knowledge. It also provided the necessary tool for tackling very complex problems.

By providing us with an external memory that can hold and display a much larger number of variables, writing helps us extend our working memory. We use it extensively for all kinds of mental work—whether we write or sketch on a blackboard, a pad of paper, or a computer screen. This is both true for individual and group work—groups frequently use blackboards, whiteboards, flip-overs and overhead projectors to provide a common, external working memory to aid their processing. For groups, it also helps synchronize the minds of the participants and foster a common understanding of the problem at hand. The more formal decomposition of tasks in larger projects, with its problem definitions and job descriptions, serves the same purpose.

Our processing is also helped by the fact (already mentioned) that writing allows us to collect phenomenally large vocabularies, allowing for great precision in descriptions and arguments. Ong (1982) considers this difference between an oral-only language and a language with a literate tradition so fundamental that he gives the latter a separate name: he calls the language of a truly literate society a *grapholect*, to emphasize its dependence on writing both for its richness in words and its style of expression.

In addition to acting as an extended working memory during problem solving, storing ideas and intermediate results, writing also allows us to do “preprocessing” by collecting relevant material, systematizing it, and thus creating a platform for decision making. For elaborate problems requiring much work, writing makes it feasible to break them down into smaller chunks and distribute them over time, again using writing to store intermediate results.

In the modern world, problem solving and decision making are most often part of a group process. We have already noted the concept of the common extended memory for groups, and also important is the ability to write memos and reports, make copies of them, and thus distribute to everyone in parallel instead of circulating hand-written originals. This makes group work a lot more efficient. But the real revolution is found in the way writing lets us distribute large tasks among a vast number of persons, synchronize and coordinate their activities, and communicate intermediate results between them. The ability to collect, systematize, and store information that writing confers upon us, and the way it allows us to distribute and synthesize problem-solving efforts, has totally revolutionized our capabilities and has made it possible to organize massive undertakings.²⁷ A literate society can therefore routinely tackle tasks that would completely overwhelm any illiterate society.

²⁷ An interesting example of a really massive, pre-computer project is the Allied invasion in Normandy in 1944. Participating in the operation were hundreds of ships, thousands of aircraft, and more than a million soldiers, in addition to a large number of tanks and artillery units. This enormous force needed not only to be equipped and readied in the ports of southern

To return to groups for a moment, it can also be noted that, for really important decision-making groups, far more expensive solutions than whiteboards and overhead projectors have been devised. The mission control centers for manned space expeditions, for instance, bristle with technology and support personnel. The same is the case with the so-called situation rooms for military high commands. These rooms are equipped to handle the real-time conduct of major wars, when the chiefs of staff must communicate almost constantly among themselves and with their units, and at the same time be able to receive and have displayed vital information about their own and enemy movements. A few large, private corporations, where the leaders deem themselves to be in the economic and market parallel to war (the slogan "marketing is war" is an indication of this sentiment), have invested in their own "situation rooms," where top management can receive high-tech, graphics-filled briefings.

The situation room is an obvious advantage when it is necessary to monitor and respond in real time to complicated events unfolding rapidly. Whether the situation room is actually of any use in a corporate top management environment, or whether it just serves to enhance the prestige of the users, is open to conjecture. The closest thing to real, functioning situation rooms in commercial organizations are probably the broker rooms in banks and brokerages dealing in currency, stocks, or raw materials, and the control rooms in industrial processing plants and power stations.

A more cumbersome operation is problem solving or decision making aimed at expressing the collective views of very large numbers of people. The basic technique developed over the millennia is the method of representation, whereby a small number of representatives are elected or appointed and are conferred the power of deciding on behalf of the electorate. For political purposes, the basis of this method was developed by the ancient Greeks, and has since only been refined and modified to suit much larger electorates—where a recourse to direct voting in the town square has not been a viable alternative.

In organizations, the organizational hierarchy itself is supposed to support this process, but it is seldom adequate to serve all the different purposes and views present in a large organization. Often, organized labor takes over parts of the function (also using the method of representation), and almost always we find informal leaders and mediators who perform simply because a number of people trust them and see them as voices for their concerns. Shareholder democracy is also an extension of the old political metaphor into the realm of organizations.

We noted above that the development of democracy in Europe and North America was closely related to the invention of printing and especially the growth of the newspaper industry.²⁸ Mass media both informed and homogenized, and

England; when the attack had started, it also had to be managed. The efforts of all the services and fighting units had to be coordinated in real time, and there was no room for time-outs to collect one's thoughts. In addition, the invasion force had to be supplied with food, fuel, and ordnance, over provisional bridgeheads, and with constantly changing front lines. Over just one of the bridgeheads (on Omaha Beach), 15,000 tons of supplies and 15,000 soldiers were brought ashore *per day* in the most hectic period.

²⁸ When the mass-produced printed word became so important, it was because there was a concomitant educational revolution—it gradually became common to learn to read and write.

they provided the public, common event space for a national identity, a national agenda, and national leaders. They are also the channel for the representatives' communication with their constituents. The development of sampled polling provides another strong feedback mechanism, and although most would agree with the truism that an opinion poll is not an election, we can see that politicians are getting increasingly sensitive to results of such surveys—thereby acknowledging the fact that they do indeed represent a very effective short-term feedback mechanism.

In large organizations, some of the same technologies are brought into service to create a corporate identity and a corporate event space. Even a technique such as polling has gained a foothold in the organizational world. It is presently used by a number of consultancy firms to assess organizational health and provide a basis for proposing remedies.

Automation

For some purposes we can overcome our limited ability to do things in parallel in a more direct way: We can build automatic machines. An automatic machine mimics the work of humans—either directly, as with mechanical arms gripping objects and moving them from one place to another, or indirectly, as when car bodies are painted by electrophoresis as they are moved (hanging from conveyors) through large chemical baths.

Automation has to a certain extent made it possible for us to transcend both our innate problems of coordination and of attending to more than one task at a time. Pure mechanical automation, which started in earnest in the middle of the eighteenth century, has made great strides, and quite complex products can be manufactured with a minimum of human intervention. Through the programming laid down in the mechanical design of machines and tools, a variety of tasks can be carried out in perfect coordination, and with a good number of parallel sessions per human operator. In addition to greater speed and precision, an automated system wastes no time making decisions—the decisions have been made once and for all through its design.

For automation can be viewed essentially as canned action, as the enactment of previous design. The machine is, so to speak, a set of crystallized decisions, a result of an extensive information-processing undertaking, ending with a carefully choreographed set of movements and work operations. It represents a total externalization of a plan for a specific production process. Once forged in steel and powered by steam or electricity, the automatic machine can repeat its designed actions again and again. And once designed, it can also easily be replicated, and our canned actions can finally be carried out in parallel by a large number of similar machines.

This is quite different from using power to increase our physical might, as we do, for instance, with bulldozers. A bulldozer allows a single individual to move hundreds of times more soil than he or she could with a shovel only, and thus increase his or hers productivity hundredfold. In principle, however, it is no more

than a power shovel. The automatic machine, on the other hand, replicates on its own certain productive aspects of the human organism. We cannot really say that such a machine is processing information, since all it does is to repeat a sequence of movements. But those movements are carefully planned and designed, just as much of the human work in an organization.

Even pure, "old fashioned" mechanical automation is thus a powerful expression of collective information processing, and it can be viewed as a part of the organization—just as man is. This aspect of automation becomes even more evident when we cross the threshold into the world of information processing, which opens up new areas for automation. Before the advent of computers, for instance, there was scant automation in the realm of administrative work. The most advanced examples were mechanical calculators, bookkeeping machines, and punch card equipment.

By harnessing external sources of physical power and multiplying our physical operations, automation has become the main basis for our phenomenal growth in material wealth. It has made it possible for us to produce goods in volumes that are many orders of magnitude greater than before. At the same time, however, it has forced standardization. For even if automation of physical operations is very efficient, mechanical automation also results in a rather inflexible production apparatus. Machines all have their very definite purposes and ways of operating, and their repertoire can normally only be changed by physical modification. It takes considerable time and effort to externalize decisions in the form of a machine. Mechanical automation is thus conducive to mass production of standardized products, but generally insensitive to rapid changes in demand.

Time for Deliberation

Whether or not our speed of deliberation has been improved is really a matter of definition. There is no doubt that both writing and modern communications technology (both physical transportation and telecommunications) have speeded parts of the total process. Information can be collected much more quickly, reading allows for more efficient information absorption, and consultations are much easier when one has access to telephones and rapid means of personal transportation. The reaction time for large organizations has therefore been considerably reduced, with notable consequences for innovation rate, the average lifetime for products, and so on. Strictly defined, however, that is not part of the deliberation process; it is a consequence of better communications, improved information retrieval, and more powerful tools for analysis. Deliberation proper is a process that is internal to our mind, and, as such, it has so far not been noticeably affected by technology.

Emotions

Can technology "augment" emotions? It may seem preposterous to ask such a question, but we must consider the evidence. Control of raw emotions has always been of great importance in human societies, and it still is. We should therefore

expect efforts to improve it by tool development. According to Wilson (1988), even a hunter/gatherer society such as the bushmen of the !Kung San "dread the prospect of tempers flaring out of control," and place much emphasis on the control and management of emotions. This is also the case for the Inuit Eskimos. In general, it seems that societies in which people are forced to live very close to each other develop strong norms demanding tight control of emotions and encourage mental training and the development of techniques for this purpose. Both China and Japan are famous for this, and India is the home of yoga and other mental techniques.

In industrialized societies, handling of emotional problems and aberrations has typically enough been professionalized and has become the subject of scientific research (psychology and psychiatry). And, as wizards of the material world, we have not been content with techniques and "empty talk." The development of psychopharmaca has proceeded from the narcotic herbs of tribal society to a bewildering array of modern medications. Even if we are not counting the more exotic (and even illegal) drugs, both sedatives and stimulants are routinely used by a large number of people every day. Hochschild (1983, p. 54) even reports that nurses in the medical department of AT&T "gave out Valium, Darvon, codeine, and other drugs free and without prescription" to help employees cope with stress and boredom on the job.

If we follow Morris (1967), we may also include much literature, photographs, and movies/TV as emotion-controlling technology. Morris notes that our innate interest in sexual activities outside the pair-bond is strong but socially denounced, and that the solution is sex by proxy, from the innocent romantic to the hard-core pornographic. A similar case may be made for our bent toward adventure and heroism, especially when young—it feeds the movie industry like nothing else. The movies and the corresponding books may provide a much-needed cathartic effect for postmodern youth trapped in a society where the challenges of life are increasingly abstract, and where physical excitement and adventure is channeled into sports that are themselves ever more regulated and loaded with safety precautions.

7 The Modern Organization

“Everywhere in the world the industrial regime tends to make the unorganized or unorganizable individual, the pauper, into the victim of a kind of human sacrifice offered to the gods of civilization.”

Jaques Maritain, *Reflections on America*, 1958.

The New Administrative Technology

The discussion in Chapter 6 has shown how our technological achievements from the advent of literacy and onwards has greatly improved our capacity for organization. We may point to three periods in particular: the slow development of literacy in the great Eastern and Western civilizations in the long period from about 3500 to 600 B.C., the development of modern numerals and mathematics from about 900 to 1600 A.D., and the development of automation, physical transport, the telegraph, and the telephone from about 1800 to 1945.

We can safely conclude that technology even before the advent of the digital computer vastly improved our storage and communication capabilities, and provided a solid augmentation of our basic problem-solving and decision-making abilities—especially when it came to groups and large undertakings. Its effect on our “processing” was almost totally indirect, however—it supported problem-solving and decision making only by storing, arranging, presenting, and communicating information. The following sections sum up the status of the preconditions as they stand *except* for the augmentation provided by computers.

Memory

The *amount* of information that can be stored is principally *unlimited*, and it does not deteriorate over time, unless the physical medium itself deteriorates. Medium deterioration is of course a problem, especially for works of art, but important information can always be renewed. Information in verbal (written) or numerical form can even be renewed without any loss of content. The stored information is therefore *accurate* in the sense that what we get out is by and large equal to what we put in. The reservation expressed by “by and large” does not pertain to symbols themselves—the words in a book printed a hundred years ago are exactly the same today, the book has not “forgotten” any of them—but to their

interpretation, which may change over time, and even change so subtly that we are not aware of it. Normally, it is not a serious issue, however. Pictorial information, on the other hand, is more of a problem—photographs, drawings, and paintings can be copied, but we lose information in the process, and there is a definite limit to the acceptable number of generations.

Even if there are no theoretical limits to the amount of information we can store, there are some practical problems, since externalized information occupies space—it has *bulk*. What we have in our heads we can easily carry around; what we store in books is another—and heavier—matter. Not to mention stone slabs—they were not practical at all, and even clay tablets did not constitute a particularly dense medium. Writing probably did not have real impact until parchment and other paperlike media were developed. However, even paper-based information is bulky, as any filing clerk will tell you, and there is a definite limit to the amount of information you can keep handy. Microfilm shrinks the physical bulk of information tremendously, but because of updating problems and cost, it has been used only for special purposes.

Then there is the problem of *retrieval*. Externalized information can be retrieved only when we know where it is. For limited amounts of systematized (indexed) information, retrieval is unproblematic. It does not take long to locate a card in a card file kept in a desk drawer, for instance,¹ and most accountants will retrieve that particular bill paid a while ago as long as you can inform them of the approximate date. For large amounts of information, and information that does not lend itself readily to indexation, the problems are considerable. Filing systems, library systems and punch card equipment represent our more or less desperate attempts to overcome this difficulty, but even in extremely well-run (noncomputerized) libraries or archives, one can only search on authors, titles and a very limited number of keywords. The necessary indexing systems are also very complicated and laborious to establish and maintain. So, even if we can store massive amounts of information, we encounter the same problem as with our biological memory: We can only access a tiny fraction of it. The difference is that the constraint on access does not reside in an inscrutable biological mechanism, but in the prohibitively long time it takes to search through large amounts of paper-based information.

Information Absorption and Dissemination

Our basic capabilities for information *input* and *output* have not been changed much by technology: We cannot speak any faster than our forefathers. The invention of writing helped somewhat, because we can read a little faster than we speak (and thereby listen). Written material is also more generally accessible (it is

¹ In fact, this is only true when you are able to search on the indexed information—for instance, the name in an alphabetized personnel file. If you are after other kinds of information, however, you may be in for hard times. I remember the personnel file at Nylands Verksted (my first employer), one of the oldest shipyards in Norway. It contained the personnel card for every worker ever employed almost since the company's inception in 1841—thousands of cards. What a treasure trove for a sociologist! But, because the worker's name was the only available search criterion, the wealth of information was inaccessible in practice. The effort required to register the information in a database was far beyond my means, and any other form for indexation would require an even more prohibitive amount of work.

physically separated from the originator) and thereby allows us to devote more hours per day to information intake. We have, moreover, become much more adept at preprocessing. Systematic selection and compacting probably give the information we do manage to absorb a somewhat higher content of relevant information. The typewriter has likewise made writing a little faster (and the result generally more legible), but the increase in speed has not been dramatic and has not made any real difference for our organizing abilities.

Communication

The area of communication, on the other hand, has been one of far-reaching innovations in most aspects. If we look at physical transportation, *travel time* (and cost) has shrunk enormously, especially in the last 150 years. Paleolithic man could travel at most a few tens of kilometers per day and normally did not stray outside an area he could traverse in a few days. Transcontinental or transoceanic travel was normally unthinkable. Today, it will not take more than 48 hours to go from almost any major city in the world to almost any other. Travel between capitals seldom requires more than 24 hours. From Oslo, I can go to New York, have a meeting, see the town, and get back in less time than it would have taken my grandfather to make a return trip to Bergen on Norway's west coast, and his grandfather again to go one-way from Oslo to Lillehammer—a town some 180 kilometers to the north.

The increase in speed for the transportation of goods is almost as great. In the 1980s, for instance, Norway's export of fresh salmon to the United States suddenly increased dramatically.² The secret behind the success was of course air transport, which makes it possible to serve a salmon in a San Francisco gourmet restaurant as little as 48 hours after it is snatched from its enclosure off the coast in the south, west, or north of Norway.³ But even for less perishable and costly goods, intercontinental transport takes a matter of weeks, or maybe a month or two at the most. Mail services are universal, and even if the distribution speed varies from country to country, two places in the world are seldom more than two weeks apart. Courier services offer considerably faster delivery. These improvements in transportation make global trade and global organizations eminently feasible, especially when paired with the advances that have been made in the communication of information.

For the developments in global transportation pale when compared to the strides taken by the communication of information. Our *range* of communication has been extended to interplanetary proportions, and the *speed* thereof to the speed of light.⁴ For most practical, earth-bound applications, we talk about

² In 1991 it suddenly shrank again to a fraction of what it was the year before, as a direct result of a penalty duty imposed by American authorities—ostensibly a measure against what was viewed as unfair government subsidies of Norwegian salmon breeders. This incident serves to remind us all that technology is not everything!

³ Such rapid transit (with its concomitant high transport costs) is not the usual—most of the salmon requires three to five days to reach its destination. Only the most experienced experts will note the very slight difference, as salmon packed in ice keeps very well.

⁴ Or almost the speed of light—electric signals in wires travel somewhat slower, and even radio signals are delayed by the necessary amplifiers and converters en route.

instant, real-time communication regardless of distance.⁵ This holds both for one-to-one (telephone) and one-to-many communication (radio and television broadcasting). In addition to the electric and electronic media, mass distribution of books, newspapers, and magazines has made possible a *massive exchange* of information. *Return channels* such as sampled opinion polls and "letters to the editor" make leaders aware of prevailing opinion, and even make people aware of what other people think—in itself a very important precondition for opinion formation.

Processing

Strictly speaking, our internal capacity for problem solving has not been increased. But the art of writing lets us utilize that capacity much better by relieving it of the task of memorizing all the information relevant to a problem. It also allows us to *preprocess* information to ease problem solving, and monitor much more complex activities by collecting written reports and having quantitative information arranged and displayed on paper. Because there are limits to what one individual can do, however, we still have to organize to solve problems that exceed individual capabilities.

But writing has also made it possible for us to *distribute* tasks both over time and among persons much more extensively than before, allowing us to cooperate in a much more coordinated fashion. The telephone has made group work easier and has increased the possibilities for coordinating people in different locations. It is this new, technological basis for organization that has so greatly increased our capabilities for collective processing and allowed us to tackle tasks of much greater scope and complexity than our preliterate forebears.

Emotions

Our basic emotions and desires have not changed, but we have learned to *control* them to a certain degree both through mental techniques, the use of social norms, projection (the use of proxies through literature, pictures, or movies) and (in some instances) medication. The basic techniques of self-control and the instrument of social norms are nevertheless very ancient indeed, and it is doubtful whether (for the purpose of organization) the differences between modern man and his Paleolithic ancestors are really significant in this respect. Our emotions are still among the major sources of organizational conflicts, disturbances, and failures.

These were the main, technologically based changes in the preconditions for organizing that allowed the great changes in organizational appearance and functioning that took place in the nineteenth and twentieth centuries. The key points are summarized in Table 7-1.

⁵ Experience shows, however, that telephone conversations transmitted over satellites in geostationary orbits suffer from the slight delay (1–2 seconds) resulting from the distance and the transmitters/converters. Because of this, there has recently been a renewed interest in intercontinental telephone cables. A new cable was, for instance, laid down between the United States and Japan in 1996. It is of course a fiber-optic cable, with a capacity of 600,000 simultaneous telephone conversations.

Memory	<p>Unlimited amounts of information can be stored outside the brain without loss.</p> <p><i>Main constraints: retrieval becomes problematic when volume increases, large amounts of information require considerable physical storage space.</i></p>
Information absorption and dissemination	<p>Some improvements in speed; significant improvement in accessibility.</p> <p><i>Main constraints: our own input/output limitations.</i></p>
Communication	<p>Physical transport revolutionized, communication of information doubly so—information can be transmitted instantly regardless of distance. Mass media allow information dissemination on a massive scale.</p> <p><i>Main constraints: high cost of large volume point-to-point electronic communication and low social “bandwidth” of the affordable channels.</i></p>
Processing	<p>Greatly improved by better preprocessing and storage of intermediate results. Far better monitoring of complex events. Much better possibilities for distributing tasks over time and between many persons, as well as for coordination and cooperation over distance. Vastly improved capacity for mechanical automation through unlimited replication of “canned” processes.</p> <p><i>Main constraints: Externalization of information processing still not possible to any significant degree. Processing capacity per se not significantly increased.</i></p>
Emotions	<p>Some improvement in control.</p>

Table 7-1: Main technology-based changes in preconditions.

Into the Modern Age

It took a long time to discover and exploit the new organizational possibilities opened up by evolving technology. For a long time after the invention of writing, the state remained the chief domain for organization, and the feudal structure, the main organization type in literate societies. Religious hierarchies were also most often modeled on the feudal state, with divinely sanctioned offices corresponding to the nobility’s secular positions based on lineage and inherited rights to land. The administrative technologies provided by literacy were only used to support already existing organization practices. Literacy was moreover limited to a very small part of society—the ruling elites, a number of their servants, the religious establishment, and a few others—and so the information economy of the feudal structure was still necessary to manage large states and large religious or military organizations. Economic organization remained small-scale, mostly of the Simple Structure type—either with one owner/manager, or with a small number of

partners dividing the managing role between them. (A partnership may also be viewed as the commercial variant of the Councilcracy.) The structure provided by family was almost always there as the dominant pillar.

This situation lasted for a very long period of time—more than 2000 years, if we count the time from the more widespread development of literacy in the Mediterranean until the start of the Industrial Revolution in England. There were of course important developments taking place in that interval, but by and large they were all variations and refinements within the scope of the organizational forms discussed in Chapter 5. Not even the considerable growth in literacy that came with the development of printing and the availability of (relatively) cheap books in Europe and the United States from the sixteenth century onward produced any significant developments in organization—with the possible exception of the slow but steady growth of representative democracy in England. The revolutionary changes in the preconditions for organizing that were provided by the invention of writing were simply not exploited. This fact can serve to remind us that new capabilities do not force development in themselves. They only exist as potentials until they are actually discovered, explored, and employed.

The best explanation we can provide for this failure to take advantage of available administrative technology is that the material needs for large organizations besides the state, the armed forces, and the Church were simply not there. The vast majority of people all over the world still worked the land, the traditional organizational structures were quite adequate, and the preeminence of the land-holding nobility in the body politic of the feudal states was in harmony with this state of affairs. The craft-based production of material goods still did not achieve a volume where production needed more organization than the direct supervision provided by a master or a “foreman.” The same was the case with trade—as long as transportation was slow and fairly expensive, volume was low and could easily be handled by the traditional merchant and his few assistants. Chandler (1977) describes how this was the case in the United States right up to the 1840s. Even in Europe, where both the scientific revolution and industrialization started, there was not much innovation in organization before the middle of the nineteenth century.

But, as we now know, a revolution was brewing in Europe and the United States, where a long and slow accumulation of knowledge and development of new tools now accelerated. The application of external power (especially steam) and the construction of machines for manufacturing production boosted the output of the growing factories, whereas the advent of trains, swift sailing vessels, and later steam ships provided cheap, rapid transport. These developments cleared the field for business ventures many orders of magnitude larger than before.

The new opportunities, however, could not be realized through the traditional, small-scale business organization, as they entailed production and transport of unprecedented quantities of both raw materials and finished goods. Building commercial organizations capable of handling much larger numbers of people and spanning much greater distances than before thus became one of the major challenges of the new entrepreneurs.

The Growth of Complexity

The Starting Point

Prior to the Industrial Revolution, work tended to be holistic in character—meaning that one person usually carried out a complete set of tasks. This does not mean that there was no specialization at all—even hunter/gatherer societies show some rudimentary differentiation of roles, and medieval society displayed a rich set of specialized occupations, notably in the crafts. Even so, work was usually quite varied. A craftsman, for instance, would do almost all the work on an object, from obtaining raw materials to the finishing touches and even the delivery to the customer. Apprentices and journeymen would often do some of the more tedious chores, but the craftsman was always in control of what happened—coordination took place by means of informal communication and mutual adjustment. The information processing was managed intuitively and without significant formalized structure.

Farmers likewise carried out all the different tasks associated with their position, and merchants would usually have a very personal relationship not only with their customers and suppliers, but also with the different work processes required. They might hire laborers to handle the goods, and clerks to do various administrative work, but there was not any great degree of specialization. By and large, business was a family affair or a partnership—where the partners worked largely in parallel with similar tasks, rather than dividing work according to functional specialization (Chandler 1977). You may well say that this is the spontaneously natural way to work for a human—it has dominated all the way from hunter/gatherer society up until the spread of industrialization.

If there was a hierarchy in the business, it would typically be of the *task-continuous* type (Clegg 1990), in which a person at a certain level would master all the activities of lower levels. The owner, mastering all the tasks in the business himself, would usually be very competent to coordinate the activities of the others. The importance attached to such mastery is illustrated by the fact that it was usually considered obligatory for heirs to such small family businesses to work in subordinate positions for many years, at all organizational levels and with all the different tasks, before being considered ready to take part in the direction of the business. Many family-run businesses still subscribe to this principle.

Scaling Efforts

The first steps toward industrial production and modern organizational forms consisted of a more intensive exploitation of traditional approaches. Entrepreneurial artisans increased the number of apprentices and/or journeymen in their shops; in some trades, such as building and shipbuilding, masters increasingly took on total contracts for the construction task and then proceeded to put together teams of the necessary craftsmen to complete the job. But even this extended approach was kept within the Simple Structure model—the work force or team was usually not larger than the number of people the entrepreneur himself could oversee.

Another approach to expanding the production of goods was increased use of the “putting out” method, whereby a master or a merchant contracted out work to households or independent craftsmen working in their homes. This method of

production was extensively used in Europe, and one merchant could have more than a hundred such contractors working for him. None of these practices were new, however—according to Goody (1986), they were already routine in Assyria more than 3000 years earlier—in 1900 B.C.

People working under the putting-out system had considerable freedom in their daily life; they could to a large extent decide their own working hours. To illustrate this, Chandler quotes the historian Blanche Hazard (Chandler 1977, p. 54):

The domestic worker had enjoyed all the latitude that he needed or wished. He sowed his fields and cut his hay when he was ready. He locked up his ten footer⁶ and went fishing when he pleased, or sat in his kitchen reading when it was too cold to work in his little shop.

Descriptions such as this make us reflect on what we have lost through industrialization—and it is no wonder that the first factories had great trouble getting skilled persons to show up regularly for work every day. They still tended to go fishing or swimming when the weather was good, or to be absent the day after a particularly intense celebration. Such privileges are not easily surrendered.

In the struggle to find suitable new ways of working, old practices were stretched in yet another way, even as the trend toward specialization and factory organization was becoming more pronounced. Building on traditions from craft shops and contracting, *internal contracting* became a fairly widespread way of organizing production—especially where specialization was not too extensive (Chandler 1977, Clegg 1990). In this type of arrangement, the factory owner negotiates a contract with a number of subcontractors specifying a number of goods to be delivered over a certain time period, usually a year. The factory owner would typically provide floor space, tools, raw materials, and so on, and pay the subcontractor a lump sum, possibly with the addition of a minimum foreman wage. The subcontractor then hired his own people to do the work, paid their wages from his own contract money, and supervised their work himself.

Another form of internal contracting developed later as a result of the merger waves that resulted from the growth of larger regional and national markets in the last half of the nineteenth century (Chandler 1977, Clegg 1990). The amalgamated companies that arose through the mergers were too large to be managed by traditional means, and the necessary administrative techniques for large-scale, task-discontinuous organizations were still not fully developed. The former owners were therefore often asked to continue to manage their old companies, but now as internal contractors, with lump-sum payments for providing agreed volumes of their goods or services within the larger whole. As Clegg says, such arrangements to a large degree reconstituted the task-continuous style of management in pockets within the larger companies.

Internal contracting had the same kind of advantages in information economy as we have already seen in the feudal structure: It effectively encapsulated the production process within the work group or the acquired firm and relieved the

⁶ A common term for the small workshops such workers usually put up as annexes to their homes. A length of about ten feet was the usual size of these shops.

top management from worrying about the details of the daily work process and the need to build up an administrative staff. They only had to manage their contractual interface to the subcontractors. These advantages have helped such arrangements to survive to the present day—even in advanced industries in the leading countries of the world. For instance, you will find that Japanese car factories are surrounded by entire districts composed of small, family-owned workshops (Clegg 1990), barely surviving in a harsh contracting system that can be viewed as a combination of internal contracting and putting-out.

The more intensive use of practices such as contracting and putting-out that marked the immediate preindustrial period in Europe and the United States can definitely be interpreted as a sign of stress on the old order. The changes wrought through technological progress were accumulating, and the craftsmen and businessmen of the day were feverishly trying to accommodate them by scaling up their traditional work processes and organizations.

However, their traditional organizational practices could not be scaled up to accommodate the fine-grained specialization that was now developing, with its accompanying needs for rigorous planning and detailed control of the activities of large numbers of people. In the internal contracting system, coordination between the subcontractors was mostly handled on an informal basis, and it was often less than optimal. Top managers had little information about real costs and waste in production, for instance. A closer coordination of the entire production process and more direct supervision and control of costs and quality was difficult to achieve with the traditional approaches, and the concept of centralized planning and total coordination of production gained ground along with the increasing specialization. Even among traders and transporters, the increasing volumes of goods and raw materials required new approaches.

The Birth of the Machine Organization

The New Needs

As we have already noted, the most pronounced features of industrialization were the use of increasingly sophisticated fabricating machinery and the mechanization of transportation, both accompanied by growing functional specialization. In their turn, these developments invited factory production on larger and larger scale. To coordinate the efforts of large numbers of specialized workers, new work practices and organizations were needed.

There were probably two main reasons for the development of functional specialization: One was the growing pressure toward increased productivity, the other the scarcity of skilled workers (craftsmen).

Then as now, it took several years to train an artisan practicing his traditional, holistic craftsmanship. The limited availability of craftsmen and the slow training process represented a serious bottleneck for industrial growth. Extensive specialization in production thus became a prerequisite for the rapid growth the industrialists pursued: it allowed them to hire unskilled laborers and train them only in their particular narrow tasks—a process requiring maybe only days or a few weeks at the most. In addition, such workers were much easier to control and command than the traditionally quite independent craftsmen.

The decisive advantage of specialization, however, was its impact on productivity and the way it supported mechanization. Specialization and mechanization together brought us the productivity revolution of the nineteenth century. The roots of specialization are certainly older and can be found for instance in early attempts to organize craft production in larger units, such as the case of simple specialization in tenth century English textile "industry" mentioned by Mintzberg (1979). However, until the advent of the mechanized factory, it played no important role.

One of the first descriptions of thorough specialization was Adam Smith's famous example of the trade of the pin maker, presented in *The Wealth of Nations* (published in 1776), where he identified eighteen different operations involved in making pins. He also observed that the specialization developed in pin production resulted in a productivity far superior to that of a traditional, holistic approach. Although the pin-making process represented primarily an elaboration of the craftsmanlike approach, it clearly pointed the way to a new era. It was not until the nineteenth century, however, that functional specialization became widespread, was supported by mechanization, and ushered in a new type of organization.

In the United States, extensive specialization was first implemented in the manufacture of small arms early in the nineteenth century, coinciding with an advancement in the precision in manufacturing of finished parts to the point where parts of the same kind became interchangeable, allowing the final products to be assembled without the extensive adjustments of the preindustrial and early industrial era. Eli Whitney, the inventor of the cotton gin, was the first (in 1801) to demonstrate publicly the assembly of guns from piles of standard parts (Morgan 1986); the American Springfield Armory is generally reckoned to be the first factory to achieve such production on a large scale (Chandler 1977). In Britain there is evidence of the application of the general principles of specialization in the organization of Boulton and Watt (the steam engine manufacturers) as early as 1830 (Hollway 1991).

Specialization subsequently spread to other industries, but the development did not really accelerate until after 1850, developing into what was known through the latter part of that century as "the American System of Manufactures" (Pine 1993). However, this approach to work organization requires much more emphasis on coordination and control than the craft shop approach and its derivatives. As Koolhaas remarks (1982), it entails splitting all the problems of design and production—an integral part of the craftsman's work—away from the worker. Those tasks must now be carried out by specialists on design and planning, and the workers are only required to carry out their ordained tasks, which becomes more and more specialized and narrow as mechanization and automation progress. This process was accelerated when industry made the transition to the second generation of mass producing systems, pioneered by Henry Ford (discussed later).

The responsibility for coordination in these systems is removed from the workers and shared between the central planners and the plant supervisors. To manage the production process and ensure that the throughput at each step in the production process matched the total process, and that the quality of each worker's output satisfies the standards required for the assembly of parts into

working products, stringent measures for quality and production volume become necessary. Specialization in production therefore calls for a much more sophisticated approach to information processing and communication and, consequently, to organization. It cannot be fully realized within the framework of a Simple Structure, and it is also easy to see that it is impossible (above a very modest scale) without writing.

Clegg (1990) is talking about the same processes when he points out that the growth of large organizations with extensive functional specialization constituted a decisive break with the task-continuous organization. It was no longer possible for any one person to master all the specialized tasks in the organization, and the direction and supervision of activities on lower levels had to be indirect and based more on formal standards—also dependent on writing.

Even if writing provided the necessary tool for handling large amounts of information and building complex organizations, however, literacy had to be widespread to be really practical for large-scale administrative purposes. That was exactly what happened in the eighteenth, and nineteenth centuries, which saw the advent of mass literacy and an unprecedented spread of knowledge through printed books and newspapers. In addition, the new communication technologies—the rapid physical transport, the telegraph, and the telephone—made it possible to build not only complex and large organizations, but organizations that spanned great geographical distances.

Within a short period of time, then, many of the traditional constraints of human physiology were considerably amended by new tools. The simultaneous changes in the preconditions for production and organizing combined to open vast new territories for human industriousness and ingenuity, and development finally surged ahead. It changed forever not only the commercial sector of society but also the political one, at least in Europe—the fast-growing European *bourgeoisie* did not in the long run accept the political monopoly held by the king and the land-owning nobles.

The Transition to a New Organizational Form

Nowhere did the new developments take stronger hold than in the United States. (There are probably good reasons for this, which are elaborated on later in this chapter.) This is reflected in the rapid growth of the mass-producing American industry and in the fact that the most influential theoretician of functional specialization and the man who applied it most successfully were both Americans.

The man who developed this line of thought to its natural conclusion was Frederick W. Taylor, and the man with the greatest practical success was Henry Ford—who, after the introduction of the moving assembly line, managed to manufacture cars at close to half the cost of his nearest competitor, all while paying his workers the highest wages in the industry *and* getting immensely rich himself (Chandler 1977). When he introduced the assembly line in his Highland Park plant, the amount of labor expended to make a car dropped from 12 hours, 8 minutes to 2 hours, 35 minutes. Six months later it was down to 1 hour, 33 minutes. This breakthrough inaugurated the transit from the first generation of mass production systems, such as the American System of Manufactures, to the second—the Fordist systems (Pine 1993). The first-generation systems still

incorporated a lot of the qualities of craft production, and primarily achieved higher productivity by moderate specialization backed by tools that augmented the workers' efforts. They thereby retained much of the flexibility of craft production and could turn out quite varied products with small retooling costs. The second-generation systems developed specialization further, increased the dependence on machines, and introduced automation to a much greater degree. Productivity increased dramatically, but flexibility was correspondingly reduced and the cost of retooling for new products increased.

As both corporations and public institutions grew to staggering new dimensions, the necessary administrative workload also grew, and the sheer volume of it became much more than one or a few individuals working in a fairly unstructured manner could handle. According to Chandler (1977), the need for extensive administrations first arose in the rapidly expanding railroad companies, where the administrative tasks grew with each new line, each new car, and locomotive.

The men who faced the challenge of establishing the first major, private administrative apparatuses had few models to learn from. Their major source of inspiration must have been the fantastically successful new methods for material production—whether it was in mass production of industrial goods or in the large construction works of the time. They were all civil engineers, and there is reason to believe that they (as most people will do) tackled the new problems with methods from their existing repertory, rather than from, for instance, the military model. As Chandler says (1977, p. 95),

There is little evidence that railroad managers copied military procedures. Instead, all evidence indicates that their answers came in response to immediate and pressing operational problems requiring the organization of men and machinery. They responded to these in much the same rational, analytical way as they solved the mechanical problems of building a bridge or laying down a railroad.

There is no doubt, however, that at least some of them were acquainted with military organization, since the military academy educated some of the best civil engineers. Morgan (1986) thinks the military did indeed provide an important paradigm for organization; he gives special mention to Frederick the Great's reorganization of the Prussian army in the middle of the eighteenth century—which preceded the great railroad and manufacturing companies by about 100 years. But Frederick the Great and the first large-scale industrialists may have had a common source of inspiration. According to Morgan, Frederick the Great was especially fascinated by automatons and mechanical toys, and through elaborate drills, increased specialization of tasks, and standardization of weapons and uniforms, he wanted to shape his soldiers into the human equivalents of mechanical toy men. Behavior and equipment should be standardized to allow easy replacement and interchangeability in war, and the men should learn to fear their officers more than the enemy.

But even if Frederick the Great increased specialization in his army, a military force at that time did not have very extensive specialization. Planning capacity was also limited and information economy was very important. We should not be confused by the fact that there were great numbers of soldiers, or that the

hierarchy of command was very elaborate, because when they battled, they all did more or less the same in parallel. Rather than being a model of the emerging industrial corporation, the military still built on feudal roots and was in many ways more like a massive replica of the preindustrial artisan shops.

The enormous success of the mass-producing factory and of engineering must have provided both a more immediate and a more powerful model for the organization of all kinds of activities than military organization. Taylor himself believed that his principles were equally valid for clerical work, and he was not the only one. Henry Ford, for instance, also believed in the general applicability of the principles of mass manufacturing. Fiol (1991), in an interesting comparison of the apparent management philosophies of Henry Ford and today's manager of Chrysler, Lee Iacocca (as they appear through their books), presents some revealing quotations from the inventor of the moving assembly line (p. 560):

"A great business is really too big to be human. It grows so large to supplant the personality of the man . . . the business itself becomes the big thing.

"We do not believe in the 'glad hand,' or the professionalized 'personal touch,' or 'human element.' It is too late in the day for that sort of thing."

[A business] "is a collection of people to do work and not to write letters to one another. It is not necessary for any one department to know what any other department is doing . . . It is not necessary to have meetings to establish good feeling between individuals and departments. It is not necessary for people to love each other in order to work together."

It was no wonder, then, that the functionally specialized, procedural work model was adapted even for routine administrative work and clerical production from the very beginning. The trend toward imitation of the factory grew through the 1920s and 30s, as new office buildings were constructed with the explicit purpose of facilitating the flow of paper among office workers, who were no longer given separate offices, but housed in factory-like halls (Sundstrom 1986). Some offices even used conveyor belts to carry papers from one operation to the next!

At about the same time, Max Weber delivered another strong impetus in this direction through his analysis of bureaucracy and his deep conviction that it represented the ultimate in rational information processing. To quote Morgan (1986, pp. 24–25):

He noted that the bureaucratic form routinizes the process of administration exactly as the machine routinizes production. In his work we find the first comprehensive definition of bureaucracy as a form of organization that emphasizes precision, speed, clarity, regularity, reliability, and efficiency achieved through the creation of a fixed division of tasks, hierarchical supervision, and detailed rules and regulations.

And, we might add, written documentation. To Weber, it was precisely the fact that all aspects of the matter under consideration as well as all the decisions were committed to paper that made everything else possible: specialization and hierarchical supervision (documents could be passed on), impartiality (decisions could be audited, and they could be contested and appealed to higher authorities)

and the application of rules and regulations (they could be written down in unequivocal form).

But writing was not only a tool for increased efficiency and impartiality. The new information storage and communication capacities that became available with the growth of literacy had their greatest potential as tools for managing complex work and large organizations, and they allowed the decisive transition from the Simple Structure discussed in Chapter 5 to the archetypal large organization of the modern era—the Machine Bureaucracy as Mintzberg terms it.

They also led to a depersonalization of coordination. In nonliterate society, complexity had to be kept to a minimum, and authority relationships were strictly personal—building on recognized power relationships between particular individuals. Enlarging a Simple Structure necessitated extensive delegation of power from one individual to another, bound together by personal loyalties and dependencies—often reinforced by family connections. Information flows had to be kept to a minimum, and this was achieved through encapsulation of complexity at each level in the organization, as discussed in Chapter 5.

In the new paper-based, functionally specialized organizations, a large part of the practical coordination effort was shifted away from the direct, personal relationships of nonliterate organizations toward files, written plans, instructions, rules, and regulations. One still had real persons as superiors, of course; their presence was undoubtedly very important, and in some parts of the organization (notably in the bottom layer of manufacturing or construction organizations) authority and coordination would still be very personal. But, as complexity and organization size increased, the growing and strongly regulated flows of work, control information and staff information (Mintzberg 1979) carried a larger and larger part of the day-to-day coordination, and, for many employees, the human face of direct, personal authority was to a great extent replaced by the rule of paper-based plans and regulations.

The principle of functional specialization that was the hallmark of these new organizations was further reinforced by the nature of paper-based information storage itself. A file cabinet—perhaps the single most important element of pre-computer administrative technology—had the very constraining property of being accessible in only one physical location, and if a person did not work on the premises, there would be a number of tasks that he or she could not easily carry out. The account of a bank customer, for instance, could only be read or updated in the main office or (if the bank had decentralized account administration) in the branch office keeping the account.

Another constraint of paper-based files is that they normally have only one index—if you have a file of persons, for instance, you must choose whether you want to organize it by name, by date of birth, or by address (to mention the three most common keys). Cross-referencing paper-based files is extremely time-consuming, and really only viable for historical (and thereby unchanging) information. When paper-based files grow really large, their monodimensional nature tends to favor a procedural, specialized model of administration. Files kept in the form of punch cards and processed with the help of card counters and sorters were of course more flexible, but not sufficiently so as to create a fundamentally different situation.

These practices of organization and information processing formed in the nineteenth and early twentieth century still have a very strong influence on the way we work: Large tasks are broken down into smaller steps, each allocated to a person specializing in his or her particular subtask. Any particular matter to be processed is then passed along from specialist to specialist, each one incrementally adding his or her contribution, and each one (together with others with the same specialization) responsible for storing and maintaining the information (files) needed for their particular operation. The total result is often finally authorized by a manager. The holistic approach survived in small organizations, but the functionally specialized, rule-based, procedural orientation dominated larger corporations and public institutions, and is still pervasive.

The Limits of Monolithic Bureaucracy

As they grew, the functionally specialized organizations became increasingly unwieldy, since they did not have the coordination of the total work flow based on mutual adjustment that is inherent in the holistic approach. Coordination had to be handled through planning, written communication, and hierarchic management—tier upon tier of managers, finally converging in the president's office. The larger the organizations became, the more energy had to be devoted to the coordination of their various functional departments.

Of course, the formal structure would always be somewhat alleviated by informal horizontal links facilitating daily operations, but functionally specialized organizations are nevertheless inherently difficult to manage—they require large management resources and are slow in responding to changes in the environment. As Williamson noted (1975), reports (upward) and instructions (downward) are liable to interpretation at each organizational level, and therefore tend to become more inaccurate for each level they pass through. If there are too many levels in the hierarchy, this “control loss,” as Williamson terms it, can isolate top management from reality. When a certain size is reached, such organizations simply threaten to atrophy.

The most monumental example of the failure of large-scale functional specialization is perhaps the collapse of the communist economies in eastern Europe. It was not only the absence of competition that made those societies rust out, it was also the serious breakdown of coordination that was a consequence of the attempt to organize whole societies as monolithic, functionally specialized corporations. In the former Soviet Union, for instance, a country with about 290 million inhabitants, there were numerous examples of important product classes where production had been allocated to one large, specialized factory only.

One is reminded by this of the fact that Frederick W. Taylor's ideas were well received by the Bolsheviks in the young Soviet state (Morgan 1986). According to Clegg (1990), they were in fact introduced by Lenin himself. Braverman also notes the enthusiasm and quotes (1974 p. 12) Lenin as saying that the Taylor system

. . . like all capitalist progress is a combination of the refined brutality of bourgeois exploitation and a number of the greatest scientific achievements in the field of analysing mechanical motions during work, the elimination of superfluous and awkward motions, the elaboration of correct methods of work, the introduction of the best systems of accounting control, etc. The Soviet republic must at all costs adopt all that is valuable in the achievements of

science and technology in this field. The possibility of building socialism depends exactly upon our success in combining the Soviet power and the soviet organisation of administration with the up-to-date achievements of capitalism. We must organise in Russia the study and teaching of the Taylor system and systematically try it out and adapt it to our ends.⁷

It is also quite evident that Taylor's extreme emphasis on planning, control and rational behavior corresponded very well with central Marxist and Leninist dogmas as they were practiced in the Soviet Union under Lenin and his successors. Mintzberg (1979, p. 334) quotes former Sears & Roebuck executive James Worthy, who noted interesting parallels between communism (at least as it has appeared in practice) and Scientific Management—such as the strong tendency to view workers as *"means rather than ends, doers rather than planners or initiators; to be manipulated—by persuasion if possible, by coercion if necessary—in other interests and for other needs than their own."*⁸

It is in fact tempting to suggest that the Soviet Union in many ways represented a monstrous attempt to create the largest Tayloristic factory organization ever. What we can learn from this experiment is that monolithic, functionally specialized organizations do not scale well—they may work quite perfectly up to a limit, but then gradually crumble under the sheer weight of the required coordination. The total work flow of a whole society is orders of magnitude too great to be coordinated within a single hierarchy—it is indeed much too complex to be deliberately coordinated at all. All the successful economies of the modern world have in common a large private economic sector evolving according to principles resembling those of Darwin's "survival of the fittest." As the organization ecologists have pointed out (see for instance Hannan and Freeman 1977 and 1984), there are many parallels between an open economy with independent actors and the ecological systems we find in nature, and today's free-market economies have achieved effective large-scale mutual adjustment (increasingly at a global level) only through each unit's simultaneous reactions to and exploitation of its immediate environment.

There is of course considerable disagreement about how unfettered the actors in such an economy should be allowed to operate, both with respect to moral considerations and from an efficiency standpoint. Judging from the relative successes of the American, Japanese, Swiss, and Scandinavian approaches (both in economic and social terms), for instance, the answers concerning the optimum degrees of freedom in the economy are by no means clear. But very few people today would dispute the soundness of the basic principles of the open economy.

It is also interesting to view this in the perspective of information economy: What happens in the free-market economy is that the complexities of operation are encapsulated within independent companies, minimizing the amount of information that has to cross organization boundaries. It is precisely this encapsulation and the resulting simple interface to the world (such as product properties and prices) that makes organizations interchangeable and permits the

⁷ Braverman's reference is V. I. Lenin, "The Immediate Tasks of the Soviet Government" (1918), *Collected Works*, vol. 27 (Moscow, 1965), p. 259.

⁸ Quoted from Worthy's *Big Business and Free Men*, Harper & Row, 1959.

competition and dynamic, continuous adjustments that are the hallmarks of an open economy.

But let us return to the corporate dimension. As we just noted, the growing organizations of the early twentieth century were coming up against the limits of the available administrative solutions. Remedies had to be found. True to the human penchant for iterative development, the innovations were grafted onto the existing, functionally specialized structures. In the corporate world the honor for creating the major new model is most often bestowed upon Alfred P. Sloan, Jr., one of the managers of General Motors during its turnaround in the early 1920s (Chandler 1977, Williamson 1985). Pierre du Pont, who had bought heavily into GM in the preceding years, took over a controlling position after salvaging Durant from his financial troubles following GM's near bankruptcy during the collapse of the automobile market in September 1920 (Chandler 1977). After becoming president of GM, he brought Sloan in to help him with the cleanup.

They quickly realized that the sprawling empire of companies assembled by William C. Durant needed much closer attention than Durant had given it. However, they decided against creating a centralized company organized in a single tier of functional departments. The company's activities were, in Chandler's words, "too large, too numerous, too varied, and too scattered to be so controlled." Such a configuration would also swamp the top managers with administrative tasks pertaining to the daily operations, and prevent them from devoting the necessary time and energy to the tasks du Pont saw as the most important ones for top management: strategic planning and business development.

Du Pont and Sloan's response to this situation was to establish within the company autonomous operating units, called divisions. Each division was given the responsibility for a particular niche in the car market (more accurately, a price bracket), and was given complete control over all the resources and functions necessary to manufacture and sell its own cars. This meant that the total work flow of General Motors was divided into several self-contained work flow domains, each with its own independent internal coordination. Separate financial and advisory staffs kept close tabs on the development in the line divisions, constantly reviewing their performance according to plans and forecasts and continually revising budgets and forecasts not only according to past performance, but also with an eye on the national income, the state of the business cycle, seasonal variations, and the expected market share for each line of products.

Top management in General Motors was consequently relieved from its position as the crowning apex of work flow control and the resultant day-to-day administrative chores, and could concentrate on long-term development. As the levels of coordination became fewer, the divisions also became more nimble actors in their respective markets than GM could have been if managed as one integrated company. This represents the *Divisionalized Form* in Mintzberg's classification (presented in Chapter 3).

In our perspective, however, divisionalization was not an innovation at all, but simply a recourse to the fundamental administrative principle of feudal type societies—simplification by encapsulation of complexity—and for the same reason: to achieve the information economy necessary to manage within the constraints of the available administrative technology. From their vantage point,

Sloan and du Pont simplified the organization immensely through divisionalization—they converted it from a vast array of tiered departments into a small number of operating and staff divisions, which they controlled chiefly through sales targets, budgets, and profit rates, just as the feudal king used tributes and quotas for military contribution as his main instruments of coordination.

We may say that Sloan and du Pont simplified GM by encapsulating the complexity of car manufacture within the divisions, “hiding” it from their view as general managers, thus reducing the information flow between the divisions and company headquarters to a trickle. Each division was of course still a complex, hierarchical, procedural organization full of functionally specialized departments. But, being much smaller than GM as a whole, and with simpler objectives, the divisions were easier to manage.

In this connection, it is also quite interesting to note that the railroad company generally considered to be the best run in the United States in the last part of the nineteenth century was the Pennsylvania Railroad, which deviated markedly from the monolithic organization of its competitors. Even more of a structural parallel to a feudal type state, it was organized into five self-contained, geographically delimited units, which in their turn were composed of smaller geographical units with a great degree of independence in operations (Chandler 1977), but with the same kind of tight, central control of key performance parameters later developed at GM. The central management and staff handled external strategies for expansion and relations with connecting roads; they determined and supervised technical standards, and closely monitored the financial performance of the different units. There was also a centralized purchasing department.

So the final verdict may not only be that divisionalization was no more than a reinvention of one of our oldest administrative techniques, but also that it was Pennsylvania’s president from 1852 to 1874, Edgar J. Thomson, and not Alfred P. Sloan, Jr., who should be awarded the honor for reviving it as an organizational tool for large corporations.

The principle of encapsulation became the basis for modifications at lower levels in the organization as well. The goal is always to reduce the burden of coordination by establishing organizational units that have as much mutual adjustment as possible. Instead of a functionally specialized organization covering several markets and/or delivering many products or services, one can for instance organize a department or organizational unit responsible for a specific market or a product/service, or even for a certain product in a certain market. This ensures increased responsiveness to the environment, by reducing the number of organizational layers that need to be activated to arrive at decisions concerning product strategies, customer service, or manufacturing methods.⁹

⁹ While facilitating coordination and responsiveness, market-based, or product-based organizations may suffer from disadvantages when it comes to economy of scale and sustaining necessary expertise. Creating several independent production units requires it to duplicate many functions, which can lead to higher overall costs. If the decentralized specialist groups become too small, specialists may find them less attractive places to work, since they think a certain number of like-minded colleagues is a prerequisite for maintaining and developing their skills and knowledge.

Very few organizations are consequent in following only one pattern, however. Most often, different structures will be applied at different levels, and, even within one main level, one may find numerous exceptions from the main structure—usually as a result of ad hoc responses to pressing challenges from the environment. A bank handling loan applications by passing them along through a functionally specialized organization, for instance, might react to a sudden surge in application volume or increased competition, by forming a separate loan department. The goal would then be to process applications faster and more efficiently by assigning one manager to direct coordination of all the necessary activities.

As already indicated, the development just described was both strongest and most consequent in the United States. But not even there did the organizational forms portrayed here—in Mintzberg's terminology the Machine Bureaucracy and the Divisionalized Form—replace all others. Even today, 90% of the six million businesses in the United States have less than 20 employees, and it goes without saying that they are not organized like Machine Bureaucracies. The situation is just the same in other industrialized countries. In Norway, for instance, about 80% of even the industrial firms have less than 20 employees. If we include companies between 20 and 50 employees, the figure rises to 90%, employing close to 35% of the total work force in Norwegian industry.

Consequently, the older organizational forms, such as the Simple Structure and the Adhocracy, are obviously thriving. The Simple Structure is, among other things, still a natural form for the small shop; for an entrepreneurial startup driven by one individual's vision, as well as for crisis management. The Adhocracy has survived as the preferred structure for many knowledge-based companies (such as consultancy and law firms) and organizations dominated by research and development—even organizations so large that they would otherwise be candidates for bureaucratic organization. Of course, in larger organizations, the pure form of the Adhocracy must be diluted by various methods of group representation and combined with a measure of hierarchy.

For the organization of really small companies, the technological innovations of the Industrial Revolution have not meant too much, since coordination anyway depends on close, informal contact, and specialization is generally limited. Moreover, most small firms are local businesses, with their market in their immediate environment, and therefore have relatively simple logistics. The most dramatic effect for craft-type shops was probably that they suddenly faced competition from standardized, mass-produced goods marketed on a national or even international scale.

The new preconditions, however, as we have just seen, allowed entrepreneuring people to build much larger and more complex organizations than before. For those larger companies, which tried much harder to routinize tasks, the effects of functional specialization and the limitations of available administrative technology combined to make the Machine Bureaucracy the dominating organizational structure and divisionalization the main remedy for handling complexity too great for a monolithic structure.

A New Concept for Coordination

The Bureaucratic Advantage

We have already concluded that the bureaucratic organization could both grow larger and operate more efficiently than earlier organizational forms, and we have also said something about the reasons for this. To understand fully the nature of the change, however, it is necessary to take a closer look. And it is all the more worthwhile to do so, because the development of the bureaucratic organization also contains the seeds of a new intellectual tool—the *explicit, conceptual model*—that will not fully come into its own until our use of computers matures in the next century.

As noted earlier, Weber's main explanation for the bureaucracy's effectiveness was the superior skill of its clerks. They are well educated and highly specialized, and they continuously polish their proficiency through their work, following the guidelines laid down by their superiors. He compares the bureaucracy to a machine—it functions in much the same way as a modern factory producing goods in a very efficient, partly automatic manner (Weber 1968, p. 973, p. 975, italics in the original):

The decisive reason for the advance of bureaucratic organization has always been its purely *technical* superiority over any other form of organization. The fully developed bureaucratic apparatus compares with other organizations exactly as does the machine with the non-mechanical modes of production. Precision, speed, unambiguity, knowledge of the files, continuity, discretion, unity, strict subordination, reduction of friction and of material and personal costs—these are raised to the optimum point in the strictly bureaucratic administration, and especially in its monocratic form . . . Bureaucratization offers above all the optimum possibility for carrying through the principle of specializing administrative functions according to purely objective considerations. Individual performances are allocated to functionaries who have specialized training and who by constant practice increase their expertise.

Weber here clearly attributes the efficiency of the modern organization to the increased productivity and quality at each step in the production process. If we generalize this argument for both manufacturing and clerical organizations, we may say that it is *specialization*, the concomitant *superior skills* of the employees and their *improved tools* that do the trick. And the arsenal of tools includes not only the "hard" tools and machinery of material production, but also office implements such as files—which, through their capacity for implicit coordination, were extremely important administrative tools.

This is not a sufficient explanation, however. Specialization and improved skills may increase quality and efficiency at each step in the process, but there is still the challenge of coordinating the work of the multiplying ranks of specialists and making it possible to build and run large organizations while preserving the advantages achieved at each step in the production process.

A more comprehensive explanation is provided by March and Simon (1958). After explaining the basic process of factoring complex problems into parts that can be handled by one organizational unit or one person, they turn to the problem of coordinating large organizations with high internal interdependence among

tasks—that is, organizations with a high degree of internal specialization, requiring careful and extensive coordination to operate efficiently.

They recognize two basic methods for such coordination: *coordination by plan*, which is based on preestablished schedules, and *coordination by feedback*, which relies on continuous transmission of information about the workings of the different parts of the organization.

Coordination by feedback requires open lines and fairly intensive communication between the coordinator and the coordinated. It corresponds to (and encompass) Mintzberg's direct supervision and mutual adjustment, which began as the two basic (intuitive) coordination methods used in small-scale, oral societies (discussed in Chapter 5).

However, the heavy load coordination by feedback puts on the communication channels in the organization becomes a severe penalty when the organization grows, since human communication is so labor-intensive. Relying on coordination by feedback alone, the effort needed to coordinate an organization will grow much faster than the organization itself, and, without some kind of simplification scheme, an organization would not have to become very large before coordination breaks down and confusion reigns.

There are two main ways to solve this problem. One is to abolish the need for coordination as far as possible, which was the essence of the encapsulation of complexity inherent in the feudal system. This "evasion tactic" was the only available method in preliterate societies, and it was later revived in the form of divisionalization. It can only work, however, when there is no need to coordinate persons or processes belonging to different subunits.

The other is what March & Simon (1958) terms *coordination by plan* (termed *coordination by program* in Figure 3-1 on page 61), which requires much less communication and thus emerges as strikingly more efficient (March & Simon, 1958, p. 162, italics in the original):

The capacity of an organization to maintain a complex, highly interdependent pattern of activity is limited in part by its capacity to handle the communication required for coordination. The greater the *efficiency of communication* within the organization, the greater the tolerance for interdependence. The problem has both quantitative and qualitative aspects.

As we noted earlier, it is possible under some conditions to reduce the volume of communication required from day to day by substituting coordination by plan for coordination by feedback. By virtue of this substitution, organizations can tolerate very complex interrelations among their component parts in the performance of repetitive activities. The coordination of parts is incorporated in the program when it is established, and the need for continuing communication is correspondingly reduced. Each specific situation, as it arises, is largely covered by the standard operating procedure.

Following March & Simon (1958), it becomes clear that the efficiency of the bureaucracy, both in its blue collar and white collar versions, is based mainly on the fact that work is standardized and the coordination of work is *preprogrammed*. The various tasks are first analyzed in considerable detail, and prescriptions for carrying out work and solving the most common problems are specified. Once they have learnt those prescriptions, then, the workers or clerks are able to execute most of their work without further instructions.

We can clearly see how this is a direct continuation of central principles behind coordination in the Simple Structure (discussed in Chapter 5). The *focus* is exactly the same: both in the Machine Bureaucracy and the Simple Structure the necessary coordination is achieved through *directing work*, as opposed to the *information sharing* of the Adhocracy. But whereas the Simple Structure relies on *direct supervision* for its coordination, the Machine Bureaucracy relies on *indirect supervision*: The role of the physical supervisor is assumed by the standardized work rules (the *program*), which represents a much more efficient way of directing and coordinating people.

Mintzberg (1979) clearly builds on the passage from March & Simon quoted above when he describes the coordinating mechanism of the Machine Bureaucracy—in fact, he quotes briefly from it himself (Mintzberg 1979, p. 5)—and his *standardization of work processes* is roughly equivalent to March & Simon’s coordination by plan.

The ultimate in preprogrammed work is of course the automatic machine, which represents (as we noted in Chapter 6) a carefully designed program forged in steel, repeating its designed actions again and again without further human guidance. It is also worthwhile to contemplate the fact that the impressive efficiency of the automatic production line resides not only in the speed with which each particular operation is performed, but just as much in the perfect, automatic coordination of those operations.

We can then extend the taxonomy of coordinating mechanisms presented in Chapter 3 with two new variants, both dependent on technology (Figure 7-1).

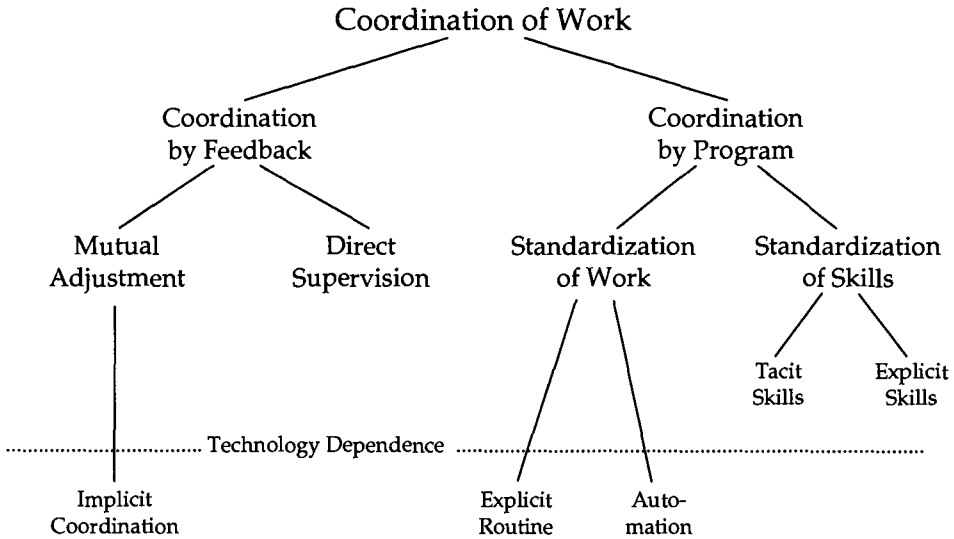


Figure 7-1: Taxonomy of Coordinating Mechanisms Extended by Precomputer Technology.

The first one I propose to call *explicit routine*, the other simply *automation*. The explicit routine is the “program” you end up with when you consciously design an organization. In larger organizations it will usually contain both organization charts, overall process descriptions, and job descriptions. It will normally be based on a planning process involving at least a basic level of explicit modeling and design.

I have not included here any extensions to any of the two mechanisms under standardization of skills. It may be argued that textual representation of knowledge opened up new frontiers for the use of explicit skills. However, my view is that, although the textbook certainly made it easier to teach the same skills to many people, it did not change the mechanism per se. The way it functions is not related to the medium for the original knowledge transfer.

In addition to the two extensions defined above, the era of organizational tools also opened up for a development of the coordinating mechanism mutual adjustment. Considerable extension is possible if the adjustment is mediated not by direct information exchange, but by indirect communication through a common information repository of some sort. To be practical, however, this common repository depends on technology for the externalization of memory: Although it is conceivable that implicit coordination could be used with a person’s memory as repository, it is hard to see how it could be of real importance before the invention of writing and number systems.

As we noted in Chapter 6, writing was—as far as we can ascertain today—first used for storing administrative information (Goody 1986): itemized, often quantitative information such as sums of money, numbers of cattle, amounts and kinds of goods, names of people, and sizes and locations of landed property. This was by all probability the purpose of its invention. Only later did it become a medium for discourse, for art, and for accumulation of knowledge and reference material. However, since the written discourse and the accumulation of knowledge and reference material were decisive for the development of philosophy, religion, science and politics, and thus were more visible (and exiting), those aspects of writing have easily attracted most of the attention in historical analysis—even if the Industrial Revolution and the evolution of modern society have depended just as much on the meticulous record keeping of merchants, master craftsmen, industrialists, engineers, civil servants, and, not least, their clerks. Their tidy accounts, their production plans and inventory lists, their neat file cards and protocols with customers and suppliers, details of business transactions, land registers, and tax records became the lifeblood of an ever more complex society.

The most obvious advantage of writing was that it fixed information permanently, relieving the mind from the burden of remembering administrative detail and permitting the accumulation of much more information than was possible when relying on human memory only. However, the externalization of memory represented by the written record also created exactly the kind of information repository needed for indirect coordination. Records kept together in a file made it possible for many persons to work with the same information as a basis for their decisions, and changes introduced by one would apply for the work of all the others, without any need for meetings or other forms for personal communication. This new, inherent integrity of information provided what I

prefer to term an *implicit coordination* of the people who worked with it: a coordination of work that is an implicit, automatic effect of working from a common base of information, and which does not need extra communication or any special effort to oversee those actions directly.

At least within a narrow area, then, a fairly large number of people can coordinate at least part of their activities through the implicit coordination they receive by accessing the same files. By working out from a continuously updated, common kernel of information, they directly modify each other's actions without ever meeting face to face. It thus provides a level of mutual adjustment among them, extending the use of this mode of coordination to a significantly larger number of people than was earlier possible. For a bank clerk, for instance, it is not necessary to notify all the other clerks about a change in a customer's account balance; it is only necessary to post it in the books. Any other clerk who checks the balance afterwards will then receive information about the update then and there, and can act accordingly to any new demand from the same customer.

Although implicit coordination works through effecting mutual adjustment through common information, it is sufficiently differentiated to be considered a separate coordination mechanism. As such, implicit coordination was the first coordination mechanism made possible through technological development, and it thus marks a watershed in organizational history. Its use, however, was limited before the development of large private and public organizations in the nineteenth century.

It is also of interest to ask if there has been any technology-based modifications of direct supervision. Some will perhaps argue that the developments of communications technology in the nineteenth century, especially the telegraph and telephone, have indeed made a difference and allowed direct supervision to be used over much greater geographical distances. This is of course true: The geographical reach of direct supervision was greatly extended by pre-computer communication technology, and larger organizations spanning greater distances could be kept under close control. The space of constructible organizations was thus extended, but I will maintain that this did not imply the creation of any new coordinating mechanisms: It was still one person giving orders to others. Although implicit coordination represents something genuinely new (coordination not via direct communication, but indirectly via a common, external information repository), direct supervision via telephone or letter represents little more than an amplification of the principal's voice.

The teaching of *explicit skills* has of course been strongly enhanced by the development of literacy, but, again, there is nothing new in principle, and it is doubtful whether it is more important now (relatively speaking) than it was 400 years ago, at the height of the European guilds.

The Constraints of Standardization

Compared to older organizational forms, the Machine Bureaucracy offers great economy in coordination and information transfer and is very efficient in turning standardized inputs into standardized outputs. However, the penalty is inflexibility: It can only handle inputs and deliver outcomes that are defined in the underlying conceptual model. Because the actual formulation of both the model

and the standardization rules necessitates analyses and planning procedures that are exceedingly time consuming, requiring among other things large amounts of interpersonal communication and decision making, changes in the model and the "machine" are very expensive and take a long time to accomplish.

Therefore, Machine Bureaucracies are very slow in adjusting their behavior to changes in their problem domain. In very dynamic environments, they simply cannot keep up. That is why one has to revert to more flexible coordinative schemes for highly unstable problem domains. If the environment is simple, Direct Supervision will be close at hand; if it is complex and especially if it requires knowledge in multiple fields, Mutual Adjustment will be preferred, at least at the most crucial levels. In war, for instance, the chiefs of the different services will work very closely together, and during large and important combined operations they will usually spend most of their time in the same room, conferring continuously while adjusting the actions of their respective services in real time. (That is what war rooms are all about.)

What this means is really that to use Standardization of Work as a coordination method, and to reap the great rewards it offers, it is necessary to have models and a modeling capacity that can keep up with changes in the environment and operating conditions. In other words, there is a need for a professional staff to analyze change requirements; design the new routines, rules, and/or machine combinations; and then manage their implementation. The great savings offered by automation and the new organizational form thus also carries a penalty, which is greater cost for maintenance and change.

If the cost of updating the model becomes too great, or if there is a need for change too often, the organization is forced to adapt a coordinating mechanism that needs less analysis and planning but craves more resources in daily operation. There are very real tradeoffs to be made here, and organizations that straddle the crossover point or experience significant changes in the dynamics of their environment very often run into huge problems trying to adapt their structures and coordination methods to the new realities of life.

Explicitly Designed Patterns of Action

Both methods of coordination by standardization (of work or of skills) have old roots and have been used in non literate societies, for example, in craft and trade. In their old versions, however, these coordination methods were largely implicit in tradition and customary ways of working and organizing. The circumstances of their use did not require formal planning or written documentation. Consequently, they did not contain explicitly designed work programs; rather, they grew out of customary practice and were transferred from generation to generation as part of the continuation of a craft, a trade, or the social order.

As we have already seen, however, there is a definite limit to the level of complexity that the unaided human mind can handle. The new organizations, with their elaborate interdependencies, were far too complex to be conceived and run within the framework of an oral tradition, and by unaided memory alone. Both their manufacturing and clerical parts required detailed and explicit analyses of both the operational requirements and the interdependencies of the different

steps and levels in the process, to be followed by careful and detailed design and planning of operations. Writing was an indispensable tool for this work, as well as for the design and construction of the new tools and machinery that were so important to the new developments.

Following Ong (1982) and Havelock (1986), there is also good reason to believe that a mature literate tradition, a developed *literate mindset*, was a necessary prerequisite to this new analytical approach to work and organization. People from oral cultures seem to have trouble using and manipulating the symbols and abstract categories used for complex analysis and planning. The oral mindset is concrete and person oriented, and it correlates with the basic organizational structures (relying on personal authority) that we explored in Chapter 5. The literate mindset is abstract and role oriented and correlates well with bureaucracy, where work is specialized and authority is tied to positions, not particular persons.

In the modern organization, then, work is no longer organized in accordance with custom and tradition, but according to a *conscious* design based on an *explicit* analysis of the desired outcome and the available means. In my view, this represents the decisive break with the past and marks the transition to a new paradigm for the organization of human work. The old paradigm, developed in an oral world, was characterized by a reliance on tradition, tacit knowledge (Polanyi 1967) and theories-in-use (Argyris 1980), and was focused on personal relationships and holism in work. The new one, born in the first fully literate societies, builds on conscious analysis and explicit design and focuses on the coordination of interdependent, specialized tasks. It will almost gleefully break with tradition when that is instrumental to improvements in effectiveness and efficiency.

If we look at this from the perspective of action-oriented organizational theory, we can perhaps express it more clearly. In Chapter 2, I expressed my support of the view that organizations are constructed, and mainly defined by the recurring patterns of action their members engage in: Organizations cannot be physical entities with life and behavior of their own; every last bit of activity must be traceable to one or more actual persons. And the people who actually perform these actions are constantly interpreting and reinterpreting other people's actions and their own, adjusting their behavior accordingly. It is from these partly stable, partly changing and interacting patterns of action that the systems character and systems properties of organizations arises, and it is these properties that we try to describe in systems and contingency theory.

Within the oral paradigm, the patterns of action more or less *emerged*—because they were based on tacit knowledge and theories-in-use, they were seen as an inevitable part of the social fabric, as a part of the natural order of things. However, the explication of design that forms the basis of the Machine Bureaucracy meant that patterns of action were *consciously constructed* for a specific purpose, partly separated from the larger society and constantly open to inspection and improvement. The seeds of this development were perhaps sown when the craftsmen of the towns in medieval Europe discovered that Aristotle was wrong in claiming that only living beings could be a source of productivity, and that investment in equipment and power sources such as the windmill and the water wheel could increase their production dramatically (Dahl 1984).

A large part of the important recurring patterns of action in the modern organization are therefore consciously designed, and the road to greater efficiency seems always to go through greater sophistication and thoroughness in design. Indeed, the most efficient production is achieved through automation, which builds squarely on a total, conscious design of recurring patterns of action, or—to comply with the tradition of reserving the term “action” for human activity (Silverman 1970)—recurring patterns of machine movements.

The Emergence of the Conceptual Model¹⁰

The Machine Bureaucracy, as we have described it, is a production *and* coordination “machine” with a specific purpose—it is consciously designed to accomplish certain tasks or solve certain problems. It is designed on the basis of a detailed analysis of a set of purposes, tasks, and relevant environmental factors that its creators deem relevant to its success. This set we may call its *problem domain*. The designers need to have not only a knowledge of the features and events in this problem domain, but also a set of postulates—a theory—about how those important features and events relate to each other.

To use a systems term (which may give an unfamiliar ring in the ears of organizational theorists and practitioners alike), we may say that the design is based on an at least partly explicit *conceptual model* of the problem domain.

Everyone knows what a *model* is. We have grown up with them—dolls, play houses, toy cars, and model airplanes. As grown-ups, we use models to comprehend complex artifacts and phenomena. We build models of ships to study the way they behave at sea; we build models of airplanes to test in wind tunnels, and of harbors to see how piers and dredging will shape waves and influence local currents. Even skyscrapers are modeled and tested to ensure they can withstand strong winds.

These are all physical models, the ones with which we are most familiar. What, then, is a conceptual model? The mental set, described in Chapter 4, is a form of conceptual model. It is the basis for our comprehension of the world and our actions. However, our mental sets are generally not something we are aware of as models or make explicit in the form of conscious descriptions.

In general, we can define a conceptual model as a conceptual representation of a limited (bounded) part of reality, that part which we are interested in for our particular purpose. The reason for making a conceptual model is always to establish an understanding of reality that is sufficient for initiating sensible, effective actions toward that part of reality that the model represents. It is therefore crucial that all the aspects of reality that are important for our purpose are represented in the model—objects, phenomena, the relations between them, and their static and dynamic properties.

This model will of course only represent a simplification of reality and will most often only describe the features that the designers judge to be sufficiently important, and not self-evident. The organizational designers will then use this model—which represents their best understanding of the problem domain—to

¹⁰ I am indebted to my colleague Dag Solberg for the explanation of conceptual models given below.

work out the details of the division of work, organizational structure, task formation, work instructions, and the like.

By this, I do not mean to say that the pioneers in organizational design used the term “model” or were aware of the concept of modeling as a tool. Even today, the use of this term in connection with organizations and organizational design is by and large limited to the fraternity of systems analysts and designers. However, even if the people who work out the designs and task structures of organizations do not use the term and are not aware of the concept of conceptual models, the descriptions and plans that form the basis for their designs are models nonetheless.

We may well say that even the traditional organizations of oral cultures built on conceptual models of their problem domains. But those models were not made explicit—they existed only as theories-in-use (Argyris 1980). They were therefore not open to inspection or conscious elaboration and could not serve as a basis for innovative design. The innovation that made it possible to design the modern organization with its intricate interdependencies was the *explicit* model, based on a conscious analysis of the problem domain and documented on paper.

This new type of conceptual model was open to inspection and improvement and could therefore serve as a basis for working out the operational planning and standardized work procedures that underly the efficiency of the Machine Bureaucracy. It could also be used to establish a necessary minimum of consensus throughout the organization regarding important goals and operating principles, another condition for making large organizations work.

The foundation of the new organizational paradigm, then, was the explication of the conceptual model, allowing a new approach to coordination that increased efficiency by drastically reducing the control and communication needs—another proof for the pivotal role of the coordinating mechanism in defining organizational structure and operating characteristics.

Variation of the Species

Culture Revisited

In Chapter 2 I concluded that the influence of social and cultural factors on the local constructible spaces was too varied to incorporate into my analyses of the enabling powers of technology. I will still argue that they are, but the question is as follows: Does this variation represent a problem for my analysis?

The rather neat account of the growth of modern organizations given in this chapter is to a large extent in accordance with Chandler's (1977) interpretation. Chandler explains the rise of the modern corporation (and thereby the machine organization) by the driving forces of the technological developments of industry and transport *and* the concomitant development of a national mass market for industrial products in the United States. Companies grew because their internal coordination was more efficient than the market-based coordination of small, independent firms, and because the larger firms had much more power for market penetration and domination. It was the large, homogenous national market in the United States, Chandler argues, that caused the large, multiunit firm to flourish in

the United States before it became a decisive factor in European business. He acknowledges that legal and cultural differences also had a role in delaying the development in other countries, but he does not seem to doubt that the American experience will sooner or later repeat itself everywhere else.

In fact, in the last pages of his book, Chandler makes it quite clear that he views the development of the modern American corporation as the first instance of a general development process that will successively repeat itself in other countries. It will happen partly because of the development pressures in their indigenous economies when they reach the proper stage, and partly because of a diffusion of knowledge about industrial organization provided by the American example. This is a view shared by Williamson (1975, 1985), but he offers a more narrow and clear-cut explanation than Chandler. He also acknowledges that social and legal factors have an impact, but argues forcefully that the logic of *transaction costs*—the cost of exchanging goods or services between people and across organization boundaries—eventually prevails. If the costs of such transactions become too high, companies will try to internalize them to achieve control and more efficient operations. This will especially happen in situations of uncertainty and change. If internal coordination becomes too costly and inefficient, large organizations will crumble or split up, and more efficient market-based coordination will take over.

Chandler (1977) was neither the first nor the only scholar who attributed divergencies in the developments in Europe and the United States to cultural and historic causes. Already de Tocqueville¹¹ noted the differences between French and American politics and administration, and Crozier (1964) underlined the differences between France and the United States as well as between France, England and Germany. However, these two and many others who have posted similar conclusions disagree with Chandler when he maintains that the rest of the world necessarily will come around to the American model.

They point out the fact that the Industrial Revolution originated in what is now loosely referred to as the Western industrialized world, and the first large, private organizations were accordingly also products of those societies. Many of the organizational traits we used to take for general principles may thus be no more than artifacts of our own particular culture. Chandler and Williamson, who concentrate most of their arguments around developments in the United States, may easily be unduly influenced by American peculiarities. This point has become especially acute through the undeniable success of Japan and a number of other Asian countries after the Second World War, in particular during the last ten to fifteen years.

Does this criticism, then, undermine the validity of the analysis we have made in this chapter about the ways technology has extended the space of constructible organizations? To answer, we must first look into the matter in a little more detail.

Some Lines of Criticism

Important instances of the criticism against the convergence theories of Chandler and Williamson are Granovetter (1985), Hamilton and Biggart (1988),

¹¹ In *Democracy in America* (*De la démocratie en Amérique*), first published in 1835.

and Clegg (1990). Granovetter discusses the tendency of theories of economic action to offer explanations that are either *undersocialized* or *oversocialized*. Undersocialized explanations fail to take into account social factors—the typical example is the classical and neoclassical “rational man” theories of economics, which assume that every individual acts with perfect, self-interested economic rationality, unbound by norms and the expectations of others. Granovetter acknowledges that Williamson’s focus on institutional and transactional considerations differs from neoclassical theories, but maintains that Williamson’s theories are still clearly on the undersocialized side, paying too little attention to sociological, historical, and legal arguments. Oversocialized theories, on the other hand, picture humans as more or less passively succumbing to the prevailing social forces. Granovetter mentions the “substantivist” school of anthropologists, represented by Polanyi, Arensberg, and Pearson, as an example, and points to a relation to Marxist thought. In my view, orthodox Marxism is a typical example: Class properties and distinctions take preeminence over individual characteristics, and every citizen is reduced to a stereotype caught up in the inexorable processes of history.

As Granovetter points out, undersocialized and oversocialized theories ironically both end up by robbing us of most of our humanity and discretion—the undersocialized theories by making us mere slaves of a rather narrow logic, the oversocialized by making us robots programmed by our environment to merely enact prevailing norms. Granovetter argues that economic action is thoroughly embedded in both the actor’s social environment and his or her personal values and goals. Rationality cannot be judged on the basis of narrow slices of a person’s life only.

It may, for instance, be perfectly rational in an economic sense to invest savings in stocks. The person who nevertheless stashes all savings in a bank account may do so because he or she has a spouse who strongly prefers to avoid risks. To value harmony at home higher than increased dividend is an eminently rational act in a real-life situation, even if it does not figure in economic equations. Organizational politics may make it subjectively rational for an individual to behave in ways that are economically irrational for the firm. And history and traditional authority structures may heavily influence company organization without determining it: Many aspects of organization may be imported from abroad, or may even come as a result of the idiosyncrasies of powerful organization members.

Hamilton and Biggart (1988) attack both the market-based theories of Williamson and Chandler and the theories that explain national differences in organizational structure on the basis of culture. They see three main approaches for explaining organizational patterns (p. S52):

Three frameworks purport to explain industrial arrangements and practices: a market approach that emphasizes economic characteristics, a cultural approach that sees organization as the expression of patterned values, and an authority approach that explains organization as a historically developed structure of domination.

Hamilton and Biggart assert that economic theory predicts that firms of similar size, trade, and stage of sophistication should show the same kind of structure

anywhere in the world, and that cultural theories assume that such firms will be organized the same way within one particular cultural sphere, and differ only across cultures.

To test both hypotheses, they look at firm structures in three successful countries in East Asia: Japan, South Korea, and Taiwan. If economic factors alone determined organizational structure and practice, then Asian enterprises would be much more similar to Western (especially American) enterprises, and they would not show great internal differences. Similarly, since the three countries are strongly related culturally (all of them drawing heavily on Chinese culture and tradition and having intertwined histories), their organizations should not differ too much among themselves, even if they differ from Western firms.

Economic organization, however, differ markedly in the three countries, and all of them are different from the United States and Europe. To explain these substantial differences in organization, Hamilton and Biggart conclude that the preexisting authority structure is the key variable (1991, p. S87, italics in original):

We argue that enterprise structure represents situational adaptations of preexisting organizational forms to specific political and economic conditions. Organizational structure is not inevitable; it results from neither cultural predispositions nor specific economic tasks and technology. Instead, organizational structure is situationally determined, and, therefore, the most appropriate form of analysis is the one that taps the historic dimension.

Given this conclusion, then, this analysis suggests that the key factors in explaining economic organization may not be economic, at least in the economists' usual meaning of that term. Economic and cultural factors are clearly critical in understanding the *growth* of markets and economic enterprise, but the *form* or structure of enterprise is better understood by patterns of authority relations in the society.

The arguments presented by Granovetter as well as Hamilton and Biggart agrees with that of Clegg (1990)—and Clegg also draws on their work. His key issue is precisely the paramount importance of embeddedness, institutional frameworks, and modes of rationality, and his criticism of Williamson (and a number of others, including Chandler) goes along the same lines. Drawing on a broad selection of empirical material, he shows both how structures differ between cultures and within them, and how they may vary considerably even within countries, markets, or enclaves that are homogenous in most other aspects. Clegg concludes that the diversities offered by contemporary organization forms cannot be interpreted just in terms of market-based explanations, and he also argues that Hamilton and Biggart's analysis (among others) of East Asian companies shows that the same is the case for explanations based on cultural aspects only.

He does not, however, agree with Hamilton and Biggart's assertion that the decisive factor for the structure of an enterprise is the pattern of authority relationships in the society. Clegg prefers a more complex explanation, encompassing a wide variety of contingencies, and in this he seems to be much more in tune with the central theme emerging from the last 30 years of organization research (discussed briefly in Appendix A): that there are a large number of contingency factors which have been shown to influence organization structure. Summing up the arguments, he says (1990, pp. 162–63),

... organization forms are human fabrications which agencies¹² will structure using whatever discursive rationalities¹³ they can secure. These rationalities will vary in their institutional location, drawing not only from occupational identities, or from the regulatory framework of law, accounting conventions and so on. In addition, they will also draw on whatever resources find expression in a particular context, local resources which are particular for that context.

In essence, what Clegg is proposing is that there is no such thing as a one-dimensional explanation of organization structure or behavior, and, thereby, that there is no single, driving force behind the development of economic organizations. He expresses this quite clearly (1990 p. 204-05):

Theoretical arguments in organization analysis have tended to be deterministic. The most obvious examples of this are contingency theories of a "culture-free" variety (Hickson et al. 1974¹⁴) but is also the case with certain kinds of institutional theory, such as Biggart and Hamilton's (1987: 437¹⁵) hypothesis that "[l]eadership strategies in any one sociocultural setting will have strong underlying similarities." Against either form of determinism one might instead want to argue that contingencies and institutions should be seen as providing the arena in which power-players will seek to utilize whatever resources are available in constructing local organizational practice, shaped to whatever mode of rationality, against the last of the organizational imperatives. Organizations are the arenas within which some things will tend to hang together and be adopted by power-players as a bundle, while other forms of combination may be far less likely to occur as a coherent package, perhaps because they are less coherent or because the alliance which could make them so lacks a position in the field of power to be able to constitute the necessity of its choices.

A Common Ground

We can conclude, then, that the structure of modern organizations vary, and that there are many important factors on different analytical levels that contribute to that variation. It only serves to underscore one of the basic tenets of general systems theory touched upon in Appendix A: the concepts of equifinality and multifinality. As Crozier (1964) remarks, when analyzing the reasons for that French economy lagged behind the British from the start of the Industrial Revolution until after the Second World War, the most baffling fact is not that some countries in the industrialized world lag a little behind others, but that the differences are not greater.

¹² In Clegg's sense, an *agency* is an entity that makes things happen. It can be an organization, a part of an organization, or an individual.

¹³ Rationality as it appears to the agent under the full (and dynamic) set of circumstances under which he operates.

¹⁴ Hickson, D. J., Hinings, C. R., McMillan, C. J. and Schwitter, J. P.: "The Culture-Free Context of Organization Structure: A Tri-National Comparison," *Sociology*, 8 (1974), 59-80.

¹⁵ Biggart, N. W., and Hamilton, G. G.: "An Institutional Theory of Leadership," *Journal of Applied Behavioral Science*, 23-24 (1987), 429-41.

Of course, the examples of the communist countries in Europe, of Argentina,¹⁶ and the divergent development trends in Asian nations show that there are indeed limits to this multifinality—you cannot succeed by *any* mix of means—but the fact remains that there are no single prescription for success, and no single pattern of development and organization that is destined to percolate through the world and gradually make all organizations and societies similar. And there is no such thing as technological determinism—a particular technology or set of technologies does not invariably lead to the same organizational solution. Using whatever material we have found in our environment and in our own minds, we have created a panopticon of practical solutions that shows great leeway for variation.

Nevertheless, the iron constraints of our biology and our tools are still there, and not one of us can operate outside them. Complex technology and large-scale production of goods and services require organizations much larger than the artisan shop, and, in this sense, the technology of the nineteenth and twentieth centuries had a deterministic streak: To exploit it for the creation of increased material wealth, we *had* to build large organizations. Further, all large organizations have to tackle the challenges inherent in the coordination of large numbers of people. If we look at organizations in developed countries, we will therefore find a lot of common ground as well. And, as more cultures and societies have gradually sought to build increasingly complex organizations and even more complex societies, they have all faced the problems posed by the constraints of our human biology and the nature of our tools.

However different the authority structures in large organizations may be, for instance, they all *have* an authority structure. Despite major variations in job definitions, in the proportion of workers that are skilled, in job rotation schemes and distribution of authority, all firms above a certain (rather small) size still *have* job specialization. And, because of this, they all *have* planning functions, coordination needs, and extensive internal communication. Even the light-footed Taiwanese manufacturing firms, relying more on their ability to adapt fast to changes than on forecasting future market trends, have to plan their production at least a month or two ahead. The national and cultural variations we find today are thus largely results of the considerable human range in the ways our basic human drives find their expressions.

We may basically say, then, that humans who constitute an organization face the same kind of problems collectively as each one of them faces as an individual: As a collective, they must choose one or more domains for the organization's activities, they must decide upon some objectives and goals, they must decide how to reach those objectives, and they must carry out the necessary actions to accomplish them.

In an individual these activities are highly integrated and managed by one mind that is also directly coupled to a sensory apparatus giving continuously updated information on the environment and the result of its actions. For an organization, it is much more complicated.

The decision about domains and objectives does not need to be all that problematic, it can be made by a single person or a small group (provided this is

¹⁶ Argentina was among the most developed nations around the turn of the century, with a standard of living on par with both the United States and the most advanced nations of Europe.

accepted within the organization). However, the decision maker(s) will need information about the environment and the organization's activities and their effects; in large organizations, their own immediate observations will not suffice. They will have to rely on information originating at many points within the organization and outside it, information that is processed and channeled, often through many levels and stages before reaching its destination. Decisions on objectives and means to accomplish them must then be translated into operational plans and actions, which must be channeled back through the organization, the actual operations must be continuously controlled and coordinated, and the results observed and communicated through the organization to serve as the input for course corrections (feedback). Simultaneously, the necessary maintenance activities must be carried out to ensure that the organization members are reasonably happy and equipment work as it should.

In oral societies the constraints of human physiology will keep organization at a fairly simple level, and people will depend to a very large degree on their own immediate work and actions for their survival and well-being. In a developed, literate society, on the other hand, one of the key aspects of human life is the extent to which the citizens as individuals are constantly dependent on the extensive collective information processing taking place in innumerable large and small organizations. This information processing is really pervasive. Even in organizations established to produce material goods, information processing is often the major activity if measured in work hours. Its level of complexity is also orders of magnitude greater than the collective processing of even the most advanced oral societies, and is extended further through the use of advanced automation.

We have discussed this at some length in the preceding chapters and concluded that the constraints on human communication and memory are the basic problems in the control and coordination of organizations, and that control and coordination are the most pressing operational problems of all collective human undertakings. The example of situation rooms and control rooms that were mentioned during the discussion of tools for collective information processing serves to underline the paramount importance of control and coordination in collective endeavors. Such rooms are nothing less than organizational/technological devices aimed at the most challenging of all organizational tasks: the real-time monitoring and control of very complex and rapidly unfolding events.

The subject of organized, collective information processing has therefore risen to a much more prominent position in modern societies than in preindustrial civilizations. The preoccupation in both public and private enterprises *in all cultures and societies* with subjects such as formal and informal organization structures, lines of authority, communication channels, job designs, and management styles, as well as the fervor of the discussion, is a clear expression of the universally perceived gravity—and the universal validity—of the problem.

The development of the *Divisionalized Form*, then, represents our best effort so far to harness this complexity within the bounds set by the modified preconditions that has emerged from the technological development of the last 3500 years. It is reasonable to assume that the possibilities awarded by these preconditions have largely been exhausted in this period of time, as millions of attempts to create and run successful organizations throughout the nations of the world have employed a

great breadth in innovation and angles of attack. To evolve distinctly new organization schemes, we will therefore need new technological developments, such as the emerging information technology that is the subject of this dissertation. Only they can modify the preconditions further and thereby enlarge the realm of the possible. It is, however, up to us to explore the new frontiers—it is people who discover, invent, and act, new developments do not come about on their own just because they are feasible.

This is in good accordance with the framework of the present study, which builds on the notion of *physical and cognitive preconditions* for organization building, defining the limits of the possible in the organization domain, and how the development of tools has changed them. Within the limits set by these preconditions, which amounts to the total *space of constructible organizations*, other constraints will also operate—cultural constraints, the traditions of power arrangements, of markets and competition—to define the many *local constructible spaces* one will find around the world.

Within the spaces defined by these constraints, within their innumerable nooks and crannies, human beings maneuver, motivated by a diverse mixture of basic drives, dreams, and emotions, as well as more elevated considerations. And, as we all know, such individual mixtures vary enormously, and they are not determined by the environment alone (as the oversocialized theories imply). Not infrequently, they will come into conflict with established social values, leading to breaches both of trust, custom, and law. That is what makes the study of human action both so frustrating and so fascinating, and why theories explaining human action and social evolution from just one perspective always remain inadequate.

III IT and the Preconditions for Organizing

The four chapters in Part II have tried to show how human limitations have constrained the development of organizations and how we have developed a succession of tools to alleviate or circumvent these limitations.

Chapter 4 (“Confined by Physiology”) began by looking at the six basic human preconditions in more detail. The fickleness of our memory, our limited information processing capacity, and the very short range and limited channel capacity of our natural means of communication are the main factors delimiting our natural capabilities for organizing. The chapter also noted that we are only partly rational beings and that our actions are strongly influenced by emotions, rooted in the deeper and more archaic parts of our brains.

Chapter 5 (“The Dawn of Organization”) explored the problems of organization building in societies without significant tools for organizational purposes, and tried to determine the extent of the space of constructible organizations in such societies. I suggested that there were two basic structural configurations, the Adhocracy and the Simple Structure, building on the two primeval coordinating mechanisms—mutual coordination and direct supervision. For larger structures, where one ruler or one council could not manage the complexity, the iron constraints on human memory, communication, and information processing-capabilities forced a reliance on two principles: the *delegation of authority* and the *encapsulation of information*.

