Office Automation

R. J. Spinrad

Summary. The automated office has the potential to change significantly the ways we handle the substance of our working lives. Advances in electronics and computer systems enable us to do much more than just upgrade individual office functions. We can now restructure our basic information handling modes to allow an immediacy of interaction not previously available. The tedium of paperwork is sharply reduced and it becomes much easier to work collaboratively with others. The electronic desk becomes the professional's link to a widely distributed array of information sources and services.

When I arrive at my office in the morning and begin my work I flip a switch and press a few keys and an index of incoming messages is displayed on the screen before me. Since I am pressed for time I read only one relatively urgent message. Moving a pointer, I position an arrow on the screen and press a button. Instantly, the message I have selected is displayed. I read it easily, since messages sent directly from screen to screen tend to be short and direct. After some thought I send a message to a colleague asking for help in organizing a somewhat lengthy response. Then I set about the principal work of the morning, completing some equipment layout by directly manipulating the on-screen diagrams.

Meanwhile, my colleague is structuring an answer to the urgent inquiry. He calls to the screen an old, but relevant, report, composes an appropriate "cover letter," and sends it on to me. Later, after I have added some new information to the response, I send it via the network linking the North American parts of our organization. The message is automatically stored for future reference and, if a printed copy is desired, it is available in seconds from the nearby copier-printer.

This is how I handle my daily "paperwork." My office is more automated than most because I am in an organization doing work at the frontiers of this exciting field. Nevertheless, the intellectual tools I work with are the clear precursors of those that will radically change the way most "knowledge workers" will handle their daily tasks in the future.

The author is vice president, research at the Xerox Palo Alto Research Center, Palo Alto, California 94301.

Office Systems

Rapidly dropping equipment costs are now making it possible to offer some practical support to the professional awash in a sea of information. More than half of us who labor outside the home work with words, numbers, or pictures (*1*). Yet, until very recently, the equipment we used had changed little. The product improvements that were made were gradual. They did not support substantive changes in the ways we did things. As electronic and computer technology began being applied to office equipment the first designs were emulative ones: the new devices—with radically different internal structures—were made to simulate the old ones. (In like manner, the first transistor radios were built on large, sturdy metal chassis with the tiny transistor sockets nestled under the towering componentry that used to surround the vacuum tubes.)

In time, product emulation was succeeded by enhancement. Designers provided greater print speed, better image quality, easier editing, automated file trolleys, and coded microfilm storage. But, fundamentally, they were not changing the system; they were just mechanizing its manual parts. Electronic typewriters, word processors, facsimile equipment, dictation banks—all were enhancements of the functional elements of an unstated, undescribed office system built around paper.

In the early 1970's people working in the field sensed that electronics technology had the potential for supplementing or replacing large parts of what was called the "office information system." This notion had as its root an even more tenuous perception—that there was an office information system. People tried to explain it to one another by describing, for example, the "filing function," the "keying function," the "mailing function," and the "editing function." They examined the interactions among these functions and convinced themselves that there was structure, order, and utility there and that, therefore, there was a system. It was difficult, however, to say just what the overall system structure was. People knew how to design word processors, copiers, and facsimile units. They seemed to be part of an office information system. But where was the system? How could there be a system where the component parts were not interconnected and interrelated? In fact, the word processors and copiers and facsimile units did form a system, but it was not an electronic one. The system elements were electronic, but the system itself was manual.

The system's working unit was a piece of paper with an image on it. It was an extremely flexible and versatile vehicle. It could be carried, filed, mailed, copied, scribbled on, typed upon, and crumpled and tossed. It was the medium for the message. It became clear that any office information system that we designed would have to provide a replacement for the piece of paper or an equivalent to it.

The clear utility of the image-on-paper message at first blinded us to its other, fundamentally important attribute. The paper not only bore the message, it was, itself, the "interface standard" between the various office units. The $8\frac{1}{2}$ by 11 inch page fitted into file cabinets, slid out of typewriters, spun on facsimile drums, and was replicated by copiers. We did not expect our information to come to us on either postage stamp– or bedsheet-sized pages. (Our typewriters, copiers, and facsimile units did not "interface" to postage stamp– or bedsheet-sized pages.)

