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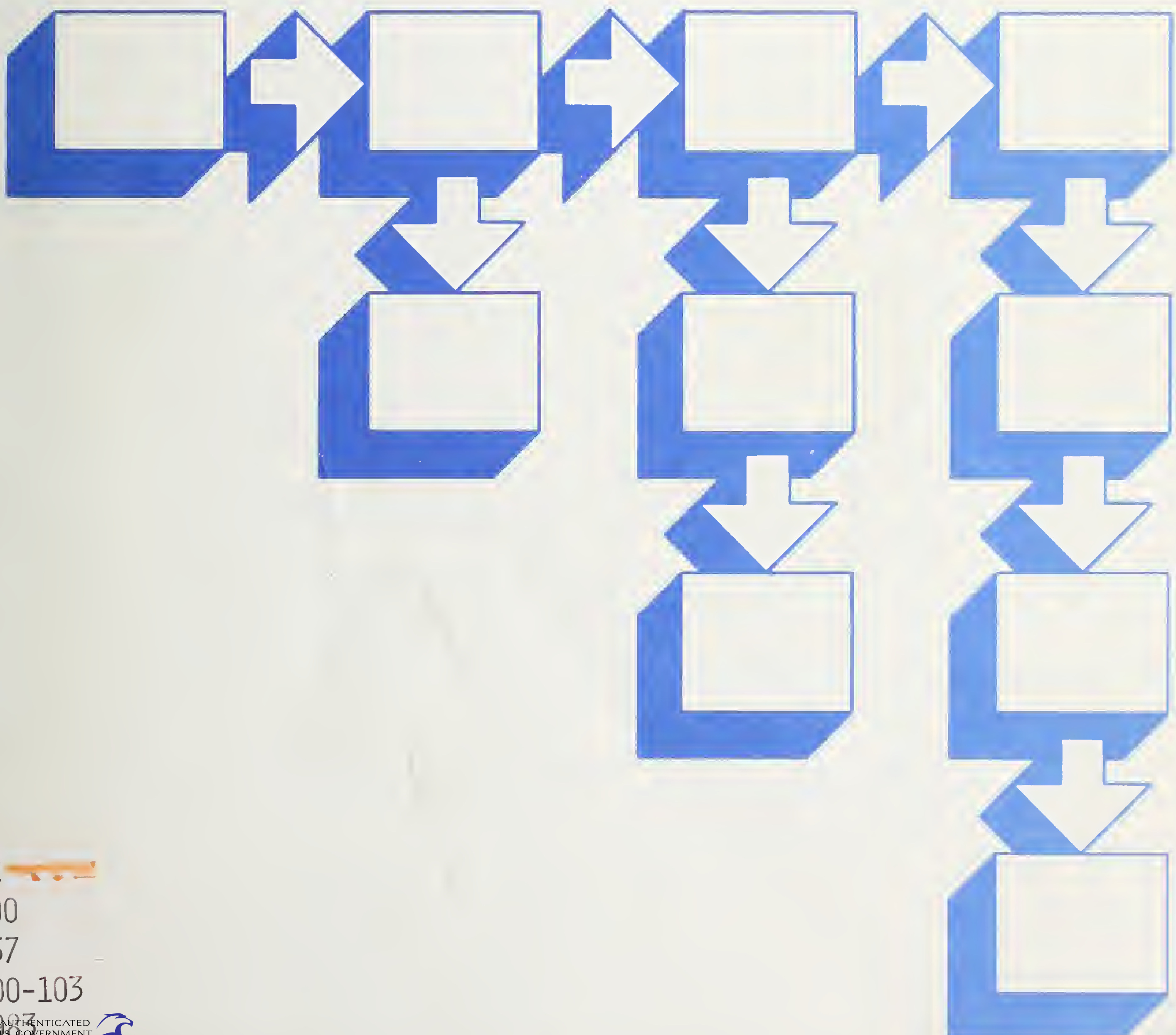
Future Information Processing Technology - 1983



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Future Information Processing Technology - 1983

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Institute for Computer Sciences and Technology
National Bureau of Standards
Washington, DC 20234

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ABSTRACT

The document contains the 1983 Technical Forecast for the information processing industry through 1997. It consists of six parts. Part I forecasts the underlying technologies of hardware and software, contains a discussion of changes in the information industy and market, and forecasts products and systems of the future, e.g., general-purpose systems, distributed processing systems, office systems. Part II contains Federal agency staff comments on Part I. Part III summarizes a teleconference in which a number of industry ADP users and vendors reviewed Part I. Part IV provides cost estimates for computer systems, subsystems, and terminals through 1997. Part V discusses the current and potential rules and regulations of the Federal environment and how they may affect the Federal inventory of ADP equipment. Part VI discusses management strategies for the new information technologies with emphasis on microprocessors.

KEY WORDS: computers; cost estimation; distributed processing systems; end-user computing; Federal ADP regulations; general-purpose computer systems; information processing industry; management strategies; microcomputers; office systems; technology forecasting.

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We would like to thank Frederic T. Withington of Arthur D. Little, Inc. for his extensive contributions, and the following Federal agencies for their assistance: Defense Mapping Agency, Department of Defense, Department of Education, Department of Health and Human Services, Department of Housing and Urban Development, Department of the Interior, Department of Justice, Department of the Treasury, General Services Administration, Institute for Computer Sciences and Technology, National Aeronautics and Space Administration, Office of Management and Budget, Securities and Exchange Commission, Smithsonian Institution, and Veterans Administration,. Our thanks also go to Whit Dodson, of IDC, who was principally responsible for developing Part V and to Lisa Stevenson who was an invaluable consultant in the preparation of Part VI.

FOREWORD

The Institute for Computer Sciences and Technology (ICST) is responsible for the development of standards and guidelines which lead to "the economic and efficient purchase, lease, maintenance, operation and utilization of automatic data processing equipment by Federal departments and agencies" (Public Law 89-306). In order to fulfill its responsibilities, ICST gathers and integrates information needed for the timely selection of technical areas to be investigated and for monitoring and revising existing standards and guidelines. To those ends, ICST develops technology forecasts, projects trends in the Federal ADP inventory, gathers data relating to ICST product usage, and conducts studies on the costs, benefits, and impacts of its products.

While the information gathered and compiled is primarily used to help ICST guide its own program, certain studies are, we believe, of more general interest. When widespread interest is expected, ICST, through publication, disseminates the relevant documents. One case in point was our September 1981 technology forecast, *The Effects of Future Information Processing Technology on the Federal Government ADP Situation*. That forecast, which was prepared for ICST by Arthur D. Little, Inc. and General Systems Group, Inc., was based in part on a similar forecast prepared by A. D. Little for the Defense Intelligence Agency (DIA).

The 1981 forecast (as well as this report) belongs to the "expert opinion" category of technology forecasts and was thoroughly reviewed by ICST staff members -- experts in their own rights. Not surprisingly, the expert opinions differed on several points and those differences were, in themselves, of interest since they provided a basis for discussion and analysis that proved valuable to ICST's planning process. Thus, when we published the report we included the staff comments -- identified as such -- in the body of the forecast. Other Federal agencies indicated that they found the comments as valuable as we did.

Therefore, when we prepared this updated and expanded forecast, we circulated the draft report to all of the Federal agencies and invited their staffs to submit comments. Comments from 15 agencies were received and each comment was discussed with the contractor, Frederick Withington of A. D. Little. In most cases, the comments were incorporated into subsequent drafts of the report. In those cases where the staff comments were at odds with the opinion of the discussion team or were deemed to be beyond the scope of the forecast, they have been included separately in Part II of this report.

This 1983 forecast has been a consortium effort by a number of Federal agencies. ICST and DIA worked closely together from its inception. DIA provided the funding for the initial draft, which emphasized technologies of particular interest to the intelligence community. ICST provided the funding for subsequent drafts in which the emphasis shifted to civilian concerns including descriptions of ADP market factors. The joint effort by DIA and ICST, working with A. D. Little, produced a solid working draft of Part I of this report.

Staff members of the Department of Energy (DOE) joined ICST in reviewing the draft of Part I and working with A. D. Little to develop the final product. Both DOE and ICST staff members made considerable substantive contributions to the body of document. Staff members of the Department of Agriculture reviewed that draft and prepared a management overview which is included here as an introduction to Part I.

Part I is therefore the result of a joint effort. Certain sections in Part I are flagged, by the words "staff comment". The flagged sections are keyed to staff comments in Part II.

Part II contains the staff comments which either express views divergent from material in Part I or provide additional information on a particular subject.

Part III summarizes the results of a teleconference in which a number of private sector ADP users and vendors reviewed a draft of Part I. Staff from A. D. Little, ICST, and DOE served as resource people for the subgroups of the teleconference.

Part IV presents estimates of future system costs. This Part was prepared by A. D. Little for DIA and is included here because of its general interest to all Federal agencies.

Part V discusses the current and potential rules and regulations in the Federal environment and how they may affect the Federal inventory of ADP equipment. Prepared by the International Data Corporation (IDC), this part was funded by ICST and co-managed by ICST, General Services Administration (GSA), and the Office of Management and Budget (OMB).

Part VI is comprised of a discussion of the management strategies for end-user computing -- in particular, the microprocessors. This part was prepared by Aurora Associates, Inc. and is based in large measure on interviews conducted with staff members of several agencies. The Environmental Protection Agency (EPA) provided significant help in developing this Part. Part VI was funded by ICST.

We have been particularly pleased by the enthusiastic cooperation of the various Federal agencies as well as by private sector ADP vendors and users. It is our intent to periodically update the forecast and we are looking forward to expanding the working consortium in subsequent editions.

We would very much appreciate comments and suggestions from our readers, addressed to P. Powell, Information Processes Group, Institute for Computer Sciences and Technology, National Bureau of Standards, Bldg. 225, Washington, D.C. 20234.

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PART I: FUTURE INFORMATION PROCESSING TECHNOLOGY

OVERVIEW

Prepared by

U. S. Department of Agriculture

CHAPTERS 1-5

Prepared by

Arthur D. Little,Inc.

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and Technology
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OVERVIEW: PREFACE

This section of the forecast was prepared by the Planning Division of the Office of Information Resources Management of the United States Department of Agriculture. It originally formed part of the USDA planning document, "Technological Environment Survey"--a document which, in turn, drew on an earlier draft of this report for much of its source material.

Because the material includes a concise summary of the lengthy Part 1 of this forecast, with USDA's permission we reprint it here.

1. INTRODUCTION

The technological environment is presented in this document as technologies and strategies. The technological areas presented are:

- o Automatic Data Processing
- o Telecommunications.

The strategies presented are:

- o Distributed Processing Systems
- o Office Systems
- o End-user Computing.

Finally the following sections are presented:

- o System Costs
- o Compatibility and Transportability of Software
- o Information Control and Security
- o Personnel and Maintenance Implications

2. MANAGEMENT SUMMARY

Plans for future improvement of Information Resources Management (IRM) are laid against a backdrop of increasing conversion of manual operations and procedures to the use of automated techniques. Real productivity increases in the industrial environment came only after management adapted mechanized systems to processes which had previously been manual. People using machines have made possible the twentieth century advances in production of goods, farming, mining, travel, and communication. The growth of automated technologies such as computerized information manipulation, enhanced office text preparation devices, electronic information transfer, and micrographics has developed because these devices and systems increase productivity in each environment. In an era of expanding production requirements, coupled with the rising cost of human resources, automated techniques are being increasingly employed.