Adhocracies do not scale well, but the Simple Structure can easily be scaled up by encapsulation and delegation, preferably with geography and lineage as structuring elements. Such a system provides an extreme economy with respect to information processing, communication, and memorizing. Based on land rights and family lineage, this feudal type organization contains its own structuring information; that information is constantly enacted in everyday life and thereby reinforced in everyone’s memory. At any level, the number of people the ruler must deal with is thus kept within manageable limits. It can be viewed as a forerunner of the Divisionalized Form.

Chapter 6 (“The Power of Technology”) discussed the nature of tools and how the most important precomputer technologies alleviated our original constraints,

gradually allowing for extensions of the space of constructible organizations. The single most important innovation was undoubtedly the art of writing, which made it possible to externalize memory and thus lifted many of the constraints placed upon us by our limited recall. Even more important for the development of organizations was the accessibility of written information for large numbers of persons. The emergence of *implicit coordination* of the people who work with an *active file* marked a watershed in organization history. There was also a gradual development of a literate mindset, characterized by abstract and analytical thinking and extensive use of symbols, finally extended to the vast majority of the population through printing and mass education.

The other great field of organization-relevant innovation concerned communication—which quickly became the bottleneck for organization building when the memory barrier was lifted. Communication has two aspects, which for a long time were one and the same: physical transportation of people and goods, and communication of information. Even if we know of regular courier services as early as 2000 B.C., communication technology capable of serving as an infrastructure for mainstream organization building had to wait for the Industrial Revolution. However, the bandwidth problem remains: regardless of channel capacity, we can still only absorb 250 words per minute, and output even less than that.

When it came to information processing, the ability to write down intermediary results and collect written information made it possible both to process much more complex problems and to time-slice (work on many problems more or less in parallel) much more easily. The real revolution, however, was the way writing let us distribute large tasks among a vast number of persons, synchronizing and coordinating their activities and communicating intermediate results between them. A literate society can therefore organize massive undertakings and routinely tackle tasks that would completely overwhelm any illiterate society.

Finally, mechanical automation helped us overcome our limited ability to carry out physical operations in parallel. The machine is, so to speak, a set of crystallized decisions, and it represents a total externalization of a plan for a specific production process. Thus, even coordination is automatic in an automated production line—that is one important reason for its phenomenal efficiency. However, even if a steady succession of tools has enhanced our capabilities, important parts of the basic limitations have prevailed—notably in our abilities to communicate and process information.

In Chapter 7, (“The Modern Organization”), I then tried to assess the relationship between the development of these tools and the emergence of the modern organization. The most significant developments did not appear until the needs of the growing firms during the Industrial Revolution outgrew the capacities of traditional organization. The key concepts here were specialization and mechanization, which required much more emphasis on coordination and control and entailed splitting the problems of design and production methods—an integral part of the craftsman’s work—away from the worker. This called for a much more sophisticated approach to information processing and communication, and, consequently, to organization. The Machine Bureaucracy was born.

The development of the Machine Bureaucracy depended on the emergence of a new concept for coordination—indirect supervision by the means of standardization of work processes—which resulted in two new coordinating mechanisms: explicit routines and automation. Both these new coordinating mechanisms depended on writing; automation required additional technological advances. With the addition of implicit coordination, there were now three new, technology-dependent coordinating mechanisms available that supported the development of very large and efficient organizations.

The new organizations also represented another decisive break with the past: They required detailed and explicit analyses of both the operational requirements and the interdependencies of the different steps and levels in the process, to be followed by careful and detailed design and planning of operations. The patterns of action constituting the new organizations were thus *consciously constructed* according to a *conscious* design based on an *explicit* analysis of the desired outcome and the available means. Explicating analyses and design and committing them to paper, the new organizers also created (unknowingly) the first explicit conceptual models of organizations. By lifting the models out of the subconscious world of tacit knowledge, and literally spelling them out, they also opened them up for conscious inspection and improvement. This is the foundation of the modern organization. The chapter concluded that it is reasonable to assume that the possibilities awarded by these preconditions have largely been exhausted by countless trials and errors, and that we will need new technological developments to evolve distinctly new organization schemes.

It is now time to proceed to precisely analyze these developments. The approach from now on will be more detailed, and divided into three parts (Part III, IV, and V). Part III delve into information technology itself and the way it helps us relieve main limitations above and beyond what earlier tools have done. Part IV will move on to discuss the new organizational opportunities that information technology opens up. Part V will return to the subject of structural configurations, now with information technology as a prerequisite.

Part III starts with Chapter 8 (“Information Technology Development Trends”), in which I try to assess the state of the art of the technology and the likely achievements in basic performance improvements during the next decade. Chapter 9 (“The Impact of IT on Individual Capabilities”) will proceed to analyze how information technology can improve the capabilities of the individual over and beyond the contributions of earlier technology. Following the conclusions in Chapter 2, that organizations are constructed and that their system properties derive from the qualities of the actions performed by individual organization members, this discussion really represents the foundation for the analysis of possible new organization forms and practices. To balance the fairly technocentric discussion in Chapter 9, which mainly explores the basis for the technical space of organizations, Chapter 10 will end this part by discussing emotional barriers and defenses against technology-based changes (“Emotional Barriers and Defenses”)—problems which are, in my view, generally underestimated and ignored by the industry.

The discussion in the chapters both in this part and the following will presuppose a basic knowledge about information technology, although I do provide some explanations for the uninitiated in the text (and the footnotes). As a

further help to those who are new to the field, I have included a brief history of computers in Appendix B. It can hopefully serve some of the same purposes for organization professionals as Appendix A does for computer professionals.

8 Information Technology Development Trends

"O that a man might know
The end of this day's business ere it come!"
Shakespeare, *Julius Caesar*, 1599–1600

Imagined Trends, Market Trends, and Deep Trends

The past achievements of the industry are indeed impressive, and the pace of technological change we have witnessed in the fifty years since ENIAC's inauguration has been breathtaking enough. Already, much has been achieved that has irrevocably changed the preconditions for human work and organizations. Even with this ballast, however, it is easy to get caught by the present level of technology and forget that it is changing even as this is written (and read!), producing new possibilities and enhancing existing ones. To look ahead toward the possible extensions to the space of constructible organizations, we must therefore also try to discern the basic development trends for computer-based systems at least a decade or so into the future.

However, the properties of computer systems are multifaceted, and the products that are brought to market represent a bewildering array of tools and gadgets, with market lives of a few years at the most—some as short as a few months. Often, they are so complex that the average user never utilizes more than a fraction of the power available. This profusion of products, presented through numbing marketing blitzes, followed up by extensive coverage not only in the trade press, but increasingly in the general news media, makes it difficult to distinguish the important from the insignificant, and the truly revolutionary from the superficially sensational. We must nevertheless try to do precisely that—to make a tour of the cutting edge of technology, illuminating the most important development trends without being led astray by marketing hype and general excitement.

Trend analysis and prediction is a popular sport in the industry, and there are many who make a living from it. I like to classify the touted trends in three classes: imagined trends, market trends, and deep trends.

The *imagined trends* are those that are most often presented in more or less sensational stories about the future; the sort of journalistic science fiction that both the trade press and the general news media succumb to from time to time. Not infrequently, leading industry figures will also venture into this terrain. A persistent vision in this class is the idea that we all will end up as high-tech couch potatoes, working, living, and entertaining almost solely by means of the wall-sized screens (or even three-dimensional holographic display units) in our living room-cum-office. This idea is not new, by the way; drawings of such rooms were presented as early as a hundred years ago (Dahl 1984)—the only difference is that movie screens, telephones, and printing telegraph receivers (for continuous news services) took the place nowadays reserved for computers, fax machines, and videophones.

One of my historical favorites in the class of imagined trends is a statement about the promises of the steam engine by a J.A. Etzler in 1842, quoted by Augarten (1984, p. 284):

Fellow men! I promise to show the means of creating a paradise within ten years, where everything desirable for human life may be had by every man in superabundance, without labor, and without pay; where the whole face of nature shall be changed into the most beautiful of forms, and man may live in the most magnificent palaces, in all imaginable refinements of luxury, and in the most delightful gardens; where he may accomplish, without labor, more than hitherto could be done in thousands of years.

General John J. Carty, chief engineer of AT&T around 1900, offered a prediction that was more modest, but nevertheless illuminating in its naive belief in the blessings of technology, specifically the peace-making qualities of the telephone (Pool 1983, p. 89):

Some day we will build up a world telephone system making necessary to all peoples the use of a common language, or common understanding of languages, which will join all the people of the earth into one brotherhood. There will be heard, throughout the earth, a great voice coming out of the ether, which will proclaim, "Peace on earth, good will towards men."

This was written at about the same time as the Japanese general Oyama pioneered the use of telephones in warfare—his troops strung telephone wires behind them as they advanced against the Russians in the Russo-Japanese war in 1905, connecting all the regiments along a 100-mile front to fifteen regional headquarters, three group headquarters, and finally to the general himself, sitting in his headquarters ten miles behind the front line. Oyama's victory was squarely attributed to this innovative use of the telephone (Pool 1983). Today, we need look no further than to the recent grisly war in former Yugoslavia to learn that a common language is no guarantee for peace, love, and brotherhood.

Imagined trends are generally not the product of a misinformed conception of the technology itself, although they may be that as well. Usually, they are based on sound knowledge about technical specifications. However, the crystal gazers usually demonstrate a basic lack of understanding about human abilities and preferences, and fail dismally in their assessments of the interplay between technological possibilities and human nature. Therefore, they will consistently

believe that just because something is technologically possible, it will by necessity become a widespread practice. Returning to our subject, I believe that the common prediction today that the world is rapidly moving toward a situation where most organizations will be networked “virtual” organizations constitutes nothing more than an imagined trend. It is built on the undeniable communication and networking capabilities of computer-based systems but assumes, by analogy and in a rather uncritical manner, that organizational structures will be mapped directly onto the prevailing system architecture. I will return to this subject in later chapters.

Imagined trends are not wholly false, of course; they often contain solid grains of truth and may describe aspects of the future. They may even come true in more limited contexts. However, a critical eye is essential when trying to gain insight into what will constitute the main possibilities opened up by new technologies.

Next, there are *market trends*, which are the prevailing developments in market shares and sales of different products. They are notoriously difficult to predict, not least because new, unexpected products tend to crop up all the time. One of my cherished possessions in this connection is a graph produced in 1986 by IDC, one of the big players in the market analysis and forecast arena, forecasting the developments in market shares for the “Primary Operating System Environments” for the next ten years (through 1996). Among other (and lesser) mistakes, one stands out: Microsoft Windows, today the totally dominating environment, is not mentioned at all. This is not so strange, since it was not really introduced until 1987, when Microsoft’s own Excel spreadsheet was the first application to take advantage of it. However, it should teach us to be humble before the task of predicting market trends, and enlighten us so we are not deceived by forecasters.

There is an air of magic ritual about forecasting, by the way. I never cease to be baffled by the willingness of otherwise sensible persons not only to accept the detailed projections of market research bureaus, but to pay a lot of money for them as well. As we all know, even the present market share for a product, which can be measured through questionnaires or by watching sales statistics, can never be exactly determined. There will always be inaccuracies because of sampling errors and/or errors in registration or classification of data—most likely in the area of several percentage points. The same applies, of course, to historical data. When one begins to project into the future, the error margins quickly increase. Anyone who tells you that a particular product will have a market share of 23.7% (or even 23%, without the decimals) three years from now is either a fraud or incompetent in his use of methods (or both). For most product categories, there are *no rational bases whatsoever* for projections with greater accuracy than five-percentage steps (or even ten). The rest can only be interpreted as an unconscious belief (of a partly magic character, and formed by the definiteness and closed logic of the number system itself) that opinions expressed in numbers are somehow more accurate than those expressed in words.

Interestingly, I once criticized a representative of the Gartner Group (a well-known technology assessment company in the computer business) for presenting excessively accurate predictions, suggesting that they should use at least five-percent intervals. He readily agreed but went on to tell me that they had tried to do precisely that—but that their customers would not accept it: They viewed the

honest and methodically sound representation of real error margins as unprofessional and inaccurate work, and craved the (clearly magical) assurance of exact numbers!

Luckily, however, we do not have to occupy ourselves with market trends here, since the virtues and deficiencies of specific products are of no consequence for our purpose. What *are* important are the general capabilities of the technology, the capabilities that allow the products in the first place. I call the course of their development *deep trends*, and these have fortunately proved to be extraordinarily stable over a period of at least one or two decades. As long as we keep to them, we have much greater chance of being largely correct even for predictions stretching ten years ahead or more. As an example, we may return to the IDC forecast mentioned earlier: IDC was wrong when the company predicted that OS/2 would lead in market share in 1996, but it was wrong for the right reasons. Their forecast built on the belief that rapidly increasing price/performance ratio of PCs would make them proliferate (which they did); that a multitasking, graphically oriented, windowing environment would win in this new market (which is what happened); and that this environment would thereby rise to the top slot in market share (which it did). However, it was not OS/2, the obvious candidate at the moment, that succeeded, but the soon-to-come Microsoft Windows.

Three Basic Characteristics

First, it is necessary to establish the basic characteristics of computers and computer-based systems. When we look at the multitude of computers and computer products on the market, listen to the salespersons pushing them, and become inundated by market forecasts and imagined trends, it seems like a bewildering jungle. However, if we take a closer look at the properties of systems past and present, all their capabilities and functions can be related to three basic properties or characteristics.

First of all, computer systems of all kinds *process* information—they operate on it in some way or other. This capability has two aspects of equal importance. The first is the actual operations on information (for instance, adding numbers together); the second is the program—the specific instructions deciding the way the physical logic of the processor itself shall operate. The instructions are usually layered in sets of increasing power and complexity, with a fairly simple set closest to the hardware (the instruction set doing the translations to the machine code actually switching the logic gates), then a more complicated set guiding the general housekeeping functions of the system (the operating system), and finally a set of instructions constituting the application program itself. Next, computers also *store* information, usually both programs and data, but at least a program of some sort. Third, they *communicate* information—it must be put into the computer in the first place, the results must be presented to the user, and information is often transmitted to other systems, either for further processing, storage, or presentation.

The decisive underlying technology here is of course the representation (described in more detail in Appendix B) of information and programs alike in *digital* form—in 1s and 0s. All digital information is thus represented by absolute values that can be copied, manipulated and transformed indefinitely without

attenuation, unlike the progressively degrading amplitudes of analog technology. Without digital representation of information, the computers and applications described in this and later chapters would largely be impossible. For an account of the ramifications of the principle of digital information representation that is both entertaining and enlightening, see Negroponce (1995).

Processing

Operations on Data

The most basic property of computer systems is the actual operations on data. This is particularly evident when we look at the very first computers: the electronic ones of the late 1940s and the 1950s, the electromechanical contraptions of the 1930s and early 1940s, and the purely mechanical calculators of the three preceding centuries.

When it comes to processing, speed is obviously important, and it has grown to become more important than we originally thought. If you had described the processing power of the modern PC to a computer engineer or computer user in 1955, he would have wondered how a single person could possibly utilize more than a fraction of that capacity. The users of today, with PCs strained by the demands of the latest version of their Windows-based office suites, know better. In fact, as we enter the new world of pervasive IT, of graphical user interfaces, of multimedia and giant databases, our thirst for increased processing power is more acute than ever before. Will we ever be satisfied? There is no reason to believe that the annual increases in power that we have grown accustomed to will slow down in the foreseeable future. The predictions for the next ten years here are fairly safe: We can even maintain the present rate of progress simply by the gradual refinement of existing technology. But let us not jump to conclusions—let us evaluate the developments a little closer.

Today, data processing has come to mean more than numerical calculations. Computers process not only figures, but text and graphics as well (including live video). They store and retrieve vast amounts of information. At the bottom, however, it is still just binary number crunching. The speed of the computer is of course directly dependent upon the speed of these basic calculations, but in modern, complex computers the speed of the primary and secondary memory,¹ the capacity of the transfer channels between the processor and the memory, and a host of other factors are also of great importance.

The key to the incredible increase in speed and the impressive reduction in price we have seen over the last three decades lies in the constant refinements of

¹ By primary memory we normally understand the semiconductor memory (chips) holding the data and the program the processor is currently working with/on. It loses its content as soon as the power is switched off. Secondary memory usually denotes the magnetic or optical disks where programs and data are stored more permanently, and where the processor can fetch them and load them into primary memory when needed. Tape is now largely relegated to the role of a back-up medium or a medium for archival storage, sometimes called "tertiary storage."

the integrated circuit. As noted earlier, the number of discrete components that can be put on a single chip has increased tremendously. Memory chips have the largest number of components—because of the geometrical regularity of the design, their components can be much more densely packed than logic chips. The standard memory chip today has sixteen million storage cells (16,777,216 to be exact), each consisting of one capacitor and one transistor, plus the necessary circuitry to read and write to the cells. The number of discrete components therefore approaches 40 million. The 64-million cell chip is in the pipeline. Around the turn of the century, we can expect one-billion cell chips to be produced under laboratory conditions, reaching volume production maybe around the year 2005 (if other technologies have not overtaken semiconductor memory in price/performance by that time). Such a gigabit chip will be able to store (with today's 8-bit character standard) about 134 million characters, the equivalent of about 45,000 pages of text like this one—more than many people will read in their whole life. After a couple of years in regular production, it will probably cost around \$8 to \$10 in small quantities. We will return to the memory chips later when discussing storage.

Developments in Processor Speeds

Because of much more complicated designs, microprocessor chips cannot achieve the transistor density of memory chips. The same level of technology that produced the 16-million cell memory chip has given the present state-of-the-art microprocessor chips about 5.5 million transistors. This requires that the connecting circuits on the chip have a width (a "line width") of only 0.35 microns—or less than a thousandth of a millimeter. In comparison, the first one-chip processor (Intel's 4004, launched in 1971) had a mere 2300 transistors.

The developments in performance and price/performance have been remarkably stable for many years, and we can safely expect much more complicated chips to appear in the coming years (see Figure 8-1), even if the number of transistors does not increase at the same rate as for memory chips. Processor chips with 25 million transistors or more should be expected around the turn of the century, if the problems involved in designing and error checking (or "debugging"²) the logic of such complex chips can be solved—something that is already a bottleneck in microprocessor development. When the number of discrete components rises linearly, the number of possible combinations rises exponentially, and the problems of error checking quickly reach staggering proportions. Automated checking is necessary, and ever more powerful computers are required to do the job within reasonable time frames. It can thus be said that the development of advanced microprocessors has much in common with von Münchhausen's famous trick of escaping from the bog by pulling himself up by his hair.

²"Debugging" is computerese for finding and correcting errors ("bugs"). The term is used mostly for software but is also used for errors in chips and other electronic components in computers. The etymology of the term is not 100% clear, but computer lore will have that it was invented when a module in one of the very first vacuum-tube computers was short-circuited by a moth. The Computer Museum in Boston displays what is claimed to be a photograph of the actual moth.

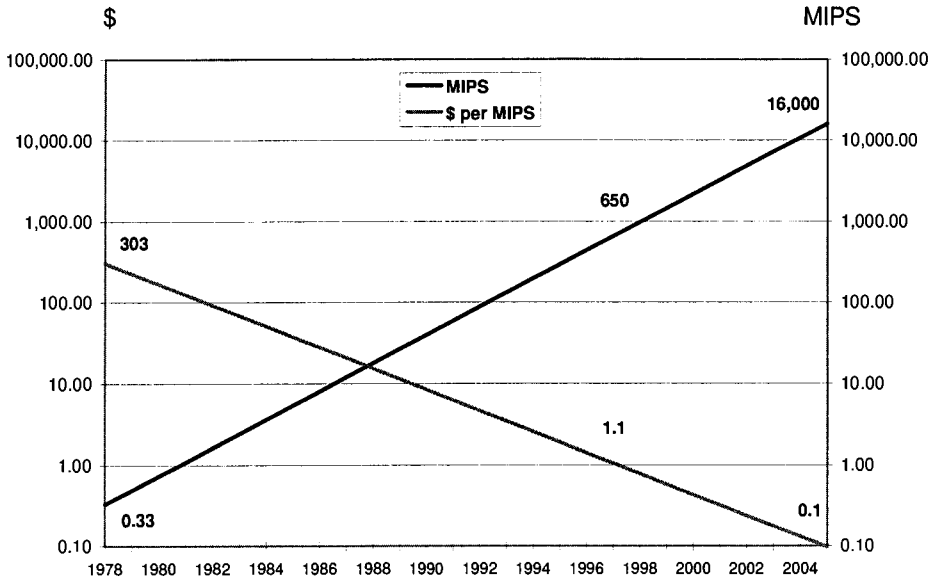


Figure 8-1: Development trends for microprocessor price/performance. To ensure comparability, the figure is based on the development of the Intel microprocessor family. Due to breaks in benchmark continuity, figures are nevertheless very approximate. Prices relate to the most advanced chip widely available at any point in time (older and less powerful chips will be much cheaper and have better price/performance ratios). Figures are compiled from articles and advertisements in numerous issues of Byte, PC Magazine, and Scientific American.

Such “superchips” may contain several processors and have considerable redundancy in the form of “spare” units (only activated if one of the others fails). Their processing power is very difficult to predict, because the architectures (basic designs) are likely to be different from the ones we now use, utilizing among other things some sort of parallel processing.³ For tasks involving pattern recognition, such as speech and character recognition, processors based on neural network designs (mimicking the basic architecture of brain tissue) may become

³Parallel processing means just that – doing several operations at the same time. Today, extensive parallel processing is used mostly for specialized purposes, such as picture processing and fluid dynamics, where it is fairly simple to break the computation down into “modules” that can be executed independently. Massively parallel machines with up to several thousand processors are already in operation for such applications, with immense gains in speed over “conventional” supercomputers with serial processing. There are considerable hurdles to be overcome before parallel machines can tackle the bulk of ordinary commercial applications. However, we can expect great strides to be made during the next ten years, especially in the realm of database management and transaction processing, where servers with a moderate number of processors are already becoming common.

commonplace.⁴ Such chips may also help making computers more user-friendly by "learning" from what their users do.

Regardless of what architecture(s) evolve as the most successful and most widely used over the next decade, we can safely guess that the new chips will be much more than ten times as powerful as today's processors, maybe fifty times as powerful. Such chips will probably require that the line width is shrunk to around 0.15 microns—which is indeed possible, considering that a width of 0.07 microns has already been reached under laboratory conditions (Thompson 1996). The obstacles on the road to volume production for such circuits are formidable, however—the lines are much too fine to be painted by visible light, and one will probably need to employ deep UV light or even X-rays or electron/ion beams to project the masks (the patterns to be etched into the silicon) onto the chips. The 0.07 micron components just mentioned was produced with X-ray lithography. At this level of miniaturization, moreover, we will start to hit fundamental physical barriers. If the components are made still smaller, they will be subject to quantum effects and will no longer be reliable. Fortunately, there are other basic technologies that may be able to take over the baton when the time comes, and there is no reason to expect any significant slow-down in the perennial increases in processor speed even after the turn of the century.

Consequences for Computer Systems

The increase of power at the chip level does not automatically translate into corresponding gains in power at the system level. But, rather than being less, the gains in system power are in fact likely to be *even greater* than the gains in processor speed, as new, parallel architectures are perfected. The gains will come for systems on all levels, from the most humble PC through database servers and high-end transaction-processing⁵ machines, as well as workstations and supercomputers for technical and scientific applications. Moreover, a number of specialized processors will be added—such as graphics processors, communication processors, I/O processors and math processors. As noted earlier, an average user will have a multitude of superfast processors working for him or her—allowing for much more sophisticated software and greatly improved user interfaces.

The overall consequence will be systems vastly more powerful than the ones we use today—in fact, even the *relative increase* in total system processing power during the next ten years is likely to be far greater than the relative increase in the previous ten years, not because the individual processor chips are going to increase their performance on a higher rate, but because the average system will contain a much larger number of processor chips. If some of the basic problems of

⁴ Much research is currently being done on processor designs mimicking the interconnections between nerve cells in brain tissue, and several chips have already been designed, for example by Intel and Bellcore (the research laboratories of the seven regional Bell companies in the United States). Neural network processors have a high degree of internal parallelism and may be able to "learn" from "experience" by modifying their own processing according to general rules and the outcome of previous tasks. See Barron 1990.

⁵ *Transaction processing* is the term used for data processing involving on-line registration and requests for information. Typical examples are airline reservation systems, banking systems, and systems for mail order processing.

parallel processing are solved, standard processors may become even more commodity-like than today and fall into a pattern resembling the one we now have for memory chips: extremely high volumes, low prices, and liberal use. This will allow not only for new qualitative jumps in user friendliness, but also for the use of substantial processing power in the most trivial circumstances. Not many years ago, people joked that even toasters would have processors in the future. Today, some toasters *have* processors, which help them toast the bread to the same degree of crispness regardless of whether the slice comes from a freshly baked loaf or from the freezer.

Together with the advances in storage media and communication, the increases in available processing power will also usher in the inclusion of high-quality sound and pictures, including live video. Multimedia PCs are already swamping the marketplace, but their capabilities will increase dramatically (without significant price hikes) during the coming decade, and many forecasters (beware!) predict the demise of the "dumb" TV.

Programmability—Logic Over Matter

In the account of the history of computer-based systems in Appendix B, it is noted that the stored program was really the feature that made the computer come into its own as *the Universal Machine*. At the time, it probably did not seem to be all that significant—mostly a matter of speed and convenience. It is, in fact, of far greater importance. However, as is often the case with human achievements, the last step across a momentous dividing line seems no longer than the steps preceding and following it, except when viewed in retrospect through the spectacles of history.

We have earlier contemplated the nature of the automatic mechanical machine and called it the externalized or crystallized result of an information-processing undertaking, with the programming logic forged in steel. A mechanical desk calculator is a fairly advanced automatic machine, on which one can set parameters (the numbers to be operated on) and choose one of four modes of operation (addition, subtraction, multiplication, or division). It thus has a certain flexibility, larger, for instance, than a steam hammer, but smaller than a Jacquard loom, which can turn out tapestries and other textiles of an astounding complexity and variety. But in their essence they are all very specialized and limited machines—they cannot go beyond their narrow, designed set of objectives. The loom cannot print newspapers, the desk calculator cannot draw curves (even if you can use it to calculate points on the curve), and there is not much a steam hammer can do but pound.

In many ways, ENIAC was just an electronic version of the Jacquard loom, optimized not for weaving, but for solving mathematical equations. But, in important respects, it was also more advanced than the loom. It could punch intermediate results on cards that could later be fed into it for new rounds of calculations, it could loop, repeat subroutines, and do conditional jumps, that is, branch the execution of the program in one of several directions based upon the results of previous calculations. It was more adept at solving equations than any other machine at the time. However, it was still not very flexible.

The development that created this machine had been incremental, with a lot of different persons contributing to a large number of small steps. It is debatable whether any of those steps involved a paradigmatic shift, a transition from one kind of machine or tool to a fundamentally different one, and if the computer is thus different in principle from previous machines. Norbert Wiener (1954) makes the distinction between classical automata, which follow a preset pattern (for instance, a clockwork or a music box with dancing figures), and self-regulating machines, which respond to changes in their environment. The self-regulating machine receives information *input* from the environment and answers with an information *output*. For a simple self-regulating machine, such as an automatic door, the output is most often a physical action (the door's sensor detects an approaching person, and the motor opens the door).

For a computer the output can take several forms, from a representation in an internal memory to the engagement of physical actuators. But it is important to note, as Wiener did, that there are many self-regulating machines that are not computers. Whether there are computers that are not self-regulating is in many ways a matter of definition. If you define a computer as a general purpose, programmable, logical machine, all bona fide computers must be self-regulating in Wiener's terms. If you include any humble calculating circuit, you cross the threshold to automata. A quartz watch, for instance, has a small (rudimentary) calculator in it. You may argue that it indeed receives input from an oscillating quartz crystal, and divides the oscillations down to output pulses that drives the hands or the display of the watch. But the computing circuits only carry out a preset operation; they cannot detect any slowing in the pulses from the quartz crystal, and will only "mechanically" divide them by the preset factor. A quartz watch with three crystals, however, in which the circuits constantly compare pulses, eliminate the most aberrant, and drive the display based an average of the two others, would represent a self-regulating piece of equipment.

Even if the computer at the outset did not constitute something principally new, the quantitative changes it has undergone since its inception add up to a decisively qualitative difference between the computer of today and other kinds of machines. To draw a parallel, we may well say that both the earth and the smaller asteroids are lumps of rock circling the sun. But there are enormous differences between them, rising from their different size and relative positions. The modern computer has a complexity, flexibility, information-processing capability and storage capacity so immense compared to any other machine that it constitutes a totally new class. The possibilities it opens up are in many areas profoundly different from those that arise from more traditional tools, and they are all rooted in its paramount characteristic: its programmability.

By programmability I do not only mean the way we as end users can program the computers we buy or use the program packages we buy with them. Laying out chips and building computers are in fact programming activities as much as anything else—as it constitutes the design of the machines' basic logical structure. And the logic content of computers is increasing all the time, in step with the miniaturization of electronic circuits. Whereas ENIAC was a 30-ton agglomeration of rather crude matter, with a very modest logic content, a modern microprocessor, three orders of magnitude more powerful, is almost immaterial—weighing less than one gram without its protective coating. Even a complete

computer, with screen, mass storage, power supply, and keyboard, can now weigh less than half a kilo.⁶ More so than any other tool, a computer is becoming an expression of the human mind rather than the human hand. Indeed, the hardware can be viewed as a kind of materialized spirit—its power coming not from physical force, but from its speed and accuracy in carrying out logical operations. Microelectronic chips are today's medium for this logic, but there is no necessity in this—it only means that such chips are the most economical and convenient carriers at our present technological level. Other technologies will take over later, and, in a not too distant future, logical operations may be carried out by the manipulation of single electrons and photons—indeed, at the laboratory level, we are fairly close to that already, and there is currently interesting work underway on the theory for quantum computers (computers with circuits so small that they use single atoms for switching). When intangible logic is thus contained in almost immaterial quanta of energy, one realizes that the old philosophical debate about mind and matter is not nearly over yet.

In fact, if we look a little further ahead than the ten years perspective we have adhered to so far, the evolvment of the computer may give this debate a new fervor, a new perspective, and a whole new set of arguments in the coming century. I have always been a skeptic when talking about computers eventually attaining the same level of complexity as the human brain—partly because the brain is so exceedingly complex, and partly because our knowledge of its intricacies and operation is so limited. However, when we consider the strides made in the 46 years since the completion of ENIAC, versus the more than 300 million years that have passed since the mammals and the reptiles evolved from their common ancestor (and the development of the brain started long before that), I am not so sure anymore. Earlier, we discussed the power of computers around the turn of the century. But how powerful will they become further into the future? In the February 1996 issue of *Internet World*, science fiction writer Vernon Vinge points to the fact that if the current trend in processing power improvements continues, computer hardware processing capacity will reach what we now estimate to be the level of the human brain already between the years 2030 and 2040. What about the situation in a hundred years? In five hundred? Two thousand? Will we be able to develop software that can take advantage of this tremendous processing capacity and create entities with higher processing capacity than ourselves? If so, what will the consequences be? Who knows—but one thing is for sure: The computers of the more distant future are going to be incredible indeed when judged by today's standards.⁷ As Arthur C. Clarke used

⁶ Both Atari Portfolio and the Poquet computers, introduced in 1989, were full-fledged, IBM PC-compatible computers weighing about half a kilo. Hewlett-Packard's 95XL weighed 300 grams; the latest Psion, 275 grams.

⁷ Many people may find such speculation impertinent or repulsive—it is not fashionable today to speculate on developments more than ten to twenty years ahead. Indeed, one feels almost immorally optimistic not accepting as fact that the human race will annihilate itself either through nuclear war (most popular until recently) or pollution and depletion of natural resources, or both, within a relatively short time span (currently most popular). If one accepts that we will linger on and most probably continue our quest for knowledge and technological improvement, the longer perspectives become quite intriguing, not least when thinking about computers: Maybe the computers of the next century will be sufficiently complex and

to say, any technology sufficiently more advanced than the one we know will always look like magic.

The Future of Software

To say something about the future of software is the most difficult task of all. The number of companies and people engaged in software development and the latitude for creativity in that area is so large that almost anything can happen. Luckily for the soothsayer, however, there are a few constraining factors in the shorter run—a few de facto focal points of market weight and attraction that applies considerable pressure toward a measure of predictability, at least as to the main trends.

Appendix B briefly traces the main threads in the history of software evolution, from the machine code of the early computers to the standard packages and development tools (earlier termed 4GLs, fourth-generation languages) of today. Packages, tools and the “normal” programming languages will develop further, but there are clear tendencies to greater flexibility, differentiation, and specialization. There is also talk about expert systems and artificial intelligence (AI). In addition, the user interfaces are increasingly becoming graphical and windows-based, and we are witnessing the first moves away from the paper-derived form and logic for information presentation.

Standard packages are becoming more and more flexible and rich in functions, in some instances bordering on becoming specialized development tools with the added benefit of some easily accessible basic functions. The modern spreadsheet products for PCs are good examples of this—most people think about them as standard packages, but they are probably more accurately described as specialized development tools for economic (or even general numeric) modeling and reporting. Most users only scratch their surface, since it takes a level of competence well above the normal user’s to mine their more advanced capabilities. The same thing is happening with word processors, and spreadsheets and word processors that can work together make it possible to develop fairly sophisticated office systems without ever resorting to “real” programming—especially within the windowing systems now available. We can expect rapid development in this area in the coming decade, giving us very powerful tools for developing advanced office support systems.

Moreover, this development is not restricted to PC-based mainstream applications. Standard packages for general ledger, payroll, and all the other administrative chores also becoming more flexible and easier to adjust to a customer’s special requirements. In the world of really heavyweight applications, products such as SAP R/3 and Oracle Financials, covering sales, production, logistics and accounting for medium-sized to the largest enterprises, are already extremely flexible and allow for extensive customization.

The bottleneck will become not so much the systems themselves, but the level of knowledge and skill needed to really take advantage of them. For the average

user (at least as he or she is today) these products already represent a significant degree of overkill.

Meanwhile, the development tools are evolving, too. They are directed toward the development of most kinds of administrative applications, and have added considerable depth and breadth in functionality over the past ten years. The power of their internal languages has also increased, automating even more of the routine development tasks. Because of the mounting competition, and the premium that the user community is increasingly putting on flexibility and the escape from vendor lock-in, the vendors have been forced to allocate a considerable part of their development resources toward making their products compatible with as many computer platforms and with as many database products as possible. This has already heated up competition significantly. We have already experienced a considerable reduction in their numbers, and there will probably be more casualties in the years to come, as a few winners consolidate their positions in the marketplace. Probably, we will end up with a handful of products, all with their special merits. Their power, coupled with new and considerably more efficient methods for application development, will probably lead to a certain renaissance for custom development—both as an alternative to standard packages and as an affordable way of fulfilling needs not easily satisfied by packages.

All this notwithstanding, the programming language is not dead and will still be an important tool in the next decade. The old mainstays COBOL, FORTRAN, and BASIC are yielding to newer languages, however. COBOL will have a lease on life as long as the traditional mainframes run the kind of software they do now, but little new is going to happen with it, and its domain will largely be taken over by standard packages and development tools—which are increasingly being used for the development of larger administrative applications, both custom systems *and* standard packages. For the newer, window-based PC and workstation applications, the languages of choice are C (which lies at the bottom of most of the products in that area) and increasingly graphically oriented languages (such as Visual Basic) and object-oriented (OO) languages (such as C++). Indeed, for some classes of applications, especially highly interactive ones, the object-oriented languages (supported by object libraries and application- or business-specific shells) may prove to be more efficient even than today's crop of ordinary development tools, provided that there is a concomitant change in the way systems are designed. The number of OO languages is increasing, as new ones are developed and older languages acquire OO-like features. A hot newcomer is the Internet-compliant language Java, which is attracting adherents faster than any previous programming language. It is nevertheless too early to call any winners yet.

With the growth of the object-oriented software tools, a new way of analyzing and structuring information systems is also gaining acceptance. As indicated earlier, we are moving away from the process-oriented structuring of conventional programming toward the information-oriented structuring of object-oriented languages. I think the change is very significant and is a part of the erosion of the paper paradigm discussed later in this chapter.

A lot of people have been talking for a long time about *artificial intelligence (AI)* and *expert systems*. It has repeatedly been hailed as the new computing panacea,

providing computer systems with the ability to learn, to exhibit “intelligence,” to handle “fuzzy logic,”⁸ to record the knowledge of experts, and subsequently to provide users with adept advice within those expert’s domains. It has also repeatedly been predicted to become a major new growth market. Despite a number of interesting and useful implementations, however, the success has not arrived, and the field has for some years been struggling with an identity crisis and paradigm battle (Ryan 1991). Although AI development has proceeded at a much slower pace than its proponents envisioned, this should not lead us to believe that it is dead or will continue to be inconsequential. But the problem is that our knowledge of the human mind and its processes is still very limited; it simply does not provide a sufficient platform for effective simulation. Apart from a number of fairly simple expert systems and “intelligent” active support features for other software, AI’s most important contribution may be that it will help us to understand our own mind, and thereby also the common properties and processes of intelligent systems—machine and living. With a deeper understanding of cognitive processes, however, AI may return with a vengeance further down the road.

On the practical side of software, some of the most exiting developments have been taking place in the field of *user interfaces*. The increasing power of PCs and workstations has allowed the implementation of more intuitive user interfaces, heavily based on graphics. Because we are able to absorb information much faster from pictorial representations than from text, graphical visualization is inherently much more efficient than character-based interfaces (if properly designed). The graphical user interfaces (GUIs) now available, such as the variations of MS Windows for IBM-compatible PCs, Finder for Apple MacIntosh and OSF Motif for UNIX (to name the three most popular), are only the second generation: the assembly code of GUIs, so to speak. They are evolving toward a more advanced level, however, especially through added internal hooks and piping, allowing applications written for them to function very closely together. This makes it possible to hide almost totally from the user the fact that he or she is actually using a number of separate products. The development we see here—the expansion of the document concept through linking of applications⁹ and hypermedia¹⁰

⁸ “Fuzzy logic” denotes logical operations that are not deterministic (like “straight” logic) but have a more or less strong stochastic or otherwise indeterminate content. Human deliberations are the prime example, and “fuzzy logic” an attempt to mimic them.

⁹ Tight linking of applications can give all the advantages of integration while keeping the advantage of being able to shop for the best or most suitable specialized applications. The most interesting developments are taking place within the operating system extensions created by the various windowing systems. The most popular system, MS Windows, now provides facilities for achieving almost seamless integration between those applications that are developed to take advantage of them. A document is increasingly considered an object in itself, not belonging to any particular application. For word processing and basic formatting, the word processor is invoked, for tables and calculations, a spreadsheet is invoked, and for graphics (over and above the graphics the spreadsheet can deliver), a paint or drawing program is invoked.

¹⁰ Hypermedia systems allow one to hide additional information behind words, tables, graphs, or other features in a document. The features with hidden information are marked with special symbols or color, and the information is accessed by placing the cursor on the feature and pressing the “return”-button (or clicking, if the system is mouse driven). A window will then

properties, also marks the beginning of a truly epochal change: the erosion of the paper paradigm. I consider this process so important that it merits a special discussion, because of the new possibilities it opens up, and as an example of how deeply ingrained old technologies are in our ways of thinking and working, shaping both the form and the content of new tools. We shall return to this later in this chapter, after we have covered the two other basic characteristics of computer systems.

Storage

Initially, storage was not exactly a strong point for computers. ENIAC could store only twenty 10-digit numbers in its internal accumulators while running—a meager 800 bits. Its program was “stored” in the switchboard-like pluggable wiring and in the settings of the numerous switches, and the data was fetched number by number from punch cards. Because of its limited ability to store intermediate results internally, more complicated calculations usually meant that intermediate results had to be output to punch cards, which then had to be loaded for the next sequence of computations. The first stored-program computer, the Manchester Mark 1, had a CRT-based internal memory of between 6,144 and 12,288 bits but still had to rely on paper tape for secondary storage. The first UNIVAC computer represented something of a breakthrough with its internal memory capacity of 84,000 bits (10.5 Kbytes in today’s language) and its magnetic tape secondary storage with megabyte capacity (up to ten tape units storing more than one megabyte each). The first practical microcomputer, the Altair, had a basic capacity of just 256 bytes (2048 bits) when it appeared in 1975, but soon 4 Kbytes add-in boards were available. When Apple II was launched in 1977, it had 16 Kbytes of memory as standard (expandable to 64 Kbytes, as the Altair).

Still, limited memory capacity for a long time represented a serious bottleneck for computer performance, since the size of the memory decides both the size of the program modules running at any particular time, as well how often the computer must access its secondary (and much slower) storage medium for reading and writing data. Especially when sorting and indexing (common database operations) the amount of available memory has a very decisive influence on execution time.

The low capacity and high price of secondary storage likewise limited the computer’s role as an archival device—especially for on-line storage of data for instant access. Today, the situation has totally changed, and it is still changing fairly dramatically from year to year. Storage capacity is becoming ever cheaper, even when measured in relative terms against the increasing demands from new hardware and software. Although there are still some problems at the extremes, especially in high-end graphics processing, ample storage is now increasingly taken for granted.

open to display the hidden information – for instance, an explanation of a word, more detailed information on a product mentioned, or underlying numbers for a table or a graph. Information in such a window may contain more marked features, allowing the reader to delve still deeper for even more detailed information.

Trends in Memory

Since the early 1970s, semiconductor memory has ruled the memory market. As noted earlier, the price performance ratio has improved steadily for 20 years, and still shows no sign of slowing down. In Appendix B, it is noted that one megabyte of memory (chips only) cost \$20,480 in 1975 and fell to about \$5 in the fall 1997. As we can see from figure 8-2, the same capacity will probably cost around 40 cents in 2005, when the gigabit chip will be approaching peak production¹¹ (barring major unforeseen engineering problems).

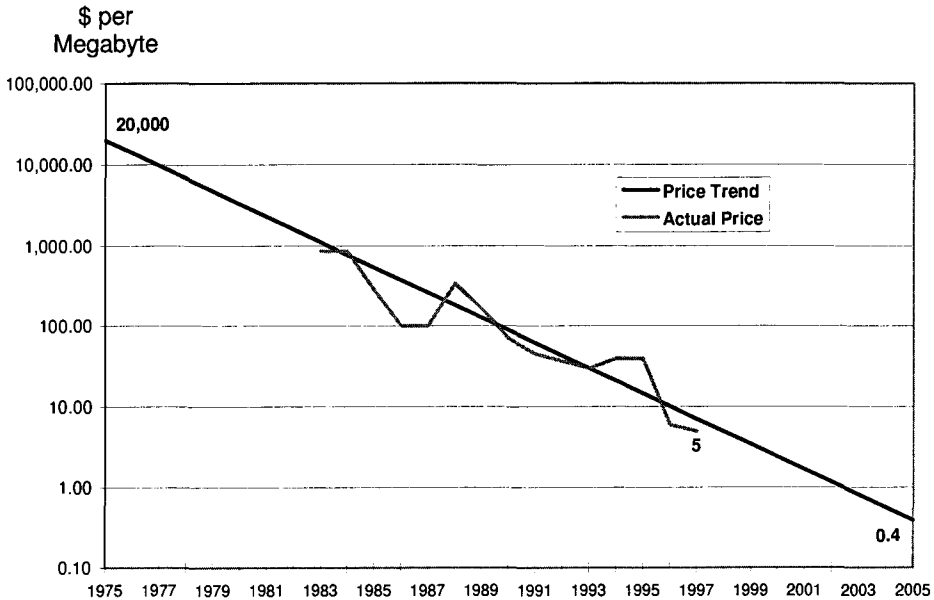


Figure 8-2: Development trends for memory prices. Figures represent approximate end-user prices and are compiled from articles and advertisements in numerous issues of Byte, PC Magazine, and Scientific American.

To put this discussion into perspective, what is today a really large database—for instance, with 20 gigabytes of data—in the year 2005 can be put into

¹¹As noted in the section about processor development trends, the pace of technological improvement in semiconductors has been extraordinarily predictable over the last 20 years, and it shows no signs of significant deviation from the established learning curve. The actual prices for memory chips, on the other hand, have oscillated, because production and demand have not developed synchronously. The peaks and valleys of the actual prices never seem to deviate by more than a factor of three from the regression curve (Baldi 1991), however. That may sound like a lot, but with the price reductions we are talking about in this context, it does not make much difference when comparing different points in time. If this development trend holds true the next nine years as well, for instance, the price for one megabyte of semiconductor storage in 2005 should be minimum 13 cents, maximum 120. Even 120 cents is pretty cheap compared with today's prices, and, being at the top of a cycle, the price would then be expected to fall rapidly, crossing back through the trend line in two to three years.

semiconductor memory with about \$8000 worth of chips. Given that boards, power supplies and support electronics will not cost more than a few hundred dollars, the price to put a 20 GB database into memory should be less than \$9000 (end-user price). It is important to note that all prices given here are nominal dollars for the actual year. In 1997 dollars the price for the 20 GB memory bank would of course be considerably lower (conceivably about \$6000), and the 1975 price for a megabyte correspondingly higher—about \$56,000.

By the turn of the century, it is likely that ordinary memory chips will be used as a second-tier main memory, with faster chips making up the working memory. Already, the trend toward small but fast cache¹² memories is quite clear. With the gigabit chip, we will approach the limits for further improvement of the venerable silicon memory chip. Larger chips may be manufactured by increasing chip area, but continued shrinking of transistor size will come up against the emergence of quantum phenomena—the chance jumping of electrons across the insulating barriers. Because of the unpredictable nature of these quantum jumps, they will destroy the reliability that is so important for computer memory. It would be foolish, however, to suppose that this signifies any permanent barrier to further improvement in the price/performance of computer memory. Other technologies are already on the horizon, and even newer ones are bound to appear further down the road.

One promising line of research involves the use of light-sensitive crystal lattices, in which polarized laser light can store and read information in the form of holographic patterns. Work in this field has been going on since the 1970s, but it is only now that the many technologies necessary to realize this idea has developed far enough for practical solutions to become possible within reasonable economic limits. Its developers today position it mainly as a new kind of mass storage (competing with magnetic and optical disks), but the specs (described in the next section) suggest that it can also compete favorably with standard semiconductor memory. When fully developed, it may dwarf the capacity of the gigabit chip, and if it can be manufactured cheap enough in “small” packages as well, it may even preclude the gigabit chip’s development.

For the last ten years at least, the increase in memory price/performance has been faster than the increase in need for memory capacity. This trend seems to continue, and we are on the verge of being able to use memory freely, without bothering too much about the cost. This will have significant consequences for how computers will look and operate in the years to come. It may even relegate the familiar hard disk to more archival purposes. Semiconductor memory cards for very light portable computers have already surfaced as an alternative to floppy disks.

¹² A cache is an extra fast (and much more expensive) memory acting as a buffer between the processor and the ordinary (main) memory. The cache stores the most frequently used instructions and data, as well as intermediate results from the processor. The contents of the cache are dynamically altered in accordance with the changing requests from the processor. The goal is to keep the processor as much as possible from accessing the slower main memory directly.

Trends in Mass Storage

The first mass storage devices were punch cards and paper tape. Then magnetic tape came along, but even if it represented a great improvement in speed and capacity, it was still a sequential medium—to get at a piece of information in the far end of the tape, one had to spool it from one reel to another. The first random-access medium was the magnetic drum memory of the late 1940s and early 50s, but a satisfactory solution was not found until magnetic disk memory was introduced by IBM in 1956 and used in the IBM 305 RAMAC computer. The disk in IBM's first unit was 24" (61 cm) in diameter, had 50 platters stacked on top of each other on the one shaft, and stored 5 megabytes of data. Today, over 8 gigabytes can be stored in a 3.5" unit, and disk development has now by and large relegated magnetic tape to a position as a medium for backup and archival purposes.

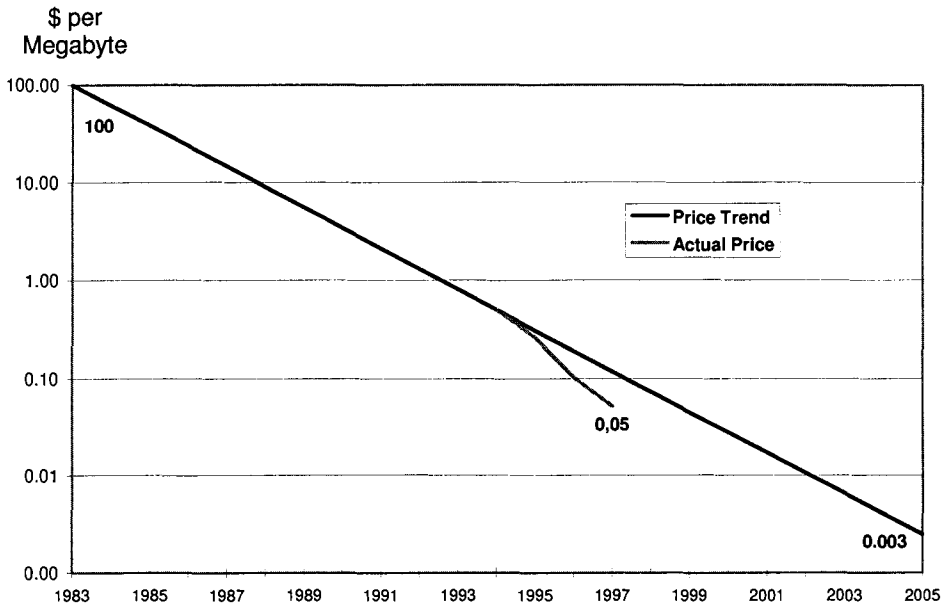


Figure 8-3: Development trend for magnetic disk prices. Figures represent approximate end-user prices and are compiled from articles and advertisements in numerous issues of Byte, PC Magazine, and Scientific American.

The smallest disks available today, developed for portable computers, are 1.8" (4.6 cm) in diameter, weighing about 65 grams. They can store up to 420 megabytes, or about 160,000 pages like this one. Similar units with 560 megabyte capacity will soon be available. Cost-effective magnetic disks today store information at a cost of less than 5 cents per megabyte (end-user price), or around 1% of the price for semiconductor memory. That is already only a fraction of the cost for storing text on paper, if printing and storage shelf/cabinet costs are counted (around \$15 per megabyte). Paper is even likely to lose most of its

advantage for graphics storage within the decade, since magnetic recording promises a further increase in storage density of at least 15 to 30 times the present one.

Interestingly enough, disk prices have fallen considerably faster than the price of semiconductor memory. In 1985 the price for one megabyte of disk storage was about \$30, or about 10% of the price for a megabyte in chips. Today, as noted earlier, disk storage costs about 1% of semiconductor memory, and over the last two years prices have started to fall even faster than projected. If this new trend holds for the rest of the decade, disk storage will become "almost free" at the turn of the century, at less than one cent per megabyte.¹³ Five years later, the price will be only a tenth of that again. Even better performers for very high-volume storage are in development—one among them is in commercial use already (optical disks) and is one upcoming (holographic storage).

When optical disks were first introduced in the early 1980s, they were predicted to the place of magnetic ones, because their potential storage densities were one to two orders of magnitude larger than for (then) existing magnetic disks. But, whereas optical disks have shown a fairly slow rate of improvement, magnetic disks have, as we have seen, improved their price/performance ratio at the same blistering rate as memory chips. Optical disks still pack data more densely than magnetic disks, however, and will probably continue to do so. They also have the advantage of being removable—the disks themselves can be taken out of the drives for transport or safe storage. Another advantage for the CD-ROM and write-once disks is their archival properties—conservative estimates are that they will retain their data uncorrupted for at least 60 to 100 years (Harvey 1990). All magnetic media lose their data gradually over the years and must be refreshed from time to time (tapes in archives are usually refreshed every two or three years).

Optical disks come in several varieties. CD-ROM disks are much like the CD audio disks we have now gotten used to. The information is imprinted on the disk in a factory, and it can only be read. It is perfect for distributing large amounts of data (one disk can hold about 500 megabytes, or about 170,000 pages like this one). Write-once disks are written by burning small holes in a substrate on the disk with a tiny laser. They can be written only once and then read as often as necessary. Rewriteable optical disks combine optical and magnetic technology, and achieve storage densities on par with other optical disks. They can be written, erased, and read many times, just like a conventional magnetic disk.

Commercial optical media range in capacity from about 500 MB to 2 GB. For archival storage with on-line access, optical disk "jukeboxes" or "silos" are far superior to other solutions. They consist of a number of drives, a stack of disks,

¹³ Some of the same reservations I expressed about chip development are of course valid for disks as well. But since there are more producers of disks than of memory chips, and the investment needed for a production line is lower, prices have tended not to stray much from the expected curve. Disk capacity and prices have followed smooth curves for the last 13 years at least (I do not have sufficient data earlier than 1983), and the predictions should be accurate within a factor of less than two—that is, according to the established trend the price should be between 1.5 and 6 cents per megabyte storage space in the year 2000. However, we are already inside that interval—and if the new trend continues, year 2000 prices may well end within the 0.4 to 1.6 cents range.

and a mechanism for retrieving and mounting the disks. The largest units are about twice the size of a large refrigerator and can store more than a terabyte of data. Mounting time for disks in such units vary from 10 to 20 seconds, which means that a user never needs to be more than 30 seconds away from any data item in archival storage.

Optical drives are somewhat more expensive than their magnetic counterparts, but, because the disks are removable, they are cheaper when it comes to storing large amounts of data and are gaining ground wherever there is a need to store unalterable data for prolonged periods of time. Write-once disks store data for less than 10 cents per megabyte (disks only), CD-ROMs for one-fifth to one-tenth of that. CD-ROMs packed with data sell for about \$25 and up, and the price is determined almost solely by the price of the contained information. They have already become a very important medium for the distribution of large amounts of information. CD-ROM drives now cost from \$100 and upward, about the price of a good floppy drive. Current development work on multilevel CD-ROMs are expected to push their capacity into several gigabytes.

Among the more exciting developments in data storage today is the holographic storage of information in light-sensitive crystals. This holds the promise of a possible revolution in storage, as opposed to the evolution (although rapid) of other, "traditional" storage technologies. Although progress has proved to be slower than anticipated (Parish 1990, Baran 1991, Psaltis and Mok 1995, Thompson 1996), the first commercial products are underway, helped by recent advances in laser technology, camera CCD-chips, and crystal manufacturing. Current prototypes store several hundred megabytes in crystals the size of a sugar cube, and commercial systems with a capacity of 100 gigabytes¹⁴ are targeted for development (Psaltis and Mok 1995).

Just as astounding as holographic storage's density is its speed. Prototype write speeds, at 8 MB per second, already exceeds the performance of magnetic disks, and read times are a hundred times faster (800 MB per second¹⁵). In theory it should be possible to read as much as 100 GB, the equivalent of 37 million pages like this one, in just one-tenth of a second. Even if such staggering speeds will never be reached, and it will take many years to perfect holographic storage, it shows that there are indeed new technologies underway that will at least let us continue the pace of development that we have seen so far into the foreseeable future.

All of the mass storage technologies surveyed here promise to deliver abundant capacity at very low prices within the end of this decade, including

¹⁴ To give you an idea of just how much information 100 gigabytes—100 billion bytes — represents, an average 300-page book contains around 875 kilobytes of text and weighs about two-thirds of a kilo. A terabyte of text would fill 115,400 such books, weighing about 77 tons!

¹⁵ It may seem strange that writing to this memory device is so much slower than reading. The reason is that the write process involves forming an image of each "page" of data, and the speed of the image-forming technology of today therefore becomes the limiting factor—faster image forming will directly increase write speed by the same amount. Reading the stored image by the use of charge-coupled devices (the same technology as used by today's solid-state home video camcorders) is much faster. Bellcore reports recent successes with microscopic, chip-based laser arrays, however, that promise to increase the write speeds to the same level as the read speeds projected by the MCC team.

storage and real-time playback of high-definition video movies. This will mean that digital storage media will become the most economical and compact alternative for *all types of information storage*. As Nicholas Negroponte has pointed out (Negroponte 1995), this will put a significant pressure on the traditional media and possibly reduce their roles considerably.

Communication

Communication, as denoted here, is a many-sided thing. Some may puzzle over the fact that I include both input and output of data under the heading “communication.” One reason is that input and output constitute a kind of communication, a case of information transfer. More important, input and output will increasingly include direct data capture from sensors, data interchange through common database access and messaging between computers. That way, they become inseparable from communication. But let us start with the basics.

Basic Input

For any piece of data to be processed, it must of course be loaded into the computer along with the pertinent programs. Loading the first computers was no mean task, involving punch cards, paper tapes, and even toggle switches. Punch cards were in fact widely used up through the 1970s, also for programs. Programs are today normally loaded from disks or tapes of various kinds; data are originally either keyed in, received from other systems (treated later in “Computer-Mediated Communication”) or captured directly from sensors. Data can of course also be generated internally in the computer as a result of transformations or processing of original data. Once registered, data is stored in a mass storage device like those discussed earlier.

Keyboards have been with us for a long time and have not changed much since the *qwerty* keyboard was devised a hundred years ago—with the explicit goal of lowering typing speed sufficiently to prevent the type arms of the newly invented typewriters from colliding and getting stuck! This shows us, by the way, the enormous inertia of established standards. Although more efficient keyboard layouts have been devised (for instance, the Dvorak keyboard), it seems that the old standard is going to dominate the coming decade as well. And keyboards are still our main instrument for communicating with computers, even if there has been much talk about machine recognition of speech and handwriting. Both are available in limited forms today, but are not yet practical in mainstream applications. Reliable, commercial speech recognition equipment still requires training (the intended user must pronounce the words a few times to establish the pattern to be recognized), and the vocabularies are limited. Most handwriting recognition software still requires the user to write in capital letters, and with considerable precision. Recent demonstrations of pilot systems that seem to recognize normal handwriting raise the possibility of a breakthrough in the next few years, but it is too early to assess the systems’ real-life capabilities.

The problem is that both speech and handwriting recognition belong to the difficult field of pattern recognition, where humans excel and machines are

ineffectual. Reliable recognition of continuous speech with normal vocabularies from arbitrary persons is exceedingly difficult for a computer, and will require both more sophisticated software and a lot more powerful hardware than presently available. Recognition of natural, flowing handwriting from arbitrary persons is even more difficult, and will probably take more time to solve than speech recognition—which will probably come a long way toward a general solution before the turn of the century. Whether speech recognition will succeed in the marketplace is open to conjecture, but if we really want to talk to our PCs instead of tapping keyboards, I think we will get that option for a reasonable cost sometime around the year 2000. General handwriting recognition is more in the blue, and it is difficult to say if it will meet with success outside a number of niche markets—especially if general speech recognition becomes an affordable reality. However, it may be a preferable interface for editing and making corrections in text entered by dictation or by keyboard.

Direct data capture by way of sensors is rapidly becoming more important, however. It is no longer only a question of lab data or temperature and pressure in processing plants. Increasingly, our shopping is registered automatically by light pens or label scanners, payments (for goods, bus tickets, and pay phones) initiated by card readers communicating with smartcards, toll road passage certified by machines reading chips glued to a car's windshield, and so on. Because of the huge savings in labor hours it normally represents, there is a very strong impetus for increasing the extent of automatic data capture, and we will see even more of it in the future.

Basic Output

Printing

ENIAC communicated by punching cards. Its successors rapidly learned to address their users through screens and teletype printers. Printing became the method of choice, a form of output that could be produced with maximum efficiency and allow the user to read at his leisure without tying up precious processor capacity. When processors became less costly and more powerful, and users more craving for the direct responses of interactive computing, screens became increasingly important, and are today the predominant medium for communication between computers and their users. Printing is still very important, however, and paper is still the preferred medium for final output and presentation. The main reason for this is the inadequacy of present screen technologies, which we will return to in a moment.

Let us first consider printing, a mundane activity that was revolutionized during the 1980s through the development of the low-cost laser printer. Laser printing allows for complete freedom in the use of graphics and different fonts, combined with the printing speed of a copying machine.¹⁶ Combined with

¹⁶This is no coincidence, since the printing engine of any laser printer is the functional equivalent of the printing unit of a modern office (xerographic) copying machine. The sole difference is that, whereas a copying machine prints the picture projected onto the printing drum by the optical system under the glass upon which you put your original, a laser printer prints the picture the laser beam "paints" on the drum. Printers using LEDs, LCD shutters or even ion beams to paint the picture are also often (mistakenly) called laser printers—and

modern word processing software, it gives the average user the ability to routinely produce documents with a finish that required expensive typesetting and offset printing as recently as 1980. Such capabilities can today be had for considerably less than \$1000, and for those of us who remember the clattering one-page-per-minute typewheel printers of yesteryear, even the humblest laser printer represents an incredible improvement.

The main deficiency in printing today is the lack of color—or, more correctly, the price of color. Color printing with a quality that is increasingly comparable to the black-and-white output of laser printers is indeed available, but it is yet too expensive to be widely used. There is no doubt, however, that the price/performance equation even in this field will improve to the point where high-quality color printing becomes economically attractive for “the rest of us.” There is, moreover, a clear tendency toward the development of digital color copiers¹⁷ that can function as both printers and scanners, providing us with a really versatile tool for the acquisition, manipulation, and presentation of text and pictures.

There are several competing technologies involved in color printing. It is not yet clear which one will dominate when the market matures, but the outcome seems quite clear: Color printing in the 1990s will go the way laser printing went in the 1980s. It is tempting to assert that black-and-white printing will always be considerably cheaper, but it is really a matter of where the volume will be. Color is of course intrinsically more complicated than B&W and should therefore invariably cost more, but in a mass market, it does not always turn out that way. Consider photography: Even if color film and prints are intrinsically more expensive than B&W, color costs (a lot) less for the average consumer today—simply because all the big consumer-oriented labs only do color, thereby reducing B&W prints to handicraft work produced by your local photographer. So we will have to wait and see—market penetration will decide.

Remote Printing

Printing also has a communicative side. The fax machine has been a runaway success the last ten years and has so far completely outstripped any and all attempts to establish comprehensive, public, international electronic mail networks. The reasons are obvious: It is low-cost and very easy to use; utilizes existing telephone connections (and thereby addressing conventions); transmits the output from any program and printer, including one's *pen*; and accepts graphics as well as text. Electronic mail will definitely win in the long run (more about email later), but the fax machine is, at our present level of technological sophistication, a very simple and elegant solution to the ever-increasing thirst for rapid communications. The recent proliferation of fax-capable modems and PC-

understandably so, since the average, nontechnical user would not know what an “LCD-printer” or “ion-beam printer” is.

¹⁷ A digital copier does not project the picture to be copied directly onto the printing drum. Instead, it scans it, today most often at a resolution of 300 dots per inch (12 dots per millimeter), and then “paints” the picture on the printing drum with a laser beam, just like a laser printer. The advantages are that it gives improved rendition of half-tones, the picture can be edited and enhanced in different ways, and the copier can also serve as a printer and scanner—and even as a fax machine, if properly equipped.

based fax software has to a large extent made the PC-fax functionally equivalent to a printer: the fax-modem appears on the printer menu and can be chosen as the current printer, speeding the output from a PC as easily to a fax machine on the other side of the globe as to the printer in the next room. From the receiving fax machine, it will appear with the same layout, the same typefaces, and the same graphics as if printed on a local printer.

If the receiving machine is a plain paper fax machine, the output will appear on normal paper, looking almost as if printed locally. We may term this *remote printing*—denoting printing over local- and wide-area networks, as well as via the public telephone network. Until screens supersede paper as the main medium for information presentation, remote printing will enjoy great popularity—and severely reduce the volume of ordinary first-class business mail. This will become even more true if color printing takes off, since the increased bandwidth of ISDN and especially ATM¹⁸ will easily accommodate color remote printing, allowing any fancy letterhead to be faithfully reproduced at the receiving end.

If remote printing by computer-fax becomes really widespread, the next natural step will be to eliminate the detour via paper and present the documents directly as a picture on a screen at the receiving end—screen-fax, we could call it. This is done already in some instances, but is used only for short messages and memos, due to the deficiencies of the present screen technology. However, it is already being eclipsed by email, which is now rapidly being standardized as a consequence of the phenomenal growth in the use of Internet.

Screens

In the preceding section I asserted that the screen technology available today is inadequate and the main reason that we still rely so heavily on paper. Whereas all the other vital parts of a computer system have enjoyed a very rapid and sustained increase in performance, screen development has been sluggish. One of the reasons is of course that CRT screens,¹⁹ the face of standard computer terminals and PC monitors, are a main part of commercial television sets, and the manufacturing techniques had therefore traveled a considerable distance along the learning curve before the product entered the computer business. It is now apparently approaching the limits of its potential, but other technologies are slow to take over. The exception is portable computers, CRTs are impossible to use because of their bulk, weight, and power consumption, and LCD²⁰ screens have become standard.

To do away with paper, we need screens that are large enough to show us a lot of information simultaneously, so we can work the way we are used to—with several information sources available concurrently. The screens must have good contrast and high resolution and provide a comfortable position for reading.

¹⁸ Integrated Services Digital Network and Asynchronous Transfer Mode, respectively. The public telephone networks of most industrialized countries will be upgraded to ISDN standard during the 1990s, allowing higher transfer rates for computer-based communications. There is now also a development towards ATM as a commercial product, promising transfer rates several orders of magnitude greater than standard ISDN.

¹⁹ Cathode ray tube.

²⁰ Liquid crystal display.

Preferably, the viewing position should be easy to change, to let us keep our normal habit of shifting back and forth between positions when reading a report or a book. CRTs cannot fulfill this. True, they have high resolution (but not that much higher than 20 or even 40 years ago) and good contrast, they can display any hue of color, and they are fairly cheap—as long as they are kept small. But they are bulky, and, if large, extremely bulky as well as expensive. A 21" monitor weighs around 30 kilos, and, like any other monitor, sits on the table facing you—while information is most comfortable to look at when resting almost flat on your desktop or in your lap. A 21" inch monitor will also cost many times the price of a 15" (\$2000–3000 versus \$ 250–400), and is actually still too small. What we really need is one-meter screens or larger—flat screens that are part of our desktops, preferably tiltable, and possibly with a detachable panel for comfortable reading. With an adequate resolution and contrast, screens like that would really take a bite out of the paper market—we would not need printouts to proofread, we could distribute documents electronically via networks or floppies (or other removable mass storage media), and the receiver might prefer to view the information on his or her screen instead of printing it out. Even the hour of the CD-ROM-based magazine might finally come, and the fax machine would at last feel the competition of screen-fax and/or global electronic mail.

Unfortunately, such screens will not be available for a number of years. There are potential technologies available, but they will need considerable time to achieve the sizes and prices necessary. Most promising are LCD panels, electroluminescence, and field-emission displays.²¹ Recently, interesting advances have been made in the field of electrophoretic particles (microencapsulated particles that can be flipped by an electric field), raising hopes of screens as thin as sheets of paper with the same contrast and viewing angles as a printed page (Chinnock 1997).

Whether or not we will see large desk screens in wide use within the coming decade is still impossible to tell, it depends on the progress of these new technologies. Salvation by the sudden emergence of a new, rapidly deployable technology is not likely, since the development of a totally new technology into a mature commercial product normally takes more than a decade. In the meantime, however, we will have to make do with conventional technology, and we can expect large CRTs to decrease somewhat in price. Already, 17" displays are emerging as a new standard for professional use, and the continuing fall in the price of graphic processors are making high-resolution graphics a lot cheaper. It remains to be seen whether this will be a development sufficient to eliminate parts of the paper mountain, but I think there is a chance that we may at least see the beginning of a change.

²¹ Field-emission displays (FEDs) have not attracted much attention, but this is a potentially very interesting technology (Baran 1991b). It builds on many of the same principles as the conventional CRT, but instead of the CRT's single-electron cannon "painting" the picture on the phosphorus-covered inside of a large, evacuated glass tube, the FED has several microscopic electron emitters per pixel (or, point on the screen), sending their electrons across an evacuated gap of only 0.1 millimeter between the base plate and the phosphorus-covered, flat glass screen. FEDs promise thin, flat screens with high resolution, color, good contrast, low power consumption, and good manufacturability. The last point is not least important, since large LCDs are notoriously difficult to manufacture, especially color LCDs.

Telephones and Videophones

In an earlier discussion of the way technology has enhanced communication, we touched upon both the telephone and video-based communication. The further development of both has for many years depended on microelectronics and computer technology. Telephone switching has already become a task for specialized computers (digital switches), telephones themselves are increasingly chip-based, cellular phones are crammed with microelectronics, and the whole transmission system is now in the midst of a change from analog to digital signaling (ISDN and ATM²²). There is also a movement toward one or a few digital standards for cellular telephones, which means that, at least in Europe, there will be a truly international network in place around the turn of the century, allowing the owner of a GSM-standard cellular phone to place and receive calls from his own set regardless of which country he or she is in.

Other developments in telephony are voice mail and the self-service switchboard. Voice mail is really only an auditive parallel to email: You can leave messages for someone who is not at his desk or otherwise busy, and he can retrieve the messages when he likes. In this respect, it functions just like an answering machine. But you can also distribute your voice message automatically to any number of people connected to the system, just like when using email. The self-service switchboard represents an attempt to automate switching, access control, and simple direction-giving.

The limiting factor for video telephones and video conferencing has been the excessive cost associated with the high-capacity lines needed for the transmission of live video. Considerable progress has been made in compressing video signals, however, and we are now close to achieving acceptable, slow-frame color video transmission over a standard ISDN channel.²³ New compression techniques (based on fractal mathematics) may improve video transmission further, but will have to await sufficiently fast processors.²⁴ However, ATM may reduce the need for elaborate compression schemes, since it will allow transfer rates in copper cables well above the requirements of high-quality video transmissions²⁵ even with today's compression techniques.

²² ISDN stands for Integrated Digital Services Network, ATM for Asynchronous Transfer Mode. ATM is a second-generation standard for digital communication that will allow transfer rates several orders of magnitude greater than ISDN. ATM is already available on a limited basis in many countries and is expected to supersede ISDN fairly early in the next century.

²³ The standard capacity for a subscriber channel in an ISDN network will be 64 kilobits per second, or the equivalent of 8000 characters per second. Two or more channels may be "lashed" together to provide greater capacity. Standard modems today (1996) achieve a transmission speed of 14.4 to 19.2 kilobits per second over the (presently analog) telephone network. Advanced modems achieve 34 kilobit/s or even higher. Data compression schemes may increase the amount of data actually transferred but do not change the basic bit transfer rate.

²⁴ Real-time decompression at the rate of 30 frames per second is possible already, but fractal compression of live video is extremely computation-intensive and cannot be done in real time yet—not even with specialized processors. Proponents of fractal compression expect this to change during the coming decade, however.

²⁵ Standards for ATM connections are defined from 2 megabit (Mbit) and upward, and can use copper as well as optical fiber cable. The attainable capacity over copper cable depends on the cable quality and the distance to the switch. ATM technology can already deliver 155 Mbit in local area networks for distances up to 100 meters. Uncompressed, live video requires about

In a growing number of countries, ATM is already available for larger customers in selected areas, and coverage is growing. It is difficult to forecast the speed of development in this area, but it already seems quite safe to predict that ATM will become a commercially interesting alternative for most organizations within a decade or two. *This means that high-quality video conferencing is bound to become available at affordable prices, even before the public telephone networks are fully rewired with optical fiber into every home and organization.*

The days when we seriously considered the need versus the cost before placing an intercontinental telephone are by and large gone already, and the same thing will happen with computer-based communication. Combined video and computer conferencing—with simultaneous viewing of screens and exchange of comments and data—will be cheap enough to allow widespread use. It is difficult to say when the prices will come down to acceptable levels, but it is bound to happen, probably in the first decade of the next century.

Computer-Mediated Communication

Electronic Mail and Computer Conferencing

In addition to remote printing and the improvements of telephones and video, the computer has also given us a whole new medium: the combination of *electronic mail* and *computer conferencing*. The two are really just variations of the same basic capability, namely, the computer's capacity to store and forward messages. A piece of electronic mail is directed toward to one person or a defined set of persons, while a contribution to a conference is put in the public domain of that conference, allowing all participants to read it. It remains in storage or is deleted at the discretion of the conference moderator. An electronic bulletin board is thus essentially a conference.

Both mail and conference systems operate in the same way: From your terminal or PC you can enter and retrieve messages and files to/from a database residing on either a local machine or a remote one, accessed via public or private networks. In the case of email, the database will be called a *mail server* and will either store your message (if it is intended for a local receiver) or send it along across a wider network (such as the Internet) toward the recipient's mail server. The electronic nature of the transfer means that it is almost instant (if the volume is not very large), regardless of the distance. The fact that it is stored in a database also means that the receiver does not need to be on-line: He or she can access the database and retrieve messages when it is convenient. Electronic mail thus represents a cross between the letter and the telephone, a medium for instant, yet asynchronous information exchange.

Up to now, email has suffered because of a lack of standardization regarding address formats, message formats, character encoding, and the mechanisms for attaching files to messages. As late as in the early 1990s, the process of standardization seemed slow. Now the phenomenal growth in Internet use is rapidly establishing *de facto* standards in all these areas. There are still problems,

140 Mbit, and with today's compression technology, 2 Mbit is sufficient for good quality video conferencing. ATM technology can already deliver 155 Mbit in local area networks for distances up to 100 meters.

but the market pressure on the vendors has increased dramatically, and those who want to survive in the marketplace must converge toward a common set of solutions fairly rapidly, because the users will flock to the solution that ensures them the most painless communication. We can expect a dramatic increase in the use of email in the coming years, and the use of file attachments will become a viable alternative to fax and remote printing.

Shared Data and Messaging

As noted earlier, automatic or semiautomatic communication mediated by computer systems will play an increasing role in our use of information technology. It will involve applications running on the same machine as well as communication between systems residing on different computers. It is nothing new in principle; as mentioned in Appendix B, the SAGE computers (the core of the American early warning radar system) were already linked when they were deployed in the late 1950s, and the modern concept of networked computers was developed in the last half of the 1960s. Establishing contact on the basic level is one thing, however. Sending files or terminal traffic back and forth (making applications “speak” to each other) is something quite different—even when they reside on the same physical machine. The fact that two applications are running on the same computer does not necessarily mean that they can share data in any meaningful way.

Basically, information interchange can be effected in two different ways: Either you can share the data among applications and tasks by common database access (by common physical database, by common database format, or by help of translator programs bridging different formats), or you can have the applications send messages to each other. The common database approach is really the computerized parallel of the concept of the *active file*, described in Chapter 6—a unified collection of organized information for administrative purposes. (As such, it can be argued that it does not belong under the heading “Communication.” It is treated here because of the communicative aspect of the way it relays information between applications. In Chapter 9, when we discuss how the information technology modifies the preconditions for organizing, this aspect of storage will again be brought back to the discussion of memory.)

The common database is often the natural solution inside an organization, or at any rate for those parts of an organization that have to work intimately together. The messaging concept will most likely be the right answer for communication between organizations and between various parts of a large organization, where shared databases are not a convenient solution.

Common database access means that information captured or keyed into one application or task module²⁶ can be accessed, processed, and presented by other applications or modules. Data registered through a production control system, for

²⁶ The boundaries of applications tend to follow the boundaries between task clusters in the traditional organization—general ledger, for instance, or order entry, inventory control, or payroll. The different applications in their turn consist of a number of task-oriented modules, usually organized around specific screens. The modules can in many ways be viewed as applications within the application, and in less traditional future systems, they will probably be grouped differently (and quite a number of them may even be eliminated). The distinction is therefore somewhat arbitrary.

instance, are immediately available for the sales support system, keeping sales representatives continually updated on the status of individual orders. The same data can be directly utilized by an inventory control system (ordering replenishments for parts or raw materials that are running low), and a transport scheduling system (supporting the shipment of finished products). An order entry system may in its turn supply input data for the production control system, possibly by way of a separate or integrated system for production planning and scheduling. An executive information system may cull data from all of the various systems, presenting a coherent and continuously updated picture of the main activities in the organization.

This is not yet a description of the common situation in user organizations,²⁷ but it should gradually become so. Common database access is bound to become a cornerstone in administrative computing. Going external, however, messaging becomes necessary, and message transmittal in the form of automatic data transfer irrespective of application or computer type is not trivial. It is not necessary here to describe the many layers of communication protocols needed, but I will point out that communication on the application level requires a considerable amount of standardization, both between vendors (equipment and software) and between users (data formats). If an order is to be dispatched automatically by a inventory control system and directly received and processed by an order entry system in another company (running on a computer from a different and incompatible vendor), even the number and definition of the data fields, as well as their size and content must follow strict standards—otherwise, the receiving computer may mistake an order number for an amount to be shipped, and the name of an article for a company address. Such standardized definitions must be established for all the different types of “documents” required.

This standardization is really what such messaging, or *electronic data interchange* (EDI) is all about. Several standards have been created through the years—national standards, industry standards, and even company-based standards (large companies are able to dictate their suppliers and strongly influence their customers)—although none of them have been really comprehensive. Today, there is a broad effort underway to create a truly international standard—or, rather, set of standards—for commercial applications. The work is carried out under the auspices of the United Nations. The UN/EDIFACT²⁸ effort aims at establishing a definite international standard for all main types of documents used in international business, regardless of industry. It has been underway for a number of years; the first standards have already emerged, and more will follow in the years to come. There is also work underway on standardization of drawings and graphics, an important area for the manufacturing industry. Creating standards involving so many nations, agencies, and industry associations is indeed a promethean effort, and it is destined to take

²⁷ In most organizations the various systems (and few organizations will have systems in all these areas) will most likely be of different origin, use different databases and formats, and even run on incompatible machines from different vendors. In some industries (notably, the automobile industry), integration has become fairly advanced, but, even there, much improvement is needed.

²⁸ United Nations Electronic Data Interchange for Administration, Commerce, and Transport.

a long time to complete.²⁹ The rewards for its accomplishment are so great for all parties involved, however, that it is also an effort destined for ultimate success.

In addition to this basic standard, we can expect supplemental conventions to develop at many levels—within organizations and between trading partners and manufacturers and their suppliers. The net result will be a lot less keying in of information,³⁰ with concomitant savings in labor hours. The consequences may prove much more profound than simple savings, however, a subject we will return to in later chapters.

The Escape from Paper

In Chapter 6 we discussed the transition from orality to literacy, and the fundamental changes it wrought both in our way of thinking and in our intellectual and material development. But, in addition to style and form, writing also brought us a physical format for information presentation. The written word is a material product with both design and packaging. Both have an interesting history, which we unfortunately cannot detail here. Suffice it to say that after centuries and even millennia of tablets, scrolls, and various other formats, the sheet and the book gradually became the preferred solutions. Sheets are easier to manufacture than scrolls, and books have the advantage of being random access devices—you can open them on any page.

That sheet of paper, the page, has been with us ever since, and it is today the paramount setting for all kinds of information: Almost everything has to fit a page. Even as I write this, a thin dotted line appears on my computer display, telling me that I have reached the end of the current page—yet there is no such thing as a “page” in a computer text file. The creators of my word processor, however, knew full well that the intended product of my keyboard efforts would be reams of pages from the laser printer down the hall, and therefore provided me with that unobtrusive cue to help me with my formatting.

In the beginning, computers were not at all slaves of the paper paradigm, but as soon as printers entered the scene, their output was brought under page control. Even the computer screens were at the outset no more than print displays, a more convenient way for operators to receive messages from the computer and control their own input. Indeed, early VDUs³¹ were dubbed “glass teletypes,” signifying that they did little more than display what would otherwise have been printed on the teletype printer.

Even if it has an interactive nature and can display varied information, the traditional computer screen is treated largely as “reusable paper”—information is displayed in an orderly, serial format that resembles a paper-based presentation as much as possible. For office support systems (such as word processing, spreadsheets, presentation graphics, and report generators for extraction and presentation of database contents), the ideal has always been to make the screen

²⁹ Indeed, it will never be completed—there will always crop up needs for alterations and new standards. But the main groundwork and the standardization of the main document groups are well underway.

³⁰ It is estimated that about 70% of the information keyed into a computer today has already been registered in another one (Thorud et al. 1991).

³¹ Video display unit.

look as identical to the prospective paper output as possible, even to the extent that black letters on a white background are preferred, like a sheet of paper—in spite of the fact that this combination is not necessarily ergonomically preferable.³² The reason paper is white and print is black, by the way, is simply one of convenience and tradition: All papers and paper-like materials (such as papyrus and parchment) have natural light, whitish colors (ranging from yellow or gray to white), and it is also far easier to make dark inks that cover light surfaces well than white ink that will cover dark surfaces satisfactorily.

The paper paradigm can be traced further in software design, from the on-screen, visual index cards of archiving systems and simple databases, to the drawers, folders and documents presented by the latest in office support systems. The reasons are twofold: First, most of what we compose on the screen is finally destined for output on paper, and must therefore be designed to fit the page format produced by the printer. Second, the software designers all seem to think that the friendliest computer is the one that provides the user with an emulation of his or her paper-based past, and thus attunes itself to the user's established mental set for office work.

This is obviously a legacy of the past, but how could it be otherwise? As both Ong (1982) and Havelock (1986) note, it takes an oral culture generations to pass from an oral form of expression (with formulaic style for mnemonic purposes) to a truly native, literate (chirographic, written) style. We have more than 5000 years of chirographic tradition behind us,³³ and with less than 50 years of computer experience (with only about twenty on any significant scale), we are doomed to mimic the past—we need time to adjust, to enter into a working relationship with the new technology, to iterate our way toward more computerate manners. As the systems become more powerful, however, and (not least) the screens bigger and more comfortable to read from, things are bound to change. Indeed, we can already see the first portents in actual systems and in laboratories.

The evolvment away from the paper paradigm can be illustrated with three generations of user interfaces. The first one, which we are now leaving, is the character-based interface. The next, which is now ascending, is the graphical window environment. The third is an experimental design, so far in the laboratory stage.

The *character-based* user interface should be familiar to most computer users—except perhaps the latest generation. In its basic form, it is a command interface, where the computer exhibits some kind of prompt to show that it is ready to accept commands. You then type in your command, and press the return button for execution. It is a thoroughly chirographic interface, even (as is often the case)

³² Research done by professor Ivar Lie at the Laboratory for Optometry and Visual Neuropsychology at the Psychological Institute of the University in Oslo has shown that there are individual preferences, probably rooted in physiological variations in the eyes. Some people are more strained by positive contrast, some by negative. The differences in strain are both subjective (as perceived by the research subjects) and objective (measured as changes in eye muscle capacity).

³³ According to Ong (1982), Sumerian cuneiform writing, the first system of writing we know of, dates to about 3500 B.C. Egyptian hieroglyphs date back to 3000 B.C., Indus Valley script to 3000–2400 B.C., Chinese to 1500 B.C., Minoan or Mycenaean to 1200 B.C., Greek to 650–700 B.C. (Havelock 1986), Mayan to 50 A.D., and Aztec to 1400 A.D. (Ong 1982).

when it is amended by a menu structure—essentially a list of command options that you can choose between, either by typing the full command or a number, or by moving the cursor to the desired menu item. You then press the enter (return) button to execute. The analogy between the computer menu and the printed menu, list, table of contents or index is obvious. Most applications in such an environment will use the same format, essentially presenting information in typewritten script on your reusable glass “page.”

The *graphical, windowing* interfaces, which are now rapidly supplanting the character-based interfaces, differ from them in several aspects. The most obvious difference is the graphics itself—the fancy fonts, the cute symbols (“icons”), the pull-down or pop-up menus, the dialogue boxes, and buttons.

The windowing environment represents both the ultimate in paper mimicry and the first serious departure from the paper paradigm. On the paper side, it still retains the page—a window is usually only a window opened to a page with information formatted as if on paper. You can scale the window, but generally not the information within it—the text or graphics will not shrink or grow; only the area you see. You can stack or tile windows, but their contents live their separate lives as separate “pages.” The command interface still contains many lists (pop-up or pull-down menus, file lists, font lists, etc.), laid out in traditional fashion. The application formats (for calendars, databases, word processors) mimic their paper equivalents as closely as possible (which is pretty close, thanks to steadily improving graphics). These are in fact the least radical properties of the windowing systems, even though they often attract the most attention.

But there are more groundbreaking features to be found. Some of the controls are distinctly nonpaper, for instance, the buttons and the sliding controls used for positioning and the mixing of color. Even if they are borrowed from well-known mechanical and electrical appliances and thus do not represent “native” computer innovations, they show us that the computer can do more than simulate pen and paper. More exciting still are the developments in the direction of object orientation, hypermedia, and “hot links” between applications. Object orientation allows you to treat chunks of information as entities separate from the applications that created them (if you want to modify the information, it will call the application automatically). Separate chunks may be fused in objects of a higher order (still called “documents”).

A higher-order object consisting of chunks of text, spreadsheets, and graphics is nevertheless little more than a compound document, a collection of pages containing some text, some numbers, and some drawings, and it will still print neatly. The next step is that the information in the various chunks that make it up consist not of the information itself, but merely of pointers to where the information is stored. When that source information is modified, the modification will also automatically apply to the compound document. Since several compound documents may contain pointers to the same information, a single update may modify a large number of compound documents. They will still print without problems, but version control now becomes more important.

Consider, then, the possibility that the link is made conditional—like an electronic footnote. A word, a picture, or a table can be marked as a button, and when you activate that button, the link will come to life and retrieve the supplementary information. This is the basic idea of “hypermedia.” A “document”

with such buttons would be harder to print, but it could still be done, if it were acceptable to convert the buttons to footnote markers and the supplementary information to footnotes. However, since the size limits commonly associated with footnotes are not a natural part of a screen-based hypermedia environment, the footnotes in the printed version might not conform to the expected format of a paper-based document.

But hypermedia goes further than this—it can be nested. The supplementary information can contain its own buttons, pointing to even more information, where you will find still more buttons, and so on. What hypermedia really is about, is a three-dimensional information structure where you can establish both factual (providing explanations or supplementary information) and associative links, building an information structure that will be totally unprintable. Some of the information chunks may consist of live video or sound, which is even less representable on paper.

The windowing interface is thus a product with a Janus face, straddling the fence between the old and the new. But there is no doubt which side is growing fastest, and there are undoubtedly a number of efforts underway to develop it further. The feverish activity going on in the Internet marketplace is perhaps the strongest force today, with much emphasis being placed on multimedia features. Less spectacular, but perhaps just as important for the future, are efforts such as the Information Visualizer project at Rank Xerox's research laboratories (Xerox PARC) in Palo Alto (Clarkson 1991)—the birthplace of the original graphical, windowing user interface.

An experimental interface like the Information Visualizer leaves the paper paradigm behind it for good, and explores the computer's ability to represent dynamic, three-dimensional objects. The overview screen does not present you with a paper or desktop metaphor, but with something more resembling a doll's house with the front wall removed. You peer into a number of rooms, each containing a number of three-dimensional objects. The rooms can represent your different main tasks or task clusters, or information clusters that you frequently need to access. If you are a salesperson, for instance, a room may represent either a task or task cluster—such as obtaining new leads or putting together next year's sales targets and budget—or all the tasks and information connected with a major customer. The objects in the room represent the tasks and information and are miniature views of the actual information representations. If you choose one particular room, you can zoom in and enlarge it to fill the whole screen.

Information in the rooms is displayed in two main formats and a host of auxiliary ones. All information of a hierarchical nature, such as a file directory structure or an organization chart, (or, conceivably, a hypermedia structure) is displayed as various forms of three-dimensional tree structures. The "trees" can be rotated, "twigs" and "branches" can be pruned and grown back; it is as if you could move around the tree and in between its branches. This way of visualizing complex hierarchical information really taps into the power of visual-processing ability, and gives one a much better comprehension of the information structure than any paper-based representation possibly could. It also allows surprising amounts of information to be presented on the screen. One of the trees referred to by Clarkson holds the first 650 nodes of the Xerox organization chart, an 80-page

document when printed on paper. Another tree displays the host computer's total directory structure, containing 10,000 files in 600 directories.

For linear information, such as a calendar, the Visualizer has an animated "Perspective Wall," sliding around two 120-degree (approximately) corners, with a "present" section directly facing you, and the future and the past receding into infinity from the corners to your right and left, respectively. Select an item anywhere on the wall, and it will slide to put it on the section facing you. The wall gives you a total view of any calendar, no matter how many years it covers, and will always give you most detail for the period closest to the date you have chosen. Its function for other types of linear information is similar. For information that do not fit into the hierarchical or linear mold, the Visualizer provides numerous other possibilities for information display. We do not know if the next commercially available generation of user interfaces will look exactly like this, but we can safely guess that they will contain an increasing number of elements that break with the paper paradigm for screen-based information presentation.

Future Information Representations

When really large, affordable screens with good reading comfort become available, all the technologies discussed here will experience a surge in development and demand. The new situation will even be felt in small details that are important in everyday work—such as the ability to choose the size of the letters when you read something. Reading from paper, you must adapt your vision to the letters printed there (if necessary, with glasses); when reading on a screen, particularly with highly graphical programs not meant for producing printed information, you have a choice. Two millimeters? Five? One inch? Just say the word—or even tell the system to read it aloud for you! By that time, it will be able to—with a voice of your choosing and without the hassle and extra equipment you need today.

Hypermedia

The previous sections outline some of the characteristics of hypermedia, describing the concept of conditional links. Links, however, can have many properties. They can be *bidirectional*, meaning that you can not only point to a reference like in a footnote, but you can also, from the reference, be able to trace all the works referring to it. The links can also have different granularities: A link can point to a book, paragraph, or word; a picture or a section of that picture (possibly even a single pixel); a passage in a piece of music (or even a single beat); and so on. There can also be different types of links, with different access levels, and you may be able to establish filters, showing you only the types of links you are interested in. A distributed hypermedia system could also have "document sensors" that constantly monitor documents or parts of documents, carrying out certain actions when triggered—for instance, notifying the original author if someone else updated a piece of information.

The idea of a hypermedia system was first presented by Vannevar Bush in his famous 1945 article about the Memex (Bush 1945). However, since the computer was yet in embryo, he was thinking about a microfilm system. The idea was brought into the computer world and matured into the mother of all hypermedia

systems by Theodor H. Nelson. His brainchild, the Xanadu hypermedia system, was designed with the idealistic goal in mind of providing an engine for a world-wide, instantaneous hypertext publishing network, in which the distributed databases would be connected through hypertext links (Nelson 1988). The idea was that Xanadu should enable the network to physically store a particular piece of information in only one location, while allowing it to be incorporated in any "document" on any server in the network via links. Despite the somewhat grandiose initial aim, Xanadu became a real piece of software, with 30 years of development work behind it. It never succeeded in the marketplace, but it was well-known and admired in the inner circles of the software community and can undoubtedly be nominated as the mother of all hypermedia systems.

Today, the baton has been handed off to the Internet's World Wide Web. The Web is simple compared to Xanadu, but the size of the amalgamated information bases you will find there is already staggering, and is growing every day. In principle, any word in a document or even any point in a graphic presentation stored on a server linked to the WWW can be connected to any other piece of information available similarly available, by hiding the address of the linked information behind that point. With an appropriate browser based on a graphical user interface such as Windows or the MacIntosh Finder, one can use a mouse and click through an almost infinite web of information. It does not have any of the advanced features of Xanadu, and the links must be manually maintained. However, it has made the task of searching for information on the Internet a lot easier, and it represents a first step on a very interesting road.

Advanced hypermedia systems will make it possible to establish "living" information bases, where revisions are automatically accessible to all links, and where the revisions themselves can trigger messages to all interested parties, who have referred to that information and may wish to revise some of their own documents. Full version control will be possible, and it will also be possible to backtrack all revisions and reconstruct the original document, if that is required. If write-only storage media are used, such a system will make it possible to operate without paper even in highly formal environments, such as government offices, because of the audit trail left in the system.