This convenient compatibility was, of course, not surprising. File cabinets and copiers and in-baskets were designed to match the $8\frac{1}{2}$ by 11 inch interface standard. Any electronic typewriter, file cabinet, or copier, and even any electronic in-basket, had to match a comparable electronic interface standard to qualify as a component of an electronic office information system. This, then, set the theme for many of the subsequent developments in office automation. Individual elements had to be designed as part of a coherent system structure. There had to be common representational and protocol standards for creating, displaying, printing, communicating, and filing electronic documents (*2, 3*).

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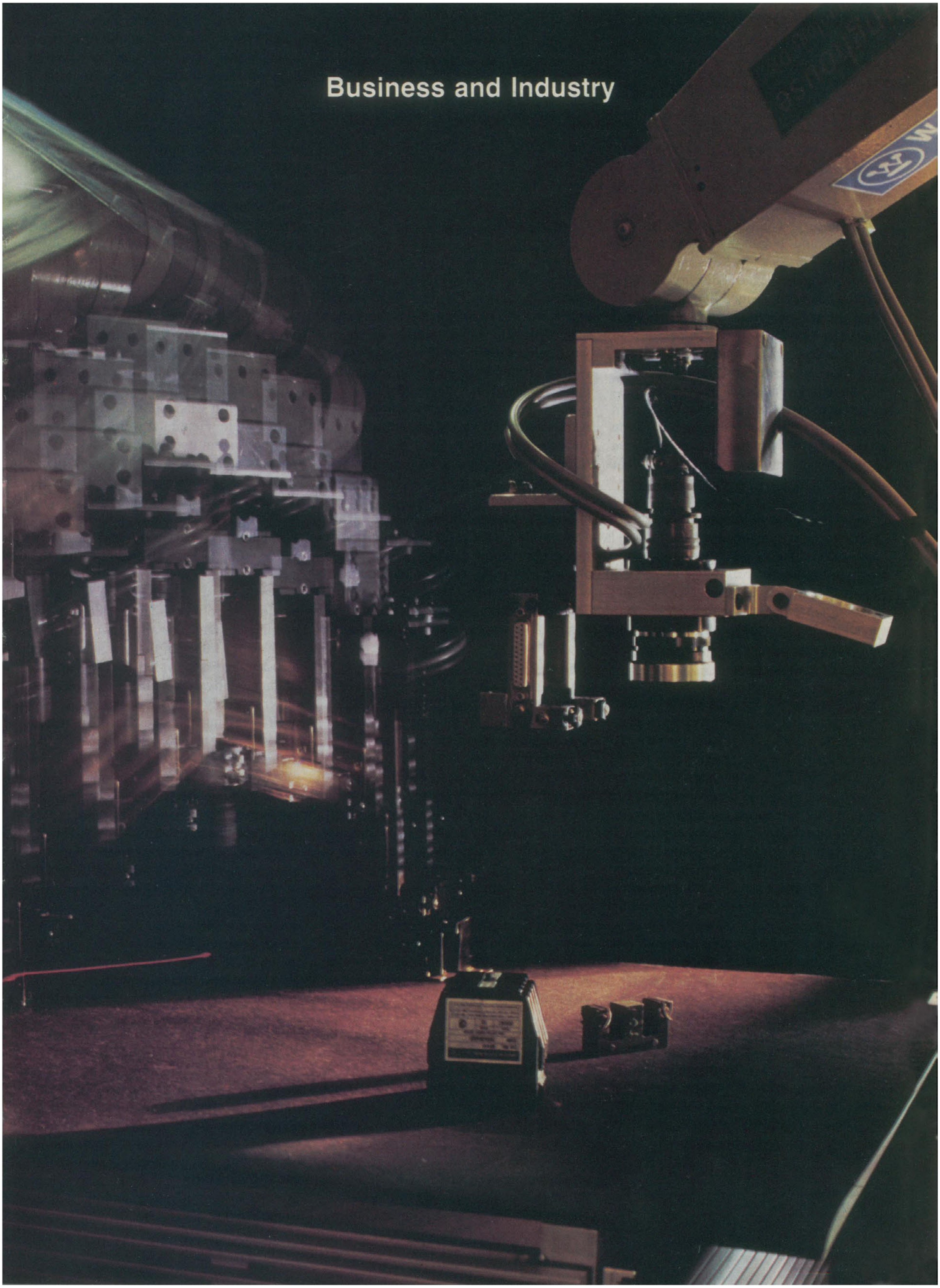
Business and Industry



The Technical Base

The technology was ready. Our understanding of systems architecture and of the constituent electronic, computing, and device technologies allowed a flowering of alternative system structures and componentry (*4*). The organizational paradigm that eventually came to dominate is called "distributed processing." Exploiting the radically lowered electronics costs, a distributed processing system is one in which each element of the system has its own computational, storage, and communications capability. Each terminal (or electronic desk), each printer, each specialized file, and each unique office service unit acts autonomously in handling its own task. All are linked by (typically) a high-bandwidth communications channel that enables them to share load, perform specialized functions for one another, and handle the interactive business of the organization. The on-site communications networks are, in turn, interconnected by common-carrier links, creating a large, geographically distributed network of systems, subsystems, and work stations, each speaking the same language. Such integrated office systems are just now being offered commercially.