Most of the future developments will be based on the use of additional breakthroughs in the exploitation of very large and large scale (VLSI and LSI) integrated electronics circuitry. These circuits were primarily an outgrowth of the research programs of the 1960's and 1970's. Microprocessors, or computers on a chip, are finding their way into a wide range of devices from the automobile to electronic games to intelligent computer terminals, personal computers, and mainframes. Their use will be limited only by human imagination and the capability of manufacturers to keep up with the demand and to show an increased profit through their implementation in products.

The growth in the use of this technology has accompanied a corresponding increase in the types and amount of information that are being recorded and used. This growth is causing a dramatic change in the requirement to properly manage information to assure maximum accuracy, effective utilization, and minimum redundancy.

2.1 AUTOMATIC DATA PROCESSING

The technological capabilities that will be available to the Federal government over the next five years offer tremendous opportunities to improve the performance of all mission programs and to reduce operating costs through increases in productivity and efficiency of personnel. The only limitations or failures in tapping these vast technological opportunities will be from either a failure to make adequate investment to acquire and to learn to use the needed technology or a failure to plan adequately and to manage the implementation of the new technology. Even with adequate capital investment, good planning, management and training, the Federal government will find it extremely difficult to keep up with the pace of technological growth and capability. A brief discussion of some of the current and expected technological changes over the next several years is included in the paragraphs below.

2.1.1 Technological Changes In Computer Hardware. The foundation for the modern-day digital computer technology is that of the vacuum tube and later of the basic transistor developed in the early 50's. The development of integrated circuit technology (a dense collection of minature transistors also called "chip" technology) in the 60's and 70's was the major breakthrough leading to the high processing speeds and expanded storage capabilities, lower unit storage costs, and divergent application opportunities that exist today and which will continue to expand in the future.

Two indicators often used to measure the advancement in integrated circuit and computer technology are the density of components on each circuit or chip, and the number of operations per second that can be performed (speed is usually defined in terms of MIPS-millions of instructions per second or MFLOPS - millions of floating operations per second). Circuit densities of 64,000 components or more per chip are available in the marketplace today. It is projected that by 1986, densities of up to 1,000,000 components per chip will be commonly available. With respect to processing speed, some of today's largest computer systems are approaching 100 MIPS. By cascading or coupling a number of individual processors, the effective processing speed that can be achieved is almost limitless. The practical limits facing integrated circuit technology development are the problems associated with heat dissipation as circuit densities increase and the inherent propagation delays between components within the chip (limited to the speed of light).

As circuit densities increase and high volume demands allow for expansion of production capacity in the marketplace, unit cost of chips continues to plummet. These decreases in unit cost and increasing capabilities will continue to expand the opportunities for many new and different uses of the technology in military, commercial, and consumer applications.

2.1.2 Technological Changes In Software. Throughout the history of computer technology, software has lagged behind hardware in terms of sophistication, performance capability, and reliability. The almost infinite variety of ways in which software (computer programs) can be designed, organized, and implemented has inhibited the development of standardized techniques and languages and slowed the transition process from old to newer technology. In recent years, software maturity has become the dominant factor in terms of cost and developmental pace of new computer systems. Software development and maintenance continues to be highly labor intensive and continues to increase in size and complexity with each new generation of computer equipment.

Current trends in software technology center around efforts to improve higher order programming languages and tools to make computers easier to use and to increase programmer productivity. Another major goal is to provide the capability for non-ADP professionals to develop their own systems and solve problems more easily without requiring the services and skills of ADP professionals who continue to be in short supply. Many new products in the form of automatic programming aids, ultra user friendly languages, data management tools, and other programmer and user aids will continue to be introduced over the next several years. Development of new software standards in such areas as operating systems, development of cross compilers (a programming tool), and emulators will be emphasized to make software and applications more portable and less costly to convert and maintain.

In the coming decade, software changes will be more significant to computer users than will hardware changes. Hardware trends will result in reduced cost, but software trends will bring changes in the way the typical data processing installation functions and the relationships between the data processing department and users.

The trend toward ease of use is the result of terminal proliferation, greater user familiarity with electronic devices, and the growing discontent of users who are often told that the programming staff will take two to three years to design and implement a new application. The objective of the newer software is to support computer systems that can be programmed and operated by non-computer trained personnel.

The software tools that will enable user personnel to develop applications will also make the professional programmer more productive. Software products that perform input, processing, and output are beginning to appear in the marketplace. These new products will gradually replace today's programming languages for most applications and will require more hardware resources as a tradeoff for their user friendliness.

2.1.3 Application Of Technology. Computer based technology will continue to be applied as the core of new and innovative products which can be applied in the home, office, laboratory or field to assist professionals and nonprofessionals in the performance of their functions. Such products as executive and professional workstations, integrated office systems, and intelligent communications networks will continue to be introduced and expanded in capability at relatively decreasing cost.

2.1.4 Integration Of Technology. Technology will continue to be integrated into the working environment of nearly all functional areas and organizations within the government. The distinction between computer, communications, information management and other previously separated environments is becoming more difficult to maintain because of the effects of technology integration. Overall, technology integration is expected to yield significant benefits to the Federal Government. However, the price to be paid will be ever increasing complexity resulting from the increased need for coordination in the design, implementation, management of the technology, and the new applications supported by the technology.

2.2 TELECOMMUNICATIONS

The telecommunication industry is currently undergoing a dramatic change from a predominantly monopolistic to a competitive environment. In addition, there is a change underway from an analog electromechanical environment to a sophisticated electronic digital based technological environment. This includes digital information transfer switches, utilizing the latest, very large scale integrated electronic circuitry, fiber optic and satellite transmission media, and the inclusion of integrated digital computers in the provision of total telecommunications facilities.

Telecommunications management in the past has primarily addressed the transmission of the human voice from one point to another using wires or radio waves as the communication medium. Modern telecommunications facilities include the use of satellite relay stations, glass fibers carrying light waves, laser beams, and totally solar-powered ultra-high frequency transmitters in addition to the former media.

In addition to the transmission of the human voice, the new facilities are required to accommodate the transmission of digitized information from large and small computers, facsimile machines, communicating office text processors, various high and low speed data collection and monitoring devices, and video (visual) images. The ideal total system will include support for all voice and non-voice transmission and associated services required by a corporate or government entity. Industry is now perfecting the ability to translate the human voice into binary form (bits of information represented by a series of 1's and Ø's). This translated form may then be carried over facilities designed primarily for the transmission of traditionally digitized information such as computer files, automated office text, digitized facsimile images, remotely sensed information, and other information converted to digitized form. This merging of many kinds of information into digitized forms is making it more practical to provide a total telecommunications support facility.

Standards for linking distinct communications networks are being addressed by organizations such as the International Standards Organization and The Institute for Computer Sciences and Technology at the National Bureau of Standards. In the near future, we should see the results of the work being done in the area of linking distinct communications networks (also called internetworking).

2.3 DISTRIBUTED PROCESSING SYSTEMS

The evolution of distributed processing systems is more constrained by market and industry readiness than by technical factors. Most distributed data processing systems are justified on the basis of a single application which is generally transaction processing-oriented and dependent upon several geographically distributed but functionally integrated databases. It is usually the case that once a distributed processing system is installed other local applications are added to the system to increase the effectiveness of local management or operations. However, the successful distributed processing systems as a rule retain centralized control of the databases and programs which are essential to the operation of the main application for which the system was justified. Prudent users perform a careful analysis of each application on a case-by-case basis to determine whether an application is more effectively implemented using a distributed data processing solution.

2.4 OFFICE SYSTEMS

Office systems are (from the technical viewpoint) supersets of distributed processing systems. Both incorporate microprocessor-based systems (MBS's). Both serve end-users in their local offices. However, while distributed processing systems traditionally deal primarily with data processing, office systems deal more with text, voice, and image material. Many users of distributed data processing systems are already adding limited text and image processing capabilities to them.

Industry structural constraints are slowing the development of office systems. Multi-media office systems require the skills formerly resident in four separate industry sectors (i.e., office products, computer hardware, computer software, telecommunications); a vendor competent in any one of the four must acquire the skills of the other three before it can offer mature multi-media systems. It also appears that the modular information appliances for end-users in business and professional applications are converging with those in consumer electronics (a fifth sector), requiring a new form of retail distribution system. Inter-active video disc systems for corporate applications have their roots in consumer video disc technology*, for example, but it seems unlikely that present consumer-oriented retailers can develop or sell such systems.

Office systems will evolve gradually, then, with single-medium systems (e.g., word processors) slowly combining functions with other single-medium systems (e.g., for distributed data processing and telephone service). Our observations of user behavior support this view; most organizations can assimilate only small office system changes without disrupting their activities and require about one year between changes.

2.5 END-USER COMPUTING

Within the last decade, it is probable that the greatest change in the government ADP environment has been the tremendous growth in end-user computing via personal computers and terminals.

By the end of this decade, end-user computing will account for well over half of all computing performed in most government agencies--a level that has already been reached in a few organizations and is about to be reached in others. This trend represents a dramatic change from earlier centralized data

*Ed. note: The vocabulary and spelling used in this field is still in flux. In this report, the term "video disc" is used in the broadest sense, denoting general information storage technology and is not limited to home entertainment technology.

processing where users could have only limited access to data via terminals. Many of today's users have direct contact with the computer without the requirement of an interface by a computer operator.

Government managers express little actual concern about the astonishing growth of minis and micros within their organizations. Almost universally, they seem to be adjusting comfortably to the arrival of the machines. Most have come to the realization that the successful managers of the future will have to make far greater use of computers than in the past; they know they must become knowledgeable about ADP and make intelligent use of the technology in order to survive as managers.

Typically, government executives view the cost of personal computers relative to the potential benefits that they expect their agency to derive as being a sound investment. Personal computers are viewed as offering the cheap computing that has been promised for years; government managers seem eager to explore ways to make use of the new technology now that it has arrived.

2.6 SYSTEM COSTS

The cost of technology will continue to decline, relatively speaking, over the next several years. Conversely, it can be viewed that costs will remain stable (disregarding inflation) with a significant increase in technological capability per dollar invested. Competition in the market place coupled with demand for new technological products is expected to continue the historical cost/technology growth trends for the next several years.

2.7 COMPATIBILITY AND TRANSPORTABILITY OF SOFTWARE

Users would like to be able to transport their programs across product lines; to be able to select among competitive vendors' offerings for every system module without having to reprogram existing software. Vendor independence cannot be guaranteed unless a comprehensive set of universally supported standards exists. Some standards exist now and others are slowly emerging, but the process is slow because of its inherent complexity and manufacturer self-interest.

A user wanting to remain as vendor-independent as possible should observe the following four guidelines in preparing new systems:

- Programming should be in standard high-level languages.

- Programs should be modular. In particular, input/output and file processing functions should be separated from computational ones.

- Inter-system communications should be conducted according to ISO standards, which will probably be supported by all vendors at this level.