Multimedia

Multimedia has been touched upon earlier—it simply means mixing what we now perceive as separate media: paper-borne information, such as text, drawings and pictures; moving pictures, such as film, video recordings, and computer-generated animations; and sound (which is also a part of film), such as speech, music, and other recordings. The computer is increasingly able to deal with them all, and, in a couple of decades, they will become so native to the computer that we will cease to regard them as separate media—they will just represent different aspects of computer-based information.

Multimedia is only possible when we leave the paper paradigm, and it will therefore benefit greatly from the development in that direction. To really come into its own, it, too, will depend on the advances in display technology—even without paper, there will still be so much text around that affordable screens with good reading comfort will be necessary. Only when they arrive will the

multimedia compound document, the electronic magazine, and so forth really happen.

There are even more exotic alternatives on the horizon: Research has already started on the possibilities for holographic displays, allowing for three-dimensional representations. Work done at MIT's Media Lab (among others) indicates that it will be feasible some time in the future. If so, it will give an entirely new twist to video conferencing and make simulated presence almost as good as being there.

3D³⁴ Modeling and Simulation

Holographic displays would also add a new realism to the 3D CAD and modeling systems already in use in engineering, architecture, design, and science. These systems are also leaving the paper paradigm behind. Starting as drawing tools mimicking the original paper-based drawing process, they are now increasingly able to generate full-bodied three-dimensional models of the drawn objects—models that can be rotated, exploded, and enlarged to reveal detail. If the object is a house, the system may allow you to do a walk-through on screen, studying how the light flows through the windows and the effects of different forms of interior lighting schemes and color options. A model of a processing plant can reveal any conflict between the positions of various equipment, a very interesting property when planning, for instance, petrochemical plants, with their bewildering cobwebs of piping. The models on screen can now also be reproduced as physical models in what almost amounts to an "object printer," where a thin beam of UV light solidifies layer upon layer of polymer.³⁵

Computer models can in turn be animated, to simulate, for instance, production processes, thereby bringing the design process one step further. Numerical simulation is nothing new, of course: Even old ENIAC was involved in that. But when we leave the printouts behind and coordinating mechanism couple it with animated models showing the result of the simulations in real time, our comprehension of the outcomes is brought to an entirely new, more sophisticated level. Instead of struggling with reams of data, taxing our working memory to the limits and beyond trying to visualize the effects, animations can bring the vast capacity of our visual system into play, improving our understanding many times over.

³⁴ Three-dimensional. Simpler CAD-programs (computer-aided design) are two-dimensional; the more advanced allow three-dimensional construction and rendering as well.

³⁵ A platform is positioned just below the surface (about 0.5 millimeter) of a polymer bath. The UV beam, controlled by the computer system, draws the bottom layer of the model on the polymer surface, which solidifies when hit by the light, and adheres to the platform. The platform lowers 0.5 millimeter, the beam hardens the next layer, and so on until the model is completed.

The Structuring of Information

The Functional Approach

We noted above that the paper paradigm can be traced in software design through the way information is represented on the screen. But the matter runs deeper than that. If we look at how information has been structured both in storage and processing, we will find very strong influences from traditional administrative practices. After all, when computers entered the administrative scene in the early 1950s, mankind had been storing and structuring information in writing for about 5500 years. The protocol and the file were the established hallmarks of administration. During the previous 150 years, the world had seen the growth of modern organizations, routinely handling large amounts of information and conducting vast amounts of business and public transactions. The technology, methodology and mental sets for doing such work were firmly established. No wonder that the computers and the budding systems analysts and programmers were contained in that reigning paradigm. Just note the computer vocabulary: Computers still store their data in “files,” the collection of data belonging to one entity (such as a person) is called a “record,” and the individual pieces of information (such as date of birth or address) are located in “fields.” Information is located through “indexed” keys.

First of all, computer files came to mimic paper-based files and punch card equipment. When computers were first employed for administrative purposes, it was to replace large filing systems based on paper or punch cards, and they were designed and used more or less as electronic filing cabinets. Information items about a person or whatever entities the register dealt with were put in fields collected in records, which were direct descendants of the file card. One located a particular record through a *key* (normally, a name, address, or some kind of unique identification number), just as in a manual file.

The database was really nothing more than an elaboration of this scheme, allowing several indexes as well as pointers relating records through connecting fields. A database can be compared to a manual file with extensive cross-referencing, which is possible simply because the computer is so much faster at indexing and searching than humans. Early databases only allowed pre-determined pointers that were part of the application program code, and were thus extremely inflexible. In effect, they even required one to establish as part of the program specification all the report formats one would ever want—a hopeless task in a changing business environment.

You might, for instance, suddenly want to produce a report on the relationship between employee tenure and salary. If you had not envisaged that on beforehand, and the program did not already specify a relation between those two items, you would be in for trouble. To establish the new relation, you would have to modify the program code, and the old pointers and definitions could well be hidden within algorithms deep down in the program. That is why any functional change (including the creation of new reports) used to cost so much and carry the risk of creating new errors and inconsistencies. Later databases became more flexible, but at the price of more complex software and a much heavier work load for the computer.

The most flexible of the traditional databases is the relational database, which, in theory, allows any field to be linked to any other field whenever desired. It is, however, considerably more craving than the older databases when it comes to computing power, since, down below, it still has those old indexed files of records, now connected with a myriad of crisscrossing pointers, changing with changing requirements and very difficult to monitor.

As electronic filing cabinets, the computers fitted quite nicely into the existing routine structure. And, as programs evolved to support the routines themselves, it was just natural that they, too, were structured basically in the same way as traditional office work.

The main determinant for the structure of work is the way large tasks are broken down—decomposed—to the basic tasks people actually perform when they work. (As established in Chapter 2, the reason for having organizations in the first place is that we have to carry out tasks that are too large for any individual to complete alone—at least within a reasonable span of time.) In Chapter 7, we discussed the genesis of large-scale administration and concluded that the classical model for administration was molded on the mass-producing factory emerging in the second half of the nineteenth century, and reinforced by the characteristics of large, paper-based files. It prescribed functional specialization, fixed procedures, and detailed rules and regulations. Routine tasks were decomposed into separate steps or operations, similar to an assembly line, and often described in detailed manuals.

In a bank, for instance, an application for a loan would be handled in a very specific way, varying chiefly by the nature of the customer or the amount applied for. There would be rules for who would receive the application; register it; file it; obtain the required information from the customer's deposit accounts; check if he had other loans already, if the collateral offered was already mortgaged or not, if he had ever defaulted on other loans or payments; suggest a decision; confirm the decision; notify the customer; arrange for the appropriate mortgage bonds; and so on. Typically, the loan application would travel from person to person, each one of them adding some information or performing an operation. The job design was procedure oriented: It said who would do what to which piece of information and in which order.

Computer programs, following the well-trodden paths of 150 years of administrative work, were also viewed as procedures, decomposed into single steps of operation on the various data files. Systems people call this method for decomposition *functional* (Coad and Yourdon 1991) or *algorithmic* (Booch 1991), and the resulting design and programs *structured*. Another vital characteristic of this approach is the distinction between program and data. *Data* are viewed as given, something you analyze to design a fitting database—your filing system. The program contains the operations you want to perform on the data, and to design the program you analyze *functions*. Or, to use the language of systems theorists; traditional, structural analysis is based on the assumption that reality is composed of *entities* and their *states* on the one side, and *functions* on the other.

Functional or algorithmic decomposition and structured programming as a method was also reinforced by the very nature of the computers themselves, since they all complied with the basic scheme devised by John von Neumann in his

famous "Report on the EDVAC" in 1945.³⁶ A von Neumann machine (as all computers following his basic principles are called) is characterized by serial processing—it has *one* central processor, fetching and executing *one* instruction at a time. Almost all computers to date have been von Neumann machines, and even if computers based on parallel processing are now becoming more common (and will probably become very important in the course of the 1990s), von Neumann machines still dominate the computing scene—especially for administrative data processing. It is only within the domains of science, engineering, and the visual arts (such as fluid dynamics, aerodynamics, and picture processing, especially animation) that parallel architectures have really made any headway.

Because systems based on functional decomposition and structured design are built like trees of specialized routines, there is a great degree of interdependence between different parts of the system. Changes in one subroutine may require changes higher up in the system, which in their turn have consequences for many other subroutines. As such systems get larger, they therefore become very complex, and the interdependencies very difficult to keep track of—which means they also get increasingly difficult to change. However, the needs of the users always change over time and force modifications of the system. Since the cost for altering the main structure of a system based on functional decomposition is usually very high (it is often tantamount to developing a new system), changes tend to consist of ad hoc patches and additions crisscrossing the original logical structure. This further increases complexity and makes the system less and less comprehensible, until one reaches a point where it becomes unstable, because its procedural labyrinths are no longer fathomable. Changes may suddenly have unpredictable consequences in unexpected parts of the system, and one is faced with the choice of using it as it is without further changes, or discarding it completely to build a new one.

As mentioned in Chapter 7, similar ills may befall functionally specialized organizations. If we return to the example of the processing of loan applications, a change of organization in any of the departments involved may have consequences for the loan evaluation procedure. Conversely, an alteration of the applications procedure may require changes in several departments. Changes may therefore require supplemental routines and consequently increase the total complexity of the organization.

The Object-Oriented Approach

The complexity and inherent inflexibility of the systems built on functionally decomposed designs made reflective systems people look for ways to simplify things, and from their work grew the object-oriented approach mentioned earlier. It, too, has interesting parallels (and indeed forerunners) in the organization domain—such as the feudal type state and the divisionalized enterprise.

³⁶ EDVAC (Electronic Discrete Variable Computer) was the direct descendant of ENIAC and was also conceived as a project for the Army Ordnance Department—the same organization that financed the construction of ENIAC. The report was the first outline of a design for a stored-program computer, but the project had many delays, and EDVAC was not completed until 1952.

The underlying principles of the object-oriented approach to systems analysis and design are exactly the same as those applied to achieve maximum information economy in organization, and which we have analyzed in Chapters 5 and 7: the reduction of complexity by modularization, hierarchy and encapsulation.

The basic metaphor for the object-oriented model is the modularity found in human cognition and natural hierarchies—for instance, the hierarchy organism-organ-cell (Booch 1991). A cell manages its own internal processes, and the fact that all the cells in the organism do so in parallel relieves the central coordinating mechanism (as does the brain in an animal) of an impossible burden of coordination. Indeed, it also makes feasible organisms, such as plants, that are without any central coordination at all. For organisms that do have central coordinating mechanisms, such as mammals, the brain does not exert any direct control over intracellular processes; rather, it controls cell behavior by sending the cells chemical messages—either by broadcast (for instance, by releasing adrenaline into the bloodstream) or by selective messaging (as when firing nerve cells to activate specific muscles or muscle groups).

This is basically the same concept that lay behind Sloan's and du Pont's management of GM's divisions by sales targets and budgets—leaving the internal workings and initiatives in the divisions for the division management. The pure organizational example would be an organization consisting of self-managed teams. Some professional organizations can, like Mintzberg's Adhocracies, come fairly close to this pure type—innovative consulting companies and fast moving, high technology start-ups, for example. As we have seen, even on the national scale there is an "object-oriented" solution—the capitalist, free-market economy, where independent companies ("objects") chart their own courses and cooperate through the exchange of "messages"—contracts, money, goods, and services. As history has shown, this is a superior coordination method for very complex organizations, such as large national states.

If we return to the organismic metaphor, a cell—for instance in the liver—is an example of an *object*. It would belong to the *class* "liver cells." The liver itself as a complete organ would constitute a higher-order object, containing both liver cells and other objects (e.g. the gall bladder and blood vessels), and belong to the class "livers," a subclass of the main class "organs." The organism would be our problem domain if we were only interested in its internal composition. If the area for study included the organism's interaction with its environment, including other organisms, the complete organism would in itself be an object of a still higher order than the liver, and a member of its own class—for instance (if it was a mouse), the class "mice."

Like an actual cell or team, an object (in the data-processing sense) has an internal structure—it stores its own data, or states, as well as the rules pertaining to those data and their representation. Its internal structure is thus encapsulated and hidden from the environment—the environment only "sees" the object as the messages it can receive and send and the behavior it can display. The class defines the properties that are common for all the objects in it, and the objects in their turn "inherit" them. Changes in the class description therefore instantly apply to all the relevant objects. An object communicates with other objects through messages, and the receiving object "knows" what to do when it receives a message. No master program is thus needed to direct the detailed processes within each object,

and any object is interchangeable with any other object having the same “message interface.”

The focus of object-oriented decomposition, then, is not the functions and procedures found in the problem domain, but the items or entities of interest for the system contemplated (Booch 1991, Coad and Yourdon 1991). Since those entities are generally much more stable than particular procedures, object-oriented systems are less susceptible to needing major changes as business requirements change. The changes that will be required are also easier to implement. In addition to being much more adaptive, object-oriented systems are able to handle much greater complexity than functional systems, through their use of encapsulation and hierarchies of objects and classes. They will also, in most cases, offer better representations or abstractions of reality than functional systems.

Earlier in this section, we linked functional decomposition and structured systems to functional organization and the paper paradigm. Object orientation represents a break with this tradition. It shakes information structuring loose from the file cabinet and the procedure, and returns to the main avenues of human cognition: objects and classes. As noted in Chapter 4, objects and object classes are indeed the pillars of human cognition: We cannot comprehend the world until we have established notions of object classes (e.g. “cars”), their properties and their relationships to other object classes. The object-oriented approach is therefore much better suited to analyze the domains of human work and cognition and to create systems that are compatible with human thinking and human work.

A Summary of Information Technology Properties

Computer-based systems have three basic characteristics. First of all, they *process* information, both data and programs. Next, they *store* information, and, finally, they *communicate* information. These capabilities are founded on a digital representation of information (both data and programs). The development in hardware capabilities has been breathtaking, and it continues without abatement.

The development in processing speed has been stable for quite a long time and will continue to increase at a rapid, steady rate in the foreseeable future. Quick calculations on a binary level are not very interesting in themselves, however. The key to the harnessing of computer cycles is the programmability of computers—the possibility to have immensely complex sets of logical operations executed automatically.

Initially, storage was a weak point for computers, but things have changed. Prices for semiconductor memory and for magnetic and optical storage have dropped steadily, and, in the year 2005, a megabyte of semiconductor memory (able to hold a million characters, or about 300 pages of simple text) is likely to cost around 40 cents, and a megabyte of magnetic disk storage, a minuscule 0.3 cents.

Communication speeds have also increased tremendously and are set to increase even further—both through the use of fiber optics and by clever new ways to boost the capacity of old copper cables and coaxial cables. However, our own basic input and output speeds have *not* changed—we still have to read or listen to the information that is communicated via computers, and we still have to

key in what we want to send. Speech will be possible to use in not too many years, but our talking speed is also an old constraint that will continue to limit our bandwidth of communication—no matter how many zillions of megabytes we can transfer between two computers in one second. Color printing will become ubiquitous, and email will eventually allow remote printing (by the receiver) of most types of documents. Yes, we will still be printing for many years to come, since screen technology is the slowest to develop, and it will still take a long time to produce screens that are large enough, light enough, cheap enough, and with good enough display quality to compete with paper in convenience and comfort. Such screens will come, and we will probably live to see them, but it will take many years.

Videophones are still in their infancy; they continue to await the cheap, large-transmission bandwidth that is necessary to achieve the quality they need to become really popular. A lot will happen here in the coming decade or two, and I believe video conferencing and videophones will be common organization tools in not too many years.

Email and computer conferencing are already becoming quite popular, and the explosive growth in Internet use is now gradually providing us with the standardization that email lacked for so many years. There are still considerable obstacles to effortless exchanges of formatted documents, though.

Computer-based communication really only comes into its own when systems communicate directly with each other. Such interchanges between systems can basically be effected in two ways: either by sharing data among applications by common database access, or by messaging between applications. EDI (Electronic Data Interchange) involves a set of standardized formats for such messages, and the UN EDIFACT effort aims at establishing a definite, international standard for all main types of business documents. There are also a number of supplemental and business-specific standards.

As the processing power and screen technology develop, we will see new forms of information representation. So far, we have been living within the paper paradigm even to the point of having computer screens mimic paper as closely as possible. When screens improve to the point where we cease to print out information, this will change, and hypermedia, 3D graphics, animation, and sound will be used extensively—not to play movies on the screen, but to represent information in a compact format that takes advantage of the fact that our capacity for absorbing visualized information is vastly greater than the trickle we can take in when it comes to verbal communication.

However, the matter runs deeper than representations on a screen. The structuring of information for storage and processing has been profoundly influenced by literate administrative practices. Computer programs have been viewed as procedures, decomposed into single steps of operation on data files (*functional* or *algorithmic* decomposition). The resulting design and programs have been called *structured*. Another vital characteristic of this approach is the distinction between program and data. *Data* are viewed as given, something one analyzes to design a database. The program contains the operations to be performed on the data, and to design the program one analyzes *functions*.

When functional programs grow large and complex, however, they become labyrinthine, just like overgrown bureaucracies, and almost impossible to change.

The new principle for the structuring of information systems is called object orientation, and it borrows its basic principles from the modularity found both in human cognition and natural hierarchies such as the hierarchy *organism-organ-cell*. A cell manages its own internal processes, and all the cells in the body do so without the need for detailed central coordination. An object in a system may thus store its own data and has its own repertory of operations, but its environment will only "see" the messages it can receive and send. The format and content of these messages constitute its interface with other modules and are the only things other modules need to "know" about it. Most of the complexity in a system is thus encapsulated within objects, and one object can be replaced by another as long as their interfaces are the same. This is, by the way, exactly the same principles that have been used to achieve maximum information economy in organizations from the rise of feudal society to the Divisionalized Form. It finally shakes information structuring loose from the file cabinet and the procedure and returns to the main avenues of human cognition: objects and classes.

9 The Impact of IT on Individual Capabilities

“Memory is like all other human powers, with which no man can be satisfied who measures them by what he can conceive, or by what he can desire.”

Samuel Johnson, *The Idler*, 1758–60

We have now established a reasonable understanding of the central properties of information technology—at least those that are relevant for the human faculties singled out in Chapter 3 as the most important for our ability to organize. We must now try to assess how they enhance our capabilities over and beyond the contributions from earlier technology, since this is the key to understanding possible extensions of the space of constructible organizations. This follows from the conclusion in Chapter 2 that organizations are constructed—any extension of the space of constructible organizations must therefore be based on changes in the abilities or available options of the individual organization members, which again translates into changes in the actions that make up and derive their meaning from the recurring patterns of action in the organization. These patterns constitute the main processes both within the organization and in its relations with its environment, and it is from these actions that the systems characteristics of the organization emanate.

Memory Performance

In Chapter 6 we discussed the significance of the externalization of memory provided by the art of writing (later augmented by printing). It had profound consequences for our administrative capability, our problem-solving ability, and our capacity for knowledge accumulation. Practically all our advances in knowledge and technology—that is, the very foundation for our present material prosperity—rest squarely on the invention and exploitation of writing.

Except for a certain refinement of the material means for filing and archiving, however (such as the invention of more elaborate classification schemes [e.g.

library systems] and, eventually, the punch card), very little happened to the basic efficiency of information management up through the centuries (and our biological memory has hardly improved noticeably). The usability of stored information (externalized memory) was also severely constrained by several factors: the need for physical access to the storage media (files, books, etc.), the large amount of work involved in the search and retrieval of information items, and the slowness of the human input/output process (reading and writing).

The computer is now changing this—we are in the middle of a revolution in information storage and retrieval that will still roll with considerable speed for several decades, and may bring changes as fundamental as those brought by the introduction of writing itself. That revolution is built on three pillars: *compact and cheap storage*; *universal access*; and *automatic search, retrieval, and registration*. The most important application is the *database*.

Pillars of the Memory Revolution

Compact, Cheap Storage

The theoretical space available for information storage will not increase as we make the transition to digital storage. This may seem surprising, since data already takes up so much less space on both magnetic and optical disks than on paper. However, the earth is pretty large, and, as previously noted, there is always a blank sheet of paper or a new file card available. You may even contemplate the fact that microfilm is *not* a child of the electronic computer—and microfilm density can be enormous, especially for ultrastrips (which is, literally, microfilmed microfilm). However, digital storage is already overtaking even microfilm in compactness and price.

The new digital media will provide extremely compact and cheap storage, allowing us to hoard immense amounts of information almost anywhere. The rapid advances in mass storage media mean that it is already economically feasible to store almost any reasonable amount of information at your deskside, and the prices are swiftly falling to a point where cost will be irrelevant as long as the information is even remotely useful. In fact, the limiting factor is already the price of the information itself—either the price of purchasing it, as in the case of commercially available information, or the cost of producing or collecting it, as with information indigenous to the organization or available through partnerships or other business relations.

Just to put the meaning of compact storage into perspective, let us go back to the CD-ROM described in Chapter 8. One single disk (which has exactly the same size and look as a compact disk) can store the equivalent of 200,000 pages like this one, or about the same as 650 conventional, 300-page books (text only—graphics generally need more space than characters and reduce the number of pages). With a portable computer equipped with a CD-ROM drive in your briefcase, you can therefore, if you have the need or fancy, carry with you a sizable library. In fact, if you carry your portable computer in one hand, and a medium-sized briefcase full of CD-ROM disks in the other, you could walk around toting the equivalent of a library with more than 100,000 volumes. (When the new standards for higher-density disks take over, this figure will increase by one order of magnitude—to one million.) The price for the 200+ disks is difficult to estimate, because the price

of CD-ROMs usually reflects the cost of the information they contain. The manufacturing costs for the bare disks (excluding the information on them), assuming a normal production volume for each one, should be in the region of \$250 (about a dollar apiece, give or take 50%). This is quite a step forward, when you contemplate the fact that it would take a 2.5-kilometer bookshelf to hold the 100,000 books the disks replace.

You may argue that information stored on CD-ROMs cannot be updated, and that is correct. The information on CD-ROMs is pressed into them at a factory, just as an audio CD is, and they are therefore strictly a medium for mass distribution of static information. They are not a storage medium for active files with administrative records. As we noted in Chapter 8, however, magnetic storage is also rapidly becoming cheaper and more compact. An array of state-of-the-art magnetic disks with the same storage capacity as the briefcase with CD-ROMs described earlier could probably (as of early 1997) be built as small as a normal desk drawer unit, and should not cost more than about \$25,000—still significant, but much less than the cost for the building and shelves needed just to house the 2.5 kilometers of books. If magnetic disks continue the development they have seen the last 15 years, the same amount of information should fit in less space than a bread-box around the turn of the century, at a cost of about \$2500. Another five years later, one disk should suffice, costing less than \$500. And, in contrast to information contained in books, disk-based information can be modified, is searchable, and is available on-line from any connected terminal.

If the developers of holographic memories make good on their promises, moreover, the information density of digital media should increase further by one or two orders of magnitude in not too many years, allowing our briefcase to hold the equivalent of tens of millions 300-page books. That brings us into the hundreds of kilometers of bookshelves.

Figures like this, and the price levels predicted in Chapter 8, mean that we in not too many years, we will be able to store all the information we wish or need to have almost anywhere for an almost negligible cost. In fact, we will be able to store much more information than we can normally afford to either buy or produce. Only live, digital video and sound will have storage costs and space requirements that will merit second thoughts about acceptable volumes, unless one's needs are really massive. "Normal" data such as text and numbers are by and large beyond cost considerations already,¹ which means, among other things, that we can continuously collect and accumulate the meaningful part of the administrative information produced by our own computer-based information systems, and have it constantly accessible on-line for reference, monitoring, and analysis.

¹ The price for storage still varies a lot according to what class of systems you use and which vendor you are dependent on. The estimates given here are for the most cost-effective solutions, which you find in the microprocessor-based market (PCs, workstations, and microprocessor-based servers) where competition is toughest. Given an unfortunate combination of system type and vendor, you may lag several years behind.

Universal Access

Like written files, digitally stored information is also available to all and anyone who are allowed access. But, compared to the written file, which requires that you (or someone else on your behalf) physically walk up to it to retrieve information, digitally stored information is very much more accessible. Anyone so authorized,² and with a terminal connected to the system, directly or through a communications network, can access it, regardless of geographical location or time of day. It is, moreover, *simultaneously* available to a large number of users³—how many is determined solely by technical factors such as system capacity and the number of communication ports, and the limits here are steadily and briskly being pushed upward.⁴ In principle, information stored on a system connected to the public telephone network is accessible from almost anywhere in the world—indeed, with the portable satellite terminals now available, the qualification “almost” can be removed, if one is willing to pay the price.

The rapidly increasing capacity of international telecommunications carriers will steadily improve this accessibility and eventually include affordable transmission of high-quality, live video.⁵ This will in turn tend to erase the difference between local and remote storage, even if it will take time to reduce the international telecommunication rates to a level where they will not act as a brake on long-distance communication. We can, however, already discern the contours of the technology that will allow this to happen (e.g. phase-multiplexed optical fiber and later maybe superconducting cable). It should therefore become theoretically and practically possible to store an information item in just one physical location in the world, and nevertheless make it comfortably and instantly accessible for anyone with a computer and a connection to the global telecommunications network. The Internet is already making this happen faster than anyone believed possible.

This will make it possible even for the largest multinational corporations to consolidate their operational databases into either one virtual base (distributed

² And, as we all know, even the unauthorized can gain access, if security precautions are too lax. Security considerations are important, but I doubt whether they will seriously limit the uses of information technology in organizations. There is currently a lot of work being done to make systems and transactions more secure. The main areas for reserve will probably be sensitive information about individuals (privacy considerations) and very important secrets—public or private.

³ In actual “production” databases, where records are modified all the time (as in a booking system), only one user is allowed to write to the record at any one time. If the hardware and software are adequate, however, the user will seldom notice this.

⁴ If we envision future computer systems—of, say, twenty years from now—with extremely powerful parallel processors, Holostore mass storage and direct fiber connection to a fiber-based telecommunication network, their transaction capacity will be several orders of magnitude greater than the most powerful systems available today, and may approach the capacity needed to service very large, worldwide user groups.

⁵ This is not going to happen in the 1990s, since it will require a sweeping renewal of the public telecommunication networks, probably with fiber all the way to the individual subscribers, or at least to local nodal points for coaxial cable connections (utilizing existing TV cable networks). For the private subscriber, it is therefore a prospect for the somewhat longer run—two or three decades at least. For business subscribers, it may be available earlier—at least for large organizations with a high communication volume.

among many physical sites) or even into one centrally located physical base, (most likely with a continuously mirrored copy in one or two other locations for security considerations). The actual solution chosen would depend on the level of integration required by the running of the organization and its business activities. The idea of a central database for a multinational corporation may seem preposterous at this point in time, but I am not so sure it will look that way in twenty years.

Automatic Search, Retrieval, and Registration

Vast amounts of information are of no use if you cannot retrieve the items you need and manipulate them the way you want. It has thus far been assumed that we can easily retrieve whatever we want from the massive amounts of information that computer technology allows us to store. In principle, that is true. The basis for this is of course the fact that the digitally stored information is written on the storage media by a computer, and the same or another computer can therefore also read it. There may be practical obstacles, such as incompatible storage formats, inflexible database structures, inadequate application software, and the like, but they all represent temporary shortcomings or are the results of the vendors' commercial considerations. They are not consequences of the technology's inherent properties, and they can always be overcome—even if it may cost a lot of money sometimes.

The fact that digitally stored information can be read by a computer means that the computer can also process it. Leaving the transformations of data alone here, we can note that the computer can index, sort, and compare with enormous speed. It can retrieve one record from among millions in a small fraction of a second, and, just as quickly, store it again after changing it. It can select groups of records on the basis of certain properties and sort them according to various other properties, it can count them, and so on. The computer's outstanding ability to search vast amounts of information in an incredibly short time, and extract, combine, and concentrate data, again makes for a momentous difference between computerized and paper-based files.

Let me give an example. My first job was in the personnel department in a fairly large shipyard in Oslo. The shipyard was old; it was started as an engineering workshop in 1841, and moved to the sea front and turned into a shipyard in 1854. Countless workers had passed through its gates since then. A succession of devoted personnel clerks, however, had scrupulously kept the file cards for the people who left, probably in case they should return later (a common practice—many alternated as sailors). In the 1970s, when I worked there, the personnel office had a complete file of more than 100 years of employees. What a treasure trove for a sociologist! But, alas, the only indexing established for the cards was alphabetical sorting by name, and the effort required to extract even a fraction of the wealth of data they contained and register it in a computer file was prohibitive. So, although the information was physically there, it was not accessible in practice. Had it been in a database, analysis would have been easy—and of great interest—not only for scientific purposes, but also for the company.

The computer's ability to search and select is still best for structured data as in this example, and it will most likely remain so in the foreseeable future. Other forms of information, such as free text, sound, and pictures, are much more

difficult to handle. In my view, the structured database also has a much greater potential for supporting organizational change than the free-form information base. We shall return to that question later.

The Database

The Structured Database and that Significant Record

As we noted in Chapter 6, writing was most probably created to keep records for business and public administration (Goody 1986). The first material memory technology was thus used for storing administrative information—itemized, often quantitative information such as sums of money, numbers of cattle, amounts and kinds of goods, names of people, sizes and locations of landed property. Only later did it become a medium for discourse, for art, and for accumulation of knowledge and reference material.

But because the written discourse and the accumulation of knowledge and reference material were decisive for the development of philosophy, religion, science, and politics, and thus were more visible (and exiting), those aspects of writing easily attracted most of the attention in historical analysis.

Nevertheless, the Industrial Revolution and the evolvment of modern society depended just as much on the meticulous record keeping of merchants, master craftsmen, industrialists, engineers, civil servants and, not least, their clerks. Their tidy accounts, production plans, inventory lists, file cards, protocols with customers and suppliers, details of business transactions, land registers, and tax records became the lifeblood of an increasingly complex society.

The great importance of record keeping is evidenced by the fact that all new technologies for information storage make their debuts in the realm of business and public record keeping—computers included. As described in Chapter 8, when the computer first ventured beyond research and was adapted for administrative purposes, it was indeed for record keeping and tabulation.⁶ The same was the case with punch card equipment half a century earlier.

When we talk about records, we mostly mean information that is precisely defined and put into a strict format. Good accounting practice, for instance, incorporates very stringent requirements both for the kind of information that is necessary and how it should be recorded. Likewise, banks and insurance companies need to record quite a number of exact pieces of information about their customers—beginning with names, addresses, and, in most modern societies, personal identification numbers.

When this kind of information is stored in a database, the items of information and the form they are going to be stored in are decided on beforehand, and for each item a corresponding field is defined in the database. The field is normally designated at least as numerical (only allowed to contain numbers) or alphanumerical (allowed to contain letters, numbers, and punctuation). Normally, it has a maximum number of positions, or even a mandatory number of positions (as with dates and article numbers). There are also a number of other design

⁶ There were two private customers on Univac's order books in 1948: Prudential Insurance Company and the market research company A. C. Nielsen. The very first computers, such as ENIAC and the Mark I, were only that—*computers*. They did not have any mass storage that could accommodate records.

options for each field, for instance, if the field is going to be indexed for faster search and retrieval. When its contents have been defined, the database therefore also “asks” for the appropriate information through the form it presents as the registration screen. For each person (or other entities that we want to store information about) registered, then, a record is created that contains all the predefined fields.

The advantage of storing information in this highly structured form is that it can then be easily retrieved, counted, and classified; numbers can be used in calculations; names and addresses can be used to produce mass mailings; and so on. It is simply a prerequisite to automatic processing: The programs must “know” exactly what kind of information they shall retrieve, where it is stored, on what form, and exactly what to do with it and where to put it afterward. It is structured databases such as these that lie at the bottom of almost all the familiar success stories about profitable use of IT that circulate in the business world (and in the realm of public administration, for that matter).

The Free-Form Database

There is quite a lot of information that is impossible to accommodate in a structured database such as those just described. In fact, even these databases will often contain a “comment” field, wherein unstructured, textual information can be entered—information that is too important to be left out but too special to be defined in advance, or simply too varied to be included in a classification scheme.

The first attempts to use computers to store and retrieve more “soft” information were just a few years behind the applications focusing on structured data. As early as the second half of the 1950s, 20 years of headnotes of design patent law cases had been entered into an IBM 305 RAMAC (the machine with the world’s first magnetic disks). At the same time, what was probably the first full-text “database” came into being when Professor John F. Harty of the Health Law Center of the University of Pittsburgh used the university’s computing center to solve a practical problem: the actual implementation of a bill passed in the Pennsylvania legislature to replace the term “retarded child” (and all its permutations) with “exceptional child” (and the corresponding permutations) in the state’s health statutes (Bing and Harvold, 1977).

After two consecutive tries with groups of students reading the statutes and substituting terms, and with still too many errors remaining, the complete text was registered on punched cards—and the substitutions left to the computer. Harty then found that the machine-readable text could be exploited in much more exciting ways as well, and he went on to develop what was probably the world’s first full-text search and retrieval system—teaching the computer to spot words or combinations of words and return the texts that contained them.

The benefits are here already—just think about the full-text databases now offered by many leading newspapers around the world, or the improvement in literature searches provided by computerized book and journal catalogues. If (as they will be sometime in the future) all published book and journals were available *in extenso* in machine-readable form, searches would be even more effective.

Of course, no search is perfect, as everyone with some experience in database delving will agree, and it will probably never be. Some experience provided,

however, computer searches are already much better than laborious manual searches. Even if computer-based searches will not find all the relevant information, and often (especially in the case of free text) not even the majority of it, the catch is always much bigger than with manual searches, and the performance of computer-based systems is so much better than the old, paper-based ones that they can only be compared in principle. In practice, they are so different that they merit completely different approaches to administrative work, and, indeed, a totally new view of how information ought to be structured.

But we are far from the situation where all the information of interest to us is available in information bases. It is still found mostly in books and journals, in loose-leaf binders, archives, even piles on desks and shelves. True, there is already a staggering number of information bases available throughout the world; the Internet is growing day by day, and an increasing number of CD-ROM disks are published—but the information they contain is still small compared to the total amount of information available only on paper. And to transfer just the most important ten percent of the existing paper-based information to digital storage is a task of gargantuan proportions. The all-encompassing information bases we have been alluding to remain therefore mostly a potential, not a fact.

Nevertheless, it is a fact that the amount of information available in information bases, especially on the Internet, is rapidly growing. Some of the most successful ones up to now have been news services mentioned earlier, economic information (especially stock and commodity prices), market information, library services, and services providing news on economically interesting research and patents. In addition, a large number of sundry information repositories and news groups have sprung up—some of them commercial, but the vast majority idealistic and nonprofit or marginal-profit.

Until recently, the various database services were offered mostly as separate services, with ample variation in log-on procedures and command languages. The right base is often hard to find, is often fairly expensive, and difficult to use. Few have been commercially successful to date.

Today, there is a massive trend toward using Internet as a gateway, to capitalize on the millions of users who already have access to that net—and to reach the large numbers of new users who obtain access every day now. Although the Internet has its own set of problems, we can safely predict that it will rapidly become the universal access and presentation layer that the information base business has always lacked. The chief obstacle today is a reliable and simple mechanism for payment, allowing a pay-as-you-go approach for information retrieval. The present regime—wherein one must be a subscriber to obtain the more valuable, commercial information—is not flexible enough.

The available search engines are also still fairly primitive, but we can expect improvements. One approach, described by Stein (1991), does not build on hypertext links, rather, it relies upon workstation software that will automate access to the network and the various servers, and incorporate “intelligent” features to assist searches. After posing the first question, the user can browse through the items found by the system, marking those that are most to the point, and ask the system to find “more like those.” By gradually refining this “relevance feedback” to the system, it should be able to come back with more and more relevant hits. When you have thus built a good profile of your interests, you can

even leave the system to do automatic, periodic searches for you, to keep you continually updated on new information items within your domains of interest. This resembles the agents described by Negroponte (1995) and others.

It is impossible to say now which concept will be most successful, or if other schemes will enter the fray. There is also bound to be disagreement about the probable pace of development. This is not so important for our purpose, since there is little doubt of the general direction in which we are moving: It will only be a matter of time before most of the information we need in the course of our daily work will be accessible through our workstations, with very capable search-and-retrieval tools available—probably even tools that will be able to continuously (and in the background) build and maintain links and search profiles from the factual and associative jumps we do during our normal search activities. The tools will apply both to external and intra-organizational information bases, and will not only be useful for text searches, but for sifting through all kinds of stored information, whether for business, public, or private purposes.

When that happens, our active information repository will become vastly larger than it is today. Comfortable, speedy access is critical for information to be used, and scarceness of time and economic resources will always tend to severely limit our search for information. A lawyer I once met summed it all up in something he called *the law of arm's length*. He put it this way: "You know, 99% of the time, you make do with the information you can reach out and grab without leaving your desk chair." Which is, of course, the reason why people keep private copies of central files, why they buy books that are available in a library three blocks away, why they make copies of everything that may come in handy at a later stage. It also means that 99% of the time we make do with the information we *remember that we have and know where to find*. Because even the information stored in our offices is liable to get lost within a meter or two of our desks. We may simply forget about it altogether or be unable to remember exactly which book, binder, or file it is in and not have the time or energy to sift through hundreds and even thousands of pages to find it. As long as we do not index anything and everything, we have to rely on memory as our prime search mechanism even for externally stored information.

The general significance of digital mass storage is therefore first and foremost the increased accessibility it gives to stored information—structured data, free text, sound, and pictures. The combination of cheap, digital storage; cheap telecommunications; and very powerful search tools will create an information domain lying between the information we store in our brains and traditional written information. Access is of course not as swift as the recall of something we remember clearly, and the ripples of association will also still flow faster in the brain. But for the vast volumes of information we cannot even hope to remember, and, even more significantly, all the information we have never heard about at all before our new tools find it for us, we will have an access that is many orders of magnitude faster and more exhaustive than before. Less time will be spent in search activities, and the yield of relevant information will be much greater. It should allow our own information processing to draw on a much larger set of facts and viewpoints than before. In fact, the limiting factor will be our own innate capacity to absorb and digest the information.

This new memory technology is not quite like our own memory, but it is much more than a traditional file cabinet, a bookshelf, a library—so much more that it deserves a new name. To keep in tune with the trend-setting term *artificial intelligence*, we may call it *artificial memory*. This term is not entirely new (Simon [1976] refers to it as already in use), but it has up to now been used to denote all kinds of records outside human memory—chiefly libraries and paper-based files. However, since it has been used so sparingly and since it matches the now thoroughly established *artificial intelligence* so well, it seems easier and wiser to change its content rather than to coin an entirely new term. It will still fit Simon's (1981) definition of the trichotomy natural-synthetic-artificial.

In theory, IT may also place a world of information within "arm's length"—which is what much of the current excitement about the Internet and the so-called "cyberspace" is about. However, that law is about not only physical distances, but also mental distances: If we do not know the map of "cyberspace" as well as our own desk and bookcase, we will not use it as readily. And, at least for the present, "cyberspace" is not very user-friendly, its information repositories are extremely varied and uneven in quality, indexing is quite haphazard, and there are no generally agreed indexing schemes or search methods. Doubtlessly, this will improve, but it may take quite some time—we should not forget that the inertia of the Net increases with its size and information richness, and there is bound to be both funding and organizing crises in the years ahead.

Capacity for Work and Information Processing

The Externalization of Processing

In Chapter 6 we concluded that the invention of writing brought us the externalization of memory. Looking back over about 5000 years, this conclusion is uncontroversial, and it is correspondingly easy to analyze the main consequences of literacy. Although some may consider it more impetuous to say that the invention of computers heralded the *externalization of information processing*, I think this is already accepted by most people working with the technology. It might even be said that externalization of processing has some modest roots in mechanical automation and computation devices—however, it is the information-processing power of the digital computers that really opens up the new frontier.

As noted in Chapter 4, when it comes to conscious mental work and problem-solving, we are basically serial processors (as distinguished from the large amount of parallel processing involved in our sensomotorical activities). This has of course not been changed by information technology any more than by previous inventions. No matter how advanced the workstation on your desk, when the telephone rings, you will still lose the thread of your work, and the conversation will effectively block any other serious mental activity. This one-trackedness of our mind still combines with the restrictions of our working memory to put a limit to the number of variables we can handle simultaneously.

Our key strategy for overcoming this problem has always been simplification—singling out a few variables as the most important ones, and shutting out the rest. As our cultural evolution accelerated, externalization of

memory⁷ and division of labor became important techniques as well, and, with the invention of writing, they both gained tremendously in importance. As noted in Chapter 6, writing made it possible for us to establish a sort of second-tier working memory, greatly enhancing our capacity for solving complex problems. Writing also allowed us to accumulate knowledge, keep records, and expand our vocabulary to allow more precise expressions. We achieved a vastly superior understanding of nature and of causal relationships, allowing for an enormous increase in the complexity of the problems we could solve. Likewise, it significantly improved our administrative capability and the possibility for decomposing problems into manageable tasks, thereby allowing us to tackle problem solving on a grand scale.⁸

What the art of writing thus provided was a set of tools that made it possible for us to exploit our innate processing power to a much larger degree. What the computer offers, in addition to a much improved external memory, is the opportunity to unload some of the information processing itself—in addition to furnishing us with improved support tools. (Well-designed computer-based support tools may make task switching even easier than written notes and records could, and increase precision by organizing information better.)

At the personal level a properly equipped workstation can keep parallel work processes going—such as sending and receiving faxes in the background, sending and receiving voice messages, calculating large spreadsheets—and even do database selections and sorts while a person works on other tasks. There is also the prospect of “intelligent” agents that can take care of more complex tasks—such as automatically searching designated databases for information of interest, setting up telephone connections, and other routinized chores. Both Apple and Hewlett-Packard have highly polished videos showing “agents” doing all kinds of chores. Apple’s agent even reveals “him”self on the computer screen in the likeness of a handsome young man, speaking impeccable American English.

However, the concept of the agent is mostly a gimmick at this time, and it neither is nor will be the most important example of the externalization of processing—at least not in the foreseeable future. The computer’s potential for automation and processing of quantitative information is in my view much more important. The potential definitely does not lie in trying to use computers to mimic our own complex information processing. Computers and humans are too different to make that a success.⁹

What computers are good at is mimicing certain *aspects* of the human mind. But this must not fool anyone into thinking that those aspects are inconsequential or unimportant. Experience has already shown us that computers excel in

⁷ Even in oral societies, symbols are used to represent complexity in trade, social relations, and religion and to serve as important tools for handling complexity.

⁸ Of course, the enhancements did not spring into full bloom at once. It was more like a potential slowly realized, and crowned by the great engineering and research projects of the twentieth century. Intellectually, at least, the preeminent achievement of pre-computer, collective problem solving was perhaps the wartime Manhattan Project—developing and building the first atomic bomb.

⁹ What the distant future will bring is of course impossible to foretell. In my lifetime, however, I do not expect computer systems that can effectively emulate humans on an overall basis—research on neural networks and artificial intelligence notwithstanding.

performing logical operations; in information retrieval, selection, sorting and monitoring; and in number crunching and quantitative conversions (such as converting information from numbers to pictures)—types of processing that are extremely important in administrative work, material production, science, and in all kinds of information analyses. It is when we exploit computers to offload processing work of this kind from our own minds that we really experience dramatic changes in productivity. Indeed, the speed of computer processing now allows us to perform tasks that would be impossible (even in theory) with human brainpower alone—no matter how many persons the project employed. There are simply not enough people on earth to carry out all the calculations involved in, for example, ten-day weather forecasts—and if there were, you would surely not be able to organize them (let alone pay them!).

The Quantitative Revolution

The main contribution of information technology towards mastering complexity (at least so far) is the way it allows us to manipulate quantitative information—information that can be expressed in numbers and categories. This sounds rather narrow at first, but when you look into it, you will find a vast array of applications where the computer has greatly enhanced our ability to handle complex tasks by carrying out processing at a scale that would not even be theoretically possible without computers.

The simplest example is the hand calculator, available in a large number of versions from elementary products to advanced products with an impressive array of mathematical tools. The versatile spreadsheet is well known by now, and there is also a large number of specialized products for budgeting, financial modeling, and the like—even on the scale of national economies.

On the operational side, trading systems allow brokers to constantly monitor market movements, and, by taking care of the administrative details of the deals (one might say that much of the knowledge of the administrative details is embedded in the system), the systems allow brokers to concentrate on the contents of the deals instead. Process control systems (with a lot of embedded knowledge about the processes) allow small crews of operators to monitor entire plants. Yield management systems such as American Airline's allow a few people to analyze and implement sweeping and detailed price changes for millions of airplane seats. Flight and weapons control systems on modern military aircraft give the pilot the ability to control and coordinate tasks that would have demanded a sizable crew just a decade or two ago.

The engineering world is capitalizing on increasingly sophisticated drawing programs, providing not only 2D drawings of parts and subassemblies, but even 3D models of parts, subassemblies, and final products. The 3D programs can, for instance, often reveal if design errors have resulted in conflicting positioning of parts (a common error, for instance, when designing complex chemical plants, with all their piping), and they can allow architects (as well as their customers) to “walk through” buildings on screen. Programs for finite element analysis (calculating load and strength under various conditions) allow for fine tuning of design in a way that was simply not possible before, because it was too laborious to compute and analyze the complex interrelationships of stress in materials.

Computer modeling and animation give an unprecedented compactness in presentation of numerical models.

In science the computer is invaluable both as a tool for analysis and as an experimental engine in its own right. Chaos theory, for example, was quite simply not discovered before the computer was available, since the nature of the regularities in chaotic systems was too complex to comprehend except when modeled on a computer (Gleick 1988).

It is easy to continue with more examples, but it is hardly necessary. The computer's ability to handle numbers, and to present them graphically on the screen, has meant a revolution in number-related tasks that is, in my opinion, at least as great as the original contribution of written numerals. The reason is twofold.

First, even if it was possible to develop advanced theory in mathematics, physics, and engineering without computers, much of that knowledge was simply impossible to use in practice because of the enormous burden of calculation. Cheap and powerful computers are now allowing almost any scientist and engineer to routinely do calculations that were simply unthinkable 50 years ago, even if the entire GNP of the western world could have been devoted to the task. For instance, finite element analysis is now a practical, everyday tool of engineering—not merely an exotic, theoretical possibility.

Second, the computer is capable of tracking and showing us causal relationships between variables—sometimes between a few (as in a simple spreadsheet model), sometimes between an exceedingly large number (as in a weather model for a ten-day forecast). The computer thus functions as an automatic preprocessor, combining a large number of predefined causal relationships into a few aggregate ones that we can comprehend and manipulate in our own minds.

The advancement of artificial intelligence is involved in this development as well. Heller (1991) describes, for instance, a system for routing trucks developed by Carnegie Mellon University and DEC. Incorporating rules developed by interviewing the experts in the trucking company, it has allowed the same experts to reduce the company's continuous-mileage transport costs by ten percent—not because it "knows" more than they do, but because the system is able to take all the rules into account every time, even if time is scarce (as it usually is in the transport business).

Artificial intelligence also has the potential to become an important tool for supporting real-time monitoring of complex technical installations, where it is essential to aggregate and choose between different signals to maintain an overview of the main events. Complex installations, such as oil-drilling platforms, require operators to monitor several thousand signals (Laffey 1991). Especially in a crisis, human operators are likely to be overwhelmed by information and thus unable to coordinate actions and respond fast enough to deal with the situation. According to Laffey, both the Three Mile Island accident and the Bhopal disaster have been attributed to such "cognitive overload," just as the airplane crash described in Chapter 4. Because AI systems are computationally intensive, speed is still a serious problem for using AI in real-time applications, but that is bound to be taken care of both by advancing hardware and new programming tools. Laffey mentions several examples of systems already in use, mainly in space applications

and process control in manufacturing plants. When the cost falls, such systems will be attractive for a large number of real-time applications. They will not completely supplant human operators but will probably reduce their number and help them handle both daily chores and emergency situations more effectively.

Automation

As we noted in Chapter 6, automation is our only way to achieve the capability of working on many tasks in parallel. It is done by building machines that are capable of autonomous or semiautonomous operation. Simple automation can be seen as an enhancement of the capacities of the individual operator, who can produce more by using machines as tools in his or her work. However, more sophisticated automation may replace scores of workers of many different trades and must be seen as a tool on the organizational level. We shall return to this last (and most important) aspect of automation in Chapter 12. At this point, we shall only discuss the main differences in principle between mechanical and computer-based automation.

In Chapter 6, we spoke of the classical automatic machine as a crystallized set of decisions forged in steel. This information is contained in the physical shape of the machine's different parts, since it is the shape of the parts that determines their movement and makes them able to govern the movement of adjacent parts or the workpiece or do operations on it. Because one part can only have a particular shape, its information content (and processing power) is low, and to make a machine with a relatively high information content (able to do complex operations or different types of operations), one must use a very large number of parts, making the machine correspondingly complex, expensive to manufacture, and also less reliable (one of the main concerns of mechanical engineers always is to reduce the number of parts as far as possible).

Throughout the nineteenth and the twentieth century, mechanical automation has nevertheless been developed to a very high level of sophistication. Even highly delicate operations, such as the production of light bulbs, have been fully automated solely by mechanical means (Bright 1985). However, there are definite limits to what can be achieved by mechanical automation alone, since the amount of information that can be embedded in traditional machinery is small—even if impressive feats have been pulled off by ingenious use of pneumatics and analog electrical devices.

Another area of importance to automation concerns linking sensor input to operations. Some such links are simple to establish by mechanical means; the best known is probably the classic thermostat with a bimetallic switch. Combined with heating and/or cooling equipment, it can keep temperature within a predefined interval. But, even in this field, the complexity achievable without the help of computers is limited. Despite much ingenuity in using electricity and even pneumatics to combine and weigh signals, information processing (and, thereby, automation) could not proceed beyond certain limits—witness the control rooms of pre-computer power stations or factories in process industries, where a large number of operators would walk around, all the time reading dials, turning wheels, pulling levers, and flipping switches.

In Chapter 8, I argued that computers are not different from mechanical machines in principle. Even digital computers can be built with mechanical components alone. To automate by computers, we still have to analyze the required functionality carefully beforehand, and we still have to plan and describe in painstaking detail every action and reaction a machine or complex of machines is going to carry out. The material difference is that the information, instead of being embedded in the physical shapes of parts (as in a purely mechanical setup), is simply lodged in the software and hardware logic of the computer.

This difference, however, translates into an enormous divergence in the level of complexity we can operate with and the speed by which the embedded information is processed.

Computers are in their very essence automatic machines (as noted in Appendix A, the very first electronic computer was designed to automate the calculation of firing tables for guns), and the use of computers always involves the automatic execution of very large numbers of predefined sequences of activities—as a direct response to input, as a consequence of information already stored in the computer, because of a message coming from another program or computer—or any combination thereof.

Some of the routines are internal to the computer systems, such as the conversion of key presses to characters on a screen or requests for a piece of information to a disk search and retrieval procedure. Some are external, such as the process of directing an automatic teller machine to dispense money when you request it and your account balance allows it, or even more complex processes (e.g. generating animation sequences by interpolating between two drawings, landing aircraft, or running entire chemical plants).

So, whereas mechanical automation always depends on detailed, physical design of each and every part, computer programming can rely on hierarchies of instructions, where the lower levels are automated and thus “invisible” to the designers of the higher levels. The actual, detailed instructions reaching the hardware are today deeply buried within programming languages and tools allowing manipulation on much higher levels. In addition, since programs are immaterial, the room for complexity is almost infinitely large compared to physical automation, which is limited by material restrictions. The result is that even small computer programs (and even the programming that is inherent in the circuit designs) are immensely more complex than mechanical automation can ever aspire to. The computer therefore allows us to build logical “machines” that are many orders of magnitude more complex than any physical machine we could conceive of. Electronic processing is also infinitely faster than the movements of wheels, levers, pistons, valves, and other actuators can ever be.

In addition, machines controlled by software can easily be reprogrammed, either for optimizing or for making different products. Their scope of action is limited, of course, by the physical constraints of the machinery—a lathe cannot spray paint, and a robot arm cannot mill steel parts—but, within their domains, computer-controlled machines allow great flexibility for setting up new work procedures. What was earlier impossible to change or required new parts or rebuilding can now be done by changing parameters or code lines in software—a much simpler and more economical alternative.

As the processing power of the controlling computers is increased, the scope for automation in production and control is therefore drastically widened, and no final limits can be seen. Computer-controlled systems can collect and analyze very diverse and sophisticated signals from a broad variety of sensors, can direct all kinds of machinery, and can be equipped with an array of responses covering almost any conceivable eventuality—also error conditions and accidents. Any process that can be precisely defined can in principle be automated. This is not to say that we do not experience limits today, but it is very difficult to determine which ones are fundamental and related to basic constraints in the nature of computers and computer-based systems, and which ones are simply due to the present immaturity of our computers, our software and our theories of computers and their use. I suspect that very few of the constraints we have experienced so far are of the fundamental kind.

Computer-based systems are also very reliable when we consider their enormous complexity. This may sound strange in the ears of the average computer user, regularly frustrated by inexplicable error conditions and just as indecipherable error messages. Considering the number of discrete electronic components contained on the chips in an average PC, however, and the number of code lines in the software employed, we might be more surprised by the fact that it works at all than by the relatively few errors that occur. If we count each separate component on the processor chip, the memory chips, and all the other chips for a separate part (which it really is, even if it is miniaturized beyond normal comprehension), and do likewise for every line of source code for the programs normally run on the average business PC, that PC will consist of several tens of millions of parts—probably somewhere between 20 and 50 million. How reliable, for instance, would a car with 30 million parts be? A modern airplane, such as the newly rolled-out Boeing 777, has approximately 3 hree million parts—and needs regular, extensive servicing to operate within acceptable safety limits.

Time for Deliberation

When humans deliberate, they need time—time to think through the problem under consideration, to mull over likely and unlikely consequences, to weigh the preferences of possible solutions. Whether or not IT can speed up this process is a matter of definition—the situation here is quite parallel to the one discussed in Chapter 6.

Deliberation in itself is still an internal process of our minds, and, as such, it is no more augmented by information technology than by writing. But, if we look at the whole process involved in reaching decisions in organizations, including the collection of relevant information and consultation with others, considerable improvements are possible, mainly in the area of information collection and communication. McKersie and Walton quote an example from a high-tech organization (1991, p. 252):

Our experience with electronic conferencing has been very positive, given the limitations of the current generation of software. It is not unusual to have 6 to 10 remotely located managers (many more if you count indirects) actively participate in formulating, reviewing, editing, and approving a document/plan. During my last weekend in Washington, an important issue arose late Friday

that required an official written agency position Monday morning. A few phone calls locked in the key experts (five different states) for an electronic brainstorming session on Saturday. I got initial thoughts from everyone on electronic mail Friday night (ideas were iterated once or twice) as well as access to information and graphics from local databases with comments and proposed rewrites or reorganizations with appropriate rationale. Three iterations were completed by 5:00 P.M. and a draft was electronically forwarded to three senior managers at their homes for approval. After incorporating their revisions, the position paper was approved and printed for an 8:00 A.M. meeting Monday morning with the head of the agency.

There is no doubt that the agency in question would have managed to produce a written position by Monday morning even without computers, relying on telephone and possibly telex. But it is equally clear that the availability of electronic mail and remotely accessible databases made it much easier to produce the required document, and with a better result. The advent of new software and screens superseding the paper paradigm will strengthen this development.

In addition, the growth of artificial memory and the kind of information systems discussed in Chapter 11 will help to speed the decision-making process. Especially in crisis management and other situations where fast responses to complex events are necessary, advanced information systems can significantly enhance our decision-making capabilities.

Communication

Human Communication—A Flash of Symbols

From Artifacts to Waves and Currents

In Chapter 6, we identified two main types of communication: the physical transportation of goods and people, and the transfer of information. Before the telegraph,¹⁰ transfer of information over almost any distance was only an aspect of transportation, since it invariably involved people (messengers) or paper or paper-like materials and therefore relied on physical transport.

The telegraph, and, later, the telephone, radio, and television, changed this and established information transfer as a separate category—the symbols of human communication escaped from the world of paper and parchment and became embodied by radio waves and the currents of telegraph and telephone wires.

Computers do not change this in any basic, physical sense. Electronic mail and telefax are much more efficient than the telegraph, but they still rely mostly on electrical signals traveling along a wire—in some instances probably even the same physical wires that earlier carried the telegraph traffic. Even the introduction of satellite communication and optical fiber do not change anything in principle—it is still a matter of transmitting symbols instead of physical objects, even if the

¹⁰ As we noted in Chapter 6, there were various techniques for rapid communications before the telegraph—from beacons and “talking drums” to homing pigeons and semaphore lines. But their capacity was low, almost all of them were special-purpose, and they did not play any significant role in the broader communications context.

capacity of the carriers probably has increased beyond the wildest dreams of both Bell and Marconi.

The context of communication has also broadened to include not only communication between human beings, as was the case with all the pre-computer communication technologies, but also direct communication between computer systems. Of course, one may always claim that it is only a matter of mediated communication between humans, since there is always a human user somewhere downstream and a programmer somewhere upstream. Both the user and the programmer are usually so far removed from the direct effects of the communication, however, that I would maintain that system-to-system communication is a separate category that merits its own considerations. I will elaborate somewhat on that at the end of this chapter.

When it comes to physical transport, the consequences of information technology have been mainly indirect: The ship, the airplane, the train, and the automobile are not inventions of the computer age; neither are the steam engine, the diesel engine, the petrol engine, the jet engine or the electrical motor. But, of course, there are important contributions that improve the performance of our physical transportation systems, both with respect to design, operation and administrative support. Modern jet liners, for instance, could not have been designed and built without computers, they could not have been flown without computers, and computer-based navigation and air traffic control systems allow greatly increased regularity under almost all weather conditions. Routing systems for railroad cars are computer-based, trucks are directed with the help of computer-based systems, and computer systems keep track of each single package transported by express freight companies and courier services. Electronic customs systems, as Norway's TVINN,¹¹ speed the transport of goods further by eliminating delays at the border. The contributions of information technology to physical transport are marginal, however, compared to the improvements originally brought by the development of the prime movers of goods and persons: ships, trains, cars and airplanes.

Our Very Own I/O Bottlenecks

The great breakthroughs in the history of human communication, then, were the written word, printing, the telegraph, the telephone, radio, and television—all of them developments of the pre-computer world. Even the telefax, which is now well on its way to eclipsing ordinary letters as the prime medium for written business communication, is an old invention from the nineteenth century, although microelectronics was needed to make it cheap enough and provide the necessary document quality to really make it popular. Computer technology has so far not provided breakthroughs of a similar magnitude, and its ability to do so in the near future is in my view generally overestimated—despite the advent of several interesting technologies: electronic mail and conferencing, cellular phones, videophones, and, of course, the fax.

¹¹ TVINN was the second or third such system in the world when it went in regular production in 1988. (New Zealand was first, and Singapore came along about the same time as TVINN.)

The reason for this is simply that communication is not only a matter of transporting symbols from one person to another. As we concluded in Chapters 4 and 6, there is also the problem of the actual *absorption and dissemination* of information (the human input/output, so to speak), which represents a far more formidable problem than increasing the bandwidth of long-distance information transfer. Actually, there is even a third important aspect of communication, which we shall not discuss here, but which merits separate studies: the question of how well *meaning* survives the encoding/decoding processes involved in human communication.

Although bandwidth is an interesting issue, it is definitely not the only issue. Electronic communication as well as digital storage and computer assisted search and retrieval certainly allow access to vast information resources. But even if we can unearth mountains of relevant information, how can we absorb it all and really use it? Information must still be read off the screen or off paper printed out by the system. The cry is in fact already going up in corporations worldwide, from overloaded managers and professionals: What we need is not *more* information, but the *key* information. The immediately felt problem for most people is not one of increased communication or even of search and retrieval, but of sifting the information that pours in anyway, and finding time to absorb the day-to-day business data that is already there. As Long remarks (1987, p. 45),

By providing a manager with the capacity to call up more and more analyses, there will be an implicit pressure for him/her to do so. If the problem is that the manager does not know what the real problem is, then provision of more unfocused information may only confuse the issue, particularly since the anonymous and impersonal source of the information generally makes it difficult to check on the validity and strength of that information.

Simon (1976) has made a wry remark that is quite appropriate to this matter. After referring to a description in the New York Times of a new computer system installed by the U.S. State Department for receiving the 15 million words received per month from its 278 diplomatic missions throughout the world, and with the ability to print out 1200 lines per minute (the old teletypes could only manage 100 words per minute), he says (1976, p. 284),

A touching faith in more water as an antidote to drowning! Let us hope that foreign ministers will not feel themselves obliged to process those 1,200 lines per minute just because they are there.

The sad fact is that our innate capacity for information absorption remains the same as before, as does our capacity for disseminating information. Our eyes, ears, and mouths are the same as our forefathers', and even if some people from time to time speculate about the possibilities of interfacing computers directly to the brain, we can safely rule that out as a useful option in the foreseeable future.¹²

¹²I do not, however, think it wise to rule it out forever. It is impossible for us to determine the limits of technology and biology a hundred or two hundred years from now. But we can safely conclude that our present level of scientific knowledge is nowhere near sufficient to allow it, and that, if at all possible, it will take a long time to achieve.

In particular, the computer has not done very much to improve on our ability to express ourselves. It has made it possible to compose text somewhat faster, but that is about all. Of course, we can now produce much better looking material than before; our presentations can be studded with graphics and nice fonts. But it still takes much time and effort to present the result of our thought processes to others, or to transfer knowledge. For example, I often wish that I could transmit a batch of information in one short, massive flow, presenting all aspects simultaneously. Instead, I have to painfully formulate the slow, serial trickle of syllables, words, and sentences that constitute human language, keeping the (fairly powerful) processor of my current PC waiting for input about 99.9 percent of the time.

However, the computer is of much more help when it can be used for transforming information in such a way that it speeds our perception, even if both the challenge and the remedy vary according to the nature of the information.

For this purpose we can broadly divide information into two categories: One is verbal and pictorial information, which has to be read or viewed in the ordinary way to be of any use; the other is numerical information, which lends itself much more readily to concentration—which is the key to improvement.

Verbal and Pictorial Information

Information embedded in text or pictures is intrinsically resistant to automatic concentration. Text can be condensed by rewriting and the creation of summaries, but both are labor-intensive tasks that will require human processing in the foreseeable future.¹³ Live pictures can be run at higher-than-normal speeds to allow a viewer rapid scanning, and still pictures can be presented in small sizes to the same effect. The main advantage of computer-based storage and search with respect to such information, however, is the fact that the system's search capabilities should return information with a higher content of relevant material than manual searches. That is, even if it will not help us to absorb more information, the information we ingest should be more relevant—giving us a higher "intake" of useful information.

Apart from the improvement provided by the basic capabilities of database search tools, work is being done on various other kinds of tools, helping us to concentrate the information presented even more. Associative searches and hypermedia links have been mentioned, and experiments are also made on structuring (Winograd 1988) and programmable filters (Robinson 1991) for electronic mail and conference contributions.

In addition to this, new ways of information presentation and representation as discussed under the section on the erosion of the paper paradigm in Chapter 8 should make it possible to get a somewhat better overview of complex textual and pictorial information, especially with the advent of larger screens. However, our absorption of this kind of information cannot be improved dramatically—at the very most, we are probably talking about a doubling, not orders of magnitude.

¹³I do not rule out some kind of automation or semiautomatic assistance here in the (distant) future, but it is going to be extremely difficult to design software that can reliably glean the essentials from long documents and present them in an intelligible way. We are at the present a very long way from reaching such a goal.

Numerical Information

Numerical information is quite another matter, however. Because numbers very often lend themselves to graphical representations, they allow us to tap into the very powerful visual-processing capacity of the brain—there is no doubt, for instance, that a pie, column, or line chart conveys information much more quickly than the tables they are based on. Three-dimensional charts add even more information (if used correctly).

Graphical representations are nothing new—scientists and economists plotted graphs long before the advent of computers. What *is* new is the speed and ease with which the conversion can now happen, and the forms the graphs may now take. Graphs used to take a long time to produce, even simple ones, and only the most important or complex information was the subject for such VIP treatment. Today, with a modern spreadsheet or statistical package, graphs are almost a free lunch to be had once your data are registered. Administrative packages of various denominations also increasingly include graphic capabilities, and spreadsheets steadily improve their capacity for extracting data from administrative programs for further analysis. Indeed, spreadsheets are now evolving into all-purpose tools for reports and analysis.

A quite different example is found in the new naval navigation systems, in which the combination of satellite navigation and electronic maps lets the helmsman follow the ship's position continuously on a screen showing both the map and a representation of the ship. The small ship on the screen moves as the ship moves, and the map rolls continuously in the direction of movement. For fast crafts operating in narrow waters, such a system is much safer than traditional navigational aids, which require the helmsman himself to judge the ship's position on the basis of observations and readouts from a number of instruments.

The most sophisticated visual representation systems today are found in engineering and scientific data processing, where information is presented not only as static graphs, but also as animations. Especially impressive are simulations based on numerical models—be they of new airplanes, waves generated by projected boat hulls, car suspensions, cloud development, or cosmological events. Animation in particular can concentrate numerical information to a very high degree and present us with clean and comprehensible representations of enormously complex data. Such tools have up to now been very expensive because of the large computational power required. But, because of the ever decreasing cost of raw computing power, this fascinating class of tools is now rapidly becoming available for almost anyone.

Animated simulation, mentioned earlier in the discussion of the paper paradigm, is in my view a branch of software with a great future. Animated simulation may not only help in designing physical objects (e.g. factory production lines, cars, or houses) but also aid in all kinds of data analysis. Even social science survey data can conceivably be animated, with moving planes and shapes visualizing the mapping of multivariate distributions and correlations. In business, animation should be able to provide very interesting tools for analyzing and monitoring key variables (budget and real)—in production, sales, and accounting—and, not least, in *combinations* of these areas. I believe such tools will

be applied in all areas where there is a need to analyze or monitor complex numerical relationships.

The New Channels

Although our innate bottlenecks for information absorption and dissemination largely remain in place, the channels for information transfer have seen significant development on all levels—from the physical (from copper to fiber, from earthbound radio to satellites) via basic representation (from analogue to digital) and bandwidth (including multiplexing) to presentation (application level). The physical capacities have been mentioned earlier; here we shall concentrate on the usable applications and their implications.

Electronic Mail and Conferencing

The most touted aspects of computer-mediated communication are electronic mail and conferencing. There has been (and still is) much excitement over this new medium, and the most exuberant predictions about a world of unrestrained communication are routinely aired at conferences, in journals, and in newspapers. Lately, the growth of the Internet in particular has raised the spirits of many journalists and salespersons to almost hysterical levels. Electronic mail is also much used as an entrance point to computer use for managers and is therefore often somewhat oversold as a productivity tool.

What electronic mail provides is simply the ability to transmit written material instantaneously and have it stored for later presentation in case the recipient is not present. Good email systems also make it very convenient to answer, by automatically applying the address of the sender to the reply, posting a reference to the original message, and so on. At its best, therefore, email functions as something of a cross between letters/memos and telephone conversations—it has the speed of the telephone but does not require the sender and the receiver to be simultaneously available at their respective terminals. It can therefore be very efficient for people who are away from their desks a lot and can significantly reduce the number of unanswered telephone calls. For frequent travelers it is a convenient means to keep in touch with the home office regardless of time zones and office hours. It is particularly useful for communication across time zones—especially for intercontinental communication, where time differences can be so large that there is no overlap of working hours.

Most of this is also true for the fax, which—together with the fact that the fax is very easy to operate and can be hooked up to an ordinary telephone line without any fuss—is the reason the fax has enjoyed such a phenomenal success over the last decade and is still much more widespread than electronic mail. However, email has one very important advantage that will ensure its eventual victory over the fax: The information you send by email is machine-readable, which means it can be edited by the receiver—a very important point in group work. And it is not only text that can be transmitted in this manner. Data of any kind can be attached to the electronic “letter”: parts of databases, spreadsheets, accounting information, drawings, and so on. And all the information can be directly stored on the disks of the receiving computer, making it retrievable and even searchable in the normal

way. This advantage will make electronic mail a very important tool for people who have to cooperate across geographical separation—indeed, it even makes it simpler to co-author documents in the normal office setting.

Before email can really establish itself as the main medium for written communication, however, communication protocols and, especially, file formats will have to become more standardized than today. Such standardization is slow work, but the advantages are so obvious that a formidable pressure is building from both the user community and the telecom operators, a pressure that is sure to lead to successful solutions in the long run. As noted earlier, the recent phenomenal surge in Internet use has greatly increased the pace of this development.

Developments are also under way for “screen sharing”—where two or more people are allowed to “share screen,” in the sense that everyone sees the same screen picture on their VDUs and they all have access to it, allowing the screen to function as a sort of electronic blackboard. The goal is both to develop systems that can function in meetings where the participants are in the same room (when the common screen typically will be projected onto the wall) and in meetings/conferences for people sitting in different geographical locations. In that case the computer hookup must be supplemented by an audio line, allowing people to speak to each other as well as write and draw on the screen. It is too early to assess the impact of such systems, but they will clearly facilitate cooperation over distance, particularly in small groups.

Ordinary conferencing systems, on the other hand, are (as noted in Chapter 9) really just an elaborate form of email systems, where exchanges are open to all participants in that particular conference (there are usually many simultaneous conferences on one conference system). Conference systems are useful for spreading information fast to many people (“bulletin board” function) and for conducting group-oriented work.

Experience shows that we intuitively perceive email as a new medium with a new set of properties: The casualness induced by the easy, instantaneous, and paperless transmission of messages; the ease of replying; and the absence of the formalism associated with paper combine to make email messages much more “oral” in their form than ordinary letters (or even memos). For instance, people often use joking expressions in a way normally only found in oral exchanges—a fact that has created some problems, since a joke may be difficult to interpret in the absence of the parallel signals of voice inflection and body language. Jokes are therefore more liable to be interpreted at face value, sometimes leading to misunderstandings, even insults. Various remedies have been devised to alleviate this—from the simple, bracketed ones (ha, ha!) to more sophisticated symbol conventions, the best known being the basic “smiley” (one must turn the page 90 degrees clockwise to appreciate its full glory): :-).¹⁴ Because of its informal character, email can also function as a valuable feedback channel for managers. It tends to elicit comments more in line with what the manager would get through an informal chat with a subordinate, while preserving the time-saving (for the

¹⁴ There are of course variations: :(:-() :-7 :-| :-o :-> :-s :o) :o(ε:o) and so on. In fact, a book about “smileys” has now been published, and its collection is far larger than you would think possible.

manager), asynchronous nature of the written memo. Through conscious use of electronic mail, it is therefore possible for managers to appear more accessible to a much larger number of their subordinates. The informal and private character of an email system unfortunately also makes it conducive to gossip and slander—it is in many ways a new and much more efficient office grapevine.

Electronic mail is not the panacea that some people seem to think, however, and many of the predictions about email and conferencing have a lot in common with the generally euphoric predictions made about the telephone around the turn of the century. We therefore have good reason to maintain a relative calm.

The main point is simply that email does little to speed our comprehension. We may *transmit* messages more easily, and, yes, it is somewhat easier to compose them. For simple messages they also tend to be terser (and thereby more efficient) than other written or oral messages. Word for word, however, they still take the same time to read as other written material, and the same time to ponder as information in any other guise. Because it does not enhance our basic communication capacity in any dramatic way, email will therefore not represent the revolution in communication that many predict. We already spend a fair amount of our time communicating, and to use email more we must use less time on other channels. To fulfill the predictions of some of the most eager proponents of email and conferencing, we would have to forgo all or most other tasks, and that is just not going to happen. According to Robinson (1991), many users in organizations with electronic mail networks even now receive from 30 to 100 messages per day, which is probably already taking them to the limits of their capacity. Imagine being away for a few days, and then having to empty the mailbox!

No doubt remedies for overload will be found—indeed, some are already available (such as filtering and automatic prioritizing based on keywords) and more sophisticated schemes are under development. That is not the point, however. The crux of the matter is that we have about the same limit for output and input of verbal information as our forebears of hundreds and thousands of years ago, and with the size of the nozzle thus being relatively constant, we gain little by increasing the diameter of the hose, or by connecting more hoses.

Although distance education can make teachers more effective by saving them travel time, I always wonder when I hear proponents of distance education extol how PCs and modems will also make it possible for so many more students to achieve direct contact not only with national experts, but even with leading international academicians. I keep getting this vision of a poor professor, already straining under the effort required to keep a decent dialogue with the students physically present at his own institute, one day receiving the joyful message that he is now going to be available, through electronic mail, to 10,000 new students nationwide and 5 million more worldwide! Telecast lectures and remotely accessible text bases is one thing, that will work; unlimited return channels are something entirely different and will not work.

Phones and Voice Mail

Cellular phones have also caused much excitement in recent years. It must be the feeling of freedom associated with the removal of the physical connection, the illusion that we may now roam the sea, the forest, the mountains, or the prairie

while remaining in touch with the office and the world that brings in our money. This feeling of freedom is perhaps also compounded by the status attached to mobile phones in their early and more expensive days. The cellular phone does not entail any revolution in our communication abilities, though. Combined with a modem it will make a real difference for people who need to conduct their business on the go, but, for the majority, it will only afford a number of conveniences and a marginal increase in efficiency. It will not usher in really significant, broad changes in organization.

A part of the new telephone environment is voice mail. It has largely the same kind of advantages and disadvantages as email, with the added advantage of the extra information contained in voice inflection, and the added disadvantage that it is not text and thereby not as useful in our predominantly chirographic work environments. Some managers like the way their messages to subordinates get a more "personal" touch when delivered in their own voice. There are examples of systematic use of this effect. One of the most well-known ones is Debbi Fields' use of voice mail to communicate daily to the store managers in her chain of Mrs. Fields cookie stores (Walton 1989). The voice mail system also allowed the store managers to send voice messages to her, which they often did. For Debbi Fields it was mainly an instrument of control, but also a channel for informal feedback. It consumed a considerable amount of her time every day, but it gave her a very direct channel for influence, and the store managers, a feeling of direct contact. It did this while preserving her power to decide when to listen and when to speak, and she could still keep command of her schedule.

The use of self-service switchboards changes very little, except that it may reduce the number of available positions as switchboard operators and make some services cheaply available on a 24-hour basis. It is thus mainly another (and sometimes quite annoying!) instance of computer-based automation.

Videophones and Video Conferencing

The slow but steady progress toward affordable videophones is probably of far greater interest. But even videophones will not increase our capacity for information absorption—their contribution will be that they may reduce the need for travel and make it possible to have a close working relationship without meeting in person too often. We do not know for sure yet, since the high cost of videoconferencing up to now has precluded widespread use, and the necessary facilities have not been suitable for desktop installation—making it inconvenient to use even in those organizations where it has been made available.

However, the videophone is already on its way to become an add-on card that can be integrated into the PC or workstation, and, as volume picks up, the price should fall toward that of an advanced graphics card (probably the \$1000 range). As ATM becomes more widespread, quality will improve tremendously. We will therefore be able to utilize the screens we will have on our desks anyway, and even today's screens are large enough to show at least two pictures of acceptable size simultaneously. The larger screens gradually becoming the norm in the years ahead (17"–21") should allow us to conduct small video-meetings (up to seven or nine participants) on our desktops as soon as the video equipment and transmission itself become cheap enough. The even bigger screens that are bound to take over as soon as technology can provide them at a reasonable cost should be

able to display pictures of an even larger number of participants, as well as a common working space for sketching, writing, and presentation of pictures or output from various programs.

The arrival of affordable desktop videoconferencing could make a really significant difference to cooperation over distance. The added information provided by the picture of the person(s) we are talking to could make the videophone an instrument for comfortable conferencing—good enough to replace “real” meetings in most instances when travel (short or long distance) is involved.

It is therefore likely that video conferencing, within the scope of 10 to 15 years, will finally provide the necessary means for reducing the need for “physical” meetings significantly. Whether this will actually happen, however, depends not so much on the technology itself, but on people’s preferences—they must actually *prefer* video meetings in instances where they would previously have traveled. It is still too early to tell if this will happen, but we might guess that at least a major part of the really frequent travelers will welcome the opportunity to spend less time on the road or in airports, whereas those who make only a couple of trips a year will want to hold on to what they experience as a welcome escape from the daily routine.

An indication is given by Long (1987), who quotes a survey by Johansen and Charles¹⁵ in which only 27% of the interviewed knowledge workers felt that “too much travel” was a “major pain.” Furthermore, only 6% rated “less travel” as a major benefit of new office systems, and 59% considered it among the least valuable benefits. Long also quotes Livingston,¹⁶ whose study shows that even among frequent travelers (15 or more trips per year) not more than 45% wished to reduce travel, and a meager 16% of the infrequent travelers (5 trips or less per year) wished to do so.

A significant catch, of course, is that if desktop video conferencing really reduces the perceived threshold for holding meetings and becomes popular, it could well increase the total number of meetings. This is reported in a study of ten U.S. firms by Hansell, Green, and Erbring, quoted by Long (1987). This study also found that about half of the respondents reported an increase in the total time used for communication after the video-conferencing system was introduced, whereas the other half reported no change. An example of an increase is the daily video meetings conducted by the people responsible for market operations in the European national banks in order to coordinate their efforts in stabilizing the continent’s monetary systems. These meetings could only take place via video or telephone. Such an increase in meeting activity could be productive in some instances, but not necessarily always.

A reduced threshold for meetings (through video conferencing) also means that the threshold for follow-up meetings with superiors will be reduced—something that could once again reduce the independence of geographically dispersed organizational units.

¹⁵ Johansen, R. and Charles, J.: “What Users Say About Teleconferencing and Beyond,” in Johansen, R. (Ed.): “Teleconferencing and Beyond: Communications in the Office of the Future,” New York, McGraw-Hill, 1984.

¹⁶ Livingston, D.: “Teleconferencing,” *Computer World OA*, 1983.

Video conferencing will also facilitate the cooperation of work groups without colocation, even if it will not eliminate it for groups working really close together, especially groups doing creative work where cross-fertilization is important. No electronic channel can yet replace the richness of informal, personal dialogue—the chat in the door of an office you were passing while you were really heading for the copier, the chance meeting by the coffee machine, the inspired but unplanned discussion during a break in a late-night dash to meet an approaching deadline. As a manager I once talked to said: “It’s so much easier when you meet people in the corridors.” The attempts to recreate such avenues for unplanned, informal communications by electronic means have so far not met with success (Johansen 1988). We may also suspect that problems of a more intricate or delicate nature will lead to travel no matter how widespread video conferencing becomes. Indeed, Spiller and Housel¹⁷ (quoted by Long) found that some corporations experienced that their “travel costs have increased as better communication with distant operations reveals problems which require in-person appearances of top-level executives.”

But, for more routine administrative work, for coordination, following up on work in progress, and for sorting out the daily problems cropping up in every organization, video conferencing should be adequate in many instances. It could therefore make geographically dispersed organizations more feasible, especially if they are otherwise advantageous—for instance, because of market considerations or the availability of energy, raw materials, or suitable personnel. It may also be very useful for bringing cooperating, but otherwise independent organizations closer together.

Better Hoses, Same Nozzles

To sum up, computer-based systems provide a couple of new “hoses” for information transport, and significantly improve some of the old ones. The “nozzles” at both the transmitting and receiving end have not changed very much, however. Our basic capacity for input and output of verbal information (be it oral or written) is still the same bottleneck for the communication process. We already use so much time for communication (especially if we include the time used for reading printed material) that we can hardly increase our total communication volume very much, except for using time now spent on travel and unanswered telephone calls. Increased use of new channels will therefore normally entail a reduction for old ones. The main impact of electronic mail may therefore well be the fact that it allows for instant exchange of information in machine-readable form, with all the advantages this implies.

A Summary of the Main Impacts

Computer-based systems usher in a revolution in the performance of our externalized memory. That revolution is built on three pillars: *compact and cheap*

¹⁷ Spiller, R. and Housel, T.J.: “Video Conferencing—a New Training Tool,” *Sloan Management Review*, Fall 1985.

storage; universal access; and automatic search, retrieval, and registration. The most important application is the *database*.

Digital storage media are already very compact and cheap, and the technology is rapidly getting better and cheaper. A medium-sized briefcase filled with CD-ROMs can hold the text of about 100,000 300-page books, and an array of magnetic disk holding the same amount of information costs about \$25,000. At the turn of the century, the same disk array should cost less than \$2,500, and high-density CD-ROMs should increase the briefcase capacity to 1 million books.

In contrast to the written file, which requires that you physically walk up to it to retrieve information, digitally stored information can be accessed by anyone so authorized, regardless of geographical location or time of day. It is, moreover, *simultaneously* available to a large number of users. Just as important, digitally stored information can be read and processed by a computer. Leaving the transformations of data alone here, we can note that the computer can index, sort, and compare with enormous speed. The computer's outstanding ability to search vast amounts of information in incredibly short time, and extract, combine and concentrate data, makes for a momentous difference between computerized and paper-based files. This is especially true for information in highly structured form (the records in a structured database) but, even for text and other information items stored in free-form databases, accessibility is dramatically increased. The standardization of information access and presentation effected through the development of the Internet will bring vast amounts of information within armchair reach.

However, the greatest achievement effected through the digital computer is the *externalization of processing*. The fact that we can now have information processed outside the human head will prove to be at least as important as the externalization of memory brought about by the invention of writing. But the computer can only mimic certain aspects of the mind—notably, logical operations, especially all kinds of calculation. The narrowness of the computer's proficiency must not fool us into believing that it is inconsequential. It allows us to manipulate vast amounts of quantitative information very cheaply and quickly, something that translates into a revolutionary ability to handle a great number of complex matters—from budgeting to finite element analysis, from weather modeling to process control, from airline reservation and yield management to command and control systems in the armed forces. It allows us to keep track of a vast number of variables and their interrelationships—complexity on a scale that we were not even able to approach before—and through this it will also allow us to develop automation to a level of sophistication that will completely overshadow all that mechanical automation has ever achieved.

The great breakthroughs in human communication (excluding physical transport) are the written word, printing, the telegraph, the telephone, radio, and television—all of them developments of the pre-computer world. Even the telefax is an old invention from the nineteenth century. Computer technology has so far not provided breakthroughs of a similar magnitude, and its ability to do so in the near future is in my view generally overestimated. The reason is simply that communication is not only a matter of transporting symbols from the desk of one person to the desk of another—there is also the problem of the actual *absorption and dissemination* of information (the human input/output, so to speak), which

represents a far more formidable problem than increasing the bandwidth of long-distance information transfer. However, the computer can be of great help in transforming information for faster absorption—especially quantitative information, which can be represented through graphics and animations, making information absorption vastly more efficient. The possibilities are far less promising for verbal information, which is one of the reasons why email and computer conferencing will have limited impacts. The bottleneck is still in our heads; and the nozzles there remain the same size, no matter what the width of the hoses leading up to them.

Videophones and video conferencing will definitely become common when quality transmission becomes cheap enough, but the effects are uncertain. So far, telecommunications (which we have had for more than a hundred years, even internationally) have not led to any measurable reduction in physical travel—but the technology has perhaps contributed to more meetings overall and stronger centralized control in organizations.

10 Emotional Barriers and Defenses

“Men live but by intervals of reason under the sovereignty of humor [caprice] and passion.”

Sir Thomas Browne, *A letter to a friend*, 1690

In Chapter 6 it was noted that technology and scientific methods are indeed used to affect emotions—from drugs and psychotherapy to movies. IT does not seem to bring much new in this respect, except for making existing products more sophisticated. We may, for instance, observe that Morris’ remarks about our need for sex by proxy can be extended from literature and movies to computer-based systems. Just as in video, the sex industry is among the pioneers in multimedia, something that can be ascertained just by browsing the back alleys of the World Wide Web or looking at the last few pages of the classified ads in *PC Magazine*. If we are to believe the more easily excitable journalists in the trade press, virtual reality is the next frontier—although I have an inkling that it will be harder to provide adequate tactile feedback than the enthusiasts seem to believe. Reading about this, one is reminded of one of the bleak worlds described by Olaf Stapledon in his 1937 novel *Starmaker*, in which broadcast brain-stimulation was advanced to a stage where simulated experiences became more important than reality. Ultimately, this civilization developed the possibility for their citizens to retire into a completely vegetative-simulated existence: lying permanently on a bed, connected to life-supporting machinery, one could indefinitely immerse oneself in broadcast simulations.

Some may feel it inappropriate or at least not very serious to draw such matters into the discussion. However, the immediate and widespread exploitation of new technology for sexual purposes can serve to remind us that our basic drives and emotions are with us still, and in no small way either—if the fervor of the development efforts reflects the size of the market. We are not intellectual beings with rational purposes all the time. The cases that have been (rather gleefully) reported in the media about people on all levels in organizations who have been calling sex telephones from their offices for considerable sums of money offer further evidence of how raw emotional cravings can override even strong rational

criteria and organizational (as well as social) norms. Emotions are an issue in organizations whether we like it or not, and the whole range will be present—from the despicable to the noble.

So far in Part III, technology and the rational use of it has had the whole focus. However, as noted at the end of Chapter 7, we are also emotional beings, and we have needs and desires that may go less well together with information technology than our rational selves would like to believe. Before we go on to analyze the rational use of technology in organizational contexts it seems therefore highly appropriate to consider some emotional issues as well.

Organizational Effects on Emotions

That emotions were something that affected workplace behavior was not generally acknowledged until after World War II, and the first significant impetus in this direction only came after the Hawthorne studies (the experiments were conducted between 1927 and 1932) established it as a fact of social science (Hollway 1991). Hollway quotes Roethlisberger and Dickson (Hollway 1991, p. 72), describing the early experimenters at Hawthorne as

carrying around in their heads the notion of “economic man”, a man primarily motivated by economic interest, whose logical capacities were being used in the service of this self-interest. Gradually and painfully the experimenters had been forced to abandon this conception of the worker and his behavior . . . they found that the behavior of workers could not be understood apart from their feelings or sentiments.

Since the Hawthorne studies were published, the scope of work psychology has been both broadened and deepened through human relations, organizational development, and the concept of organizational culture. Practical efforts have focused not so much on job content and design as on selection and motivation building, which is far less intrusive with respect to work processes and organization design. It is significant that today’s emphasis on organization culture can be interpreted as a return from organization development’s focus on organization and job content to the more pure motivational effort of early human relations (Hollway 1991), and that the proliferation of psychological testing indicates a preference to fit persons to jobs rather than the other way around.

I am not sure if this can be said to represent an advance in work psychology. It could well be that the development of the modern organization and of modern society pose new challenges to our basic emotional apparatus, which it is poorly equipped to cope with, and which a recharged motivation only can serve to gloss over. It seems reasonable to believe that our emotions have co-evolved with our physiological abilities to cope with the challenges of everyday life—a life that for perhaps 95% of our existence as a species¹ has been life in a hunter/gatherer band, and for the rest (save the last 200 years) a life of subsistence farming and simple crafts.

¹ *Homo sapiens*, which has existed for about 300,000 years. If we count in the whole genus *Homo* (about 3 million years), we talk about over 99%.

Physiologically (genetically), we are probably best equipped to do physically varied work of a fairly routine character, with limited amounts of problem solving and crisis management. To put it in the words of David Fontana (1989, p. 6),

The human body has evolved over thousands of years to meet external threats by mobilising and then standing down, but the environment in which we now live has changed to such an extent since the Industrial Revolution that, once mobilised, our army² is neither able to fulfill its brief for fight or flight, nor to be sure that the danger is passed and stand down. Our modern society doesn't usually allow us *physically* to fight or run away when we face stressors, nor does it remove these stressors so that we're allowed to relax. We remain in a constant state of preparedness for action which we aren't permitted to take, and the body after a while begins to feel the effects. Many thousands of years hence, perhaps, human physiology will have evolved beyond the fight-flight response, and produced something capable of adapting as necessary to the actual demands that life makes upon it. But for the present, we're using a system developed over millions of years for living close to nature, to cope with an environment which has changed out of all recognition in little over a century. No wonder the system has a tendency to break down.

During the last 200 years, an increasing number of people have entered into jobs that consist mainly of problem solving and crisis management, and the problems have grown increasingly complex and abstract. Quite a few of these problems may even be impossible to solve in a satisfactory manner.

Many jobs are also of such a nature that the people doing them cannot easily see their significance either for the organization or for any particular end product, and they are deprived of the inherent meaning we find in work that is whole and with an immediate bearing on our own or our family's survival—as is the food foraging and tool making in a hunter/gatherer band.

It would be understandable if such situations generated considerable stress and emotional problems—which they seem to do. In a survey conducted by an American insurance company in 1991, 46% of American workers felt that their jobs were very or somewhat stressful, and nearly 27% reported that their jobs were the single greatest source of stress in their lives (Quick et al. 1992). Factors such as high work pace, repetition of work, lack of control over work and work situation, quantitative overload (too much work), and qualitative overload (too difficult work) are reported to be among the chief sources of occupational stress (Ross and Altmaier 1994).

Growing complexity is, in fact, an increasingly prominent characteristic of modern society as a whole—and an increasing number of people find it difficult to understand how it works, what their options are, and how they can claim a meaningful place in it. Even everyday life requires a growing sophistication in abstract thinking and symbol handling, from filling in forms to the operation of computers and other electronic devices, and many people probably feel that society is closing them out. This may especially be the case for unemployed people—for many, the job and its social setting has provided a reason for being, which is lost with their job for (Fineman 1993)—although the degree of distress

² The author likens the physiological responses of the body under threat to the mobilization of an army.

varies considerably among cultures and with differences in other variables, such as economic situation and education (Feather 1990).

Many jobs are also much more monotonous than any we would encounter in our "natural" state, and therefore probably produce a strain on our emotions. Finally, many modern service jobs demand a significant degree of "emotional labor" (Hochschild 1983, Putnam and Mumby 1993)—the effort exerted when "individuals change or manage their emotions to make them appropriate or consistent with a situation, a role, or an expected job function" (Putnam and Mumby 1993, p. 37). Typical examples are the consistently smiling attitude of the McDonald's salesperson or the airline hostess, and the professional consolation of the cancer ward nurse.

We should be careful, however, not to think that our emotional situation has necessarily deteriorated as a whole. Small peasant villages pose their own emotional strains, as does life in the extended family. The work of the serf or the tenant farmer could be harsh and monotonous enough, and serfs as well as servants have always had to do emotional labor to please their masters—who up through history have had considerably more gruesome sanctions to apply than the sack.

Emotions and Organizational Constraints

As noted in the section on emotions in Chapter 4, our emotional apparatus was best adapted to small groups, and it might have dysfunctional effects in larger organizations, especially organizations built on the rational model. As we made the transition to modern society, emotions became a double-edged sword.

On the one hand, positive emotions bring social bonding and cohesiveness (as they did in the roving band and as they always have in the family) and oil the inner workings of organizations. Emotions are vital for producing the *esprit de corps* and individual motivation that makes organizations flourish and that can bring about success even in the face of what seems like insurmountable problems or opposition. They also provide us with many of the spices of organizational life.

On the other hand, as we noted, emotion-based social bonding functions (in line with our primate nature and hunter/gatherer origins) primarily within the local group—the people we meet in the flesh and interact with on a daily or almost daily basis. Although it is extremely useful for building cohesiveness in small organizations, this trait is just as likely to bring divisiveness in large ones—pitting departments against department, and work group against management.

This mechanism works on many different levels, not least geographical. It is quite common, for instance, in large multiplant companies, that the different plants exhibit strong, even fierce, independence and view company or division headquarters as a remote and largely irrelevant entity, only noted for its "interference" in local affairs. Clearly, such strong plant loyalty can be an asset in the efforts to improve locally, but a liability when it comes to achieving close cooperation and coordination in a larger organization. Building the necessary minimum of loyalty among people and organizational units who are geographically dispersed and who seldom meet requires both strong, persistent efforts, and considerable energy on a continuous basis is necessary to maintain it.