Supporting these systems innovations is a vast increase in the availability and power of the constituent technologies. For example, very large scale integrated (VLSI) chips of impressive power are being developed. Eventually, they will have several million active elements, operate at 100-picosecond internal cycle times, yet cost only a few tens of dollars. Individual chips will combine memory, logical processing, input-output interfaces, and, if appropriate, analog-to-digital conversion, allowing "intelligent" equipment functions to be dispersed to an unprecedented degree. The limiting factor in the development of such chips will be the ability of human designers to cope with their logical complexity. Fortunately, flexible information-processing systems similar to those used in office automation will help the designers manage these problems. Some systems of this type are already in use (*5*).

Local communication networks using optical fibers are likely to become common toward the end of the decade, providing bandwidths of 1000 megabits per second throughout an area a few kilometers wide. Overkill by today's standards, these networks will be needed as the graphical richness of our electronic communications increases. Broadband digital circuits for long-distance communication will also become available from a number of common carriers. These will be necessary to support the intersite communications traffic at a level comparable to the intrasite flow.

New storage technologies will enable radical reductions in costs (*6*). Already it is cheaper to store reference files magnetically than on paper. Over the next few years we will see this crucial transition take place in a cost-effective commercial sense, making a large proportion of the information used in our daily activities directly accessible through standard office systems.

For most applications, rotating magnetic memories will continue to dominate the field. Introduction of metallic media and the new vertical recording techniques will provide improved performance at lower cost. By the mid-1980's fixed disks with capacities in the many hundreds of megabytes should be in production. Floppy disks with capacities in the tens of megabytes should be quite inexpensive.

Optical memories with capacities of 10,000 to 100,000 megabytes will be made. Write-once storage material of archival quality will enable inexpensive mass storage while magneto-optic erasable materials will allow storage functions intermediate to those of write-once optical and magnetic memories.

Even after voice functions become practical, the screen will still dominate. For very high-quality images, cathode-ray tubes will provide resolutions of 1500 to 2000 lines per screen width. Medium-resolution, thin, low-power displays, suitable for use in compact terminals, will probably be made by using liquid crystal or electroluminescence technologies.

Isolated utterance speech recognition will be incorporated into the electronic desk. So will image and character recognition tools, all made practical by the integrated circuit revolution. However, as with integrated circuit design itself, the limiting factor in coalescing all these technologies into office systems will be the ability of people to comprehend and manage the complexities involved. All the groups working in this area will have access to the same basic hardware technologies. In the future, the major functional distinctions between different systems will be provided by their software.

Software

Today's large software systems are mankind's most intricate and complex creation. Software systems have, over the last few decades, evolved into almost bewilderingly complex hierarchies of control. At the most elemental level, microcode does the pick-and-shovel work of turning switches on and off, manipulating integers, and testing conditions. The level above that handles simple expressions, accesses storage, and manipulates lists. Each succeeding level works at a higher level of abstraction, using as its tools the symbolic services offered by the level below it. In turn, each provides to the level above it a set of richer, more sophisticated building blocks to be used as the tools for its more global constructions. At the top of the pyramid are, ideally, languages and systems of exquisite generality and breadth, which are themselves used to construct the specific applications demanded by our information-hungry society. In a sense, the programmer labors much as the medieval masons did, forced to leave the ultimate completion of his intellectual cathedrals to succeeding generations.

The fruits of the electronics revolution are such that we can afford to do anything we want—if we can only program it. Software is the dominant challenge in office automation. Program and system development will become the bottleneck in achieving the levels of performance and function that the available hardware technologies and low costs will readily allow. Software will be the major development cost element for the foreseeable future.

So, more slowly than we might wish, office systems will evolve. Beyond the now familiar word-processing and text-editing functions, what can we look forward to?