- Hardware modules that are to be retained as the information systems evolve (terminals, communications controllers, processors) should as far as possible have their specific functions and interfaces established by microcode and software, rather than by fixed wiring.

It is easier to establish standards for new applications than to retrofit them to existing ones. In many organizations, old, non-standard applications will be running for many years alongside new ones, until it becomes cost-effective to replace the old application with a new one or a commercial package.

2.8 INFORMATION CONTROL AND SECURITY

Commercial requirements for access control and data security are generally less stringent than those of military security. This summary is confined to commercially available products and techniques.

Physical access to terminals and machine spaces is currently controlled by passwords, identity cards, terminal identifiers and the like.

Logical access to computer software and databases will be subject to improved control.

For the relatively few commercial users desiring data encryption, the ICST standard will be satisfactory. We envision no major effort to improve the level of security provided.

2.9 PERSONNEL AND MAINTENANCE IMPLICATIONS

After 1985, the end-users of the new systems will do much of their own programming via interactive dialogues with easy-to-use software, so they will no longer need to work through application programmers. However, user organizations will need central groups of highly-trained technicians to establish the environment in which the end-users work: to select the hardware and systems programs, to establish the standards, to define the software tools available to the users, and to perform information resource management functions. The emphasis will be on personnel quality rather than quantity. A cadre of experts will be required whose technical knowledge may be greater than presently needed. Application programmers will still be needed for the organization's production applications, perhaps as many as are now employed in many organizations. However, their numbers will not rise proportionately to the total amount of programming done in the organization.

The application programmers remaining in user organizations will be equipped with improved tools to help them, often resident in their versions of the multifunction workstation (the "programmer's workbench"). Paradoxically, however, the productivity of the developmental programming function itself is not likely to be enhanced much. Developmental programming is the most intricate, the most skilled and the most highly variable in the components of data processing system development; hence, it is the least likely to be automated.

The new software development aids should primarily be considered as tools for developing bigger systems better. The paybacks will be found in areas other than programmer productivity, such as documentation, maintenance, end-user training, and faster response to small problems.

Operations personnel requirements should slowly decline: system modules of all types should become increasingly automatic in operation, requiring less loading of programs, scheduling, changing of media, etc.

Maintenance of electronic modules will become much easier and less costly. Unfortunately, the reliability and maintainability of electromechanical peripheral devices (disk drives, printers, etc.) will not increase so much. Combining this fact with a probable proliferation of information system modules in relatively inaccessible field locations, the result may be that overall cost and quality problems of system maintenance will remain at approximately their present level.

3. ACKNOWLEDGEMENT

The principal information sources for the USDA report were the following three documents:

- A report developed for the Institute for Computer Sciences and Technology at the National Bureau of Standards (NBS) entitled, *The Effects of Future Information Processing Technology on the Federal Government ADP Situation*, September 1981, prepared by Arthur D. Little, Inc. and an updated draft version received in August 1982 by USDA.

- An addendum to DOD Intelligence Information System master plan entitled, *Future Information Processing Technology* December 1981, DOD/DIA prepared by Arthur D. Little, Inc.

- A report developed for Lister Hill National Center for Biomedical Communication, Bethesda, Maryland, entitled, *Communications Technology Forecast* January 1979, prepared by Bolt, Beranek and Newman, Inc.

Each of the three documents listed above contains more detailed information concerning particular technical areas than that given here. The following documents which used the first Arthur D. Little publication listed above as their principal source, were also used as secondary sources of information. They are:

- *IRM Long-Range Planning Document*, Volume 1, prepared by the U.S. Department of the Interior, December 1981.
- *ADP Long-Range Plan* prepared by the U.S. Department of Energy, December 1981, Appendix C - ADP Technology Forecast Summary.
- *Trends in ADP Technology* prepared by the U. S. Department of Transportation, September 1981.

The Technological Environment Survey was compiled and edited directly from the above documents by the Planning Division of the Office of Information Resources Management of the United States Department of Agriculture.

1. INTRODUCTION

This report contains a forecast of future information processing technology and products during the next fifteen years. Because the products offered by the industry are determined by the vendors' entrepreneurial decisions as well as by the potentials of technology, the report also contains a forecast of changes in the information industry and market.

This report consists of five chapters.

Chapter 2 contains forecasts of the underlying technologies to 1997: processor modules and supercomputers, logic and storage modules, input/output technologies, and software.

Chapter 3 contains an overview of changes occurring in the nature and structure of the U.S. information industry and its markets, and a forecast of its future structure. Emphasis is placed on qualitative factors that would tend to advance or retard the availability of products based on future technology.

Chapter 4 forecasts the results: the nature and approximate timing of future general-purpose computers, distributed processing systems and office systems, and implications for user organizations.

Chapter 5 summarizes the report. It briefly describes the technological and product developments forecast in earlier chapters, and implications for users. Figure 5.1 presents an overview of all the forecasts in tabular form.

2. FORECASTS OF UNDERLYING TECHNOLOGIES

This chapter presents our forecasts of the technologies that will be used in information processing systems. It is divided into the following four parts:

2.1 Processor Modules
2.2 Logic and Storage Components
2.3 Input/Output Technologies
2.4 Software

2.1 PROCESSOR MODULES

2.1.1 Introduction

This section contains a discussion of general-purpose and special-purpose processor modules which are likely to be incorporated into computer systems of the 1980's and 1990's.

This section is divided into four time periods;

- The 1982 state-of-the-art;
- 1982-1987;
- 1987-1992; and
- 1992-1997.

Within each of the four time periods, four types of processors are discussed:

- General-purpose processors;
- Parallel processors;
- Supercomputers;
- Mass storage systems.

Novel principles of processor architecture will be incorporated in all four of the processor types during the forecast period. These are discussed in the text. The timing of their appearance in commercial products is also summarized in figure 2.2 and in the discussion of general-purpose processors of 1992-1997.

2.1.2 State-of-the-Art

2.1.2.1 General-Purpose Processors

The majority of today's smaller processors are bus-oriented with one or more processors dedicated to each major system function and interconnections made via a wideband communications bus. A few general-purpose systems follow the same approach. As software and high-speed buses are developed, larger computers (presently centered around storage controllers) are also likely to become bus-oriented. When they do, they will probably be offered to users in a modular fashion, an approach which will also be followed by the smaller systems.

The use of microcode is increasing rapidly. Substituting for wired logic, microcode permits greater flexibility (because it can be changed) and a higher level of autonomy in each processing module (because systems program functions can be distributed to the modules as microcode). Microcode (and most other software) will be independently priced by the manufacturers.

Most of the microcode is implemented in the form of special purpose instructions which are utilized by the software portions of operating systems and support software (see section 2.4). Within the past few years, these instructions have become so complex that they have in effect become subroutines which work integrally with the system software.

Most of the microcode has been treated as proprietary to the manufacturer which generated it. While the tools used to generate microcode are not made available to the user or the general public, microcode modules are beginning to be sold separately. Pressures for standardization and interoperability may cause manufacturers to release specifications for standard microcoded functions, but it is not now clear that this will happen.

2.1.2.2 Parallel Processors

Current commercially available parallel processors are primarily intended for structured mathematical processing and for signal processing applications, such as seismic data processing, radar, and sonar data processing. These specialized processors are generally used in conjunction with (or have incorporated in their structures), general-purpose von Neumann type processors to handle the system control and those parts of the data processing problems which are not amenable to parallel processing solutions.

Up to the mid-1970's these systems were quite expensive, with purchase prices beginning at over $500,000 and ranging to over $100,000,000 for the experimental ILLIAC IV. Recently, however, as large scale integration offered dramatic improvements in price performance, signal processing, and matrix manipulation, add-on array processors for minicomputers have begun to be actively marketed for as little as $10,000. Recent advances in semiconductor technology and memory (both random access and serial memories) and logic areas have encouraged R&D efforts in parallel processors, due to their promise of decreased cost and increased reliability.

2.1.2.3 Supercomputers

Supercomputers are the high-powered processors with numerical processing throughput significantly greater than that of the largest general-purpose computers. The definition of a supercomputer changes as a function of time and the throughput capability of the largest general-purpose systems. In 1982, we define supercomputers as systems which have a capacity of over 50 million floating point operations per second (MFLOPS). (This is maximum or burst-made capacity not sustained speed.)

These systems can be divided into two general classes. The first class consists of systems which are designed to operate in real time, generally for military types of signal processing. They fall outside the scope of our study and are not covered in this report.

The second class of supercomputer consists of those systems which are intended for scientific use, and which operate on a non-real time basis. These systems have been undergoing a slow evolution over the past several years. After testing several architectures, the industry has settled on the vector type of supercomputers. Two major manufacturers (Control Data and Cray Research, Inc.) dominate the industry at the current time. Their largest systems have a capacity in the order of magnitude of 100 MFLOPS. Both have announced new systems which promise performance capacities of 1.5 to 3 times the capacity of current systems.

Both the Control Data and Cray machines are beginning to incorporate parallel processing principles to a significant degree. Several of the Japanese general-purpose computer manufacturers are also working on supercomputers that combine conventional and parallel principles. (If their targets are achieved, these Japanese machines are likely to be the world's fastest when delivered.) The matrix manipulation "Array Processors" have also started to encroach upon the supercomputer market, but only for those classes of problems which fit their rigid architectures.

2.1.2.4 Mass Storage Systems

Current mass storage systems mainly consist of various forms of mainframe-controlled storage hierarchies. These hierarchies normally contain:

- a mainframe cache memory,
- a slow semiconductor mainframe memory,
- several billion bytes of moving head disk storage controlled by a separate, simple controller,
- magnetic tapes to act as archival storage, again controlled by a simple controller (the tapes can be either in reel or cartridge form).

These systems automate the movement of data between levels of the hierarchy, as well as vastly increasing the storage capacity of the hierarchy.

The combination of two or more storage technologies in a single device provides characteristics which cannot be obtained with a single technology. The most frequent example of this type of development is in the area of disk systems. New products will combine serial-addressed inexpensive semiconductor or bubble devices with moving head disks to combine the storage capacity of the current disks with vastly reduced average access times. Alternatively, the mainframe memory can be backed up by a larger page buffer, sometimes called a "solid state disk." Cray Research, for example, has announced such a device.

Electro-optical devices such as video discs (see section 2.2.4.3 for more detail) are expected to play an increasing role for mass storage of potentially vast proportions. They are also likely to find use in hierarchical structures, with semiconductor cache memories complementing their slow access characteristics. These approaches include the Content-Addressable File Store (CAFS) system, as offered by ICL. This system combines a specially modified set of discs with several associative processors to form an associative database processor. This processor allows processing speeds in the order of one to two orders of magnitude over what can be obtained using serial architecture. Associative processors such as these have the potential for supporting very large databases (>100 billion bytes) without the need for the complex hashing and indexing mechanisms required when using general-purpose processors.

Several other types of database processors are also being offered, usually by small, entrepreneurial companies. These generally have limited capability, but improved models are likely to appear. They are available in the $30,000-$150,000 range, and some have specialized hardware for database management.

In the software area, the industrial laboratories are concentrating on operating systems, telecommunications, and database management software which will permit already existing application programs to make maximum use of the new storage hierarchy capabilities as they become available. The enhancements of basic access methods to permit paging, streaming, and automatic accesses to the entire database are examples of such work. Other research in the "working set" characteristics of large files and the properties of automatic migration algorithms is also being actively pursued.