However, in the world of humans, almost any difference can serve as a basis for divergence in culture and loyalty—not only geographical distance, but also product affiliation, profession, status, and age, to mention some of the important ones. The natural preeminence of such local cultures and loyalties over an identification with the organization as a whole probably constitutes one of the most serious constraints on the size an organization can attain and still operate effectively and efficiently, and successful large companies devote considerable resources to foster common, company-wide sentiments. Especially in multinational companies, the problem of fragmentation is one of management's main concerns, and a driving force behind their demands that prospective managers circulate through several countries and companies during their career buildup (Bartlett and Ghoshal 1989).

All organizations experience emotion-related problems, and much energy is daily spent coping with them. From time to time they may become serious and require considerable attention and effort to solve, and sometimes an organization will encounter conflicts so severe that it simply goes under—it dissolves, is taken over by others, or simply goes bankrupt.

IT and Emotions

If it is correct that the increasing complexity of society as a whole and of many work situations does not match our emotional predispositions as developed through millennia of hunter/gatherer life and subsistence farming, the situation is hardly improving. Based on the rapidly increasing use of computers to master ever more complex tasks, the tendency toward greater complexity and abstraction in work is continuing today. A steadily growing number of jobs are performed either through computer systems or with such systems as important support tools, whereas simpler jobs are eliminated in large numbers.

This is not unproblematic—after all, why should our emotions, which represent the oldest and most basic part of our consciousness, be better adapted to computer-based work than our bodies are to screens, keyboards and mice? If we contrast the tools provided by information technology (as described in the last two chapters) and their possible use with the life situation that has formed us as animals and produced our basic physiological and psychological makeup, we will easily see a number of areas where the exploitation of the new tools in the name of logic and reason will clash with older parts of our psyche. These main areas seem to be the *increasing abstraction and complexity* of work, the inherent *relentlessness* of a tireless technology built on logic and an unwavering demand (and capacity) for preciseness, and the *social isolation* that can grow from screen-based work.

Abstraction and Complexity

The process of abstraction is fundamental to the use of information technology—you always interact with a *representation* of the thing or process you work with, not the real thing itself. Even in word processing, you leave behind the paper and work on a virtual document. This means that you must be able to understand the relation between the representation and the thing or process

behind it, and you must learn to relate to unfamiliar cues and impressions. Usually, complexity also follows abstraction, as the ability to manage more complex tasks will often be one of the main reasons to use IT.

Zuboff (1988) has described and named some of the most important changes that have happened to our everyday work in the course of this process. She has done so by exploring two central concepts: the qualitative changes in the required set of skills as we make the transition from *action-centered* to *intellective* skills, which we will discuss here, and the *informating of work*—the deepening of the understanding and responsibility that increasingly sophisticated control systems thrust upon us—which will be discussed in Chapter 14.

From Action-Centered to Intellective Skills

In Zuboff's (1988) terms, then, we are experiencing a transition from a reliance on action-centered skills to an emphasis on intellective skills. Action-centered skills are the skills of manual labor and of the direct control of machinery. They are, so to speak, the skills of the body—acquired through extended hands-on experience, and relying heavily on tacit knowledge (Polanyi 1967) and theories-in-use (Argyris 1980), even intuition. In many ways, action-centered skills correspond to the oral mindset discussed in Chapter 6. This correspondence is also noted by Zuboff (1988). Explaining the transition to fully computerized process control in a paper mill she studied, Zuboff says (1988, p. 71):

A fundamental quality of this technological transformation, as it is experienced by workers and observed by their managers, involves a reorientation of the means by which one can have a palpable effect upon the world. Immediate physical responses must be replaced by an abstract thought process in which options are considered, and choices are made and then translated into the terms of the information system. For many, physical action is restricted to the play of fingers on the terminal keyboard. As one operator put it, "Your past physical mobility must be translated into a mental thought process."

She goes on to quote a manager with prior experience in pulping (1988, p. 71):

In 1953 we put operation and control as close together as possible. We did a lot of localizing so that when you made a change you could watch the change, actually see the motor start up. With the evolution of computer technology, you centralize controls and move away from the actual physical process. If you don't have an understanding of what is happening and how all the pieces interact, it is more difficult. You need a new learning capability, because when you operate with the computer, you can't see what is happening. There is a difference in the mental and conceptual capabilities you need—you have to do things in your mind.

The transition described here is very similar to the passage from an oral to a literate mindset, but it is even more dramatic. Not only does work in a control room involve the acquisition of a set of abstract symbols and categories that describe the machinery and processes used in production (artifacts and events in the real world), it also requires the ability to understand what is happening in the production process through the nature, values, and interrelations of those symbols. On top of that, the operators must also be able to exert precise control over the production process (real-world artifacts and events) through a highly

abstract, symbol-based interface, without any physical contact with the actual process at all (with the exception of some error situations). The contrast is quite precisely described by another manager from the paper mill. He also gives a clear indication of the informing effect of the new systems (Zuboff 1988, p. 72):

The workers have an intuitive feel of what the process needs to be. Someone in the process will listen to things, and that is their information. All of their senses are supplying data. But once they are in the control room, all they have to do is look at the screen. Things are concentrated right in front of you. You don't have sensory feedback. You have to draw inferences by watching the data, so you must understand the theory behind it. In the long run, you would like people who can take data and draw broad conclusions from it. They must be more scientific.

Evidently, the abstraction of work—which is one of the outcomes of this transition—represents a quite dramatic change in the work situation. It therefore seems reasonable to expect emotional problems to crop up, both because of the changes in the individual work situation and as a result of the concomitant (and inevitable) changes in organization roles. There are probably many people who will find it difficult to adapt to this kind of work, and to a situation of greatly increased personal responsibility and the loss (at least partially) of the protection that has traditionally been built into workers' collective culture and bargaining (Lysgaard 1961).

Responsibility and Role Conflicts

As we shall see later (Chapters 12 and 14), the new computer systems not only force an abstraction of work, but also impart a deeper understanding of the processes they are used to manage and increased possibilities for improving the performance of that part of the organization—or even the whole organization, as in the case of the control room operators in the paper mill Zuboff studied (see Chapter 12). With such an increase in understanding and control follows a corresponding increase in responsibility, which means a transition from a relatively simple job with a limited and stable set of rather concrete problems to tackle, to a job where a lot more time is devoted to problem solving, and where the problems are more complex, more abstract, more varied, and more difficult. This change is noted also by Walton (1989).

To cope successfully with the new job, people have to make deep changes in traditional attitudes to work, turning away from the old tenet that one is not responsible for anything outside the narrow frame of one's own job. A change here will in turn undermine old peer group identifications. If you start to feel (and respond to) responsibility for a larger part of the organization (or the whole organization), your identification is already shifting out of your peer group and is becoming more like the attitude formerly exhibited only by managers. This can cause considerable problems and conflicts between long-time fellow workers, with serious emotional fallout, as reported by Zuboff (1988).

But computers do not only tend to make work more complex and more oriented toward problem solving. The changes described are also often accompanied by a greater emphasis on teamwork and flexibility, which, for many people, can be another source of stress and insecurity, since such demands can

also easily be perceived as resulting in less autonomy: Instead of carrying out well-defined tasks with a mutually recognized, limited set of responsibilities, one is suddenly at the mercy of events over which one has little control. Problems crop up and demand solutions, and one never knows what one will have to do next. Zuboff quotes an operator reflecting on such a job situation (1988, p. 405):

They say the new technology will require a flexible system, you have no choice but to go where they send you, when they send you. You can get to earn high pay, but you have no choice about what your job is, and you can't have your own job. You never know what to wear to work—do you wear your good Levi's or do you wear your greasy ones?

Zuboff then comments on this statement (op. cit.):

This statement represents the operators' worst fears—that the loss of control over one's work would invade the most intimate and ordinary details of everyday life. Stumbling around the bedroom on a dark morning, trying to get ready in time to have a cup of coffee before leaving for the plant, the worker must ask, What do I wear? What kind of day should I look forward to? What is in store for me today? Will I feel good about the things I am asked to do? Without the capacity to set one's expectations, it is difficult to locate oneself emotionally. It is easy to feel helpless, as if one is at the mercy of others.

Rigidity and Relentlessness

Then there is the issue of the untiring nature of computer-based systems, their inherent craving for precision, and their narrowness in only responding to and reporting information types that have been defined beforehand. Taken together, these characteristics can easily translate into rigidity and relentlessness, if special care is not taken to avoid just that. Zuboff (1988) describes several examples. An interesting case is the Work Force Supervisory System (WFSS) of what Zuboff calls Metro Tel, a part of a large telecommunications company.

The WFSS was designed to manage the maintenance of telephone switches after the operation of the switches as well as error detection and analysis had been centralized as a result of computerization. The system used two main databases: one containing information on the work to be done in each electronic switching station (ESS), and another with information on the personnel available for these assignments.

Prior to the introduction of that system, each worker was a member of a crew assigned to a particular ESS (which meant a single building) and headed by a foreman. The crew was responsible only for the maintenance of its local ESS, and the foreman decided job priority and assigned individual workers to tasks. When error detection and analysis were centralized to switching control centers, each covering an extended geographical area with many ESSs, a new situation arose. Because error detection and analysis were no longer local, tasks did not have to be locally assigned either. That meant that maintenance workers did not have to be "wedded" to one particular ESS; they could be dispatched from the center as the need arose, with precise instructions for each job.

With this new angle of attack, there was suddenly a need for a considerable new bureaucracy to manage the queue of tasks and assign them to capable

workers, and the situation quickly approached a mild chaos. There was also the new problem of supervising workers working in isolation in the (now more or less deserted) ESSs.

The WFSS was designed to solve these problems. From a work identification number, it prioritized tasks and automatically determined the time they should take to complete. Then it assigned jobs to the individual workers that put together should match the priority listing, match the worker's skill level, and give each worker a workday lasting the prescribed 8.5 hours. Instead of reporting to the foreman at their ESS, the workers now reported to the system each morning, receiving a description of that day's work. Of course, they also had to report back to the system each time they completed a task, and this information was available to the centrally located foremen—giving them a very accurate view not only of each worker's progress through the day (or night, this was a round-the-clock operation), but also of their accumulated productivity. Failures to meet the calculated repair times would show immediately.

For the workers (and even for the foremen) this represented a dramatic change. Under the old system, they lived in a traditional work organization, with ample human contact, and with all the ambiguities and flexibility of normal human interaction intact. As one foreman expressed it (Zuboff 1988, p. 334),

Back in the old days, if a guy says he didn't want to do something, you had to start trading favor with him. Now it doesn't work that way. The computer says, "Bingo—you got this assignment Tuesday night. Here is the information, do it!"

This particular foreman favored the new system (at least initially), since it relieved him from what he felt were "uncertainties and personal terrors associated with managing reciprocities," to put it in Zuboff's words. Two others said (p. 331):

I can know if the work is getting loaded properly and if the craft has done his job right. You can see roadblocks instantly. I can look each day and see everything that I have loaded, if it's done, if not, why not. I can know everything in an instant.

It is beautiful now. I can track my people's work. All I have to do is type the craft's initials in and see how he is progressing and see what his total workload was. What is his productivity? Before, we had to judge people more on hearsay. Now we have it black on white.

The workers, however, quickly perceived the system as rigid and unrelenting—it was no longer possible to negotiate tasks and times, and it was hard to gain acceptance for extra time if unforeseen difficulties cropped up. When management started to use the system's efficiency ratings to evaluate workers, even many foremen cautioned against it. Among other things, they pointed to the fact that the best people tended to get the most difficult jobs (the system was biased to do just that), jobs that often required more than the calculated time to finish. That would not show up in the statistics, and the best people could therefore end up with the worst ratings.

The foremen also discovered that they lost touch with their old people, and knew next to nothing about new hires, whom they only met as numbers in the

system. They started to lament the loss of flexibility and the circumstantial but important knowledge that only diffuses through personal contact (p. 333):

In the old environment, the supervisors would arrive at the same building as the craft and greet you in the morning. He would be able to walk around and talk to you, and he would see how you were doing. You had that camaraderie of communication through the visual. Now you are basically just dealing with computers and checking on people. I can't see my men in the field now, because I look through the computer. If someone has a problem, I can't work it out with him like I used to. Does he need some time off? The computer doesn't know his problems. It doesn't want me to know if his kid just passed away or if his wife has problems. Maybe I need to lay off him for a while and then later I'll know I can count on him.

After some time, the foremen also learned that the system was being used to rate them as well, and they were beginning to feel the same sort of misgivings as the workers about the omnipresent monitoring the system represented. As a former worker, recently promoted to foreman, said about the WFSS system, also reflecting the feelings of the majority of workers (p. 352),

I hated it. It was too close. I could no longer hide anything. Management could monitor me hour by hour, and that was kind of scary.

After a while, the system was being widely experienced as too precise (in quantitative terms), too rigid, and too unrelenting to live with—it left no room for human judgment or for the pockets of privacy, ambiguity, and personal relations that human emotions crave. The outcome should have been predictable: To reclaim some of their lost room for maneuvering or to correct what they perceived as distorted reporting, people started to cheat the system—feeding it false information, ignoring some job assignments and claiming they had never received them, and so on. Zuboff quotes several foremen to this effect (p. 353-54):

If a man puts the time in and the computer makes him look bad, where is the justice? We have to manipulate the computer to show how good or bad people are trying.

If we let the computer run us, we look bad, so we manipulate the computer. We are not trying to cheat anybody or steal. We are trying to deal with the human element involved.

It is a vicious cycle. If my boss sees that he did not meet his boss's productivity, can't he change the data too? He wants everybody's printout to look good. How much cheating is going on? Who knows?

Cheating the system can of course be interpreted as a manifestation of bad discipline and general irresponsibility among employees. After all, we know that discipline in such matters is, to a large extent, is as an acquired quality—the development of industrial culture through history (briefly mentioned in Chapter 6) as well as the differences between national cultures today testify to that.

But, for most of us, there also seems to be a final threshold, beyond which we cannot be pushed without serious consequences. We all need a sphere of privacy, a certain room for maneuvering, a minimum of slack. That men are not machines

is generally regarded as a truism, but sometimes we seem to forget that truisms are in fact true. Our basic emotions are not rational, they cannot be eliminated, and systems that encroach too much on them are bound to cause problems.

The Significance of Design

The objection can of course be made here that the WFSS system mirrors a rigid and inhumane management philosophy more than necessary features of computer-based systems, and that other design decisions could have produced a system with quite different characteristics. That is true to some extent, and a lot of people working with systems design and development have been quite concerned about this and sought ways to build "humane" systems (a good approach is presented in Eason 1988). The WFSS system could, for instance, have been designed not to schedule work and calculate necessary time automatically, but only to provide foremen with information as a basis for their decisions. It could have provided fields for comments and other unstructured information. It could have provided the workers with some latitude in choosing the order and priority of tasks.

However, computer-based systems are based on logic, and their strengths are first and foremost the storage, retrieval, and automatic processing of structured, preferably numerical, information. They therefore have an inherent tendency toward rigidity and relentlessness, especially in environments where increased efficiency is highly valued (which includes most places in today's industrialized societies), and one therefore seeks to exploit these strong points. To escape the worst outcomes, it is especially important to avoid machine-paced work and detailed surveillance, and to position computer-based systems primarily as tools, not as automated managers.

Social Isolation

Humans are social animals and generally dread social isolation—*loneliness* is indeed a very negatively loaded word. Isolation is also a traditional punishment, and extreme isolation has always been a central instrument for those who want to break someone down psychologically.

Common sense would imply that isolation in the workplace is generally no more desirable, and research seems to bear this out (Sundstrom 1986), although Sundstrom remarks that "isolation and its effects have apparently not been systematically studied in work places" (1986, p. 295). Isolation is reported to be more tolerable if the work is interesting (Sundstrom 1986), but even then a certain level of social contact is preferred—there are few people who do not venture out of their offices for a chat a few times during the day.

Technology-induced social isolation is nothing new. Noise and machine layout in factories have often created jobs where it is impossible to talk to or even have eye contact with fellow workers, and, as mentioned earlier, it was not until after the Hawthorne studies that feelings and social relations really started to be acknowledged as important factors in the workplace (Hollway 1991). Social contact has been a factor in factory layout since then, but it is impossible to tell how strong the impact has been across industries and national cultures.

As with older forms of technology, the introduction of information systems can easily produce social isolation for workers and professionals alike. If information is stored in databases and channeled through computer systems instead of human contacts, if email replaces a significant part of all telephone calls, and video conferencing does the same for travel and face-to-face meetings, our social interaction at work can be reduced significantly both in volume and quality³ if steps are not taken to avoid it.

Social isolation was one of the complaints raised against the WFSS at Metro Tel, but it can be more pronounced in other situations. The obvious case is the caseworker supplied with a terminal giving him or her a total set of tools and all information necessary for completing work. Zuboff (1988) describes a typical example from a large insurance company that had introduced a computer-based system for processing dental claims. One of the benefits analysts told the following story about life before and after the introduction of the system (1988, pp. 139–40):

I think we're all more separate now. Before, there was more that I could help someone out with. There's not really that much I can do now. You just don't seem to get to know people the way you did when you were paying manually, because you don't interact. The office has become much more impersonal now, because we don't talk to each other. The girl who pays the Consolidated Underwriters' claims sits right in front of me. There was a question on my claim form. She didn't turn around and ask me. She sent me a letter. She didn't realize it was me. I said, "Cindy, do you know that you sent me a letter?" She said, "Did I really?"

In addition to the isolation produced by the systems themselves, seclusion is often intentionally maximized to eliminate "chat" and increase productivity. The benefit analyst comments (1988, p. 139):

We used to be able to see each other and talk. Sure, sometimes we just talked about what we were going to make for dinner, but we always worked while we talked. Most of the time, we talked about something related to a claim. Then with the new system, they put in two filing cabinets between us, because we weren't supposed to see each other anymore. But there was a small space between the two cabinets, so she could still turn around and look at me, and we would talk across to one another. Well, one day a manager walked by, and I was asked who left this space there. I said that was how they left it when they put the cabinets in. The manager had them move the cabinets together because they don't want us talking.

Most of the workers who were affected by this system reported sharply reduced satisfaction with their work, both because of the isolation they experienced as well as the monotony of screen-based work and what they felt was the relentless tempo of their new, system-paced work situation. It represents another example of heedless exploitation of some of the technology's strong points.

In addition to the negative effects that such isolation has on the individual worker, it seems fairly obvious that it is detrimental to any efforts in the direction

³ To me, it is obvious that a reduction in "bandwidth" means a reduction in quality of social interaction: Being there is better than video contact; a live voice is better than letters on a screen.

of improving employee morale and building an enthusiastic corporate culture. It may therefore run counter not only to employee well-being, but also to the total interests of the organization. If there is no social interaction at work and if the work situation is experienced as stressful and socially impoverished, loyalty is bound to drop and corporate culture will suffer.

Emotional Barriers to Virtual Organizations

A popular theme the last few years has been the prospect of “virtual” teams and “virtual” organizations. The meaning is seldom clearly defined, but a “virtual team” generally implies that the people in the team work in at least two different locations. Often there are more locations, or one or several team members may be traveling most of the time. The defining feature is that the team members use one or more electronic media, such as email, computer conferencing, video phones/conferencing, common calendars and common information bases as their main communication channels, and they have little face-to-face contact.

“Virtual organization” usually has two main meanings: It may (a) either designate several more or less conventional companies working very closely together (even fronting the market as one organization) with the same kind of electronic channels as teams communication as medium, or (b) an organization where a large number of the organization members use such channels as their main (or even only) medium for contact with each other and the rest of the organization, thus forming the virtual teams that carry out the work and represent the main organizational structure.

Today, many seem to believe that the virtual organization is the main candidate for the title “organization of the future.” I think that is a superficial judgment with a very weak foundation. We shall return to this question in connection with a discussion of groupware in Chapter 11. Here, we shall consider how emotional aspects may act as barriers or brakes on the establishment and success of virtual organizations—at least the of the latter type, where the organization members use only or mainly electronic communication channels for their interaction.

As a species, we have developed from forebears who lived in groups (our closest living relatives, the apes, still do so), and we have, by all probability, maintained that habit throughout the history of our species. The environment that formed our basic emotional apparatus has thus been the small group and the small tribe. True to that heritage, we tend to achieve closest contact and build the most durable trust and loyalty toward the people we meet most often and over extended periods of time—whether they are (originally) involved in our work or not. We like to look people properly in the eyes to assess their worth.

Face-to-face contact is the richest communication channel we have, and *any* electronic channel is significantly poorer—even top-quality video equipment cannot measure up to physical presence, let alone the barren dialogue of email. Of course, our extraordinary flexibility (Berger and Luckmann 1967, see also quotation on p. 121) will allow us to build human bonds by the help of very narrow channels, such as email (or even through old-fashioned letters, as some people continue to do), and some people may even build very strong relationships that way. Indeed, the first Internet marriage (where the couple met and courted on

the Net) has already taken place—although, undoubtedly to the chagrin of true cyberspace devotees, the bride and groom chose to appear before the parson in (physical) person.

My assertion is that given our basic psychological makeup, the richer channel will in general produce the stronger bond. And, if this is true, it stands to reason that organizational loyalties in a virtual organization, where members' face-to-face contacts mostly involve people outside the organization, will be significantly lower than in a more conventional organization where people meet physically almost every day. The chances that organization members will be tempted to let their ideas and initiatives take off in other directions should also increase. It should also be much more difficult to build a strong organizational culture and a corporate identity that people can identify with when the organization is virtual and offers few opportunities of normal social encounters.

A virtual organization, then, will normally not be able to display the same cohesiveness, resilience, and endurance as a "physical" organization, and should therefore experience a handicap that must be outweighed by other factors. I therefore doubt that the fully virtual organization—without a physical location and built fully on electronic communication—will become a common form. Flexibility in structure and personnel is good up to a point, but extreme flexibility may all too easily translate into instability, disloyalty, and inefficiency. I also suspect that if a *really* important problem cropped up, the responsible person(s) in a hypothetical virtual organization would still pack their suitcases and go—to bring into action the intangibles that are impossible to convey by electronic means: the sensing of an atmosphere, of a handshake, or the intimacy of a lunch or dinner conversation.

A New Gender Gap?

In an age where the equal status of women in society is a very important issue, and their victories often must be defended for long periods of time before they become ingrained features of social life, it is not without peril to talk about differences between the sexes. However, it is probably not too controversial to point out that there seems to be a difference between men and women when it comes to social abilities and the need for deep personal relations and rich dialogue. Men are generally acknowledged to be less interested in personal matters, to pay less attention to feelings, and to make do with a terser dialogue. Women get more involved in social relations, seek out more personal information, and generally try to build more complete relationships.

If this is true, it follows that women will find virtual organizations and electronic communication channels less satisfying than men, will be less ready to enter into such more narrowly based interactions, and thus prefer conventional organizations to a larger degree than men. This could lead to a new kind of gender gap in working life. It could also offer at least a partial explanation of why there is such an overwhelming majority of men in IT-related occupations (normal office use excluded): The human-machine dialogue could simply be more to the male liking, devoid as it is of emotional content.

Information Technology as an Emotional Booster

After all these reservations, it is necessary to point out that information technology can also help to strengthen both organizational loyalty and culture in situations where colocation is impossible for old-fashioned reasons, such as the need to locate close to markets or sources of raw material or energy. One of the main problems in national or international organizations with many sites is just to build and, not least, to maintain a sense of organizational unity. Elkem, for instance, one of the organizations that has sponsored this study, has a number of smelters both in Norway and in the United States. Many of them started as independent enterprises and were later acquired, and many of them are located in small, otherwise rural communities—a long distance from company headquarters or even the division headquarters. These plants are by tradition fiercely independent and often resent “meddling” from corporate management. In addition, the company has the Atlantic divide to overcome. Forging a sense of organizational unity in such an organization is not easy, and the lack of a community feeling is perhaps the single biggest obstacle to organizational streamlining in this type of organizations.

Even in organizations with less geographical and historical distance to overcome, the task of building company identification can be formidable. Some of the energies bound in the social identifications at the primary and secondary level (team/department and site/plant) must be transferred to the higher levels. Mature international organizations have established a lot of practices to achieve this, especially at the management level (Bartlett and Ghoshal 1989). Mandatory temporary relocations to one or more foreign sites as part of a career track is but one of them.

In such organizations, electronically mediated contact is of course better than no contact, and email and conferencing (particularly video) can build a sense of community, especially among like-minded people. It can therefore be an interesting tool for building coherence and cooperation among experts of the same trade who are spread out among different sites, as well as cooperating units at different sites.

A General Caveat

Industrialization and the emergence of large organizations have brought us far away from the content and conditions of our primeval work conditions. IT will most likely transform our work further. We should therefore take the opportunity from time to time to remind ourselves that, in our discussions of technology, systems, and structures, we must not forget that people are what both society and organizations are about.

Even if they have a rational side that interfaces well with the technology, people are also living humans with a profoundly emotional nature that must be taken into account and that has great value in its own right. When discussing matters like the subject of this dissertation, it is easy to forget that economic efficiency is not an end in itself and should not be pursued to the detriment of basic human values. In a competitive world, many people have a tendency to regard such a view as a luxury one cannot afford, and it is indeed often difficult to harmonize with a realistic attitude toward pressing economic realities in

organizations fighting for survival. We can only hope that the steadily increasing material prosperity in industrialized societies will gradually lead to a more relaxed attitude and a greater interest in using the increased productivity to improve our lot in a broader sense. We should remember the words of Blaise Pascal (from *Pensées*, 1670): "*The hearth has its reasons which reason does not know.*"

IV Extending the Space of Constructible Organizations

In Part III of this dissertation, we have discussed how computers have delivered another quantum jump in the history of organizational tools. In my view, information technology already ranks on the level of writing itself, and it leads to profound changes in some of our preconditions for organizing. The most important improvements over pre-computer technology, as analyzed in Chapter 9, are:

- ♦ Computers allow, for the first time, the externalization of processing, an ability of enormous importance. Work that previously required the attention of human minds can now be offloaded to machines, greatly increasing our capacity for certain kinds of processing. A potentially limitless “energy” source for these categories of mental work has been created.
- ♦ Quantitative tasks are presently the most important by far: for example, number crunching, format conversions (as when going from numbers to graphical representations), retrieval, selection, and sorting. Computing tasks that were theoretically impossible to carry out 50 years ago are now routine.
- ♦ Computer processing vastly extends the scope for automation and elimination of tasks in both manufacturing and administration. In fact, the incredible potential of computer-based automation compared to mechanical automation is today unfathomable.
- ♦ Computers can concentrate quantitative information enormously by presenting it in graphical form, especially when combined with animation. By thus exploiting the large bandwidth of our visual

system, information technology allows us to absorb such information much faster than before.

- ♦ Computer processing also greatly enhances our insight and understanding of complex matters and improves our ability to handle complexity. It significantly extends the coordinative reach and power of one person or a single team.
- ♦ Artificial intelligence and embedded rules and information can support work, both in time-critical and in knowledge-intensive activities.
- ♦ Computers also usher in a new revolution in memory. The database offers an improvement over paper-based files so large that it is of a quantitative as well as qualitative nature.
- ♦ Structured databases are so far the most important, with their vastly improved implicit coordination achieved through global reach, enormous capacity, and blistering speed.
- ♦ Free-form databases (text, sound, and pictures) are interesting and have important economic potentials but are considerably less important for organizational purposes.
- ♦ Computers increase available communication bandwidth by several orders of magnitude. The most important aspects are direct system-to-system communication and remote access to databases.
- ♦ Of less but still significant importance are email, computer conferencing, video conferencing, and other team support tools.

When we go on to discuss what kind of new possibilities these advances open up for organizing human work, we must remember that not even information technology can cure all ills, and that a number of important constraints remain in force:

- ♦ The human input/output capacity is basically unchanged, with the exception of quantitative information that can be represented graphically. All information in verbal form must still be read or heard, written or spoken, and this iron constraint shows no sign of yielding.
- ♦ This constraint still also puts absolute limits on the number of people with whom we can maintain a meaningful two-way communication—all new electronic media notwithstanding.
- ♦ The usability of databases, especially free-form information bases, is also severely constrained by the limits of human input/output and processing capacities. Simply increasing the amount of available information is not necessarily beneficial.

- ♦ Just as with previous technology, human internal processing and deliberation are not speeded up, even if our ability to handle complex work and parallel work processes is greatly enhanced.
- ♦ The limits of our own mental capacities now manifest themselves in a new way: The recent (and imminent) advances in information technology, especially in hardware, place such storage and processing capacities at our disposal that the main constraint for building more sophisticated and complex systems has become our own ability to first adequately analyze and understand the problem domain, and then design and install the intended systems.
- ♦ Neither our physiology nor our emotional makeup is adapted to the kind of highly abstract, problem-oriented work that fills an increasing part of our workdays. The result is often physical and mental strain that can lead to reduced morale, reduced performance, and even injuries.
- ♦ The preeminence of face-to-face contact in the establishment and maintenance of primary group identification may reduce the viability of virtual organizations. This constraint may affect women more than men.

Part IV attempts to establish how this new set of preconditions will allow us to extend the space of constructible organizations. That is not a trivial undertaking. In fact, the structuring of the discussion itself has been among the most difficult aspects of it, since the main dimensions—application type, organizational level, and type of effect/potential—are overlapping and impossible to isolate analytically. The most important application types span all organizational levels, and the main new effects/possibilities are results of combinations of applications, often working at several levels at once.

The first chapter discusses the individual and team level—because they represent the primordial elements of organization as well as the fundamental building blocks of larger organizations, and because there are a number of application types (among them some of the most hyped-up ones) that apply first and foremost to this level.

Then I will move on to discuss the core of the matter: the larger organizational context and the tools and potentials that apply to the organization as a whole. This discussion is centered on the three themes that I think embody the most important potentials provided by information technology for organizational change and improvement.

Each theme is treated in a separate chapter. The first is “Routines and Automation,” which will continue to represent an extremely important contribution to the development of modern societies, allowing enormous increases in productivity—something that will have a number of interesting side effects. Computer-based automation also includes automatic routines at various levels, which is a very important prerequisite for the two other themes. The second

theme, "Coordination by Default," is about how the use of databases can contribute to the age-old problem of coordinating the work of all organization members, both improving on existing arrangements and providing new ones. The third theme, "Comprehension and Control", is about how information technology is used to procure previously unavailable information and to make information more accessible, thus improving our understanding and control of both our work and the organization. This has clear implications for organization structure and the way organizations can be run.

At the end of each of these three chapters, I will discuss the possible extensions that the examined aspect of information technology may offer to the space of constructible organizations.

11 The Individual and the Group

“One man may hit the mark, another blunder; but heed not these distinctions. Only from the alliance of the one, working with and through the other, are great things born.”

Saint-Exupéry, *The Wisdom of the Sands*, 1948

In Chapter 9, we discussed how information technology can improve individual capabilities in those areas that are most important for our ability to organize. In accordance with the view of organizations as constructed and constituted through individual actions, these improvements represent the foundation for any IT-induced change of a systemic nature.

However, there is another side to these improvements: They improve the isolated productivity of the individual. In this chapter we shall discuss these possible improvements and try to assess whether such improvements can in turn be used for inducing organizational changes and improvements. We shall also discuss the group level before moving on to the subject of larger organizations in the next chapters, since the small group has, throughout human history, represented a basic level of organization with its own distinct needs and priorities.

The Individual Level

Support Tools

When talking about gains in personal productivity from computers, people mostly think in terms of increased efficiency for standard office work—for example, faster production of documents (with word processors), budgets and related calculation chores (with spreadsheets), presentations (with graphical packages), and communications (with electronic mail). Even though these are the applications that drives much of the investments in computer systems in offices right now, they are not the most important, and their potential impact on organization is in my view limited; it may represent no more than a significant

reduction in the number of typists—a contribution to the general trend of eliminating routine work. These represent mainly what we might term *bounded improvements* in productivity—local improvements within the confines of the jobholder's usual set of tasks and responsibilities. A typical example might be the salesperson who can complete a few more customer contacts and dispatch a few more letters and offers every day with the help of a PC-based sales support program and a word processor.

We will find the same effects in the realm of science and engineering, such as systems for statistical analysis, computerized equipment for chemical analysis, and CAD (computer-aided design) systems. They generally deliver much higher gains in personal productivity than the standard office tools mentioned earlier, however—simply because they tap much deeper and more directly into the numerical processing power of the computer. The combination of simulation and animated graphical presentation of the results alone has been extremely advantageous. Just imagine the difference for an engineer designing the front wheel suspension for a new car: earlier, it meant trial and error supported by time-consuming and rudimentary manual computations, or (just a few years ago) poring over computer printouts, trying to envision what the numbers really implied. Today, the simulated behavior of the new suspension can be *seen* in real time on a computer screen as it travels over various simulated surfaces.

As long as they are isolated systems, however, just supporting the work of the individual professional, even engineering and scientific workstations do not have any more impact on organization than office tools do. Their main effect so far has been a significant reduction in the number of draftsmen and calculation assistants (a parallel to the decimation of typists). The really exciting processes do not start until the systems are linked into design databases or planning and production systems, but, then the systems become more than personal support systems.

In the ordinary office environment, there is always the danger that the increased productivity will be eaten up through increased output of material of low significance or through unnecessary embellishments such as fancy layout and presentations laden with ornamental graphics. It often takes both a conscious approach and good management to really make savings stick.

Cell Automation

In organization terms, some of the same can be said about isolated automation of single tasks—what we might term *cell automation*. In both offices and factories, automating single tasks can increase local (cell) output per employee many times over. In an office it can, for instance, be used for address selection and printing; in a factory, for computer-controlled machine tools.

In both instances the computers provide not only greater speed, but also much greater flexibility, because of the almost infinitely greater complexity allowed in computer programs compared to mechanically controlled machines. However, unless the automated cells are linked into some sort of department- or organization-wide system, the traditional coordination methods and organizational structures will most likely prevail, and the bounded productivity improvements will not translate into significant changes on the organizational level.

By this, I do not mean that bounded improvements in productivity are unimportant. There are significant (in some instances even spectacular) savings to be had, especially in science and engineering, as the price/performance ratio of processors continue to improve. Processing power that used to be reserved for multimillion dollar supercomputers is now invading the desks of rank-and-file engineers and scientists, opening up a dramatic increase in productivity and an ability to tackle problems with a complexity many orders of magnitude greater than before. The demand for processing capacity is rising fast, and, in many areas of science, the proliferating use of very powerful computers is going to greatly accelerate the pace of progress.

Increasing the Span of Competence

Are there, then, any personal support systems that support significant changes in organization? I think there are—and that the key notion is the attainable *span of competence*. The area of interest here is the degree of specialization in the organization, and the amount of coordination and information transfer it necessitates.

When we discussed the emergence of functional specialization in organizations in Chapter 7, it was attributed both to the resulting increase in productivity as well as the need to reduce the time used for training. But there is of course also another and more fundamental reason for specialization, rooted in both the limitations of human memory and our low rate of information absorption: it is simply not possible for anyone to become proficient in everything.

This is of course not a barrier for the narrow, repetitive jobs of mass-producing industry, but it becomes an important constraint and determinant for design of organizations or parts of organizations where more complex tasks dominate. Typical examples are thoroughly professional organizations like universities, research laboratories and hospitals, but most organizations (and every large one) will have jobs where the limits to a person's effective, attainable *Span of Competence* become a design parameter. In a travel agency, for instance, no one can give a customer expert advice on travel in every part of the world. In a bank, no clerk can advise you on all aspects of the bank's services. In a government department, no single person will have the necessary knowledge to carry out more than a fraction of all the varied tasks falling within the department's responsibility.

This is not to say that all specialization in such organizations is based on the natural limits in the diversity of knowledge that humans are able to maintain—on the contrary, in most organizations, there is considerable room for broadening the area of responsibility for individual employees without the need for recourse to new tools. My point is only that it is not possible to broaden jobs indefinitely without coming up against fundamental human barriers, and risk a rapidly decreasing quality of the work in question. This is undoubtedly the cause behind a significant part of the functional specialization in modern organizations. Computer-based systems, however, do have the potential to expand our effective span of competence through *artificial memory*, *artificial intelligence* and *embedded knowledge*.

Artificial Memory

Even with present text retrieval systems, it is possible to offer much easier and more comprehensive access to laws, regulations, precedents, guidelines, policy handbooks, solutions to previously encountered problems and so on than when relying on printed or written media alone. Future systems will improve this further. With so much faster and exhaustive information retrieval, it should be possible to support decisions and problem solving for broader fields of work than we can safely master without such assistance.

Artificial Intelligence

Artificial intelligence (AI) clearly also has the potential to help stretch our span of competence. It has already been demonstrated that expert systems can improve decisions. Rasmus (1991), for instance, reports how an expert system introduced by Southern California Edison incorporated the company's policy for computer purchases and allowed the departments to configure their own PC purchases in adherence to the central guidelines without assistance from the DP department. DEC's XCON system and the successor XCEL is well-known (Walton 1989, Heller 1991). XCEL helps DEC's salespeople to arrive at the best systems configurations for their customers.¹ The pace of development here has been slower than predicted, however—even for XCON, perhaps the most extensively used expert system and certainly one of the most widely reported successes, it was deemed necessary to have a human expert check each and every "decision" (Long 1987). Nevertheless, there is little doubt that such systems will play an important role in the future within particularly well-defined problem domains.

Embedded Knowledge

Embedded knowledge is not the same as an expert system. It simply means that a computer-based system may have "knowledge" embedded in it as a part of its data structure and its functions. A simple system for computing annuities, for example, has embedded in it the rules for such computations. A bank clerk with access to a system like that can advise a customer on the size of his annual payments for a particular loan without knowing anything about how to compute annuities himself. All computer systems have such embedded knowledge to a greater or lesser extent, and many computer systems are therefore able to extend the span of competence of their users.

One interesting problem turns up as more and more knowledge and rules are embedded in systems—both in this simple sense and in connection with the rule-based inference engines of AI programs: Work rules, regulations and even the substance of laws may end up as embedded information in computer programs designed to support office work. The problem is particularly important in the government sector, where an increasing number of regulations and even law clauses are embedded in systems used for administrative purposes.

When this happens, it becomes more difficult not only for the public to fully understand how the laws and regulations are applied, but also for the lawmakers to control whether their laws are actually *correctly* represented in the systems.

¹ With several tens of processor options and a multitude of peripheral equipment, it is not a trivial task to configure a system that is properly balanced for its purpose.

Experience has shown that you cannot always trust programmers to render law into code and carry the lawmakers' intentions through unscathed. We can therefore anticipate a growing need for *system auditors*, people who can scrutinize systems and see if the embedded rules are actually in accordance with the rules, regulations or laws they are meant to express. We may even see laws passed demanding that all systems with laws or government regulations embedded (which will include accounting systems) *must* store all rules pertaining to those regulations or laws in separate tables (and not have them "hard-coded" into the body of system code) for easy auditing. In my view, such legislation is long overdue already.

Embedding laws in systems may also make them harder to change, because of the limits of the systems they reside in, and simply because nobody may have a complete knowledge of the systems involved. There are already stories circulating about how proposed changes in taxation have had to be abandoned or postponed because the necessary changes to the revenue service's computer systems demanded rewrites too extensive to meet deadlines.

I have no doubt, though, that such problems will be overcome and that systematic use of all the tools available—both artificial memory, artificial intelligence and embedded knowledge—will make it possible to broaden the range of tasks people can carry out with an acceptable level of quality, in some instances considerably, and thus make it possible to eliminate even more coordination and control activities.

Another aspect of this combination of support tools is that it will make it possible to improve the quality of professional work overall. Appropriate systems built on this technology should allow physicians to make better diagnoses, judges to pass sentences that are more consistent, and caseworkers to achieve greater consistency and quality in their work—in short, to help most professionals to adhere more closely to professional standards. Viewed in this perspective, this collection of tools should provide us with a much improved version of Mintzberg's (1979) coordinating mechanism standardization of skills, which is defined more narrowly to standardization of explicit skills in Figure 7-1 on page 176. I suggest the name *system-supported skills* for this new, computer-dependent coordinating mechanism (see also the extended taxonomy of coordinating mechanisms in Figure 13-1, page 339).

Response Assistance

Finally, systems based on the concepts behind artificial intelligence should be able to help by suggesting responses in complex operative situations, especially during cognitive overload or when time is a critical factor for other reasons. The systems could even be designed to take action without "consultation" with the human operator if the time allowed for response is so short (as it may be in an emergency) that the human operator cannot be expected to react fast enough. Such systems could probably prevent tragedies like the airplane crash mentioned in Chapter 4 and disasters like the Chernobyl nuclear reactor meltdown.

But Personal Productivity Is Not the Key

The analysis in Chapter 7 showed that the main stimulus behind the industrialization and the developments of the modern, bureaucratic organization in the nineteenth century was the tremendous productivity increases that could be obtained through functional specialization. This specialization, however, led to a fragmentation of the production process, which in turn necessitated close coordination between a large number of highly interdependent tasks. This was something that the traditional organizational forms could not deliver, especially not as the production volumes and organizations started to grow rapidly. The result was the modern bureaucratic organization, using standardization of work as its main coordination method.

If a technology-induced increase in workers' productivity could drive this great change, it may seem natural to ask if computer-based increases in personal productivity today could have the potential to play a similar role. In my view, the answer is no—the basic characteristics of the technologies involved are very different, and the keys to exploit them therefore quite dissimilar.

The increase in productivity achieved during industrialization was generally accomplished by breaking production processes down into simple, separate steps that could be performed fast with a minimum of training, and then enhancing productivity at each step by the use of specialized tools and rapidly increasing amounts of external power—first waterpower, then steam, and finally electricity. The developments of narrowly specialized work operations and of effective (and equally specialized) tools were intimately related and each drove the other (as well as energy consumption) forward. And, even if a number of the steps in the production processes were later partly or wholly automated, the main effects of the technology were still local and did not reduce the total needs for planning and coordination.

The increased use of energy has in fact been pivotal. Today, the energy consumption of industrial production in a modern economy such as Norway's is more than 1000 times the energy the employees alone would produce if they were engaged in heavy physical labor. If smelters and other energy-intensive industries are excluded, the energy consumption in Norwegian industry is around 400 times the potential output of its employees.²

Later, when automation developed further, it encompassed increasing numbers of production steps and also provided all or most of the coordination between those steps, but its effects were still local with respect to the total organization, and the need for coordination both of the production process and the overall organization could still only be met by standardization of work and a bureaucratic organizational model.

² An adult doing hard physical labor such as digging and shoveling expends about 0.15 kWh per hour, which equals a continuous output of about 0.2 horsepower. Norwegian industry in 1992 consumed about 300 Mwh per employee, which (with an average work-year of 1750 hours) means around 170 kWh per hour—equaling a continuous output of about 230 horsepower. If energy-intensive industries such as smelters are excluded, energy consumption per hour per employee is about 63 kWh, the equivalent of a continuous output of approximately 85 horsepower. Sources: *The Economist Desk Companion* (1992), *Statistical Yearbook of Norway* 1994.

Industrialization, then, built on specialization of work, the use of specialized machinery for physical manipulation, and a general use of external power. To apply that productive force effectively required large amounts of information processing (planning and coordination) that had to be carried out manually.

We have come a long way along this road, and a further increase in productivity at any isolated step in a process—even if it is substantial—is in itself not enough to change the picture significantly when we talk about organization. Output of the total organization may well increase greatly, but as long as the improvement is built on isolated achievements at single steps in the process, the organization itself is not likely to change very much.

In contrast to the specialized machinery of traditional industry, the computer is a general, information-processing machine that is able to adapt to an extremely wide array of tasks. The strength of information technology is first and foremost its ability to support coordination and planning, and to carry automation (including automated coordination according to exact specifications or plans) to new levels of complexity and sophistication. *Information technology should therefore be expected to affect first of all the design and coordination of work processes and the linkages between different tasks, and achieve its greatest effects through directing physical processes of far greater complexity with superior efficiency and flexibility and with much less overhead than before.*

Extensions to the Constructible Space

Isolated elimination of routine jobs in itself, then, offers fairly limited extensions in the space of constructible organizations. Nevertheless, the potential increases in personal productivity should allow some changes. The most important opportunities are probably connected to de-specialization and an increased use of self-service.

Elimination of Routine Jobs

The bounded improvement in personal productivity effected through the office tools and cell automation described earlier has fairly little to offer with respect to new organizational structures. The main opportunity there lies in the elimination of routine jobs. We have touched upon this already: Many of the tools in the personal support category do the kind of work that was previously provided by secretaries and various kinds of assistants.

Routine jobs may also be eliminated by more comprehensive changes, such as in the accounts payable function at Ford (Hammer 1990, Hammer and Champy 1993), which will be described in some detail in Chapter 13. However, we are then not talking of reductions based on increases in personnel productivity, but of a thorough reorganization facilitated through the use of the coordinative power of a database.

The groups hardest hit by elimination based on personal productivity tools have up to now been filing clerks, typists, draftsmen, and assistants performing various kinds of calculations. In the long run, most routine office jobs are in danger—as their functions are either automated or eliminated. The routine jobs with the best chance of survival are those that have the character of physical

services: The janitor and the cleaner will survive, for instance; we will still need some people in the canteen, and most organizations will prefer a human receptionist to greet and direct visitors. But, if the entire organization shrinks, there may be even fewer such jobs around.

De-Specialization and Knowledge Support

Broadening the span of competence through the use of system-supported skills has somewhat more to offer, since it may allow us to decrease job specialization. Perhaps we should rather call this re-integration or even *de-specialization*—to emphasize that we are now able to alleviate some of the problems that job specialization created in the first place.

De-specialization is not a universal option. It builds on two pillars: easy retrieval of information on the one hand, and embedded knowledge and AI on the other. These tools primarily support de-specialization of jobs that require people to collect information from many sources for further processing, or for use in decision making on the basis of law, rules, or regulations—the archetypal *bureaucratic* kind of job after Weber's definition.

The important aspect of this is that de-specialization, by reducing the number of steps in the work process, also reduces the need for information transfer, one of the most time-consuming activities in any large office, and a major source of errors and misunderstandings.

The main reason that functional specialization met with much less success in the office than in the factory can be found precisely in the much higher volume of information that has to be transferred from person to person as part of the work process there. In the factory a piece of hardware coming down the assembly line embodies most—if not all—of the information needed by the workers. The information is absorbed quite literally at a glance, and, consequently, one attracts very little penalty—if any—in the form of increased time for information transfer when one increases functional specialization.

A transaction so simple that it only needs to be registered or stamped can be processed in much the same way in a white-collar "line." As soon as it becomes a little more complex, however, requiring some kind of assessment and decision making (what might more readily be termed a *case*), it will normally be accompanied with a lot of written information—usually both the basic information collected at the point of entry and the information produced as a result of the work done on it so far. Often, there will also be a need to transfer informal, oral information.

Any increase in functional specialization in the office will therefore normally incur a considerable overhead in the form of information transfer. Not infrequently, absorbing all the relevant information and making sure that one understands it correctly takes longer time than doing the actual work. As noted earlier, numerous information transfers also create ample opportunities for errors, misunderstandings, and loss of information. We have probably all been victims of such mishaps in our encounters with bureaucratic structures. Indeed, many of us have been guilty of producing them as well.

Reducing the number of information transfers in an organization will therefore contribute greatly to its productivity, especially since interpersonal communication itself is so difficult to make more efficient. As our previous

analyses have shown, this is the most recalcitrant of all our innate constraints when it comes to tool support. Despite all our gadgetry, it takes about the same time to transfer information from one mind to another today as it did a hundred years ago—and, if we talk about people at the same location, it takes the same time as it did 10,000 years ago.

How far can the concept of de-specialization be developed? Can we, for instance, imagine computer-supported superprofessionals covering many disciplines, or supermanagers taking over the responsibilities of entire present-day management teams? What the distant future will bring is not possible to foretell, and history has taught us not to try. In the foreseeable future, however, such a scenario is simply impossible, because the knowledge that can be embedded in systems, even in AI-systems, is mainly of the “hard” kind: simple facts, or pretty simple if-this-then-that rules. Even advanced AI systems are extremely limited compared to a human mind.

All our “softer” knowledge; our experience; our tacit knowledge; our ability to interpret facts from a context and previous experience; our ability to form overviews, to judge and weigh information and decision alternatives is impossible to embed or mimic in a system. In a professional and managerial position, extensive experience and background knowledge is always needed to respond sensibly to problems or execute tasks in a satisfactory way. Even if we could build a system that would allow persons without such experience and background knowledge to respond adequately in many or even most instances (a daunting, but perhaps not impossible task in certain circumstances), they would be at a complete loss when more complex situations arose. Or, even worse, they might think—erroneously—that they had a good answer and then happily execute it, since they did not know enough about the implications to understand their own shortcomings.

The limiting factor, then, for integrating professional and managerial jobs is not so much the nature of the tasks themselves, but rather the extent of the knowledge and experience that is necessary to fully understand their implications. For some jobs (for instance, in sales) the number of personal, external contacts that must be maintained is also a limiting factor on the number of functions one person can shoulder. Everyone with experience in sales activities knows that personal contact is extremely important and that it cannot be totally supplanted by more “efficient” computer-mediated, semiautomatic communication.

Self-Service

However, the opportunities range further than this. Of particular interest is the possibility of offloading tasks onto the customer, thus removing it from the organization altogether. Supportive systems with elements of AI and/or embedded knowledge may allow for much more extensive self-service than we have been used to. Automatic teller machines have already introduced us to personal support systems that allow us to complete some kinds of bank transactions ourselves. The types of transactions that have been made available for self-service so far have been few, but there are more advanced machines (and systems) coming up, and the concept should be possible to develop to the point where the bank itself all but ceases to exist (we shall return to that particular case in the next chapter).

There are doubtlessly other areas where computer-supported self-service will surface. Airline tickets are already sold this way in some places, betting systems should be eminently possible, and insurance (at least some kinds, and more advanced than the travel insurance you can buy from vending machines at some airports) is a product that should also lend itself to similar self-service systems. The filing of applications for various purposes is another area open for computer-supported self-service solutions.

Although self-service is a phenomenon all by itself, it can also be seen as an aspect of de-specialization, since the logic behind both is the same: Systems guide us through; because they “know” how things are to be done, they help us get at the necessary information, prompt us for our contributions, and then perform the transactions on our behalf. The organizational effects may be profound, even if the customer may not feel de-specialized—a lot of specialized jobs will disappear because customers take over their work, and large parts of existing organizations may be eliminated.

Conclusions

The various improvements in personal productivity discussed earlier have already made possible changes that have had significant impact on organizations, and more is bound to come. As personal productivity continues to improve and cell automation and self-service proliferate, organizations of all sizes will be able to reduce their payrolls further—at least in the parts of the organization where the improvements are implemented. This is of course not the only source of workforce reductions—it is not even the most important one, as we shall see later. However, it will allow for significant reductions. A reduction in the number of employees will also allow them to reduce the number of administrative layers somewhat—in particular, de-specialization should contribute to this.

However, the changes are relatively simple: By and large, they consist in workforce reductions. Even if de-specialization may involve an integration of jobs and thereby a marked reduction in the need for information transfer, it provides no particular platform for really inventive organizational changes. There are no genuinely new principles involved—the IT-based advances in personal productivity mainly represent improvements and extensions of the development process started in the eighteenth century.

Granted, the improvements are dramatic in some respects and may foster significant local changes in many organizations, as typing pools are dissolved, assistant draftsmen made superfluous and jobs broadened. The improvements in productivity can even be said to be of epochal proportion in quite a number of scientific and engineering disciplines. Organizationally speaking, however, they do not significantly expand the space of constructible organizations, nor do they build significant pressures for evolution in totally new directions.

Groups and Teams

All organized activities are instances of cooperation, and, in that sense, cooperation can be thought of as more or less synonymous with organization.

When talking about cooperative work in connection with the use of information technology, however, it is the team and the work group that is in focus. The discussion in this section will therefore be limited to that level; a group small enough to let each member have more or less direct contact with all the other members.

I have quite intentionally made a distinction here between the concepts "team" and "work group." Although these expressions are frequently used as synonyms, at least in everyday speech (I often do so myself), they have distinctly different connotations in a more precise theoretical context. A group or work group is a fairly loose term, designating any relatively limited number of people who work in conjunction with one another for a common purpose. A team in its more precise sense is a small and tight-knit group with a common purpose, a strong sense of commitment, and a genuinely shared responsibility for the outcome of their work. It is this genuine commitment and shared responsibility that serves to distinguish the true team from the work group, not a particular way of working. As Katzenbach and Smith says (1993, p. 21, italics in original):

Teams are discrete units of performance, not a positive set of values. And they are a unit of performance that differs from the individual or the entire organization. A team is a small group of people (typically fewer than twenty) with complementary skills committed to a common purpose and a set of specific performance goals. Its members are committed to working with each other to achieve the team's purpose and hold each other fully and jointly accountable for the team's results. Teamwork encourages and helps teams succeed; but teamwork alone never makes a team.

The definition offered by Katzenbach and Smith is a bit more stringent than the meaning attributed to the term by many other authors, however, and some of them will be referred to in the following. I will therefore use the word "team" a little more liberally than if I were to follow the preceding definition to the letter.

Anyway, even according to this definition, teams and work groups should have the same kind of needs for coordination and work support and thus reap the same benefits (and share the same problems) from using information technology.

The use of computers in group support is perhaps the aspect of computer use that receives the most attention at the moment (together with multimedia, the Internet and the concept of "electronic highways"). In my view, this attention is not warranted by its actual contribution to organizational transformation and efficiency (this goes for multimedia and the Internet as well). It is, however, easy to understand why it arouses so much interest: It talks directly to our primate, emotional side; it is all about humans being human together, rather than functioning as machine-like parts in a machine-dominated organization. Using a term from organization theory, Cooperative Computing and the development of groupware may in many ways incarnate the human relations movement of the computer scene.

Cooperation among humans is almost synonymous with communication. The exchange of views and ideas, the transfer of information, and working out decisions and making them known involve copious amounts of communication, with meetings as the main instrument. People who continuously grumble about "all the time thrown away in meetings" only demonstrate that they do not

understand the nature of human cooperation or the burden of coordination placed upon us by any organized activity. They may simply believe in commanding instead of cooperating, and thus feel no need for advice, for discussions, or for building motivation.

There are of course good and bad ways to conduct meetings, and in many, more work could be accomplished in less time. Some meetings are undoubtedly even unnecessary—but I also know about a good number of necessary meetings that were never held, to the detriment of the organization in question. The fact is that any organized activity will require meetings, and, the more dynamic the situation is, the more meetings will be required. It is no accident that the supreme military commanders in critical situations or during major offensives meet continuously during the most intensive phases to coordinate the efforts of their respective services—they are not locking themselves into their separate offices to do “real work.” As noted earlier, such real-time coordination is what war rooms are all about.

It is no wonder, then, that much of the work being done in the area of cooperative computing involves either support for face-to-face meetings or tools for electronic meetings. Johansen (1988) even concludes that such efforts can best be categorized according to their support for meetings or activities related to meetings. I would like to propose another classification scheme, however: *meeting support*, *work support*, and *infrastructural support*.

Meeting Support

Meeting support involves both systems to support face-to-face meetings and systems designed to allow “electronic meetings,” where people do not have to actually meet in person. Work on such systems started quite early in the computer era—for instance, quite a lot of the original work of Douglas Engelbarth, the “father” of groupware and graphical user interfaces, involves systems for the enhancements of meetings. Work on support systems for face-to-face meetings and “electronic” meetings started at about the same time (aside from telephone meetings, which were in fact used to some extent early in this century before automatic exchanges were introduced and made them technically difficult to set up).

Meeting Support Systems

The main approaches to meeting support systems have been various forms for electronic white boards and group decision support systems. The aim has been to provide tools for better structuring of meetings, easier integration of contributions from the participants, and better documentation of the results.

The results so far have been fairly meager. It is difficult to make tools that truly contribute to real-time, human communication processes, and it is even more difficult to make them so easy and intuitive to operate that they are adopted for use outside the rather narrow circle of groupware developers and enthusiasts. I think there are potentials for improvement here, however, and I believe that the electronic white board will slowly develop into a useful tool—but that development will take many years. Perhaps the most important initial contribution will be the ability to retrieve and display information from corporate

and external databases, to provide a common platform for discussion, and to quickly satisfy needs for ad hoc information that may arise during meetings.

Most of the development in this area has been devoted to meetings in administrative environments that work mainly with language (text)—that is the case with all the systems described in Johansen (1988). This can perhaps be explained by the background of the researchers, their institutional settings, and the all-too-common preoccupation with the problems of top management.

However, the analysis of where the computer contributes most to enhance our own abilities suggests that the potential for useful meeting support tools should be much greater in the professions already working with highly graphical applications, such as printing, advertising, architecture, and engineering design. Electronic white boards in those environments, in the form of large-screen, common workspaces, could serve as very important productivity instruments for design groups. And if, in the future, one succeeds in harnessing more advanced graphics and animation for the display of more administratively oriented information, the electronic white board may gain in importance even here.

Electronic Meetings

Among the tools for meeting support, those meant for supporting fully “electronic” meetings have aroused by far the most widespread interest. They may involve telephone, video, computer conferencing, and screen sharing. Screen sharing means that everybody participating in the meeting can see and access the same picture on their displays. The focus of development lies in the direction of video conferencing, preferably combined with screen sharing. With a sufficiently large screen and sufficient bandwidth on the transmission lines, it would then be possible to conduct workgroup meetings onscreen. One part of the screen could be occupied by the live pictures of the participants; the rest could be available to material for presentation and manipulation.

Simpler solutions may involve telephone conferencing with screen sharing or real-time computer conferencing (with all the participants on-line at the same time). Traditional computer conferencing, in which participants log on at different times and keep exchanges going for days and weeks, does not seem a viable tool for meetings, but for easy exchange of written statements and expositions—it is more like an electronic journal or bulletin board.

The analysis in the previous chapters indicates that such solutions will be a good tool for groups where the participants know each other, and will make it easier to maintain cooperation in spite of geographical separation. It also suggests that the improvements will be especially important for those who work with strongly graphical applications—geographical separation is more of a handicap for them than for groups working mainly with text and numbers, and they have more to gain from screen sharing. However, the need for colocation and face-to-face meetings cannot be totally eliminated—at least not yet.

Work Support

Meetings are certainly indispensable to coordinate and reach decisions. Meetings also quite often function as problem-solving work groups. Thus they encompass most aspects of group work. However, groups do not only work when

they meet, the members also work by themselves on their part of the group assignment. Most of that work is probably accomplished with the help of various personal support systems, but, in addition, groups need tools that can support such work within a common framework, and help integrate the various contributions. Electronic mail, conferencing systems, and group authoring programs (programs supporting the production of joint documents or other forms of joint information presentations) are such tools, along with common databases.

A typical example of computer-supported group work was quoted in Chapter 9 (from McKersie and Walton, 1991 p. 252); in the example, telephones, a conferencing system, remotely accessible databases and word processing were used to produce a joint document with a number of remotely located managers.

As noted in Chapter 9, that document could doubtlessly have been produced without computers, but probably with lower quality. More advanced tools such as video conferencing and screen sharing would further increase the edge that computer-based systems will give over pre-computer tools. Even here, however, I think the potential is greatest for work involving strongly numerical and graphical applications, such as engineering design (CAD). By having a common database representing the total object to be designed as basis, a true design-group-oriented CAD tool should offer both full coordination and coherence of the overall design parameters and of the interfaces between modules, while, at the same time, allowing the individual designer to work on his/her part of the assignment. When fully developed, however, such a system becomes much more than groupware—it becomes a very complex system for coordinating the work of a total organization or even many organizations. We shall return to this subject in Chapter 14.

Although they do not, strictly speaking, belong to the groupware class, workflow also merit attention, since all the vendors insist that they belong here. The vendors probably do so because groupware as a concept is very much in vogue, and also because they do not have very many other products to include, besides calendars and email systems.

Workflow tools are meant to speed work along from point to point in a work process, and they also take care of some of the most routine aspects of that process. As Thé says (1995, p. 65),

Workflow automation software is a toolset for developing applications to manage, measure, and revise work processes that span the efforts of multiple workers and applications (and sometimes span multiple organizations)—a kind of CICS³ for both people and programs. Personal productivity software aims to improve worker performance while doing tasks; workflow aims to squeeze out the time between tasks, which sucks up far more of the total time a process takes than many would believe.

Workflow tools, then, build on a rather traditional approach to office work, aimed more at speeding it up than changing it. The underlying model is still that of a chain of individual caseworkers each doing an incremental part of a total task.

³CICS: Customer Information Control System, an IBM program product that enables transactions entered at remote terminals to be processed concurrently by user-written application programs. It also includes facilities for building, using, and maintaining databases. It is prerequisite for interactive data processing on for IBM mainframes.

The products provide instant transport of all electronically stored material between caseworkers and also make it much easier to monitor progress and to find out where in the process a particular case is at any particular time. Householding functions save time for caseworkers with chores such as filing and routing. Workflow tools can undoubtedly increase productivity in most procedural environments, but in the process they tend to cement existing routines and inhibit more creative solutions built on automation and elimination of tasks—a subject we shall discuss in the next chapter.

Infrastructural Support

To function properly, groups require a certain infrastructure. In traditional terms, we would say that they need office space for work and meetings; they need a common “memory” in the form of files and archives; they may need support personnel of different kinds. We would also prefer groups to work at the same location and in adjacent offices, not only because of the efficiency (easy access to each other and no travel time to meetings), but also because colocation is generally deemed necessary to build the team-spirit that is so important for successful teams. Friendship and team spirit need a certain volume of interaction to grow, and preferably ample and regular opportunity for informal contact. The close proximity of a common work area is required to achieve the necessary volume of such interaction.

Computer-based systems can improve such group infrastructures in several ways. The most obvious one is perhaps the database—both the text base and the structured database. When everyone can easily access and use the same information as a basis for their work, the general coordination of a group is automatically improved. Group calendar systems can also be of help in groups where the members spend much time away from a common office and have difficulty keeping tabs on each other to arrange meetings, etc. Computer-based project management systems also represent an improvement over earlier tools and can significantly increase the flexibility in larger projects when it comes to tackling unforeseen events and changes in plans and priorities.

Then there is the issue of personal communication. When analyzing the merits of electronic communications in Chapter 9, I concluded that the new channels still did not measure up to face-to-face contact in social and professional communication between humans. However, I also concluded that video conferencing especially would allow us to reduce the number of required face-to-face meetings and could function quite satisfactorily in many instances, especially for people who already knew each other well. When we now discuss the subject of group infrastructural support, it is interesting to consider the possibilities for using electronic communication to improve team building in teams that cannot, for various reasons, work in the same place—something that is usually believed to be a necessary prerequisite for building and maintaining the strong, mutual commitment that is the hallmark of the successful team.

The attempts that have been made to create electronic “spaces” for spontaneous and informal communication have not been very successful (Johansen 1988), however. The technology has been too constraining to allow for the casualness required for successful informal interaction to develop. Small

screen formats, mediocre sound quality, and the high price of video communication have combined to limit the usefulness of video conference systems. Computer conferencing systems, especially the numerous bulletin boards for computer enthusiasts, have actually shown some capacity for creating and maintaining electronic "cliques," but mainly among young people or others with time to spare.

The trouble is that communication is a time-consuming affair, and, no matter the quality of the channel, communication with more people subtracts more time from the time available for "real work."

With the greater availability of bandwidth that is bound to come in the future—due to the development of data compression, new transmission techniques, and the increased use of optical fiber in telecommunication networks—possibilities for "virtual groups" may improve, however. With sufficient bandwidth available, we can have not only videophones, but video-wall rooms (shall we dare to nick-name them *vidwams*?) where one or more walls consist of a high-definition video screen showing a similar room in another location. With sufficiently advanced sound systems, it should be possible for geographically separated groups to achieve a fair semblance of the experience of actually being together in the same room.

Such rooms should also contain or give easy access to video cubicles (*vubicles*) where single persons or small groups could sit down to have a closer chat with someone at "the other side." *Vidwams* could serve partly as relax areas, where people could come in to see if anyone was there, partly as meeting rooms or rooms for presentations—or may be even as canteens. It is likely that the effect of seeing and hearing even in such an electronically mediated way would help build stronger ties and loyalties than geographically separated groups could otherwise achieve. Let us just remember that the time constraint, mentioned earlier still apply: *vidwams* will not make it possible to work closely with significantly *more* people than before—even if successful, they will only allow about the *same number* of people to work closely together in spite of geographical separation.

Extensions to the Constructible Space

Could group support tools then give rise to new ways of group cooperation, or even new organizational schemes? Many people seem to think so—especially, of course, proponents of groupware and what is termed *computer-supported cooperative work* (CSCW). See, for example, Greif (1988, p. 6):

CSCW research is examining ways of designing systems—people and computer systems—that will have profound implications for the way we work.

It is not entirely clear what those implications will be, however. The speculations cluster around a small number of themes. The main argument is that computer-based tools will increase group productivity and creativity through improved coordination and communication, by allowing groups to do more work in real-time group mode than before (direct work on the same screen, for instance), and by better supporting and structuring the work done individually.

It is also believed that this improvement in group productivity and increased communication capacity will result in increased emphasis on teams, more horizontal communication and thereby flatter and more democratic organizations (see, for instance, Drucker 1988, Johansen 1988, Greif 1988, Keen 1991). This is by no means clear, however. As Rockart and Short remark (1991, p. 205),

Unfortunately, the team-based literature to date is highly speculative. As a general model of organizational structure, it leaves many questions unanswered. Primary among these are the long-term implications of organizing in such a manner that moves primary reporting relationships away from the more usual hierarchical, functional, geographic, or other product structures. These structures work to immerse employees in pools of "front-line," continually renewed expertise.

Johansen, whose account of groupware products and research is very factual and realistic, makes his own reservations in the introduction to his book *Groupware* (1988). After underlining that his conclusions "lean toward the upsides of groupware," he lists his concerns—among them that there may be too many meetings, overdone teams (too many participants without reduction in other responsibilities), increased control over team members, too much structure, and a tendency for people to only join teams that use the systems they know.

It should come as no surprise that I also belong to the skeptics in this area. I do not doubt that computer-based systems can provide valuable tools for improved group coordination and communication and, in some instances, increase productivity significantly. But I do not think that the improvements will be sufficient either qualitatively or quantitatively to transform group work or make groups and teams so much more effective that organization structures can be radically changed.

As mentioned earlier, the gist of group work is communication—sharing information and views, building a common understanding of problems, and forging common decisions. These are exactly the areas where the analysis in Chapter 9 suggests that computers can contribute the least. To comprehend the ideas and thoughts of other people, we still have to listen and read, and it matters little how fast information can be transferred from computer to computer when the time spent to write, read, speak, and listen does not change. We still need to reflect upon that information at our own pace to respond sensibly to it. Cooperation simply takes a lot of time and effort, and it does not seem very likely that we can escape these fundamental constraints in the future.

I do not mean to suggest that computer-based systems will be entirely without impact on the way groups work. Neither do I think that there will be no new opportunities for organizing. But I do think that the effects in this area will be much less dramatic than the CSCW enthusiasts predict.

The fact is that the kind of improvements in group productivity delivered by the kind of systems discussed earlier—such as coauthoring systems, meeting assistance, electronic mail, and group calendars—will not change significantly the nature of the tasks that groups can tackle. They will only allow them to be somewhat more efficient, produce work of somewhat higher quality, and function more independently of physical proximity.

To increase the productivity of groups and teams in itself should, moreover, not have too much of an impact on organization, aside from strengthening the general trend toward increased productivity and reduced manpower requirements. The production aspect of groups and teams really only gets exciting when we transcend the boundaries of the group itself and look toward integration with the total organization—as when engineering design groups work through systems that link their work directly not only to other design groups, but (through a common database) also to production, sales, and distribution.

For the organization as a whole, the reduced dependence on colocation may turn out to be the most important opportunity, especially if effective means (such as the vidwams proposed here) can be found to foster real team spirit and the development of a common organizational culture across geographical divides. That would make it easier to exploit other aspects of computers as well—such as the increased reach of direct supervision and the implicit coordination of company-wide databases—for better coordination of companies with far-flung operations.

For example, companies with geographically dispersed manufacturing operations turning out similar products could benefit considerably from a close coordination of those operations—to the point of running them as one integrated factory based on integrated computer systems encompassing both sales, production, and warehousing/distribution. However, due to the normal human process of primary-group identification, the spirit of independence of such plants is usually quite fierce, often leading to considerable resistance when it comes to close coordination with sister plants under the auspices of what is perceived as a remote and faceless division management in the division headquarters. If vidwams, videophones, conference systems, and electronic mail could help to establish cross-plant work groups and a primary-group identification among key personnel from all the plants as well as the headquarters, such an organization would be much closer to succeeding with tight coordination than before. The same technique could possibly be used to build cross-company loyalties at select levels in multinational companies, to support coordination efforts built on other aspects of computer use.

To achieve this is not easy, however. Because of the iron constraints of the human communication apparatus, even systems such as those discussed here do not make it possible to increase the total communication volume in an organization very much. The people who participate in this form of communication would either have to reduce their communication with the people they work with locally, thus putting some of their local relationships at risk, or significantly increase the amount of time they allocated for communication.

To use expressions from network theory (Lincoln 1982), computer-based systems would not make it possible to significantly increase either the *density* or the *connectivity*⁴ of organizational networks, although the links could possibly be

⁴ The *density* of a social network is a measure of the number of links between the nodes (nodes can be persons or groups, depending on the level of analysis). It is calculated as the ratio of actual ties to potential ties. The *connectivity* denotes the degree to which nodes are linked to other nodes either directly or indirectly (through other nodes). A maximally dense network (for instance, a group where every member has a direct link with every other member) will also have a maximum connectivity, but a fully connected network (for instance, a hierarchical

others, span greater geographical distances, and thus change the structure of both inter- and intracompany networks. It is therefore doubtful whether the use of information technology will be the decisive factor for allowing team-oriented organizations to achieve flatter and more democratic structures. Computers *can* help flatten the organization, but not because of groupware—it is rather the systems for personal support discussed in the preceding section and the automatic coordination coming up in the next chapters that will provide the major impetus in that direction.

It is also quite doubtful whether it was the prospects of groupware and computer support that arose the interest and faith in teams in the first place. As Johansen (1988, p. 5) quite correctly notes, the increased emphasis on team-oriented organization probably has reasons other than computer technology:

Coincidentally with the new technology trends, the U.S. business environment—including that of nonprofit organizations—is becoming increasingly team oriented. In fact, the concept of business teams is becoming popular quite independently from the trends toward groupware.

He then goes on to list a number of the reasons, including deregulation, the trend toward contract work, increasing geographic spread for companies, and the declaration of team-oriented companies as models for the business world.

There may even be more basic reasons for the emphasis on teams and the interest for groupware, however. Both the debates about teams and the development of groupware are products of the academic and professional communities (which include most managers), which have a well-developed propensity to prefer teams. Their educational backgrounds have accustomed them to professional discourse as an indispensable tool for developing ideas and solving complex problems, and their jobs more often than not require them to work in close cooperation with colleagues in their own profession as well as people in other professions. Most of them *like* discourse-rich environments; they *want* to work in groups, and would quite naturally like to see the team concept gain ground—hence a fascination for groupware.

By this, I do not mean to say that groups and teams are not important, or that professional discourse is superfluous—on the contrary, discussions are indeed indispensable for much of the work that professionals do, such as planning, product development, business development and administration and problem-solving in general. Let us not forget that after the family, the team is probably the oldest and most basic organizational structure we have. But the feeling that teams are all-important and an answer to most of the problems of contemporary organizations may reflect just as much the local work environment of the team champions as the functioning of large organizations in their entirety. To the extent that the team concept is growing in importance throughout the organization, as indeed seems to be the case, this growth could also be an artifact of progressing automation and elimination of routine jobs: automation largely passes by jobs of the kind that professionals use to have, and thus increases the proportion of team-

organization where everyone is linked to the top manager through their bosses) can have low density (as if no one in a hierarchy has links with people other than his or her boss.)

oriented work in the organization even if the absolute number of people working in teams remains the same.

Consider, for instance the control room operators in the fully automated process plant discussed in Chapter 13. To tune the factory and squeeze maximum production and the desired quality out of it, operators can no longer work in isolation: They may have to team up with both process engineers, product specialists, and marketing people. In that sense, the workers have been changed from isolated operators responsible only for discrete steps in the production process to team members with joint responsibility for the total result. Thus, it seems to constitute another example of the transition from hierarchical, command-chain organization to a team-oriented approach in industry.

Appearances are deceptive, however. A closer analysis *also* suggests that the job as control room operator is not a continuation of the earlier manual work but, rather, an (incidental) appropriation of the work of the production manager and his immediate subordinates—a group of people that has *always* had to function more or less as a team. It is thus not a question of the transformation of jobs or job roles: The former jobs of the control room operators (control of the discrete steps in production) have simply been eliminated through automation, and the operators themselves have been thrust upon a totally new set of duties and responsibilities, requiring an entirely new set of job roles—resembling rather closely that of the production management team.

The sum and substance of this is that teams are important because they are superior instruments for coordination and problem solving, and, as more and more routine work is eliminated, a larger and larger proportion of the work that is left in the organizations will be the kind of work that requires cooperation and teams. *Paradoxically, therefore, computers may enhance the importance of the work group and team not through support for them, but rather by eliminating most of the jobs that do not belong in groups or teams in the first place.* Then, of course, the technology may also facilitate group work and make groups and teams even more useful and flexible than they used to be.

12 Routines and Automation

"The machine yes the machine
never wastes anybody's time
never watches the foreman
never talks back."

Carl Sandburg, *The People, Yes*, 1936

Automation—The Cornerstone of Computing

Routine Automation

As noted in Chapter 9, computers are in their very essence automatic machines, and all their great powers ultimately derive from their immensely fast execution of automatic routines. The programmability of computers has given automation of physical production a new boost and has extended our means for automation far beyond what could have ever been achieved by mechanical means. Computer-based automation will continue to evolve over the coming decades, much as mechanical automation and the harnessing of energy sources such as water, coal, and oil have developed over the last 200 years.

By improving our abilities for information storage and retrieval, and by providing us for the first time with the possibility of externalizing information processing, information technology also has the potential to let us attack all tasks that involves handling and processing of information—the rapidly increasing processing power and the growing sophistication of available programming tools every year significantly extend the limits of what can be done. In general, we may say that most work will be touched by information technology, at least as a supportive tool, and in many cases tasks will be wholly or partly automated or eliminated. The more routine the task is, the easier it will be to dispose of.

The first and most basic application of computers has been just this: to automate simple routine tasks of the kind that were previously governed by standardization of work, the main coordinating mechanism of Machine Bureaucracies. This is still the dominating way to use computer-based systems—from word processing (automating important parts of the tasks earlier associated with the production of typed or printed text) to accounting (automating the arithmetic and most of the reporting) and claims processing in the insurance

business (automating a great deal of filing, writing, and control). Such automated routines are in fact the most important part of any computer-based system—even those that seem to be about quite different matters. A program for finite element analysis, for instance, helping engineers to decide on the optimal form and thickness of mechanical parts, works its magic simply by repeating programmed routines based on mathematical formulas; a CAD system draws, redraws, fills in surfaces, and adds shadows by doing just the same. It is such fine-meshed, meticulously defined, and programmed routines that make up the programmed patterns of action defined in the introduction to Part V.

Quite often, in the heated discourse about the great potential of information technology for society, organizations, and individuals, and the wondrous feats that “technology” can pull off, we seem to forget that in the end it all boils down to routines consciously designed and programmed by real humans, having specific functions, and representing their creators’ actual meanings and intentions.

In addition to the automation of simple routines, computer-based systems will also often direct and even pace the work of their users. Typical examples of this are systems for caseworkers in large white-collar bureaucracies, such as the system for dental claims processing in a large insurance company described by Zuboff (1988), which is briefly mentioned in Chapter 10. Computer-based systems thus generally incorporate explicit routines on two levels: the closed routines “hidden” in the applications program’s internal functions and the open routines that incorporate the dialogues with the users and structure their work.

The creation of such *programmed routines* is obviously a development that falls within the bounds of the basic coordinating mechanism that Mintzberg (1979) calls *standardization of work*. Its immediate forerunner is the explicit routine, which was developed on the basis of writing and was the main coordinating instrument behind the development and growth of the modern organization (see Chapter 7). I have positioned it accordingly in Figure 13-1 on page 339. However, programmed routines represent an advance in relation to explicit routines that is greater than the original development of explicit routines and the concomitant blueprint of the modern organization.

The traditional use of explicit routines requires that the workers learn all the routines, or at least learn those that are used most often, and remember when and how to retrieve other relevant routines. Experience shows us that only the routines that are thoroughly learned (internalized) are systematically used in the daily work situation; others may be overlooked, forgotten, or fall into disuse for various other reasons. The process of renewing or changing routines is difficult, because it requires workers to “actively forget” the old routines—to get them out of their system—and thoroughly learn the new ones. Because the number of routines that can be retained as active in a work situation is fairly low, the repertory of any one organization member will be naturally limited, and the capacity for branching (alternative routines) will be low.

When routines are programmed into computer-based systems, the situation is quite different. First, a significant number of routines can be automated completely. Second, the routines that enter into the user dialogue can be much more numerous and diverse, since the user does not have to remember them all actively, just how to operate the system and relate to the dialogue. This can be compared to the difference between our active and passive vocabularies—which is

quite significant, as anyone who has learned a second language will know. In addition, the system can incorporate assisting features giving users a broader span of competence.

A good example is the system developed at IBM Credit (Hammer and Champy 1993). IBM Credit finances the computers, software, and services sold by IBM—it is a profitable business to IBM, and quite large: if independent, IBM Credit Corporation would rank among the Fortune 100 service companies. Prior to redesign, each application for credit went through a five-step procedure, taking on the average six days to complete before a quotation letter could be delivered to the IBM field salesperson who had requested it in the first place. During these six days, the deal was still vulnerable for several reasons: The customer might obtain financing elsewhere, fall prey to another computer vendor, or even cancel the acquisition altogether. The pressure to reduce the turnaround time was therefore considerable, and it was also highly desirable to reduce the number of calls from impatient sales representatives wondering where their customer's application was sitting.

A closer look revealed that the actual work on an application averaged only 90 minutes—the rest of the time it was either sitting on a desk or on its way between the five desks it had to visit before completion. A total redesign was then undertaken, where most of the applications were completed by a single caseworker, supported by a new computer system. How? Hammer and Champy explain (Hammer and Champy 1993 pp. 38-39):

How could one generalist replace four specialists? The old process design was, in fact, founded on a deeply held (but deeply hidden) assumption: that every bid request was unique and difficult to process, thereby requiring the intervention of four highly trained specialists. In fact, this assumption was false; most requests were simple and straightforward. The old process had been overdesigned to handle the most difficult applications that management could imagine. When IBM Credit's senior managers closely examined the work the specialists did, they found that most of it was little more than clerical: finding a credit rating in a database, plugging numbers into a standard model, pulling boilerplate clauses from a file. These tasks fall well within the capability of a single individual when he or she is supported by an easy-to-use computer system that provides access to all the data and tools the specialist would use.

IBM Credit also developed a new, sophisticated computer system to support the deal structurers. In most situations, the system provides the deal structurer with the guidance needed to proceed. In really tough situations, he or she can get help from a small pool of real specialists—experts in credit checking, pricing, and so forth. Even the handoffs have disappeared because the deal structurer and the specialists he or she calls in work together as a team.

Hammer and Champy claim that IBM Credit in this way cut the average process time to four *hours* and increased the number of deals handled *100 times* without any increase in workforce.

The IBM Credit case represents a quite innovative use of computers to redesign the work process, and not exactly an implementation of a run-of-the-mill administrative system. However, even in more commonplace systems, which often represent little more than an "electrification" of older, manual routines, we can usually find traces of all the strong points of computer-based systems exploited by IBM Credit: the automation of simple routines, the implicit

structuring of work, the embedding of rules, and support for decisions. As the sophistication of the user organizations as well as the systems vendors and software developers grows, we can expect them to increasingly take advantage of the more advanced possibilities.

What and How Far Can We Automate?

Automation has proved to be a very powerful approach for increasing output and improving an organization's competitiveness. Especially in material production, it has been the most important determinant of organization for the last 150 years at least. It stands to reason, therefore, that we can expect organizations in general to continue to explore the possibilities offered by automation, and to seek to increase their output per employee. In my view, the potential is still great, and just as great—if not greater—in the white-collar as in the blue-collar sector. Computers are new as human tools, and it stands to reason that we are only in the beginning of a long and exiting development. If the technology's history so far has any predictive value at all, the coming decades (and even centuries) will see continuous, rapid improvements both in the basic technologies, in available hardware products, and in application systems that will consistently dwarf earlier achievements. This should hold at least in my lifetime *and* that of my children. I believe therefore that we have just started in our efforts to automate work, both in the factory and in the office.

It is not easy to define what kind of work will be automated into oblivion and which tasks will survive—our present knowledge and experience provides a meager model for extrapolation and our imagination is a guide of dubious merit when we speculate about the possibilities in the longer run. However, with due caution, the possibilities, at least in the near future, seem to be greatest in three broad areas:

1. Material production (especially factory production)
2. Immaterial production and services—any product or service that mainly consists of information or information procurement
3. Internal administration in all trades

In spite of 150 years of improvement, there are still massive opportunities for increased automation in factory production—indeed, considering the immature nature of information technology (compared to the long history of mechanical technology), we have barely scratched the surface. Still, we tend to automate on the conceptual basis of mechanical engineering, and the most astounding innovations, in my view, await the development of production methods that are natively dependent on a copious use of processing power.

So far, we have probably come farthest in this direction in the process industries, where we have also seen some of the most spectacular improvements in productivity over the last couple of decades—whole production units such as refineries or paper mills have been totally automated. Great strides have also been made in mechanical industries, however. In the late 1970s, for instance, Fujitsu built a metalworking factory not far from Mt. Fuji that covered 20,000 square meters, employing 82 workers on the day shift and only one control room

operator during the night. His only task was to surveil the working industrial robots and automatic machine tools from a central control room. A traditional factory of the same size would have employed almost ten times as many people, and there were still plans for reductions (Hatvany et al. 1985).

If we turn away from material fabrication, the possibilities for automation are generally excellent in almost any business that deals mainly in information, especially when we include computer-supported self-service as an aspect of automation. The most extensive automation can be achieved when the information is structured, and especially when it is quantitative. Banks are prime examples of such businesses. They have been the subject of major changes over the last three decades, and there is more to come. I shall elaborate somewhat on this in a moment.

For businesses such as newspapers and publishing houses, often hailed as the archetypal information-mongers, we must distinguish sharply between the editorial side and the distribution activities—of which printing has been (and still is) the central part. Writing and editorial work is highly labor-intensive and it will have to remain so (even if it can be computer supported through the use of word processing and the like). On the distribution side, printing is already highly automated, but electronic channels and media do offer the possibility of further automation. However, drastic changes here will require the customers to change their habits and to leave paper as the preferred medium. I think this will happen more slowly than many enthusiasts believe, and the reason is simply that screen technology still falls far short of the portability, comfort, and ease of reading offered by printed media—and it is likely to do so for a good number of years yet. The exception is the kind of concise factual information that up till now has been found in dictionaries, encyclopedias, directories, news clippings, the like, and where reading comfort is not a very important issue. For this kind of information, digital media have already gained an important position, and will rapidly achieve dominance.

Leaving the domain of single lines of business, there are also significant automation possibilities in internal administration in all kinds of trades. The function where computers are most widely applied is probably accounting, where it has led to considerable reductions in labor hours. However, even areas such as the administration and use of customer data (as in insurance companies), sales (on-line order registration and semiautomatic fulfillment, or even self-service ordering through customer terminals), and logistics (automatic restocking through point-of-sale registration, etc.) have been the focus of much change over the last decades.

The prospect of automation in the office has been the subject of much discussion. Arguments have centered on whether office work can be automated at all, and many research projects have concluded that such work in its very nature is too unstructured and dependent on human judgment to allow significant automation. I shall return to this discussion later in this chapter, and will only say at this point that I think the possibilities are far greater than many people would like to think.

However, the development of automation will happen in close interplay with the development both of information technology, other technologies, and methods

for analysis and design, and it is not possible to predict the development for more than a few years ahead.

It is perhaps easier to say something about where the opportunities seem to be the most slender—to point out the work that depends too much on human faculties the computers cannot mimic (at least not yet), or that require physical skills and dexterity machines cannot match. There seems to be three broad classes of such work:

1. Work where judgment and creativity are central—for instance, research and development, design, policy making, journalism, artistic work, and management other than routine supervision.
2. Work where human physical dexterity and skill are paramount, as in handicrafts, the performing arts, domestic work, and chauffeuring. Some jobs are safe because we *want* humans to perform them, as in handicrafts and the performing arts; other remain because they are (at least for the time being) very difficult to automate, such as in much domestic work, transport, and repair work.
3. Work where the emotional component of dealing with a fellow human is important, such as psychiatry, much sales and service work (especially personal services such as hairdressing or waiting tables), and teaching.

Many jobs have components from more than one of these classes—waiters also depend on their dexterity to do their job, and craftsmen often combine skill and creativity. Work such as nursing combines all three. When a job scores high on one or more of these properties, it means that it depends on human qualities, and the incumbents will be difficult to supplant by nonhuman agents or automatic procedures.

A word of caution is warranted, however. Even if we may think so, the human aspect of a job is not always the most important to us. We readily forgo the social pleasures of exchanging everyday niceties with a bank clerk in order to retrieve money faster and more conveniently from an automatic teller machine, and we have been swift to prefer the low prices and fast throughput of the self-service store to the old over-the-counter shop. Our culture has put increasing value on efficiency and in many ways fostered an acceptance and even glorification of neutral impersonality in business matters—conditioning us to tolerate or even prefer the self-service concept in more and more situations. Indeed, the reluctance many senior citizens show in front of self-service devices is not only grounded in their unfamiliarity with the appropriate techniques; it is just as much grounded in the fact that their cultural values have not adjusted to accept the absence of human contact in those situations. Jobs that look safe now because of their emotional component may therefore be in danger if this trend continues—such as the more routine aspects of teaching, which may become seriously threatened by “self-service” learning based on multimedia computers, with their combination of programming, video, sound, and databases.

The Potential of Evolving Automation—An Example

To illustrate some of the potentials of automation and the iterative nature of its development, I would like to elaborate on these ideas in an example. And since automation so far has progressed farthest in the factory, I think it is more interesting to use an example from the white-collar world—where the changes have hardly begun.

Mechanical automation has come a long way, and is one of the main pillars holding up the material wealth of the industrialized world. Up until the computer entered the scene, however, automation in the realm of administrative work was sparse. Punch card equipment was probably the most advanced, and it may be the only example of true automation. Bookkeeping machines and mechanical desk calculators more approached the nature of tools. Even punch card equipment was a modest achievement compared with the extensive automation in the production of material goods.

The computer, however, is profoundly changing this state of affairs, and the changes have proceeded further than most people realize. A large part of the work that is strictly procedural and routine in nature has already been automated to a greater or lesser extent, especially work associated with large files of administrative information—and the pace is accelerating. But the automation is often gradual and fairly unobtrusive (for everyone except those made redundant). It is not always easy to spot for an untrained eye. For a familiar example, let us take a short look at the development most banks have gone through during the last 30 years or so.

Traditionally, banks are mainly filing and accounting organizations. Before the computer era, they used mechanical bookkeeping machines of various kinds. For each transaction, the customer's account card was manually located in the filing cabinet, placed in the appropriate machine, and the amount deposited or withdrawn was entered manually on the keyboard. After the record was completed, the file card had to be put back into its folder in the cabinet. This work was carried out in central filing or bookkeeping departments, and the inputs for their work were the receipt forms and vouchers they received from the various branch offices and departments that had the direct customer contacts. Typically, there were separate departments for different types of accounts—one for savings accounts and another for checking accounts, for instance. To get an overview of the bank's total relationship with a particular customer would therefore involve several persons and quite a lot of work.

This was a very labor intensive setup, and was only feasible when there were few transactions. The number of transactions was low because society still mainly operated in the cash mode—wages were paid in cash; goods and services were paid in cash. Besides, it was cumbersome both to deposit and to withdraw money—you had to go to a branch office of your bank,¹ bring with you your bank

¹In some countries, such as Britain, one even had to go to the particular branch that administered one's account. In Britain this system partly survived even up quite recently—as late as 1990, a Norwegian journalist working as a correspondent in London lamented the fact that he had to have one account in a branch office in the suburbs where he lived, and another at a branch in the city center, where he worked. The downtown branch office would not allow him to draw money on his suburban account and vice versa.

book, and wait your turn at at least two different counters. I can still remember the stuffy atmosphere of the savings bank of my childhood savings account—where you first walked up to the appropriate counter, presented your errand and your bank book, and then waited until the teller called your name through a loudspeaker. The counters, moreover, were different for withdrawals and deposits, although the teller window was the same.

There were also a number of instruments to conclude transactions outside the premises of a bank, such as the check, the giro, and the credit card. As long as bookkeeping was manual, even they depended on a fairly low volume to be viable, and it was not until the introduction of computers in the 1960s that the banks were ready to promote a more active use of bank accounts, with personal checks as an important feature. It was also computers that made it possible for the credit card companies to start their rapid expansion.

At first, the computer-based systems only replaced the manual files and the bookkeeping machines. Still, the customer's interface with the bank was as it had always been, and the receipt forms, the vouchers, and the checks were still collected and registered at a central location. Some of the manual operations were eliminated even at this stage, however, such as the retrieval and replacement of account cards, work with the bookkeeping machines (being replaced by punching), and much accounting work. The punching and the automatic processing by the computers were so much faster than the old methods that the transaction volume could increase many times over without an increase in workforce. Moreover, printouts of the account balances could be distributed to the branch offices, giving them much better information on their customers.

Then came the next step—terminals at the counter, allowing the clerks to register the transaction directly in the database, eliminating the need for a central punching department. At first, the systems generally did not operate in real-time—transactions concluded at the counter terminals did not update the production database directly but were collected for batch processing (usually during the night). Since then, the trend has been a development toward true on-line systems with real-time updating of the production database.²

This change did eliminate many routine jobs in central bookkeeping departments, but the instant availability of customer information also facilitated a significant reorganization at the customer interface—the counter. Specialization was reduced, to the effect that most of the usual transactions (deposit, withdrawal, currency exchange, cashing of checks, etc.) could be completed by any one of the clerks working at the counter. A lot of paper-pushing was eliminated in the branches, and branch offices were furthermore authorized to give loans and credit to a larger degree than before.

The next step was to introduce automatic teller machines, allowing customers to wrap up some of the transactions themselves. Later development has provided EFTPOS³ terminals in shops, allowing you to use your smart card to pay for what

²Not all banks have come this far. Some still collect transactions locally during the day and transmit them to the central computer for processing during the night. The reason may be telecommunication costs or simply old systems.

³Electronic Fund Transfer at Point Of Sale—the card reader and auxiliary equipment that lets you pay with your bank card in shops and elsewhere.

you buy, thereby concluding a direct and immediate transfer of money from your account to the shop's. Quite a few banks now also allow customers (at least professional customers such as companies) to link up to the bank's systems through a modem, and complete certain types of transactions from their own computers, and an increasing number are making it possible for customers to access such services through the Internet. The net result is that a lower and lower percentage of the transactions conclude on the bank's own premises or involve any of the bank's employees.

The development just described has been gradual, with each new step building on the preceding one. The degree of automation has increased for each step, both by direct automation of tasks and by eliminating the need for certain operations altogether. If we look at the rise in transaction volume over the last 40 years, the productivity has increased enormously, and the service level for most customers (those who can handle cards, teller machines, and computerized answering devices) has improved dramatically. But, to a surprising degree, all this has happened without the banks making any real changes to the basic definition either of what a bank account is or of what a central file is. Most banks still regard the account as their basic entity, not (as one should think) the customer—even to the extent of sending separate account statements in separate envelopes for each account a person might have. What we consider a revolution is so far *not* a result of a radically new concept of banking; it is just a consequence of having made the mechanics of record keeping infinitely more efficient through automation. It is also another example of how change that is basically quantitative can have results that are perceived as qualitative by the user.