Services

Whether the professional is preparing a report, using a service, automating a routine task, or just browsing for information, the electronic desk provides the medium for interaction. However, the very richness of proferred services may be intimidating. For that reason, a lot of attention will be paid to the way the services are offered. Command structures will be consistent across different functions. (The command structure itself will be hidden by a cosmetic layer of intuitive graphic, voice-, and motion-response tools.) Underlying all this will be a substantial body of knowledge about how humans deal with machines, about their cognitive models, their representational preferences, and their typical error patterns.

The use of message systems to combine transmission of text, images, and

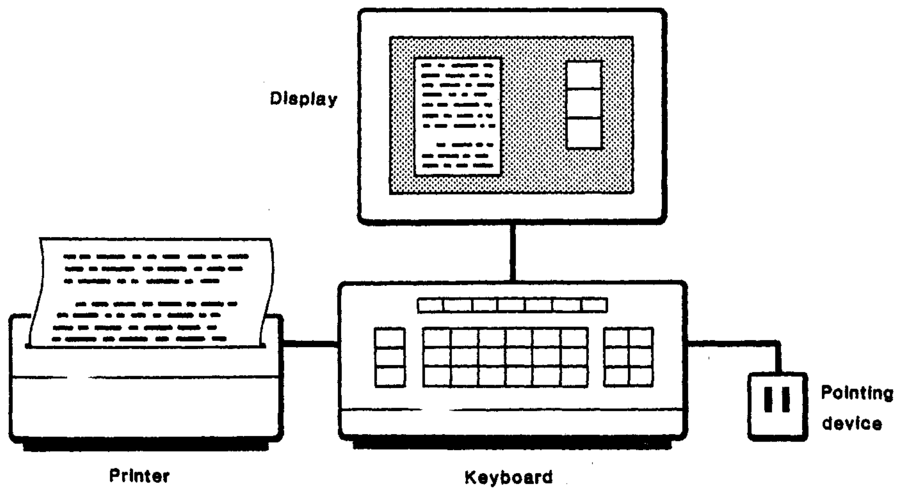


Fig. 1. The electronic desk includes a keyboard, display screen, pointing device, and printer.

audio information will become widespread. Document creation and distribution will change radically. One person sitting at an electronic desk will be able to create a report, including graphics, in a form ready for immediate distribution or printing. For high-volume, high-quality publication, page masters will be readily prepared. Searches in centralized data files will proliferate as many private and public database services arise to fill a variety of needs. "Search-assistance" programs will be available.

The network's ability to handle digitized voice will allow telephone service to be provided on the office system. Limited voice input and control will be incorporated. Services will be provided for storing, editing, and distributing audio information. It will be possible to conveniently associate such audio files with other text and image files stored in the system. Voice annotation of documents and drawings will be common.

As the display more and more becomes the focus of the user's activities, we can expect its function to broaden. An obvious extension will be its use for commercial television. Picturephone service, when reinstituted, will use the same screen. Videodisk and videotape files of both still and motion pictures will be displayed there. Interactive searches of large image-based information stores will be common (on-line encyclopedias). These last will allow multimodal presentations: text, fixed images, and moving pictures (slow motion, fast motion, freeze-frame) with accompanying sound. After a while, full color displays will be the norm.

In time, services will expand beyond those intended to directly augment the professional's data and computational base. Calendar management functions will be provided. Discipline-specific decision support systems will be developed (*7*). "What if" simulation models will be offered in a number of professional domains. Problem-solving languages designed for use by the professionals in a specific field—reflecting their particular models and jargon—will be available. And, for more stylized information manipulations, it will be possible to step the system through a sample calculation or table-structuring task and expect it to replicate the process (*8*).

System Growth

To make these ideas more tangible, it is useful to outline the evolutionary growth of one particular system configuration (*9*).

All work starts with the electronic desk (see Fig. 1). This unit consists of a large display screen, a keyboard, and a convenient pointing device (for indicating to the system a particular part of the displayed image). Backing up this equipment, in a small desk-side unit, are the local processor, the personal (local) file, a smaller removable media storage unit, and the communications connection that links the desk to the rest of the system. Simpler installations also include a local printer; more sophisticated ones do not.

The basic electronic desk configuration allows the professional to handle all his or her self-contained work. Such work might include the reviewing and updating of personal files, the storing of notes, preparation of documents, creation of diagrams, figures, and charts, and all the local computations necessary to support these activities. In installations with local printers, the production of a printed document is often the end point of a particular working session. A number of professional activities require no more than these capabilities.