2.1.3 1982-1987

2.1.3.1 General-Purpose Processors

Systems will continue to become more modular throughout the entire forecast period with each module becoming associated with a single or small set of functions. Most modules will be equipped with a capability for directly supporting or executing high-level language statements in microcode. Such a capability permits faster execution of programs that are written in the appropriate languages (e.g., Pascal, Ada (Ada is a trademark of the Department of Defense), COBOL, FORTRAN, or PL/1) without requiring logic circuits of extremely high speed. Such capabilities are already present in numerous processors. Both interpretive and compiled versions of several languages will become available.

The compilers will produce an intermediate level of code which can be efficiently executed using microcoded routines. The interpreters will directly execute the source code.

Input/output processors will also use microcode. Future introductions of microcode for input/output processors will cause their capabilities to evolve in the direction of more independent operation, a higher degree of internally stored program capability, and more versatility in controlling communication networks directly without interruption of the central processor unit.

Microcode and systems programs will be largely separately priced by 1987, so their costs must be added to hardware costs. The present 10 percent - 15 percent of system cost for systems programs is expected to have increased to as much as 40 percent - 50 percent of system cost for some users by 1987.

2.1.3.2 Parallel Processors

During the early to mid-1980's, we expect to see three general types of parallel processors become widely available from manufacturers of both mainframes and minicomputers. The vector processor consists of multiple pipeline processors which are optimized to handle large scientific, signal processing, and Fast Fourier Transform types of problems. The systems produced by CDC, Cray, and Floating Point Systems are current examples of this type of system. They will steadily improve in price-performance across a broad price range.

The second type of processor consists of multiple associative memory type processors. Each of these processors will be used in conjunction with a general-purpose system using channel-to-channel, shared disk, or high-speed bus links. It is expected that they will come in a variety of sizes and be used for scientific, commercial, and office automation applications. Systems of this type are currently being produced by ICL (CAFS) and Britton Lee.

The third type, which is similar to the Burroughs Scientific Processor (whose development was prematurely terminated), and the Denelcor HEP, consists of multiple processing units (optimized for floating point matrix operations) combined in a single system with one or more controlling instruction interpretation units. This multiple instruction-multiple data (MIMD) type of processor has been progressing very slowly over the past several years. It now appears as if it may not come into large-scale use until the late 1980's, if at all. Its market niche is rapidly being filled by large pipelined processors, such as those produced by CDC and Cray. Trilogy Systems' planned product also seems destined for a similar market niche.

The non-associative parallel processors will continue to be used for specialized jobs such as signal processing, linear equation solving, air traffic control, graphical data processing, etc. Associative processors will be experimentally used for database processing. Associative processors are expected to appear in relatively large numbers only towards the mid-1980's, whereas the vector processors are already becoming available at reasonable prices.

All of these processors will be composed of LSI (large scale integration) or VLSI (very large scale integration) chips, and will be hardwired. The vector and MIMD processors will be controlled by normal machine level instructions, while the associative processors are expected to be of relatively fixed function with a very small instruction set.

2.1.3.3 Supercomputers

The Cray and CDC vector type of supercomputers are expected to dominate the supercomputer market for the next three to five years. Cray has already announced two new systems, the larger of which is expected to have a 300 MFLOP capacity with a main storage size of over 10 million words. Due to the time required to develop new supercomputers and the early state of the many competing architectures which are being discussed in academic circles, there appears to be no new system architecture which could come into commercial production during this period to rival those of the two industry leaders.

Speeds will increase. The latest supercomputer announcement incorporating increasing parallelism claims speeds in the 600-800 MFLOP range. One thousand MFLOP speed should easily be obtained during this period. Due to the increased throughput of general-purpose systems in combination with attached array processors, it is likely that such a hybrid configuration with 100 MFLOP capability will be considered to be in the general-purpose computer class by 1987.

2.1.3.4 Mass Storage Systems

File processors will begin to supersede today's disk file controllers, with greatly expanded capability. Recently announced versions (the IBM 3880 Models 11 and 13) already manage a hierarchy of storage devices (magnetic tapes or tape cartridge devices, disk drives, and large buffer storage) in such a way that the contents of the entire file library of the user will be available to the system on-line, but with the access times to parts of the file automatically adapted by the system as it moves portions of the file up and down the device hierarchy in response to demand. The file processors will also perform a substantial part of the "housekeeping" that is now part of the operating system or the database manager, and which is the same for all users. By moving these file control or housekeeping functions from the central processor to the file processor, the user will obtain higher throughput from the central processor and greater ease of use because the file control functions can be separated from user programs and performed in an automatic manner.

The specialized peripheral device manufacturers and the database management system vendors have already begun to deliver fully integrated back-end database processors. The major manufacturers are expected to follow soon. These systems are expected to be priced from $200,000 for a complete system with software, processors and one billion bytes of on-line storage to $1,000,000 for a system with eight to ten billion bytes of on-line storage. Some of these systems will be based on specialized disk files and groups of associative processors. These systems would substitute for the software DBMS systems and would preserve the major DBMS interfaces and the user query language interfaces. These systems will be especially useful for databases which contain little hierarchical structure and/or where users frequently query the database with "fuzzy" or only partially formulated requests. The first commercial system of this type (from ICL) has already shown the ability to retrieve a name and address from the London telephone directory using only the first initial, a partial spelling of the last name and a general area of London as the address.

2.1.4 1987-1992

2.1.4.1 General-Purpose Processors

Bus-oriented system architectures will predominate. The modules in the system will perform a variety of specialized functions, largely determined by microprograms in control stores associated with each module. It should be possible to modify the function of a module (within limits) by changing its microprogram. For example, a given module can be emulating the function of a past hardware-software environment while another is working in a new native mode.

Special microcode modifications will be made on an extra-cost basis by the manufacturer. Costs for such modifications will be relatively high, but may be acceptable to users requiring large numbers of modules.

2.1.4.2 Parallel Processors

More types of specialized processors with internal architectures specifically adapted to the class of problems to be solved will become commercially available. Array processors and associative processors will become normal parts of large general-purpose systems. MIMD processors will also be available in small numbers for specialized purposes.

Data driven type processors, in which the control algorithms are either hard-wired or microcoded permanently into the processors, are expected to become available primarily for control type operations in the mid-to-late 1980's. It appears that they could be incorporated in the general-purpose computer systems of the mid-to-late 1980's to take the place of the current software or microcode implemented processors. Such processors would improve the throughput of general-purpose systems by off-loading functions performed in parallel at high speed.

Most types of parallel processors are expected to be in full production during this period. Special architecture processors for all sizes of systems will be made available for such tasks as voice recognition, pattern recognition, image manipulation, and other specialized tasks needed to support the multi-media distributed networks of the period.

Parallel processors using special very large scale integration (VLSI) chips are expected to be emphasized due to the nature of the tasks to be accomplished and the advances in technology. The availability of compilers and other software development tools which permit easy use of these systems will be critical in establishing the relative popularity of the various competing architecture systems.

2.1.4.3 Supercomputers

Three major processor types will be available for use as supercomputers during this period. They are:

- o Multiple Instruction - Multiple Data (MIMD) processors;
- o Vector processors; and
- o Data driven processors.

The supercomputers of this period will achieve throughputs of 500 to 1200 MFLOPS, with main storage sizes in the range of 50 million to 500 million words. Supercomputer development will be aided by the very high speed integrated circuit (VHSIC) developments currently being sponsored by the Department of Defense.

The successful architecture(s) will in part be determined by the ability of the new systems to run the older vector processor software. Some of the larger users have already stated that an incompatible system would have to have three to five times the throughput of compatible vector processors before the users would consider converting their existing programs to use the incompatible systems.

2.1.4.4 Mass Storage Systems

During this period a variety of mass storage systems from simple cache disks through complete back-end processors will be available to meet the many storage needs of the users. These systems will be produced at many price levels allowing systems from small through extra large to have some type of intelligent mass storage system at costs which are no more than 1/3 of the overall system costs. In systems which support multiple databases, multiple database processors with varying amounts of private and shared mass storage will become common. The costs of these subsystems will be dominated by the storage costs, with the costs of the processors and interconnecting logic forming 10 percent or less of the overall system costs.

The eventual role of associative processors and memories is not yet clearly defined. For example, they could largely solve present structural and relational problems in databases and permit much faster processing of database oriented transactions. Text searching could also become a major use of such systems. However, the improved cost performance of conventional systems may make these problems less severe for many users, and in any case the evolution of software and user applications for more radical forms of processors will take many years. As was indicated earlier, associative processors will most likely be used for applications where "fuzzy" or semi-structured queries are used in conjunction with a relatively unstructured database.

Some of the more complex file processing systems will be able to handle simple queries without any application processor intervention. In such systems, queries will be directed from the input/output processor directly to the file processor and back again, thus freeing the application processors for the more complex computationally-oriented tasks and increasing the parallel processing capacity and thus the throughput of the overall system.

2.1.5 1992-1997

2.1.5.1 General-Purpose Processors

By this time the manufacturers will be incrementally introducing varieties of new and improved application processors as well as new types of special processors as technology and marketing constraints permit; there will be no more "generations" of entire systems. These new processors will connect to the same buses as the older processors and work as part of the same integrated systems. Thus, users will be able to upgrade their systems through a gradual evolutionary process rather than replacing complete systems.

In most cases, these new processors will be upward compatible from the older processors in terms of software but not in terms of microcode. Thus, any specialized microcode generated for users on a contract basis may be obsoleted by the introduction of a new processor. However, as long as all of the application processors on a system are not replaced at once, the manufacturer can generate new microcode for the new processors while users employ the old microcode on the old processors during the development period.