If you take a closer look, moreover, the banks are still plagued by a solid heritage of their original paper-based systems. Giros and checks, for instance, still require a great deal of manual handling (including punching) and today represent a serious drain on the banks' profits, since banks are generally not able to (or do not dare to) charge their customers what it really costs to process paper-based payments.

But, the story does not end here. Banks seem ripe for much larger changes over the next thirty years than over the last, and some banks may be able to operate with only a fraction of the workforce that is common today, even with the most sophisticated of current systems. We shall return to that a little later—but, at this point, we must first confront the debate on the limits to automation, especially for automation in the office.

Limits to Automation—Real or Imaginary?

The Debate on Office Automation

As noted in the discussion in Chapter 1, there is widespread doubt about the actual impact of computer-based automation so far, especially in the office—no one really disputes that computers have eliminated a lot of jobs in manufacturing. We have all seen glimpses in TV of robot-populated, fully automated production lines, especially in the automobile industry, and these are not even the most important examples: Process control systems, for instance, have probably contributed far

more (however, since they are not as photogenic as robots, they tend to be less noticed).

For office jobs, on the other hand, there is quite a lot of debate. I argued in Chapter 1 that the doubts about past achievements are mainly grounded in reliance on invalid measures, and that the achievements have been considerable, in spite of a fair number of more or less spectacular failures. Some of the best proofs, in my view, are the great increases in transaction volumes that banks and insurance companies have been able to absorb over the last three decades, with only a modest increase in staff, or even no increases at all. Many banks today are in fact reducing the number of employees, while substantially increasing the number of completed transactions—mainly due to such instruments as auto-giros, self-service terminals and EFTPOS-equipment.

Likewise, there is also significant disagreement on the future possibilities of automation in the office. Although no one would deny that a lot of jobs in accounting and filing have disappeared, and that even more such jobs will go in the future, doubts have been raised about whether less narrow jobs can be automated. Most office jobs are simply seen as being too diverse, involving too many exceptions, and requiring too much judgment to be defined in the exact algorithms needed for a computer. In one sense this is true; in another it is not.

It is certainly correct that most classical "office work" does not readily lend itself to straightforward automation. Numerous studies on this subject in the early 1980s, where the researchers monitored the activities in various kinds of offices, showed that office work was very complex, and even seemingly trivial tasks required quite a lot of knowledge, judgment, and nonroutine activity (see, for instance, Maus and Espeli 1981, Lie and Rasmussen 1983, Strassman 1985, Long 1987, Schmidt and Bannon 1992).

The general conclusion from these studies and many later discussions is that early hopes of automating the office in the same way as factory production were naive and built on an superficial and overly simplistic understanding of the nature of office work: There were simply too few repetitive activities that could be automated, tasks were too unstructured to lend themselves to automation, there were too many exceptions to the rules (insofar as there were any formalized rules at all), too much of the activity was concerned with uncovering and correcting errors, and the activities generally required the collection of information from many different sources and the execution of considerable judgment. To quote Schmidt and Bannon (1992 pp. 22–23),

According to the traditional "bureaucratic" conception of organizational work, people perform a number of tasks according to a set of well-specified "procedures" that have been developed by management as efficient and effective means to certain ends. The traditional formal organization chart is presumed to show the actual lines of authority and the correct pattern of information flow and communication. However, the conception has been proved highly idealized and grossly inadequate for analyzing and modeling articulation of the real world cooperative work arrangements.

Due to the dynamic and contradictory demands posed on a social system of work by the environment, task allocation and articulation are renegotiated more or less continuously. This has been documented thoroughly in the domain of "office work" and many other arenas. For example, a number of studies of office work, conducted by anthropologists and sociologists, have emphasized

the rich nature of many allegedly "routine" activities and the complex pattern of cooperative decision-making and negotiation engaged in by co-workers, even at relatively "low" positions within the organization.

Long, summing up his review, says (1987, p. 51):

Overall, conclusions based on a realistic picture of the office and its occupants suggest that the scope for the outright "automation" (elimination) of jobs in the near future is quite small, except with respect to semi-professionals and some routine information-handling and coordinating roles.

The conclusion drawn by Long, Strassman, and Schmidt and Bannon, as well as many others, is that the main scope for computers in the office is to support the work of professionals and managers: "Stimulating an improved quality of performance or the provision of new and/or better services," as Long puts it (1987 p. 46). The growing number of people occupied with R&D activities concerning *computer supported cooperative work*, or CSCW (to whom Schmidt and Bannon belong), are especially vocal in this respect.

It is undeniable that the possibilities for directly automating more complex office jobs are limited, in the sense of having a computer system replace humans by more or less mimicking their behavior. But that does not mean that automation in a wider sense of the word is blocked.

Even in material production, directly mimicking human behavior is not the way we normally automate—we do not design machines that wield or directly mimic the use of traditional hand tools. True, there are some examples where precisely that happens, as when a paint line is robotized by letting human spray painters guide robot arms equipped with spray guns by hand until they "learn" the painting movements. But in most industrial automation, automation is in large part achieved exploiting the intrinsic properties of machines, not by building human-like automatons. In my view, that will also be the strategy that will continue to revolutionize material production: The real potential in the future lies in matching the intrinsic properties of computer-controlled production systems with new materials and production processes that cannot be utilized without them. New advances such as chemometry—the use of sophisticated sensors and mathematical models for the control of production processes—is perhaps a harbinger of things to come (Lundberg 1991).

I believe that the situation is the same even when it comes to office work and that the studies mentioned earlier overlook the fact that even if most of the activities of office work themselves cannot be automated, the peculiar properties of computer systems—especially the processing power and the coordinating effects of their databases—can nevertheless be harnessed to *eliminate the need to carry out such activities altogether*. The job cuts achieved through this can be as just as dramatic as those effected through classical automation. Consider the following example.

Task Elimination: An Example

One of the most cited examples of the elimination of a whole set of tasks is the reorganization of the accounts payable function in Ford in North America

(Hammer 1990, Hammer and Champy 1993). Indeed, this project is probably one of the cornerstones of the term “business process reengineering.”

The accounts payable function consisted of typical, old-fashioned office work—the clerks in the AP departments checked invoices against purchase orders and receiving documents, and (if the three matched) then authorized payments. The work sounds simple, but of course it was more complicated than this. Quite often, the three documents did *not* match: The delivery might be different from the order, and the invoice could easily differ from both. Several kinds of information had to be collected and compared, missing papers had to be located, inconsistencies cleared up, and so on. There was need for copious amounts of communication, with people within the company as well as suppliers sending the invoices.

Looking at an accounts payable office in isolation, one might well conclude that the scope for automation is scant, and that the best solution would be to offer the people working there various support tools to make their work more effective (for instance, electronic mail).

Initially, that was probably also the project team’s conclusion, since they were working to reduce the head count in its account payable departments, which totaled more than 500 employees just in North America. The project was part of a company-wide offensive to regain ground lost to the Japanese in the late 1970s and early 1980s. The initial analysis proposed a project that would use computer support to reduce the number of people to 400, which must have seemed pretty good. However, Ford had recently bought a 25% interest in Mazda, and Ford executives noted that the (admittedly smaller) Japanese company handled the comparable functions with only five people.⁴

A deeper analysis—sparked by this, and taking the total problem domain into account—revealed that most of the work in the accounts payable departments was a consequence of the intrinsic shortcomings of paper-based administration, and that computer-based systems simply allowed for the *elimination* of most of the work, by offering a superior *integration of the information* with a more far-reaching *implicit coordination* as a result.

Ford’s subsequent project ended up eliminating the accounts payable departments in its traditional form altogether. Instead of using 500+ labor-years to check and compare invoices against purchase orders and receiving documents, and then authorizing payments, all purchase orders are now registered in a database. When a shipment arrives at the receiving dock, it is immediately checked against the database. If matched by a purchase order, it is accepted and

⁴ Strangely enough, I have not found any account of what Mazda actually did to achieve this result, neither in the book by Hammer and Champy nor anywhere else. However, the manager of a productivity program sponsored by the Royal Norwegian Research Council related to me that Mazda in effect delegated the full responsibility for stocking the production line to their suppliers. The suppliers are allowed access to Mazda’s production planning system and can thus deliver their parts directly on the line when needed. All Mazda needs to do, then, is to count the number produced of each model—knowing that, they also know exactly how many parts they have received from their various suppliers. The beauty of this system is not only the total elimination of parts administration and accounting on Mazda’s hands, but also the automatic exclusion of faulty parts from the payments (they will be eliminated by quality control during production).

registered as received (if a match is not found, the delivery is returned). The system then automatically generates a payment transaction and prepares the check. As the system went into operation, Ford notified its vendors that invoices were no longer accepted (they would go directly to the trash bin); they should just send the goods. Ford estimates that the change has reduced the work needed to handle the control and payment functions (which is really the reason for an accounts payable department) by 75%. In addition, there are no discrepancies between the financial and physical records to worry about, material control is simpler, and financial information more accurate.

This is a prime example of the possibility for eliminating work through deep analysis of the problem domain, of the strong effects of the inherent coordination in a unified database, *and* of the value of the integrity of the information it delivers.

Mazda's achievement is even greater and is apparently also effected through the coordinative effect of the database: The suppliers are allowed full access to the production system and can thereby deliver their parts directly on the production line, perfectly coordinated with the succession of models coming down it. Presumably, Ford did not want their suppliers to have the same access.

This example becomes even more interesting when we consider it in light of the discussion about automation and the subject of groupware and CSCW: One can easily envision a solution to Ford's problem along the lines of CSCW—with workflow tools to speed electronic or scanned documents around the caseworker circuit, with email to enhance their cooperation and their contact with the suppliers' accounts receivable people, and with conference systems and videophones to solve the most difficult cases. It is, however, difficult to see how even the most exquisite system along these lines could have approached the efficiency attained by the project carried out by Ford, which relied on task elimination instead.

Banking: A Possible Next Step

To elaborate somewhat, let us return to banking to discuss what extended automation and new concepts for using the strong properties of information technology can allow. So far, what has been exploited is relatively straightforward automation through the exploitation of the range and speed of the database, as the accounts (the central administrative files of the bank) have become available for access not only in the main office, but also in branch offices and even in shops and the customer's own office or home.

This concept can be extended further, however. It is already technically feasible to conclude nearly *all* payments as direct, automatic transactions against bank accounts—it is just not economical yet, due (mainly) to the cost of card terminals and telecommunications. But, in not too many years, it will become economical for almost all purposes. Further, a much broader spectrum of the transactions you need to carry out will be possible to complete via office terminals, automatic teller machines, or home computers. What will then happen to the banks?

Consider the following: As a private bank customer, I have fairly limited requirements—I need to keep my money in a safe place, I need to pay bills and

receive money from employers and others, I need to deposit money to earn interest, and from time to time I need to borrow. I also need to receive information on my transactions and the current balance of my account(s). How can I get these services most conveniently? Not by venturing out on the streets to seek out a branch office (mind the opening hours) or by mailing checks!

To me, the perfect solution would be a "banking system" residing on my own PC. For safety, it could incorporate a card-and-code based identification system (there are already PC readers for traditional bank and credit cards available, and the rapidly proliferating PCMCIA standard for external peripheral devices promise even more advanced possibilities). Off-line, I could set up my transactions, and then ask the PC to execute them. A short (and thereby cheap) automatic call to the bank's central computer would download my instructions, upload confirmations, upload notifications of other transactions concluded toward my account since my last connection, and update the balance and transaction history kept by my local database. That way, I would always have a complete history of transactions available without bothering the bank (after all, it is my money and my information), and I could play around with statistics and budget information as much as I wanted.

The upload could also contain the bank's current offers on interest rates, it could include electronic invoices from my creditors (which means that I could send my own invoices through the system as well). Perhaps I could also deposit a mortgage bond on my house in the bank, giving me a credit limit within which I could grant myself loans at the then-current terms (contained in the latest upload). Another advantage would be that I could have the same access to my "local" banking services no matter where I was in the world, as long as I had access to a public telecommunications network.

There are already services available from a number of banks incorporating parts of this concept. However, they are not yet complete and do not yet adhere to common standards. If the interface between such a local system and the bank's system was standardized, and not proprietary to the bank (or if one of the proprietary interfaces was emulated by others and thereby established as a de facto standard), I could not only use the system for my business with one particular bank, but use it to obtain competing offers and conclude business with other banks as well, not to mention insurance companies, stockbrokers, mutual funds, and others. In my view, the growth of financial services on the Internet will greatly contribute toward such standardization.

A logical conclusion to such a development could be that there would no longer need be any for banks in the traditional sense—what I would need would first of all be a clearing central that could carry out the money transfers (also the many small transfers coming as a result of electronic payments in shops, etc.) and keep an officially authorized version of my transaction account(s). Then I would need various service providers to offer me various alternatives for depositing money, for loans, for buying stocks or parts in mutual fund, and so on. The clearing central could even be organized as a public institution (a new role for the central bank, when paper money becomes almost extinct?), operating on a regional, national, or even at an international basis.

Technologically, such a development is already perfectly feasible, and there is no need for exotic new inventions. Commercially, development along these lines

is highly probable, as the development in basic technologies makes the necessary equipment and communication capacity cheap enough—even if it is too early to predict the specific directions and speed of change. As hinted earlier, the new development in Internet banking will probably speed the development toward the fully electronic bank further.

Another notable undertaking in this connection is the ESPRIT project *Conditional Access for Europe (CAFE)*, which has studied the possibilities for developing a European-wide system for “digital money” based on a credit-card-size computer (Bjørken 1992). Their concept is a card that can be loaded with money from one’s bank account, and then used for all kinds of purchases (as cash and credit cards are used today) as well as for paying bills over the telephone network. The card and the payment system should incorporate advanced cryptography to ensure maximum security and should allow payment without leaving “electronic traces” in the form of name or account information.

Interestingly enough, European central banks (at least some of them) have been partners in this project. If we view it in the context laid out earlier, we can see the contours of an international network of clearing centrals run by the central banks⁵ (or by a European Central Bank), serving CAFE-type cash cards as well as the “personal bank” described earlier, or even a (very potent!) combination of the two. With a European standard for the cards and automatic currency conversion, we could even have a *de facto* Euro for cash transactions, without the need for anyone to give up their cherished, national currency.

Whatever the direction and speed of development, one thing is for sure: The banks will have to change more during the next 25 years than in the previous 50, and the facilitator will be the mounting automation provided by information technology—automation that increasingly exploits the special properties of computer-based systems. Banks, or the organizations that replace them, may end up as largely automated organizations with very few employees, and there may be considerably fewer of them left. If earlier communication revolutions in historic times teach us anything, it is that, when improved communication enables businesses to reach out beyond geographically delimited markets, it also means that all those businesses face a proportionally larger set of competitors. Moreover, as some take advantage of the situation and expand aggressively, local businesses who thrived mainly because the lack of communication shielded them from competition will find themselves in great trouble and will be bought up or driven out of the market in large numbers. The larger and more perfect market emerging from this process will foster greater focus on price and performance, and, in addition, people will not bother to keep tabs on a multitude of firms. The result will be—just as in conventional brand-name business—that a small number of the players will grow large and destroy the others. If the Internet becomes as important for a number of businesses as many people think, it spells not only opportunity for all but also ruin for many. The only alternative will be to concentrate on niches where big players cannot or do not bother to compete—but

⁵ A Norwegian commission presently working to propose new banking laws has already suggested that the clearing function in Norway should become a responsibility of the Norwegian central bank. The basis for the proposal is the delays in money transfers consciously implemented by the banks in order to hold on to their float revenues.

these niches are not big enough to sustain more than a fraction of the original players. So, the Internet is no more of a boon to the small, local business than the railroad, the car, and the telephone were.

Circumventing the Maginot Line

If we look at these examples—one real and the other (so far) imaginary—in light of the debate on the scope for automation of office work, we can see that the Maginot line of the inherently indeterminate nature of office work can simply be circumvented. Quite spectacular achievements can be made without having to force the presumed barrier at all.

Consider the Ford example: With a traditionalist approach, it would indeed be very difficult, if not impossible, to develop a computer system that could automate the accounts payable function—that is, to make a system that could automatically compare purchase orders, receiving documents and invoices, check for consistency, investigate and resolve mismatches, take corrective action if necessary, and finally authorize payments.

Taking those tasks for granted would therefore create problems for automation. In fact, that was in all probability what the project team at Ford first did (Hammer 1990, Hammer and Champy 1993). If their initial efforts (in line with the arguments of Long and the CSCW proponents) only aimed at providing the people in the accounts payable departments with better support tools for their jobs, they were actually quite clever to achieve a projected improvement of 20%.

When they rethought the problem in light of their discoveries at Mazda, however, the people in the project realized that most of the tasks and routines carried out by the 500 people in accounts payable were nothing more than consequences of the way work was traditionally defined and organized, and *not* intrinsically necessary for the reception and payment of shipments from Ford's suppliers.

When they managed to analyze the deeper functional necessities behind the existing procedures, they ended up with a system where the computer's special properties were used to eliminate a whole slate of operations and completely rearrange work.

Of course, the Ford case is not an example of pure automation; it includes both automatic routines and the coordinative effects of a common database for purchasing, inventory, and accounts payable. However, that is the nature of computer-based systems—they usually exploit several of the strong aspects of information technology simultaneously. This creates problems for orderly analyses and expositions such as the present one (I must wait until a later chapter to discuss the coordination part), but not for the application of the actual systems.

Extensions to the Constructible Space

Shrinking the Organization

Automation, then, allows us to eliminate work both through straightforward task automation, as in a pulping plant, and by contributing to task elimination, as described in the example from Ford. The development in banking really

incorporates both. Quite often, we will see that organizations are able to reduce their head count even as they manage to increase their total production—banks are good examples of this, even if they have increased the size of their organizations over the years. Many people take this as a proof that computers do not deliver the productivity they should, but looking at size alone is grossly misleading. If we look at the volume of bank transactions—any kind of transactions—the number of transactions per employee per year has increased dramatically over the last 35 years, as computers have taken over for bookkeeping machines, counter terminals for forms and vouchers, auto-giros and customer terminals for manual giros, and finally card-operated teller machines and EFTPOS-equipment for checks and cash transactions. Viewed in this light, the banks have achieved a very impressive increase in productivity.

Moreover, they have done so while drastically reducing the size of that part of the organization that performs the bookkeeping operations, the original main function of the bank. Because of the increasing use of computers, bookkeeping has actually been collapsed to a small fraction of what it was.

The reason the bank organizations have not shrunk dramatically in the same period has been an increase in other aspects of the banks' activities. Tasks such as arbitrage, sales, and advisory activities have grown considerably in volume, along with customer contact at the counter and the various functions necessary to assess risks and give loans, manage funds, and so on. The structure of the bank's organizations has thus changed quite markedly, away from an overwhelming emphasis on mass transaction processing toward a relatively high proportion of more varied work of a professional nature.

If the development in banking conforms to the scenario outlined earlier, however, the future reduction in workforce requirements will not be offset by new demands for services, and we will witness a further contraction of the banking organizations, as more and more functions are automated or eliminated. We may also see more specialization, not only in niches, as today, but as a general trend that almost no bank can escape, and where some banks will specialize in highly automated routine services (high-volume, low-value transactions), whereas others will develop into highly competent financial service organizations concentrating on non routine (low-volume, high-value) transactions.

Organizational Truncation

There are more dramatic examples of task elimination, however. Especially within the process industries, such as paper production and oil refining, advanced automation has led to an outright truncation of the organization: Almost all of the manual tasks in production—which means practically the whole factory organization—have been eliminated. This development has been analyzed in some detail by Zuboff (1988), who bases her book partly on the automation-based transformation of two pulp mills and one pulp-and-paper mill.

Before automation started in these factories, each step in the process was run by skilled workers who controlled locally their particular vat, boiler, or blender. They had some contact with the production steps directly ahead or after their own but were otherwise isolated from the rest of the process—except when something really went wrong, and the whole factory had to stop. This fragmented control of

the production process naturally meant that a considerable number of coordinating positions were required—the total production process had to be coordinated by foremen, supervisors, and, finally, the plant manager. Mechanical automation had allowed a fair degree of centralization of control, but it was only when computer-based systems entered the scene that it was possible to thoroughly automate the production processes and eliminate next to all manual positions.

What happens, then, when a production process is fully automated and the control of the entire factory is centralized not only to a single control room, but (in principle, at least) to a single terminal?⁶ As Zuboff (1988) shows, the persons in the control room are suddenly, with the support of the system's processing power and information concentration abilities (modern process control displays are highly graphical), in a position to directly control and run the entire plant, without any intervening organizational apparatus. Of course they do not run the plant in the sense that they manually control the process (which execute under the control of computer programs), but they supervise it *and* are able to improve it by tuning the program parameters as they gain experience with the equipment and the way it operates. The depth of their control has been dramatically increased—they almost literally run a joystick-controlled factory.

What has really happened here is that the systems have *eliminated the entire operating organization* at the factory floor, the entire operating core in Mintzberg's terminology, and left only the roles of the production manager and his support team untouched. The organization has not only been reduced in size; it has been *truncated*—one part, which was earlier the largest one, has simply disappeared, and only machines have come instead. Of course, there is still need for small teams of workers to maintain the plant and to tackle emergencies, but the daily control of the production process can be left to one person (in principle), or (more likely in practice) a small team of persons. According to Mintzberg (1979), such an elimination of an operating core configured as a Machine Bureaucracy will mean that the total organization is going through a metamorphosis: Its character changes in a profound way, since staff and management, populated by many more team-oriented professionals, will now come to dominate its structure.

It is very interesting to note how this has generally not been understood in plants that have been automated. Almost without exception, the jobs in the control room have been defined as transformed versions of the local control jobs earlier performed by skilled workers, and it has been the workers who have been trained to fill them. Our analysis here, however, indicates that the control room jobs are not a continuation of the work on the factory floor at all; rather, they represent key plant management responsibilities: to direct the operation of the plant such that it achieves optimal performance, given the existing business objectives (product and quality mix).

Before automation, the managers and their process engineers had to pursue this goal indirectly, working through supervisors and foremen, trusting both their

⁶ Normally, you will see a number of terminals in a control room. That is more an expression of the present state of the technology (requiring several screens to display all vital information) and safety precautions (the need to have more than one person available in case of emergency), than of the technology's basic characteristics.

judgment and the judgment of a large number of skilled workers. Improving the quality or yield was very difficult, since so much of the process depended on tacit knowledge, and the control over process parameters was quite crude.

When such a factory is fully automated and the whole organization at the factory floor is eliminated, control can be exercised directly, without human intermediaries. In addition, control over the production process is dramatically improved, it can be based on accurate measurements, parameters can be adjusted in minute increments, and systematic experiments can be made in order to improve both yield and quality. The direct control of the total process and the tuning activities are definitely not a customary part of rank-and-file factory work; they belong squarely to the traditional domain of management and engineering.

Quite naturally, this mismatch has led to conflicts between control room operators and production managers, their subordinates, and staff. Zuboff describes this in some detail (1988) and explains the reasons quite accurately: Clever control room operators will, after some time, develop a deep understanding of the total process and will increasingly be able to tune it for greater economy, increased production and/or improved quality. Managers, who do not have direct access to the control systems and the information they provide about the processes, will fall behind and will not be able to either direct or control the operators' work in a meaningful way. Frustrated over losing their positions as those who can best comprehend the total process, they will often try to reassert their authority by giving the operators directions anyway—directions that are likely to be inferior in most cases, since they are based on inadequate information and a lack of experience with the system. The operators, in their turn, will feel this both as an encroachment on their newly found responsibility and an affront to their professional competence. Both parties will suffer, together with the plant's economic performance.

Ideally, then, control room responsibilities should have been left with plant management and the engineering staff, and the systems designed accordingly. It is they who should have been trained to use the systems for controlling and optimizing production. If it is desirable, for moral or political considerations, to appoint former workers for such jobs, one should be very conscious of the implications and provide educational programs, discretionary powers, and benefits that match the real responsibilities of the job—because, in the highly automated factory, it is the people who master the systems and understand the information they provide who decide the profitability of day-to-day operations.

Hyperautomation

Already, information technology has helped us develop the extent and sophistication of automation far beyond what was possible by mechanical means alone. Looking into the future, the scope for progress is still vast, and the limits are difficult to define. Advances have already been dramatic enough to warrant a new term to distinguish this new breed of automation from mechanical automation as we have seen it develop over that last century: it could be called *hyperautomation*. Hyperautomation is the computer-dependent variant of automation, and it can be mapped under that entry in the taxonomy of coordinating mechanisms shown in Figure 7-1 on page 176 (as I have done in Figure 13-1 on page 339). In principle,

hyperautomation is not different from automation, but, just as for computer-based information storage, the sheer power of the new tools is so great that they must nevertheless be judged to be qualitatively different.

We may see great organizational changes in connection with hyperautomation, as in the examples described earlier. By shedding almost all the workforce in its operating core, a company can be transformed from a Machine Bureaucracy to something much more like an Administrative Adhocracy (Mintzberg 1979). There is also no doubt that the use of information technology will make such transitions possible for a much larger number of organizations than mechanical automation ever could.

Hyperautomation also makes it possible to integrate a much greater span of organizational distances into one coordinated process, not least because it allows the automation or elimination of significant administrative processes. We have thus already seen process-oriented automation expand along value chains (Porter 1985), even outside the boundaries of the principal organization.

Prominent examples of this can be found in the automobile industry, which has for a long time been at the forefront of automation. When building their new factory in Sunderland in northern England, for instance, Nissan invited important suppliers to establish their own factories at the perimeter of their main plant site and tie directly into Nissan's production control system. The objective was to have the suppliers deliver their parts directly on the assembly line, to save storage space and handling costs.

As soon as the basic body of a new car is put on the painting line in the Nissan main plant, a transponder is attached to it, containing the complete specifications for that particular car.⁷ This is particularly important, since the broad range of colors and options offered today's customer virtually ensures that no two adjacent cars coming down the line will be identical (the company claims to offer customers 20,000 varieties of their vehicles). When the body leaves the paint line, the transponder is read by the central production control system, which broadcasts the information to the subassembly stations and component supply points as well as the suppliers that are tied into the direct delivery system. The manufacturer of seats, for example, receives the necessary specifications three hours before the seats are to be fitted (Christopher 1992). Only then do they start their own production, assembling the front and rear seats to match the car model, colors, and other details determined by the model and the customer's choices. Every 15 to 20 minutes, a transport shuttle leaves their factory, taking the finished seats directly to the appropriate supply point at the assembly line, where they arrive just before the car they belong to.

What we see here is an extremely tight coupling of a number of independent organizations, a coupling that is even tighter than you will normally find between departments within a single organization. Nissan's own plant, by the way, operates according to the same principles—its press line for body panels, for instance, is carefully synchronized with assembly, to the point where the total amount of doors, bonnets, and boot lids in process amounts to less than what is required for one hour's production.

⁷ Information drawn from the company information package.

Even though these supplier organizations all have their own independent owners, administrations, and economies, for the purpose of producing Nissan automobiles, they function as one amalgamated organization with a common coordination infrastructure. We shall return to this kind of organizational setup in Chapter 16, since it constitutes a new organizational configuration.

Hyperautomation is a tool that offers dramatic new opportunities for the design of organizations, and that may also greatly affect the development of society. The possibility of organizational truncation and the establishment of strongly coupled organizations are genuinely new extensions of the constructible space. However, the new tools and even the new organizational configurations work fairly well with established organizational practices and structures. For all the work that is not eliminated by the new systems, it is eminently possible to use common structures and coordinating mechanisms. Though I am not certain, I would guess that the remaining operating cores of both Nissan/Sunderland and the suppliers are predominantly Machine Bureaucracies, and that staff and management still operate much as they used to. It would certainly be possible. This fact is perhaps also one of the main reasons why hyperautomation has developed so fast, and organizational truncation and the development of strongly coupled organizations have kept pace with this development. It is only natural that more unconventional approaches (if they are possible) will take a longer time to develop and deploy.

Consequences for Society

As we have just seen, the consequences of extensive automation are dramatic for the organizations involved. The more organizations exploit the potential computers offer in this direction, the more the consequences will also be felt on the societal level. Increasing automation will irrevocably change the labor market, and the great advances in productivity will provide a steadily increasing material prosperity, if the accompanying environmental problems can be solved.

The developments in the labor market have actually been underway for some time, apparently as a continuation of a long trend starting with industrialization and the mechanization of agriculture. First, industry overtook agriculture as the major employer, but, as industrial productivity increased through automation and increasing use of energy, it was overtaken by the service sector (including public services and administration). The further contraction of the industrial sector can easily be interpreted as a continuation of this trend, trailing the agricultural sector by a number of decades.

However, even without venturing into a discussion of the development of a service economy, information economy, or the postindustrial society, it can be stated that we are experiencing a break with this development; we face a new situation with unclear consequences. The significant difference between former developments and the present is that, up until now, the routine work eliminated in one sector has always been supplanted by routine work in another. As the available positions for farmhands dwindled, up went the number of positions for factory work; and as their number in turn declined, the great white-collar bureaucracies expanded to offer a new set of jobs.

What is happening now is that the remaining routine jobs in both industry *and* in the service sector continue to be decimated, but no new ones seem to be appearing: Almost all new jobs are less routine than those that disappear. The required level of education rises, and it becomes more and more important to be able to think abstractly and to understand and manipulate symbols instead of physical objects. This tends to be true within most occupations, even traditional ones.

A simple example of this is a subtle change in the situation of secretaries who do a lot of typing. In the days of the typewriter, their core professional skill was of the action-centered type—it was the physical skill of hitting the correct keys very fast. The typewriter was a simple and very concrete tool, and its operation and few controls were well understood by the secretaries. They were the undisputed office masters of typing and editing. Today, where most professionals and managers have their own PCs with the same word-processing software as the secretaries, the situation is significantly changed. True, the secretaries are usually still the fastest key-hitters, but they are generally no longer the masters of their tool. In most organizations and departments, there will be a number of professionals who are more proficient than the secretaries in using the advanced functions of word-processing software, and the secretaries will often have to turn to them or to support personnel for help. The case is the same for errors and system breakdowns: The secretaries do not have the general knowledge about their computers to escape from even relatively simple error situations, and they again need help from someone else. Many secretaries experience this as humiliating, and as something that undermines their former position as specialists.

We often see that even extensive training does not change this situation significantly. The task of typing and editing has become so much more abstract, and the writing tool itself so exceedingly complex and symbol oriented, that it is much more easily mastered by the professionals, who generally have extensive training in handling symbols and abstract problems. On the average, professionals may also have greater natural abilities in that direction to begin with.

Are we all able to live up to these new requirements? Or will there be a sizable number of people in our societies who will never find a job they can master? Will we have to stimulate the creation of more simple service jobs, which can offer a decent and respectable living to those who do not want or do not master intellectual work? At the moment, these questions do not have clear answers; they only echo growing political concerns (at least in some countries) about the "two-thirds society," where the fortunate two-thirds of the population is employed and grows more and more prosperous, whereas the unfortunate third is unemployed and only becomes poorer. Although it is not the theme for this dissertation, this question represents a problem that will affect every aspect of society.

13 Coordination by Default

"Harmony would lose its attractiveness if it did not have a background of discord."

Tehy Hsieh, *Chinese Epigrams Inside Out and Proverbs*, 1948

In Chapter 7, I argued that the implicit coordination achieved through the use of common archives or files was the first new coordinating mechanism made possible through the use of technology, and that it has played an important role in the development of the modern office organization. Its elegance and efficiency stem from the fact that it allows coordination to be achieved not by actively directing people, but simply by recording information and making it available. However, as long as it was tied to paper, its potential was severely restricted. It did not come fully into its own until the advent of information technology, or specifically, the structured database.

As noted in Chapter 7, there are two main constraints that apply to paper-based files. First, they are accessible in only one physical location, and if one does not work on the premises, there are a number of tasks one cannot easily carry out. Second, they normally have only one index (e.g. *either* name, date of birth, or address), since cross-referencing is extremely time-consuming and expensive and therefore really only viable for very important, historical (unchanging) information. Computer-based systems lifts these restrictions, through automatic indexing, automatic search and retrieval, and electronic communication.

The Structured Database

That Significant Record

The great importance of record keeping is, evidenced by the fact that new technologies for information storage seem to make their debuts in the realm of business and public record keeping—computers included. As described in Appendix A, when the computer first ventured beyond research and was adapted for administrative purposes, it was indeed for record keeping and tabulation.¹ The same was the case with punch card equipment half a century earlier.

¹There were two private customers on Univac's order books in 1948: Prudential Insurance Company and the market research company A. C. Nielsen. The very first computers, like

In my view, a vastly extended implicit coordination represents one of the most revolutionary aspect of computers—and one we find behind most of the familiar success stories that circulate in the business. Paradoxically, it is also among the least talked about. The reason is probably that it does not reside in highly visible equipment such as personal computers and scientific workstations, or in the increasingly advanced software and add-ons to those ubiquitous eye-catchers. It does not jump at you like a fancy multimedia presentation program—you cannot walk into a computer show or an office and *see* implicit coordination, unless you take the (often considerable) time needed to study and understand the applications and databases accomplishing it.

As we have seen earlier in this chapter, tools for implicit coordination are nothing new. Nor is it new, either, that they are undervalued. But, today, computers have brought new dimensions to implicit coordination. True, the database is logically in many ways just an extension of the paper-based file. But, as argued earlier, the increases it offers in speed, availability and ability to handle complex information are so great that it becomes qualitatively different from the paper-based file. In addition, the fact that the information in a database is in machine-readable form, and thus available for automatic operations, increases the difference further.

Computers allow us to store an almost infinite number of records, to store very complex information, to access that information from anywhere, to seek out individual pieces of information in a fraction of a second, to store them back just as quickly, and to do automatic operations of great complexity on them in a very short time. The central aspects of this new functionality are the *reach*, *capacity*, and *speed* offered by the implicit coordination achieved through the use of databases.

Reach

The coordinative reach of a database is, as we have concluded earlier, a function of the available communication arrangements. If communication lines with sufficient capacity are available, the geographical reach can cover the whole earth (and more, if that should be required!). Thus, with a true, on-line banking system, for example, a transaction registered against your account in any one branch office is immediately reflected in an updated total for that account in the central database—and so instantly available for all the other branch offices as well. You can therefore expect a coordinated response from the bank—no matter which branch office you walk into, the amount of money they would be ready to give you should be the same.

Capacity

Reach is one important determinant of the coordinative power of the database; another is the number of people that can be simultaneously coordinated. As with geographical reach, there are no definite theoretical limits here—the achievable capacity is determined by the level of the available technology and is rising all the time. To my knowledge, the largest capacity displayed by single databases today are the airline reservation systems. The three largest are SABRE, Galileo, and

ENIAC and the Mark I, were only that—*computers*. They did not have any mass storage that could accommodate records.

Amadeus. As mentioned in Appendix B, Amadeus is probably the largest today, with 180,000² terminals generating probably more than 6000 transactions per second at peak load, which is close to the limits of today's technology. When the first such system, SABRE, was introduced in 1964, it taxed the capacity of the fastest machines then available with its 1200 teletype terminals (Hopper 1990).

If the development continues at the same pace—and there are no reasons why it should not—a single physical database should be able to accommodate at least 3 million on-line transaction-processing terminals in the year 2020. My guess is that we will reach that level even earlier—maybe as early as the first decade of the next century—due to advances in parallel processing and new storage media such as the Holostore. For less transaction-intensive applications, the number of terminals could be considerably larger. It is not necessary to tax the limits of the possible performance ranges to extract great value, however.

Speed

In theory, the reach and capacity of coordination described earlier are not dependent upon computers. Information can travel the world on paper as well as on wires and airwaves, and a paper file can thus be accessible for anyone, almost without regard for distance. There are many library services in the world demonstrating this principle daily, and the Japanese *kanban* system, supporting the original development of demand-driven just-in-time production, was originally based on humble cardboard cards. Indeed, many smaller Japanese companies still rely on such cards in their daily production.

But reach and capacity is not everything—it must be coupled with speed. If we look again at the examples described earlier, we will see that none of them would be feasible without the instant transfer that is the hallmark of electronic communication. And even that is not enough—it must also be combined with the instant registration, retrieval, and transmittal offered by computer systems. It is precisely this combination of reach, capacity, and speed that makes the database qualitatively different from the paper-based file (and from *kanban* cards, for that matter).

As an example, we can go back to SABRE, the first airline reservation system, developed by American Airlines and IBM from 1954 to 1964. Before SABRE began operation, all flight bookings and changes were received through telephones (note that telephones provide instant or almost instant transfer) and recorded manually on blackboards and index cards (Hopper 1990). When the development of SABRE started, however, the booking department of AA had begun to look really strained; by the time SABRE was finished in 1963/64, it was probably coming apart at the seams.

The reason is not difficult to see—the number of persons needed to answer all the telephones was increasing dramatically and changes to the cards and blackboards were cumbersome to effect—and, as the number of callers and clerks steadily rose, the update problems increased even faster. In addition, there was a significant time lag between the actual confirmation of a seat and the moment this was known by the other clerks, and that time lag could easily lead to trouble.

² Personal communication from a representative for Amadeus in Norway.

Today's traffic volume would probably not even be theoretically possible to handle the old way—already in 1990, SABRE's database contained 45 million fares from 650 airlines, there were up to 40 million changes every month, and more than 500,000 passenger name records were created every day (Hopper 1990). Today, SABRE handles booking for more than 400 airlines, 35,000 hotels and 50 car rental companies. It has over 30,000 agency locations, more than 130,000 terminals attached, and in 1996 it processed over 5200 transactions per second and peak load (according to the company's annual report for 1996). Without the automatic and extremely fast reads and writes of the central computers, the perfect coordination described in the preceding section would be impossible to achieve.

A Word on Multiple Databases

As noted in Chapter 9, it is often not feasible or even desirable to coordinate a set of activities through a single database. I believe that the single-database solution will become increasingly important inside organizations as both software and hardware improve and communication lines become cheaper. The reason is that this solution is simply superior with regard to speed, integrity, and administrative overhead. But there will be a considerable period where solutions with multiple databases will dominate, and, in interfirm linkages, they will probably dominate in the foreseeable future.

Databases may be linked in several ways. A database may be split among several geographically dispersed machines but still be logically organized as a single database. In that instance, calls for data residing on another machine than the one where it originated are be passed along to the machine with the required piece of information. A database may also exist in several copies, with mutual updating taking place at preset intervals. In principle, this is simply a single database split physically. The reason for this setup is almost invariably that telecommunication costs makes such a solution cheaper than a centralized database.

Much more common, however, is the situation where the linked databases are quite different from each other—they use different software, belong to different applications, and run on different kinds of machines. As described in Chapter 9, we can then use electronic messaging to automatically update those parts of the different databases that we need to synchronize. The messages can either go automatically as a result of internal processes in the application programs or be directly triggered by the people using the systems.

Such linked systems may be very large. The largest existing one is probably the SWIFT network used by banks for international money transfers. Most large banks throughout the world are connected to this network, and billions of dollars are moved over it every hour, constantly updating account databases in banks worldwide, with an unknown total of terminals attached. A transaction entered on a terminal in Oslo may withdraw a certain amount of kroner from an account in a Norwegian bank database, and update an account, for instance, in Italy with the corresponding amount of lire.³ In turn, this would cause an Italian bank clerk to

³It may take some time—a day or two—because there may be old equipment and batch-oriented systems involved, or the banks may want to sit on the money for a certain amount of time to earn some interest, but, technically, the transfer could happen immediately.

allow the owner of the Italian account to withdraw money from it without any other notice or instruction—his actions being guided by the implicit coordination provided by the linked databases.

Even tighter coupling can be found in the automobile industry, where the large producers have sophisticated computer links with their main suppliers and resellers, particularly the suppliers. Electronic messaging systems synchronize the databases of the production systems so that the deliveries from the suppliers precisely match the needs of the assembly plant—down to the delivery of assembled bumpers in racks directly to the appropriate station at the assembly line every few hours, with types and colors exactly matching the order in which the cars come down the line.

In networks with linked databases, the speed need not be much lower than for a system based on a single database, but it often is—there may be batch processes involved, as when all or some of the databases in the network collect all pending changes to other bases and transmit them in bulk once or twice a day to save on telecommunication costs. Or, delays may be deliberately introduced for other reasons, as is often the case with money transfers—the banks want their float just as in the old days, no matter how fast the technology may allow them to operate.

In my view, however, only unified databases can deliver the maximum advantage from database technology. Information should be registered when and where it is created or captured, and (to ensure full information integrity) stored in only one place. Central databases thus offer an inherent advantage over distributed ones, since a distributed database, where the same information may be stored in several physical locations, will incur a great deal of processing and communication overhead to maintain integrity. As communication costs continue to fall, the central database will therefore grow in popularity.

System-to-System Communication

The basics of system-to-system communication were briefly discussed in Chapter 8 (“Shared Data and Messaging”). Technically, this is a question of either common database access (communication through operations on common data) or messaging. The main advantages of a common database—as concluded in Chapter 9—are its inherent coordinating power and the elimination of misunderstandings and mistakes due to diverging or missing information in separate systems and archives. The integration of administrative systems along value chains (e.g. the chain *order entry—production scheduling—production control—inventory control—transport scheduling*) will also make possible extensive reductions in workforce and substantial reductions in time from order to delivery.

I believe that the common database is much better and more efficient than messaging for coordinating a total chain, but it is often not a possible solution for interorganizational purposes. Today, it is often not feasible even within organizations, because of the nature of existing systems portfolios and organizational structure in corporations and public institutions. Messaging is the natural answer, and all the more so because it is logically fairly similar to the function of a unified database. As already noted, the main advantage of the common database is its integrity of information and implicit coordination of the activities centering on it. What we do through messaging is to synchronize key

aspects of the databases involved—the databases exchange information about their states, allowing automatic coordination to take place: Orders update production schedules, invoices are matched against purchases; payments are matched against records in accounts receivable. Even the manual procedures they replaced had the same function—to coordinate behavior in different organizations or organization parts.

Messaging is going to be particularly important as long as systems remain fragmented, and even intraorganizational databases are diverse and incompatible. It will allow automation of many existing routines, increase speed, and on labor hours without requiring any fundamental changes in the logical administrative structure.

At first, standardized messaging (such as EDI) even tends to conserve existing practices, because of the nature of the standardization process itself. The creation of international standards for messages involves a large number of countries, standards organizations, and trade organizations. To be accepted, any standard will have to build on existing, widely used documents and forms that are part of the traditional way the old companies of the world organize and do business. The whole EDIFACT standard is a witness to this fact—the catalog over standardized document formats reads like a textbook on accounting and business administration. Examples (taken from the catalog in Thorud 1991) are as follows:

IFTMAN	Arrival Notice Message
IFTMBC	Booking Confirmation Message
CREADV	Credit Advice Message
CUSDEC	Customs Declaration Message
DEBADV	Debit Advice Message
DESADV	Dispatch Advice Message
DOCAPP	Documentary Credit Application Message
PAYEXT	Extended Payment Order message
IFTMBF	Firm Booking Message
INVOIC	Invoice Message
DELJIT	Just-In-Time Delivery Message
PAYORD	Payment Order Message

From the outside, extensive use of EDI may thus make an organization and the way it operates look and feel very different, due to improved coordination, increased speed, and reduction of errors. Below the surface, however, most of the old functions and procedures might still be intact, even to the extent that the old, isolated applications still run—now only augmented by EDI-compatible front-ends. In other words, existing procedures have just been “mechanized.” But the quantitative change (increase in speed) is so great that the consequences are often perceived as qualitative.

Bearing in mind the accounts payable function of Ford described in Chapter 12, you will see from the preceding list (where you find both a DESADV, an INVOIC, and a PAYORD message) that an uninventive solution based on the use of EDI is eminently feasible, and it easily could have been compounded by the use of email and other groupware applications. The result would have been an impressive system, yielding far less improvement than the much more radical solution eventually adopted by Ford.

We have focused this discussion on the communication of information between administrative applications. There are also, of course, important uses of messaging and common database access in areas such as the collection of sensor information (in process control and other manufacturing systems, as well as in air traffic control and other types of monitoring systems) and direct control of physical devices (as in manufacturing and military systems). But the principles are the same, and the benefits derive from the same basic mechanisms: integrity of information, implicit coordination, and fast responses.

Extensions to the Constructible Space

Computers do extend the scope of implicit coordination—they offer real-time coordination almost regardless of volume and geographical distance, and, because of the accessibility, coordination can also easily be a cross-process. But how does this extend the space of constructible organizations? In my view, there are opportunities on three main levels: inside the single organization, on the interorganizational level, and on a level where it can be debated if we are really talking about organizations at all.

The Single Organization

Banks, Automobiles, and Airplanes

As a coordinative tool inside the single organization, implicit coordination has already proved some of its mettle. We have already talked a lot about banking—especially in Chapter 12—and there is little doubt that it is the coordinative power of the database that is the main force behind the flexibility of modern banking. The instant or near-instant availability of account information has made it possible to eliminate a lot of back office work and control procedures, to broaden the jobs of the personnel working at the counter, and to extend services reliably both to self-service devices (e.g., automatic teller machines) and to external agents (e.g., shops and filling stations).

However, even if the database is vital for banking, and extensive in the sense that it allows any clerk in a branch office anywhere to meet a customer's request in the same way (that is, with basis in the same information), the coordinative aspect is fairly narrow—the clerks will be coordinated in their assessment of the customer's financial status, but, aside from that, the actions of one clerk will have little or no implications for another. However, it is worth noting how even this fairly simple and narrow application of implicit coordination leads to revolutionary changes in banking, and how the addition of automation—especially in combination with “intelligent” self-service solutions such as those

postulated in the Chapter 11—can allow a total transformation of single organizations as well as an industry.

The potential is wider than this, however. To find an example, we need go no further than to an example from the previous chapter: the revolution in Ford's accounts payable departments. I shall not repeat the description, but only underline the fact that it was the use of a fairly simple database that made the whole thing possible. There is even an element of cross-process coordination to be found in this example, since the information in the database not only turned out to be useful for the procurement of parts and payment of suppliers; it also saved a lot of work in financial reporting. The reports were now both more up to date and more reliable, since information on parts and payments was available at all times from the database and were always consistent and up to date.

Even more illustrative is the situation at Mazda, where the same database served as a coordination point for orders, production and supplies from subcontractors. The data integrity and implicit coordination offered by the single database provided perfect synchronization of the manufacturing process ("procurement to shipment," as Hammer and Champy [1993] prefer to call it), the sales process ("prospect to order") and the order fulfillment process ("order to payment"). The same is, in all probability, the case for the Nissan factory in Sunderland, also referred to in the previous chapter, although details are lacking in the available description. Indeed, it is this potential for cross-process coordination that is the main motive for the general movement toward registering data only once—at the point of origin—and storing it in one place only to ensure integrity.

A different example of the strong coordination that unified databases can provide can be found in the aerospace industry. The Boeing 777 is the first airplane whose full structural design was done in an integrated CAD/CAE⁴ system (Stix 1991, Moeller 1994). A modern jetliner is a very complex piece of machinery (the 777 has some 3 million parts), and with traditional, paper-based design, a major part of the job is to manage the thousands of drawings describing the various parts; correct them when there are changes; and to ascertain that adjoining parts actually fit together, and that no two parts (including piping and cables) occupy the same space. This job is so complex that it is simply impossible to complete on paper—to really find out if all the parts fit, and whether cables and piping collide, physical models and mock-ups in full scale have traditionally been necessary to sort things out. During the actual manufacturing of the first airplanes, makers even had to make last-minute changes due to conflicts and problems that had not been discovered during the design phase.

With the 777, all the design work was done on workstations equipped with a three-dimensional (3D) design program, which made it possible to draw each part, display it as a 3D picture, rotate it to view it from different angles, test movements, and so on. Because of the integrated database connecting all the workstations, neighboring parts could then be joined together on-screen—any engineer could call up the parts adjoining the one he or she was working on to check if they fitted together. The screen even provided the telephone number of

⁴ CAD: computer aided design. CAE: computer-aided engineering.

the person working on that particular part, in case there should be need for consultation.

The parts could also be assembled on-screen to modules and to a complete model of the entire aircraft, including such vitals as cabling and piping. The fit between parts and modules could thus be tested without the need to build models and mock-ups, and the software could detect if any two parts—for example, two cables—occupied the same point in space. The design program and the database took care of the coordination and ensured that the work done by any of the thousands of engineers matched with what the others did—without the need for human liaisons.

Besides the digital design itself, Boeing also took advantage of the coordinative powers of the system to integrate about 15 different design and engineering steps into a single overlapping process. As Stix writes, manufacturing engineers were able to write tooling specifications as soon as design on a part had started, and could provide feedback on manufacturability early in the process. Some of the CAD data could also be fed into CAM⁵ systems and used directly to manufacture parts. Likewise, the same data could drive automatic testing equipment, examining parts for mechanical accuracy (mechanical tolerances are very narrow in this business). According to an article in the *New York Times*,⁶ Philip M. Condit, Boeing vice president in charge of the design project, said that the system allowed the engineers in this large project to work together just like the team of less than 100 engineers who designed the B-29 bomber during World War II.

The actual size of the 777 project team, however, is not clear—the number of workstations and people actually working on the design, has, surprisingly, been impossible to ascertain. The article by Stix says there were 2200 workstations at Boeing's main design site in Seattle, served by eight IBM mainframes, and that there were more workstations and additional mainframes at several subcontractor sites in Kansas and Japan. Moeller says there were 1400 terminals and four mainframes in all. The article in the *New York Times* referred to earlier asserted that 5600 people at 18 sites were involved in the Seattle area alone. Personal communication with sources at Boeing has not helped very much to clarify this, since Boeing regards the CAD system and the way it is used as a competitive advantage important enough to be shielded from detailed reporting. It seems reasonably certain, however, that the number of people involved in the design was higher than 5000, and that at least two to three thousand of them were equipped with workstations.

The 777 project did not save Boeing time in the period up to the first roll-out of the new plane, due to the time it took to train the large number of engineers—not only to use the new system, but to “think” in 3D and to work in cross-departmental teams. However, with that job now done, and the entire structure of the plane in digital form, Boeing spokesmen are confident that there will be spectacular savings in the development of new versions. Moeller (1994) quotes Larry Olson, director of computing systems at Boeing, as saying that custom versions can now be built in eight months, compared to the previous 52—an 85%

⁵ CAM: computer aided manufacturing.

⁶ *New York Times*, November 1991. My copy of the article does not contain the date, but it is probably November 12.

reduction in lead time! It seems reasonable to expect that the system will save Boeing considerable time when they embark on the design of their next new aircraft, and that it will be extended to cover larger parts of the total aircraft design.

Bigger, Better, and Brisker

These examples illustrate the main strength of the database as an organizational tool: the ability to provide coordination as a spin-off, as an implicit effect, of the data storage itself. Coordination that earlier required significant, even massive, efforts can now be effected without any human mediation at all, with much greater speed, and with much better precision. Computer-based implicit coordination should make it possible to build and maintain *much larger organizations* than before, to make large organizations *much more responsive*, and to *improve the quality of their output*. The condition is of course that common information lies at the base of their main activities, as they indeed do in banks and in design projects. For manufacturing operations such as the Mazda and Nissan factories, a common information base must be augmented by advanced automation to achieve the maximum advantage. Indeed, the same can be said about banking, where the combination of the database, automation, and self-service will soon make it possible to run vast transaction-processing operations, covering great geographical areas, with a surprisingly slim organization.

The increased responsiveness does not only come from the speed with which one organization member can retrieve information, for example, in case of a simple customer request. Just as important is the fact that changes in the common information base are instantly incorporated into the basis for everyone else's work. This means that it will take considerably less time and effort for the organization to come up with a consistent response to a request that involves more than one person or group. This will be true for relatively simple cases as well as really complex ones, such as an airline's request for a custom version of the 777. The consistent information and the instant updates will allow a large organization to respond in ways that were earlier only possible for organizations small enough to have almost every relevant person working in the same building—taking advantage of the richness of face-to-face communication. The consistency of the common information will also contribute significantly to the quality of the organization's output by increasing internal consistency and accuracy.

Decentralization

That the implicit coordination achieved through the use of databases eliminates a lot of administrative tasks that use, to be necessary to coordinate work. Those tasks were earlier the main responsibility of middle management. However, they were also combined with decision making—and when the coordinative tasks are eliminated and middle management is correspondingly decimated, not all the decision making is rendered unnecessary. Someone, then, still has to take care of it, and it tends to follow the information on which it rests—migrating toward the customer interface, or the parts of the organization where the customer's requests are met. In most instances, this will mean a decentralization of authority (vertical decentralization in Mintzberg's terminology [Mintzberg 1979]). To illustrate, let us detail the banking example a little bit.

An important effect of the introduction of modern banking systems has been the transformation of work at the counter level. Before computers, or, rather, before the advent of counter terminals, the clerks working at the counter were little more than paper pushers. Their most important decisions were whether to accept a check or an identity card.

The introduction of terminals (especially on-line terminals) changed that. First of all, it eliminated much of the registration work (that is, most of the paper work), even if the transaction still had to be registered. However, with an on-line system,

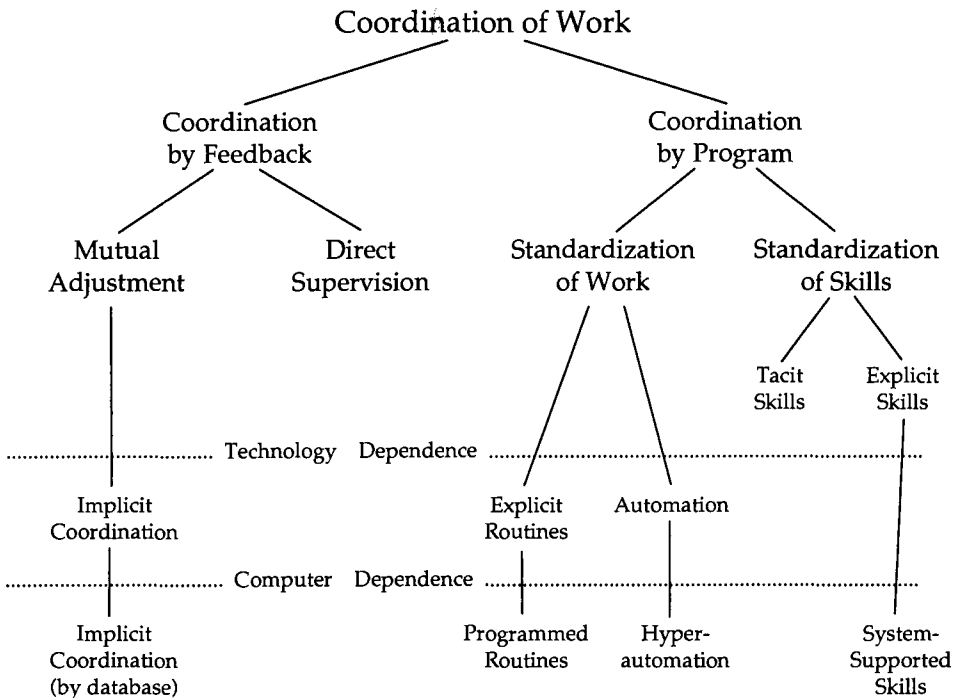


Figure 13-1: Taxonomy of coordinating mechanisms extended by the use of information technology (preliminary)

the clerk could now immediately see if there was sufficient balance for the amount the customer wanted to withdraw, transaction histories could be retrieved, and accounts could be opened and closed on the spot, to mention a few of the new possibilities. Since this also meant that important parts of a customer's total relationship with the bank were available at the counter,⁷ however, and additional information on creditworthiness was increasingly available in commercial databases, many banks started to authorize some of their clerks to grant small loans and credits to customers.

⁷The degree to which actual banking systems can do this varies, but the limitations are rooted in the specific implementations rather than the properties of computer systems in general.

This was indeed a revolution, and it was the instant availability of information at the customer interface that invited the delegation. Earlier, information had to be collected from many sources within the bank itself, where it resided in paper-based files, and the retrieval process had to follow established archival rules and mail routines. All this took time and effort—information travels slowly when it sits on paper that has to pass through several hands. To collect this information was therefore back-office work, and managers coordinated it and reviewed the results before making the final decisions.

Under the new setup, the counters were usually divided into two zones—one where customers concluded their normal transactions (such as withdrawal, deposits, payments, and so on) in terminal-equipped teller windows, and another where they could conclude more “elevated” business (such as opening an account or applying for a small credit on a salary account). This development was usually also followed by an increase in the sizes of loans and credits that branch managers could authorize.

Used for decentralization in the manner just described, computers will undoubtedly lead to a reduction in the number of organizational levels and an increase in the authority and freedom of judgment in the bottom layers of the organization. This leads many people to argue that IT is first and foremost a technology for decentralization, and that empowerment of employees and moving responsibilities down the ladder of authority are prerequisites to success when implementing computer-based systems in the organization. I disagree with this view, which I consider overly optimistic, just like the claims of the CSCW⁸ enthusiasts that computers will foster the proliferation of networked teams. I shall return to this subject in the next chapter, where I will argue that computer-based systems can also be used also as a tool for centralization. In my view, computers will not force the abolishment of hierarchy, but, on the contrary, provide a platform that extends our options—the space of constructible organizations—in both directions.

Implicit Coordination as an Expression of Mutual Adjustment

In Chapter 7, I classified paper-based implicit coordination as an expression of mutual adjustment. It should then follow that computer-based implicit coordination is such an expression as well, and indeed it is (Figure 13-1).

Just like its paper-based counterpart, it works by effecting an indirect, mutual adjustment between all the people who use the database for their work. In most cases, it cannot provide total coordination—designers of neighboring parts on the 777 had to talk to each other from time to time, as did people working with different aspects of the design process. But it is nevertheless sufficiently powerful to allow a radical reorganization of the entire process, and it extends some of the functionality of mutual adjustment to a potentially vast number of people.

The simple elegance of the principle of computer-based implicit coordination—where extremely detailed, complex, and time-critical coordination can be achieved without any direct coordination effort, unfettered by geographical distance—represents the second great power of information technology, on par with hyperautomation.

⁸ Computer-supported cooperative work, see Chapter 14.

Coupled Organizations

In Chapter 12, we also discussed the case of separate organizations tightly bound together and coordinated through common computer systems. The focus then was on automation, but there is no doubt that the foundation for the development of hyperautomation along value chains will always be one or more common databases, sometimes synchronized by messaging. The same will be the case with most other arrangements for tight organizational cooperation. The implicit coordination provided by databases is therefore a pivotal factor in such coupling of independent organizations. The reason is of course the same as for single organizations: Computer-based implicit coordination is a very efficient coordinating mechanism, requiring little or no manual work. It will also function independently of geographical distance; the upper limit on the number of coordinated persons or organizational entities is very large already and is rapidly rising.

As long as the coordination achieved through computer-based systems is sufficient, then, there will be few technical constraints on the size of such ventures. The main limiting factor now is not the technology, but simply the will to cooperate and to undertake the painstaking analysis, standardization and design that is required to make such structures work. As noted in Chapter 12, the task is already formidable when the goal is systems for single organizations, and the work required to standardize the format of information items across organizations can frighten the most hardened project manager. Even reaching agreement on simple things, such as the number of digits in the order number, can be difficult enough to delay projects for considerable periods of time. This also serves to underscore the fact that such tight coupling is not easily established, and the easy way in which terms such as “network organizations” and “virtual organizations” are used today belies the effort it takes to establish them and the losses involved in opting out once the cooperative structure is working.

However, I definitely think we will see more such constructions in the future; and I have already hinted that I believe they constitute a new kind of organizational configuration—but that part of the discussion must wait until Chapter 16.

On the Fringes of Organization

One of the examples I used earlier in this chapter to throw light on the way databases provide implicit coordination was SABRE—the airline reservation system created by American Airlines. Its operation (or the operation of any other big reservation system, for that matter) is quite astonishing, if you really think about it. If I walk into my travel agency in Oslo (which operates a few of the 65,000+ terminals with connection to SABRE) to book an airplane ticket from Hamburg to Rome, the agent can instantly tell me whether there are any seats left—he or she can even tell me how many seats are left on the different flights available, and if any of them are discounted. And if—while I mull over the timing and pricing of the different flights and try to make up my mind about which one suits me the best—a customer in a travel agency in Sydney books the last seat on the flight I eventually choose, *my* agent will immediately know, and will politely tell me that the seat is no longer available. I then become the victim of an implicit

coordination spanning half the world, taking place inside a database that is even physically located on a third continent. Or, to put it more positively, the implicit coordination of the reservation database saves me from clashing with an Australian in the plane at Fuhlsbüttel Airport, arguing over whose seat it really is.

What is really happening here, when tens of thousands of travel agents daily book flights for their customers on SABRE (or Amadeus, the major European system)? The coordination implicit in the common database keeps them constantly informed about everyone else's bookings; new flights; changes in pricing, departure, arrival times, and so on. Clearly, there is a strong element of organization present—if they did not have their computers and database, they would need an enormous hierarchy of coordinating managers and professionals to carry out the same work—except for the fact that the whole feat would be totally and utterly impossible without the database in the first place.

Of course, this mass of travel agents cannot be said to make up an organization in our normal understanding of the word (as defined in Chapter 3). But no one can deny that their common database connection ensures that their behavior appears organized in certain key aspects—their actions are coordinated in the sense that *any* booking has the potential to modify the behavior of *any* other agent connected to the database, and such modifications do routinely occur. It is not an organization, but it is certainly organized, representing what can be considered a new kind of structure. We shall return to this discussion in Chapter 16.

14 Comprehension and Control

*"Knowledge is the true organ of sight, not the eyes."
Panchatantra, c. 5th century A.D.*

Comprehending the Complex

Getting to Know

In Chapter 9, we discussed briefly the way the processing power of computers has made it possible to comprehend and handle much more complex tasks and problems than before. It is of course not only processing that is involved—as with most application areas, several of the strong points of computers are involved at the same time. In this instance the registration and storage of structured data (especially in quantitative form) and communication are essential.

This has at least two interesting aspects. First, computer-based systems make it much easier to aggregate, communicate, and display key information. Important information about sales, for instance, that used to be available only periodically (say, once each month) and lag weeks or even months behind actual sales can now be updated daily or even in real time. Second, in a growing number of instances, the computer systems will register and report previously unavailable information, thus creating new feedback chains and throwing light on formerly unknown or unfathomable causal relationships. Let us explore this in some more detail.

Availability of Information

Information technology improves the availability of information in two ways. First, as Zuboff (1988) notes, the increasing use of computer-based systems means that a larger and larger part of the information used and processed in an organization is captured and registered in the organization's computers. The systems will often capture and retain information that has not been collected earlier at all, because it was too difficult or too expensive (e.g., registering every single item sold in a supermarket at the point of sale). Second, the access to this information is greatly improved both by storage in integrated databases allowing remote access and by machine-to-machine communication.

Information transfers that earlier had to involve many people can now happen automatically, and with great speed. The speed itself is very important—information registered in a database is immediately available to everyone with access to it, and information communicated between computers is moved very quickly. This means that you can have information continuously updated in real time: There need not be any perceptible delay between registration at the point where the information originates and its use hundreds or even thousands of kilometers away.

Information Concentration

As previously noted, it is of no avail to collect heaps of information if it causes our input channels to clog up. With increased information availability, we also need information concentration—the refinement of “raw” information into a form that is easier to comprehend. This may happen in several ways. One of the most obvious possibilities is through transformations, as when numbers are turned into graphs. It may also take place through aggregation, as when we compile statistics. Statistics can then be further concentrated by being converted to graphs. We may design compound measures—numbers that represent a weighed synthesis of several other numbers. We may let the computers select information items for us, and, for instance, only show us values that deviate from the expected.

The more of these techniques we use, the more information we are able to monitor, drawing on the computer’s ability to continually trace and display the relationships between a large number of variables—in theory, an almost limitless number. In practice, there are of course limits—but only limits set by constraints on data capture and our modeling and programming capabilities. As noted earlier, even a humble spreadsheet represents a real extension of our working memory, showing us instantly the ramifications of changes in single or multiple variables, thus greatly enhancing our understanding of the total system—whether it is a budget or the layout of a logistics operation. When represented graphically, the information is even more accessible. This fact is employed in modern brokerage systems, where brokers can follow (in real time) the continuous changes in exchange rates, interest rates, stock or commodity prices both as numbers (in one window) and “living” columns (in another). The columns make it very easy to note the trends; the numbers provide the precision needed for actual trading decisions. Through the constant updates they get from the screen, brokers are thus able to reflect on and manipulate more complex relationships than before.

Other examples of systems that allow us to deal with otherwise intractable complexity are modeling systems for complex physical processes, such as weather forecasting systems, and modern military fire control systems. The computerized fire control centers of modern naval units such as an aircraft carrier group can simultaneously track and engage a large number of targets—ships, aircraft, and missiles—using a diverse array of weapons (including own aircraft). Fighter planes now have computers that allow pilots to engage several enemy aircraft simultaneously. Indeed, the military forces of the modern industrialized countries are rapidly becoming extremely computer-intensive. The allied offensive against Iraq in January 1991 relied not only on modern weapons and a lot of firepower, but just as much on a very sophisticated communication and control infrastructure. With a high skill level in organizing and operating computerized

weapons as well as communications and control systems, it is possible to achieve a planning capacity and a tactical coordination on the battlefield that is simply out of reach for less skilled and poorer equipped forces.¹

The ultimate goal here is of course to simplify and crop information down to a volume small enough for us to absorb. This represents a new twist to the old story of simplification. But it is also something really different: It means simplification by *inclusion and concentration*, not by *selection and omission*. Whereas, as naked humans, we had to rely on our experience and intuition to choose the few select parameters we could manage to monitor and process, we can now build systems that allow us to monitor all or a large number of the parameters we suspect are of interest, and then have the systems select and concentrate the information on the basis of explicit rules built into them. The systems may even have a heuristic character and be able to modify themselves on the basis of accumulated measurements (artificial intelligence). I think we are just in the beginning of a very interesting development in this field.

Causal Relationships

The exposure of causal relationships and the closing of feedback loops are among the most important contributions of computer-based systems. The more the activities and information in an enterprise are committed to computer-based systems, the more the relationships between different parts of the enterprise's activities are going to be revealed and laid open for intervention. Because information stored in machine-readable form is so much more accessible, and the computer-based tools for analysis so much better than the old manual ones, increased use of computers will make it possible for us to uncover deeper and more complex causal relationships than before, and establish or close much more sophisticated feedback loops. Combined with the computers' outstanding ability to aggregate, concentrate, and present quantitative information, this will significantly expand the limits of what single persons or small groups can comprehend and direct. The means for doing so will also grow increasingly sophisticated, as we move away from the paper paradigm and begin to exploit the full depth of the new possibilities for manipulating and presenting information.

If all the activities that lend themselves to digital representation are indeed represented in an integrated database, and that database is structured after a suitable model of the enterprise's business domain, it should be possible to surveil and tune the total organization's activities in a very sophisticated way—especially in manufacturing enterprises with extensive automation. Just-in-time production control systems of the automobile industry represent precisely an effort in this direction.

¹ In addition, such coordination and control also build on the impersonal discipline, reliability and efficiency that have become part of the industrialized cultures. Precise coordination of large organizations is very difficult when one operates within a more oral culture, with its emphasis on emotions and personal relations, and where appearance may be judged more important than fact. That is probably why highly industrialized countries are so overwhelmingly efficient in large-scale battlefield warfare, much more so than their firepower alone should warrant, and why forces from less developed societies only stand a chance if they can drag the war down to the guerrilla level, where more or less isolated man-to-man or platoon-to-platoon battles dominate.

Similar effects should be possible in chains of enterprises making up an extended value chain (from raw materials to retailing). On a societal level, intelligent use of computer-based systems should make it possible to reveal interdependencies and establish feedback loops that could significantly improve public administration, thus making possible more efficient use of public funds.

Informating Work

According to Shoshana Zuboff, it is this general contribution toward a deeper understanding and more sophisticated control of complex processes that stands out as the most important aspect of computer-based systems. We have touched upon this in Chapters 10 and 12, but I would like to introduce Zuboff's concept more directly.

In her book *In the Age of the Smart Machine* (1988), Zuboff opens with an explanation of what she calls "a fundamental duality" of information technology (1988, pp. 9–10):

Thus, information technology, even when it is applied to automatically reproduce a finite activity, is not mute. It not only imposes information (in the form of programmed instructions) but also produces information. It both accomplishes tasks and translates them into information. The action of a machine is entirely invested in its object, the product. Information technology, on the other hand, introduces an additional dimension of reflexivity: it makes its contribution to the product, but also produces a voice that symbolically renders events, objects, and processes so that they become visible, knowable, and shareable in a new way.

Viewed from this perspective, information technology is characterized by a fundamental duality that has not yet been fully appreciated. On the one hand, the technology can be applied to automating operations according to a logic that hardly differs from that of the nineteenth-century machine system—replace the human body with a technology that enables the same processes to be performed with more continuity and control. On the other, the same technology simultaneously generates information about the underlying productive and administrative processes through which an organization accomplishes its work. It provides a deeper level of transparency to activities that had been either partially or completely opaque. In this way information technology supersedes the traditional logic of automation. The word that I have coined to describe this unique capacity is *informate*. Activities, events, and objects are translated into and made visible by information when a technology *informat*es as well as *automates*."

To Zuboff, automation and informating form a hierarchy, where informating "derives from and builds upon automation" (1988, p. 11). Automation is nearly always the goal when IT-based systems are introduced, and up to now informating has come largely as an unanticipated effect, which almost no organizations have understood and very few have exploited. The informating aspect of the technology is for Zuboff the real revolutionary one, the one that will cause most of the organizational changes in the future. Although she acknowledges that IT has the potential to replace large numbers of humans through automation, in her opinion it only "perpetuates the logic of the industrial machine, that over the course of this century, has made it possible to rationalize

work while decreasing the dependence on human skills" (1988, p. 10). Only informing can bring real change (1988, p. 11):

The informing capacity of the new computer-based technologies brings about radical change as it alters the intrinsic character of work—the way millions of people experience daily life on the job. It also poses fundamentally new choices for our organizational futures, and the ways in which labor and management respond to these new choices will finally determine whether our era becomes a time for radical change or a return to the familiar patterns and pitfalls of the traditional workplace.

In Zuboff's view, it is only by starting with informing objectives that it is possible to design systems and work organization in such a way that one can reap the full benefits of the technology. Concluding the book, she emphasizes this again, and ends with a quote from a worker at one of the paper mills she studied (1988, p. 414, italics added):

The informed organization does move in another direction. It relies on the human capacities for teaching and learning, criticism and insight. It implies an approach to business improvement that rests upon the improvement and innovation made possible by the enhanced comprehensibility of core processes. It reflects a fertile interdependence between human mind and some of its most sophisticated productions. As one worker from Tiger Creek mused:

"If you don't let people grow and develop and make more decisions, it's a waste of human life—a waste of human potential. If you don't use your knowledge and skill, it's a waste of life. Using the technology to its full potential means using the man to his full potential."

In Zuboff's eyes, the technology's informing capacity also represents an appealing aspect of the technology, because it seems to favor increased use of human intelligence, learning, and teamwork, and a concomitant decrease in hierarchy and the application of Tayloristic principles: This is simply necessary to reap the full benefits of computer-based systems.

I fully support Zuboff's view that the informing capacity of computer-based systems represents a very important and genuinely new addition to our arsenal of tools. It is absolutely central to our growing capacity for managing complex tasks and projects, and, in my view, it is one of the technology's three most important contributions—on par with hyperautomation and the coordinative powers of the database.

However, I disagree at some points. First, I do not believe that information technology necessarily favors empowerment and a decrease in hierarchy in general. Like earlier communication technologies, it can be used both for centralization and decentralization, and it is not a given that decentralization and empowerment will be more attractive or productive in all circumstances. I shall return to this subject a little later.

Second, I do not agree that computer-based automation operates "according to a logic that hardly differs from that of the nineteenth-century machine system." Even if many of the basic principles are the same as those that apply to mechanical automation, I nevertheless believe (as I argued in Chapter 12) that the degree of automation that can be achieved with computers is so dramatic in comparison

with mechanical automation that it represents something qualitatively new. The effects of hyperautomation and the elimination of work that can be achieved through the use of information technology will contribute just as much as informing (or more) to the changes we will experience in our organizations and in society.

Finally, I do not agree that such automation, or the use of information technology for other purposes than informing, necessarily implies a decreasing dependence on human skills: on the contrary, as noted in Chapter 12, it entails an *increasing* dependence on knowledge. However, the requirements for knowledge may well be unevenly distributed in the organization, and I think the narrow statement that automation decreases the dependence on human skills is based on a “local” interpretation of skill—that is, on looking only at the concrete (and presumably lost) skill of a worker who is replaced by machinery of some kind. In my view, one must look at the total set of skills required for a certain production process. To achieve a sophisticated level of automation, it is necessary to develop equally sophisticated skills in analysis, engineering, and planning to design and build the necessary machinery and computer systems and to operate the resulting production units. This is, of course, the reason the most advanced automation can only be accomplished by the most highly developed industrial and scientific cultures. The skill required to automate is actually much higher than the level sufficient to carry out the work without automation—but the skill is of another kind; it is more intellective, to use Zuboff’s terminology. It will also normally reside in another part of the organization, and partly even outside the organization itself—in consulting firms and the companies that make and install the necessary systems and machines. Moreover, as an increasing number of routine jobs are eliminated, the jobs left will in most instances require a higher skill level than those eliminated, which means that the average skill level in the organization will rise. As we also noted in Chapter 12, however, the skills required in both the automated and the informed organization will increasingly be of the intellective kind, and the ability to work through symbols and abstract thought will become much more important.

The fact is that currently available technology already permits us to control more complex matters than we can tackle at our present level of sophistication. The scale of manageable complexity is already limited not by the technology itself, but by our ability to plan and design the systems, and to interact with and through them. The reason is simply that to build a system that can help us manage complex matters, we must first understand these matters thoroughly—as well as analyze and describe them very closely. Only then is it possible to design the control systems in all their painstaking detail and devise the interfaces that will allow people to use them effectively. As we proceed along the learning curve, then, and set out to tackle more and more complex tasks, the ability to analyze and understand the problem domain, and then design the total system/organization combination, quickly becomes the crucial factor—not the technology itself.

Extensions to the Constructible Space

By making information extremely accessible and increasing members' understanding of both an organization's problem domain and its internal workings, information technology adds a new contribution to its extensions of the space of constructible organizations. As recognized in the old proverb "knowledge is power," the increased knowledge should, first and foremost, make it possible for those with access to make quicker and better decisions and to supervise and direct more complex tasks and operations than before. This was, by the way, the main point made by Leavitt and Whisler in their pioneering article on the effects of computers on management (Leavitt and Whisler 1958). They predicted that top managers would be prone to use this opportunity to recentralize authority that had been delegated only because overwhelming complexity had made central decisions untenable.

What kind of opportunities will this open up? Does it primarily favor the development of more centralized, more tightly reined organizations, or of decentralized organizations, where management layers peel off and empowerment and self-organized team becomes the order of the day? The answer is not evident—just as for the telephone (Pool 1983), arguments and examples can be produced that point in both directions. In fact, the question seems to function almost like a Rorschach test: Those who think central control is a good thing eagerly eye what they see as the opportunity to use automation, improved communications, faster reporting, and better information retrieval and analysis to strengthen management's grip on the organization, whereas those who would like to wrestle power away from bosses finally see their chance to decentralize operations, devolve responsibility, and empower employees.

George and King (1991) made a thorough review of the debate on computing and centralization, drawing on 65 studies and discussions. Their material clearly shows that there are no simple relationships to be found. Numerous empirical studies can be marshaled in support of all the main hypotheses—that computer use leads to centralization, that it leads to decentralization, that they are unrelated, and that their use will only reflect the already established propensities in the organization. George and King conclude that there can indeed be a relationship, but that it is not a simple causal one (1991, p. 70):

Rather, we believe this relationship is filtered through an organization's history and context and power structure and takes form through management action in a manner best accounted for by reinforcement politics perspective.

They assert that the centralization/decentralization debate in its traditional form can be declared to be over, but that research into the matter should continue in order to learn more about the intricate relationships between information technology and organizations.

For our purpose, it is still worthwhile to analyze this matter in a little more detail, taking the nature of the technology and the way it alleviates our innate constraints as the starting point.

The debate is in fact even older than Leavitt and Whisler's article, as the telephone provided some of the same advantages as computer-based systems

have. Pool's conclusion for the telephone was that it facilitated some centralization of control, while allowing a dispersal of activities (1983, p. 59–60):

More important, the existence of a telephone network facilitated the creation of great industrial complexes having activities in many locations. Indeed that is a better way of describing the process than trying to fit it into the simple categories of centralization or decentralization. Bringing dispersed activity under one management was centralization, but permitting an organization's activities to be geographically separated is decentralization.

However, according to Mintzberg's definition of decentralization (1979), the physical (geographical) dispersal of facilities alone does not qualify to be called decentralization in an organizational sense. True decentralization must involve a decentralization of *decision making and power*. In this perspective, the telephone appears mainly as a tool for centralization, perhaps with the qualification that it helps to democratize the organization by making it easier to strike contacts across organizational levels and divides. Pool cites several authors to that effect.

Pool's conclusion seems more valid for computer-based systems than for the telephone. They can facilitate both centralization and decentralization. The question is what *kind* of centralization and decentralization we can achieve, and, additionally, if the potential is greater in one direction than in the other. In Chapter 13 I concluded that computer-based systems support decentralization by distributing information and by facilitating a reduction in the number of middle managers. I shall return briefly to this subject at the end of this chapter. First, however, it is necessary to explore the ways in which information technology can support centralization.

Possibilities for Centralization

Pool (1983) says that the telephone makes it easier to centralize control, and that, precisely because of this, it allows greater physical dispersal of operations: the *controlled* can be given a physically longer rein, since the *controller* is confident that the new means of communication will enable him to maintain the desired level of control anyway. This relationship can be seen as an aspect of a more general relationship between control, distance, and complexity: Control is inversely related to the distance between the controller and the controlled, and to the complexity of the problem domain.

From this, it follows that any technology improving communication and/or the handling of complex information and feedback chains will improve control if distance and complexity are kept constant, and allow greater distance and/or complexity with an unchanged level of control.

There is much historical evidence to support this. Before the advent of radio and international telephone and telegraph links, for instance, masters of merchant ships had great discretion in accepting freight assignments, deciding which ports to call at, whether to do repair work, and so on. Being away from the home port for months, often years, at a time, they constantly had to (and were expected to) make important business decisions on behalf of the owner. The advent of radio, telegraph, and telephone, however, effectively reduced them to mere navigators

and crew managers, since the improved means of communication allowed the owner to gradually bring the business decisions home to his own office.

As we have noted earlier, diplomacy has seen the same development—when it took months to consult one's government, the post as ambassador was really an important one in political terms. Today, it primarily covers certain administrative and ceremonial functions, in addition to public relations and local information gathering (and even intelligence activities). Pool himself vividly describe the moment when this development was brought home to American (and other) diplomats—and I quote him at some length here, because the story is interesting in itself and because it illustrates so well the correlation between communication and control (1983, p. 88, italics added):

In the spring of 1931 world economic conditions had deteriorated to a crisis level. The German government was ready to default on its loans from US banks. After having decided on a moratorium on all war debts as the wisest course of action—a decision reached only after lengthy phone conversations with over thirty leading members of Congress—President Hoover faced the challenge of placating the French government. Because of the urgency of the situation, the President had not even consulted with the French before announcing the planned moratorium on June 21, 1931. The French were outraged upon hearing of Hoover's decision. It was at this point that long-distance telephone diplomacy was used.

According to Hoover's memoirs:

During this period and subsequent weeks, I was in hourly touch with our representatives in London, Paris, Berlin, and Vienna by transatlantic telephone, and they were in similar close touch with one another. It was the first time that such extensive use had been made of the telephone by our government officials . . . and the telephone afforded far better understanding and much quicker contact than were possible with the slow coding and decoding of formally phrased cables.²

The calls were effective, and on July 6, an agreement was signed with the French; but not before having aroused a certain amount of furor in other parts of the world. A June 29 headline in *The New York Times* read, "Phone Diplomacy Arouses Belgians," and the ensuing story read, in part, as follows:

Belgian politicians are working overtime this weekend on an answer to President Hoover. It transpires that European diplomacy has been abruptly awakened from a centuries-long sleep during the past week by urgent telephone calls from Washington.

Quickly, politicians have realized President Hoover was listening in.

This breach of diplomatic precedent has startled Europe, a Belgian politician declared, relating how Europe was being hustled by new American methods. It is a new world without distances, he said, which makes diplomats feel they have outlived their usefulness when the heads of States can discuss matters almost face to face.³

Pool also refers to Casson's description of how the Japanese general Oyama used telephones to win the Russo-Japanese war in 1905 (1983, p. 90): -

² Robert H. Ferrel: *American Diplomacy in the Great Depression*. Bloomington, Ind., Archon Books, 1969, pp. 106–15.

³ Herbert Hoover: *The Memoirs of Herbert Hoover*. New York, The Macmillan Company, 1952, p. 72. *The New York Times*, 28 June 1931, p.1; 29 June 1931, p.10.

Casson⁴ describes how the Japanese troops in a crescent 100 miles long moved forward stringing telephone wires behind them, running from each regiment and battery to divisional headquarters, and these were wired in turn to general Oyama who sat ten miles behind the line and sent his orders. The Japanese victory was attributed to this communication feat.

Obviously, General Oyama achieved a much better grasp of the complex, evolving battlefield situation than his Russian counterpart; could respond much faster and more accurately; and could take advantage of flaws in the defense before the defenders were able to redress them. As noted in Chapter 6, the Russian fleet also became a victim of inadequate communications and was routed by the Japanese in the Strait of Tsushima.

In these examples, the telephone improved control because it allowed rapid collection of information at a distance. It also made order giving much more efficient and swift. It was used as a tool for centralizing both intelligence and command. However, computer-based systems do much more than facilitate human communication—as we noted earlier in this chapter, they also make information available to anyone with access, and they can concentrate information and expose causal relationships not previously known or fathomed. In addition, systems with embedded knowledge, artificial intelligence, hyperautomation or clever use of the implicit coordination inherent in databases can allow wholesale elimination of tasks. By virtue of this, information technology can facilitate centralization in at least three ways: by furnishing managers with greatly improved information about real-time performance, by large-scale elimination of tasks, and by automated supervision. Task elimination was discussed in detail in the previous chapter, but I will nevertheless include it here, since the perspective now is a little different.

Centralizing by Informing

As I said earlier, I do not agree with Zuboff's (1988) postulation that the full potential of computer-based systems could only be achieved through the empowerment of organizational members and a concomitant devolvement of power. I do agree that this is true in many instances, but I maintain that the informing aspect of information technology also offers a potential for very efficient centralization of power.

As concluded in Chapter 9, computers cannot move verbal information from one person to another very much faster or over a longer distance than the telephone can. But, by virtue of their processing capacity, coupled with the range and speed of database access, they can automatically collect quantitative information from a multitude of sources (often as an implicit effect of automated procedures), aggregate it, and present it to a human in an easily accessible form. This process can happen quickly enough to present the information in real time or very near real time, and provide a central management with very accurate and adequate information about the main activities of an organization. Such automatic collection of information from a multitude of sources was what made the SAGE system described in Appendix A so revolutionary: It made it possible to organize

⁴ Herbert Casson: The Social Value of the Telephone, *The Independent*, 71, 26 Oct. 1911, pp. 904–5.

a real-time, central combat control center for the air defenses of the northern United States. This facilitation of central commands is still one of the main functions of combat control systems.

However, let us consider instead a more civil case in point, where computer-based systems allow increased centralization of control through automatic collection, aggregation, and presentation of vital business information. The much-quoted example from Benetton (Clegg 1990) provides an interesting illustration. This Italian maker of clothing (mostly sweaters and other knitwear) developed a business strategy that was based on real-time monitoring of color preferences in the marketplace by the help of a computer-based system. Their subcontractors (about 200 small family outfits in their home region in Italy) produce only undyed clothes. Small batches of clothes in assorted colors (assumed to be the most popular that particular season) are sent to the Benetton shops the world over in the beginning of each season. Every sale is registered at the cash register and transferred electronically to Benetton's central database, where it is aggregated with data from the other shops. It is thus immediately available for analysis, and Benetton's central management know straight away which colors sell and which do not in their different markets. They can then go on to dye the clothes that are produced accordingly. Changes in demand throughout the season are instantly registered and reflected in production.

The weak point in this system, by the way, is the time lag between the registration of the sales information and the delivery of the new batches of garments to the stores—the sales profile may well change in the time it takes to go through the whole cycle. Ideally, delivery to the stores should be daily; based on the sales the day before; and modified by any accumulated experience about typical variations relating to time of the year, holidays, and day of the week. The Swedish clothes chain H&M (Hennes & Mauritz) has a comparable system that lets management pinpoint slow sellers early in the season and begin selective clearance sales both to preempt their competitor's clearance sales and to draw extra crowds into their stores while the rest of the collection is still "hot."

The organizational implications of systems such as these are perhaps not visibly dramatic, but what happens is that management in the central headquarters has just as good a knowledge of the developments in the local markets as the shop managers themselves, and they get it just as fast. Indeed, because of the computer system's ability for information concentration and calculation of trends, central management probably knows *more* about the total action in the local market than the people in the individual shops. Their managerial reach then naturally extends much further down the organizational hierarchy; in fact it will extend right into the shelves in the individual stores: Because of the informing aspect of the systems, and their greatly improved overview over customer choices from day to day, management's effective *depth of control* in the organization is greatly increased—and the shop managers' freedom of action correspondingly reduced. What is left of it can often be taken care of by less experienced personnel, since it is no longer necessary to have store managers with a thorough knowledge of the local market or of the trends within the industry.

One can of course argue that the information here presented to a central management could instead be fed back to the store managers, giving them a tool

for ordering and organizing their sales activities. Although the feedback itself of course is technically unproblematic, such a procedure would not necessarily represent an improvement for the organization as a whole. Marketing and sales activities for chain stores have to be centrally initiated and coordinated to a large extent, and orders based on local modifications and expectations may just as well be less than more accurate compared to those based on a broader material.

Anyway, the point here is not that the technology will force a development in one direction or another (we repudiated such determinism already in the introductory chapters), or that one direction will, by necessity, yield better results than another, just that *the technology extends the constructible space in both directions*. Information technology makes it possible to centralize command in large organizations with great geographical spread to a much larger degree than before, and to extend central management's direct reach of supervision to a much greater depth in the organization.

Information technology here clearly enables a significant extension of direct supervision as a coordinating mechanism. The extended mechanism is qualitatively different from the previous version—much more so than the enhancements brought by the telephone, and I believe the changes merit a separate term: *system-supported supervision* (Figure 14-1).

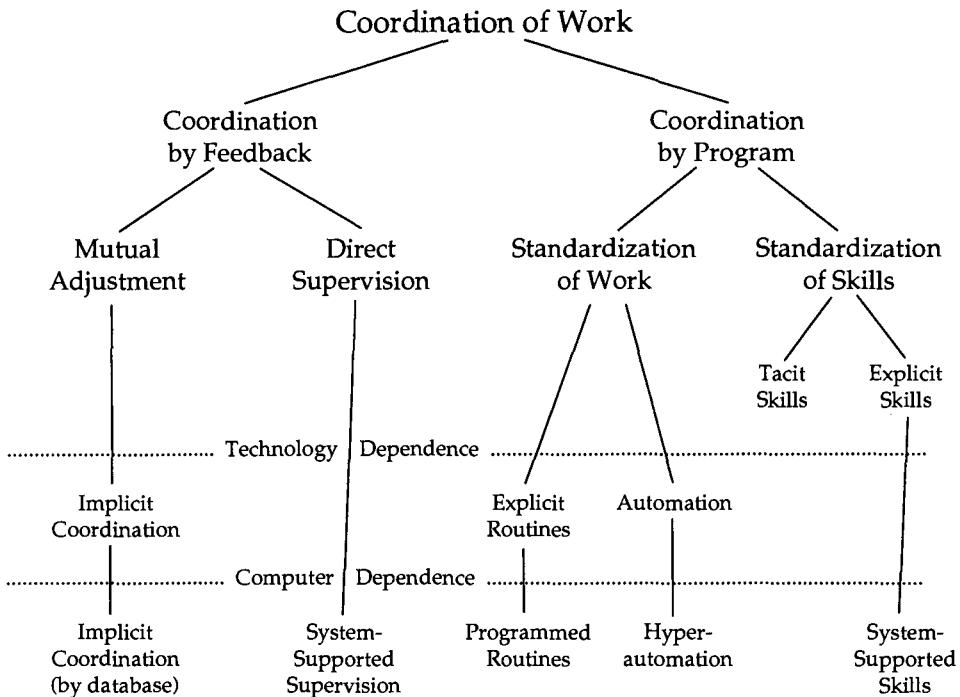


Figure 14-1: Taxonomy of coordinating mechanisms extended by the use of information technology (preliminary)

System-supported supervision usually means conscious direction of work to great depth and/or great breadth in an organization based on information gathered and presented through computer-based systems. Directions to subordinates can be given directly by personal communication (including email and voice mail), indirectly as new parameters in application programs or databases, or it can just follow as a consequence of deliveries and loads of concrete tasks. The core is that the results of the subordinates' work can be monitored in sufficient detail through the system, in real time or with a negligible time lag.

Centralization by Hyperautomation and Elimination

Hyperautomation and task elimination have already been discussed in Chapter 12. The point made there was that these options open up possibilities to truncate the organization—to eliminate large parts of the routine jobs and thereby change the organizational configuration from a Machine Bureaucracy to an Administrative Adhocracy. Our focus here is on centralization and depth of control.

Hyperautomation in Zuboff's (1988) mills led to a total centralization of control in the factory. Prior to the introduction of computer-based control systems, the physical control of the process was spread throughout the factory; afterward, control was centralized to one room. In principle, a fully automated factory such as this could be controlled from a single workstation. The qualified jobs (for skilled workers, foremen, and supervisors) outside maintenance were more or less eliminated, and the factory organization was thus effectively truncated below the level of the production manager and his support team.

One of the interesting properties of this brand of centralization is that it is often not viewed as centralization at all, and may even be mistaken for decentralization. Because the positions in such control rooms are almost invariably given to skilled workers that formerly worked on the factory floor, it is not infrequently interpreted in terms of devolvement of responsibility and decentralization of power. To me, it is obviously the opposite: a centralization of power built on the elimination of lower organizational levels. As I argued in Chapter 12, the new powers of the control room operators are not a result of devolvement, but of a *de facto* functional promotion. The fact that control room operators often find themselves in conflict with their superiors over how the system should be run only corroborates this—as their new responsibilities force them to assume large parts of the role of production manager, it is just natural that such a conflict will develop. Maybe it will be easier to see this if we perform a thought experiment with *Ceramico*, the enterprise of Mrs. Raku—Henry Mintzberg's archetype of a growing organization (Mintzberg 1979), briefly described in the beginning of Chapter 3.

Mrs. Raku started out by doing everything herself, and obviously had full control of every aspect of her business. In other words, centralization was total. As soon as she started to employ others, control began to slip, but it remained strong as long as everyone worked in the same room. As the enterprise expanded ever further, finally becoming a divisionalized corporation, Mrs. Raku had to rely on a growing hierarchy of managers, and her direct control over day-to-day activities diminished sharply. She probably felt the frustration that so many entrepreneurs show when they suddenly have to work through others, and she became a

“normal” top manager—far removed from the everyday details of business, and obliged to work through echelons of people with wills and views of their own.