However, most work is done in a larger context. This means that the pro-

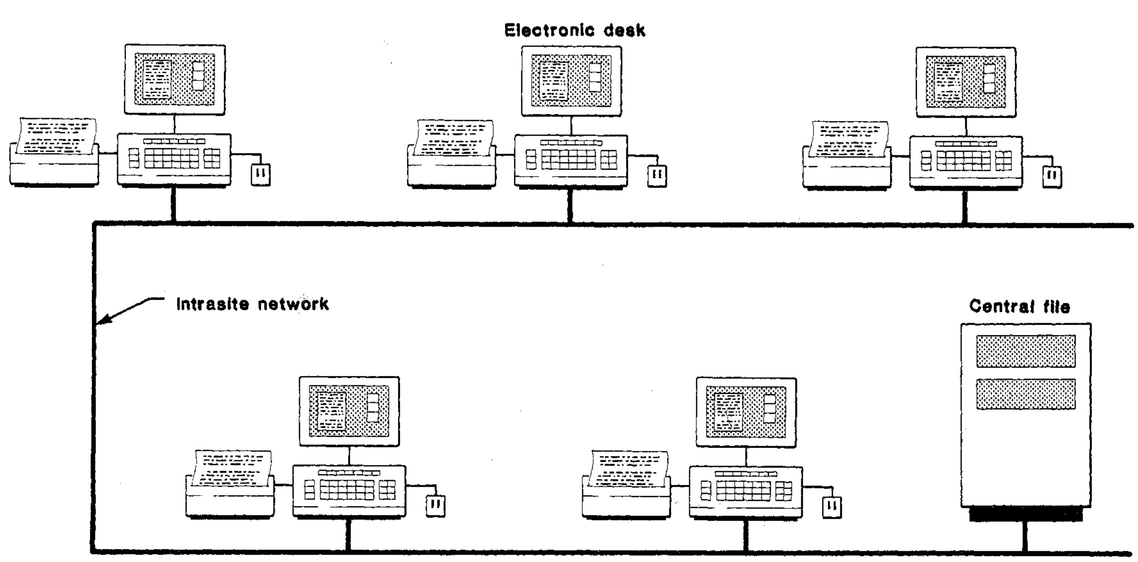


Fig. 2. The intrasite network links many electronic desks to one another and to a central file.

fessional needs to be "in touch" with other people or other information sources. For purely local interactions the intrasite network will suffice. For the new user, access to the organization's central files is usually the most important capability. A well-designed office system offers remote file access as a natural extension of its local file recall system, even though the hidden, internal mechanics of connection and retrieval are much more complex. (There are, of course, the normal rules of conduct appropriate to the use of any shared resource, whether paper or electronic.)

Once the desk is linked to the office network, all the other benefits of the larger system become available. Typically, if the organization already has a number of desks on-line, the electronic message exchange system begins to be of great use. In large electronically linked groups paper mail tends to be used mostly for formal (official) documents. The communicating office system then has a configuration like that shown in Fig. 2.

With the link to the larger system established, the professional user slowly begins to do things in a different way and, more important, to change ideas about what can be done. The printing service is an example of this. The sophisticated displays of the newest office systems are capable of presenting an extraordinarily rich variety of images. Because the screen is "bit-mapped" (that is, each minute picture element is individually capable of being shown as light or dark) there are no practical limits to the kinds of images that can be created and displayed. At its simplest, this means that text can be presented in any one of a number of type styles, in a range of point sizes, and in normal, bold, or italic form. Line drawings, charts, and graphs with a variety of shadings, sizes, and textures are possible. Halftone images can be portrayed as necessary.

This richness of graphical presentation is, however, soon frustrating to the professional user if he can only look at it on his screen or send it to a colleague to view. Here is where one of the more important shared services comes into play: raster printing. In the same way that the screen image is displayed by individually turning the spots of light on and off, so can an image be "painted" on a photocopier drum. One way of doing this is with a laser scan, creating what is called a laser printer. Other techniques are also available.

These versatile devices are capable of replicating the on-screen image in printed form. (Actually, they do it at higher resolution.) However, they are expensive and few individual users can afford them. They are therefore provided as a shared service. Instead of each desk having its own raster printer, the services of a single printer are shared among a number of users. Experience shows that, if the raster printer is located within about 50 meters of the user, the substantial advantages it offers make it the output device of choice, being consistently used over the more limited printer next to the desk.