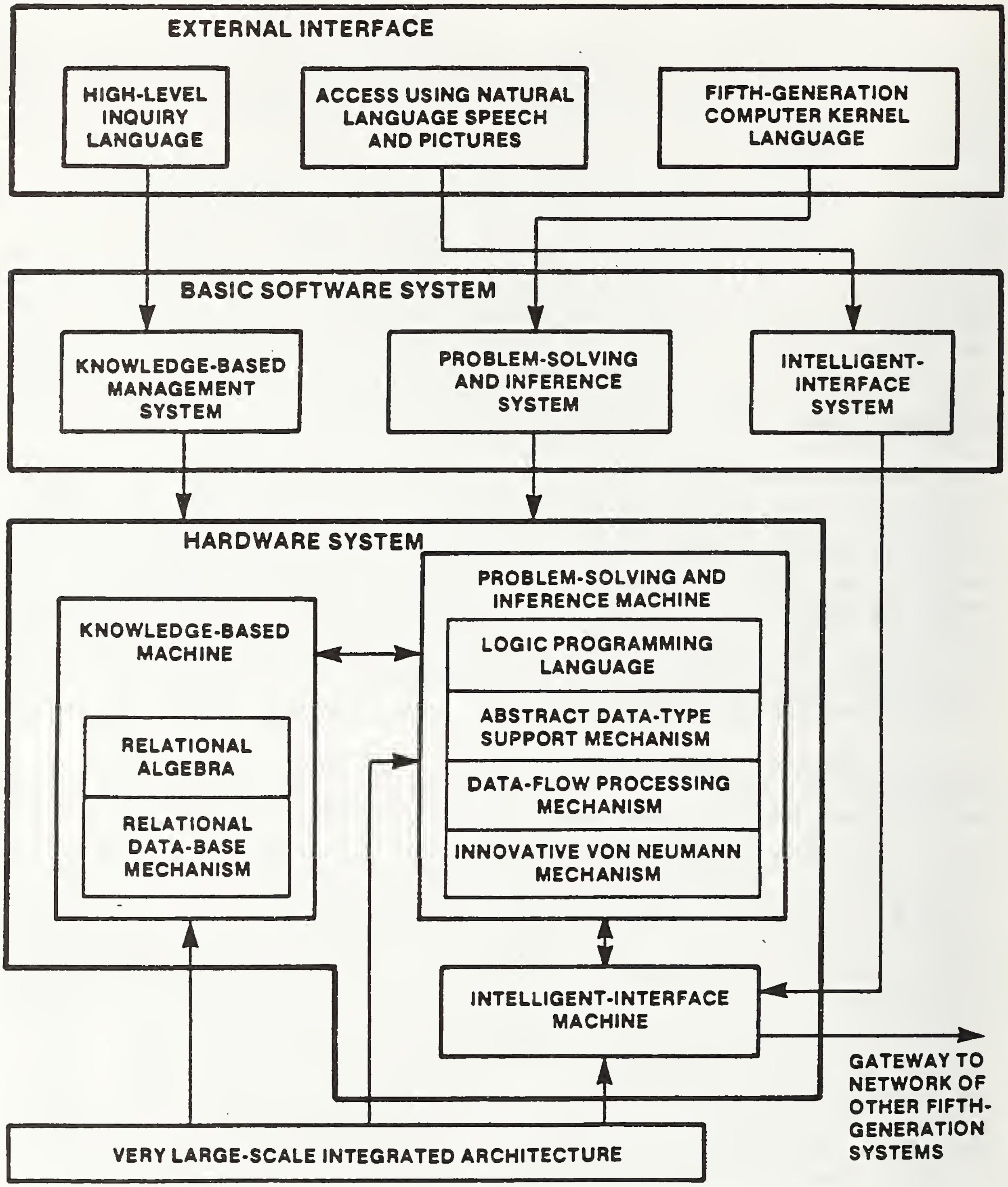
The data driven or data-flow type systems should become standard products during this period. Some types (with fixed programming) will be used as subsystems in large processors, as the hardware implementations of control algorithms such as for processor scheduling, or for other special-purpose applications. Programmable data-flow processors are primarily being investigated for use in various signal processing applications and in other applications where a great deal of parallelism could be effectively used. This latter type of data-flow processor would directly compete with the various types of MIMD processors.

The "Fifth Generation" computer system, (so named by its Japanese proponents), now being heavily publicized and supported in Japan, is intended to replace all sizes of currently produced general-purpose systems. It is intended to be more cost effective than current-day systems, and to be accessible to non-data processing trained users by means of voice and picture input mechanisms (figure 2.1). The heart of this system is to be based on artificial intelligence, knowledge-based system concepts which are now slowly moving from laboratory development to commercial implementation in a few very specialized areas.

At the present time, work on the "Fifth-Generation" system is in the research stage. It will be several years before sufficient data is available to determine how closely its goals can be met.

We forecast that this type of system will slowly evolve from the earlier modular systems rather than appear in the form of completely new systems which replace the older systems. Many of the functions shown in figure 2.1 could be implemented in special-purpose processors which could be added to modular processors. In this manner, the manufacturers would lessen the chance of competitive penetration into their existing customer base by slowly upgrading their systems rather than requiring a total swap-out of equipment. In addition, using the gradual upgrade method, the user's investment in existing application software could be more easily protected, and gradual upgrades of existing application systems could be accomplished over an extended period.

By 1997, then, we believe that some significant aspects of the fifth-generation knowledge-based systems are likely to be available (at least for professional, analytic, and decision-support functions). They are likely to appear as specialized processing modules teamed with more conventional ones in bus-oriented systems.



Source: Japan Information Processing Development Center

FIGURE 2.1 POSSIBLE FIFTH GENERATION ARCHITECTURE

Figure 2.2 summarizes our views of the rates at which novel architectures are likely to appear in the various kinds of processors.

2.1.5.2 Parallel Processors

Most parallel processors of this period will be built using specially designed large-scale chips. Improvements in the design, automation, and software generation facilities of the period will permit these chips to be developed and programmed at relatively low costs, thus encouraging a proliferation of different types of chips for such specialized jobs as voice recognition, pattern recognition, graphic data processing, and signal processing. These will be incorporated into specialized functional modules of bus-oriented systems.

2.1.5.3 Supercomputers

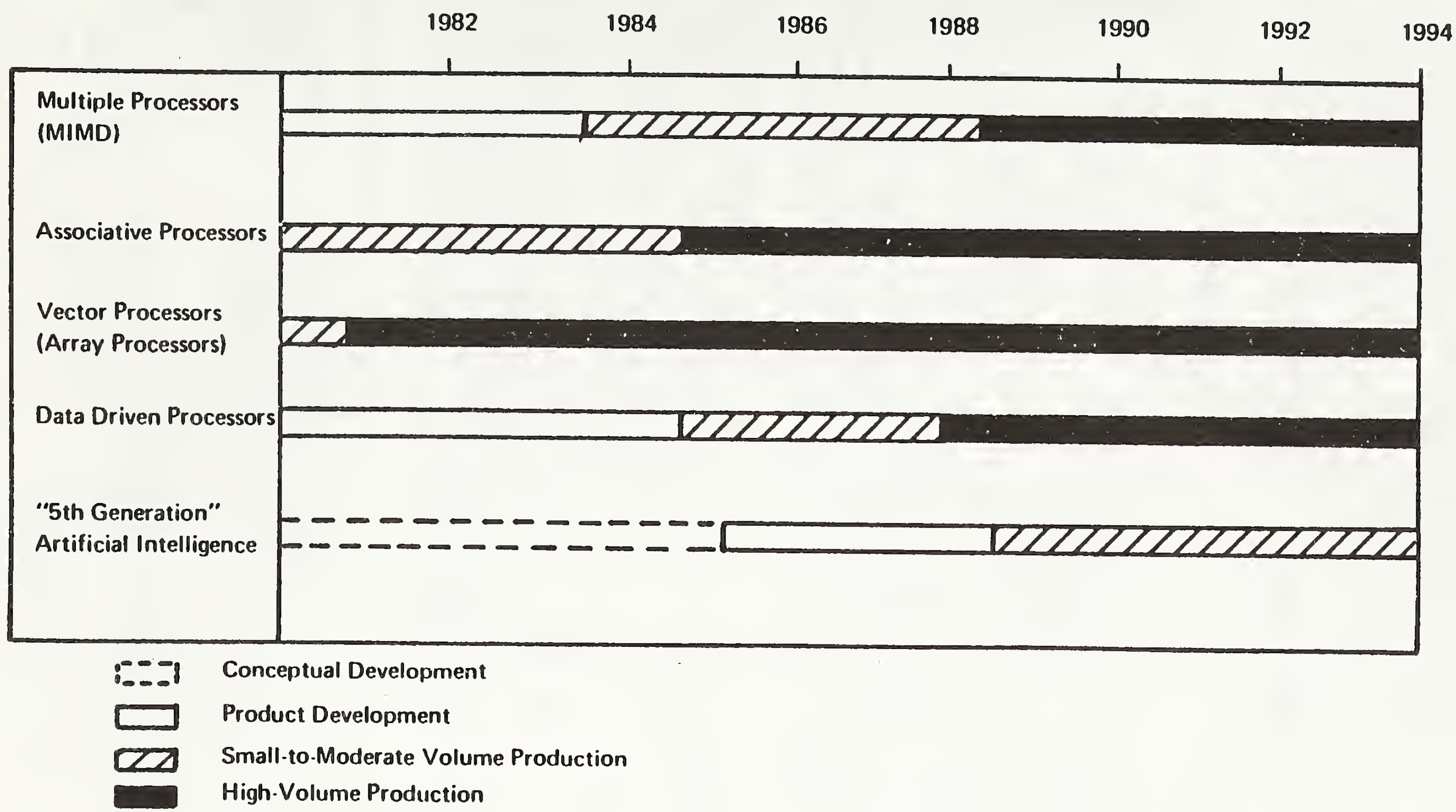
Studies in the late 1970's and early 1980's have identified several classes of problems which require systems having throughputs in the one hundred thousand to one million MFLOP range. These problems include simulations of reactors, complex process plants, petroleum reservoirs, and weather models.

Therefore, we project that systems with significantly increased throughput and main storage capacity will continue to appear through the 1990's. These systems will probably require non-silicon based circuit technologies, even though high degrees of parallelism are employed.

It seems likely that systems having throughputs approaching one hundred thousand MFLOPS will become available by 1997. Most of the improvement relative to today's supercomputers will come from the twenty-fold improvement in circuit speed forecast below; the rest is expected to come from architectural improvements. The exact architectures of their systems cannot be clearly defined, although it is known that they must involve a very high degree of parallelism in order to avoid physical limitations of signal propagation. It may be that the long-range pacing factor in supercomputer performance will be software, particularly the ability of compilers to fully exploit the parallelism inherent in the applications.

2.1.5.4 Mass Storage Systems

Advances in mass storage technology, particularly in magnetic bubbles and electro-optical devices, will permit larger volumes of non-volatile removable storage to be put on systems of all classes. During this period much of the storage will be occupied with non-coded information such as video signals, pictures, documents in facsimile form, and voice recordings. The hardware structure and variety of mass storage systems from cache disk through complete back-end processors will remain unchanged from the late 1980's, but the software will have been significantly modified to be able to process this non-encoded data. Special



Source: Arthur D. Little, Inc.

FIGURE 2.2 PROJECTED DEVELOPMENT PERIODS OF PROMISING ARCHITECTURES indexing schemes and knowledge-based associative routines primarily contained within the back-end processors themselves will have been developed, using attributes of the data to permit easy retrieval of specific items and the correlation of data contained within multiple items. Separate hierarchies for specific types of data will be developed.

Costs of such systems will continue to be dominated by the cost of the storage media and mechanisms rather than by the electronics and software. However, the software associated with these mass storage systems will represent an increasing proportion of the total mass storage system costs, reaching perhaps 15 percent of the total system costs for large, complex mass storage systems with specialized processing algorithms. As with the general-purpose processors, it is likely that the manufacturers will provide, on a contract basis, specially microcoded or designed chips to implement complex types of data manipulation.

2.2 LOGIC AND STORAGE COMPONENTS

2.2.1 Introduction

This section is organized by type of technology. Section 2.2.2 is devoted to semiconductor technology, covering semiconductor logic and processor storage. Section 2.2.3 discusses potentially competitive technologies for logic and processor storage. Section 2.2.4 discusses mass storage technologies; magnetic disk, magnetic tape, and video disc. Finally, section 2.2.5 summarizes the cost and performance forecasts for all the competing types of storage components in a common form. The discussions in this section speak of continuous evolution; point forecasts of performance and price appear in the tables and figures.