Now, imagine if information technology made such strides that Mrs. Raku could totally automate production (except for maintenance and transport), as well as most of the administrative work—having the salespeople in the field update the production system directly, the designers’ CAD systems seamlessly link up with the computers controlling the production machinery, purchases and payments handled more or less automatically through EDI-type transactions, and so on. Maybe she could then get almost all the information needed to run the company directly from the computer systems, and could gather the few people who really needed to make decisions in one room—or at least along one corridor. Then much of her lost control would return, and the enterprise would become re-centralized—in the sense that routine work and the work of middle management would be eliminated, concentrating control in far fewer hands. Here, both hyperautomation and system-supported supervision would be used to its fullest potential, and to use an alluring metaphor, we could say that Ceramico would become a *joystick organization*—a company where all or almost all activities were directly controlled by one person or a very small group of persons, with the help of sophisticated, computer-based systems.

This possibility is not as far-fetched as it may sound—in fact, the hyperautomated pulp mill and the modern automobile factory (e.g., the Nissan Sunderland facility) represent long steps in this direction, and we can expect the development to continue. The great communication capacity of computer-based systems also opens the possibility to stretch the depth of control in joystick organizations over large geographical distances. The most likely early candidates for such large-scale centralization are probably process industries with a global market as well as a global spread of their production facilities and sources of raw materials.

Centralization by Remote Control

As noted in Chapter 7, the success of the modern organization was built (among other things) on extensive use of standardized, explicitly described work procedures. In a way, the use of such standardized procedures represents a “remote control” of organization members—their work is, to a large extent, directed by rules laid down by a combination of managers and staff personnel, saving huge management resources compared to organizations based on direct supervision. And, as noted in Chapter 12, administrative computer programs, with their embedded routines, coordination mechanisms, and directions for work, make it possible to extend and refine this control.

However, the increasing sophistication of computer programming can be exploited to increase such “remote control” even further by embedding AI-like functions and making systems active in supervising and directing workers—to let systems assist or even replace human managers.

An example of a fairly simple system of this kind is given by Zuboff (1988), in the case of the WFSS system of Metro Tel discussed in Chapter 10. Metro Tel (the alias of a U.S. metropolitan telephone company) developed the Work Force Supervisory System after the company had made the transit from electromechanical switches to the new computerized ones. Before the change,

maintenance was carried out by local crews of workers assigned to particular foremen at particular switching stations. The advent of computerized switches allowed information about errors to be collected centrally, for both registration and diagnosing—which also meant that the need for local crews disappeared. The paperwork necessary to manage ambulatory workers and foremen proved crushing, however, and a computerized solution was developed.

All the maintenance work could then be registered in the WFSS, which also held a database with the necessary information about all the workers. The system automatically scheduled the workday for each worker, taking into account the location of the tasks (including which floor in the building) and their expected duration to minimize travel time and achieve a workload that had the best possible fit with the length of the working day. The workers started their day by logging into the system to receive a printout of that day's work and reported back to the system for each task that was completed.

Even if there were still foremen in the organization, they now worked primarily through the system, entering tasks and monitoring workers through the statistics produced as a result of the task data, the information about completion, etc. logged by the workers. The algorithms in the system then set priorities, calculated the time for completion, and scheduled work for each individual worker.

Siemens-Nixdorf in Norway employs a similar system for its nationwide crew of maintenance workers.⁵ Their system also includes an inventory database, because, to offer speedy fixes, the service personnel keep a select inventory of spare parts in their cars at all times. When the system "sees" that they need new parts, replenishments are automatically dispatched by post.

An example of a more complex system is a suite of programs used in the Mrs. Fields cookie shop chain, briefly mentioned in Chapter 9 (Walton 1989). The company tried to incorporate into the programs Debbi Fields' own expertise in running cookie shops, developed in the early days of her enterprise when she personally managed one of them. As Walton notes, cookies are perishable products, and success depends on good management (1989, pp. 34):

Like other retailers who sell perishable products to a walk-in clientele, Mrs. Fields cookie stores rely upon weekly, daily and even hourly selling initiatives and careful management of stock.

As the number of cookie shops grew from a few to dozens and then to hundreds, it became more and more difficult for Debbie Fields and her growing numbers of managers to ensure that the store managers ran the shops the way they wanted them to. Training and supervision were extremely time-consuming, since the shops were geographically dispersed, and the company relied on a mainly young and inexperienced work force that was also highly mobile (short-term).

The company attempted to solve these problems by applying a number of computer-based systems. For instance, a voice mail system allowed Debbie Fields to address all her employees (or select ones) directly whenever she wanted, and an

⁵ Personal communication from sources in Siemens-Nixdorf Norge.

email system allowed the employees to address her. The core system, however, was a program called the Daily Planner. In this program the company tried to embed as much as possible of Debbie Fields' own experience, selling techniques, and management principles.

Every day, the program required the store manager to enter a number of information items, such as a daily sales projection (based on sales the same day last year, adjusted for a growth factor), the day of the week, the weather, and whether it was a school day. Walton quotes a description of how the program works (as it would be experienced by a store manager) from one of Mrs. Fields' regional managers, Tom Richman (Walton 1989, pp. 36–37):

Say, for example, it's Tuesday, a school day. The computer goes back to the store's hour-by-hour, product-by-product performance on school-day Tuesdays. Based on what you did then, the Daily Planner tells him, here's what you'll have to do today, hour by hour, product by product, to meet your sales projection. It tells him how many customers he'll need each hour and how much he'll have to sell them. It tells him how many batches of cookie dough he'll have to mix and when to mix them to meet the demand and to minimize leftovers.

The computer revises the hourly projections and makes suggestions. The customer count is OK, it might observe, but your average check is down. Are your crew members doing enough suggestive selling? If, on the other hand, the computer indicates that the customer count is down, that may suggest the manager will want to do some sampling—chum for customers up and down the pier with a tray of free cookie pieces or try something else, whatever he likes, to lure people into the store.

On the other hand, the program isn't blind to reality. It recognizes a bad day and diminishes its hourly sales projections and baking estimates accordingly.

The Daily Planner was not issuing orders that the store managers *had* to follow. It was meant as a guiding and suggestive tool. Inexperienced store managers followed its advice most closely; older hands allowed their own experience to override the system when they thought it best. The computer systems in the shops also helped in a number of administrative tasks, such as workforce scheduling, interviewing of applicants, payroll, and maintenance of bakery equipment.

Even if store managers might override the suggestions of the Daily Planner, they needed to keep the sales up, because their daily results were picked up by a store performance monitoring system, revealing their results to the headquarters based "store controllers." Results lower than expected were sure to attract immediate attention.

It is interesting to compare this use of computer systems with the thought experiment we just performed on the case of Henry Mintzberg's Mrs. Raku. Debbie Fields readily admitted how difficult it was for her to delegate authority when the company began expanding (Walton, p. 39):

Management theory claims that it is wrong not to delegate authority to those who work for you. Okay, I'm wrong, but in my own defense, I have to say that my error comes from caring too much. If that's a sin, it's surely a small one. Eventually I was forced, kicking and screaming, to delegate authority, because that was the only way the business could grow.

Like almost every entrepreneur, Debbie Fields was loath to relinquish her direct control of the baseline activities in her company—so she tried to hold on to that control through the use of computer systems. She tried to remote-control her shop managers, automate performance control, and establish a communication system that would let her completely bypass middle management. In my view, this represents a serious effort to build the kind of systems suite described in our discussion of Mrs. Raku, to create a real-world example of a joystick organization.

If we compare this with a traditional approach to standardization of work—such as the extremely detailed handbook reportedly governing all aspects of work in McDonald's hamburger restaurants (Morgan 1986)—the distinguishing feature of systems like those used by Mrs. Fields are their dynamic features: They do not only contain static rules; their algorithms adapt their output according to significant circumstances (such as time of the year, day of the week, weather, if it is a school day) as well as a constantly updated repertory of past experience (sales are related to performance on the same day in previous years)—and they do not only answer queries; they “act” proactively, giving directions for corrective action when input (in the form of registered sales) deviates from what the systems' designers (and thereby top management) deem appropriate or acceptable. In addition, the systems (unlike a handbook) report sales directly to centrally placed managers, providing them with the ability to monitor performance on a daily basis (or, if they so wished, in real time). The combination, then, of system-supported supervision, programmed routines, and a dash of artificial intelligence creates a very powerful extension of the explicit routines of the traditional Machine Bureaucracy.

When systems replace managers, as in the examples described earlier, we should expect problems to crop up if the systems severely reduce the amount of human interaction. After all, humans are social animals and normally crave a certain level of social contact. As we concluded in Chapter 10, this is exactly what happened in the case of Metro Tel's WFSS—most workers missed the old days when they worked in one building as a member of a fairly stable team, and had frequent contact with their foreman and fellow workers. The new situation turned their job into a lonely one, traveling between largely unmanned switching centers and only reporting to computer terminals.

In Siemens-Nixdorf there are fewer complaints, probably because many of the service personnel work in small communities throughout the country and would not have any interaction with colleagues anyway, and because they meet people (often people they know from earlier visits) from the user organization on all their calls. They have been deprived of their daily telephone contact with the central service organization, though. Finally, Walton does not report any problem of this kind from Mrs. Fields, which may indicate that there were at least no major difficulties. In that case, it seems reasonable to assume that store managers fulfilled their social needs through their constant interaction with crew and customers.

Possibilities for Decentralization

It seems quite evident, then, that information technology can allow for increased control and centralization of power, just as the telephone has. But what

about the promise of decentralization of authority and empowerment of employees?

According to Mintzberg's definition, Pool's example of the telephone's decentralizing effects was not an example of decentralization at all, only of dispersed activities. We might add that the reason dispersal was allowed was precisely the improved control over distance that the telephone provided. Thus, the telephone conserved or increased centralization of power and stands out first and foremost as a tool for extending the control of the centers of management—if one is not ready to accept the arguments of McLuhan, Boettinger, Cherry, and others (Pool 1983) that the telephone is functioning as a democratizing tool, allowing easy contacts across levels and departments. "On the telephone, only the authority of knowledge will work," Pool quotes McLuhan (1983, p. 61)⁶. Although I readily acknowledge that any technology that makes communication easier and less formal will have some democratizing effects, I think that the matter is considerably more complex than the quote from McLuhan indicates, and that the telephone in itself plays a fairly minor part in the total causal relations behind the democratization of the workplace we have seen especially in the latter part of this century.

When we turn to information technology in its full breadth, however, we face a different situation—computer-based systems represent more than a new communication channel and can extend the possibilities for decentralization in several ways.

Decentralization by Information Availability

Perhaps the most basic contribution is the integrity and availability of information stored in databases, as we discussed it in Chapter 13. We concluded there that, by making updated information directly available anywhere in the organization without the need for intermediaries, many middle-management tasks can be eliminated. Not all of the decision making is, though, and it tends to follow the information on which it rests, migrating toward that part of the organization where the information is utilized—often positions at the customer interface. Frequently, this will also lead to decentralization of a number of other decisions that are connected to the same complex of information and customer services. In banks, for instance, people working at the counter can now grant credit and small loans to customers, since they can easily access the pertinent information about the customer. Because information about a new credit is registered immediately, implicit coordination will then see to it that a clerk in another branch does not grant a second loan that conflicts with the first.

Decentralization by De-Specialization

Another opening that we have discussed already (Chapter 11) is de-specialization. The conclusion there was that the use of embedded knowledge, artificial intelligence, and artificial memory make it possible for single persons to cover a broader set of tasks than before, and thereby facilitate decentralization, especially in connection with increased availability of information. If a broader set

⁶ The quote is from Marshall McLuhan's *Understanding Media*, New American Library, 1964, p. 238.

of tasks can be gathered in one hand, it means that there will be less need to collect information (from several people) at more central points in order to make informed decisions. It is not a universal option; it will mainly support jobs that require people to collect information from many sources for further processing, or for use in decision making on the basis of laws, rules, and regulations. Despecialization has its limits, since only "hard" knowledge is possible to embed in ordinary systems or AI systems. Tacit knowledge, the kind of "feel" developed through experience, is extremely difficult to extract and implement in systems.

Decentralization by Increasing the Depth of Control

This title may sound self-contradictory—especially after the discussions earlier in this chapter. However, the informing aspects of the technology should also be able to serve as a basis for decentralization in the sense of pushing decision-making powers down and outward in an organization.

The focus here is on the scale of manageable complexity in an organizational context. We have already touched upon the enormous improvements computers have provided in tackling complexity in the scientific and engineering sector. Models of the atmosphere, of waves, of crude oil reservoirs, of pollution—to mention a few of the applications that can be found on the many supercomputers of the world (and an increasing number of powerful workstations)—enable us to study and predict the behavior of physical systems that are vastly more complex than anything we could even hoped to tackle in the past. But complexity is also a challenge in terms of organization. Summing up his book *Images of Organization*, Gareth Morgan says the following (1986, p. 339):

I believe that some of the most fundamental problems that we face stem from the fact that the complexity and sophistication of our thinking do not match the complexity and sophistication of the realities with which we have to deal. This seems to be true in the world of organization as well as in social life more generally. The result is that our actions are often simplistic, and at times downright harmful.

Morgan here points to a central aspect of our continuous struggle to cope with the world, and, more narrowly, to keep complex organizations on the road and ensure that our actions have the intended outcomes. But it is not only the simplicity of our thinking that represents a problem—part of the trouble can also be found in the limits of our coordinative tools and abilities. Complex tasks quickly require great efforts in coordination, which tends to build hierarchy: information must be gathered and related, and informed decisions can only be made by those with a position central enough to provide them with the necessary information.

Information technology also has the potential to revolutionize our ability to handle complexity in the realm of organizations. The new tools for personal support, the coordinative powers of the database, the greatly increased scope for automation, and the informing capacity of computer-based systems converge to improve our capabilities. This is perhaps the very essence of the computer as a tool—that it gives us an unprecedented handle on complexity in almost any area of application: It informs work, greatly increasing our depth of control by

providing a more complete understanding of the problem domain as well as exposing more of the consequences of our own actions.

The introduction of CAD in the structural design of the Boeing 777, described in Chapter 13, is an interesting case in point. Presenting designers with a “living” model of the evolving airplane provided the people who worked with it an immediate and much better understanding of how the results of their own work meshed with that of others in the project. Thus the individual designer as well as the cross-departmental teams obtained a depth of control earlier achievable only through laborious procedures rooted in a fairly extensive project hierarchy. The new control, moreover, was much more powerful than the old one, since it was based on a tool that could adequately reflect the dynamics of the running design process and thus provide almost *real-time* control.

The CAD system thus meant that repercussions from an addition or change in the 777 structural design could be ascertained very quickly, both horizontally (for adjoining parts) and vertically (for the subsequent steps in the engineering process), and it was possible to integrate as many as 15 previously separate design and engineering steps (Stix 1991). Cross-departmental teams thus replaced significant parts of the traditional project hierarchies, and considerable decision making power was moved closer toward the origins of design.

In this case, then, the informing aspect of a computer-based system provided an increased depth of control, which was, in contrast to the examples reviewed in the section on centralization, exploited by decentralizing power and giving new responsibilities to the lower levels in the organization—which is more in tune with Zuboff’s (1988) conclusions.

There are not many examples of this brand of decentralization, where depth of control—not sharing of information or de-specialization—is the central feature. There could be several reasons for this. First, management traditionally seeks control. Where possibilities for increased depth of control are found, one can assume that managers on various levels will be attracted to it and motivated to exploit it for centralization. Second, increased depth of control is often not planned for—the possibility only surfaces as an unintended effect and is difficult to discover and handle. The pulp mills described by Zuboff (1988) provide examples of this. Third, complexity is difficult—as noted in Chapter 8, the bottleneck for building systems to handle really complex tasks is no longer found in hardware, and not even in basic software, but mainly in our ability to understand the problem domain, analyze the tasks, and design the appropriate systems. Fourth, the decision-making power that is decentralized may not really be centralized in the first place—actually, without the benefit of computer-based systems, it may not even exist as a practical possibility! To illustrate this last proposition, which may seem puzzling, let us consider two examples—one actual and one hypothetical.

We have already discussed SABRE (American Airline’s reservation system) in some detail. Looking at the numbers associated with it, it strikes one at first as a fairly massive aggregation of information, but perhaps not too complex—after all, an airplane is an airplane; a seat is a seat; and, even if there are lots of them, the relationships in the database seem simple enough. In its first version, that may also have been the truth. But, as always, when new opportunities open up,

humans gradually develop new ways of exploiting them, building complexity along the way.

First of all, a seat is not simply a seat—there are several classes, each with different pricing. They may even imply physically different seats, as first class always has and business class often has—especially on international flights. The number of seats of each type will vary among the particular airplanes, and this must of course be reflected in the database. Pricing is quite differentiated, as airlines try to attract passengers to seats that would otherwise be empty. Airplane seats are perishable commodities; an empty seat at takeoff is equivalent to income irretrievably lost, and the airlines will therefore try to vary prices for particular seats on particular flights to squeeze the maximum profit out of each planeload. That is why SABRE contains as much as 45 million different fares, with up to 40 million changes each month.

The art of balancing pricing for maximum profit per flight is called *yield management*, which is today viewed as one of the airlines' most important competitive instruments. Good yield management can mean the difference between loss and a handsome profit, and SABRE allows analysts to manipulate seat pricing and the ratio of differently priced seats in a way that was previously simply impossible. To quote Hopper (1990, p. 121),

Consider yield management, the process of establishing different prices for seats on a flight and allocating seats to maximize revenues—that is, calculating the optimal revenue yield per seat, flight by flight. Yield management is certainly one of the most data-intensive aspects of the airline business. Computers review historical booking patterns to forecast demand for flights up to a year in advance of their departure, monitor bookings at regular intervals, compare our fares with competitors' fares, and otherwise assist dozens of pricing analysts and operations researchers. During routine periods, the system loads 200,000 new industry fares a day. In a "fare war" environment, that figure is closer to 1.5 million fares per day.

The real decision-making power in this case falls to the pricing analysts and operations researchers, especially since many of the changes will be time-critical, and there will be little time for review by line management. The better the systems become, the closer they will come to real-time control, and the less room there will be for direct management involvement, other than as a source of general policy directions. In Mintzberg's terminology, this will amount to horizontal decentralization. Insofar as the decision-making opportunities are new and only made available through the (informating) quality of the systems, it is a power that emerges directly at such a decentralized location in the organization.

We can also note that the implicit coordination of the database will then manifest itself—making the new fares immediately available directly at the customer interface (to all the subscribing travel agents the world over as well as the airline's own ticket offices)—and guide travel agents' advice to customers. It is important to note that this coordination is indeed direct and without human intermediaries—the actions of the travel agents and the people in the ticket offices are directly modified by the information entered in the database.

Now for a hypothetical example of an optimizing system (a kind of yield management system) for the health sector in Norway. Norway has a very

comprehensive, public health care system, designed to provide (practically free of charge) every citizen with all health services needed. The administration and funding of its various parts is split among the state, the counties, and the municipal authorities, causing serious suboptimalization because vital feedback loops have been severed through the system's very design.

The system works like this: If you get sick, the state pays your benefits until you are well again and can resume work. Now, say you need hospital treatment—simple surgery, for instance. The hospitals are run by the counties, and it does not matter to them (economically) that you are on sick leave, because your benefits are paid by central government budgets, not theirs. So they can safely leave you in queue for hospital admission for months—even if your operation will cost only a fraction of what you receive in benefits while waiting.

If the counties had been a little more sophisticated, they might at least have calculated their tax loss while you were sick and figured out that it would pay to operate quickly anyway, but they do not. Even if you get so sick that you need help and care at home, or (if you are old) admission to a nursing home, it does not matter to the county⁷—these services are run by the municipal authorities and are paid through their budgets. When you finally get treated, the hospital (county) will kick you out as soon as possible and leave you to the municipal services again if you need further help. This is really a classic case of suboptimalization, caused by a failure to establish the necessary feedback loops. The authority that controls the treatment is isolated from the economic consequences of a failure to treat the patient.

The reasons for the resilience of the established system are in large part political/ideological (treatment shall be given to everyone without considerations of economic character), but also that very few people have actually realized the problems caused by the lack of feedback and the costs associated with it.⁸ On top of this comes the problem of solving the problems by administration—the complexity of a coordination effort involving all levels and elements of the national health care system seems truly overwhelming.

Technologically, however, it should be quite straightforward (even if it would require substantial investments and a lot of work) to create a suite of computer systems that would allow a health administration officer to calculate the projected cost of your treatment; match it against the cost of your benefits; check the costs

⁷ Lest anyone who is not familiar with the health care system in Norway is led by this to believe that you are not admitted to a hospital in an emergency, I hasten to add that you are indeed; the queues only apply to conditions that can await treatment (even if there are bound to be borderline cases). I should also stress the point that treatment is free for everybody—and, as we know from economic theory, when a service or a commodity is free, and you cannot regulate demand by price, there tends to be an escalation in demand and a need to regulate it by queues. Of course, the severity of the cases in the queues is a function of the total resources used on health services, and that is where the political discussion always focuses.

⁸ The use of funds for sick benefits to pay for hospital treatment have just recently surfaced as a subject for small-scale trials. In the aftermath of these trials, we have seen very clearly the ideological reactions: Even if the money has been used to buy extra capacity from hospitals, and no one has been pushed backward in the queue, and the savings have been spectacular (demonstrably three to five times the initial contributions), the trials have been attacked on moral/political grounds: People who are working should not be able to get treatment ahead of pensioners just because it costs more to have them waiting.

and waiting times of the nearest hospitals and at hospitals farther off; check the prices and available capacity of certified private hospitals in Norway and other countries, and then make a decision representing a sensible tradeoff between your comfort and well-being and the cost to the health care service. Such a system would also allow the health administration to determine the total performance of the entire national service and tune the capacities of its various parts to achieve the best possible result in view of the given priorities. Because it would lay bare economic causal relations that have hitherto been obscured by the very complexity of the system, it would also give politicians a much better instrument for their decisions.

In short, a quite conventional (albeit large and complex) suite of systems could provide a degree of control over a very complex part of the public services that would be almost unthinkable with traditional tools, and much of the control would end up in the hands of officials at the “customer” interface.

The national health service is perhaps an extreme example, but there are bound to be innumerable large and small spheres of activity where suboptimization exists because of obscured causal relations and severed feedback loops. Computer-based systems could be used to close those loops and reveal the causal relations, and thus give people in responsible positions much better instruments to manage the complexities of their domains of responsibility—and even to extend their responsibilities considerably. The most serious obstacle for such developments is not technical, but, rather, is a question of that old primal part of ourselves: Closing feedback loops, revealing causal relations, and extending responsibilities for someone inevitably means that others will lose their large and small empires, have their budgets suddenly linked with someone else’s, and so forth. Such changes are bound to be painful and to feed organizational and political infighting, and they will be difficult to effect—no matter how rational they seem when viewed from the outside.

The Migration of Power

All the examples in this chapter—for both centralization and decentralization—have one thing in common: The systems build directly on the most central properties of computer systems—their ability to store very large amounts of information cheaply and indefinitely; to retrieve that information rapidly, reliably, and independently of physical location; and to present it in an accessible form, possibly also with a few analyses performed automatically before presentation. By eliminating paper-bound information flows and by automating information processing and presentation, the systems make it possible to bypass traditional paper-processing administrative hierarchies and deliver the necessary information directly where it is needed. And, as noted earlier, when the middle layers of the organization is bypassed (and gradually eliminated), decision-making power tends to follow the information upon which it is based: It migrates toward the “hot spots” in the organization, the places where the needs for decisions arise.

Here, we see the interesting split that is illustrated in the examples presented in this chapter: Customer-related decisions are pushed toward the customer interface, supported by systems used to retrieve information relevant for single

transactions, for specific customer-related tasks, or for critical operations in a production process, whereas coordinating and controlling power relating to the whole organization is drawn toward the top, exploiting automation and/or automatic gathering and presentation of information on an aggregate level. In those cases, as we saw in Boeing, where the total result is dependent on a very complex process where no single point in the organization can decide, power migrates toward the process seniors (senior professionals—those who head the project teams).

The location of such “hot spots” may vary from organization to organization, but will most commonly be found at the top (the *strategic apex* in Mintzberg’s terminology), the customer interface, and the critical stages in the production process. In service industries, such as banking and insurance, the customer interface will often also represent one of the most critical points in production. Power and authority should therefore tend to migrate toward those critical decision points in the organization, moving aggregate information upward and task-specific information downward. As Thompson says, commenting on what he considers the premature burial of bureaucracy (Thompson 1993, p. 190, italics in original),

Organizations *are* frequently becoming leaner and more decentralized, but these trends can be interpreted very differently than the fundamental break with centralized bureaucracy present in postmodern imagery. Essentially what we are seeing is a duality in which the decentralization of the labour process and production decisions (through mechanisms as diverse as profit centres, subcontracting and quality circles); is combined with increased centralization of power and control over the spatially dispersed, but interdependent units. These processes can and do operate on an international level, as Hyman notes: ‘Advances in computerisation and telecommunications facilitate the concentration of “conception” (research, planning, directive and strategic management) at corporate headquarters, while “execution” is dispersed around the globe’ (1988: 13).⁹ We can see that an enhanced technological capacity is crucial, but as a facilitator, not an independent driving force. New forms of IT software and hardware—such as management information systems or decision-support systems—put knowledge in the hands of senior decision-makers, which aids long-term strategic planning, as well as detailed monitoring of schedules, inventories and costs lower down the corporate structure. Local and lower management may have increased operational autonomy and delegated responsibilities, but mostly within a more tightly controlled framework.

However, not everything is preserved. The middle layers of any organization easily become big losers in this process, because much of their *raison d’être* is just aggregation and processing of information for superiors, and channeling of information among subordinates. As power migrates toward the strategic and operational levels, therefore, the middle layers in the organization should shrink significantly. Moreover, to exploit the potential benefits of computer-based systems, it is necessary not only to let this migration of authority and responsibility happen, but to promote it actively. It is also necessary to empower the people working in the nonmanagerial “hot spots.” Even if the framework

⁹ Hyman, R. (1988): “Flexible Specialisation: Miracle or Myth,” in R. Hyman and W. Streek (eds.), *Trade Unions, Technology, and Industrial Democracy*. Oxford, Blackwell.

becomes more tightly controlled (like the strengthened financial controls Thompson mentions in his example from British Telecom), the discretionary powers of the people in the hot spots should nevertheless be increased, if the benefits the new tools can provide are to be fully exploited.

It is also extremely important to understand that these jobs will change radically in the process—they will incorporate parts of the roles formerly filled by managers and professionals on higher levels, and demand more advanced skills, a more pronounced talent for abstract thinking, and a greater feeling of responsibility for the organization as a whole. Not everyone will be ready or able to make the transition.

It turns out, then, that Pool's proposition for the telephone holds up well for computer-based systems—the same technology that allows centralization can also support decentralization. But, as George and King argue, the movements in those two directions are neither similar nor mutually excluding—the relationships between computer-based systems and organizations are intricate and dependent on many factors, both social and technological. However, computer-based systems will facilitate the movement of aggregated information for business guidance toward the strategic apex, and information relevant for actual transactions or production processes toward the customer interfaces and factory floors—information that formerly had to be painstakingly collected, processed, and moved in paper-based information flows, involving many people and organizational levels, and even information so complex in origins or processing that it had not been available with traditional tools at all. Leavitt and Whisler's (1958) prediction that middle management would fall upon hard times is valid indeed.

Control: The More Sinister Aspects

So far, we have only discussed new opportunities for centralization and decentralization in a normal, democratic setting, where due respect for human rights and the right to privacy is taken for granted. Unfortunately, that is not always a valid assumption. It makes one shudder to think what Hitler or Stalin could have achieved with information technology—and even more at the thought that they were probably not the last of their kind to appear on the world scene (how, for instance, are Saddam Hussein, the priests of Iran, and Kim Jong Il using computers?).

Information technology gives people bent on control and surveillance a dangerous new set of tools. For example, in some countries today, you can have a small chip implanted in your dog (usually in the neck), carrying a unique identification number (Hesselholt et. al. 1992). If the dog becomes lost, an appropriately equipped police or veterinarian can read out the number by placing a reader at the appropriate spot over the chip. A national register will then inform them of the owner's name and address. The system is also useful for breeding purposes, and it is now routinely used to identify dogs in important sled races. Such systems are even applied to identify fish in fish farms for research purposes. The possibilities of this technology are daunting indeed.

A similar technology has been implemented for the collection of toll fees for automobiles—around several Norwegian cities, for example, one can find

electronic toll stations. As a subscriber, you will have a chip glued to the windshield of your car, and each time you pass through the toll station, a computer system picks up the car's identity, checking it against the central database for the city to see if you have paid. If your subscription is valid for a number of passages rather than for a period of time, the system will deduct one passage from the number you have left. It performs this operation in the few tenths of a second it takes you to pass the antenna and reach the pole with the warning light and the camera. If you have five passages or less left, a white signal will flash at you, and if you have none left or do not have a chip at all, a red light will flash and your car and license plate will be photographed. A few days later, you will receive the appropriate bill in the mail. You are not supposed to pass at speeds higher than 70 kilometers per hour, but taxi drivers have assured me that the system seems to work well past 100. I have not had the nerve to test that for myself.

One can well imagine that Hitler would have been very pleased with the ability to implant such a chip into every Jew and put up detectors in their homes and in relevant public places—and that Stalin would have taken the opportunity to do the same with suspected "enemies of the state." Judging by the enormous surveillance machinery revealed when the former East Germany collapsed, one might even ask if some leaders would be prepared to equip *all* their citizens with such a convenient identification tag, and have the muscle to actually do it. Still more chilling, it is probably only a matter of a decade or two before computers can recognize faces quite reliably, making surveillance even easier and harder to detect.

Used in this way, information technology would become the first realistic tool for achieving a measure of control at the level of or even beyond that described by Orwell in *1984*, since much of the surveillance could be automated. Access to any area could be automatically controlled, every citizen could be assigned individual restrictions on movement, and the patterns of movement of persons and even groups could be continuously monitored and analyzed by computer systems, alerting the attention of human surveillants only when anything suspicious turned up.

Hopefully, this is somewhat beyond what we would expect in democratic societies and the organizations in which we work. Indeed, to forestall unwanted surveillance, governments increasingly impose new laws and regulations restricting both their own and private corporations' leeway in collecting and using information on private citizens. For instance, Norwegian authorities have instructed the company collecting the toll fees in Oslo that they are not allowed to store information in their database about when and where a particular car has passed. Only the balance of the car's subscription account may be retained.

In spite of this, there is already talk about equipment that can be installed in every car—recording not only the amount of use, but when, where, and with what speed. The idea is that it will allow the authorities to price the use of roads directly, not only through excise duties and toll fees, and to price it differently according to date and time of day. No doubt, well-meaning people will also advocate the use of such gadgets for catching speeders and generally controlling the behavior of drivers in order to increase safety.

Related to this is the ability to monitor performance. Some of you may recall the controversy raised in the early 1980s when Wang introduced word-processing systems that allowed supervisors to monitor the performance of secretaries (the number of characters typed). Similar controls can easily be devised in many work situations involving computers. Not only can one monitor the amount of work, but often also speed, quality, the number and length of breaks, and general work patterns. We have certainly entered an age where vigilance against unwarranted surveillance and control—private as well as public—is more important than ever before. Have you, for instance, ever thought about the record of your travels that some airline reservation systems keep accumulating? Or the spending patterns revealed by your credit card accounts? The history of telephone calls registered by your telephone company? Remember that with the new digital switches now in operation in most modern countries, the destination and duration of every single telephone call can be recorded and stored.

To complete this chapter, I will relate a story brought to my attention by professor Jon Bing of the Norwegian Research Center for Computers and Law. This story shows that even the activity pattern reflected in the database of your local electricity board may have amazing potentials. In the late 1970s Rudolf Clemens Wagner, one of the central terrorists in the notorious German *Rote Arme Fraktion* was surprised by the police and arrested in his flat in Hamburg. How had the police tracked him down? They suspected that he lived in Hamburg, but they had no idea where. They knew, however, of some occasions when he was demonstrably elsewhere in Germany, participating in RAF activities. By matching his suspected travel pattern with the database over electricity consumption kept by the Hamburg Electricity Service and analyzing the resulting data closely for other clues, they were left with a very small number of flats—and in one of them, the suspect was found.¹⁰

However chilling these examples may seem, let us not make the mistake of labeling information technology an “evil” technology. The general qualities of computer systems that allow such monitoring are the abilities to record information automatically; to store very large amounts of information cheaply and indefinitely; to aggregate, transform, and analyze it automatically; and to present the results in an easily accessible form. They are the same abilities that make Benetton’s extended production system possible, and the examples given just show us that IT can, like any other technology, be used for both good and bad. It is up to us and our own vigilance to ensure that the technology is not used for oppressive purposes.

¹⁰ The example is reported in more detail in the third annual report of the German Federal Data Protection Commissioner, 1981, p. 50.

V Models and Configurations

In the four chapters in Part IV, we analyzed the way computer-based enhancements to our preconditions for organizing extended the space of constructible organizations. The main extensions can be summed up thus:

- Increases in personal productivity eliminate routine jobs. This tends to increase the ratio of team-oriented jobs in organizations.
- Computer-based systems allow improved group cooperation over distance and can improve social cohesion in teams and groups who cannot otherwise meet. The prospects of dispersed organizations (“virtual organizations”) are improved, but social and emotional constraints limit their attractiveness.
- Automation and hyperautomation allow large-scale elimination of work, even of work that cannot be automated directly. Organizations may be truncated, thereby totally changing character and even structural configuration—generally in adhocratic direction.
- The implicit coordination achieved through databases also allows for extensive elimination of work. The potential is great for both simpler (banks) and more complex work (engineering design). This will allow for much larger organizations than before; it can make large organizations more responsive and improve the quality and diversity of their output.
- Computer-based systems also make it easier to couple separate organizations closer together. The coordination may be very strong, as in extended value chains that are wholly or partly automated under common control programs.
- Implicit coordination can support large entities that are organized, but still not organizations in the classic sense.

- ♦ Computer-based systems allow extensive centralization of power through informing. Management can surveil performance in real-time, both aggregate and in detail, and supervision of subordinates can be automated (“remote control”). Work elimination also contributes to centralization.
- ♦ Computer-based systems may allow increased decentralization through improved information availability, de-specialization and increasing the depth of control. Decentralization mainly takes the form of a migration of customer-oriented decisions toward the organization’s periphery (the customer interface).

In a way, we have now achieved the purpose of our investigation: We have analyzed information technology’s strong and weak points, we have established how it allows us to alter the set of organizational preconditions, and we have analyzed how these improved preconditions in their turn allow for new extensions to the space of constructible organizations.

However, we have still not fully analyzed the consequences of the combined effects of these extensions. The discussion has verged on combining two or more of the extensions at several points in the last four chapters; however, to do so would involve an anticipation of later discussions as well as a break in the narrative. I have therefore waited until the last two chapters to bring the whole picture together. Moreover, since Mintzberg’s structural configurations were so centrally positioned in the organizational platform in Chapter 3, I cannot end this dissertation without discussing if and how the extensions to the constructible space combine to modify the configurations and perhaps create new ones altogether. This I will do in Chapter 16, “The New Organizations.”

Before that, however, I must discuss two topics that are central for understanding how intimate the connection between organizations and computer-based systems are becoming: That is, what will it really mean to build organizations with information technology? In Chapter 15, “Toward the Model-Driven Organization,” I will therefore first discuss the status of computer programs as building blocks of organizations, when organizations are viewed as patterns of action in line with the discussion in Chapter 2. As such programs become ever more prominent parts of the organizational fabric, action theory will have to confront this problem. Next, I will return to the conceptual model, which was first discussed in Chapter 7. We noted there that this model was at the hearth of the emergence of the modern organization, which was built within a literate paradigm. At first, organization designers were probably not aware that they were actually constructing models and using them for organizational improvements. Later, however, and especially after computers and computer programming were introduced, the concept of the model and modeling activity became very explicit. Models will be extremely important for the organizations of the future—indeed, we seem to be heading toward a situation where active models will make up the central elements in most organizations.

15 Toward the Model-Driven Organization

“From the moment of birth we are immersed in action, and can only fitfully guide it by taking thought.”

Alfred North Whitehead, *Science and the Modern World*, 1925

Organizations: Patterns of Action, Patterns of Logic

Before going on with the analysis, I would like to address the question of the status of computer programs—the logic governing the functioning of computers—as compared to human actions in organizations. This is especially important, since I have supported a combination of an action and a systems approach to organization theory.

In Chapter 7 I argued that the modern organization was a product of the literate society and the literate mind. Its defining feature, and indeed its foundation, was the explicit, conscious design of the recurring patterns of action that constitute organizations. I also held that automation represented the utmost in such design, but deferred to Silverman (1970) and others in reserving the term “action” for human actions, talking instead about “machine movements.” I could also have used the term “behavior,” which, according to Silverman, only designates observable, outward conduct, and can thus also be used for the operations of inanimate matter. In Silverman’s sense, “action” is more than behavior, it implies the meanings the actor attribute to his or her actions, and meaning is something that cannot exist outside a sentient mind.

Even if they embodied a modest amount of logic, of “canned actions,” automatic mechanical machines could still be seen as belonging to the old world of tools used to augment human work. As such, they could fairly easily be contained within the original perspective of the action theorists, reflected in Silverman’s definitions of “action” and “behavior.” When we enter the computer age, however, the distinctions begin to blur, because the computer, as it now appears, is not first and foremost a machine in the old sense of the word. As noted in Chapter 8, its ability to store and execute programs made the computer a new kind of universal machine, and modern microelectronics has increased the amount

of logic per gram of matter by so many orders of magnitude compared to mechanical automation as to create an altogether new realm of machines. Even the average PC must be viewed as predominantly an exceedingly complex system of logic, a logic that represents (in executable terms) a very large repertory of “canned actions” designed and implemented by systems analysts, designers, and programmers.

Because, even if the computers and programs themselves are inanimate and cannot attach meaning to their behavior any more than a pebble on the beach, the programs are the result of a painstakingly detailed analysis and design, full of both meaning and intent on the side of their creators—a process Yates and Benjamin (1991, p. 77) call the “capturing of procedural knowledge in computer programs.” This meaning and intent is to a considerable degree preserved in the structure and functioning of the programs. Of course, even computers running sophisticated programs cannot be viewed as actors on par with humans (for instance, no program has yet passed the Turing test¹), but they preserve and display too much of their creator’s intents and interpretations of the world to be brushed off as inanimate in the old sense of the word. When using a program in the course of their work, people will to a large extent be compelled to view a designated part of the world (the problem domain that the program addresses) through the eyes of the program’s creators. Most users will also have an acute feeling of engaging in a kind of *interaction* when they work with their computers—not only of wielding a tool, as when one uses a hammer to drive in nails. This interaction will of course be partly self-referential, since the computer’s response will often include feedback on the user’s own actions, but it also constitutes, in large part, an interaction with the logical structure created by the program’s designers.

This is, by the way, why it is so extremely important that systems analysts and designers not only grasp the organizations objectives, the designated problem domain and the tasks the system should support/supplant/eliminate, but also have a keen understanding of the meanings prospective users will attach to the system’s responses—which is what cognitive ergonomics is all about. (A good discussion of many of the details in this process can be found in Eason 1988).

When we use computers in an organizational context, therefore, the result will not only be a system of recurring patterns of human action—which we now should call *living patterns of action*—but a system where such patterns of action are intertwined with patterns of logic residing in computer systems, logic that represents carefully designed *programmed patterns of action*. In fact, the combined patterns of action of people and computers may be so tightly integrated and

¹ The Turing test in an experimental setup where a person is put in a room with a terminal and a keyboard, connected to a computer in another room that is either controlled by a program or by a person. The person in the first room is then asked to determine if there is a machine or a person in the other end by typing questions on the screen and watching the answers. No program has (to my knowledge) been able to consistently pass as human in such tests. A particularly elegant way of deciding the nature of the respondent that has been used is not to pose any questions at all. A computer will wait patiently for ever (if its programmer has not anticipated such a situation), whereas a human, after a fairly short while, will start asking if there is anybody out there, or if something is wrong.

intertwined that it is difficult to conceive of them as separate systems—which indeed, I believe to be wrong anyway.

To me, it is therefore impossible to escape the conclusion that this logic, these patterns of programmed action, must be regarded as an important part of the total system of actions that constitute an organization. Likewise, the process of program development must also be included, since it is there that the patterns of programmed action are determined and translated into executable logic. To underline the importance of this process and its vital role in the construction of both present and (especially) future organizations, we may even rename the program development process *program construction*.

The introduction of computer-based systems therefore creates a new level of sophistication and complexity in organization, and also a new level of abstraction, where actions are tied to symbols to a much higher degree than before and where the formalization of programmed patterns of action permeates much of the dialogues. The patterns of action that determine the structure and functioning of the organization are no longer only living patterns, created and carried out in real time by the organization members and the members of relevant parts of the environment. Programmed patterns, consciously designed, will increasingly influence the structure and functioning of the organization. They will do so directly, because important part of the organization's structure and functioning will be implemented in their programs, as well as indirectly, because the nature of these programs will strongly influence the live patterns created by the people who use them.

From Passive to Active Models

The discussions and conclusions from the four preceding chapters have one thing in common: They are all more or less task- or process-specific. That is, they are largely concerned with computer-based systems dealing with only a part of the organization's activities. This is mainly a consequence of the analytical approach I have chosen, building the analysis bottom-up from an analysis of the limitations of the unaided human and the way computer-based tools alleviate those limitations. However, it also reflects the development path for our use of information technology—starting with discrete applications exploiting the technology's most obvious properties for the automation of narrow sets of tasks, such as accounting and filing (record keeping in banking and insurance were among the first commercial applications for computers).

When applications expand beyond the single task or narrow set of tasks, we enter the next level of computer use, where focus is shifted toward larger groups of tasks or even whole processes. It is this second level that has produced most of the examples presented in the preceding chapters, and where most of the development efforts today are concentrated, at least in larger organizations. The first level, the discrete application, is now largely covered by a steadily increasing and improving supply of standard packages, some of which can be coupled together and extensively tailored to create more integrated systems. There is a clear trend in this direction in today's software development.

There is still much to do at this level—we are nowhere near exhausting the primary properties of computer-based systems and the basic, computer-dependent mechanisms for coordinating and directing work. However, as the use of information technology is both broadened and deepened and our theoretical sophistication grows, I believe we will see a development away from the (relatively) simple application of the basic coordinating mechanisms toward a third level: the construction of model-based organizations, where highly integrated suites of systems incorporate models of the organizations' problem domains—models that are sufficiently comprehensive to support a large part of the necessary coordination and direction of work. When such organizations become a reality, they will be constituted precisely through the almost seamless blend of patterns of live action and patterns of programmed action discussed earlier.

I argued in Chapter 7 that the explicit, conceptual model was the foundation of the modern organization. Whereas the patterns of action that constitute organizations just *emerged* within the traditional oral paradigm, they were to a much larger degree *consciously constructed* within the modern literate paradigm. The deliberate analysis and the conscious planning and design processes opened the organization and the work procedures to innovation and systematic improvement, starting it on a trajectory that differentiated it more and more from the familial-social-commercial continuum of organization that characterized preindustrial society.

At first, the introduction of computer-based systems seemed only to be a matter of continuing this process. However, as argued in the introduction to Part IV, such systems are totally different from any previous tool in that they represent rich, programmed patterns of action, which are closely integrated with living patterns of action, forming new hybrid structures. The programs are in turn a result of an analysis and design process much more detailed and deep-probing than any earlier, with the possible exception of the design of fully automatic mechanical machines—which also presuppose a detailed, complete, and unequivocal description of the tasks to be executed. But mechanical automation is necessarily so much more limited in scope that it really cannot be compared to computer-based systems.

In the construction of computer programs, the modeling process itself has become a conscious activity to a much larger degree than before. Although the Machine Bureaucracies of the literate paradigm were certainly consciously constructed, the designers were probably not aware that they were actually first working out a (however rudimentary) conceptual model to use as a blueprint. Today, we have taken another significant step forward, as detailed modeling has become a normal part of systems design—which means that it is also increasingly a prerequisite for organizational design, even though organization people have not yet looked seriously at the methods of systems design as a tool also for purely organizational development (which I think they should). There are now several well-developed methodologies available, as well as a good number of computer-based tools, and there is a clear development toward a closer and closer integration between analytical tools, modeling tools, and program development tools. Ideally, the model should be the main focus of program construction and maintenance, and the actual computer program code should be generated more or

less automatically by a combination of modeling tools and program development tools. Considerable resources are today dedicated to this end, in both the commercial and academic worlds.

Computer-based systems are therefore increasingly not only systems; they are also much more clear-cut representations of conceptual models than previous organization structures. We may in fact say that a computer-based system incorporates its own model while also representing that model's expression—or at least a part of the expression, since there will usually be human actors involved in a system-oriented dialogue (the exception is, of course, purely technical systems without organizational references). Even that dialogue, however, will be strongly constrained by the system's inherent model, which can only allow actions (accept input) that are defined within it. In addition to being descriptive, therefore, the model inherent in a computer-based system is not only a passive blueprint for design, it is also *active*, in the sense that it becomes a part of the ongoing patterns of actions constituting the organization. Its role in this web of actions is moreover not only receptive, but even directive, in that its reservoir of programmed actions can generate responses that guide or direct the actions of its human operators. Even the most humble computer-based system, then, involves modeling of a part of the organization's problem domain.

Take, for instance, Ford's accounts payable system described in Chapter 12. This system implicitly represents a model of the relationships between the functions of buying, receiving, and paying for goods; and it stores the information pertaining to those functions. In the model there are unequivocal definitions of what an order is, what a delivery confirmation is, what a payment is, and how they are related. When a shipment is received, information about it is no longer communicated to another clerk for processing—when keyed in on the terminal as a confirmation of a match with an outstanding order, the information is instead communicated to the *system* (and thereby to the model). According to the definitions built into the model, the system then automatically updates the inventory record and generates a payment transaction. In addition, everyone with access to the system can immediately see the status of that delivery if they need to and act accordingly.

As long as the systems are few and they only address narrow, isolated parts of the problem domain, the potential advantages of the single, computer-extended coordinating mechanisms will dominate. When systems multiply, their fields of operation will increasingly meet or even overlap, resulting in both a need and a wish to integrate their operations in order to reap the full benefits of systems use. In turn, this will necessitate a more comprehensive and unified conceptual model of a growing part of the organization's problem domain, a model that will be incorporated in the web of integrated systems. If this web of systems becomes sufficiently comprehensive, we will reach a situation where the major part of the operative actions (the interactions that are directly relevant for the organization's purposes) constituting the organization will be directed toward and through the computer-based systems, and not directly toward other humans. Somewhere around that point, we will cross a threshold: The main constituting part of the organization will be the integrated computer-based systems, their programmed patterns of action, and, implicitly, the conceptual model they are based on. The coordination of the organization members will be mediated mainly by the systems

and thereby (logically) by the model, not by direct human communication. Such an organization will not only be model based; it will be *model driven*, and the model, integrating several of the computer-dependent coordinating mechanisms, will constitute a supermechanism for coordinating organizations.

Early Examples

I believe that most organizations will reach this stage. Indeed, some organizations have already approached it, at least for part of their operations. Let us review a couple of the organizations discussed earlier with this new perspective as a guideline. Perhaps the most instructive example is the Boeing 777 case discussed in Chapter 13, since it involves the kind of model we are most familiar with: a model of a physical object.

The really interesting part of the Boeing example—and what makes it a prototype of model-driven organization—is that the CAD system the engineers worked with did not contain unrelated data or data sets, but a carefully defined *conceptual model* of the organization's main problem domain, the airplane. (The fact that the model could be visualized on a screen should not fool us into believing that it was in any way physical!) Each engineer at all times—and at his or her own discretion—had access to the fully updated (in real time) model of not only his or her own design, but of all the adjoining designs and indeed the model of the total construction (if so authorized). The evolving model also allowed project managers at all levels to follow the progress of work in real time.

If we believe the reports, the system had two main advantages: It eliminated large parts of the traditional project bureaucracy needed to handle drawings and the coordination of the efforts of the many designers and design groups, and it allowed for the integration of previously discrete steps in the design and engineering process. There is little doubt that this advance in coordination did not come from an improvement in direct interpersonal communication, but was rooted in the way the project members now communicated *indirectly but collectively* through their individual interactions with the evolving model of the aircraft. By changing the part of the model within his or her area of responsibility, the designer would *automatically* communicate that change to all the other designers, who could, in turn, respond directly to the change if it had consequences for their own work. And, when project groups had to meet (which they still had to do) to decide upon design parameters or questions related to physical production, they had the advantage of having a common, unequivocal, and updated conceptual model as a basis for their discussions.

Now, the nature and advantages of models are fairly easy to understand as long as we stick to the design of physical objects such as airplanes. Can we imagine administrative models of this kind?

Let us return to the airline booking system: We can now reinterpret it as a model of a quite interesting nature. Seemingly, it represents just another collection of aircraft models—much simpler than the Boeing 777 model, of course, but still aircraft models. In this problem domain, which concerns the sale and administration of airplane passenger capacity, only relatively few of the airplanes' properties are of any interest—mainly their number of seats, their seating arrangements, their speed, and their range.

However, the booking system does not exist to model individual, physical airplanes, but to model flights—that is, particular airplanes flying particular runs at particular times. The same physical airplane will therefore appear a large number of times in the database, each time associated with a different set of departure and destination points and departure and arrival times (maybe also with different seating arrangements, if they are modified between flights—which they sometimes are). Because locations and points in time are represented in the model, the system is even capable of modeling something much more complex—namely, the full web of all the flights present in the database, with all the possibilities they offer for interconnections and transfers to cover routes not served by direct flights. This is the part of the model that the travel agent and the passenger see and care about. To the airlines, there are other aspects of it as well—for instance requirements for crews, catering, and fuel.

For the purpose of seat reservation, then, and even for a number of the airlines' administrative tasks, the chief instrument for coordination is the system and thereby its inherent model of that particular problem domain. For seat reservation, the system is in fact the *only* coordination instrument. We can therefore say that seat reservation is an example of an activity that is 100% model driven. True, the users of this system do not constitute a traditional organization, but there seems to be no fundamental reason why "proper organizations" should not be able to base the full weight of their coordination needs on active models in the same way. It will perhaps not be possible for all organizations, due to the nature of their problem domains, but in many instances I believe it will mainly be a question of learning how to model and handle really complex domains.

Another interesting example, which we have already discussed at some length in Chapter 14, is the cookie shop operation of Mrs. Fields. The system called the Daily Planner was meant to incorporate as much of Debbie Fields' own experience, selling techniques, and management principles as possible, in order to enable inexperienced shop managers to run a shop like a professional (and to keep him or her within the style of operations that Debbie Fields preferred). The system would generate directions to the shop manager based on a number of parameters and an internal repository of rules.

We can now easily see that the people who made the system did in fact create a fairly complete model of the cookie shop's problem domain, and constructed a program that expressed that model quite effectively: For the shop managers, it must have been almost as if Debbie Fields were standing right next to them throughout the day. To the Mrs. Fields organization as a whole, it meant that supervision was by and large effected through this system and the model it represented, and to implement changes in policy or in product mix would first and foremost be a matter of changing the system (and thereby the model).

I do not have information about the flexibility of the system—if it was able to adapt to local patterns of demand, for instance—but such flexibility is certainly possible in principle: A general model can be built to adapt itself through accumulation of local data (e.g., sales patterns), and thus adjust to some extent to different local mixes of contingency factors. However, the adaptation can never exceed the limits set by the definitions in the original model. If, for example, the ethnic mix of the neighborhood is not defined as a parameter in the model, it

cannot be used for local adaptation, unless the local operators are authorized to modify the model itself.

A Typology of Models

If we look at these examples, the models show clear differences in both design and operation. The differences arise from their differences in purpose and are manifested through their combinations of the basic properties of computer-based systems. Can we discern some main types? The answer is a cautious “yes”—there are indeed clearly distinguishable types of models, but we encounter the same problem as with Mintzberg’s (1979) coordinating mechanisms and their corresponding organization types: Organizations in real life seldom represent pure forms. However, if we reconcile ourselves with the fact that our concepts, theories, and models can never represent or explain the full richness of real social phenomena, we can nevertheless appreciate how apt archetypes can help us see and understand important, often decisive, aspects of reality. Even if their explanatory power is limited, they can nevertheless be of great help and make it possible for us to analyze problems more accurately and to design more functional organizations.

I propose three basic kinds of models, each based on a combination of computer-dependent coordinating mechanisms, and each representing a main direction in the computer-based enlargement of the space of constructible organizations. They are the *regulating model*, the *mediating model* and the *assisting model*. For an informal characterization, we may nickname them respectively the “boss model,” the “peer model” and the “sage model.”

The Regulating Model

As its name implies, the purpose of the regulating model is to direct and control the activities in an organization. Regulating models often incorporate extensive automation, and the organizations that have come closest to being driven by regulating models today are probably the most advanced manufacturing organizations, for example, a number of process industries and automobile manufacturers. Perhaps the properties of regulating models are most visible in operations such as the Nissan factory in Sunderland, briefly described in Chapter 12: The production control system there manages virtually all aspects of the assembly process, including the timing of deliveries from the key suppliers located around the perimeter of the factory premises. Actually, we may well view the combined production control systems of both the Nissan factory and its suppliers as one supersystem, based on a master model, driving the operations of the combined organizations.

The model behind the Daily Planner of Mrs. Fields is also an example of a regulating model—it both directs the work of the personnel in every shop *and* controls their performance—but it is different from the Nissan model in one key aspect: It does not include the lock-step coordination of a production process with numerous interdependent steps. In the Mrs. Fields organization the shops are independent from each other, and have no need to coordinate their actions the way the different stations on an assembly line must. The coordination here is first and foremost a matter of regimentation—of securing a scrupulous and uniform

execution of company directives. We may therefore say that there are two kinds of regulating models: a *linked* model, driving organizations where tasks are *interdependent*, and an *atomistic* model, driving organizations where they are *independent*.

The regulating model depends mainly on system-supported supervision, programmed routines, and hyperautomation, but it also often incorporates implicit coordination. If we look at the completed taxonomy of coordinating mechanisms in Figure 15-1 (page 384), this should indicate that regulating models imply a combination of Mintzberg's direct supervision and standardization of work—in other words, a merger of real-time and programmed coordination. This is exactly what I believe the development of sophisticated and comprehensive regulating models will tend to do. The richness, interactivity, and computational capacity of computer-based systems will allow us to blend the two modes in a way not previously possible, and thus allow us to construct organizations that are large, extremely efficient, agile, and very flexible. In the extreme case, regulating models may allow what we have termed a *joystick organization*: an organization where large parts of the activities are either automated or directed by the systems, but where key parameters and activities are controlled and carried out in real time by the management.

The flexibility of an organization driven by a regulating model cannot, of course, transcend the limits of the model, since all allowable actions and action alternatives must be predefined and incorporated in it. Regulating models are only possible to use when tasks, their execution, and their interrelations can be defined in necessary detail beforehand. This is a tough demand, but not impossible—it has also been a prerequisite for mechanical automation, for much factory work, and for large parts of the work carried out in earlier white collar bureaucracies such as banks and insurance companies. And, since computer-based systems can accommodate much richer models and provide much better worker support than was previously possible, the prospects for building strongly regulated organizations are now greatly improved and will continue to improve in the future.

The Mediating Model

There is, however, work that is too complex and with circumstances too dynamic for tasks and outcomes to be defined beforehand—or even work that involves designing new products or processes, essentially creative work where the process steps can be known, but not their content. This is the kind of work where organizations are drawn toward the configuration Mintzberg calls an Adhocracy, and where coordination must rely on mutual adjustment or an adaptation of it. When efficiency cannot be sought primarily through pre-planning and programming, the goal must be to achieve the best possible exchange of information and ideas, to speed the process of mutual adjustment, and to ensure that conflicts are resolved and agreements reached with a minimum of effort.

This may sound like a cry for groupware—but it is not. That does not mean that the kind of systems gathered today under the banner “groupware” do not have a mission, or will not be part of systems built on a mediating model—it means only that direct human-to-human communication is very time-consuming, often inexact, and very often directed toward a set of people that includes many

who do not need the information and omit a few who actually do. We will be much better helped if we can let the systems do as much work as possible on their own, as well as help us make our own communication more precise and directed toward *only* those who need it and only *when* they need it.

An organization driven by a mediating model, then, is much more than an organization consisting of teams communicating via computer networks, accessing common information bases, and coauthoring electronic documents. If we say that an organization is model driven, the model and the suite of systems built on it must incorporate so much of the organization's functionality and dynamics that the organization members will work and communicate mainly with the system and thus the model itself, and not with particular people. This only pertains to task-related communication, not social exchanges.

The situation can be pictured as a group of people playing a board game: They may chat and joke, but their effective contributions toward their common goal (to have fun by finishing the game) and their effective, game-relevant communication with each other is made solely through their separate, individual interaction with the board and the game's rules (which are reflections of the game model). The consequences they suffer are partly a result of the vagaries of the rules, and partly of the other players' moves (their contributions). Any player's options at any point in time are a result of the rules (the model) and the accumulated results of all the players' previous moves; all players have a full view of the situation at any time; and the information available is always current.

The CAD model that was the centerpiece of the Boeing 777 design project is an example of such a model: The CAD system was the main tool both for the people working at the design and for those doing the preparations for manufacturing. The resulting structural model of the aircraft, which resided in the system's database, then functioned as the project's prime communication medium. The way it functioned is instructive: Changes were primarily *not* communicated directly to those concerned and those who might possibly be concerned; they were simply entered into the system (model). Those who *were* concerned could then extract that part of the information they needed when they needed it. Just as importantly, the information was not entered into the system in separate, dedicated operations, it was in fact *created* there as a part of the normal work process, as the designers and others used the system as a tool for their day-to-day work. Creation and communication were thus merged into one process, ensuring that the database always contained the latest version of everybody's contribution. When meetings were necessary to decide on design parameters or other problems, all the participants could therefore draw their basic information from the same coherent source. Moreover, the CAD system itself could eliminate a lot of work by automatically finding and exposing problems such as spatial conflicts, as well as helping to quickly resolve questions where the system contained the pertinent information. The system thus provided the main tools for work, structured the communication by acting as medium, made the communication a lot more precise because of its criteria for information entry and information creation, and made the communication process much more selective by eliminating most of the communication that takes place "just to be on the safe side."

The models behind the organizational clouds described in Chapter 13 are also mediating models. They may seem to be regulating, in the sense that the systems

only allow certain actions and also contain inviolable rules on how transactions are to be effected, but the essence of systems such as trading systems and reservation systems is not to direct and control the actions of the users, as it is in production control systems such as Nissan's or Mrs. Fields'. Their purpose is to ensure that all the users have access to the same status information at any time, and that this status information *always* (in real time) reflects the accumulated sum of all the users' system-relevant actions. In this way the users' actions can be perfectly coordinated by mutual adjustment without a single direct user-to-user message. The users only have to access the information that is *immediately* relevant for their own purposes and can safely ignore the rest.

The mediating model depends mainly on implicit coordination and programmed routines, but it may also contain aspects of system-supported skills to support professional work. The model's revolutionary aspect is that it makes *true mutual adjustment* a real alternative in much larger organizational settings than before. With earlier technology, mutual adjustment in organizations of more than a handful of people was only possible through representative and consultative schemes, which often generated a lot of overhead—as in the project bureaucracies of large design projects, with their innumerable drawings and time-consuming modification procedures. Comprehensive mediating models will effectively remove the theoretical upper limit for true mutual adjustment. The model requirements will be no less stringent than for regulating models, however—the problem domain must be accurately and sufficiently described, and all relevant relations between the significant items in the domain must be mapped. This is a very demanding task, but I believe we will gradually develop the necessary skill, methods, and tools to tackle it in an increasing number of instances.

The Assisting Model

There are tasks and organizations that do not belong to either of the two kinds described thus far—organizations where the “product” is professional judgment, and where there is little interdependence between tasks other than a need to conform to professional quality standards. Those standards will moreover typically be products of independent professional communities, rather than intra-organizational authorities. Examples of such organizations are universities, courts of justice, investment analysts, law firms, and consulting firms with mainly senior personnel (consulting firms where a lot of juniors do most of the work according to centrally produced methodologies are more akin to the Mrs. Fields operation²). Even organizations processing mainly nonstandard cases—such as government departments and other political and nonpolitical staff organizations—may belong to this class.

Such organizations have limited needs for coordination in the sense that there is little interdependence between tasks. Their main goal is most often to secure

² This is not intended as a derogatory remark. Everyone with some experience in this business knows that there are, by necessity, two kinds of consulting: the nonstandardized, “every case is unique” type, which requires experienced consultants who can craft a suitable approach in each case, and the standardized, volume type, where fairly rigid methods are necessary to produce consistent results with less experienced personnel.

high professional standards and efficiency in work. Often, an important aspect will be to produce outcomes that are as correct as possible according to professional standards and as uniform as possible for comparable cases. The model (and the systems) will therefore mainly aim at a best possible support for the professional staff and their work, giving them easy access to both task-specific and general information, professional standards as well as precedents.

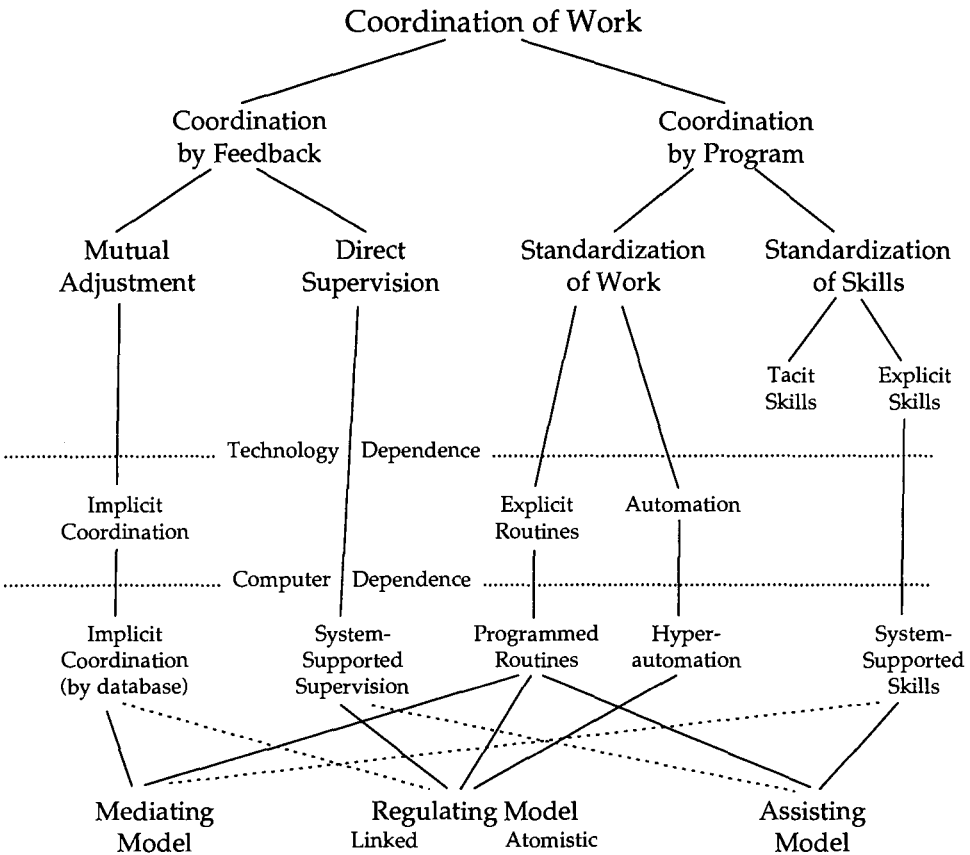


Figure 15-1: Taxonomy of coordinating mechanisms extended by the use of information technology (complete)

The assisting model may seem to resemble the atomistic regulating model in the sense that both aim to produce consistent outcomes. The crucial difference is that the regulating model incorporates a "correct" behavior and a number of "correct" action alternatives drawn up by the organization's technostructure and sanctioned by management. Its aim is to lead (and goad) often inexperienced employees toward the "correct" organization behavior. The assisting model, on the other hand, aims at supplying experienced professional employees with a tool that allows them to exercise their professional judgment in the best possible way.

If the model is limited to this, however, it is debatable whether it is able to drive an organization at all in the way the other two models can. To be complete, it must include the relatively modest coordination and control functions even such knowledge organizations have. An assisting model will therefore depend on both system-supported skills as well as programmed routines. Sometimes, there will also be a small dose of system-supported supervision—since one of the main concerns of management in such organizations often to ensure that cases are processed in due time and that inquiries and requests receive prompt answers.

The assisting model does not, in my view, offer the potential for change and increase in productivity that the two other models do, since there are definite limits to the degree that this kind of work can be automated, eliminated, or radically changed. As noted in Chapter 11, “soft” knowledge is generally not possible to incorporate in systems, and wherever individual human judgment and experience are central, computer-based systems will have limited impact.

Some Requirements for Model-Driven Organizations

Model Precision

The decisive factor for the feasibility of a model-driven organization is of course that the model and the systems that build on it represent the organization’s problem domain in a sufficiently detailed and correct way. This includes the requirement that the model is unambiguous and that the information contained in the systems has the necessary precision. The need for such a high degree of formalization may seem to be contradicted by the use of computers to achieve goals such as flexible automation (allowing a large number of variants that can be produced without retooling) or free-text searches in large text bases, but this is a deceptive and superficial impression. Behind the apparently effortless flexibility of advanced systems one will find extremely detailed and time-consuming analysis and design processes, where all the options and functions have been defined and described with utter precision. Actually, the development effort needed for really large and complex systems is often counted not in man-years, but in man-centuries.

The higher the precision is, then, both in data and in the definition of their relationships, the better the prospects for eliminating or automating both work and coordination. When the precision degrades, so does the usefulness of the model. There is, for instance, a definite threshold of precision below which the model of the Boeing 777 would be largely useless, because measurements would not be within the necessary tolerances.

The same can be said about booking systems: If departure and arrival times could only be specified to the nearest half hour, or if there was an error margin of plus or minus 10% on the number of seats, its value as a coordinative tool would be destroyed. This effect can be observed from time to time in the real world, when delays due to bad weather, industrial actions, or heavy traffic forces reality out of synch with the plan-based model. The results are missed connections, empty seats and queues of angry passengers.

We can also easily see that Ford's accounts payable system would be less than perfect if deliveries were not registered, incomplete deliveries were recorded as complete, or vice versa—or if the system did not specify the exact amount of money to be paid when goods were received and accepted.

Clearly, then, building such models is easiest when the relevant information is quantitative or possible to assign to clear categories (which do not overlap)—that is, when the information can be put into structured databases, and where unambiguous relationships can be defined between data elements. However, especially for models exploiting system-supported skills, considerable effects can also be achieved with information in less structured forms, such as text and pictures. For these purposes, the concept of hypertext may prove very valuable and allow more extensive use of unstructured data than existing tools do.

Skill and Effort

In her book *In the Age of the Smart Machine* (1988), Shoshana Zuboff says that automation “has made it possible to rationalize work while decreasing the dependence on human skills.” In one sense, this is correct. Automation—and indeed the narrow specialization that formed the basis for the tremendous productivity increase during industrialization—did in general reduce the skill level needed at the factory floor, with the notable exception of some advanced machine tools and other instances of machinery demanding fairly sophisticated knowledge on the part of the operators (often of a quite theoretical nature).

However, her assertion becomes too narrow by relying only on a “local” interpretation of skill—that is, only looking at the concrete (and presumably lost) skill of a worker who is replaced by machinery of some kind. In my view, one must look at the total set of skills required for a certain production process. Both automation and industrialization have sharply increased the need for skills in analysis, planning, and engineering. The construction of model-driven organizations will raise the skill threshold further and also place new demands on organization members.

In a craft operation, production more or less manages itself: Craftspeople normally do not need detailed directions. However, as we noted in Chapter 7; when one relies on specialization, the use of complex machinery, and even automation, everything has to be analyzed and described in detail, and the work process itself must be carefully designed. Industrialization and sophisticated automation, then, presuppose advanced skills both at the company level and in the society as a whole. It was therefore no coincidence that the nations that led in science, literacy, and general education were also the leaders in industrial development. Over time, specialized personnel is required on a permanent basis to take care of these tasks (forming the technostructure), since the need becomes constant—any change requires analysis and design at the same level as the original installation, and changes are always necessary, since no environment is completely static.

This is even more true in the era of information technology. First, the technology itself is extremely complex and continues to balance on the leading edge of engineering knowledge. Indirectly, it is even heavily dependent on advanced basic research in physics, materials, and mathematics. Second, the use of

information technology in an organization presupposes extensive knowledge not only of the technology itself and of the target processes or tasks, but of how to analyze and model those tasks. To develop more comprehensive systems and successfully implement them in the organization, organization theory and work psychology become important as well.

When we approach the model-driven organization, the demands grow further. As work is increasingly informed, and more and more routine tasks are either automated or eliminated, the remaining work will to a large degree be conducted onscreen. It will require a fairly advanced ability to think abstractly, understand symbols, and work through symbol manipulation. We will need an advance in skills—at least in total, often at all or most levels in the organization. The new skills are indeed different from the old, and almost always of a more abstract nature, but they are not less demanding. They often necessitate quite sophisticated theoretical knowledge.

The parallel with industrialization also extends to the increasing need for a professional technostructure. As noted in Chapter 12, computer-based systems always require a higher degree of formalization and standardization than manual procedures, which again presupposes a detailed analysis of the relevant tasks and an understanding of how they relate to each other—an undertaking that can be very demanding in itself. Then the new combination of system and tasks must be designed, preferably in such a way that the most powerful aspects of the technology are exploited. This is no mean task, either (as learned at Ford). To build models and system suites for the model-driven organization only raises the demands further. And, just as before, any subsequent change in the organization or the way it works means changing the model as well as the systems, requiring planning and analysis on the same level as the original effort—making the need for a competent technostructure a permanent one in every organization of some size that uses computer-based systems for more than simple tool substitution.

In fact, since the use of computer-based systems requires significantly more work on analysis, planning, and system construction than previous technologies, and the use of such systems automate or eliminate large numbers of jobs, the size and importance of the technostructure must increase in both relative and absolute terms as computer use expands. However, just as during industrialization, the increased efforts and resources that go into analysis, planning, and systems construction will pay off handsomely—if the process is soundly managed. In computer-intensive industries, therefore, competitiveness will increasingly hinge on the competence of the technostructure and on its ability to combine systems competence with knowledge about organizational structuring and development. Top managers for this new combination (the title, if drawn from a constructivist vocabulary, should probably be *pattern manager*, but I suspect that something like *organization design manager* will sound more attractive) should find themselves as sought after as top CEOs, and top professionals in the field should become the brightest stars on the professional firmament in the first half of the next century. Correspondingly, CEOs without understanding of computer-based systems and the way they interact with the organization will find themselves on an increasingly overgrown sidetrack.

16 The New Organizations

“Life is a petty thing unless it is moved by the indomitable urge to extend its boundaries. Only in proportion as we are desirous of living more do we really live.”

José Ortega y Gasset, *The Dehumanization of Art*, 1925

The Evolution of Mintzberg’s Configurations

In Chapter 3, I concluded—mainly inspired by Mintzberg (1979) and Galbraith (1977)—that coordination is the linchpin of organization. In most of my subsequent discussions and analyses, I have therefore concentrated on the evolvement of coordinating mechanisms, especially how technological innovations affect existing mechanisms and allow new ones to emerge. These changes are the main enablers behind the appearance of new types of organizations, whether they are genuinely new types or just represent variations or extensions of old ones. Therefore, they also serve as the main avenues for extending the space of constructible organizations.

Part IV outlined what I see as the significant computer-dependent coordinating mechanisms, based on the previous analyses of how computer-based systems enhance our capabilities for work, communication and information storage and retrieval. I discussed their potential for extending the space of constructible organizations, using both actual and imagined examples. Although I hinted at possible new organizational configurations, the discussions were focused on the separate coordinating mechanisms and their individual potentials.

In Chapter 15, I also evoked a more integrative perspective by arguing that the implementation of models in computer-based systems for the first time makes it possible to work with *active* models rather than passive, turning models into a kind of supermechanism for coordination. Models are no longer paper-bound descriptions used as passive blueprints for design; they are embodied by computer-based patterns of programmed actions, and thereby become part of the total sum of the patterns of actions that define the structure and functioning of an organization. When an organization model becomes sufficiently comprehensive and sophisticated and is implemented through a sufficiently integrated system suite covering the essential parts of an organization’s problem domain, the active model will begin to govern and drive the organization’s most significant patterns

of actions. What I have termed a *model-driven organization* will then emerge—a new and revolutionary phenomenon in the organizational world, which will become increasingly dominant in the realm of medium-to-large organizations in the coming decades.

However, the picture painted so far is still somewhat fragmented, and it would be advantageous to arrive at a more consolidated view, as Mintzberg (1979) does with his *structural configurations*: “natural clusters” (1979, p. 302) of the elements of his study (the coordinating mechanisms, the design parameters, and the contingency factors) that seem to capture the salient features of most organizations into five broad classes (see Table 3.2, page 58). We may ask, can Mintzberg’s configurations be modified in any way in the computer age, and can we see altogether new configurations on the horizon?

An interesting aspect of this analysis is Mintzberg’s (1979) proposition that we will find in each configuration a dominant pull on the organization, indicating the direction in which the organizational structure will develop if it is not checked by environmental factors or control problems. If the concept of pulls is correct and the pulls are correctly described, we may learn a lot by looking at if and how computer-based systems will change the barriers for how far an organization may be pulled in the desired direction.

In this chapter, I shall first discuss the impact of information technology on each of Mintzberg’s original configurations, and assess their potential for modification. I will then propose two new configurations, the *Meta-Organization* and the *Organized Cloud*.

Empowering the Simple Structure

I suggested in Chapter 5 that we could regard the Simple Structure and the Adhocracy as the two fundamental organizational configurations of the human race, since they represent the two basic ways of coordinating work. The Simple Structure is perhaps the simplest of all the configurations, at least when we talk about organizations larger than the handful of people who are able to communicate freely all to all. To use Mintzberg’s own words (1979, p. 306, bold type in original),

The Simple Structure is characterized, above all, by what it is not—elaborated. Typically, it has little or no technostructure, few support staffers, a loose division of labor, minimal differentiation among its units, and a small managerial hierarchy. Little of its behavior is formalized, and it makes minimal use of planning, training and the liaison devices. It is, above all, organic. In a sense, Simple Structure is nonstructure: it avoids using all the formal devices of structure, and it minimizes its dependence on staff specialists. The latter are typically hired on contract when needed, rather than encompassed permanently within the organization.

Coordination in the Simple Structure is effected largely by direct supervision. Specifically, power over all important decisions tends to be centralized in the hands of the chief executive officer. Thus, the strategic apex emerges as the key part of the structure; indeed, the structure often consists of little more than a one-man strategic apex and an organic operating core.

The typical Simple Structure is the start-up, the small entrepreneurial firm owned and managed by the founder, but even larger organizations can be dominated by strong and charismatic leaders. This is quite common in less developed countries, which are more dominated by the traditions of oral culture, and where the literate forms of organization have correspondingly less appeal. In the European/American sphere, it probably had its heyday with the great American trusts in the late nineteenth century (Mintzberg 1979). Sometimes, organizations with other configurations will temporarily take on some of the characteristics of the Simple Structure if a serious crisis renders their more elaborate decision-making schemes inadequate. However, both in the latter case and in the case of the great American trusts, we may question the purity of the configurations—if an organization is very large, it will be impossible even for an extreme autocrat to have that kind of direct, personal control over day-to-day operations that is the hallmark of the Simple Structure. Such an organization will therefore have strong bureaucratic features, but people will tend to look more toward the top manager's apparent preferences than to written rules, and the top manager will feel (and be!) completely free to intervene in any matter or decision anywhere in the organization.

In the classic Simple Structure the defining feature is that control over day-to-day affairs is extremely centralized, most often in the hands of one person. The predominant force pulling on such an organization is the *pull of the strategic apex to centralize* (Mintzberg 1979)—to use direct supervision as far as possible, and without any delegation. We find this very poignantly expressed by Debbie Fields (Mrs. Fields cookie shops) in the statement quoted on page 358, where she concedes being “forced, kicking and screaming, to delegate authority, because it was the only way the business could grow.” This statement, by the way, also serves to substantiate an assumption that underlies Mintzberg's arguments though it is not made explicit, namely, that growth is always a paramount objective—for entrepreneurs and administrators alike—and that the desire for growth in most cases is even stronger than the desire for control.

In the conflict between their wishes for control and growth, the entrepreneurial managers of growing firms typically agonize over the delegation of power to a layer of middle management. The reason is not only that he or she dislikes the fact that they will be separated from the direct contact with the people in the operating core. As they see it, the problem is that the associated growth most often also means an increased reliance on the more efficient standardization of work as a coordinating mechanism. In turn, this means that more power is relinquished, in this case to the professionals in the technostructure who design and maintain the standardized work rules.

To Simple Structure managers, the most appealing aspects of the technology will therefore be those that improve control and eliminate work, so that the size of the organization can be kept down and direct control can be retained. I believe they will be pleasantly surprised by the potential if they can rise above their natural distrust of professional experts—because, if they really want to exploit the new possibilities offered by information technology, they will also have to accept the need for a competent technostructure to build and maintain the new systems.

In order to increase control, the manager of the Simple Structure will of course want to exploit system-supported supervision, which is the computer-dependent

version of direct supervision. This alone should make it possible to extend the size of a genuine Simple Structure considerably. Further, the use of programmed routines with a strongly regulating content will make it possible to direct the actions of employees to a much larger extent and to a much greater detail than before. Insofar as the top manager can supervise the content of these routines directly, the use of this coordinating mechanism may give greater sense of control than traditional written routines. This will especially be the case if the systems allow fairly easy adjustments of rules and/or parameters. Such systems may therefore also allow Simple Structures to grow larger without becoming full-fledged Machine Bureaucracies. However, there is a threshold here where control will cease to come directly from the hands of the top manager and pass into a process of rule standardization where the decisive influence is wielded by a larger set of people. The organization structure will then topple over and become a variant of the computer-supported Machine Bureaucracy discussed in the next section.

Finally, extensive hyperautomation and elimination of work can allow extensive reductions in the number of employees in an organization, while keeping up or even increasing its economic size. This may allow Simple Structures to expand further into the territory of mass-producing Machine Bureaucracies than before. However, since the Simple Structure cannot easily accommodate really large organizations, such an expansion would probably at some point lead to either stagnation or a transition to a computer-supported bureaucratic form.

It is of course also possible that the greatly increased flexibility offered by computer-based automation can be harnessed to lower the production costs of small batches or even semi-tailor-made products to a level where they can compete directly with the products of traditional mass-producing Machine Bureaucracies. In such a case, a multitude of small Simple Structures may develop and effectively replace formerly dominant mass-producers. This would be in line with the ideas of flexible specialization on the basis of craft traditions put forward by Piore and Sabel (1984). As they point out, such developments have taken place before, although on a different basis. In particular, they point to the developments in the textile industry in Italy's Prato area in the 1930s and 1950s.

To exploit computer-based systems to extend operations without relinquishing control, the manager of the Simple Structure will have to learn quite a lot about the technology and the systems in use in the organization, since he or she will have to use the systems themselves in order to achieve the control they want. They will also have to learn to work closely with the computer professionals in their new technostructure. In fact, a significant part of their control efforts will have to be channeled into the supervision of systems construction and maintenance.

In short, I believe that computer-based systems have enlarged the space of constructible organizations considerably in the direction of allowing increased size and economic clout for organizations configured as Simple Structures. Technology-conscious entrepreneurs and autocrats should therefore have the opportunity to invigorate this configuration and perhaps even increase its importance relative to other configurations. In organizations that have grown too large for the pure configuration, it should be possible—at least in a number of instances—to revert back to a more clean-cut situation through significant workforce reductions coupled with computer-supported supervision.

Does this mean that the configuration itself is modified, or is it only a matter of an electronic invigoration of the traditional Simple Structure? I think there is a continuum building here that will eventually pass the threshold to a qualitatively new configuration.

Even moderate use of computer-based systems will allow a Simple Structure to outgrow the limits of its pre-computer forebears without changing very much in principle. However, as system use develops and covers larger and larger parts of the operations, things begin to change: Control is increasingly effected through the systems, and a growing part of the top manager's time is devoted not to supervision in the form of face-to-face contact, but to systems design, parameter setting, and system-supported supervision. With maximum exploitation of the technology, the result should approach the organization described in the thought experiment with Ceramico at the end of Chapter 14.

Emergence of the Joystick Organization

At this point, I think the threshold has definitely been crossed, and a new, computer-based configuration has emerged. I think this new breed needs a name of its own. I propose to keep the name suggested in the discussion of the hypothetical Ceramico example, and will thus call this computer-dependent version of the Simple Structure the *Joystick Organization*.

It will definitely be model driven and rely on a regulating model with a clear emphasis on information aggregation (system-supported supervision) and easy manipulation of key parameters in the controlling systems (programmed routines). There will often be extensive automation in the operating core, even to the point of organizational truncation. The top manager will run the organization mainly through interaction with the systems, not with people—other than a few close assistants. The Joystick Organization will continue to cherish the centralization of the Simple Structure and will keep its forebear's organic structure and low degree of specialization and formalization. It will thrive in the same environments (simple and dynamic), but it may grow larger than the Simple Structure, at least in economic size.

Contrary to the Simple Structure, however, the new configuration will have a significant technostructure, since it will need a sophisticated IS department to take care of (and often develop) the extensive systems needed for its daily operations. The head of this department will be one of the top manager's closest collaborators.

Some readers may protest that such a revival of a modernized Simple Structure flies in the face of the common prophecy that information technology will first and foremost promote flatter organizations and a greater reliance on teams, cooperation, and devolvement of power. My answer to this is that the technology does not in itself promote any particular arrangement; it is an enabler that opens up possibilities in a number of directions—just like earlier technology. Within the constructible space available to them (the local space, which is the constructible space restricted by local contingency factors), individual actors will exploit the technology in the direction they prefer. People who favor cooperation and devolvement will seek out features supporting teamwork and decentralized decision making; people who want control will move in the opposite direction.

As an illustration, we may note that while Marshall McLuhan was writing about the democratizing effects of the telephone in the corporation ("On the

telephone only the authority of knowledge will work.”¹), Harold Geneen was reputed to use the telephone as one of his prime instruments of control at ITT (some would even say instrument of terror!). To keep his subordinates on their toes, he would telephone them at any time, day or night, demanding rapid answers to questions about their operations (Schoenberg 1985).

Perfecting the Machine Bureaucracy

The Machine Bureaucracy is the epitome of the modern organization—indeed, many organization theorists just call this structural configuration the Modern Organization. Its defining feature is its use of standardization of work processes as its main coordinating mechanism. It achieves its efficiency through mass-production of goods or services in a highly rationalized operating core. The degree of formalization in the organization is high, and most tasks are highly specialized. Since the operating core of the Machine Bureaucracy can only achieve its impressive productivity through continuous production at a high rate of facility utilization, and since changes in the production setup are costly and time-consuming, it craves a high degree of stability in its environment. Often, it tries to influence its environment both directly and indirectly to increase stability.

To manage the normally quite complex organization and maintain its operating core, the Machine Bureaucracy has both an elaborate administrative structure and a well-developed technostructure. In fact, Mintzberg (1979) points to the technostructure as the key part of the organization, even if the formal power resides in the line managers (Mintzberg 1979, pp. 316–17, bold type and italics in original):

Because the Machine Bureaucracy depends primarily on the standardization of its operating work processes for coordination, the technostructure—which houses the analysts who do the standardizing—emerges as the key part of the structure. This is so despite the fact that the Machine Bureaucracy sharply distinguishes between line and staff. To the line managers is delegated the formal authority for the operating units; the technocratic staff—officially at least—merely advises. But without standardizers—the cadre of work study analysts, job description designers, schedulers, quality control engineers, planners, budgeters, MIS designers, accountants, operations researchers, and many, many more—the structure simply could not function. Hence, despite the lack of formal authority, considerable informal power rests with the analysts of the technostructure—those who standardize *everyone else's* work.

Typical Machine Bureaucracies are well-established, large organizations such as banks, insurance companies, automobile companies, airlines, and government services (e.g., the Customs Service or Social Security). Even the police and the armed forces are usually configured as Machine Bureaucracies. Because it is first and foremost a configuration for mass production, the Machine Bureaucracy is optimized for efficiency within a quite narrow domain, and it cannot easily adapt itself to another. It is definitely not able to live with very dynamic or very complex environments. However, its efficiency in producing standardized goods and services is so superior that it has become the dominant structural configuration for

¹ Marshall McLuhan, *Understanding Media*, New American Library, New York, 1964. Quoted in Pool 1983.

larger organizations in all modern societies. The overwhelming majority of us seem, in most instances, to prefer these standardized, cheap products to the more tailor-made (but also more expensive) products we could have had from enterprises with other configurations.

According to Mintzberg (1979), the main pull on a Machine Bureaucracy is the pull of the technostructure to standardize—that is, to increase and refine the use of standardization of work processes as the organization's coordinating mechanism. This reflects the inclination and training of the technostructure and also serves to strengthen its power in the organization.

An elaboration of the standardization of work is indeed one of the main avenues that information technology opens up, and unchecked technostructures thus have ample opportunities to engage in their favorite pursuit. However, dependent on the nature of the organization's operating core and the skills and vision of its technostructure, several scenarios are possible. The most important are staying within the paradigm, truncation through automation or self-service, and flexibilization.

The dominant approach today is to stay within the traditional paradigm, using information technology mainly in a reinforcing way—that is, to make existing procedures more efficient. Programmed routines are gradually substituted for explicit routines, there is incremental automation of routine tasks, and management uses information available in the systems to improve its control over the organization and its operations. Even what are regarded as state-of-the-art improvements do not necessarily bring a Machine Bureaucracy out of the traditional mold—groupware, workflow tools and even business process reengineering (BPR) can well be applied within the traditional paradigm. For example, the reengineering of Ford's accounts payable function did not change Ford into a nonbureaucratic organization. It is even doubtful whether the accounts payable function itself became less bureaucratic through its reengineering. It can be argued that by shifting the handling of payments over to a set of programmed routines, the task rather became *more* strictly standardized than before, and the company's relationship with its suppliers *less* flexible. Instead of receiving the shipments as they came and sorting out any problems afterward, all deviations from the agreed delivery schedules were now immediately detected and triggered the same, standardized response: a rejection of the whole shipment and a demand for a corrected one. However, the change also entailed that the internal coordination in Ford improved dramatically and that the company's relationship with its suppliers became far better coordinated and much more closely controlled, since the new system allowed the control to take place in real time, and not after the fact. This is how the benefits accrue within the traditional paradigm: through increased and improved control and regulation.

Of course, if the process of automation and elimination is carried far enough, most or even all of the operating core may become automated, effectively truncating the organization as in the process industries described by Zuboff (1988) and discussed in Chapter 12. According to Mintzberg, the configuration then changes to a variant of the Adhocracy (Mintzberg 1979, p. 458, italics in original):

The problem of motivating uninterested operators disappears, and with it goes the control mentality that permeates the Machine Bureaucracy; the distinction

between line and staff blurs (machines being indifferent as to who turns their knobs), which leads to another important reduction in conflict; the technostructure loses its influence, since control is built into the machinery by its designers rather than imposed on workers by the rules and standards of the analysts. Overall, the administrative structure becomes more decentralized and organic, emerging as the type we call the *automated adhocracy*.

However, there is an important difference between the traditional automation Mintzberg refers to and the computer-based hyperautomation that is our subject of interest: Design and control are not laid down once and for all before installation of the machinery. The reason is simply that computer-based systems are so much more complex than mechanical systems—they allow much more sophisticated and flexible automation. They may also allow a truncation by a combination of hyperautomation and increased self-service, which is what we will see at least in large sections of the market for banking services and payment transactions.

In any case, the result is that an organization with a hyperautomated operating core will need a sizable and competent technostructure not only to look after it, tune it, and continuously improve it, but also to prepare the extensive parameter controls that such systems allow and assist the line organization in their use of these controls. The more sophisticated the organization becomes in using information technology and the more it (hyper-) automates, the more the technostructure will grow and the more important it will become.

An organizational truncation based on information technology should therefore result instead in an *Administrative Adhocracy*—the configuration Mintzberg designates for organizations with very complex technical systems. Just like its sibling, the Operating Adhocracy (see the later section on adhocracies), an Administrative Adhocracy is mainly project oriented. However, in contrast with the Operating Adhocracy, its projects are not organized to fulfill customer needs, but to take care of Administrative Adhocracy's own internal needs: the upkeep and development of a mass-producing operating core.

If the organization is not too large, the automation is extensive, and the top manager of the appropriate kind, such an organization may even revert to a Simple Structure or become a Joystick Organization. Even if it keeps a team-based management style, it may approach the Joystick Organization, since the top management team in such an organization may develop a very dominating position.

The Rise of Flexible Bureaucracy

The most exiting development, however, goes along the flexibility dimension and can provide us with a revitalized version of the Machine Bureaucracy, supplying the mass commodities and services of the twenty-first century. The key here is the transition from *inflexible* to *flexible* standardization.

The Machine Bureaucracy was developed as an organization for cheap, reliable mass production of standardized products and services. In order to maximize productivity and minimize the need for training, it depended on a high degree of job specialization, detailed prescriptions and rules for the execution of work, along with fairly rigorous standards of quality and generous amounts of control. This produced a type of organization with unsurpassed efficiency within

its very narrow problem domain, but, as noted in Chapter 7, this efficiency was bought at the price of an almost total inability to tackle problems outside its underlying conceptual model and defined in the implemented routines. In short, the Machine Bureaucracy is extremely inflexible compared to other organizations, especially the Simple Structure and the Adhocracy. In manufacturing, the costs of retooling for a new product are considerable; in white-collar bureaucracies, it is both time-consuming and expensive to change operating procedures and to train people to solve new classes of problems.

This is the reason a Machine Bureaucracy is not suited for dynamic environments or for products that cannot be standardized, and the reason Piore and Sabel (1984) and Pine (1993) believe it needs to be relieved as the dominant configuration for producing goods and services in the advanced economies. Piore and Sabel, in particular, argue that the main reason behind the apparent sluggishness of the world economy the last couple of decades is precisely the mismatch between increasingly saturated and more rapidly changing world markets on one hand, and the Machine Bureaucracies' inflexibility and dependence on long, uninterrupted production runs at full capacity on the other. The uncertainty about market developments deters new investments, and that the great costs of renewing products—not to mention changing lines of business—impede the ability of the economy as a whole to shift resources quickly enough between changing demands.

The remedy proposed by Piore and Sabel is to stimulate the growth of technology-based flexible specialization, based on the paradigm of craft production. Such companies will typically be fairly small (most of them would probably be Simple Structures) and flexible enough to be able to shift their production quickly between a fairly wide range of products and with moderate costs.

Pine, in his turn, describes how old style mass production is giving way to mass customization, where flexible production lines can deliver products with great variation, where product development cycles have been shortened, and where lead times reduced to a point where even cars can be delivered to customer specifications within a few days. Pine lists three forms of companies that make up what he terms the "New Competition": Japan, Inc. (the typical Japanese manufacturing company), the Flexible Specialization firms described by Piore and Sabel, and the Dynamic Extended Enterprise, exemplified by the renewed American corporation. Pine says that although the three forms are clearly different, they are all variations of the model offered by Piore and Sabel, bringing back much of the flexibility of the craft-based firms of the American System of Manufactures (described briefly in Chapter 7).

However, as Pine's own examples show, it is not only the craft-based, small-scale company that can achieve flexibility. Computer-based systems may also allow the development of a more flexible Machine Bureaucracy, which may answer at least parts of the challenge of more dynamic markets, and become formidable competitors both for craft-based production and traditionalists among their own kind. The basis for this is of course the extreme (and increasing) richness and flexibility of computer-based systems, so dramatically different from traditional machinery and media for automation and implementation of routines. By relying on information technology and appropriate reorganization,

bureaucracies in both manufacturing and service industries can become much more agile and achieve much greater flexibility in their production.