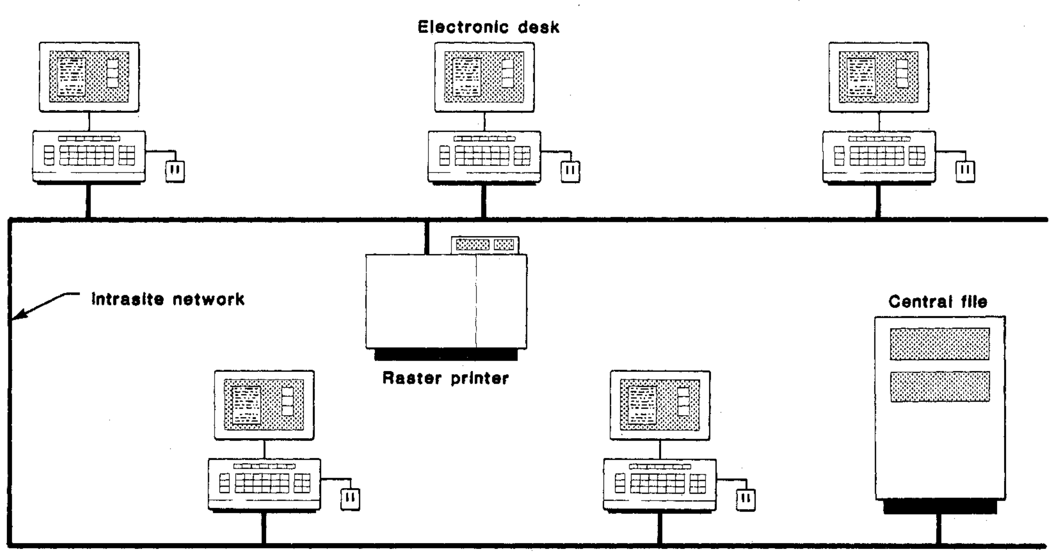


Fig. 3. The expanded intrasite network offers many shared services including raster printing.

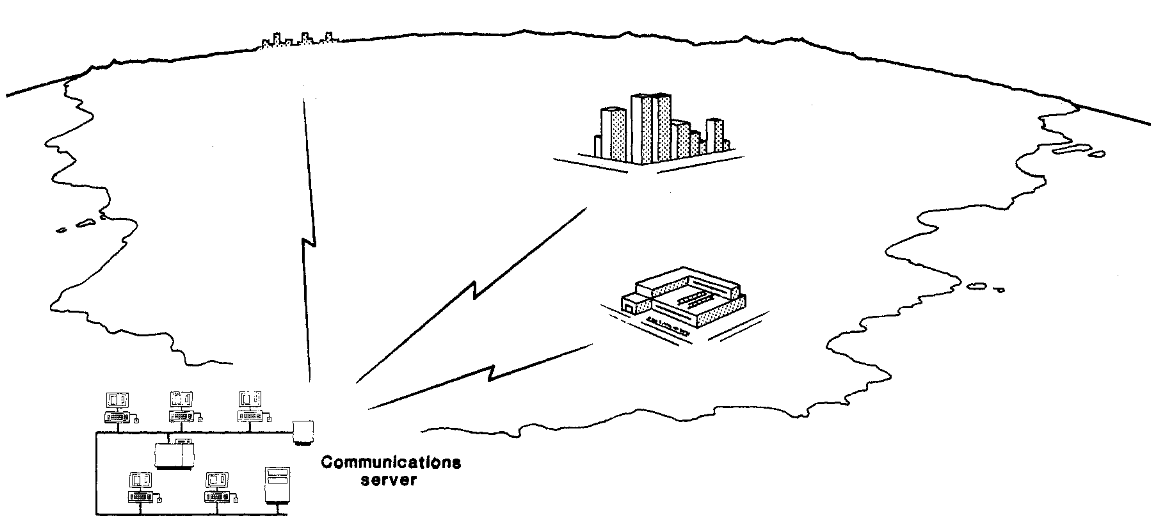


Fig. 4. The communications server enables geographically dispersed networks to be linked together via common carrier networks.