2.2.2 Semiconductor Technology

2.2.2.1 Logic Devices

These are manufactured by a variety of technologies (processes) which provide differing performance/cost trade-offs in respect to such performance factors as:

- o speed (delay)
- o complexity and memory content on one chip and in one package
- o power dissipation
- o logic form and arithmetic power
- o logic and supply voltages

- o noise immunity

- o package size and number of leads

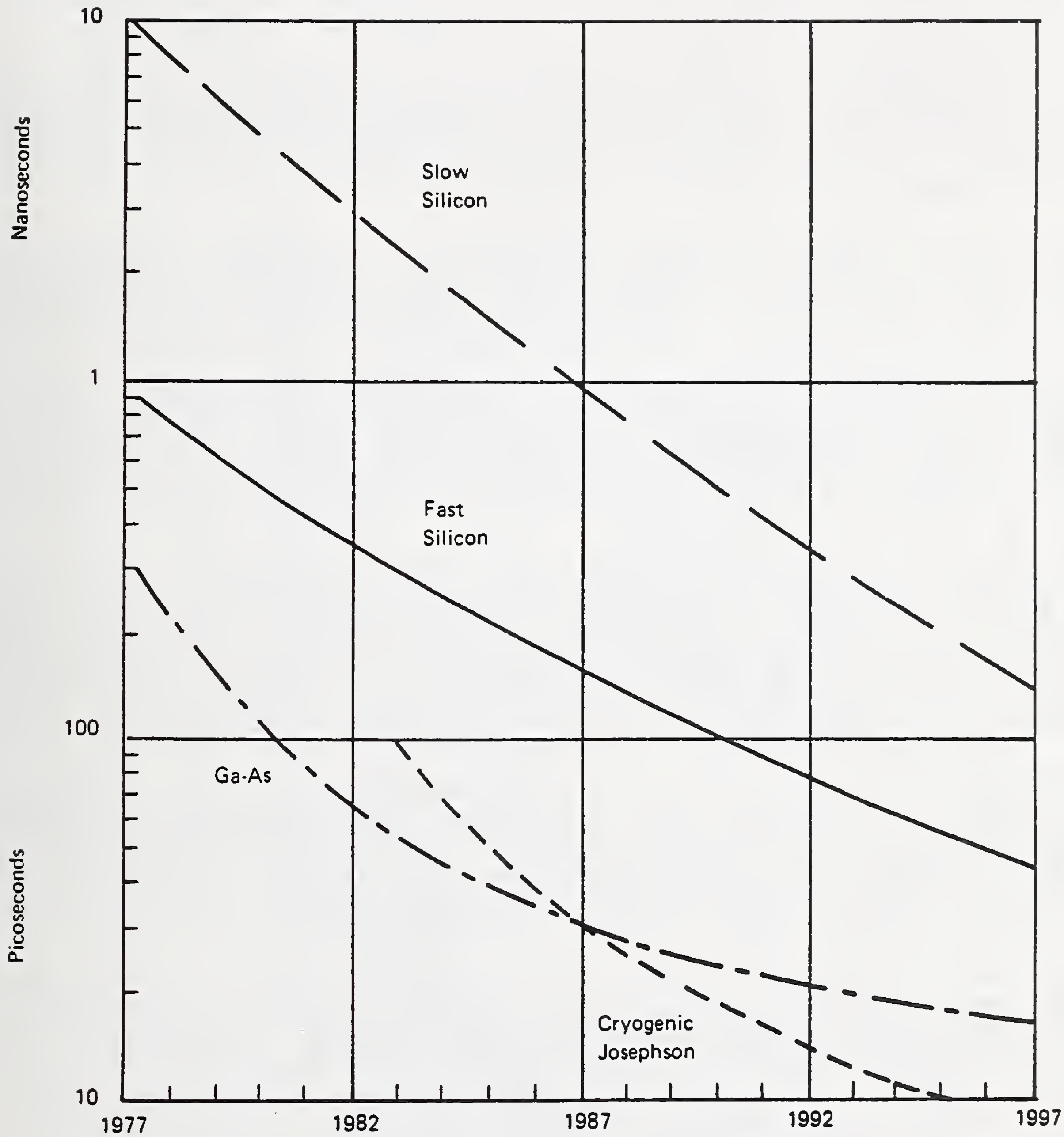
Improvements are being sought in all these areas, most particularly in regard to complexity, speed, and power dissipation. The maximum number of transistors which can be placed on one silicon chip--as well as their speed--is limited by the total power (converted to heat) a packaged semiconductor chip can dissipate. For conventional ceramic or plastic packages, this power limit is the 0.5-1 watt range. With special packages and heat dissipating fins an upper limit of 7 watts has been practical. This is required (for example) by a 32-bit microprocessor central processing unit (CPU) operating at 18 MHz and containing about 430,000 transistors in its architecture. With further improvement in devices, their internal speed can be increased by another factor of 3-5 at no significant increase in power.

Gallium arsenide discrete transistors can operate at frequencies 2-3 times higher than those made of silicon. Now gallium arsenide devices are being successfully integrated into very high speed logic circuits. Thousand-gate complex logic circuits with step delays of only 50 picoseconds have been developed in the laboratory, and such devices will be available in 2-3 years to provide still higher speed, at similar power, than silicon devices. Gallium arsenide can also be operated at higher temperatures than silicon, raising the upper limits for conventional integrated circuit packages to 1-2 watts, and for packages with fins cooled by forced air to 8-10 watts. Thus, logic devices operating at gigabit rates will become available after 1985--both in silicon and gallium arsenide.

Recently, it was discovered that cooling gallium arsenide transistors or special doping can increase electron mobility in the material, thus substantially increasing their switching speed. Such devices, while slower than cryogenic Josephson junction devices, require less costly cooling and thus may offer intermediate cost-performance trade-offs. For room-temperature high-speed operation, some specially doped gallium arsenide will be used in the future, both for logic and memory, though with less complexity than silicon devices.

Optical integrated circuits are being developed using gallium arsenide that combine optoelectronic transmission and detection devices with further electronic circuits to interface digital electronic logic with fiber-optic transmission lines. Their use will be widespread by the late 1980's.

Figure 2.3 summarizes our forecasts of the speeds of the various semiconductor logic technologies. The corresponding forecast for cryogenic (Josephson junction) technology, which is discussed in section 2.2.3, is included for comparison.



Source: Arthur D. Little, Inc., estimates.

FIGURE 2.3 TRENDS IN DEVICE SPEED – STAGE DELAY PER GATE CIRCUIT FOR DIFFERENT TECHNOLOGIES

Chip complexity has reached 450,000 transistors for several 32-bit microprocessor designs announced recently. Complexity will reach several million devices by the mid-1980's, in laboratory developments, though the rate of progress in mass-produced devices may not increase at the same rapid pace (figure 2.4).

Practical and economical chip sizes are increasing slowly from 20 to 50 square millimeters. The complexity is primarily being increased by shrinking the size of individual transistors through reduction of their feature size and linewidths of the patterns lithographed on the chips.

To achieve the anticipated complexity, linewidths achieved in processing devices by means of photolithography will be shrunk further, from two to three micron lines used in current devices to under one micron in early production by 1982 (figure 2.5).

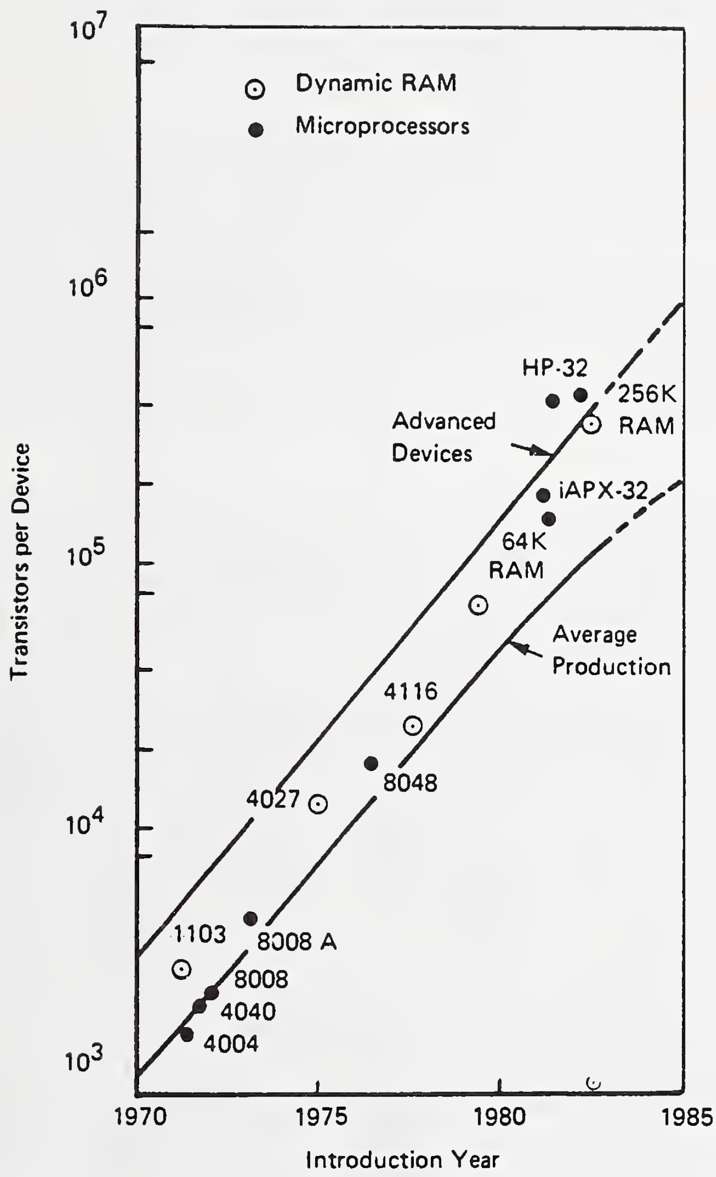
Present production uses optical lithography from masks. This becomes severely limited when one micron lines are produced. Thereafter, the most critical production steps will use electron-beam, x-ray or ion-beam exposure of resists on the device wafers or ultimately by direct ion writing for implantation and etching.

Advanced laboratory devices will have small micron and submicron linewidths earlier, as indicated also in figure 2.5. For example, the VHSIC program for achieving very high computing speeds in the one-chip signal processors plans to attain 1.25 micron lines soon and 0.7 micron lines by 1986. A distant possibility for the 1990's is optical logic, where still higher speeds may be achieved by directly processing light signals.

Semiconductor logic is rarely implemented at the discrete component level any more. Multiple components are usually fabricated on each chip, either in the form of universal or master chips, or as microprocessors. Programmable logic arrays combining memory with output registers and logic switches are becoming common. They are discussed separately.