Flexibility can be increased in three ways: by having a richer set of pre-defined (and routinized) problem definitions and responses, by increasing discretion at the organization perimeter—something that will improve the organization's capability to deal with problems within its problem domain but inadequately provided for in established routines—and by making it cheaper and easier to change the routines themselves. All of these will also help to improve an organization's agility. Agility will likewise be enhanced by more efficient and rapid internal coordination and by the availability (especially to top management) of more comprehensive and timely information about various key aspects of the organization's performance. The discussions in the previous chapters have established that computer-based systems can make significant contributions in all these areas.

As noted in Chapter 12, there is no doubt that computer-based systems can be made almost infinitely more complex than mechanical machines, which means that computer-based automation can produce more complex products and accommodate much larger variations in product types. I believe we have only seen the beginning here, since our development of production methods and materials has only started to exploit the vast potential of computer control. Even now, car manufacturers are able to produce not only cars with different colors and a wide selection of options on a single assembly line, but even different models—and still operate according to the rather extreme just-in-time principles reported from Nissan's Sunderland operation in Chapter 12. This means that the mix of models can be changed dynamically not only from day to day, but, in principle, from hour to hour. This is a considerable improvement over the situation not too many years ago, wherein one assembly line could only produce one model with a fairly limited number of options. Of course, not even these factories can suddenly change their production to boats or airplanes, but this increase in flexibility—which is still primarily built on traditional materials and production methods—is nevertheless a harbinger of a future development where even greater flexibility will be available. We may, for instance, imagine materials and production machinery that do not depend on molds, but, rather, can produce any shape designed in a CAD program on the fly. Actually, we already have a beginning in stereolithography, where a resin is hardened by an ultraviolet laser beam "drawing" on its surface, layer by layer forming a three-dimensional object on a platform that is successively lowered into the resin bath. This process is still very slow, cumbersome, and expensive, but already it is efficient enough to replace a lot of traditional wood, plaster, and plastic modeling in the making of prototypes.

The same principles apply to clerical work, only to a greater degree, since mechanical machinery (which is the least flexible part) will be much less dominating there. Both automated and programmed routines can be very complex, and allow for a large number of predefined actions. Of course, it is also possible to prepare a great number of alternatives in a manual environment, where routines are documented in writing. However, the limits of human memory and the cumbersome nature of written documentation will combine to restrict the variation that can be sustained in practice. Well-designed computer-based systems

can easily extend the practical number of routines considerably and assist in choosing the right one for each occasion.

System-supported de-specialization may increase flexibility further by increasing the range of tasks that one person can execute, thus making it possible to accommodate greater variations in task mix than before. This has been evident for a long time in banks, where the introduction of counter terminals led to a significant de-specialization, making it possible for each clerk to provide the customer with a much broader set of services than before.

We may also return to an earlier example. The changes at IBM Credit, also described in Chapter 12, involved automation of the larger part of the work and extensive computer support for most of what was left. The caseworkers thus achieved a much broader span of competence. In addition to the documented leap in productivity (Hammer and Champy [1993] claim a 90% reduction in turnaround time and a hundredfold increase in the number of deals handled), we should expect the new setup to provide greater flexibility in setting up nonstandard deals, although Hammer and Champy do not comment on it. They do, however, include IBM Credit among their examples of organizations that have increased employee empowerment—something that normally entails greater ability to tailor responses to customer requests. (We discussed this in Chapter 14, and concluded that the migration of power toward the decision-making hot spots in the organization should lead to greater flexibility and agility for bureaucratic organizations.)

Just as important as an increased repertory of predefined routines is the ability to change routines or establish new ones quickly and cheaply. In a manual environment, changes are theoretically straightforward to implement, since all it takes is to describe the change and circulate it to all concerned. However, as all who have lived in and with such organizations know, it can be extremely difficult to make changes take hold, and override established patterns of action. The required effort can be quite considerable even for small changes.

One of the great advantages of computer-based systems in this respect is the way they can be equipped with options and parameters for adjustments in their functioning. We saw, for instance, how the people responsible for yield management in American Airlines could use the reservation system to implement instant changes in the prices and options available on flights throughout the world—changes that would probably have taken weeks to effect by manual means. And, despite the fact that many view bank systems as both archaic and hard to change, there is absolutely no doubt that banks today have more room to maneuver than they did 40 years ago when it comes to rapid changes in their products—whether it is to meet attacks from competitors or to accommodate general changes in their customers' preferences. It has, for instance, become much easier to vary interest rates, to let interest rates depend on the dynamic size of deposits, to differentiate payment options, and to combine accounts in various ways.

Looking at existing systems, one will of course find great differences in how pliable they are, but rigid systems are more a result of poor analyses, poor modeling, and poor design than of technological constraints. Naturally, there are limits to the flexibility that can be achieved without renewing or replacing the

systems (which involves great cost and effort), but I believe we have a long way to go before the potential is exhausted.

Like Paul Thompson (see quote on p. 366), I therefore disagree with the postmodernist contention that information technology is paving the way for a decisive break with Machine Bureaucracy as the dominating structural configuration of larger organizations in the advanced economies. *On the contrary, I believe that information technology is already supporting the development of a leaner, much more flexible and much more agile type of bureaucratic organization than the classic Machine Bureaucracy.*

This new type of organization will depend mainly on hyperautomation and programmed routines but will also draw on the other computer-dependent coordinating mechanisms represented in Figure 15-1 (p. 384). When sufficiently advanced, it will be model driven, relying on a regulating model with an emphasis on programmed routines, hyperautomation, and (depending on the type of production) implicit coordination. The middle layers in the organization will be severely decimated, some of their power migrating upward and some downward. Through the use of improved information access and increased spans of competence, discretionary powers in matters related to specific tasks or customers will be decentralized to the operating core. Top management, however, will have much better control of the operations overall, both through their access to much better and more timely information and through the much improved process control they achieve through their command over the systems used by the operating core.

This kind of organization will be much better equipped than its predecessor to tackle variation in its environment, because it reacts much faster to changes, has a wider repertory of standardized responses, and has a greater ability to vary its product mix. To phrase it in the language of Ashby (1956), it will contain within itself a greater variety than the classic Machine Bureaucracy, and it will therefore be able to live with more variation in its environment.² Because such an organization will be much more change oriented in general, it will also have a greater ability to accomplish those major changes that must come when the demands from the environment finally outstrip its normal range of responses. I propose the name *Flexible Bureaucracy* for this configuration, to denote both its strong points and its origin.

The Flexible Bureaucracy will retain most of the design parameters of the Machine Bureaucracy, such as behavior formalization, vertical and horizontal job specialization, large operating unit size, vertical and limited horizontal decentralization and action planning. However, whereas the Machine Bureaucracy usually relies on functional grouping, the Flexible Bureaucracy will use its computer-based systems to maintain market-oriented grouping or even matrix-like structures. The Flexible Bureaucracy will be able to thrive in more complex and dynamic environments than the Machine Bureaucracy. It will retain strong technocratic control, since the computer professionals required to design and run its comprehensive systems will find a natural home in the technostructure.

I believe that this computer-based version of the bureaucratic configuration will prove a far more vigorous successor to the Modern Organization (Machine

² Ashby's law of requisite variety, see p. 34.

Bureaucracy) than the craft-oriented alternative proposed by Piore and Sabel, and, accordingly, that *flexible standardization* is a more likely solution to the problems of the classic Machine Bureaucracy than flexible specialization. Far from promoting the small organization, information technology (which is in its essence an automating and coordinating technology) will invigorate the larger organizations and make them still more formidable competitors. Indeed, of the three forms of New Competition that Pine (1993) defines within the field of mass customization, two of them (Japan, Inc., and the Dynamic Extended Enterprise) correspond much more closely to the Flexible Bureaucracy than to the craft-based type of firms envisioned by Piore and Sabel.

As a part of their metamorphosis, Machine Bureaucracies are now experiencing a period of contraction while they hyperautomate an increasing part of their operating cores and shed organizational layers by gradually shifting their coordination toward the computer-dependent coordinating mechanisms. This is, by the way, a process that has really been underway for quite some time—as early as around 1970, the employment figures of large manufacturing companies such as General Motors, Philips, and Unilever started to drop, whereas sales and capital expenditures continued to grow (Huppel 1987). After they have made this transition, they may well start to grow again—even in number of employees—although their most decisive growth will still be in economic size.

The adaptability of the Flexible Bureaucracy is not limitless, however. If it is confronted with problems not defined in its underlying model or requests outside the available range of responses defined in its systems, even as they are supplemented by empowered employees, it will come up against the same need for fundamental changes as a Machine Bureaucracy. Indeed, so will all organizations with a heavy reliance on computer-based systems. Even the IT-based Simple Structures will find that they cannot “turn on a dime” as easily as their noncomputerized brethren. Because of the enormous amount of analysis, planning, and design needed to create comprehensive systems and the conceptual models they must be based on, the required effort for major change can indeed be large. There are numerous examples of such changes that have turned into catastrophes when major new systems have been severely delayed, have suffered massive cost overruns, or have even been stranded altogether. However, there are also numerous examples of successful projects of this kind, and as our knowledge improves, our experience accumulates, and the software tools become better, the successes will probably slowly increase their share of the total. The Flexible Bureaucracy will, as other computer-dependent configurations, have another advantage: The people working in them will be more used to, and thereby probably more receptive to, change.

The Immutable Professional Bureaucracy

The Professional Bureaucracy is similar to the Machine Bureaucracy in the sense that it is meant to produce standardized goods or services in an efficient way. It differs from the Machine Bureaucracy in that its production process (Mintzberg: “operating work”) is too complex to rely on unskilled operators working according to explicit routines. As Mintzberg says (1979, pp. 348–49, italics in original),

We have seen evidence at various points in this book that organizations can be bureaucratic without being centralized. Their operating work is stable, leading to “predetermined or predictable, in effect, standardized”³ behavior, but it is also complex, and so must be controlled directly by the operators who do it. Hence, the organization turns to the one coordinating mechanism that allows for standardization and decentralization at the same time, namely the standardization of skills. This gives rise to a structural configuration sometimes called *Professional Bureaucracy*, common in universities, general hospitals, school systems, public accounting firms, social work agencies, and craft production firms. All rely on the skill and knowledge of their operating professionals to function; all produce standard products or services.

For their operating core, the Professional Bureaucracies rely on professionals—people who have received their main training in independent educational institutions. (The exceptions are of course these educational institutions themselves; they tend to count many of their own graduates among their employees.) This education not only provides them with the basic knowledge they need to carry out their work, it also teaches them what to expect from their professional coworkers and how it is customary to coordinate activities with them. The education normally also serves to indoctrinate the professionals with norms about ethical standards and proper conduct both toward fellow professionals and customers/clients. Even in those instances where systematic education continues after hiring (as in hospitals that educate specialists), the content and process are fully controlled by standards set by the larger professional community. There is little room for organization-specific programs. In their work the professionals work relatively independent of their colleagues but usually maintain a close relationship with the customers or clients they serve. Their decisions and the way they carry out their work are determined not so much by in-house rules as by their own judgment, built on the standards of their own profession.

Whereas Machine Bureaucracies generate their own standards and rely on formal authority, then, Professional Bureaucracies apply standards set by self-governing professional associations and rely on the authority of recognized expertise. The main pull in such an organization (Mintzberg 1979) is to professionalize—to extend the supremacy of professional expertise throughout the organization. This pull has three main expressions: Occupational groups not yet recognized as separate professions will strive toward such recognition, the recognized professional groups will fight for the inclusion of more prestigious tasks into their domains and if possible secure statutory monopoly on their jobs, and all the professionals will vigorously defend their own autonomy and join in the effort to keep control of the organization and relegate the administrative apparatus (including the managing director) to a subordinate, staff-like position.

This tendency is easy to observe, not least in hospitals (at least in Norwegian hospitals). Almost every occupational group in the hospitals has worked systematically to establish a separate profession, complete with its own separate education and statutory provisions for a monopoly on certain positions. The doctors were first, followed by nurses, and later we have seen the same

³ Mintzberg here quotes himself from his definition of bureaucracy in an earlier chapter, which he refers to in a parenthesis I have left out here.

development for most of the other groups, such as physiotherapists, physical chemists, occupational therapists, and nursing assistants. The establishment of new professions has often taken place in conflict with existing ones, since it usually has involved staking out claims to tasks that already belonged to one or more of the established groups. The archetypal conflict here has been (and still is) the conflict between doctors and nurses, as nurses over the last 100 years have fought fiercely and with great perseverance to improve their standing and their education and to take over a significant part of the work that was earlier the domain of medical doctors.

Hospitals are also characterized by a single-minded concentration on formal qualifications when evaluating people for new positions, even within the professions. To cross the border between two professions is impossible altogether—regardless of actual knowledge and experience—without going through the full educational program of the new profession. If the certificate is missing, the door is totally blocked. And, as hinted earlier, the educational programs of the different professions are totally separate, with no common tracks or courses.

The occupational turf in a hospital is by now largely cut up and occupied by the various professional groups, and the fight for larger domains or more prestigious tasks increasingly amounts to a zero-sum game. The hospital organization is therefore very rigid and extremely difficult to change. In such organizations one would expect game theory to apply in many instances, and it is interesting to see that alliances and conflict lines among the professions indeed seem to do so. There is, for instance, a conflict between nurses and nursing assistants, since the latter dislike to be supervised by nurses and moreover want to move up toward nursing status and take over some of the nurses' responsibilities (and positions). The nurses, on their hand, have been nibbling away at the doctors' domain for a century, and these two groups still have their skirmishes—not least in the area of administrative duties and responsibilities in the hospital wards. What is more natural, then, than mutual sympathy and goodwill between doctors and nursing assistants? Neither group threatens the other, and the nursing assistants have no trouble accepting the professional authority of the doctors. In fact, many doctors will claim that they really do not need the (now) university-educated nurses, that they would prefer to recruit only nursing assistants (who receive more limited education) and then teach them what more they need to know themselves. So far, however, the nurses have had the most success.

This main pull of the Professional Bureaucracy will receive no particular support from information technology. Actually, the Professional Bureaucracy is probably the configuration where information technology provides the most limited platform for change. The reason is simply that the gist of the work in such organizations consists of professional judgment, which typically requires the kind of "thick" or "soft" knowledge that is (at least currently) impossible to impart to computer-based systems. A number of expert systems that aid in tasks such as fault finding and medical diagnosing have indeed been developed, but they cannot—and are not intended to—replace the professionals. Rather, they are meant to function as tools for the professionals, speeding up assessment and improving the quality of their work.

There are of course exceptions to this general pattern, since a number of Professional Bureaucracies will be vulnerable to hyperautomation and/or a growth in self-service. Because, even if the largest and most visible Professional Bureaucracies are in the service sector, the configuration can also be found in manufacturing in the form of craft enterprises (Mintzberg 1979), which is the configuration favored by Piore and Sabel. Traditionally, the craft enterprise depends on craftsmen who use relatively simple tools to produce standardized goods. Because their tools are simple and often general, it is relatively easy for them to shift their output to new products if the markets change, and this flexibility makes up for some of their lack of productivity compared to the Machine Bureaucracies. However, in their competition both with Machine Bureaucracies and with other craft enterprises, they increasingly have to invest in more powerful tools and even computerized equipment. This tendency is described by Piore and Sabel in the case of the textile industry in Italy's Prato district and the Japanese metalworking industry.

To Piore and Sabel, this is a proof of the vitality and adaptability of the craft enterprise. To me, it is instead a development that will serve to reduce the importance of the independent craft enterprise in manufacturing, since the increasing use of computer-based equipment will tend to level out the field between the different configurations: The necessary investments per employee in the craft enterprise will approach those of the competing Machine Bureaucracies (gradually becoming Flexible Bureaucracies), and the flexibility of the Machine Bureaucracies' production machinery will approach that of the craft enterprise's.

This convergence in technologies will also result in a convergence in the required skills. Even if both the craft enterprise and the Machine Bureaucracy have traditionally relied on action-centered skills (Zuboff 1988, see discussion on p. 272), they have been very different in kind: The craft enterprise has employed highly skilled craftsmen who perform a broad range of qualified work; the Machine Bureaucracy employs largely unskilled personnel who have received the limited, specialized training they need in-house or even on the job. However, as the use of computer-based equipment increases, both types of organizations increasingly need operators with the sophisticated, *intellective* skills required to master the new equipment. Simultaneously, the degree of automation will tend to rise, and computer-based systems will be employed to automate the coordination of larger and larger parts of the production process, even spanning organization borders, as in the Nissan Sunderland example. Craft enterprises, in my opinion, will therefore experience a strong pull toward the Flexible Bureaucracy configuration, or toward the Administrative Adhocracy if they are able to automate their production completely.

In some instances, information technology even renders whole crafts superfluous, for instance, traditional typography (as printing once eliminated the need for scribes). Self-service can also be a threat, especially to some professions in the service sector. For instance, an increasing number of brokerages now offer customers direct access to their stock-trading systems, enabling customers to conclude deals directly from their own PCs. Although the brokerages still perform the back-office functions, this development may reduce the need for stockbrokers quite significantly and diminish their position compared to the more routine-processing back-office staff. We can expect such trends to continue, and

Professional Bureaucracies whose professional work can largely be automated, eliminated, or routinized will also develop toward other configurations, such as a Machine Bureaucracy, a Flexible Bureaucracy, or an Administrative Adhocracy—depending on the nature of the changes they go through.

In the majority of the Professional Bureaucracies, however, the dominating tasks fall into one or more of the three categories least susceptible to automation (listed on p. 312): work where qualities such as creativity, judgment, artistic skill, and emotional content are central. The professions are therefore likely to continue their dominance in these organizations, and there is little reason to believe that they will change configuration or that the configuration itself will be significantly modified. As Mintzberg says (1979, p. 367),

The professional operators of this structural configuration require considerable discretion in their work. It is they who serve the clients, usually directly and personally. So the technical system cannot be highly regulating, certainly not highly automated.

The professionals will therefore prefer systems that assist them in their work and enhance their professional capacities. However, for the same reasons, they will also take a favorable view of systems that automate or eliminate the most routine aspects of their work, and especially systems that reduce the need for an administrative staff. The potential of information technology in the case of the typical Professional Bureaucracies is therefore a development toward somewhat slimmer organizations, with a higher proportion of professionals than before, and with sophisticated support systems both for professional and administrative needs. There will be no dramatic changes justifying the proclamation of new configurations, not even for the model-driven version of the Professional Bureaucracy, which will depend mainly on the assisting model.

The technology does, however, hold a potential for increasing the antagonism between professionals and administrative staff. The latter, which is usually configured and run as a Machine Bureaucracy, tends to hold the view that professionals are a bit on the whimsical side, and that a more "structured" approach to work and better cooperation would improve both their productivity and the quality of their work. They (and even the organization's owners) may easily see information technology as a means to improvement through injecting more control and standardization into the professional sphere, and maybe even automate or eliminate some of their tasks. In such a process the administrative staff would also improve their own position in the organization. This is of course anathema to the professionals, as Mintzberg points out in the continuation of the preceding quote:

As Heydbrand and Noell (1973)⁴ point out, the professional resist the rationalization of his skills—their division into simply executed steps—because that makes them programmable by the technostructure, destroys his basis of autonomy, and drives the structure to the machine bureaucratic form.

⁴ Heydbrand, W. V. and Noell, J. J., "Task Structure and Innovation in Professional Organizations," in W. V. Heydbrand (ed.), *Comparative Organizations*, Prentice-Hall, 1973, pp. 294–322.

I believe this will be an important source of conflict in Professional Bureaucracies in the years to come. The conflict will of course become most severe in organizations where significant parts of the professional work *can* be automated or eliminated, and where the organization may even be posed for a change of configuration along the lines indicated earlier. Many Professional Bureaucracies also have strong “manufacturing” aspects, for instance, hospitals—where the flow of patients through the wards and the throughput in terms of the number of patients treated can be likened to the flow of materials and output of finished goods in a factory. Such resemblances—real or apparent—can provide platforms for attacking the traditional autonomy of the professions, and the availability of sophisticated, regulating computer-based systems for a variety of administrative and production-oriented purposes can only strengthen those platforms.

The position of the computer professionals themselves will also be interesting: Will they establish themselves as the kernel of a new technostructure, allied with the administrative staff, or will they seek acceptance as a new professional group? So far, the first alternative has been most common, something that can be explained both by history (computers were usually first brought in by the accountants in the administrative staff) and by the computer professionals’ aptitude for logic as well as systems and efficiency engineering. Because their work always tends to encroach on the autonomy of the other professionals, it is quite likely that they will have problems being accepted as a bona fide professional group separate from the administrative staff.

The Divisionalized Form Headed for Reintegration?

The Divisionalized Form is not a configuration in the same sense as the others; it is in a way a second-order form, a structure for the coordination of relatively independent organizations—organizations that have their own structural configurations and that could well exist as independent entities. As Mintzberg says (1979, p. 381),

The Divisionalized Form differs from the other four structural configurations in one important respect. It is not a complete structure from the strategic apex to the operating core, but rather a structure superimposed on others. That is, each division has its own structure. As we shall see, however, divisionalization has an effect on that choice—the divisions are drawn toward the Machine Bureaucracy configuration. But the Divisionalized Form configuration itself focuses on the structural relationship between the headquarters and the divisions, in effect, between the strategic apex and the top of the middle line.

As noted in Chapter 7, the Divisionalized Form of the modern era was pioneered by Edgar J. Thomson of the Pennsylvania Railroad and Pierre du Pont and Alfred Sloan, Jr., of GM. It is primarily a configuration for organizations that are too large or too diverse to be managed as centralized structures organized in single tiers of functional departments. Most often, it is an answer to market diversification either through growth or through takeovers (conglomeration). There are a number of intermediate forms between the Machine Bureaucracy and the Divisionalized Form, however; Mintzberg (1979) counts four subtypes.

The *Integrated Form* is characterized by purely functional divisions, each performing a step in the corporation's total value chain, and it is only a small step away from the departmentalized, monolithic organization. The divisions are locked into a common planning system and generally lack the freedom to buy from or sell to other than their sister divisions. If such an organization starts to seek wider markets by diversifying production in its divisions and allowing them to sell some of their output directly to outside customers, it changes to the *By-product Form*. Central planning is still pervasive and the needs of the sister divisions dominate, but some more freedom is introduced. If diversification and growth in the by-product sector continue, the open market may at some point in time become more important to the divisions than the corporation's internal market, and the organization moves on to the *Related Product Form*. At that point, the demands from customers in the open market become more important to the divisions than their internal, corporate commitments, and they require a much more substantive independence. The end of the line is the *Conglomerate Form*—the pure version of the *Divisionalized Form*—where the divisions are fully independent and often totally unrelated.

In this pure form the corporate headquarters will be small—Mintzberg mentions the case of Textron, where a staff of 30 executives and administrators oversaw 30 divisions with combined sales of more than \$1.5 billion (of late 1960s denomination). Corporate management will concentrate on monitoring the divisions' financial performance and on issuing policy for long-range planning. Typically, there will also be a small legal department, and in many instances an industrial relations office.

The process can also run in the other direction—from a conglomeration of unrelated companies to a tight-knit, divisionalized corporation. When du Pont took over control of GM from William C. Durant, even the monitoring and planning functions were not established, and it was at the very most a holding company—Durant managed it with the help of two to three assistants and their secretaries. Du Pont and Sloan quickly established stringent reporting and planning procedures and allocated the divisions to separate market brackets. Over the years, control was gradually tightened, and more and more common functions were instituted. Mintzberg (1979, p. 405) cites Wrigley⁵ to the effect that in the mature GM, "The central office controls labor relations, market forecasting, research, engineering, quality control, styling, pricing, production scheduling, inventory levels, product range, and dealer relations; it decides what plants are to be built, and what cars; it styles them, and it tests them on the corporate Proving Ground." There is also extensive use of standardized parts across divisions. Mintzberg concludes that the modern GM has moved almost all the way toward a Machine Bureaucracy, and is best characterized as exhibiting the *Integrated Form* variant of the *Divisionalized Form*.

This illustrates the two pulls acting on the *Divisionalized Form*—one decentralizing and one centralizing. The pull underlined by Mintzberg in his total model of the main five configurations is the pull of the middle line (division management) to balkanize—to decentralize, increase the divisions' freedom of

⁵Wrigley, L.: *Diversification and Divisional Autonomy*, D.B.A. thesis, Harvard Business School, 1970.

action, escape too detailed central planning, and reduce their dependence on the sister divisions. On the other side, the Divisionalized Form is a configuration created not for the love of decentralization as such, but as a remedy for the mounting control problems experienced as organizations (especially Machine Bureaucracies) become very large. The strategic apex in a Divisionalized Form, then, delegating authority only by necessity—will almost always be on the lookout for ways to achieve stronger central control.

Corporate management's objectives will differ, however, according to the nature of the enterprise. The main distinction here is between companies with totally unrelated divisions (true conglomerates) and companies where the divisions have related products or markets, and where synergies or increased economies of scale are conceivable (which was the case in GM). In true conglomerates the strategic apex will concentrate on monitoring results and on managing corporate finance; in companies with possible synergies, its ambitions will also cover cross-divisional planning and coordination.

Information technology will also offer new possibilities for Divisionalized Forms, and not only on the corporate level. The divisional level—the changes possible within the divisions themselves—is also very important. However, they are more or less equal to the possibilities for individual organizations discussed under the other headings in this chapter and therefore do not need separate treatment here. Consequently, we can concentrate on the corporate level, where the main dimension for change is the centralization/decentralization dimension outlined earlier, and where the main differences in attitudes are dictated by the level of affinity between divisions.

In true conglomerates, companies where there are no potential synergies between divisions, the incentive for cross-divisional, central planning is of course limited. However, corporate headquarters may well partake in the planning process in the separate divisions, or at least use their plans to monitor their progress and trigger corrective action at an early stage in the case of underperformance. The supervision may be purely financial or may cover a broader range of indicators. System-supported supervision offers ample opportunity for strengthening and refining such monitoring of financial and other quantitative information. With the proper systems in place for conducting day-to-day business in the divisions, monitoring may even take place in real time or almost real time, as in the reporting systems of Benetton and Hennes & Mauritz mentioned in Chapter 14. This will provide corporate headquarters with several options for development: closer control and participation in the daily affairs of the divisions, management of more divisions with the same staffing, and a reduction of headquarters staff while maintaining or even improving control.

In addition to improved monitoring, computer-based systems will also make it possible to elaborate the financial integration of a Divisionalized Form considerably, regardless of subtype. With sophisticated systems, corporations may run what amounts to internal banking systems, where internal transactions are netted (also across borders), liquid reserves are pooled, and internal loans and deposits are made. Many large companies, such as the Norwegian conglomerate Norsk Hydro, have had such systems for years already. At Hydro, which is regarded as one of the world leaders in this field, all transactions by divisions and their subsidiaries are made toward central, internal accounts managed by

corporate finance—no division or subsidiary ever sends money directly to another or to major suppliers, not even across borders. If a subsidiary in Norway needs to pay a supplier in the United States, it does not pay directly. Payment is made in Norwegian kroner to corporate finance in Norway, who will then pay the supplier in dollars from its accounts in the United States—accounts that in turn receive payments from Hydro's American operations for goods and services purchased elsewhere in the world. All external loans, deposits, and currency transactions are made by corporate finance. In this way the number and size of external currency transactions and ordinary bank transactions are minimized.

Hydro even operates a bank for its employees in Norway—complete with automatic teller machines installed in its offices and subsidiaries around the country, where employees can withdraw money with their Hydro cards. The bank accepts deposits and gives loans to employees, always at better terms than those offered by ordinary Norwegian banks.

The advantages discussed so far also apply to the other subforms of the Divisionalized Form—those where there are more or less clear synergies or economies of scale to be realized by coordination across divisions. However, in such organizations, the strong coordinating powers of computer-based systems can also be brought to bear. In addition to system-supported supervision, implicit coordination, programmed routines, and hyperautomation can be applied to overcome the information and control overload that earlier prohibited unified coordination of the divisions. I believe that this will allow reintegration of operations in a large number of instances, reducing the number of divisions or even transforming Divisionalized Forms to clean-cut Machine Bureaucracies or Flexible Bureaucracies. In so doing, they may also cross the threshold to become model-driven organizations, depending mainly on the regulating model.

We have seen some developments lately that point in this direction—a growing number of companies have taken advantage of computer-based just-in-time systems to eliminate regional warehouses and coordinate distribution nationally or even internationally. HÅG, a Norwegian producer of desk chairs, now delivers made-to-order chairs from its manufacturing plant in the mountain town of Røros directly to customers over most of Europe within five days of receiving the order. This feat is made possible by a sophisticated just-in-time production management system and cooperation with a forwarding agent who runs operations with the help of a computer-based distribution system.⁶ Dell, the American PC maker, runs a similar operation from its plant in Ireland.

Multinational companies are increasingly lumping national markets together in larger geographical regions and have restructured both manufacturing and distribution along the new boundaries, supporting them with sophisticated logistics systems. In Scandinavia we have seen quite a number of such moves now, as companies have organized their Scandinavian operations under one umbrella, establishing a joint headquarters in one of the capitals, often supplying the whole region directly from a single facility.

As our experience grows and systems mature, it should be possible to achieve a much higher integration than we experience today. The result could be larger,

⁶This was related to me by Steinar Ask, the project manager for the JIT implementation. The condition is of course that the order stays within the range of upholstery in stock.

faster, and more nimble multinationals, which means increased competition for businesses who believe they are local and have advantages because of their small size.

Still, it does not seem that the extensions of the space of constructible organizations will contain variants of the Divisionalized Form that amount to new configurations, neither for the conglomerate variant nor for the more tightly knit firm—at least as long as we maintain the condition that all the elements of the organization shall have the same owners or at least answer to the same corporate management. When it comes to the coordination of totally separate companies, however, we approach something new: the Meta-Organization, which will be discussed later in this chapter.

Transforming Adhocracy

Mintzberg views the Adhocracy as the youngest of his five basic configurations. As a configuration for larger, formal organizations, this is probably correct, even if it also represents one of the two primal coordination mechanisms of the human race (see discussion in Chapter 5). However, I suspect that closer study would find that variations of it have been in use for centuries and even millenia, especially in teams of craftsmen constructing buildings, ships, or other large objects.

The Adhocracy comes into its own when the environment is so dynamic that it is difficult to standardize products and perpetual innovation is necessary; and the innovative work is so complex that it requires the efforts of many experts or expert groups. Adhocracies must therefore bridge specialization in a much more dramatic way than Professional Bureaucracies, where experts cooperate by enacting their establish professional roles and adhering to their own group's particular standards. In Adhocracies the experts have to give and take, to pioneer new approaches that may break with established procedures, and to arrive at joint solutions incorporating elements from them all. Because experts are so central to the innovations that Adhocracies live by, they must also hold wide power—at least in in practice if not in formal designation. Describing the design parameters of the Adhocracy, Mintzberg says (1979, pp. 432–3, bold type in original):

In Adhocracy, we have a fifth distinct structural configuration: highly organic structure, with little formalization of behavior; high horizontal job specialization based on formal training; a tendency to group the specialists in functional units for housekeeping purposes but to deploy them in small market-based project teams to do their work; a reliance on the liaison devices to encourage mutual adjustment—the key coordinating mechanism—within and between these teams; and selective decentralization to and within these teams, which are located at various places in the organization and involve various mixtures of line managers and staff operating experts.

To innovate means to break away from established patterns. So the innovative organization cannot rely on any form of standardization for coordination. In other words, it must avoid all the trappings of bureaucratic structure, notably sharp divisions of labor, extensive unit differentiation, highly formalized behaviors, and an emphasis on planning and control systems."

Adhocracy comes in many varieties, since organizations may border on other configurations or have to meet special conditions. Mintzberg mentions at least

seven variants, with the Operating Adhocracy and the Administrative Adhocracy as the most important ones. (He does not say it explicitly, but they seem to represent two main classes, whereas the other five are subtypes). The Operating Adhocracy is the classic form, where the teamwork is undertaken to serve the customers' needs directly, and where the operating core and the administrative staff constantly mix and merge in project teams. In the Administrative Adhocracy, however, the operating core is cut off from the administrative part of the organization because it needs another kind of structure (most often it will be a Machine Bureaucracy), since it is automated or even done away with completely and contracted out to other organizations. The rest of the organization, structuring itself as an Adhocracy, can then concentrate on the innovative part of the work, leaving the isolated operating core to crank out the products. Typical Administrative Adhocracies include newspapers, where the editorial staff faces the awesome task of creating a new paper every day (different down to the last letter), while the printing plant and the distributing organization—always physically separated from the editorial offices, often even organized as separate companies—can concentrate on streamlining their repetitive duty of providing the subscribers with (from their point of view) the same wad of printed paper every day. As we have already concluded, information technology (especially by enabling much more extensive automation) will make it possible to structure more organizations as Administrative Adhocracies in the future.

The other subforms defined by Mintzberg, such as the Entrepreneurial Adhocracy (a hybrid of Adhocracy and Simple Structure) and the Divisionalized Adhocracy (a cross with the Divisionalized Form) will differ significantly in the extent to which they benefit from computer-based systems. The Entrepreneurial Adhocracy, which is really an Operative Adhocracy (usually a high-tech start-up) with an owner/manager who is also an outstanding professional (and recognized as such), will not benefit any more than small Operative Adhocracies in general. The Divisionalized Adhocracy, however, stands to gain more. As Mintzberg defines it, it is essentially a Divisionalized Form with an environment so complex that simple divisionalization does not suffice—it has to implement a matrix structure. A true matrix organization does away with the unity of command that is the hallmark of Machine Bureaucracies and conventional Divisionalized Forms, and requires close, team-oriented cooperation between the two (or even three) dimensions found in the matrix.

It is indeed conceivable that the strong coordinating powers of computer-based systems—which can allow a Divisionalized Form to change into a Machine Bureaucracy or a Flexible Bureaucracy—can help a Divisionalized Adhocracy to collapse one of its dimensions. For instance, in a product/market matrix (the most common one), the coordination of production and shipping of goods may be streamlined to such an extent that the organization may be able to collapse its matrix to essentially a market-based Divisionalized Form served by a common product division. As noted earlier, we have indeed seen tendencies in this direction lately, as a number of multinational companies have considerably enlarged the geographical regions served by one organizational unit.

Regardless of which subtype of Adhocracy we study, however, the central problem is the copious communication needed to coordinate through mutual

adjustment, the coordinating mechanism required for the kind of tasks that Adhocracies are designed to tackle. To quote Mintzberg once more (1979, p. 463),

People talk a lot in these structures; that is how they combine their knowledge to develop new ideas. But that takes time, a great deal. Faced with the needs to make a decision in the Machine Bureaucracy, someone up above gives an order and that is that. Not so in the Adhocracy. Everyone gets into the act. First are all the managers who must be consulted—functional managers, project managers, liaison managers. Then are all the specialists who believe their point of view should be represented in the decision. A meeting is called, probably to schedule another meeting, eventually to decide who should participate in the decision. Then those people settle down to the decision process. The problem is defined and redefined, ideas for its solution are generated and debated, alliances build and fall around different solutions, and eventually everyone settles down to a hard bargaining about the favored one. Finally, a decision emerges—that in itself is an accomplishment—although it is typically late and will probably be modified later. All of this is the cost of having to find a creative solution to a complex, ill-structured problem.

Although this is all necessary to solve one-of-a-kind problems, it is devastating for any attempt to compete in the field of routinized work. Adhocracies are ill equipped to handle ordinary, routine tasks, and, if they want to move in such a direction, they must transform their structures—for instance, to Professional Bureaucracies (for consulting based on standard methods and a repertoire of tested solutions) or Machine Bureaucracies (for volume production of goods). Such transformations are, by the way, seldom made without conflict and the defection of a number of experts. Those who prefer innovative work and adhocratic organization will fight fiercely against the changes, and, if they lose, a number of them will probably jump ship to join other companies more in tune with their preferences. They may even choose to set up a company of their own. This is in accord with the main pull on an Adhocracy, which, according to Mintzberg (1979), is the pull of the support staff to collaborate—which translates into the experts' insistence on organizing work in projects and participating in decision making on all levels.

How, then, if at all, can information technology help to ease the exceptionally heavy burden of communication that is the core problem of the Adhocracy? Saturated as they are with communication, and with a consistent pull toward cooperation, we should expect these organizations first of all to benefit from systems supporting communication and teamwork—that is, they should benefit more than other configurations from the use of groupware tools of all denominations. I do indeed believe they will be able to use such tools profitably, but success will not be ensured—they will need fairly firm coaching in order to use such tools for increased productivity rather than simply for increasing their volume of communication and probing their (always interesting) subject matters to even greater depths.

However, as concluded in Chapter 11, groupware (e.g., coauthoring systems, systems for meeting assistance, electronic mail and group calendars) is not going to revolutionize any type of organization—not even Adhocracies. The reason is that these types of systems really only support and facilitate the various kinds of interpersonal communication that constitute the traditional means for mutual

adjustment. They do very little to reduce the required communication volume; on the contrary, by offering improved channels they tend to *increase* the total amount of communication instead.

Groupware will therefore only allow Adhocracies to become a bit more efficient (provided the necessary coaching), to produce work of somewhat higher quality, and to function more independently of physical proximity. Groupware products will not have the power needed to allow structures very different from today's Adhocracies, since they simply do not tap into the most powerful aspects of computers.

Ascendance of the Interactive Adhocracy

The strong points of information technology, however, offer other possibilities—perhaps not so obvious, but much more interesting. The attack point is, even here, the volume of communication needed for coordination. However, the thrust is not in the direction of better tools for this communication, but toward reducing the need for such interpersonal communication in the first place.

How can that be accomplished? The answer lies in the mediating model, as presented in Chapter 15. If an Adhocracy can model its problem domain to sufficient depth and with sufficient rigorousness, it can also build systems that will shift the larger part of the coordination burden from explicit interpersonal communication (which has to be carried out in addition to the actual work itself) to a much more terse and efficient kind of communication, directed toward the *system* (or complex of systems) and effected as an *implicit part* of the actual work.

An early example is, as we noted, the CAD system used for the structural design of Boeing 777. Before the introduction of the new system, all coordination in the project organization had to rely on direct interpersonal communication, meetings, and circulation of drawings—all burdensome efforts that came on top of the actual design work. With the CAD system in place, the need for much of that communication was simply eliminated, since the required information could be presented through the system to anyone at any time. Additionally, the information itself was created and fed into the system as an integral part of the work process and required little or no separate efforts.

Unlike the implementation of groupware, the introduction of comprehensive systems based on a mediating model will allow quite dramatic changes—even large organizations may achieve real-time or close-to-real-time mutual adjustment, in some aspects comparable to the kind of coordination achieved in small groups. Adhocracies based on mediating models should therefore become much more efficient, since they will spend far less time and effort on coordination than they used to. They should also be able to react and adapt significantly faster to changes in their problem domains. This variant of the Adhocracy is definitely different enough from its traditional forebear to justify a new name: it could be called the *Interactive Adhocracy*, to connote the way it depends on pervasive, real-time, interactive systems to sustain the dynamic mutual adjustment that is the defining feature of adhocracies.

The Interactive Adhocracy will retain almost all the main design parameters of the Adhocracy, such as organic structure, selective decentralization, horizontal job specialization, high percentage of professionals/experts, and a concurrent use of functional and market groupings. The liaison devices of the Adhocracy will, however, be largely supplanted by the mediating model.

While keeping and even strengthening the superior problem-solving capability of the traditional Adhocracy, the Interactive Adhocracy should be able to come substantially closer to the other configurations in efficiency, and it should therefore emerge as a viable alternative in a much larger number of cases. To bring the creative power of this kind of organization to bear on problem domains that have, as yet, not been able to sustain costs should be a very exciting prospect in a world where most markets experience increasingly rapid changes and a mounting pressure for innovation.

There are two important limiting factors for the construction of Interactive Adhocracies. One is the extent to which the problem domain can be modeled with sufficient rigor to be implemented in a suite of computer-based systems. As we travel along the learning curve, however, and our tools and methods improve, we will be able to do so for an increasing number of organizations. The other major factor is the need for synchronization of goals and objectives. The "anarchistic" nature of Adhocracies means that their members must internalize their organization's goals and objectives to a larger degree than necessary in more hierarchic configurations. As Khandwalla⁷ says (quoted in Mintzberg 1979, p. 435),

The job of coordination is not left to a few charged with responsibility, but assumed by most individuals in the organization, much in the way members of a well-knit hockey or cricket team all work spontaneously to keep its activities focused to the goal of winning."

This will be even more true in an Interactive Adhocracy, where the volume of interpersonal communication will be significantly lower than in a conventional Adhocracy. If model-mediated mutual adjustment is to be used on a large scale, sustained attention to the maintenance of a comprehensive team spirit and loyalty toward common goals will be required. Without a common understanding of the organization's goals and objectives and of their own role in the total picture, the members of the organization will end up pulling in opposite directions, and will compromise the viability of the model.

New Configurations

So far, we have only looked at the evolution of Mintzberg's original five configurations. However, information technology may also permit the construction of totally new configurations. The discussions in Chapters 12 through 14 have hinted at two: one emerging from the strong coupling of independent organizations, the other emerging from the very fringes of organization. I will call them, respectively, the *Meta-Organization* and the *Organized Cloud*. Table 16-1 (page 416), lists the main characteristics of these two and the three modified configurations discussed earlier (see table on page 58).

⁷ Khandwalla, P. N.: "Organizational Design for Change," *Learning Systems, Conceptual Reading*, 5 (New Delhi, India, 1976).

The Meta-Organization

As we concluded in Chapters 12 and 14, the strong, detailed, and extensive coordination that can be achieved through the use of unified computer-based systems makes it possible to achieve a new kind of integration between separate organizations. Organizations such as those comprising the manufacturing system centered on the Nissan factory in Sunderland (described in Chapter 12) are indeed coordinated more closely than sister departments within most single organizations. Whether or not the organizations involved have separate owners, their operations are so intertwined and they depend so critically on each other for their daily operations that it seems very reasonable to view them as a single organizational entity. However, the fact that they have separate owners, separate economies, and separate chains of command and are joined only in a contractual arrangement makes it difficult to classify such clusters as Machine Bureaucracies or Divisionalized Forms—even if they resemble these configurations in many ways. There is also a continuum of such arrangements—from the very long-term, inclusive, and tight arrangement of the Nissan's Sunderland operations, to more temporary hookups such as the ones that may be established in the construction business to bid on a specific contract.

There are various terms in use for such arrangements, most often *network organization*, *networked organizations*, or *virtual organizations*. As they are used today, they are given quite varied interpretations, ranging from the one we are discussing here (a close cooperation between separate organizations) to single organizations where a large part of the members rely on information technology to work away from the organization's premises. The last phenomenon does not necessarily involve any new organizational developments at all. As Mintzberg points out (1979), physical distribution of services (or people) does not necessarily involve any decentralization of power, especially not when the dispersal is facilitated by much improved communication equipment—which is precisely what makes it possible to keep the normal chains of command regardless of distance. Instead, I will apply the term *Meta-Organization* to entities consisting of two or more closely coupled organizations. This term serves both to indicate the layered nature of such organizational constructs and to avoid the misleading connotations that can be attached to the other terms.

Particularly, I find the term "virtual organization" superficial and misleading—if we extend to it the connotation of "virtual" in other computer-related terms, such as "virtual memory," "virtual disks," or even "virtual reality," (a perfect postmodern oxymoron), a virtual organization should be a simulated organization—the kind you play with in computer-based management games, an imaginary organization that does not affect reality at all. Only *real* organizations can act in the *real* world.

I also prefer to avoid the term "network," which has a distinctly egalitarian connotation that does not fit many of the actual examples. Whatever the relations are between the participants in the Nissan setup, for instance, they are surely not equal. Also, the term "network" seem to imply that one can fairly easily connect and disconnect to the structure; if there is one thing that is true about setups such as the one in Sunderland, it is that it takes copious amounts of work and long-time

commitments to establish it, and, once established, it is very expensive to change both setup and participants.

A Meta-Organization may of course also consist of equal partners, with no single partner occupying a dominating role. The present terms are used with a considerable degree of looseness, however—even fairly simple cooperation endeavors such as common marketing efforts, a number of common projects, or the use of email for coordination seem to arouse the enthusiasm of the IT community and earn the participants a pioneer status, even if it is not at all different from what was earlier achieved by traditional means. In contrast, to call a construct a Meta-Organization, the activities of the different participants should be directly and unequivocally coordinated through a common systems infrastructure, preferably with a high level of automation.

Constructs resembling Nissan's in Sunderland may also exist within the boundaries of a single organization, as when a company with a number of manufacturing sites unites the coordination of their operations with a unified production control and delivery system, providing the sales force with something that looks and behaves like a single source. However, when such arrangements are set up within a single organization, it will fall into other categories that have already been discussed earlier in this chapter—notably in the sections on the Machine Bureaucracy and the Divisionalized Form.

In a Meta-Organization the participating organizations are closely bound together by comprehensive systems and are usually member only one or two Meta-Organizations—at the very most a handful. In the case of multiple memberships, the organization will typically have a corresponding number of different sites, with each physical site serving only one particular Meta-Organization. The common systems will typically coordinate a large part or even the total set of activities in the members' organization. The process of setting up the Meta-Organization requires considerable efforts over extended periods of time and is replete with planning and design in painstaking detail. Once set up, is not easily dissolved, since the process of replacing a member is almost as costly as setting the whole thing up in the first place. Members are usually specialized in relation to each other and totally dependent on each other for the combination to succeed. Because of the efforts involved, the number of members in a Meta-Organization will typically be single-digit or low two-digit, but increasing standardization may facilitate larger Meta-Organizations in the future.

The main purpose behind Meta-Organizations is to automate coordination of processes across the member organizations. They will therefore depend on regulating models, emphasizing hyperautomation and programmed routines. Depending on the problem domain, they may also use implicit coordination. The main design parameters will resemble the Flexible Bureaucracy's: a strong formalization of the cooperation, vertical product specialization among members, vertical centralization both inside the member organizations and in the cooperative effort itself, and a preponderance of action planning. The Meta-Organization's technical system and preferred environment will be the same as the Flexible Bureaucracy's—indeed, the Meta-Organization's goal will, to a large degree, be to function (at least for production purposes) just like a Flexible Bureaucracy.

Configuration	Main Coordinating Mechanism	Main Design Parameters	Main Contingency Factors
Joystick Organization <i>Early examples:</i> <i>Possibly some centralized franchising operations.</i>	Regulating model, emphasizing system-supported supervision and programmed routines.	Centralization and organic structure. Little specialization, except sophisticated technostructure; little formalization.	Small to medium size, nonsophisticated technical system <i>or</i> hyperautomated operating core, simple, dynamic environment (possibly hostile), or strong power needs of top manager.
Flexible Bureaucracy <i>Early examples:</i> <i>Possibly some advanced JIT producers.</i>	Regulating model, emphasizing hyperautomation, programmed routines, and (depending on the problem domain) implicit coordination.	Behavior formalization, vertical and horizontal job specialization, usually market grouping or matrix structure, large operating unit size, vertical centralization and limited horizontal decentralization, action planning.	Medium to large, regulating, hyperautomated technical system, environment that is simple to moderately complex and stable to moderately dynamic, technocratic control.
Interactive Adhocracy <i>Early examples:</i> <i>Possibly some design projects using advanced CAD systems.</i>	Mediating model, emphasizing implicit coordination. Project oriented. Experts have much informal power.	Organic structure, selective decentralization, horizontal job specialization, training (large percentage professionals/experts). Functional and market grouping concurrently.	Often fairly small, but can become large if problem domain is well suited for modeling. Complex and dynamic environment, sophisticated and often automated technical system.
Meta-Organization <i>Early examples:</i> <i>Possibly supplier clusters such as the most advanced ones in the automobile industry.</i>	Regulating model, emphasizing hyperautomation, programmed routines and (depending on the problem domain) implicit coordination.	Strongly formalized cooperation between a number of independent organizations. Vertical product specialization and functional specialization among organizations, vertical centralization and limited horizontal decentralization, action planning.	Medium to large, regulating, hyperautomated technical system, environment that is simple to moderately complex and stable to moderately dynamic, technocratic control.
Organized Cloud <i>Early examples:</i> <i>Reservation systems, trading systems.</i>	Mediating model, emphasizing implicit coordination.	Nonmanaged, self-regulating, except for operation of providing system. Sophisticated technostructure.	Small to very large, simple but extremely dynamic environment, sophisticated and fully automated technical system.

Table 16-1: Main characteristics of the three modified and two new structural configurations. Format adapted from Mintzberg 1979.

In spite of the considerable efforts needed to establish them, I believe we will see a growth in the number of Meta-Organizations in the future, and I believe the most prominent form (at least for a long period of time) will be clusters of suppliers built around dominating buyers, even though there will also be a growth in cooperative efforts between more or less equal partners.

However, I am generally skeptical toward the very optimistic attitude many commentators take on the prospects for imminent success of more temporary arrangements of this kind (for example, in the construction business). This optimism, in my view, vastly underestimates the difficulties and efforts involved in going beyond the email stage and setting up really close cooperation based on the use of common (or communicating) systems in areas such as design and production control. Not only is the level of systems standardization still far away from what is needed for easy hookups; the organizations involved are almost guaranteed to use different data formats and, even more important, to have different understandings of important terms and categories. For instance, when Elkem⁸ wanted to compare the performance of the different furnaces at its Norwegian and American smelters, it turned out that the terms and parameters used to measure performance were so different between the sites that it was simply impossible to make a comparison. To obtain meaningful data, it would be necessary to carry out a full revision and standardization of the terms and parameters used at the different sites—an effort so overwhelming, and sure to meet with so much local resistance, that the project was shelved—at least for the time being.

Supplier Clusters

The cluster alternative, such as the Nissan example, is most easily established—not because it is technically easier or requires less work, but because a powerful buyer can demand cooperation from its subcontractors and more or less guarantee their benefits. Such a configuration will also tend to be more stable, since the leadership position will never be questioned. It is interesting, however, to speculate on whether or not there will be any impetus toward takeovers: Will the dominant buyer prefer to acquire the suppliers when they are already functionally almost a part of its own organization?

Early in the automobile era, there was a strong movement toward such vertical integration, with Ford's legendary River Rouge plant as the pinnacle (Beniger 1986). The ultimate ambition of Ford was to start with iron ore in one end of the factory and roll out finished automobiles in the other, keeping up an uninterrupted production flow throughout the complex. The task proved too difficult, however, and the River Rouge plant was not competitive compared to plants where materials, parts, and subassemblies were purchased from specialist companies.

It may be argued that information technology now has made it more realistic to tackle such complex coordination problems, as setups such as the Nissan plant indeed indicates. However, a number of the old arguments are still valid: Specialist companies will generally be more competent in their fields, since they serve several customers and accumulate superior experience, and since they can

⁸ The Norwegian metals company that is among the sponsors of this research project.

devote their full energy to a limited set of problems. The fact that they are not a formal part of the buyer's organization also means a reduced financial risk in case of a reduced demand for cars. I therefore believe that the Meta-Organization solution will be very stable in these circumstances, since (from the point of view of the dominant buyer) it combines the advantages of competitive know-how and reduced financial risks with a level of coordination fully comparable to what could be achieved through ownership.

The Meta-Organization will also tend to be quite stable in terms of membership, since a change of supplier can be very expensive for the suppliers involved as well as the buyer, due to the high costs of systems development and adaptation. In the Nissan Sunderland example, there is the added, stabilizing requirement that the suppliers must be physically located on the ring road around Nissan's main plant.

Equal Partners

Cooperation among equal partners seems to be more difficult to establish and maintain, which should not come as a surprise. The costs involved in setting up a Meta-Organization are high, and the benefits of cooperation can be difficult to ascertain before hand. Moreover, a considerable level of mutual trust must be present from the outset, since the implementation of common systems and common procedures implies that the participating organizations will have to reveal many of their internal functions, problems, and even company secrets to each other. Such close cooperation will also easily put constraints on the activities of the member organizations—it may, for instance, be considered disloyal to do certain kinds of business with companies that are competing with a partner.

A successful Meta-Organization consisting of equal partners will tend to be somewhat unstable, since the partners will be fairly likely to develop different ambitions for the evolution of the partnership. One or some of the companies may well try to build a leading position at the expense of others; some companies may want to proceed toward a merger; some will play brakemen; and some may leave altogether for what they see as more exciting opportunities elsewhere. In the event that the cooperation is successful and free of conflicts, merger may well be a frequent outcome in the longer term.

The Organized Cloud

At the end of Chapter 13, I discussed briefly the organizing effects of reservation systems. Even though we do not consider this far-flung mass of people an organization (as it was defined in Chapter 3), the fact remains that all these tens of thousands of travel agents and others—using, for instance, SABRE or Amadeus—are perfectly coordinated in those aspects of their work that pertain to reservations for the flights, hotels, and car rentals that are listed there. In those aspects, they are even more strongly and efficiently coordinated than most members of conventional organizations. As I remarked at the end of the discussion, even if this arrangement is not an organization, it is certainly organized—and I think it is unsatisfactory to dismiss this phenomenon as not

belonging to the realm of organizations just because it does not fit the traditional definitions. I propose to call it an *Organized Cloud*.⁹

Organized Clouds are by and large products of the computer age, as they are totally dependent on the powerful implicit coordination of the database to exist—they represent perhaps the most completely model-driven organizations we know today. Their databases represent complete mediating models of their problem domains, and all interaction between the members takes place via these models.

However, we may say that they have a humble ancestor in the traditional marketplace, and somewhat more discernible progenitors in the stockmarkets and commodity markets that developed after 1700 (the world's first real stock exchange was established in London in 1698)—especially since the late nineteenth century, when traders started to use telegraphs and telephones. However, it is the reach, capacity, speed, and the interactive nature of the database that has made possible the formation of really significant Organized Clouds, and it is the almost instant information dissemination and feedback provided by the systems that breathes life into the clouds and turns them into such powerful attractors.

Perhaps the most interesting clouds at the moment are the trading systems for stocks, currency, and commodities, which have substantially changed the behavior of the financial markets. Because of the almost instant conclusion of deals and broadcast of pricing, the pace of the markets have increased dramatically over the last decades, and in the last ten years the development of program trade (trade initiated by computers programmed to react to certain price levels) has increased the speed further. There is also a discernible trend toward growth in the biggest clouds (the trading systems based in London, New York, and Tokyo, the top three financial centers of the world), and trading is increasingly done on a global basis—especially for currency. As Yates and Benjamin (1991) point out, it will certainly be technically feasible to organize global markets. I think we can expect to see the development of a hierarchy of clouds on global, regional, and national bases, with the main focus on global and regional clouds. Currencies and commodities in particular are increasingly moving toward global integration, stocks probably toward a regional emphasis with a number of premium stocks traded globally, whereas small companies and local start-ups will continue to be traded mainly on a national basis. We may also see a development of some sector clouds on a global basis, with a single trading center (and thereby a single database) contracting most of the business in one industry—for example, shipping or gold mining.

The definition of an Organized Cloud is by no means clear. Clouds exhibit some of the properties of proper organizations (as defined in Chapter 3). If we start out with the two previous examples, it is fairly evident that cloud members do not have a common goal in the sense that members of a normal organization (should) have. Although cloud members are very interested in the availability of clouds suitable to their purposes, and will willingly pay fees to have access to them, they do not have a common purpose relating to any *specific* cloud—they do not look toward the interests of a cloud in the way any loyal organization member would look toward the interests of his or her organization. However, cloud members do have *similar* purposes: The travel agents all want to book airplane

⁹ The cloud metaphor here is derived more from astronomy than meteorology—picture the travel agents as a cloud of stars, held together by the gravity of the their common database.

seats and hotel rooms; the traders all want to trade. It is precisely these similar interests that bring them into the cloud in the first place. In their transactions as cloud members, however, they look only toward their own or their clients' narrow interests, and most of them will even be member of several clouds simultaneously: Travel agents will use several reservation systems, stockbrokers may have access to several trading systems. They will quite expediently use the one that offers them the best services and the most favorable terms, just as when they shop for other products and services in the marketplace.

It would also be a little meaningless to say that clouds have a division of labor—admittedly, the members all fend for themselves, but their activities are not part of an overall effort to achieve a common purpose. Essentially, clouds are non-managed: There is no central authority that can issue orders to the members, aside from determining some basic rules. Clouds do, however, have accepted mechanisms for reaching decisions (deals), and there is a rudimentary power structure concentrated around the framework of rules for actions within the cloud's sphere of interest: There are supervisory bodies, rules about membership, and mechanisms for expulsion or punishment in case of misconduct. There is also a common memory, represented by the central database, and there is definitely a communication structure. Finally, the activities of the members are coordinated in the sense that the actions of one member have impact on the actions of other members—within an accepted problem domain and within an accepted set of rules.

In contrast with the Meta-Organization, the Organized Cloud typically coordinates only one or a few of an organization's activities, and member organizations are typically members of several clouds. Membership is defined in terms of subscription to a service or something similar, and access is usually simple, by means of a defined (even standardized) interface. A new member can typically be up and running in a matter of days or even hours. The Cloud is built on narrow, standardized interaction; members all act alike in their transactions as Cloud members; there is no specialization and no interdependence except for the logged results of the (atomized) actions.

The Organized Cloud always depends totally on a mediating model, emphasizing above all implicit coordination. Its main design parameters are that it is essentially nonmanaged and self-regulating, except for the provision of the system itself. It has a sophisticated technostructure run by the providing organization—which is probably structured as a Machine Bureaucracy or Flexible Bureaucracy. It can be small or very, very large—membership in large clouds today number in the tens of thousands, some even hundreds of thousands, and in the future clouds will consist of millions of members. Typically, clouds exist in a simple but extremely dynamic environment. The technical system is of course fully automated.

If we accept markets and exchanges as Organized Clouds, the configuration has been around from time immemorial and has served very important purposes. It may even be argued that a market-based economy as a whole can be viewed as an Organized Cloud, although, on a societal level, it is inseparable from other powerful organizational structures, both political and nonpolitical. Indeed, clouds seem to be particularly well suited for market-like purposes where the objective is to match buyers and sellers, takers and suppliers, within a framework of open

information about crucial parameters such as prices, volume, and bookings. However, the much improved communication infrastructures provided by information technology, coupled with the unsurpassed coordinating powers of the database, provide an altogether new and vastly more powerful basis for this kind of organization. As the prices for systems and communication continue to fall, as more and more businesses and private homes are equipped with computers and data communication links, and as the Internet (or its eventual successor) provides standardized access and payments, the formation of clouds will become viable for purposes with much lower yields than airline reservations and transactions in the stock and currency markets. The Organized Cloud—in its modern guise an organization fully driven by a mediating model—could well emerge as one of the defining features of future societies.

Models and Configurations

In contrast with the one-to-one relationship between Mintzberg’s five coordinating mechanisms and five main structural configurations, the coordinating models proposed in Chapter 15 can support more than one configuration. The conclusions reached on this point in the present chapter are summed up in Figure 16-1.

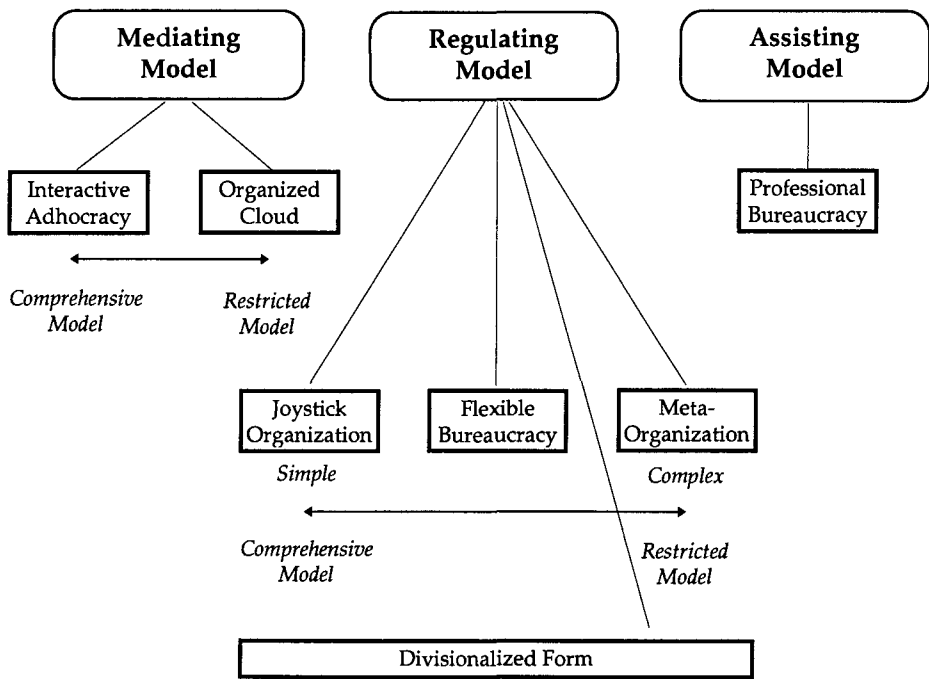


Figure 16-1: Main model dependencies of the various configurations.

The *Mediating Model* is the basis for both the Interactive Adhocracy and the Organized Cloud. However, there are differences. Models supporting Interactive Adhocracies will tend to be comprehensive, covering a broad set of activities, since they must support all or the major part of the activities in a complete organization. Models supporting Organizational Clouds, on the other hand, will tend to be quite restricted, supporting only the narrow activity that is the business of the cloud.

The *regulating model* will probably be the most widely used, at least for some time to come. It can support Joystick Organizations, Flexible Bureaucracies, and Meta-Organizations, as well as aspects of Divisionalized Forms. The Joystick Organization will tend to be simple and on the smaller side, but the model will be comprehensive in the sense that it supports a large part of the organization's total activities. The Meta-Organization will tend to be large and complex, but the model, although often quite complex in itself, will be restricted to those parts of the activities that are involved in the relationship between the partners in the Meta-Organization. The Flexible Bureaucracy will fall between these two—it will usually be more complex than the Joystick Organization, but less so than the Meta-Organization, and will usually employ models that are less comprehensive than the Joystick Organization and more so than the Meta-Organization. However, there will be great variation here—we may well see large Flexible Bureaucracies that are more complex than most or all Meta-Organizations, and there may also be Flexible Bureaucracies developing models as comprehensive as any Joystick Organization's.

Whereas the Meta-Organization is a configuration where certain aspects of separate, independent organizations are very strongly coordinated, the Divisionalized Form represents an arrangement to coordinate and control a number of organizations that are either part of or owned by the same corporation, and that are too complex taken together to be managed as one intergrated organization. The kind and degree of model support here will vary widely across the span of the different subforms of the Divisionalized Form. As noted under the discussion earlier in this chapter, highly integrated Divisionalized Forms may be able to use comprehensive models to reintegrate into Machine Bureaucracies or Flexible Bureaucracies, whereas true conglomerates may apply model support to achieve superior performance control and streamlined, common financing.

The third model, the *Assisting Model*, supports only one main configuration, one that is not among the IT-based configurations: the Professional Bureaucracy. The reason is that it is only assisting—helping professionals to perform their tasks better and/or more efficiently. Although it can be very advantageous (securing much greater consistency and quality in an organization's products and services) and also facilitate considerable reorganization of work in particular organizations, it cannot in my view support genuinely new structural configurations. Even a model-driven Professional Bureaucracy will remain a Professional Bureaucracy. Though an increased span of competence and programmed routines make it possible to reshape work processes to a certain degree, the structure of the organization as such will not change much as long as the professional judgment of experts, as well as the norms of the professional groups and of the greater professional community, lies at the heart of the organization and decides the main features of the work process.

Concluding Considerations

Long on Constraints, Short on Possibilities?

Some readers may perhaps at this stage feel a sting of disappointment—missing more spectacular technical predictions, more thrillingly novel organizational configurations, and more splendidly liberating organization structures. They may also feel that I have given too little attention to the more fashionable contemporary visions and ideas debated in the industry today. For instance, where is the virtual, networked knowledge organization based on multidisciplinary teams, assembled on the go for a particular challenge, meeting and working over the Internet and delivering its products in digital form directly to the prosumer? If you have not seen it here, it may simply be because you did not look hard enough—or because you mistook the physical topology of a technical device such as the Internet for an organizational structure.

To elaborate a little on this, let us take a closer look at the virtual networked organization outlined above. It would probably be a project organization put together to solve a particular task or deliver a particular product or set of products. To do so, the task at hand would have to be broken down into subtasks, which would be distributed among the members of the organization. These members would then have to coordinate their work and monitor it so that they would be able to produce the desired result at the agreed time, with the agreed quality, and within the agreed budget.

This coordination could be effected in several ways. First of all, one of the project members could act as a main contractor, determine everything, hire in the others, plan their work, and monitor and direct them as they progressed. What kind of organization would we then have? I leave it to the reader to decide. Then, of course, the task could be very unstructured and pioneering, demanding a highly creative effort and involved cooperation between a multitude of experts, all with a stake in the result. What kind of organization would we then have? Again, I leave the answer to the reader. If in doubt, you could consult Table 3-2 on page 58.

My point here is simply that an organization coordinated over the Internet is not necessarily a particular kind of organization (what is a “network organization” anyway?) any more than an organization coordinated over the telephone is—or an organization coordinated via telegraph or by smoke signals or messages speeded back and forth by horse riders. Here, we should especially remember the crucial difference between *dispersing* an organization physically and *decentralizing* its decision making. The nature of the communication channels has no necessary bearing on either, although better means of communication tend to make it easier to disperse people.

In my view, the metaphorical thinking dominating much of the debate about information technology and organizations today—which base organizational concepts more or less directly on products or technological solutions—is not so much a result of profound insight as it is a sign of our rather limited understanding of the deeper relationships between technological capabilities and organizational opportunities. Organization structure and functioning are more dependent on the nature of an organization’s main coordinating mechanisms and

decision making arrangements than on the nature of its physical communication channels.

Does this contradict the postulation of five new information-technology-enabled configurations earlier in this chapter? I believe not—since those configurations are primarily based not on new communication arrangements, but on *new methods for coordination*. New communication equipment may constitute a part of the technological basis for these new coordination methods, but its application does not necessarily create new organizational forms all by itself.

Practical Theory?

The main reason for the apparent lack of really exotic new organizational forms in my analysis is that my goal has been first and foremost to obtain results that have practical value. It is of course possible to make bolder predictions and envision more breathtaking organizational structures. There is, indeed, no lack of such prophecies. As I stated in the introduction, however, my basic goal for this dissertation was “to be able to offer my clients better advice and perhaps also help others who needed to understand how their organizations could really come to grips with this new and exciting technology.” I have therefore, throughout the analysis, striven to temper the purely technological possibilities with basic human constraints and preferences that will continue to limit and shape our use of any new technology.

To use a simple illustration from another technological domain: The fact that we can easily build cars that go faster than 250 kilometers per hour, and that most commercially available cars can go faster than 150, does not by itself make it practical to use such speeds routinely in densely populated areas. In fact, most countries do not deem it practical (and, hence, legal) to use such speeds under *any* circumstances (except for competitions on specially designated tracks). Likewise, the fact that information technology makes it possible for people who live in the most remote corners of the globe to work on common documents, pass email to each other, and even (in a number of years) confer via high-quality videophones does not by itself mean that organizations consisting of only such scattered individuals will be desirable or even viable other than for very special (and marginal) purposes. This is what the idea of the *space of constructible organizations* is all about—to delineate the realistically available alternatives for organizing work within a given culture and with a certain technological level.

In the introduction, I also invoked Daft and Lewin’s reference to Kurt Lewin’s remark that (in the case of encountering a new and uncharted territory) “nothing will be so practical as the development of a good new theory.” The question then, is whether I have achieved this goal—have the theoretical discussions in this dissertation provided any insights of practical value? Although I am not entirely impartial in this matter, I feel distinctly more at ease now than I did before I embarked on this project. If I get a question today about what future, IT-based organizations will look like, I can not only answer; I can present a coherent explanation for why I answer the way I do. Even more importantly, if a client asks me for help in deciding where the greatest opportunities in his or her organization are to be found, and how we should go about realizing them, I think I have a sufficient understanding of these matters to provide such help.

Some Suggestions for the Practical Use of this Dissertation

It is possible to render such assistance and to work for improvement in an organization on several levels, from the discharge of a single task to the structuring of the total organization. However, single tasks are normally not very interesting targets—and tasks are, in themselves, not tenable analytical units if you want to take full advantage of the new possibilities offered by information technology, since any task is likely to be a construction shaped by reigning conventions and traditional tools. Tasks are, moreover, loci of functions, and function-oriented analysis becomes all too easily bogged down in detailed descriptions of existing routines, obstructing our comprehension of what the organization is really doing and restricting our creativity in the design of new solutions.

To obtain a satisfactory level of insight and understanding, it will usually be necessary to analyze the problem domain quite carefully in order to secure both a tenable technological solution and a good implementation of it, even in quite small and simple projects. If the goal is (as it should be) to go beyond traditional arrangements and make full use of the new technology, it is very important that the initial analysis aims at getting behind existing work arrangements to capture the gist of the work at hand—or, rather, its objectives, since the work (the present tasks) itself may be superfluous within a new framework.

This is not a trivial requirement. A good example is the accounts payable function in Ford, described in Chapter 12. The key to the radical improvement achieved there was *not* a system that made the work of the accounts payable department more efficient; it was, on the contrary, the realization that the invoice itself—and hence most of the traditional accounts payable function—could be *eliminated* through the creative use of information technology. Such breakthroughs are the dramatic goal of most reengineering projects, but they are notoriously difficult to achieve—there are no surefire methods available, since in the end all radically new solutions hinge on the inspired creativity of the project team members. The best we can do in the way of methodology is to devise a number of coaxing excises—as Davenport suggests in his very thorough study (Davenport 1993)—and hope that creativity will manifest itself. Of course, such a process is not entirely serendipitous; good coaxing strategies will produce much better results than bad ones.

To avoid being trapped by existing procedures, it is necessary to employ a top-down approach in the initial analysis, starting with the primary objectives at the highest organizational level relevant to the project: What is, quite simply, the nature of the products and services we aim to provide? The goal should be to describe the desired implementation of these objectives at the level of products, services, customers, or clients, and to chart the way they are related. I would propose an object-oriented approach for this, since it will force us to focus precisely on the central objects and help us avoid function analysis—which all too easily get bogged down in a detailed description of existing tasks and routines. Consequently, I would use object-oriented concepts and charting notations as tools in this work and for documentation—for instance those provided in Jacobson, Ericsson, and Jacobson (1994). There are also several comparable

approaches available, although many would say that Jacobson et al. have presented the best one so far.

The analysis should then proceed on one to three main levels, depending on what is appropriate for the project in question: product-related possibilities, process-related possibilities, and structure-related possibilities. These levels correspond to the three levels of IT utilization discussed in this dissertation, as shown in Table 16-2. The boundaries between these three levels are of course blurred, but, by and large, there is a correspondence that is useful for both analysis and design.

Products and Services

Information technology has become one of the main enablers both for improvements in products and services and the development of totally new kinds of products and services. Very often, such advances hinge on one particular aspect of the technology. For instance, the development of services as diverse as today’s flexible and efficient airline reservation systems, automatic teller machines, and electronic toll fee stations has been totally dependent on the existence of powerful databases with remote access.

Level of Analysis	Level of IT Support
<p>Products and Services</p> <p><i>Changes in products and services or the development of totally new ones made possible by the use of information technology.</i></p>	<p>Direct utilization of information technology properties</p> <p>Discussions mainly in Chapter 9, some in Chapter 11, emotional defenses in Chapter 10.</p>
<p>Processes</p> <p><i>Cross-organization coordination and integration of tasks involved in the production and delivery of particular products and services or classes of products and services</i></p>	<p>Computer-dependent coordination methods</p> <p>Discussions mainly in Chapters 12 through 14, some in Chapter 11, emotional defenses in Chapter 10.</p>
<p>Structure</p> <p><i>Integration and information-technology-based coordination on the level of the total organization.</i></p>	<p>Active models</p> <p>Discussions in Chapters 15 and 16.</p>

Table 16-2: The relationships between levels of analysis and levels of IT support.

When we have a reasonably clear picture of the objectives of the organization unit we are working with, its customers, their requirements, and the kinds of products and services we would like to provide, our design work can be helped by a careful look at the discussions in Chapter 9 (“The Impact of IT on Individual

Capabilities”), which is about the strong and weak points of information technology and where it offers possibilities beyond earlier technology. Some of the central aspects of this discussion are further elaborated in Chapter 11 (“The Individual and the Group”), which also brings up the subject of self-service—a very important factor in several business areas in the future, not least financial products and services. To avoid being unduly constrained by the contemporary technological level, and to plan more realistically for some years into the future, Chapter 8 (“Information Technology Development Trends”) should also prove useful. Finally, to temper the techno-optimism and avoid the emergence of an unbridled “chip-chip-hurrah” mentality, I would recommend Chapter 10 (“Emotional Barriers and Defenses”) as mandatory reading.

Processes

Even though processes and services usually rest mainly on one aspect of information technology and thus depend directly on specific hardware and software products, their provision often involves more complex organizational processes spanning several organization units. Or, to view it from the opposite perspective, practically all medium-to-large organizations will have a number of processes that are central to their operations—some of which will produce and deliver products and services to outside customers/clients, and some of which will serve vital administrative needs. The key to these processes is coordination—of the efforts of those who are part of the process and of the customers, suppliers, and other parties inside and outside the organization.

To fathom the new possibilities for coordination provided by information technology, it should be useful to look at the chapters in Part IV. Chapter 11 (“The Individual and the Group”) is perhaps the least interesting here, but it offers some ideas on the usefulness and limitations of information technology in the coordination of workgroups and teams. Chapter 12 (“Routines and Automation”) should offer inspiration in the field of automation and task elimination, and Chapter 13 (“Coordination by Default”) provides important signposts for forays into the exiting realm of implicit coordination—a coordinating mechanism with huge potential. Chapter 14 (“Comprehension and Control”) outlines the possibilities arising from the greatly improved availability of information provided by information technology, especially the possibilities for centralization and decentralization and the concomitant migration of power within the organization. Finally, Chapter 10 (“Emotional Barriers and Defenses”) is useful for insight into avoiding the worst pitfalls of too technocratic approaches.

Structure

Today, most of the focus in the literature on information technology and organization is on the process level. Compared to the situation a couple of decades ago, when systems were still viewed mainly as specific tools for rather narrow functions in the organization, this represents a significant step forward. It is also a step up onto a higher level of complexity, perhaps the highest level we can presently handle with some confidence. However, as we gradually integrate our processes, even they will become candidates for closer integration and coordination. We then reach a level where the whole organization—and often a part of its environment as well—must be described in the same model and served

by a set of intergrated systems. This involves rising to yet a higher level of complexity—today barely within reach and only for organizations with a well defined and fairly narrow problem domain. Tackling integration at the organization level will require thorough understanding of the relationship between work, technology, and organization, and we will need advanced methods for analysis, description, and modeling. At this level, organization structure becomes one of the paramount issues.

Organization structure is a subject of considerable interest already at the process level, as key processes can involve large numbers of people and many organization units. To achieve the best possible results, it is always important to choose structures that match our objectives and the nature of the required processes and systems central to those processes. Sometimes, we have a choice between process designs calling for different structures, and it is important to know the strengths and weaknesses of those structures if the desired results are to be achieved. However, structure first becomes a paramount concern when we do not simply approach a single process, but try to go one step further and integrate processes, support functions, systems, and system use across the total organization.

When we work at this level, the matters discussed in Part IV are still important, but the most significant contributions should come from the two chapters in Part V. Chapter 15 (“Toward the Model-Driven Organization”) should serve to increase our understanding of the potential of conceptual modeling, and point the way to how such models can form the basis for really comprehensive computer-based systems and thus allow organizations to achieve new levels of integration and coordination. Chapter 16 (“The New Organizations”) discuss in greater detail what the potential is for different types of organizations. This should help make us more aware of the potentials of our own organization and the ways in which it could (and could not!) be transformed, maybe even into a totally different configuration.

Limits to Flexibility—But Not to Costs?

Throughout this dissertation I have tried to maintain a prudent attitude to the potential of information technology, especially to the possibilities we have for actually reaping its promised benefits through practical implementations. It is a very complex technology, difficult to master even in itself, and when it is inserted into such complex social constructs as our modern organizations, it is indeed a challenge to understand and manage the compounded ramifications.

I would therefore like to temper the fairly upbeat tone of the last two chapters with a few words of caution here at the end, with reference to my own discussions and to those taking place in the field of information technology and organizations today. I will consider two issues in particular: flexibility and cost, which are, in fact, intimately related.

First of all, I believe that the case for flexibility has been overstated in the general debate on these matters. I agree that information technology will allow us to build more flexible organizations that can respond more quickly and more accurately to changes in their environment and challenges from their competitors. Hyperautomation can accomodate much more variation than traditional

automation, and increased spans of competence will have similar effects. I have detailed my views on this subject in Chapter 16, particularly in the section on the Flexible Bureaucracy. However, as indicated in that section, this flexibility is highly circumscribed—if the organization comes up against a problem that requires responses outside the functional scope of its systems, it will often prove much *less* flexible than an organization without any systems at all. The reason is that in order to respond it will have to modify its systems, which is necessarily a thorough and costly process for any significant change.

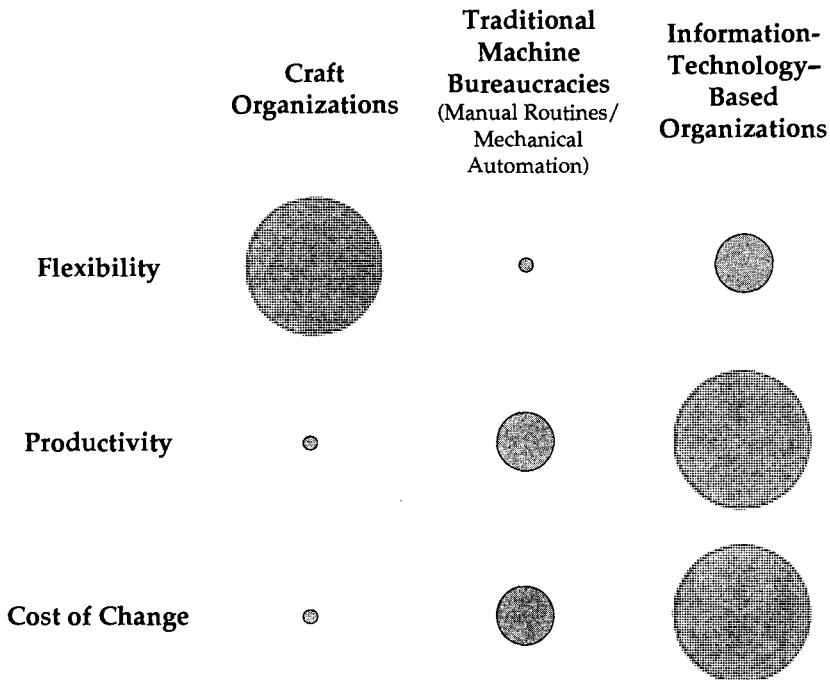


Figure 16-3: The relative merits of three generations of organizations. The areas of the circles do not correspond to exact values; they are only meant to illustrate the relative levels of performance and resource requirements of the different generations.

In theory, a computer-based organization can resort to ad hoc manual solutions just as easily as a non-computerized organization could do, but that will hardly be true in practice. The technology-dependent organization will neither have the workforce nor the culture to revert effortlessly to such traditional means of doing business, and it will often experience great trouble in the process. Not that it would necessarily help if it did revert to such means—the reason for its predicament may be that one or more of its competitors have developed more comprehensive systems capable of meeting exactly that kind of challenges. If so, even an adequate manual solution would be of little use, since it would be too

expensive to maintain over an extended period of time compared to the more efficient systems deployed by competitors.

If the new demands are such that they can be met by small adjustments or additions to the existing systems, these problems are manageable—a solution can be in place in a matter of days, weeks, or a few months (depending on the scope of the changes, the technical nature of the system, and the quality of the underlying models). However, from time to time, organizations that depend heavily on information technology will face a situation where the underlying structure of their systems and/or the basic technological solutions they employ cannot accommodate the necessary changes. They will then have to renew one or more of their systems completely, or face a situation where they may have to leave the field in question altogether, ceding it to the competition.

A total renewal of main systems is a major operation involving considerable risk, high cost, and a significant period of time. The thorough analysis, the modeling, the creative efforts involved in designing new solutions that will have to last for quite a number of years, the painstaking labor to work out the design in sufficient detail, and then the challenging process of rendering the design into executable program code, all this combine to make such projects major undertakings. Often, the great cost and considerable time required to do a thorough job on analysis and design tempt people to take shortcuts, frequently with catastrophic results: The systems either end up without critical functionality or the development process gets bogged down in endless and ill-structured modifications.

When talking about such major changes, it is also important to realize that after the introduction of new systems and routines, the people working in the organization will need considerable time to bring their performance up to par with the new tools and within their new work environment. No system can deliver peak performance without able and experienced operators, and all the important new adjoining routines must also be mastered. This is a fact often overlooked by the champions of perpetual change. Because the very fabric of any organization consists of well-established patterns of action, it stands to reason that one cannot rearrange those patterns too extensively too often and at the same time maintain an efficient organization. I started my career in the personnel department of a shipyard, and I still remember my experienced superior telling me that it would normally take a newly hired hand without previous experience a full year to reach the expected normal performance for an unskilled laborer there. It would be strange if it should take very much less time for others to develop the proficiency needed to make full use of advanced new computer-based systems in a new organizational setting with significantly redesigned tasks.

My message here is not that the problems are insurmountable, nor that they are so severe that they will pose a permanent threat to the information-technology-based organization. I merely want to underscore the fact that the increased productivity and flexibility provided by information technology comes at a cost, as do all other improvements, and that the use of this technology increases the height of the steps in the stairs leading upward—in terms of cost, efforts, *and* rewards—just as the transition from craft production to the modern organization did. Figure 16-3 illustrates the relative merits of these three

generations of organizations when it comes to flexibility, productivity, and cost of change.

It is of course possible to prepare the organization for the system renewals that has to come at certain intervals. Apart from maintaining adequate financial capabilities and an organization-wide realization that change is necessary (which are general measures important for any type of change), minor changes as well as major new development efforts can be speeded up and achieve much higher quality levels if the organization and its functional requirements are analyzed and modeled on a continuous basis—not just when a specific need arises. As I mentioned at the end of Chapter 15, any enterprise with aspirations to become a model-driven organization should have a pattern manager, and one of the duties of this office would be to continuously maintain and update the conceptual model of the organization and its problem domain. All changes to existing systems, as well as all new systems, should have this model as their foundation.

If such a model is sound, it will ensure that the systems that are implemented will be better prepared for later changes; the changes will be consistent in their basic features, and new systems will be much easier to integrate with older ones. In a large organization the maintenance of such a model may require the full-time work of several persons, but the cost involved will be recouped many times over through reductions in development costs and increases in systems quality.

Further Research

I have learned that no research report is complete without suggestions for further research. My experience as a reader also suggests that this section is often used to list all the subjects the writer would have liked to include, but could not (due to time and/or money constraints), did not know how to approach, or could not muster energy to collect data about.

Certainly, I could have delved deeper at most points in this dissertation, but the field I have tried to cover has been large, and I have had to restrain myself. (As the years went by, restraint became easier!) So elaboration would be welcome at almost any point. As I worked with the subject, however, I felt my interest more aroused at some points than others. In the more basic parts, I was particularly intrigued by the history of organization, a field that still has much interesting work left to do. We are basically social animals, and organization is an intimate part of our lives. As in most other areas, our capabilities and preferences vary and develop, and I am convinced that a closer study of organization and preferred organizational structures up through history would contribute to our understanding of the various historical epochs as well as contemporary and future organizations.

Further, it would be very useful to have critical appraisals and different perspectives on our basic organizational capabilities and the impact of information technology on those capabilities, as well as on their organizational repercussions.

However, when I really reach down to decide my own priorities for what I feel is most important for the nascent, cross-disciplinary field of information technology and organization, I would put two subjects at the top of the list: theory, and tools and methods for analysis and design.

Needed: Elaborations of Other Theoretical Approaches

In this dissertation I have used a particular line of organization theory as a starting point and tried to elaborate it in light of the new tools provided by information technology. My own feeling is that the attempt has yielded new insights into technology and organization theory alike, and I also think that the theoretical platform used here has shown considerable strength by being able to accommodate the extensions I have developed. I believe that this has served both to substantiate the kernel of the theory as well as to indicate a basic soundness in my own conclusions.

There are, however, a number of other theoretical approaches within the field of organization theory, and I think it would be of great interest to do similar exercises based on some of them. That would not only teach us more about the relationship between information technology and organizations, but also provide a test of the basic soundness of those approaches.

Also Needed: Methods for the Practitioners

My colleagues and I also need tools and methods in our everyday work. We need methods and tools for analyzing, understanding, and designing solutions for the ever more complex problem domains we will want to tackle with the help of information technology.

Most importantly, these methods and tools must have a kernel that is equally useful for organization people and systems people, so that they can serve as a basis for mutual understanding and cooperation between these two disparate groups. In the field of practical design of organizations work processes, such a cooperation is sorely needed, and I believe that a common toolbox and a common vocabulary are prerequisites to establishing that cooperation and getting it on a sound footing. If I am allotted more time for research, this is the direction I will take. I call on others to do the same.

Appendixes

A Approaches to Organization Theory

"Large organization is loose organization. Nay, it would be almost as true to say that organization is always disorganization."

G. K. Chesterton, "The Bluff of the Big Shops," in *Outline of Sanity*, 1926

Proliferation of Theories

The One Best Way

Accounts of the growth of organizational theory usually start with Taylor and Weber, but, as Scott (1987) remarks, organizations were present in the old civilizations. Even if we did not find the type of public or private formal organization that dominates our societies today, organization was nevertheless a theme for discussion several thousand years ago as well—as I have tried to illustrate by the quotation from Plato's *The Republic* in the caption for Chapter 5. In the section the quotation is taken from, Socrates has just started on his elaborate explanation of how a state comes into being, and how it should be organized in order to create just citizens. He is speaking to Glaucon and Adeimantus, two young men puzzled by the doctrine then current that justice is a mere matter of social convention, imposed from without. The two men are eager to discuss this with Socrates, who is of another opinion. Let us indulge ourselves by following Socrates for a few more paragraphs (the person replying here is Adeimantus):¹

My notion is, I said, that a state comes into existence because no individual is self-sufficing; we all have many needs. But perhaps you can suggest some different origin for the foundation of a community?

No, I agree with you.

¹ The quote is from II.368–9, on pp. 54–55 in F. M. Cornford's translation (Oxford University Press, London).

So, having all these needs, we call in one another's help to satisfy our various requirements; and when we have collected a number of helpers and associates to live together in one place, we call that settlement a state.

Yes.

So if one man gives another what he has in exchange for what he can get, it is because each finds that to do so is for his own advantage.

Certainly.

Very well, said I. Now let us build up our imaginary state from the beginning. Apparently, it will owe its existence to our needs, the first and greatest need being the provision of food to keep us alive. Next we shall want a house; and thirdly, such things as clothing.

True.

How will our state be able to supply all these demands? We shall need at least one man to be a farmer, another a builder, and a third a weaver. Will that do, or shall we add a shoemaker, and one or two more to provide for our personal wants?

By all means.

The minimum state, then, will consist of four to five men.

Apparently.

Now there is a further point. Is each one of them to bring the product of this work into a common stock? Should our farmer, for example, provide food enough for four people and spend the whole of his working time in producing corn, so as to share with the rest; or should he take no notice of them and spend only a quarter of his time on growing just enough corn for himself, and divide the other three-quarters between building his house, weaving his clothes, and making his shoes, so as to save the trouble of sharing with others and attend himself to all his own concerns?

The first plan might be the easier, replied Adeimantus.

That way very well be so, said I; for, as you spoke, it occurred to me, for one thing, that no two people are born exactly alike. There are innate differences which fit them for different occupations.

I agree.

And will a man do better working at many trades, or keeping only to one?

Keeping to one.

We need not go any further to sense the conviction underlying the text in *The Republic*: that there is a best way to organize, and that men are more or less preordained for their different occupations. In *The Laws*, Plato expressed this view even more clearly, giving a very strong statement on the one best way to organize a city-state. The notion that there is a "best way" to organize, and that humans were destined for their eventual positions, held sway (more or less) for almost 2500 years—although it was never a theory in the modern sense of the word. It is more accurate to say that nations as well as public and private enterprises were organized according to tradition and tacit knowledge, and that the structures and methods employed were viewed as "natural" or even ordained by God.

Classical Theory

The explicit theory of the one best way to organize is normally ascribed to the "classical" theorists, notably Frederick Taylor (*The Principles of Scientific Management*, 1913) and Max Weber (his theory of bureaucracy in *Wirtschaft und Gesellschaft*, 1922), but it is, as we have seen, much older, even if it then only concerned social organization.

Taylor's model sprang from factory production and Weber's from the offices of public administration, but they had a lot in common—notably a reliance on standardization of work, control of quality, fine-grained division of labor, and a strict hierarchy. They both strongly believed that the organizational models they proposed would prevail and eventually supplant all others because they were the most efficient.

Weber's interest was not in organization per se, but in the role it played in politics and economics in general. His discussion of bureaucracy therefore centered on its legal and political ramifications, as well as its part in the general *rationalization* of society—a result of the growing hegemony of rational means-ends relations. Weber viewed bureaucracy as the epitome of this development, working with supreme efficiency, and believed it would supersede all other organization forms. In Weber's eyes, this development was not necessarily in humanity's interest—on the contrary, he saw in the efficiency of bureaucracy a frightening potential to lock us into an "Iron Cage" of machine-like existence.

With Weber's own definition of sociology in mind, it is difficult to understand how he could be so sure of the inevitable and total domination of a single organizational structure. In that definition, he bases sociology squarely on an understanding of individual action and interaction, based on individuals' subjective understanding of their situation and the purpose of their own actions (Fivelsdal 1971). Supra-individual concepts such as structure, function, and system are rejected as causes. One should think that human variation would make room for more than one structural form, and at least that its grim advances could be blocked by a pervasive tendency among disgruntled individuals to choose (for subjective reasons) other solutions.

However, even if we take into account Weber's inclination to discuss institutional features by representing them in their ideal-type form in order to make the analysis clearer (and thus ending up looking more dogmatic than he really was), there is little doubt that he believed in the technical superiority of bureaucracy as an organizational form, and in its eventual triumph.

Henri Fayol and later Luther Gulick and Lyndall Urwick (*Papers on the Science of Administration*, 1937) emphasized formal authority and the role of direct supervision (Mintzberg 1979), but the spirit of their work was the same as Taylor's. You might even say, as Koolhaas (1982) does, that they were not really presenting theories of organization at all, but recipes—indicating the best solution for every type of activity, just as Plato did in the meticulous details of *The Laws*.

The early theorists' belief in the existence of final, superior solutions and their inescapable triumph can be viewed as an expression of their times—of the rapid progress of science and technology; the immense success of the mass-producing factory, the general increase in rational attitudes; and a rather naive belief in the simpleness of human affairs and their resemblance to physical systems.

Buckley (1967) has suggested that such theories represented a continuation of the "Social Physics" that (according to Sorokin 1928) arose in the seventeenth century. Its central notion was that man was a physical object, a kind of advanced machine; that behavior and social relations were subject to natural laws of the same kind as the laws of physics; and that man and society could be analyzed and managed accordingly. In politics and history the Marxian visions of inevitable

social transformations embodied much of the same spirit, even if the underlying analysis was more sophisticated.