The printer service is just one example of the kinds of shared resources that are being made available on office networks. Specialized data services—again not individually affordable—have begun to proliferate. An interesting one is the master spelling-corrector. This specialized file system connects to the network and offers a scanning service for any document submitted to it. Any word in the document that does not match those stored in the service dictionary is flagged as representing a possible spelling error. The user can make corrections as appropriate. (Not all flagged words are in error. They may be proper names, a bit of specialized professional jargon, or an unusual abbreviation. The spelling-corrector can be instructed to include these forms in its dictionary in the future.)

A wide range of specialized, network-available services can be offered. They will vary according to the particular professional disciplines being supported. There may be high-powered, complex simulation or econometric models. There can be phototypesetters or color printers. Corporate legal files may be important in another office. A group of physicians may find it convenient to have access to their clinical files. A scientist may want direct control of a tricky piece of experimental apparatus. The important point is that, once the "backbone" is there, additions are straightforward. By now the configuration looks something like that shown in Fig. 3.

Thus far, this description has covered the activities of a self-contained group. The fully functional office automation system does more than this. The missing element is the inter-organizational link. The database to be referenced or the service to be sought may not be available on the local network. The lawyer may want to scan the LEXIS file; the sociologist may be interested in Census Bureau data; the chemist may want to do a literature search; the traveler may want to see the latest flight schedules. This information is available only by expanding the office connection to the "outside world."

This is done by making one simple addition to the office network. A communications server is added. This unit's task is to connect the local network to the common-carrier communications networks. In this way the professional's desk is linked to the panoply of on-line services available today. Again, the well-designed office system insulates the user from the intricate interconnection details and offers these services through the same access tools as those it provides for its local services.

With the outside connection established, the professional community of electronically linked colleagues is substantially enlarged. Now, electronic mail, document distribution, and project collaborations are not geographically limited. Local interactions become national interactions. The only visible difference in dealing with someone 5000 kilometers away is a slowing of the interaction times because of bandwidth limitations on the common carrier lines. The structure of the interchange is the same as if they were 5000 meters away. The automated office as part of a larger system is shown in Fig. 4.

Effects on People

The operational and social implications of this new technology are hard to predict (*10, 11*). We may, in fact, witness the full blossoming of the postindustrial revolution when routine intellectual work becomes as automated as heavy mechanical work did during the 19th century. Even if we cannot accurately foretell what personal changes this revolution is likely to bring within our own lifetimes, it is worth some thought. My views are somewhat personal and anecdotal, but are based on experience with the systems under discussion.

Clearly, the most marked effects of these systems derive from their ability to provide new ways of doing things and their capacity to reduce paperwork drudgery. They set up new information flow paths and personal dependencies that will eventually change the ways in which organizations are managed. At the same time, they foster new avenues of social interaction, based on common or shared interests. At the professional level, the systems provide relief from time-consuming tedium. At the clerical level, they offer an opportunity to assume new responsibility and to develop new skills.

Those of us who have now had a few years to work with these seemingly impersonal systems have found that they tend, paradoxically, to break down the barriers to communication. Daily message traffic takes on a less formal, more conversational air. Priorities are easier to establish. And immediacy reduces the chances for misunderstanding. It becomes easier to interject purely human exchanges amid the daily routine.

For example, I am now a member of a large number of different electronic "communities." Each is characterized by an electronic distribution list so arranged that whenever a message is entered into the system it is routed automatically to all the people whose names are on that particular list. In addition to various management and research groupings, I am also a member of a community with hiking interests, a ticket exchange community, and even a "junk mail" community. A recent conversation on junk mail may help me make my point.

One afternoon, someone complained that "coat hangers accumulate in everybody else's closet except mine" and asked whether anyone could spare a handful. This turned out to be a fairly efficient way to solve his problem, but the query also sparked a couple of dozen replies, each offering some sort of tongue-in-cheek advice or explanation of coat hanger behavior. "The reason they accumulate in most people's closets is little known, but interesting," said one reply. "Beer can openers are actually the larval stage of coat hangers; when they hatch out they migrate. You probably use flip-top cans." This engendered some commentary on beverage cans, an exchange that went on for a couple of days.

One soon becomes accustomed to these services and begins to take them for granted. I am particularly accustomed to electronic mail. But recently something happened that reminded me that I was part of a different way of doing things. I received a bit of follow-up correspondence from a colleague in Vienna. The content was routine, but the way it came to me was not. Instead of receiving a letter or a telegram, I simply found his message waiting for me one morning in my electronic mail. Everything had been handled automatically from the time the message left his office until it reached mine. An integrated information system involving both private and public networks, several independent computers, and a variety of organizational procedures had delivered the message to me as a matter of course. When information-handling capabilities that are this complete become routine for the average professional, we will finally have escaped the piecemeal operations of the 19th-century office and will have achieved a new mastery of the mechanics of our intellectual environment.