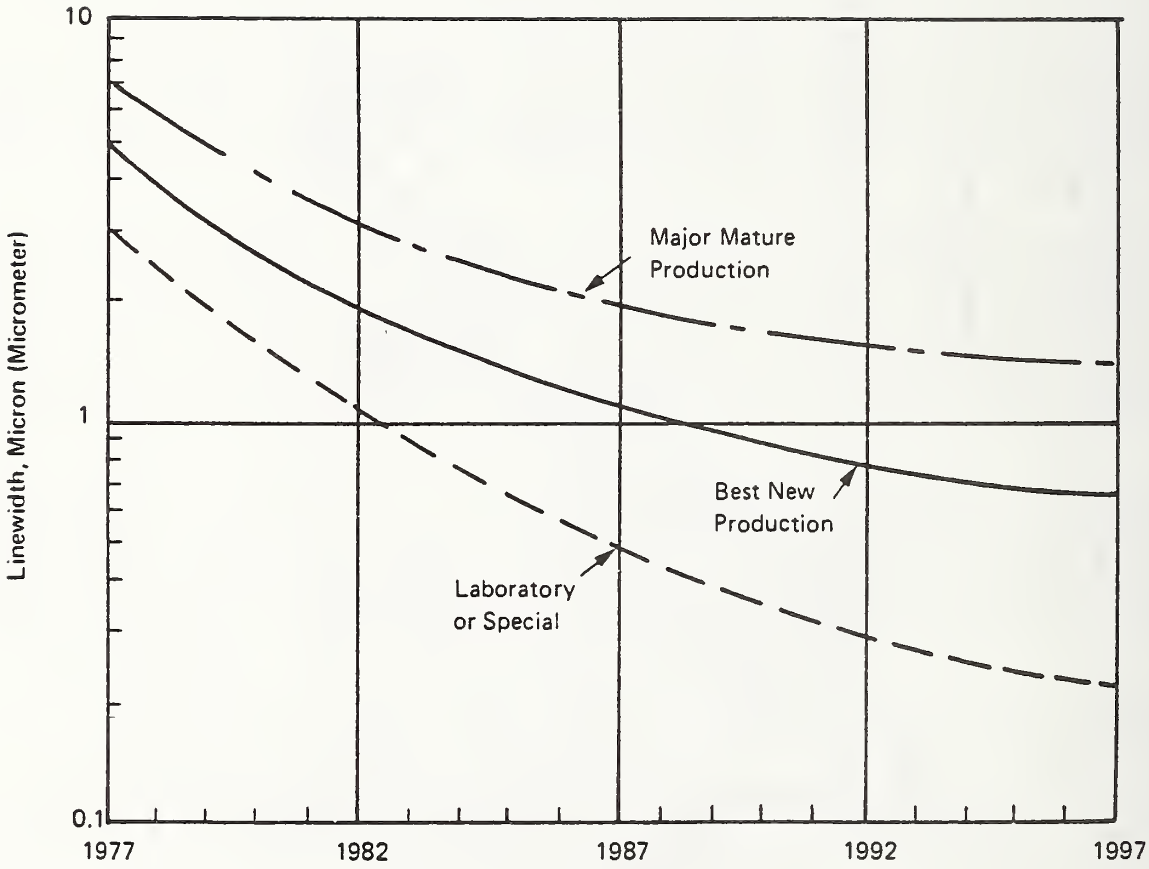
Universal or master chip (functional or gate arrays) designs have been used since the 1960's. These contain a number of elementary functions--transistors, various types of gates, flip-flops -- in a standardized array. To implement a complex function, the final masks provide the necessary interconnections. The same basic chip design, with different interconnections, can implement a number of different complex functions provided no more elements are required than are available on the chip. This method has been especially attractive for chips used in large high-speed computers. Here the small volume of any one part and the rich variety desired makes the master chip a more economical choice than a large number of individual custom designs. Such gate arrays are also being used more widely for other applications.

At present, high-speed gate arrays with 1000-8000 equivalent gates on a chip are offered under the names "uncommitted logic" or "gate array". By 1992, 100,000 gates on one chip may be in



Source: Arthur D. Little, Inc. estimates.

FIGURE 2.4 HISTORICAL DEVELOPMENT OF THE COMPLEXITY OF INTEGRATED CIRCUITS



Source: Arthur D. Little, Inc., estimates.

FIGURE 2.5 MINIMUM LINEWIDTH FOR SEMICONDUCTOR MICROLITHOGRAPHY use. These will not only have mask programmed patterns--with masks made on computer controlled electron-beam equipment--but the patterns may be directly written on the silicon wafer. In this fashion it is quite possible that successive chips on a silicon wafer will have enough different circuits written so as to implement the whole computer. This is one form of wafer-scale integration. For this, the electron beam writing equipment must first probe the elements on the wafer to route around inoperative transistors. In these cases, the electron beam pattern writer becomes the computer terminal for creating another computer.

Another programmable semiconductor device increasingly used in computers is the programmable logic array (PLA). This contains two or three levels of read-only memory with input and output latches, which is programmed for the truth table of the logic it replaces. A number of PLA configurations can be programmed (by mask, laser or blowing fuses) from each generic design. They can be programmed quickly and can replace a large combination of ordinary logic devices. Thus, PLAs are expected to reduce the cost of complex random logic circuits, especially where small numbers of a wide variety of closely similar circuits are required.

Custom designed semiconductor circuits have been used primarily where high volume of use could justify the high cost of designing a custom part. Recent advances in computer-aided design and mask manufacture have brought down the cost of designing custom semiconductor devices. A large number of macrocell circuits, representing fairly complex circuit functions already in use, can be combined in a computer-generated layout and manufactured to implement new complex functions from their Boolean or Register logic descriptions. Algorithms for circuit cell placement, for routing interconnections and maintaining all required design tolerances, have now been developed to handle custom chip designs with 5,000 to 30,000 gates automatically and larger designs with moderate manual engineering intervention. This design technology is most easily applied to gate arrays, but is also applicable to fully customized designs. By 1992, even more complex circuits may be custom designed and the circuits imprinted directly on the silicon wafers by means of electron beam lithography equipment. New one-chip architectures will be explored as it becomes easier to fabricate complex custom semiconductor integrated circuits through application of computer aided design and structured design routines and formats.

Microprocessors offer an alternative means of fabricating many logic components on a single chip. Of standard design, they are tailored to specific functions by stored programs (microcode). These are stored either on the microprocessor chip itself or on separate read-only memory (ROM).

The earliest microprocessor devices were derived from multi- and single-chip calculator devices that operate with four bits of data and instructions. The earliest units, introduced around 1971, contained some 2,000 transistors. While in electronic calculators, these could operate alone or in conjunction with separate small memory, single display driver, and keyboard interface devices; as microcomputers they might require on the order of 20 or more additional logic and interface devices to provide a working system. From that time on, more functional capabilities have been condensed onto single devices to reduce the number of additional devices per system. Bit capabilities expanded to 16 and 32 bits and input/output (I/O) and memory access improved. The following are now available:

- *4-bit Metal Oxide - Silicon (MOS) microprocessors.* These are primarily one-chip systems used as low-cost controllers for appliance and many other applications. Memory and I/O expansion are available.

- *8-bit MOS microprocessors.* These are available in a range of architectures and complexity. The most recent ones can implement a small microcomputer system on only one chip, including a considerable amount of memory internal to the basic arithmetic-logic unit.

- *16-bit microprocessors.* Introduced several years ago, these are now offered program-compatible with earlier 8-bit microprocessors, with 16-bit minicomputer software, or presenting totally new architectures with upward compatibility to serve 8-bit and 16-bit bus structures.

- *32-bit microprocessors.* These were first introduced in 1981. Some were either software compatible with 32-bit minicomputers or with earlier 16-bit microprocessor families. Others have totally new architectures and can implement high level languages, though they also can emulate the instructions of 16-bit microprocessors of the same family and can use related 16-bit peripheral controllers. Compatible floating point co-processors have been introduced which enhance the computational capabilities of a family.

- *4-bit bipolar bit-slice devices.* For highest speed, bipolar semiconductor processors must be used that allow fewer transistors to be placed on a single chip. Thus, a bit-slice architecture is used, and as many of these bit-slice devices are used in parallel as are needed to create the word length of the desired microcomputer.

In the future, microcomputers developed by the major manufacturers will fall into three or four families:

- a low-cost family, primarily based on an expandable single-chip microcomputer;

- a medium-performance, medium-priced family ranging from a single-chip microcomputer to a related multi-chip family using the same software;

- a high-performance processor and associated peripheral devices; and

- a very-high performance family for special scientific and numeric applications.

The semiconductor devices, architecture, and software will remain internally compatible within one family as it evolves in the future, but may not be interchangeable between different families.

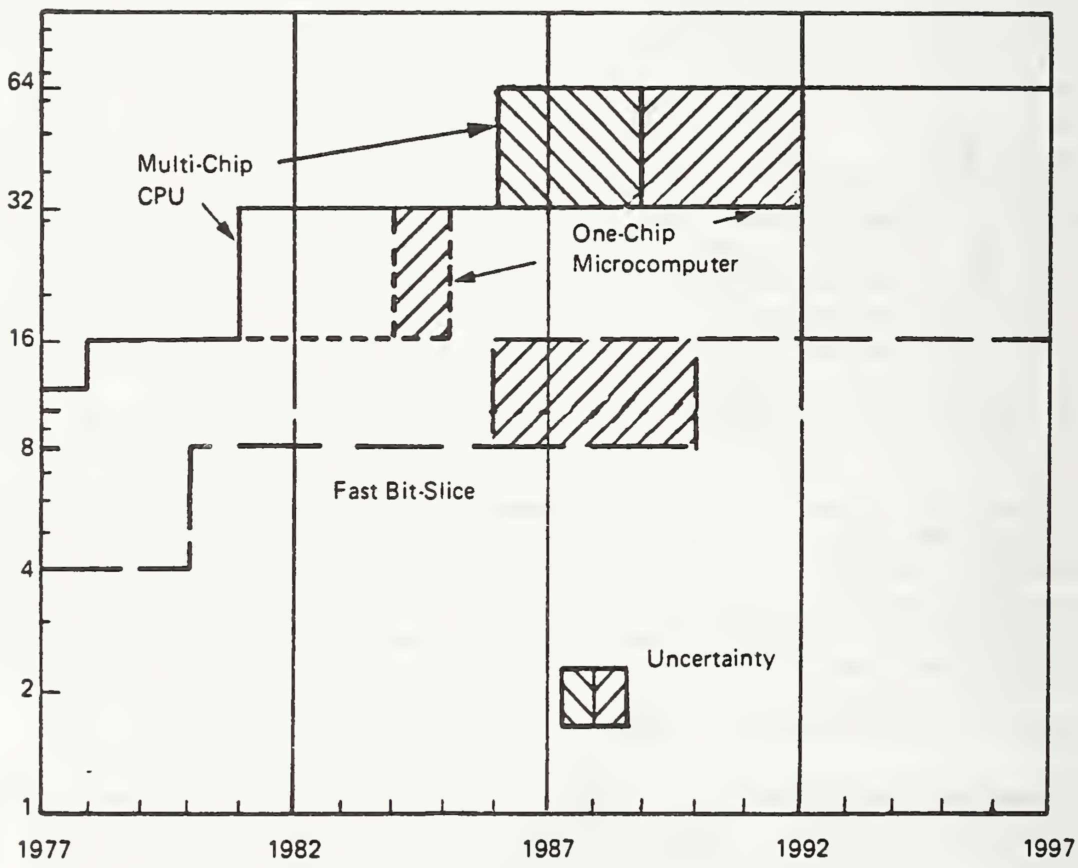
Recent demand for higher processing speeds than can be obtained from microprocessors has led to the development of arithmetic or numeric processors which can act as co-processors with several types of microprocessors. Presently such arithmetic processors can handle directly 8- and 16-bit real and complex numbers, with extensions to 64- and 80-bit floating point capability at a slower speed. Transcendental functions such as exponential, trigonometric, and logarithmic functions are readily handled. Computation speed ranges to 2 MIPS (millions of instructions per second). These devices contain up to 450,000 equivalent transistors and their architecture is derived from that of fast scientific computers. Further extensions of these capabilities are being developed with higher speeds and a wider instruction set. The computation speed will also increase with a still greater degree of parallelism in operation by use of pipeline architecture of the kind now used on the high-speed parallel multipliers.