The belief in the rationality and inevitability of things was thus a reflection of the contemporary beliefs in progress and technology, and the notion of the one best solution also appeals to our natural thirst for simplification—a faith in a “one best way” is much more reassuring than the acknowledgment of a bewildering array of optional solutions. As such, this view lingers on today—both in the minds of managers and in the offerings of consultants.²

Implied in this view is a notion of technological determinism—if there is a one best way of organizing, there must also be a one best way to utilize any new tool. Such a one-to-one relationship between a tool and its optimal use means that the tool itself will, by necessity, have strong bearings on organizational design.

It is quite obvious that Taylor included tools and machinery in his designs for factory organization, and that the properties of those tools and machines were important determinants for the design of jobs and the relationships between them. The connection may not seem just as plain when we look at Weber and his theories of bureaucracy—there do not seem to be so many tools in use. However, the most important organizational tool in history (at least before the computer) has probably been the art of writing, and Weber’s bureaucracy is explicitly based on written procedures and written information. In other words, if bureaucracy is the one best way to organize administrative work in a literate society, and it presupposes the use of writing, the properties of writing (as a tool) must be regarded as one of the most the most important determinants of bureaucratic organization—maybe even *the* most important.

In Scott’s (1987) classification of theoretical schools, both scientific management and Weber’s theory of bureaucracy are closed, rational system models. They presuppose that organizational actors are fully rational in all their decisions, that they always strive to achieve the organization’s expressed goals, and that the structure and functions of an organization are independent of its environment.

The Adequate Way

Simon’s Bounded Rationality

In the development of organization theory, the belief in the “one best way” and the closed, rational model of organizations (Scott 1987) gradually came under attack after World War II. One of the early attackers was Herbert A. Simon, who

² In the realm of consulting, it sometimes amounts to a tacit play: The consultant knows that the issue at hand is more complicated than acknowledged in his proposed solution, but he cannot emphasize the complexities, since he will then probably lose to a more “streamlined” competitor. The prospective customer knows that the consultant’s method is less than foolproof and that the project is very likely to encounter problems and cost overruns. However, he dare not choose an offer acknowledging the uncertainties, since he will then, in all probability, be criticized by others in his organization for choosing an inferior offer (not guaranteeing a painless process). The strategy in such projects is to have a project definition that is as narrow as possible, giving both parties the opportunity to treat the complications as extensions and additions to be negotiated separately. Thus both parties can save face and appear rational throughout.

developed a new theory of decision making, opposing the reigning concept of unbounded rationality in organizational and economic matters.

In his *Administrative Behavior*, first published in 1945, he attacked both the economists' image of "economic man" and the "rational manager" of the earlier management theorists. Although he seemed to accept the notion that there was an objective, theoretical "best way"³ in a given set of circumstances, he denied the possibility of finding this solution in practice (except perhaps, in some rare instances, by chance).

Simon's great common-sense realization was that humans operate with limited information and wits in an exceedingly complex world, and that they have no choice but to simplify, to operate with a bounded rationality, to *satisfice*—not maximize. In the beginning of Chapter V, the second of the two core chapters in his book, he says (1976, p. 79):

The argument of the present chapter can be stated very simply. It is impossible for the behavior of a single, isolated individual to reach any high degree of rationality. The number of alternatives he must explore is so great, the information he would need to evaluate them so vast that even an approximation to objective rationality is hard to conceive. Individual choices take place in an environment of "givens"—premises that are accepted by the subject as bases for his choice; and behavior is adaptive only within the limits set by these "givens."

In his introduction to the third edition of *Administrative Behavior*, he puts it even more strongly (1976, pp. xxvi–xxvii):

. . . the economists attribute to economic man a preposterously omniscient rationality. Economic man has a complete and consistent system of preferences that allows him always to choose among the alternatives open to him; he is always completely aware of what these alternatives are; there are no limits on the complexity of the computations he can perform in order to determine which alternatives are best; probability calculations are neither frightening nor mysterious to him. Within the past generation, in its extension to competitive game situations and to decision making under uncertainty, this body of theory has reached a state of Thomistic refinement having great intellectual and esthetic appeal but little discernible relation to the actual or possible behavior of flesh-and-blood human beings.

And a little later (1976, p. xxviii, italics in original):

Administrative theory is peculiarly the theory of intended and bounded rationality—of the behavior of human beings who *satisfice* because they have not the wits to *maximize*.

It follows from this that the realization of an objective "best way" is not a practical possibility, even if it may exist in theory. The objective, practical goal of organizational members is therefore never to find the optimal solution (even if they may think so themselves), but to find one that is *good enough* for their ends—which usually also means good enough for the organization to survive. It also

³In chapter II of *Administrative Behavior* he says (1976, p. 38): "Two persons, given the same skills, the same objectives and values, the same knowledge and information, can rationally decide only upon the same course of action."

follows that there must be many such solutions, and that different people and different organizations will more often than not choose different solutions.

In the original edition of *Administrative Behavior*, Simon does not discuss tools or technology. In light of his attitude toward decisions and organizing, however, it seems reasonable to infer a similar attitude to tools: In theory, there is always a one best way to use a tool in a given set of circumstances, but we can never hope to achieve in real life more than an approximation of this solution. Two of the added chapters in the book's third edition (1976) concern information technology. There, Simon discusses the effects IT will have on organization, but there are no deterministic prophecies, apart from the contention that computers will bring more automation and allow us to probe the alternatives more deeply when facing decisions.

Simon's theme of bounded rationality in decision making was further developed in collaboration with James March (March and Simon 1958) to cover the organization in general. In this work the organization's dependence on and interplay with its environment, which had been peripheral to the discussions in *Administrative Behavior*, were recognized as critical features. The central theme was that because of the limits in human decision making, organizations will never be fully rational—although managers will strive toward that goal. Organizations will also never be able to adapt completely to their environments, since the bounded rationality of their members will make their understanding of their environments incomplete and their adaptive behavior imperfect. The more rapid the changes in the environment are, the greater will their problems be. To help in this process, a repertory of short-term, adaptive responses are developed in organizations to cope with the more common variations in the environment without the great cost of developing new responses for each change. In highly volatile environments, adaptive change must be institutionalized as far as possible—although this is almost a contradiction in terms, and it will always be difficult to prevent adaptive structures from becoming rigid over time.

Scott (1987) also classifies the theory presented in *Administrative Behavior* as belonging to the closed, rational system model. This seems a bit unjust, since several passages in the book discuss interactions with the environment (for instance, the discussions in Chapter VI, "The Equilibrium of the Organization") and fully document that Simon does not believe that an organization is an island to itself. However, the theory of decision making that is developed in the book largely treats organizational decisions as something internal to the organization, and this may perhaps merit Scott's classification. Because the environmental connection is more pronounced in the book coauthored with March (March and Simon 1958), the theory presented there is classified by Scott as belonging to the open, rational system models. These models represent organizations as predominantly rational systems, but they recognize that organizations are continuously dependent on exchanges with their environment and must adapt to it to survive.

Transaction Costs Analysis

Another approach in the open, rational systems category is the transaction cost analysis developed by Williamson (1975, 1985). However, Williamson's interest in organizational structure centers on questions of organization size and the degree

of vertical integration. He argues that the cost of exchanging goods or services between people, departments, or organizations will decide whether or not a function will be incorporated into the organization.

The primeval, "natural" state of business activities can be seen as a situation with individual producers exchanging goods and services through the market. If markets or tasks (or both) grow so complex that the cognitive limits of the producers become overloaded or if the transaction costs increase for other reasons, there will be a pressure to increase the level of organization in order to overcome these difficulties. Applied on the current situation, this implies that existing organizations will try to internalize transactions if they believe they can execute them more efficiently than the market or if they become so complex that market-based solutions become intractable. For instance, an auto manufacturer will develop or buy its own dealer network if it believes it can sell more cars or fetch a bigger profit that way; an aluminum producer will buy into bauxite mines if it believes that this will shield it from dangerous price fluctuations.

If, on the other hand, an organization (generally assumed to be a hierarchy) becomes too inefficient in its internal coordination and market transactions become cheaper, it will tend to either crumble, shed functions, or split up. The transactions will then flow back into the market, as when a PC manufacturer decides to stop making its own motherboards because state-of-the-art boards can be bought cheaper and more conveniently on the OEM market.

Technology has a part in transaction theory insofar as it changes transaction costs in the market, inside the organizations, or both. Since information technology has a great potential for changing the conditions for coordination—both within and between organizations, it should be of great interest to the transaction cost perspective.

Williamson clearly believes that there is an optimum balance between internal and external transactions in any given situation, but he concedes that the ideal can not normally be realized, due to the bounded rationality of human actors.

The Several Best Ways

The Human Relations Movement

In his attack on the classical school of theorists, Simon was joined by the initiators of the human relations school of organizational thinking. The foundations for their arguments were laid down even before World War II, in the report from the Hawthorne studies by Roethlisberger and Dickson (1939), but, according to Scott (1987), it was Elton Mayo who gave the most influential interpretation.

The human relations school brought the individual and the social relations between individuals into focus. People in organizations were no longer seen only—not even mainly—as rational beings working to achieve the goals of the organization. It was discovered that they were just as much driven by feelings, sentiments, and their own particular interests—which could be quite different from what classical theory presupposed. Moreover, the new studies also showed that there was an informal structure in every organization, growing from the unofficial contacts people in the organization had with each other. This informal

structure could be just as important as the formal one for predicting the outcome of decision-making processes—sometimes even more important.

According to Scott (1987), there were a number of main themes investigated by the different approaches within the human relations school, and most of them are still actively pursued by researchers. The most basic is the insistence on the importance of individual characteristics and behaviors in understanding organizational behavior. This easily leads to an interest in the effects of different leadership styles, as well as in the effects of race, class, and cultural background. Formalization in work is strongly repudiated on the grounds that it is detrimental to both worker commitment and psychological well-being, and participative management, job enlargement, or, at least, job rotation is prescribed.

In fact, human relations theorists have always been eager to promote changes in organizations to produce what they see as more humane work places, and they claim that the less formal, more participative organization will also be the most productive. It is not unreasonable, therefore, to criticize at least the most ardent proponents of these views for prescribing “one best way” solutions just as much as the classical theorists (Mohr 1971). Mohr specifically mentions Likert and groups him with Fayol, Gulick, and Urwick in this respect. Mintzberg (1979) is especially harsh in his criticism, also referring to Likert. Scott (1987) notes that several decades of research has failed to substantiate most of the claims of the human relations theorists, and that they have also been criticized on ideological grounds for advocating a manipulative attitude toward workers on the part of management.

With their emphasis on humans and their psychological and social properties, the human relations theorists were not especially interested in tools and technology except as a source of repressive formalization. However, even if we might say that they inherited a belief in optimal solutions from the classical theorists, their theories implied that it was human needs and qualities, and not technology, that dictated the optimal organizational forms. In other words, it was in their view possible to design and operate organizations principally on the basis of human characteristics, and thus thwart what others viewed as technological imperatives.

In Scott's (1987) classification the human relations school belongs to the closed, natural system model. In contrast to the rational model, the natural model refuses the notion that organizations are rational instruments to achieve goals. On the contrary, they are first and foremost collectives of human beings, quite like social organizations such as families, neighborhoods, and societies. Their rational goals are often undermined by more personal or group goals, and the chief *real* goal of any organization tends to be survival at any cost. The informal structures are seen as the most the important ones, with the formal structures as little more than a stage set. Since the focus of the human relations theorists was clearly on the internal situation in organizations, it is not unreasonable to consider them closed system theorists, although there was also some concern for the effects of worker's organizational membership on their situation outside the organization.

Woodward

Whatever the specific merits of the human relations movement, there is no doubt that it constituted a major intellectual shift in the thinking about

organizations (Scott 1987, Hollway 1991). It largely created organizational studies as sociological and psychological disciplines, and the research on organizations increased rapidly. Among the new research projects were Woodward's pathbreaking studies of a number of manufacturing companies in the southeast of England in the 1950s (Mintzberg 1979, Clegg 1990), in which she showed how three basic production technologies strongly correlated with a corresponding number of organization structures: Bureaucratization increased as one went from unit or small batch production via large batch or mass production to continuous-process production.

First, this discovery led to renewed faith in technological determinism: there now seemed to be not one best way to organize, but rather a best way for each class of production technology—in Woodward's case, unit production, mass production, and process industry.

The Multitude of Ways

Sociotechnics

In England a group of researchers at the Tavistock Institute of Human Relations developed a distinct framework of their own. In addition to their "action" approach (seeking to induce change as part of their research), they also proposed that "the distinguishing feature of organizations is that they are both social and technical systems" (Scott 1987, p. 108). In their view, the core of the organization represented, so to speak, an interface between a technical system and a human (social) system. This implied that, in order to achieve maximum performance in an organization, it did not suffice to optimize only the technical or the social system, nor to search for the best match between existing technological and organizational elements. The goal should be a joint optimization of the two—creating a synergy that yielded more than could be achieved simply by adding the two together. Their preferred organizational solutions emphasized co-determination, internalized regulation, and workgroup autonomy.

They also discovered that changes at the workgroup level did not survive for long without compatible changes in the overlying structures—a discovery that was also made in a series of experiments with autonomous workgroups in Norwegian industry in the 1960s, inspired by the Tavistock group and directed by the newly founded Work Research Institute in Oslo (Thorsrud and Emery 1970). During their projects they also learned that the environment impinged on intraorganizational activities to a much larger degree than they had anticipated. Scott quotes Trist⁴ thus (Scott 1987, p. 108):

In our action research projects at that time, we and our organizational clients were baffled by the extent to which the wider societal environment was moving in on their more immediate concerns, upsetting plans, preventing the achievement of operational goals, and causing additional stress and severe internal conflict.

⁴ Eric L. Trist: "The Evolution of Sociotechnical Systems as a Conceptual Framework and as an Action Research Program," in *Perspectives on Organization Design and Behavior*, edited by Andrew H. Van de Ven and William F. Joyce (New York: John Wiley, 1981), p. 50.

Scott (1987) classifies sociotechnical theory as belonging to the open, natural system models. An interesting aspect of the theory is the belief that there may be many optimal solutions to a specific problem—the “joint optimization” of a particular technical and human system can be implemented in different ways that can be equally efficient. From this it follows that sociotechnical theory completely dispels the notion of technological determinism, a conclusion supported by Eason (1988). It also follows that there is an intimate interdependence between technology, the social system, and individual roles.

In my view, sociotechnics is here taking a position that is particularly relevant for information technology, even if sociotechnics was established as a theoretical framework before computers started to make themselves felt to any significant degree. When working with information technology in organizations, it is of utmost importance to be aware of the intimate interdependence between the computer-based systems, the individuals using them, the manual routines, and the organizational structure. Any serious attempt to optimize the use of information technology must acknowledge this reciprocity.

It is therefore quite remarkable that sociotechnical theory has remained so much out of fashion for the last decade (or even two), just the period when the use of computers has really exploded. One reason may be the general lack of interest in information technology that has plagued the social sciences overall (which probably explains the lack of a sociotechnical revival in Norway and the rest of Scandinavia); another is that those who were interested within the sociotechnical tradition tended to be drawn toward research on the cognitive aspects of computer use, especially the (literal) user interfaces of computer systems, neglecting the overlying (and much more important) question of the broader interaction of humans and computer systems in structural terms. A notable exception is the book *Information Technology and Organizational Change* by Ken Eason of the HUSAT⁵ center in England, which discusses the design and implementation of computer-based systems in organizations, broadly based on the principles of sociotechnical analysis and design, and with due concern for organizational matters.

Marxist Theory

Another theoretical approach with strong normative foundations is Marxist theory, which has traditionally approached Western organizations (both business and public) as instruments for control, domination and appropriation of surplus value. This is of course a consequence of the broader political analysis that forms the basis of Marxism, which lies behind a Marxist approach in any field. The normative aspect of Marxist theory usually manifests itself in a critical approach to existing practices, and there is much less emphasis on prescriptions for alternative arrangements, except on a societal level. Most suggestions have been centered around models for collective ownership.

Because Marxist theory is explicitly political in its outlook, it will generally hold that investigators cannot remain neutral, but will have to choose whether to legitimate and support existing practices or to transform them in ways that serve

⁵ HUSAT: *Human Sciences and Advanced Technology Research Centre*, a part of the Department of the Human Sciences at Loughborough University of Technology.

the interests of the people employed in them. Most other theories are seen as—consciously or not—legitimizing exploitation and serving to maintain existing organizational forms. Therefore the dialogue between Marxists and people working within other approaches has, at times, been quite strained.

Focus in Marxist analyses has, quite naturally, been on organizations as power systems, and the objective has generally been to reveal the nature of the suppression they represent, especially as instruments for capitalists and capitalist society. Braverman (1974) is an example of such an approach.

Marxist approaches insist that the political and economic context will strongly affect organizational structure and functioning, and advocate the necessity of historical analyses. They therefore view organizations as open systems. In addition, they maintain that the internal structure and functioning of organizations is largely a consequence of the specific interests of persons or groups of persons, both within the organization and outside it—that is, they are definitely constructed—and not simply a consequence of more or less neutral contingencies. Scott (1987) therefore classifies these approaches as belonging to the open, natural systems category.

Marxist theory's attitude to technology has been varied. Often, it seems like it espouses technological determinism. Braverman discusses this tendency, but argues vigorously that it is not grounded in Marx's writings (1974, p. 20):

Within the historical and analytical limits of capitalism, according to Marx's analysis, technology, instead of simply *producing* social relations, is *produced* by the social relation represented by capital.

Braverman's approach to technology thus resembles the action and constructivist approaches described later. However, Braverman's conception is more narrow, as he seems to think that the "capitalist property relations" dictate both the form of social relations and the labor process within the enterprise. Instead of technological determinism, we therefore get a kind of social determinism, where one subset of relations—property relations—determines the rest and thereby indirectly determines the way technology is employed.

Contingency Theory

Woodward's technologically based modifications of the "one best way" approach were soon supplemented by other studies, which refuted even the modified determinism she proposed (Clegg 1990, Mintzberg 1979). The Aston studies, for instance, pointed to size as the determining factor; other studies pointed to age, product diversification, the degree of stability in the environment, cultural factors, and so on. This new diversity was also corroborated on a more general basis by open systems theory, which showed that both *equifinality* (same result from different starting conditions) and *multifinality* (different result from same starting conditions) are facts of the systems world (Bertalanffy 1973). The emerging central theme for the theory building on these findings was that design decisions depend on environmental conditions, and that those organizations whose design and internal arrangements best match the challenges they meet in the environment will be the most successful (Scott 1987). The term *contingency theory*, which has since been used to designate this body of theory, was coined by

Lawrence and Lorsch in their (1967) book *Organization and Environment: Managing Differentiation and Integration*.

Since then, studies of contingencies have made up the main body of organization research (see Mintzberg 1979 and Clegg 1990 for thorough discussions), and variations of systems approaches have dominated. Scott (1987) classifies the “classical” contingency theory of Lawrence and Lorsch as belonging to open, rational system theory—open because of its emphasis on the decisive dependencies between organizational structure and the environment; rational because it still views organizations as predominantly rational instruments for achieving specific goals.

Scott also identifies a direction he calls the strategic contingency approach. It shares the main tenets of contingency theory—that organizations are open systems that differentiate structurally in order to respond to challenges and opportunities in their environment. In addition, it acknowledges that individual organization members and organization departments vary in their interests, motives, and power, which means that organizations must be viewed as coalitions, and not monolithic actors. A primary source of power is the extent to which an individual or group is vital in dealing with the uncertainty posed by the environment. According to Scott, a seminal work in this tradition was Crozier’s *The Bureaucratic Phenomenon* (1964).

For contingency theory, technology is just one of many contingencies (although one of the most important ones) that shape organizational structure and behavior. Although different production technologies are viewed as conducive to different organizational structures, the relationship is not seen as deterministic—contingency theory recognizes that there are generally too many variables that have bearing on organizational structure, both external and internal to the organization, for a single one of them to dominate completely. The diversity in real-life combinations will also make it unlikely that the same technology always produce the same organizational impetus.

Technology is, however, as far as I have been able to ascertain, generally perceived as production technology. It is therefore looked upon as something external to the organizational efforts themselves, a given factor that organizations must adapt to—not a tool that may change the possibilities or modes of organizational adaptation in itself, as sociotechnical theory implies and information technology promises.

Organization as Patterns of Action

The fact that organizational members and departments vary in their interest, motives, and power has been developed further to what Scott (1987) calls *theories of negotiated order*, covering both the symbolic interactionism of Goffman and the action approach of Silverman. Their central theme is that people do not behave; they *act*—only inanimate matter “behaves,” and only its behavior can be understood through an observation of the behavior itself. People always interpret the situations they are in and their own actions, and they attribute meanings to them. To understand the logic of human actions, we can therefore not rely on observation alone; we must also understand their subjective meanings for the people involved. As Silverman says (1970, pp. 128–29):

In order to make sense of an act, the observer must place it within a category he can comprehend. He might distinguish, for instance, between an act associated with work and, say, an act of friendship. At the same time, however, the act will have a certain meaning to the person who carries it out and to the people at whom it is directed. What the observer takes to be merely the repetition of the same physical action may imply totally different meanings to those concerned according to the way in which they define each situation. By concentrating on the behavior itself, it is possible to miss totally its significance to the people involved and, therefore, to be unable to predict with any accuracy the way in which those at whom it is directed will react to it.

Theories based on behaviorist views are therefore rejected—organizations cannot be seen as behavioral systems reacting to external and internal stimuli in order to adapt and secure survival. Processes cannot be treated as objective facts, something external to the individual actors (Silverman 1970, p. 130):

People assign meanings to situations and to the actions of others and react in terms of the interpretation suggested by these meanings. Thus they may respond differently to the same objectively-defined stimulus: the same supervisory behavior may be interpreted as a friendly act by one group of workers (who, because they also desire supervision of this nature, react in a favourable way), or as an illegitimate attempt to win their sympathy in order to accomplish objectives opposed to their own. The same individual even may, at different times or in different situations, assign varying meanings to what appears to an observer to be the same act.

Meanings are given to us through the social environment we grow up in; they grow from the history and present structure of society and especially the part of it that we belong to. They are sustained through our everyday actions, through our compliance with role-expectations—when we believe we are acting “naturally,” in the only possible way, we are in fact only reinforcing prevailing meanings. From this follows that meanings are also socially changeable, and changes can occur both through disruptive actions and through gradual developments, since we never comply completely with expectations, and new expectations may appear.

Organizations are therefore (just as society itself) social constructs, which exist because their members and their outside contacts continue to act according to sets of role-expectations—sets common to society and to peer and other groups, as well as sets peculiar to the organization. Therefore, Silverman argues (1970, p. 153):

. . . the relationship between organisational structure and a changing environment will not be mechanical but will be governed by the definitions of the situation used by the participants. For instance, whether a technical innovation is incorporated into an organisation will be determined not by an impersonal process whereby the organisation ‘itself’ acts to maximise efficiency but by the relevant structure of social relations and orientations.

Scott (1987) classifies this approach as belonging to the open, natural system models. Silverman (1970) himself viewed action and systems explanations as conflicting, since he perceived their views of the nature and consequences of social order as very different. Indeed, he did not consider the action approach as a

theory at all, but more as a method, a “frame of reference” for the analysis of organizations.

Weick (1979) describes organizations as accomplished by processes, and those processes in turn contain “individual behaviors that are interlocked among two or more people” (p. 89). When the behavior of one person is thus contingent on the behavior of others, these contingencies are labeled *interacts*. When the interaction is reciprocal, so that both parties’ actions are contingent on the other, it is called a *double interact*. Regular patterns of interlocked behavior produce the organizational structure.

By and large, the writers in this tradition have, from the beginning, considered technology a part of the environment, something that organizational members relate to with reference to the meanings they attribute to it and to their own situation. At least for Silverman, this is quite evident from the preceding passage.

Some of the writers that inspired Silverman (notably Peter Berger and Thomas Luckmann) have also been foundational for a similar approach, called *institutional theory* (Scott 1987). They maintain, like Silverman, that social reality is a human construction, continuously recreated through social interaction. In this interaction there will be recurring patterns, and certain actions will acquire a commonly understood meaning. This process is defined as institutionalization (Berger and Luckmann 1967, p. 54, italics in original):

Institutionalization occurs whenever there is a reciprocal typification of habitualized actions by types of actors. Put differently, any such typification is an institution. What must be stressed is the reciprocity of institutional typifications and the typicality not only of the actions but also the actors in institutions. The typifications of habitualized actions that constitute institutions are always shared ones. They are *available* to all members of the particular social group in question, and the institution itself typifies individual actors as well as individual actions.

This approach has also been adapted to organizations, and Scott points to Meyer and Rowan (1977) as a prominent example. Although they recognize that many organizations are structured mainly according to the demands made by their technology and work activities, Meyer and Rowan argue that a large number of organizations “reflect the myths of their institutional environments instead” (p. 341). Norms of formal rationality have not only become sufficiently pervasive in modern societies to be institutionalized; they have become so entrenched that they have acquired the status of myths—beliefs so widely held that they are beyond objective testing, beliefs that are true precisely because they are believed. These myths of rationality will then not only present a compelling pattern for organization, but also provide the organization with legitimacy in the wider societal context.

More recently, theorists belonging to the tradition of social constructivism (such as Trevor Pinch, Wiebe Bijker, and John Law) have also turned to the subject of technology. They argue that technology is not a pure phenomenon extraneous to society, developing according to its own internal laws of scientific logic or technological necessity. On the contrary, even technology is socially constructed, under the influence of a wide range of heterogeneous factors—concrete technologies always represent compromises between human actors with specific

interests. And, accordingly, these compromises (and hence the successful technologies) might always have been different. As Bijker and Law say (Bijker and Law 1992, p. 3, italics in original),

Our technologies mirror our societies. They reproduce and embody the complex interplay of professional, technical, economic, and political factors. In saying this, we are not trying to lodge a complaint. We are not proposing some kind of technological witch hunt. We are not trying to say, "If only technologies were purely technological, then all would be well." Rather, we are saying that *all* technologies are shaped by and mirror the complex trade-offs that make up our societies; technologies that work well are no different in this respect from those that fail. The idea of a "pure" technology is nonsense. Technologies always embody compromise. Politics, economics, theories of the strength of materials, notions about what is beautiful or worthwhile, professional preferences, prejudices and skills, design tools, available raw materials, theories about the behavior of the natural environment—all of these are thrown into the melting pot whenever an artifact is designed or built.

Technologies therefore cannot provide their own explanations, and technological determinism cannot be valid. Technologies can only be understood as part of a greater social context. There is no last instance, no single "driving force" behind change. And, like the social structure itself, technology is always an emergent phenomenon—a given technology or product must be sustained through recurring patterns of interaction, otherwise it will fall into disuse and disappear from the scene. Social structures and technologies are therefore parts of the same continuum, all shaped by human action and developed, sustained, or obviated by the actions of innumerable individuals.

Postmodern Approaches

There are a number of other "traditional" approaches to organization theory as well—such as the population ecologists, who study selection processes among populations of organizations with concepts and methods adapted from biology (Hannan and Freeman 1977). However, I will wind up this section instead with some organizational aspects of what has been termed *postmodern theory*.

Whereas the 60s and 70s were dominated by the development of the various versions of contingency theory, the last 15 years have witnessed a rapid proliferation of a bewildering array of theoretical perspectives, moving far beyond the modest pluralism of the original contingency theories. As Reed says (Reed 1992, p.1),

. . . there is general agreement that the 1970s and 1980s were a period of considerable intellectual instability, not to say upheaval, within the field of organization studies.

Not only have factors such as size, production technology, environment, and age come into focus; likewise have power arrangements, politics, culture, and history. A number of organization researchers have left what they see as drab, constrictive old paradigms for the exciting turbulence of postmodernism, chiefly inspired by developments in philosophy and literary criticism, with the main illumination coming from the works of Jean Baudrillard, Jacques Derrida and

Jean-François Lyotard (Hassard 1993), Parker (1992), Hassard (1993), and Thompson (1993) see two main schools of thought in postmodern theory, which also apply to postmodern organization theory: One is epistemological, presenting postmodernism as a theory of knowledge, a way of seeing the world; the other is ontological, presenting it as a description of a historical epoch. The difference between the two is quite substantial; indeed, as Parker (1992) and Thompson (1993) note, it is difficult to understand how the two approaches can be compatible.

Postmodernism as Epistemology

The epistemological approach is by far the one that constitutes the most decisive break with "conventional" science—according to Hassard, its defining feature is its insistence that there cannot be unequivocal relations between forms of representation (symbols, such as words and images) and an objective, external world. This means that we cannot ever really discuss "real," external phenomena, such as nature or even social structure—all such discussion becomes just a ("serious") play with words, whose meanings are impossible to ascertain. Theory formation the way we know it is therefore also impossible. Consider, for instance, Gergen's position on organization theory (Gergen 1992, p. 210):

In my view the value of organization theory does not lie in its accuracy, how well it matches or reflects the way things are. (In what way can words be matched against visual images, sounds, and the like?) Theory cannot be evaluated by its capacity to predict, for words in themselves are simply sounds or markings, lifeless and inert; words in themselves do not predict. Rather, theory gains its importance from the activities which it enables, which essentially means, by the way in which it figures in ongoing patterns of relationships.

The method for revealing this lack of correspondence is Derrida's *deconstruction*—a tool for exposing the inherent contradictions in any text. The term "text" is here given a wide interpretation, including both written and verbal communication, as well as the social context in which the communication and the deconstruction itself takes place (Hassard 1993). Derrida argues against the notion that language is just a medium for the communication of thoughts ("logocentrism"). If words cannot truly represent an objective, external world, it is equally impossible to have them represent "objective" aspects of the soul, mind, or reason. Deconstruction, meaning simply the opposite of construction, is a method for revealing the way text is constructed as well as the contradictions and dynamics inherent in it. Central here is the concept of *différance*, a word coined by Derrida to fuse the two meanings of the French word "différer"—to differ and defer. Gergen exemplifies (1992, p. 219, italics in original):

The postmodern drama begins, however, with the realization that the 'rational sayings' available to the individual are of indeterminate meaning. Derrida's (1974⁶) concept of *différance* is most applicable here for, as Derrida proposes, the meaning of any word or phrase is derived from a process of *deferral* to other words or phrases that *differ* from itself (with the single concept, *différance*,

⁶ Derrida, J. (1974): *Of Grammatology*. Baltimore, John Hopkins University Press.

representing the simultaneous and conflated processes). Thus, for example, a bit of corporate rationality embodied in the words 'Let's be logical about this; the bottom line would be the closing of the Portsmouth division' does not carry with it a transparent meaning. Rather, its meaning depends on what we make of words like 'logical' 'bottom line' 'closing' and the like. These meanings require that we defer to still other words. What does the speaker mean by the term 'logical' for example? To answer we must defer to other words, like 'rational' 'systematic', or 'coherent'.

But now the plot thickens, for at the outset it is clear that there are multiple meanings for such terms as 'logical', 'bottom line' and the like. Or, as it is said, they are *polysymous*, they have been used in many contexts, and thus bear 'the trace' (in Derrida's terms) of many other terms. For example, 'logical' can also mean 'right thinking', 'conventional', or 'superior'. Which of these does the speaker really intend? Yet, again, convolutions of complexity; for, as we find, each term employed for clarifying the initial statement is itself opaque until the process of *différance* is again set in motion. 'Right thinking' can also mean 'morally correct', 'conventional' can also mean 'banal', and so on. And in turn, these terms bear the traces of numerous others in an ever-expanding network of significations. What seemed on the surface to be a simple, straightforward piece of advice, on closer inspection can mean virtually anything.

Différance is one of the five concepts emphasized by Hassard (1993) as the key elements of the postmodern approach to knowledge. The other four are *representation* (the genuine order of things cannot be discovered), *reflexivity* (one must be critical of one's own assumptions), *writing* (language does not represent concepts with independent existence in the object world), and *decentering the subject* (the deconstruction of subjective awareness as an artifact of language).

Postmodernism as Ontology

The epistemological approach to postmodernism is not easy to understand, and it may be even harder to accept—it has altogether left what more "traditional" researchers are ready to accept as serious science. The ontological approach, however, is more accessible. The central notion here is that society is moving into a new era, which differ from the previous "modern" age in significant ways (Hassard 1993, p. 3):

. . . the social and economic structures reproduced since the industrial revolution are now fragmenting into diverse networks held together by information technology and underpinned by what Lash and Urry (1987⁷) calls a 'postmodernist sensibility'. The emphasis is placed upon 'disorganization, untidiness and flexibility'.

The goal for this strain of postmodern research will therefore be to identify the features in the external world that supports this hypothesis (Hassard 1993). A part of this tradition is also the use of other "post-"combinations, such as post-Fordism, postcapitalism or postindustrialism, which all signify a break with the "modern." Within the field of organization research, Hassard points to Clegg's *Modern Organizations* (1990) as a "work which reflects the 'epoch' orientation." Clegg is also an example of a postmodernist with a definite link to "conventional" theory and methods, and a comparison between Clegg and Gergen supports Parker

⁷ Lash, S., and Urry, J. (1987): *The End of Organised Capitalism*. Oxford, Polity.

(1992) and Thompson's (1993) contention that the epistemological and ontological approaches within postmodernism cannot be accommodated under one roof. Clegg would probably disagree, but he acknowledges the distinction between the epistemological and ontological approach.

Clegg's purpose with *Modern Organizations* is twofold: to present empirical evidence for the emergence and growth of postmodern organizational forms and, through the concomitant discussions, to tap into "important debates about the nature of modernity and postmodernity" (1990, p. 1). To highlight the main focus of his book, and also what he believes to be the defining quality of postmodernity, he continues (1990 p.1):

Rather than reflect all of the nuances of this complexity the discussion attempts to steer a simple and direct path through the debates linking modernity with postmodernity. It will do so by focusing on a common core component: that of the direction and the degree of 'differentiation' or division which characterize a period. Postmodernity, it is suggested, may be distinguished from modernity by its reversal of earlier tendencies to increasing differentiation.

The core, then, of modernity is differentiation—in organizations, especially the increasingly fine-grained and rigid division of labor. The core of postmodernity is de-differentiation—the gradual integration of jobs, the blurring of areas of responsibility, the increasing overlap of functions, the increasing flexibility, and the team attitudes.

To Clegg, Weber is the fountainhead of modernity, the great creator of rational order who casts his shadow over the whole field of organizational analysis. "Of course, it is in the nature of a colossus to cast a large shadow," says Clegg, who goes on, "The shadow will be given a name: modernism" (1990, p. 3). However, this modernity has no singular appearance, "organizations have been represented in various modernist terms" (1990, p. 3), such as the ones that have been presented on the preceding pages of this dissertation. Clegg views these all as competing hypotheses, "capable of adjudication," but argues that they are insufficient to explain the postmodern phenomena (Clegg 1990, p. 5):

... these theories are inadequate because even in their own terms they are not capable of dealing with the empirical variety of organizational realities which this text re-presents. Empirical realities are neither imaginary or whimsical: they cannot be side-stepped. They serve as an embarrassment to certain generalizing and universalistic tendencies in organization analysis.

Instead of what he sees as the overarching frameworks of modern organizational theories, Clegg suggests the use of what he calls "modes of rationality," where the focus is "on what agents actually do in accomplishing the constitutive work involved in organization" (1990, p. 13).

An agent can be a person, an organization, or a subpart of an organization. Agents act under a subjective rationality: They attempt to accomplish projects "which make sense in terms of the calculation which agents have available to them" (1990, p. 7), and they are "knowledgeable actors with a healthy regard for self-conceptions of their own and other's interests" (1990, p.13). However, subjective rationalities can differ widely, since any agent will be heavily influenced by the cultural and institutional values of their national frameworks,

which of course vary considerably. Therefore, organizational forms and practices cannot be universal; they will vary greatly from setting to setting, both across nations and within them, as agents develop their strategies in accordance with their perceived interests and the constraints of their local environments. Clegg refers here to Granovetter's (1985) concept of the social "embeddedness" of organizations.

These frameworks do not constrain agents absolutely, and they are not immutable, because they themselves are socially constructed phenomena. However, they change only slowly, and they represent the most important determinant both for how organizations are structured and for how the work. To substantiate this, and to counter what he perceives as a long-standing tendency to place excessive emphasis on empirical evidence from the Anglo-American sphere, Clegg draws his examples from other parts of the world, in Europe and (especially) Asia.

Clegg, then, views organizations as assemblages of agents on different levels, all acting under their respective local modes of rationality. They are significantly (although not totally) constrained by the cultural and institutional frameworks within which they are embedded, but they use their wits and whatever tools and methods they can muster to achieve their purposes (Clegg 1990, p. 153):

Organizations are human fabrications. They are made out of whatever materials come to hand and can be modified or adopted. Organizations are concocted out of whatever recipe-knowledge is locally available.

Around the world, Clegg argues, no discernible convergence toward a dominant organizational form can be found, as contingency theory, in his opinion would expect. Rather, we find a considerable range of functional alternatives.

Increasingly, he argues, organizations around the world—each in tune with its local environment—are assuming postmodern forms, breaking with the strongly regulated and highly differentiated form of modern organizations. Their characteristics include niche-based marketing strategies, multiskilled workforces with overlapping responsibilities and a craft-like attitude, and (if manufacturing companies) flexible manufacturing, most likely supported by information technology.

Do We Really Know Something?

After this tour of the craggy landscape of organizational theory, a newcomer to the field must feel inclined to ask if there is any help to get here at all—and a more veteran traveler may indeed question the possibility of establishing a sound platform for further inquiries. Organizations seem to be a little bit of everything. Gareth Morgan (1986) has struck a chord by presenting eight provocative *metaphors*—eight different outlooks on human organization, portraying organizations successively as machines, organisms, brains, cultures, political systems, psychic prisons, flux and transformation, and instruments of domination. By bringing forth this bewildering array of facts, theories, and conjectures, Morgan aptly illustrates the diversity in contemporary organization theory. His book and,

especially, some of the essays in Reed and Hughes (1992) force the question whether there are any commonly acknowledged, defining features of organization left at all. Are they all lost in the diversity (or even *anomie*, as Reed [1992] suggests) of the theorizing of recent years?

To me, the answer is a clear **no**. That is, there may not be any *commonly acknowledged* defining features anymore, but this is more a consequence of the theoretical debates at this point in time than of the nature of organizations and the people who make them up. If you discard the idea that it is possible to accumulate at least a base of common theory about organizations or if you draw the conclusion that any perspective is just as valid as any other, then you do not pursue different perspectives; you pursue a rather sterile *perspectivism*. You may amuse yourself and a number of others, notably people without any practical responsibility for organizations, but you will end up without influence on how organizations are actually built and run.

I do not dispute the value of different perspectives—on the contrary, they are mandatory for illuminating the rich texture of actual organizations, which is indeed Morgan's (1986) main purpose with the book. I therefore think some of the criticism, like Thompson's (1993), is a bit unjust. Morgan's stated purpose (in the introduction) is not primarily to build theory, but to explore and develop "the art of reading and understanding organizations." Organizations—or at least managers—use metaphors themselves, often quite consciously, to focus on certain interpretations. The slogan "marketing is war," which was quite popular some years ago, is an example of this.

However, the acceptance of different perspectives as useful tools for understanding organizations must not degenerate into the theoretical *anomie* that I feel is dangerously close to Gergen's (1992) point of view. To me, the most basic proof for the possibility of building theory is the simple fact that experience makes you better equipped both to understand organizations and to operate inside them. We know that most people who work their way through a number of organizations develop a "feeling" for organization that makes it possible for them to understand the nature and peculiarities of a new exemplar both faster and better than people without such experience. If, in addition, they have special talent (sensitivity) for understanding human affairs, they can become very adept, even in the absence of formal training or knowledge about organization theory. If organizations had nothing in common, if there were no basic rules that applied to how people behave in them, it would be simply impossible to learn from experience in this way—you would be back to square one every time you encountered a new specimen.

If practitioners, then, can develop such theories-in-use (Argyris 1980), theories they work by even if they do not make them explicit (or are even aware of them), there must be regularities and common traits in organizations that can be made the subject for explicit theories as well. And I think that existing theory, research findings, practical experience, and common human sense taken together makes it possible to build such theories.

However, accepting the viability of theory and the view that all perspectives are not equally important, it is just as vital not to fall in the other ditch—to select one narrow perspective and explain everything within its bounds, as classical theory, Marxist theory and transaction cost theory do. Theories built within one

perspective are not necessarily wrong, but they are doomed to cover only a part of reality. With that in mind, however, we can accept them as valid for their field and use them when they are relevant for our particular problems. Perhaps this is as far as we will ever get—organizations are exceedingly complex, and our wits are indeed limited. Maybe, however, that exactly this proposition of Simon's is an example that we may find valid general propositions after all! I cannot enter into that discussion here, however, because it would easily displace my real subject in this dissertation.

B A Brief History of Computer Systems¹

“We can chart our future clearly and wisely only when we know the path which has led to the present.”

Adlai Stevenson, *speech, Richmond, Va.*, 20 Sept. 1952

To understand the present status of the field of information technology, and the current development trends, it will be necessary to review its past history. It is short but packed with events and interesting people—so much that it will be impossible to recount the fascinating detail of the last 50 years here.² We will therefore have to contend with an outlining of what seem to be the main events.

A closer analysis of the technology immediately raises a dilemma, since a meaningful discussion of the subject is very difficult without reference to a number of basic technical matters. The risk in such a situation is always that the non-technical reader will be estranged, while the technically minded reader will be bored by the elementariness of the discussion. In the following, I have chosen first and foremost to cater to the non-technical reader, trying to explain the technical terms as we go along.

The Birth

Routine calculations have always been regarded a drudgery, and much work has been done up through the centuries to lessen the strain. As mentioned earlier, the first mechanical calculator was made by the German professor Wilhelm Schickard in 1623. Another (and much more famous) one was constructed by Blaise Pascal circa 1645 (Augarten 1984). Readers born before 1960 may remember the modern mechanical or even electromechanical desk calculators (with a motor instead of a crank), those thundering monsters of the preelectronic office. They

¹ The account given here draws mainly on Augarten (1984), but also on various contributions in Goldberg (1988), *Scientific American* (1977), and *Byte* (particularly 1985).

² Readers interested in a more comprehensive account are referred to Augarten's book. Detailed chronicles of key events or developments in the history of computer systems are published in a history series by the ACM Press (a division of the Association for Computing Machinery, Inc.).

were all designed to do simple arithmetic and were considered advanced if they could multiply and divide. For more specialized computational applications, various types of large mechanical calculators were devised and built right up to the 1950s. There were even machines that could solve differential equations—but they were cumbersome to set up, required highly skilled operators, and were painfully slow by our standards.

The birth of what is usually acknowledged as the world's first electronic computer, the ENIAC,³ illustrates the intimate relationship between our material needs, our creation of tools, and the tools' subsequent feedback on our creativity, spurring new branches of both science and business.

ENIAC was product of wartime urgency in developing new guns. As the American war effort accelerated, the number of new guns increased, as did the number of gun platforms—from ships to aircraft. To make gunsights, or elevation tables for the big guns, you have to calculate the trajectories of the projectiles, and, if you want to fire on moving targets, you must calculate how far in front of the targets you must point your gun. Those calculations were the job of the Ballistic Research Laboratory (BRL) of the Army's Ordnance Department. In 1943 BRL was falling behind the development of new guns and weapons platforms. They were depending on college graduates with mechanical desk calculators, and they were no longer able to provide all the new tables required. In their desperation they provided the funding for a speculative new project: the construction of ENIAC, an electronic calculator built explicitly to calculate ballistic firing tables for guns. When the machine was finished, however, the war was over—and ENIAC's most important contribution to the military effort came to be the basic calculations needed to design the hydrogen bomb (Augarten 1984, p. 131).

ENIAC was a speed marvel when it was first put into service. A skillful employee of the BRL (equipped with a mechanical desk calculator) needed three days to calculate a single trajectory for a typical piece of heavy artillery. BRL did have more advanced equipment, however. It had one of the most advanced analog, mechanical calculators of the day (a differential analyzer), which used 15 to 30 minutes for the same job—but it required a set-up time of about two hours. ENIAC did the job in 20 seconds, which was 10 seconds less than the shell itself needed to complete the trajectory when fired. And the calculations needed to build the hydrogen bomb were so complex that they probably would not have been possible without the aid of ENIAC. It was no midget, though—ENIAC weighed in around 30 tons, was 25 meters long and 2 meters high, and its 18,000

³ ENIAC (for "Electronic Numerator, Integrator, Analyzer and Computer") is generally acknowledged to be the first electronic computer, but there are other contenders as well, most notably the ABC ("Atanasoff-Berry Computer"), completed in 1942. The ABC, however, had mechanical components that severely limited its speed. ENIAC, a much more comprehensive and 100% electronic machine, was completed in November 1945 and officially inaugurated on 14 February 1946. It was built at the University of Pennsylvania, where you can still see it. The German Konrad Zuse built the world's first automatic, programmable, general-purpose calculator in 1941, but it was made from telephone relays, not vacuum tubes. It is interesting to note that one of Zuse's colleagues and friends, Helmut Schreyer, submitted a proposal for an electronic calculator (1,500 tubes, 10,000 operations per second) to the German Army Command in 1942 but was turned down—the army was confident that the war would soon be over and refused any project that did not contribute immediately to the war effort. (Augarten, 1984.)

vacuum tubes consumed 174,000 watts of electrical power. It could add 5000 ten-digit decimal numbers or multiply 333^4 such numbers in one second. In contrast, a reasonably powerful portable PC of today (1997) weighs 1.5 to 4 kilos, consumes a few watts of power and is more than 10,000 times as fast.⁵ The most powerful supercomputers (not counting special-purpose, parallel designs) are tens of millions times as fast as ENIAC.

Although ENIAC was programmable, it was very awkward to use as a general-purpose machine. To program the ENIAC, you had to know the machine almost as well as its designers, and a complicated program could take months to work out. Once you had written it down, you set up the machine by plugging cords (there were hundreds of them) into plugging boards which looked very much like old telephone switchboards, and flipped the larger part of several thousand small switches on the consoles. Data was provided by punch cards running through a card reader. This was not too bad as long as you calculated firing tables, which involved long series of calculations varying only one parameter. Other tasks, however, were extremely arduous—it usually took two days to set up ENIAC for a specific problem. Error correction, in particular, was a maddening task.

Clearly, the new tool would be much more useful if the programming could be simplified and one could dispense of physical rewiring altogether. The ideal solution would be if both program and data could be fed into an internal memory in the machine, where it could access them both while running—and thus save the considerable time it took to read data from external mechanical devices such as card readers. It did not take long for this to happen, but it did not happen in the United States: First to make a fully automatic, stored-program computer was a team at Britain's University of Manchester. The Manchester Mark I prototype went into operation in June 1948, and an enlarged and improved version, the Mark II, a year later. Based on the Manchester machine, Ferranti Ltd. was commissioned to build a computer for the British government. When it was installed at the computing center of Manchester University in February 1951, The Ferranti Mark I was the first computer ever delivered by a commercial manufacturer. Ferranti had beaten the American company UNIVAC⁶ by one month. The British, however, did not manage to capitalize on their early successes, and it was American companies that turned the manufacturing of computers into a new industry.

⁴ The sources are conflict here. Augarten says 333; a history of ENIAC residing on the University of Pennsylvania's Webserver (part of their virtual ENIAC exhibition commemorating the machine's fiftieth anniversary) says 14.

⁵ Speed is almost impossible to compare for processors so far apart in design and functioning. We can only indicate here that we speak of several orders of magnitude.

⁶ UNIVAC was started in 1946 by the two main architects of ENIAC—Presper Eckert, Jr. and John W. Mauchly. Because of financial difficulties in the start-up period, they sold the company to Remington Rand in 1950.

The Stored Program

Let us pause here briefly to consider the concept of the stored-program computer,⁷ an innovation that was absolutely crucial to the further development of the computer. ENIAC, more a calculator than a real computer in the modern sense, was programmed by physically wiring it, and data was fed through punch cards. Even as the first of its kind, it already approached the practical limits of complexity—as previously mentioned, programming it was extremely difficult and laborious. It was hard to imagine computers, designed in the same way, that could be orders of magnitude larger and more complex—the resulting amounts of wiring and switch throwing would make them completely unwieldy. It was a dead end.

The Manchester Mark I and the American EDVAC⁸ therefore represented a fresh start in computing, and set a course still followed by mainstream computers. Their tour de force was the abolition of the need for physical rewiring. Instead of being embodied in the positions of wires and switches, the Mark I program was set up as a pattern in electronic storage devices.⁹ The pattern was created as the machine read punch cards or tape, and it could therefore be changed in a very short time. The long setup time of ENIAC was thus eliminated, and the machine could even modify its own program while running. Because of its limited memory and computational capacity, the Mark I was a humble machine compared to modern ones, but it embodied all the principles of that new species: *the universal machine*. The essence of the stored-program computer is really its general nature—it is a logical engine, able to process all information that can be represented, directly or indirectly, by numerical values, and able to perform any operation on that data that can be represented, directly or indirectly, by logical statements. As such, it is not only able to solve equations, but to process text, sound, and pictures; control physical machines and production processes; and even simulate physical processes, if they can be represented numerically and logically. The same physical machine can do it all.

A Binary World

But even if computers came to be stored-program computers, they were still very difficult to program, as they did not understand any other “language” than the 0s and 1s of the binary number system they relied on. And we may just as well confront this basic issue here and now—a lot of the finer points about computers

⁷ According to Augarten (1984), Eckert and Mauchly were probably the originators of the idea of a stored program computer. However, the idea was worked out, refined, and committed to paper by John von Neumann, who later received the credit.

⁸ Electronic Discrete VARIable Computer. The development of EDVAC was also paid for by the Ordnance Department and started already in October 1944, about a year before ENIAC was completed. The EDVAC project inspired almost all computer efforts in the United States in the late 1940s (as well as some in Britain) and was therefore immensely influential, even if the machine itself (due to patent quarrels and bureaucratic delays) was not completed until 1952.

⁹ The Manchester Mark I used CRT tubes (like the picture tubes of television sets), where information could be stored as charged spots on the phosphorus in the tubes. CRT tubes were widely used for the first few years of computer construction, but were later supplanted by more reliable and efficient memory devices.

are much easier to understand if one gets a grasp on the two fundamental pillars of computer number crunching.

The first is the number representation. Digital computers cannot operate with decimal numbers or letters directly, as did their mechanical forebears. Decimal (or base 10) math is very well suited for gears and axles, but not for the electronic switches that computers rely on. All they can do is discern the difference between a low voltage (or none) and a sufficiently higher voltage. Computers therefore depend on a binary (base 2) number system, where a lower voltage represents 0 and a higher voltage represents 1. This, by the way, is the ubiquitous “*bit*” of the digital computer world—a 0 or a 1 represents one “*bit*” of information. By using enough positions, or bits, it is perfectly possible to represent any decimal number with 0s and 1s, and numbers can again represent letters: The first position in a binary number signifies either 0 or 1 decimal. A 1 in the next position means 2 decimal, in the next again means 4, and so on (positions are counted from right to left). The decimal numbers from 0 to 15 will look like this:

0	=	0
1	=	1
2	=	10
3	=	11
4	=	100
5	=	101
6	=	110
7	=	111
8	=	1000
9	=	1001
10	=	1010
11	=	1011
12	=	1100
13	=	1101
14	=	1110
15	=	1111

With four bits, one can thus represent 16 different numbers (0–15), and it doubles for each added bit. Eight bits can represent the numbers from 0 to 255; and this amount is called one *byte*. 1024 bytes (2^{10} bytes) are commonly called 1 kilobyte or kb; 1,048,576 bytes (2^{20} bytes, or 1024 kilobytes) are denominated 1 megabyte or MB.¹⁰ The 256 different values one byte can have make it sufficient for most countries with Latin, Greek, Cyrillic or comparable alphabets—covering numerals (0–9), letters, accents, punctuation marks, etc.¹¹

¹⁰ The ladder continues in the same fashion, with 1024 MB being 1 gigabyte (GB), and 1024 GB equaling 1 terabyte (TB). The current level of storage technology does not warrant talk about petabytes (1 PB=1024 TB), but the term will probably come into use in a few years’ time.

¹¹ Even 256 characters are not enough if all characters and accents are to have their own permanent numbers in a standardized international character set covering all alphabets. An international effort is therefore underway to establish a two-byte, standard character set. (Two bytes can represent 65,536 different characters.) If an international standard can be established, it will solve a host of problems connected with international distribution of data and programs.

The other pillar of computation is the logical system invented by the British mathematician George Boole (1815–1864). Boole, who did not have computing machines in his thoughts at all, actually devised a system that proved to be perfect for electronic computers relying on binary mathematics.

Boolean logic has three basic operations called AND, OR, and NOT.¹² Being binary in nature, they are only able to process two different entities. In the computer world, those two entities are 0s and 1s. The operations are often called *gates*, and that is really the way they function. An AND gate has two inputs, and if each of them is a 1, the operation will yield a 1 to the next gate. Any other combination (10, 01, 00) will result in a 0. The OR gate will pass on a 1 if at least one of the incoming bits is a 1, giving a 0 only when both are 0. The NOT gate will simply reverse the incoming signal, turning a 1 into 0 and a 0 into 1.

On the basis of these three simple operations, computers are able to add, subtract, multiply, divide, and perform all kinds of logical processes. Their secret is thus to reduce all problems to a large number of very simple problems, and then solve them with blinding speed. All three gates also have the property that they can be built using simple, on-off switches—that was why Zuse could build a calculator from telephone relays, ENIAC could be made from vacuum tubes, and modern computers can be made from microscopic transistors deposited on silicon chips. Interestingly enough, then, the electronic computer owes a large part of its existence to a man who died 80 years before its inception.

The First Generation

The computer business did not really get off the ground until the second half of the 1950s. The first commercial machines went to government institutions, military research establishments, and a few private corporations with large files to take care of—notably banks and insurance companies. Computers were a very exclusive commodity, and few needs could warrant one.

That changed rather abruptly with the IBM 650, introduced in 1953 and first delivered in December 1954. It could be rented (IBM did not sell its machines at that time) for as low as \$3250 a month. (In contrast, IBM's first computer, the 701, rented for \$15,000 a month.) A year later, in December 1955, 120 of the machines were installed and another 750 on order. At that point the dam broke, and IBM in particular supplied the water—the resistance in IBM's planning department was obliterated, the company accelerated, and several more machines were developed. In the meantime the company had also been chosen as the main contractor for the manufacturing of the world's first computer-controlled, radar-based early warning and air combat control system. Lead by MIT, the SAGE¹³ project was

The Japanese, by the way, are already using two bytes per character in their text processing, because they have a much larger number of characters.

¹² If you have been searching in free text databases and think you recognize their basic search statements, you are perfectly right. Most databases allow searches following the rules of Boolean logic. A search for documents containing "car AND petrol" will return only documents containing both words, the statement "car OR petrol" returns documents containing either car or petrol (or both), and the statement "car NOT petrol" will result in documents containing "car" but not "petrol."

¹³ Semi-Automatic Ground Environment. The SAGE computers were the largest vacuum tube machines ever made—one SAGE had 55,000 tubes and weighed 250 tons. It could support 50

massive in every way—it was initiated in the wake of the first Soviet A-bomb test, and cost was no concern. The SAGE computers were the first serious real-time, interactive machines with screens; they showed that computers could be used to control complex machinery (in this case, a large network of radar stations). The project gave IBM invaluable experience and access to the latest technology. On the basis of its SAGE experience, IBM was commissioned by American Airlines to develop SABRE¹⁴—a computer-based seat-reservation system. The work started in 1954, but the system did not enter into full operation until late in 1964. It had then cost \$300 million, and with its 1200 teletype terminals, it was the largest real-time data-processing network in the world—a position it has held until recently, when it has found itself vying with two other reservation systems—Amadeus and Galileo—for that title. SABRE started to sell its services to airlines other than American in 1986; it was organized as a separate company several years ago; and became a public company listed on the New York Stock Exchange in 1996. It has an annual turnover in the region of \$1.6 billion (1996).

Amadeus (owned by European carriers such as Lufthansa, Air France, and Iberia) is, with its 180,000 terminals, arguably the largest reservation system in operation today. It contains the schedules of more than 700 airlines and performs bookings on more than 430 airlines, 40,000 hotels, and 51 car rental agencies.¹⁵ It probably processes over 6000 transactions per second in peak hours.¹⁶

While SAGE and SABRE showed the world that computers could do more than solve equations and do batch-oriented records processing, the vacuum tubes were replaced by transistors (the transistor was invented in 1947, but was initially very difficult to manufacture). The first transistorized computer was released by UNIVAC in 1957, and Philco followed suit the year after. The transistor-based machines were smaller, faster, cheaper, and more reliable than their predecessors, and they started a new turn in the upward spiral of the computer business.

In 1964 IBM, also converting to transistors, introduced the 360—another watershed in commercial computing. Designed to be the first universal computer, equally suitable for business and scientific purposes, it was named after the 360 degrees of the compass (Piore and Sabel 1984). The 360 was also the first computer family: A customer could mix and match processors of various capacities with different tape drives, printers, card readers, and other peripheral units without worrying about compatibility. And, most significant of all, all the processors in the 360 series could run the same software without modifications. This fact alone was something of a revolution at a time when different computers, even from the same manufacturer, were completely different and could not share a single piece of software or hardware. The 360 was an immense success, with orders coming in at

monitors, communicate with up to 100 radars, and track up to 400 aircraft. Twenty-six were installed altogether, and the last one was not closed down until 1984!

¹⁴ Semi-Automatic Business-Related Environment.

¹⁵ Figures according to personal communication with a representative for Amadeus in Norway.

¹⁶ I have not been able to have this figure confirmed. However, SABRE processed over 5200 transactions per second at peak load in 1996 with about 130,000 terminals (according to the company's annual report for 1996), and traffic should increase with the number of terminals.

the rate of 1000 a month. The delivery time of course increased rapidly, and customers started to buy and sell places on the waiting lists!

All of the first-generation commercial computers were large and expensive—even the 650 cost a lot of money. Their processing capacity, although impressive by contemporary standards, was in fact very limited, and, for economic reasons, they had to be kept working as efficiently as possible—preferably, around the clock. Because of the cost and complexity of the computer, every routine in an organization that interfaced with a computer system in some way or another was designed primarily to allow the computer to run at maximum efficiency—to get the maximum out of the processing unit, the true heart and soul of the machine. Interactive computing, where the user interacted directly with the machine, was not even contemplated, and screens were few and far between (SAGE and SABRE were rare exceptions). The “jobs,” consisting of decks of cards, paper tape, or magnetic tape, were fed to the computer, which did its work and printed out the result on paper; all the while it was being tended by a large staff of operators and system programmers. Both the hardware and the software of the early computers were pretty “raw”; there was a need for a lot of operator intervention, and the operating system (the basic software directing the internal processes in the computer and the peripheral equipment) required constant tuning and tinkering.

Today’s big mainframe computers are the direct descendants of this first generation of computers, and, even if much has changed, they still retain many of the old characteristics. They are still big, they are expensive, and they still require a sizable, highly competent staff to tend their exceedingly complex operating systems and related basic software. There are yet application areas where large mainframes are the only solution, but their exclusive domain is rapidly shrinking, and today they represent only a small fraction of the total computing power available in the world. (This remains true even if we include the specialized high-performance mainframes called *supercomputers*.¹⁷)

The mainframe computer had its heyday in the 1960s and first part of the 1970s, before the minicomputer entered the arena in earnest. At that time, most “serious” data processing was done on the big machines, and organizations too small to afford their own signed up with service bureaus—large data centers selling computing power by retail. It is worth noting, however, that even if the mainframes have rapidly lost relative market share, the total market for computer power has expanded so enormously in the same period that there are more mainframes in operation today than at any other time in history. Nevertheless, the days of the classical mainframe are now numbered—even if it will continue to be with us for many years to come, mostly thanks to user inertia and the huge sunk cost represented by existing software. It will largely be replaced by highly parallel database servers and specialized, numbercrunching compute servers.

The Birth of Programming Languages

As we noted earlier, even stored-program computers were hard to program at first. But the incremental improvements have continued, and the development of

¹⁷ A supercomputer is an exceedingly fast computer, usually optimized for scientific and/or engineering purposes. That usually means number crunching, not records handling, as in a typical commercial environment.

more efficient programming techniques has undergone four distinct phases (we are still in the fourth one). The first phase was machine language programming—the direct writing of 0s and 1s. Needless to say, programmers did not exactly relish their work after a while, painstakingly spelling out every minute detail of the computer's operations in 0s and 1s. And, as programming rapidly became the bottleneck in computer utilization, improvements in programmer productivity became an important issue for the computer manufacturers (which it still is).

At first, as always in pioneering work, several solutions were tried, but they all had a common denominator: The goal was to express programs in more high-level symbols, which the machine itself could translate into the actual 0s and 1s it needed for its operation. The first “languages” of code developed for this purpose were simple and only covered discrete machine instructions—it was in many ways just a mnemonic shorthand, eliminating the need to write strings of 0s and 1s, but still requiring the programmers to describe all operations in painstaking detail. Today, such code schemes are called *assembly languages*. They are still used for special purposes, especially when compactness and speed is very important.

As computer use took off in the 1950s, assembly languages did not suffice to alleviate the programming bottleneck. Writing in assembly was still slow, there was a specialized assembly language for every machine (it was very close to the hardware, since it directly reflected the instruction set of the processor), and to use it the programmer needed a thorough knowledge of the hardware. Work on more advanced coding schemes continued in several places, most notably IBM and Remington Rand. The idea was to automate common subroutines such as calculations, indexing, and reading and writing to files. Automating both standard computational and housekeeping functions would free the programmer to use his time on the more creative aspects of programming—the actual tasks to be carried out. The first *compiler*—as the internal, translating program was called—was created by a team at Remington Rand. The compiler took the statements in the high-level language and translated them into the strings of single instructions the processor needed. The product was a modest success, and it spawned other efforts. In 1957 IBM released the first version of FORTRAN (FORmula TRANslation), the first full-fledged high-level programming language that was commercially viable. Because FORTRAN was optimized for scientific and engineering purposes, other languages soon followed, such as COBOL (Common, Business-Oriented Language) and BASIC (Beginner's All-purpose Symbolic Instruction Code).

The high-level languages (or, as we now call them, *third-generation languages*¹⁸) brought about a great increase in programmer productivity. Just as important, compilers for FORTRAN, COBOL, and other languages were implemented on more and more machines, and within the space of a few years, all computers on the market had compilers for the most widely used languages. This meant that programmers no longer needed to know the innards of the machines they worked with, nor did they have to learn a new language every time they confronted a new computer. The dream of portable programs was not totally fulfilled, however,

¹⁸The generations refer to different stages of development for the present languages—not to the evolutionary ladder *machine code—assembly—high-level language*, as many people believe (Booch 1991).

since the instruction sets of the different computers were not sufficiently similar to allow programs written for one to run unmodified on another. But, whereas it had been totally impossible to transfer an assembly program from one type of computer to another, a high-level program could often be transferred at a cost that was considerably smaller than the expenditure needed for rewriting the program from scratch.

Without a doubt, the advent of high-level languages brought about the first wave of computerization of business and public administration and accelerated the use of computers for scientific and technical purposes, including control of production processes. The power of COBOL, BASIC, and FORTRAN for the first time made it economically attractive to develop computer systems for a wide array of purposes, and this fueled the proliferation of computers for the next 10 to 15 years.

Transistors and Minis, Chips and PCs

The Birth of the Mini

As noted earlier, the transistor entered the scene in the late 1950s, making computers much more reliable and powerful. It also contained in it the possibility of making smaller and cheaper computers. But the concept of the mainframe persevered and continued to keep the ownership of a computer out of reach for all but the biggest or richest organizations.

In 1957, however, a new company was founded, headed by an engineer with a bent toward small computers. His name was Ken Olsen, and he headed his Digital Equipment Corporation (DEC) until 1993. Although has been in serious trouble the last few years DEC is still among the largest computer companies in the world (the ninth largest by revenue in 1996).

Olsen was convinced that there was a market for affordable computers, and DEC's first one, PDP-1, appeared in 1961 at a cost of \$120,000. It did not make much of an impact, but for those who cared to look, it showed that there was an alternative route to computing: by means of small, inexpensive machines that were easier to program and run and did not require the multitude of operators and system programmers that were the hallmark of a mainframe installation. The new *minicomputers* were also designed as interactive machines from the very start, allowing direct interaction with the user through keyboards and screens.

The big surprise for the industry came two years later, when DEC introduced its PDP-8, a machine the size of a refrigerator and costing only \$18,000. It was not as powerful as the mainframes, it could not support a large number of users, and it could run only one program at a time. But it was cheap, and most organizations could afford one. Soon PDP-8s were analyzing lab data, controlling machine tools, running payrolls, and keeping track of warehouse inventories. It became the first computer installed in a submarine. From then on, it was the minicomputer that carried the torch of the computer revolution, and scores of new companies sprang up to capitalize on the new development.

In 1958 an event just as important as the invention of the transistor took place: the first *integrated circuit*¹⁹ (IC) was produced by an engineer at Texas Instruments. The news of the feat spread fast, and others soon came up with more practical designs. The one that proved to be the right one for mass production of more complex circuits was developed at Fairchild Semiconductor²⁰ during the first six months of 1959.

At first the IC developed fairly slowly, and the computer application that was most amenable to early IC technology was memory. The first computers with ICs in them were the medium-sized B2500 and B3500 from Burroughs, introduced in 1966. In 1968 Control Data introduced the first computer composed entirely of ICs. But ICs were still hard to make, and prices were high. Only top-of-the-line computers—wherein speed advantages were more important than cost—could use ICs. But as the technology matured, things began to change. The number of circuit elements (transistors, resistors, and capacitors) on one chip increased from a few to a few tens, then to hundreds, and in 1970 the start-up company Intel²¹ startled the computer world by introducing a 1-kilobit memory chip, capable of storing 1024 bits of information.

The transition from magnetic core memory²² began, and, because the elements on a chip now numbered in the thousands, the development accelerated beyond belief. Memory and logic chips proliferated, more and more circuit elements were packed onto one chip, and prices went down. Since 1970, the capacity of memory chips has increased by *60% per year*. Meanwhile, costs have gone down to the effect that the price for one bit of semiconductor memory has decreased on the

¹⁹ An integrated circuit is an implementation of several transistors on a single piece (or "chip") of silicon. Capacitors and resistors may also be created along with the transistors, making it possible to build complete electronic circuits on one chip.

²⁰ Fairchild Semiconductor was set up in a way that came to be something of a blueprint for new companies in the computer business: Its founder, Robert Noyce, and seven of his colleagues at Shockley Semiconductor Laboratory (itself a small start-up established by William Shockley, the co-inventor of the transistor) did not agree with the line of development pursued by Shockley and quit to form a new company based on their own ideas and money from an outside partner—in this case, Fairchild Camera & Instrument Corporation. In its first ten years, the company grew to 12,000 employees and a turnover of \$130 million.

²¹ In 1968 Noyce and Gordon Moore, another of Fairchild Semiconductor's founders, left Fairchild and started a new company, Intel. Intel pioneered the development of really useful memory chips, designed the first one-chip microprocessor, and is today the undisputed leader in volume microprocessor development and production. All IBM-compatible PCs (regardless of type and size), as well as scores of other computers, are built with processors designed by Intel and produced by Intel or their licensees.

²² Memory has always been a critical part of computers. A really practical and reliable solution was not found until the development of the magnetic core memory in the early 1950s (it was first implemented in an experimental computer in 1953). It consisted of very small, doughnut-shaped, magnetic ferrite rings strung on a mesh of thin wires, with every intersection of two wires having one ring. By sending current through the wires, the magnetic polarity of the small ferrite rings could be changed or read. One ring could thus store one bit of memory. Magnetic core memory was sturdy, reliable, and nonvolatile—it retained its contents even when the power was switched off. But it was expensive to manufacture and much slower than the new semiconductor memory chips.

average²³ by 35% *every year* since 1970. Based on advertised prices in *Byte* and *PC-Magazine*, the leading microcomputer journals, the end-user price for one megabyte of memory has been reduced from \$20,480 in 1975 to \$5 in the fall of 1997. The complexity and price of logic chips have followed the same trajectories.

As the cost of ICs fell and the complexity increased, even smaller and cheaper computers than the PDP-8 could be built, and the minicomputer companies got another large boost. Their heydays lasted from the middle of the 1970s until about 1985. In the meantime, however, another revolution was in store for the industry.

The Microprocessor and the PC Enter the Fray

Even while it was working to bring out the 1kb memory chip, another revolution was brewing at Intel. *Busicom*, a now defunct Japanese calculator maker, placed an order with Intel for a custom chip set for a new series of calculators. *Busicom's* design called for dedicated logic chips for each calculator in the series, but Intel's engineers concluded that the best solution would be to build a general processor chip able to do the job in all the calculators *Busicom* wanted to make. The result was the Intel 4004, the world's first microprocessor—delivered late in 1970. The year after, Intel obtained the rights to sell the 4004 to others, and within another year a more powerful chip, the 8008, was brought to market. Sales started to pick up as electronic engineers around the globe slowly figured out how they could use the new marvels. The real success, however, did not come until the far superior Intel 8080 was launched in 1974. The 8080 was the first microprocessor that was powerful enough for a real computer, and it was the brain of the first useful microcomputer—the *Altair 8800*,²⁴ described and advertised in *Popular Electronics* in January 1975. Fully assembled, the *Altair* cost \$650; as a kit, \$395. That was for the bare computer—it had no screen and no input device except a set of toggle switches on the front. Two rows of lights were all the computer had for communication with the outside world. Terminals, printers, paper tape readers and the like cost extra and did not become available until the end of the year.

The *Altair* was a success anyway, and thousands of kits were ordered, even if the machine did not have any high-level programming language. One of the many computer enthusiasts reading the article in *Popular Electronics*, however, was Paul Allen, a friend of Harvard freshman William Gates. They telephoned Mike Roberts, *Altair's* creator, and offered to write a BASIC interpreter for his machine. Roberts agreed, and the interpreter was delivered six weeks later. Allen and Gates subsequently founded Microsoft Corporation, now arguably the most influential company in the computer business and the world's largest software company (with sales of more than \$8.6 billion in 1996, Microsoft occupied the number ten spot on the list over the world's largest computer companies overall).

²³ Memory chips have become the most important commodity in the computer business, and prices have started to behave much like the prices for many important raw materials (for instance, aluminum and other metals). Demand and production capacity continuously leapfrog each other, and prices are swinging considerably. On the average, however, prices are falling at a steady rate.

²⁴ About six months before, a computer built on the 8008 was described in *Radio-Electronics* magazine. It was called the Mark-8 and was the first microprocessor-based computer. Compared to the *Altair*, however, it was a very limited device.

The Altair fired the imagination of a lot of young electronics people, and a host of microcomputer companies sprang up. One of them was Apple Computer, started by two college dropouts, Stephen Wozniak and Steven Jobs. They sold 175 of their first product, the Apple I computer (really only a board), through a San Francisco computer retailer. They then came into contact with one of the “veterans” from Intel, who had retired as a millionaire at the ripe old age of 32. He immediately saw the company’s potential, bought one third of it, and arranged for the necessary additional funding. The company’s next product, the Apple II, became a runaway success, and Apple grew at record speed—going from \$775,000 to \$983 million in sales in just six years. Sales received a major kick after two other college students, Dan Bricklin and Bob Frankstone, came up with VisiCalc—the first spreadsheet, and the program that made the business community take the microcomputer seriously. VisiCalc was in fact just as important for the phenomenal growth of the microcomputer business as the hardware itself. The year 1979 also saw the first useful word-processing programs and the first database program for the new machines. When IBM introduced its own microcomputer in 1981, the IBM PC, it was as if the product received its official blessing—and microcomputer sales took off on an even steeper curve. Today, PCs provide most of the computational power available in the world, their importance is still growing, and the trend toward networked PCs and workstations becoming the dominant computer architecture is firmly established.

After that time, the computing power of the mass-produced microprocessors started to catch up with the proprietary (and much more expensive) minemachine processors, leading to three simultaneous developments that threw most of the traditional mini makers into serious trouble toward the end of the decade: the maturing of the PC networks; the emergence of cheap, microprocessor-based servers and minis; and a drive toward more or less standardized operating systems, fueled by the users’ growing concern about the disadvantages of vendor lock-in.²⁵

The PC’s main attractions were user control and low price—it had a price/performance ratio far superior to minis and mainframes, once again confirming a peculiar fact of the computer business: that the familiar notion of economy of scale is inverted. A unit of processing power (however one chooses to define it) is most expensive on the biggest machines, and cheapest on the smallest. And the difference is far more than marginal, it is of one to two orders of magnitude—the price of one MIPS²⁶ is about 100 times higher for a conventional

²⁵ When all vendors have their own proprietary hardware and their own proprietary operating systems, they are partially screened from competition when they are first established in the customer’s organization: Upgrades and expansions cannot be bought from any other source, and a total conversion to another vendor’s systems often entail conversion costs that look prohibitive in the short term. The customer is captured, and experiences lock-in. The mechanism of lock-in and the high development costs associated with a large number of proprietary hardware and software architectures combine to keep prices high.

²⁶ Million instructions per second—the most widely used general measure for computer speed. There are also other measures—in a scientific environment, for instance, MFLOPS (million floating point operations per second) may be preferred. There are also measures for performance in transaction processing, graphics, and various other applications. All such benchmark measures have inherent problems, because their definitions tend to favor certain computer designs. Comparisons are therefore frequently difficult (skeptics maintain that MIPS

top-of-the-line mainframe as for the PCs and workstations with the best price/performance ratio. A typical mini falls somewhere in between. The difference is compounded by the fact that not only processing power, but also memory, disk storage, graphic capabilities, and frequently even software is cheapest on the smallest machines. However, networked PCs is by far the most expensive system architecture to maintain and support, because of the great complexity involved. Some of the most annoying and difficult problems arise from a fact that is also a great strength: the enormous wealth of equipment and software that is available. Although it allows the user to find a product for almost any conceivable purpose, the use of equipment and software from a large number of independent vendors also produce innumerable compatibility problems, which cost a lot of time and money.

A natural question is then why manufacturers could still sell mainframes and minis—why those markets did not collapse with the advent of the PC. The main reason is simply that most of the backbone applications for any organization require shared data: People at various places in the organization must be able to use the same systems to enter and retrieve information from the same databases, and isolated PCs are simply not viable platforms for such applications. But the stand-alone PC is the perfect platform for such personal and processor-intensive applications as word processing, spreadsheets, and graphics, and they invaded organizations in droves. With the increasing sophistication of networking software, combined with the powerful, low-cost servers built with the new microprocessors, they were also increasingly able to attack the rest of the application base of the minis, and PC networks ate into the traditional mini market at a rapidly increasing rate.

At the same time, the stronghold of the traditional mini—the shared application—was also attacked by new vendors (and some of the old) with cheap, new machines built with PC technology and based on standard microprocessors bought in volume from the chip companies—notably Intel and Motorola. To reduce their development costs further, these vendors almost without exception opted for a *de facto* standardized operating system (UNIX²⁷), which further increased their appeal to the users. Because of an initial lack of application software, the new machines did not wipe out the old ones directly, but the pressure on prices mounted, and many of the traditional vendors found themselves in the red for the first time in two decades. A few years later, most of them were gone—they either went bankrupt or were bought by more resourceful competitors. Only the largest vendors had the necessary production volume to put their own processor architectures onto chips and achieve a cost level approaching that of the vendors using standard chips.

stands for “meaningless indicator of processor speed”), but not entirely without value—large differences are usually significant. It remains a fact, however, that the only really valid test, as seen from a user's point of view, is the actual application mix and load intended for the system.

²⁷ Actually, UNIX was never totally standardized—there are still a quite large number of variants, although the market have now converged toward a small number of main versions. It is close enough to standardization, however, to allow for fairly painless transfer of data and conversion of programs between versions.

What is left of the minemachine market today is increasingly dominated by cheap, powerful computers built with the new generations of standard microprocessors. They offer the lowest price per terminal of any system category today, but even they fall behind PC-based networks as soon as users demand the functionality and power of dedicated PCs, especially when they want graphical user interfaces such as Microsoft Windows.

The Workstation

The early development of the PC was really driven by the interest and enthusiasm of computer hobbyists, finally provided with an affordable computing platform by the evolving microprocessor. The history of the personal workstation is older, however. Some would even describe the Manchester Mark I as the first personal workstation, a notion that is correct insofar as it had a display and only one person could run his or her program on it at a time. Some would peg the honor on the display units of Whirlwind, a precursor to the SAGE. It might be more appropriate to name DEC's PDP-1 and/or MIT's LINC²⁸ (completed in 1962) the first personal workstations. Scientists and engineers of most denominations yearned for the power and convenience of a dedicated computer for their personal use, so the need for personal workstations was already identified. The limiting factor was their price—to become practical in economic terms, even the scientific workstation had to await the birth of the microprocessor.

The forerunner of modern workstations (and machines such as Apple's Lisa and MacIntosh) was the NLS (oN-Line System), built by Douglas Engelbarth and his colleagues at Stanford Research Institute in 1968. It incorporated the first mouse. Later versions pioneered windowing, graphical user interfaces, compound text/graphical documents, and electronic mail. The concept of the graphical user interface was further refined through the design of the Alto, developed at Xerox Palo Alto Research Laboratories (Xerox PARC) in 1972-73. All window-based graphical user interfaces of today (Apple's MacIntosh environment, Microsoft Windows, OSF/Motif, etc.) descend from the NLS and the Alto—the reason why the data processing-community perceived Apple's lawsuits to protect the "look and feel" of its windowing system to be both ludicrous and an affront to the spirit of the community's pioneers.

Around 1980 microprocessors became powerful enough for scientific and engineering workstations, and first Apollo and then the start-up Sun began to deliver affordable machines. Very quickly, a lot of other companies entered the fray, not the least established vendors such as DEC and Hewlett-Packard, and the highly varied requirements of the scientific/engineering community rapidly resulted in an impressive array of offerings—workstations with an enormous range in capacity. The low end today can be compared to medium-to-high capacity PCs (the dividing line is becoming increasingly blurred²⁹), the high-end

²⁸ Laboratory INstrument Computer—a machine designed at MIT's Lincoln Laboratory to support research work in laboratory environments. Initially, it was used mostly in biomedical research.

²⁹ It is mainly a question of operating systems. The scientific/engineering world still mainly relies on the UNIX operating system, whereas the office world banks on MS-DOS and Microsoft Windows. However, even the scientific/engineering market today is increasingly

models have a computational power in excess of anything but the largest mainframes and supercomputers.

Miniaturization Continues

Continued miniaturization, not only of processors and memory circuits, but also of support chips and connective circuitry, hard disks, and floppy disks, has allowed for a totally new class of computers: portables. It started in April 1981, when Adam Osborne unveiled his Osborne 1—the first complete computer with a handle. Its most significant feature, however, was its price—at \$1795, complete with monitor (albeit only 5"), two floppy drives, and an impressive bundle of software (with a total list price higher than the price of the machine itself), it was a bargain system at the time. In a workstation context it is interesting to note that Xerox introduced its Star workstation just one month later, carrying the legacy of the Alto to the marketplace, and for the first time introducing the general (computer) public to the concept of windows, icons, and mice. With a price tag of \$50,000 for a minimum configuration, however, the Star remained a star of the trade shows, whereas the humble Osborne 1 achieved commercial star status, and Osborne Computer's growth made even Apple's first years look dull.³⁰

The new niche quickly drew more contenders, and portability *and* stowability (what do you do with that home computer when you are not using it?) soon became the main selling point, especially after Compaq entered the race with an IBM compatible portable in November 1982. Looking back, we would more describe them as "luggables," as they weighed in at ten kilos or more. The first "modern" portable was the DG One from Data General, introduced in October 1984. It opened like a clamshell, had a full-screen LCD display (although hard to read), was IBM-compatible, and could run on batteries. The price was \$2895.

Portable computers today cover a wide specter, from quarter-kilo "palm-tops" to eight-kilo "luggables" with workstation power, with the main interest concentrated on the "notebook" class. A notebook computer should adhere to the A4 (or American equivalent) form factor when closed and weigh less than three kilos—preferably less than two. It should have a full-size screen, a good keyboard, a large mass storage, a floppy drive, and perhaps a CD-ROM drive. This class of machines holds the promise of becoming true "notebooks" in the sense that we will carry them everywhere and use them as a replacement for our yellow pads and calendars. With digital, cellular telephones now becoming mature products (with the concomitant low prices), we are already seeing the combination of such phones with light, portable computers—providing a workstation-on-the-go, complete with wireless network connection to the corporate database.

The main restraint on their use today is battery life (no more than five hours, usually less) and price. And, so far, nobody has come up with a really seamless

looking toward Microsoft NT (the "serious" member of the Windows family) as their future platform.

³⁰ After the introduction of the IBM PC later that year (which established a new standard), the emergence of several competitors, and an unfortunate handling of a model transition (announcing the new model while warehouses were bursting with old ones), Osborne Computer Corp. filed for protection under Chapter 11 in September 1983. The grandest rise-and-fall of a turbulent industry had come to a conclusion.

solution for the combined use of a desktop PC and a notebook: You can transfer files effortlessly enough, but the maintenance of data integrity (for instance, securing that calendars on the notebook and the desktop machine show the same appointments) is still in the early stages. More interesting solutions are emerging, though. The price, at least, will be taken care of by familiar mechanisms and will most likely continue to come down. Battery life is more of a problem and must await better battery technology or even more frugal chips and screens (if we are fortunate, we may have it both ways).

Software: The Standard Package

In the 1960s computers proliferated—mainframe sales were soaring, IBM 360 was an enormous success—and from 1963 on, the minicomputer brought computing to “the rest of us.” The third generation programming languages, now well established, provided a stable platform for the development of the myriad of application programs the new computer owners needed to put their machines to good use. But several development trends combined to put a renewed pressure on the software side, once again turning it into a bottleneck.

First, even if program development in COBOL or FORTRAN was much more efficient than writing in assembly, it was still labor-intensive work. A large application program could take scores of programmers and years of work to complete, and even small programs would take months. Almost all computer-using organizations quickly built up a large backlog of unfulfilled development requests. Compounding the issue was problem number two: the scarceness of programmers. The demand grew much faster than the supply. The labor intensity of programming also meant that programs were expensive, and the short supply of programmers drove up salaries and increased cost even more. Especially for minicomputers, this was a problem. Even if it was faster to develop on minis than on mainframes (due to the interactive nature of the minis), it was not that much faster, and the cost of developing even small- and medium-sized programs loomed high in the context of \$18,000 computers. For scientific and technical purposes the problem was not so severe, since many of the users themselves quickly learned to program. But for administrative purposes the cost and trouble of software development became a definite restriction on computer use. Clearly, the industry was ripe for another innovation, the standard package—a ready-made program for a specific application, for instance, general ledger, payroll, or inventory control.

The standard application package did not spring complete from the forehead of some super programmer, however. It started as growing libraries of subroutines and modules for doing specific operations in particular application areas. Slowly, the concept of the complete package grew, and toward the end of the 1960s the concept was more or less established. A landmark event was a court ruling in the United States, which on the basis of antitrust law demanded that IBM “unbundle” the software from its computers. Until then, software had come with the computer, included in the price. The court ruled that IBM would have to put a separate price on the software, making the purchase optional. This opened the vast IBM market to third-party software vendors, and several of the largest software houses today were founded about then. A couple of years later, IBM

launched a highly successful small business computer (a rudimentary mini), the S/32, together with ready-made software for everyday business needs. Many other vendors had similar offerings, and the sales of small systems accelerated.

The 1970s saw a substantial growth in the package business, especially in the second half of the decade. Many (if not most) of the mainframe packages available today have their roots in the late 1970s, and a new generation is just now starting to come out. The independent market for mini-based software really took off at about the same time, and, just as the compiler triggered the growth in mainframe computing, the package ensured the success of the mini. The 1980s saw the maturation of packaged software, and it now dominates the computer scene both for mainframes and minis—not to mention the PC, which lives by and for it. The mini and the software package brought the power of computing within the reach of almost any organization.

Networks and the Proliferation of Processors

The 1980s became the decade of the stand-alone PC. In the office environment it was used mainly for word processing, spreadsheets, and record keeping; in scientific and engineering environments, CAD,³¹ statistics, and acquisition of lab data were important application areas. For the users it represented a final liberation from the time-sharing environment of the larger computers, where they had to contend with other users for access to the computer's resources. The low price of the PC meant that it could fit into almost any budget, and the proliferation of PC-based software packages (with a correspondingly low price) for the first time gave the users an alternative to lining up in the computer department's backlog queue. A PC also turned out to be so much cheaper than a terminal on a large system (if we count the terminal's part of the host computer with all its associated resources) that the number of users who could justify taking advantage of computers increased significantly.

The stand-alone PC still left unanswered the need many organizations had to tie their users into organization-wide systems, however. One possible answer was to let the PC function as a terminal as well, a solution that has met with some success in mainframe environments. The PC then emulates a terminal, allowing access to the mainframe-based systems, whereas local, computationally intensive tasks such as word processing and spreadsheets can be done locally. The sharing of data between local and mainframe-based systems is not seamless, however, and in many cases, the mainframe-related functionality of the PC is not on par with the normal terminal (due to factors such as keyboard differences).

But another, more epochal development was already underway: the evolution of the local area network (LAN). The origin of the LAN is a matter of discussion, but most people would agree that the first operational network was the net connecting the Alto workstations at Xerox PARC in 1975. The first commercial network was released by Datapoint a couple of years later, but did not catch on with others. It was Xerox's release of Ethernet in 1981 that really got

³¹ Computer-aided design—mostly two-dimensional drawing (2D), although three-dimensional drawing (3D) and solid modeling have been increasing lately.

things rolling. Networks as a concept took form much earlier, however—actually, the 27 SAGE centers were all linked together.

The mother of large networks (and the germ of Internet) was the ARPA³² network, established in 1970. It linked computers at universities and research facilities throughout the United States, allowing data sharing, remote processing and mail. It grew rapidly from four nodes in December 1969 to hundreds of nodes 15 years later. Today, we have lost count—but the Internet nodes number in the millions and multiply furiously all over the world.

In the PC world, LANs were at first a welcome method of sharing expensive peripherals such as disks and printers. That was indeed also the purpose of the first LAN servers—a print server and a file server supporting the Altos on the PARC network in the last half of the 1970s. But as the power of PCs and servers grew and the networks became more sophisticated, software also evolved to take account of the new possibilities. At first, applications and data were just downloaded to the PC, and the file server acted merely as a remote storage device (disk). For some applications, such as spreadsheets and word processing, that was (and is) just fine in most cases, but, for any application involving the shared use of a database of some kind, it is not a viable solution. If the database is large, it will be impractical to download, and if many users download their own separate copies of the database and update them locally, data integrity is quickly lost—since the local versions are not revised by the input from other users. Chaos will result when a large number of such individually altered versions are stored back to the central file.

Increasingly, however, products involving shared data are now adapted to the new environment. Database products, for instance, have been split in two, with the database engine proper residing on the server and the application “front end” running locally in the PC. Several companies can offer reliability and security approaching the level of mainframes, and great strides have been made in server technology. We are witnessing a period of transition, where older, centralized computer architecture is being superseded by a distributed one, with multi-processor servers and powerful workstations/PCs connected by high-capacity networks. By the year 2000 the traditional mini and mainframe will probably have largely disappeared, relegated to a few specialized niches and otherwise only found in very conservative organizations.³³

Within the span of about 20 years, we will have moved from a situation where many users shared one processor (traditional mainframe and mini), through a

³² The Advanced Research Projects Agency of the U.S. Department of Defense. Note that the ARPA network was what is now termed a wide-area network (WAN), where multiple geographical sites are connected via (usually) the public telephone network, as opposed to a local-area network (LAN), connecting computers and workstations in one building or site via local, dedicated cables. Much of the basics involved are the same for the two types of network, however, and so the ARPA network can be viewed as the precursor to both kinds.

³³ Computers can occasionally live much longer than what is generally viewed as economical. According to Trautmann (1990), there were still IBM 360s running in small-to-medium-sized German companies (what the Germans call the *Mittelstand*) in 1990, although the machine was superseded by the 370 early in the 1970s and several generations of mainframes and minis had come to pass since then. (German *Mittelstand* companies are generally regarded to be very conservative.)

period with one user and one processor (the stand-alone PC) to the era of one user and many processors (networks with workstations). Not only will the servers have many processors and networks have servers of different types (database servers, compute servers, and communication servers), but the workstations themselves will have more than one (at least a graphical co-processor). This development is a reflection of the dramatic technological improvements over the last 40 years, which have changed the processor from a costly, room-sized centerpiece of organizational information processing to a cheap "accessory" that can be applied in the numbers necessary to do the intended job.

Software: Beyond the Standard Package

Even if packaged software came to dominate the computer scene during the 1980s, custom programming did not disappear. There are always applications that are too rare to create a viable market for a package, and there are also applications so important for the competitive edge of a company that managers are willing to spend large amounts of money to provide systems that are better than the competitors.' In addition, there is the fact that any two companies of the same size engaged in the very same business never organize their activities in exactly the same way. Often, companies will therefore find that available packages are incompatible with their usual way of conducting business, and they are often loath to change their ways. Modification of standard packages is complicated work, and, as a rule of thumb, it is generally acknowledged that if the necessary changes involve more than 20% of the code, one may as well write a new program from scratch.

Even as the number of standard packages took off, a mounting pressure was building to make software development more efficient. And, whereas some developers started to fashion application-specific, package-like products from their modules and subroutines, others accumulated libraries of routines and modules that covered the general aspects of most commercial software applications—the definition of screens, for instance, or of reports culling data from databases. Many simple applications do indeed mainly consist of a number of screens for data entry and maintenance, a database, and a few reports to tabulate the data. What they eventually had on their hands were more or less general tools for application building, relieving them of much of the drudgery of detailed programming.

Over the years, many such application builders, or "fourth generation languages" (4GL) as they were commonly called (today we speak of development tools), were put on the market—especially the first half of the 1980s saw a flurry of announcements. Today, competition has already removed many of them, and the market is rapidly maturing. Although most of these tools were at first tied to particular database products, those that survive now increasingly separate themselves from any such dependence, allowing several of the most widely used databases to serve as platforms for their programming engine³⁴. Experience shows

³⁴ This effort is helped by the fact that IBM's Structured Query Language (SQL), a formalized interface between a database and an application, has become a de facto international standard. Even if it is not completely standardized, it has made it feasible to interface a given tool with a new database.

that dramatic increases in productivity are possible with the right use of such tools³⁵; in some cases it has been demonstrated that even for major applications, a custom-made system can be developed for less money than it takes to buy a standard package and give it the necessary local color. A further advantage is that the same lead in productivity is true for maintenance and modifications, making a program developed with a sophisticated development tool inherently more flexible.

The growth and gradual refinement of development tools has therefore helped to keep custom programming alive and healthy, and we can even envisage a renaissance for tailor-made or semitailored software in the years ahead, as the products and our methods for using them improve. This is made even more probable by the fact that such tools are not “the only game in town.” A class of programming languages called *object-oriented languages*, slowly developing over the last three decades, have suddenly sprung into prominence the last few years. Their properties make it much easier to modularize software, to the extent that a programmer can have a large library of standardized modules that can be combined to new programs. Such libraries are already becoming salable products. Another trend working in the same direction is the increasing richness in functions and intrinsic programmability of modern software packages. Some of them are clearly evolving in the direction of a combination of packages and specialized tools, allowing the user to tailor it to his or her specifications without having to change a single line of the standard code. All this promises us that the software of tomorrow will be a lot more malleable than in the past, and it will be increasingly feasible to tailor organization, work processes, and computer systems for maximum performance in a given environment.

³⁵ The improvement is not automatic, however—new methods for system development are necessary to reap the full benefit. The new tools and the new methods are also more demanding than traditional systems development using COBOL or FORTRAN, meaning that not all traditional programmers will achieve the potential improvements in productivity.

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