In the end, one must wonder about the basic changes to be wrought by office automation. At the technical level, we will surely see a stream of impressive new devices and rich supporting software enabling the widespread dispersion of integrated information systems. But the most profound effects will probably occur at the personal level, in the way we do things using these systems. Certainly we will gain new power—radically increased speed and flexibility in manipulating the substance of our working lives. But, more important, we will have found a new medium for interacting with others. Because of this, these systems will have the power to draw us closer together and change the ways we work and live.

References and Notes

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10. C. Ellis and G. Nutt, *Comput. Surv.* **12**, 1 (1980).
11. C. Gaffney, "Selling office automation internally," *AFIPS Office Automation Conf. Digest* (American Federation of Information Processors Societies, Arlington, Va., March 1981), pp. 127–131.

12. I am indebted to my friends at Xerox's Palo Alto Research Center and Systems Development Department. They created much of what I have described here. Their vision, imagination, skill, and hard work made a reality of their early dreams. It has been a pleasure to have learned so much from them.

Advances in Process Control

David L. Morrison, Richard H. Snow, John P. Lamoureux

The important functions for computer process control are measurement, control, actuation, signal processing, and communication. Control and communication are accomplished by electronics, measurement and actuation by special sensors and actuators.

Summary. Advances in electronics and computers have enabled industries to attain better control of their processes with resulting increases in quality, productivity, profitability, and compliance with government regulations. With a hierarchy of computers, distributed data acquisition, and information processing and control, it is possible to achieve overall optimum performance of a plant. While further advances in microprocessors and large-scale integration will be useful to the process engineer, major improvements in process control await advances in sensor technology and software.

Computer control of processes has developed in an unbalanced way because electronics has been extensively developed through government funding. Therefore sophisticated microcomputers and other electronic hardware are comparatively cheap. Sensors and actuators, however, are in a lower state of development. There is a need for industries to devote further effort to developing sensors and actuators that they require. In the meantime, it is prudent to use microcomputers to extract the maximum amount of information from existing sensors and to provide sophisticated control over relatively crude actuators. This means that microcomputers are located in the plant near the sensors. It is also desirable to use electronics to condition signals so that information about process performance can be passed from the microcomputers to a central supervisory computer, where the process goals are set and optimized and where performance can be displayed to operators through graphs on television monitors. A review of recent trends in the paper, petrochemical, and steel industries shows that although many processes are controlled by simpler methods, the distributed method is gaining favor for complex processes.

Since Evans's review of process control in 1977 (*1*), the trend has continued toward more extensive use of microcomputers and large-scale integrated (LSI) electronics. The increased efficiency of process control through electronic advances makes it possible to improve productivity, reduce wastes, improve material utilization, and reduce energy consumption (*2*). Process controllers also maintain safe operating conditions within the plant and ensure compliance with government environmental and occupational health requirements.

Improvements have also been made in software. In addition to improved algorithms or rules for solving complex problems, software has evolved with the user in mind. Controllers now are available that can be programmed in terms of logic functions familiar to process and control engineers, rather than the computer languages that have been the domain of computer/programmer specialists. But the more complex computer systems still require these languages.

Although this article focuses on the process industries, many of the electronic and computer technologies are similar to those described in this issue by Hudson (*3*) for manufacturing industries. For convenience, we follow the simple means Evans (*1*) used to distinguish process industries from manufacturing industries. Manufacturing industries manipulate the geometries of their raw materials so that discrete parts are formed and assembled to produce an integrated, more complex, useful product. In process industries, the composition of materials generally is manipulated by chemical reaction and blending of components to convert raw materials and energy into more valuable products. Process industries also include those involving physical changes such as drying, distillation, and forming through casting and rolling. Chemicals, petroleum, metals, pulp and paper, food, cement, textiles, synthetic fuels, and power production are included among the process industries.

Microprocessors and Distributed Processing

The entire approach to computer control of the industrial system changed with the introduction in 1970 of the first microprocessor, the Intel 4004 (*4*). The subsequent development of LSI electronics leading to low-cost, reliable mi-

David L. Morrison is president, Richard H. Snow is manager of chemical engineering research, and John P. Lamoureux is associate engineer at IIT Research Institute, Chicago, Illinois 60616.

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