Figure 2.6 presents our forecast of the dates of introduction of microprocessors of successively increasing data bit width (and therefore speed), while figure 2.7 presents our forecast of the future prices of existing microprocessor classes. A corresponding price trend can be expected for the universal logic or gate array discussed above.

2.2.2.2 Semiconductor Memory

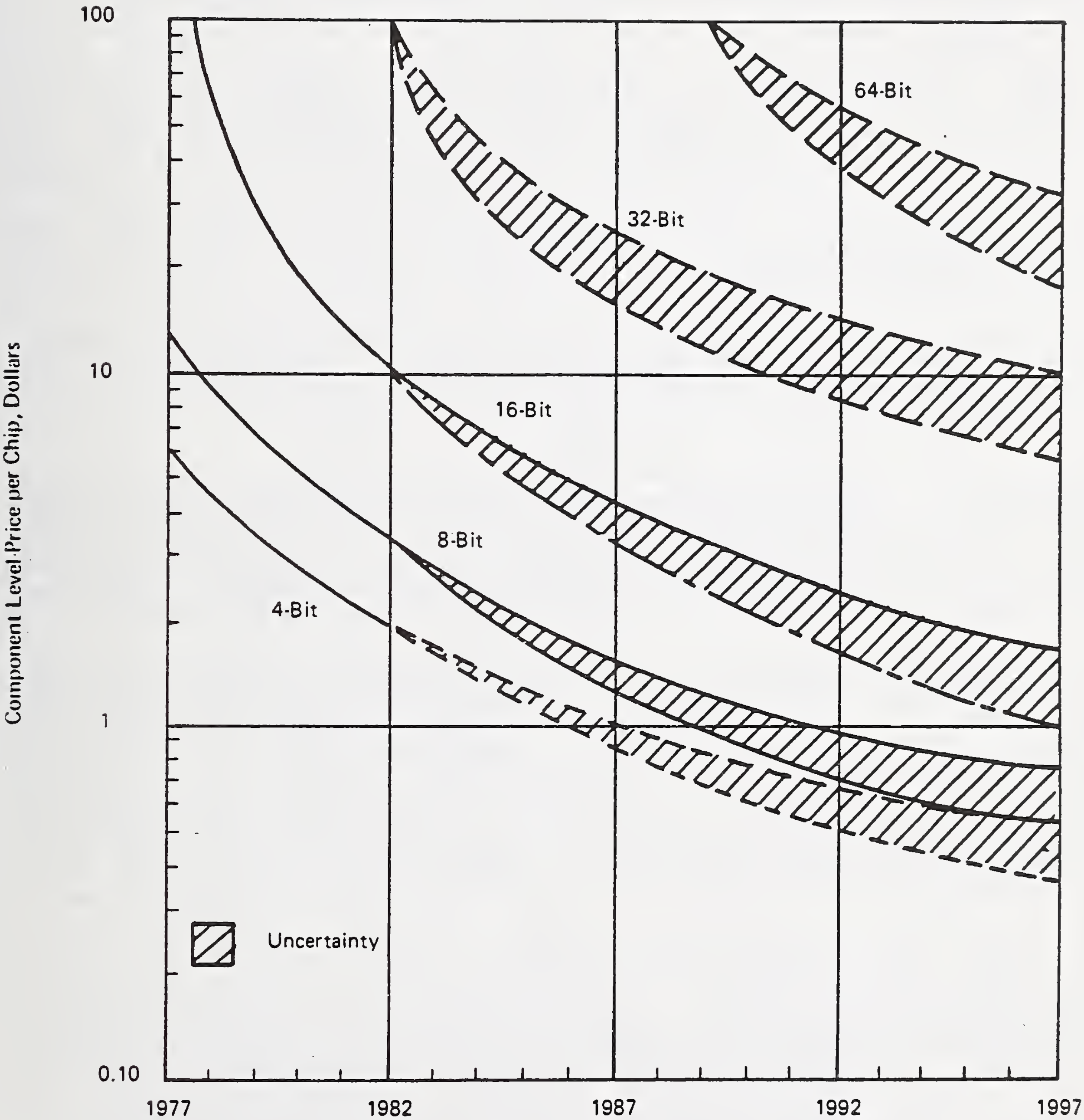
Because of their small size per memory bit, high speed, and low manufacturing cost, semiconductor memories are now used nearly exclusively. Standard semiconductor devices can provide 64,000 bits of random-access memory (RAM) or read-only memory (ROM) storage on one chip, and 256,000-bit chips are now being developed, so that for many small-scale applications such as terminals and minicomputers the requisite amount of main, control, and program memory can be obtained with just a few devices.

Major performance factors of semiconductor memory are complexity per chip, speed, and price. Slow dynamic RAM devices with access in the 100-300 nanosecond range are now beginning to be available



Source: Arthur D. Little, Inc., estimates.

FIGURE 2.6 MICROPROCESSOR BIT CAPABILITY VS YEAR OF INTRODUCTION (FOR ONE- AND MULTI-CHIP ARCHITECTURES)



Source: Arthur D. Little, Inc. estimates.

FIGURE 2.7 MEDIAN MICROPROCESSOR PRICE VS TIME (1000 UNIT PURCHASE) with 16k- to 64k-bit complexity at a price of 10 millicents/bit or less (in large quantity orders); faster static RAM chips with 30-50 nanosecond access times are available with 16k-bit and 64k-bit complexity at prices of 80-150 millicents per bit.

Conventional semiconductor memories will continue to be manufactured throughout the forecast period. Figure 2.8 and 2.9 show our forecast of the complexity (number of bits per chip) of RAM and ROM semiconductor chips. High-speed chips (tens of nanoseconds access time today, declining to a few nanoseconds by the 1990's) will increase from about 16k to a least 100k bits per chip. General-purpose slower-speed chips, with access times of about 200-300 nanoseconds today declining to perhaps 30 nanoseconds by 1997, will increase to several million bits per chip. The "million bit chip" should become available by 1989.

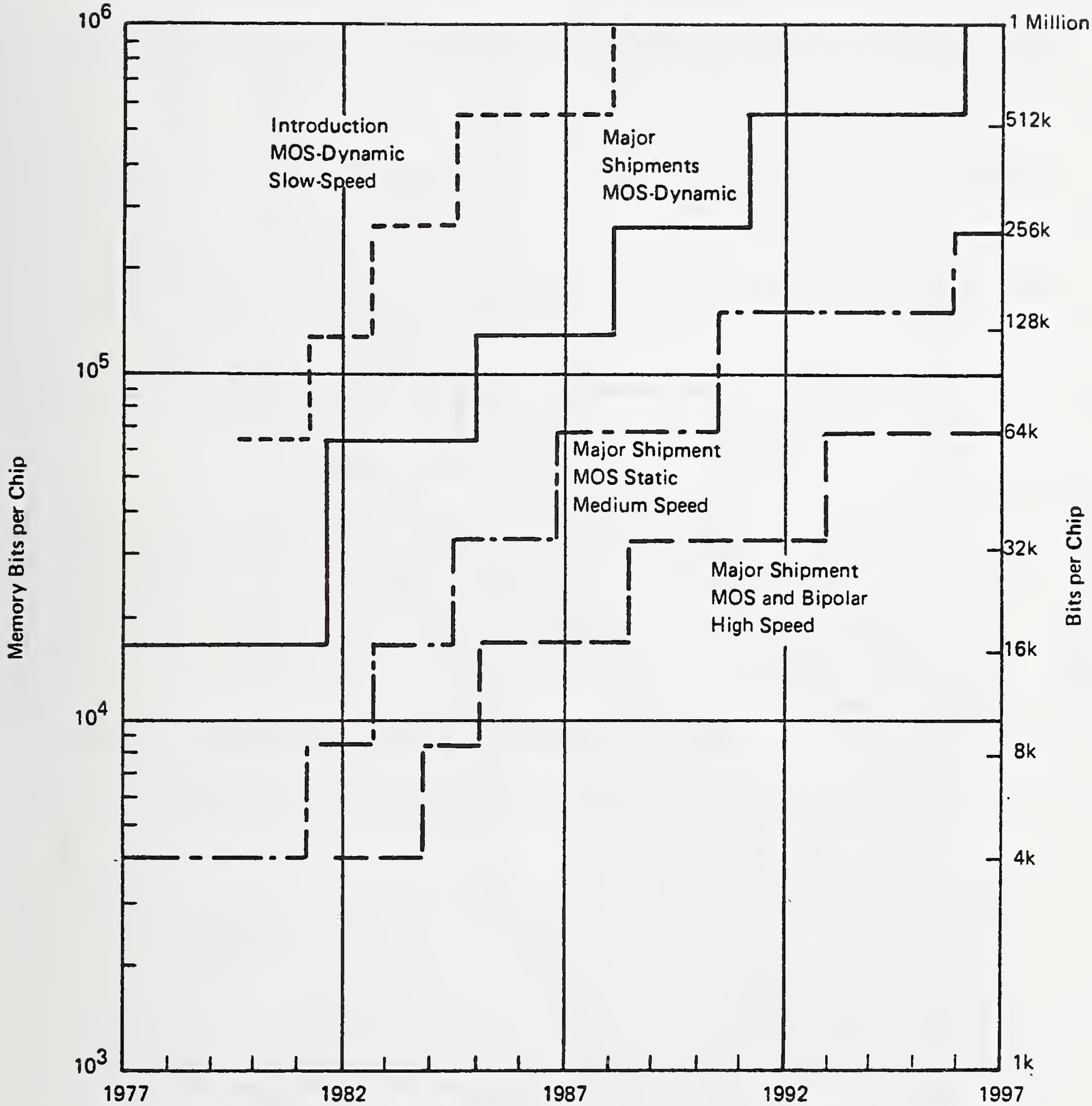
Good manufacturing yields to achieve high bit content and low cost are being aided by use of redundant bits for replacing defective bits on-chip.

Figures 2.10 and 2.11 show our forecast of semiconductor memory prices per bit for the RAM and ROM types, respectively. Both slow- and high-speed devices should decline in cost by two orders of magnitude by 1997.

Fixed or rewritable fast storage is becoming increasingly important. Mask-programmed read-only semiconductor memory (ROM) is low in cost and has advanced to 128k-bit complexity using dense geometry. A 2-level storage cell has also been introduced to increase storage density. An experimented 1-megabit character generator chip for Kanji displays has also been described.

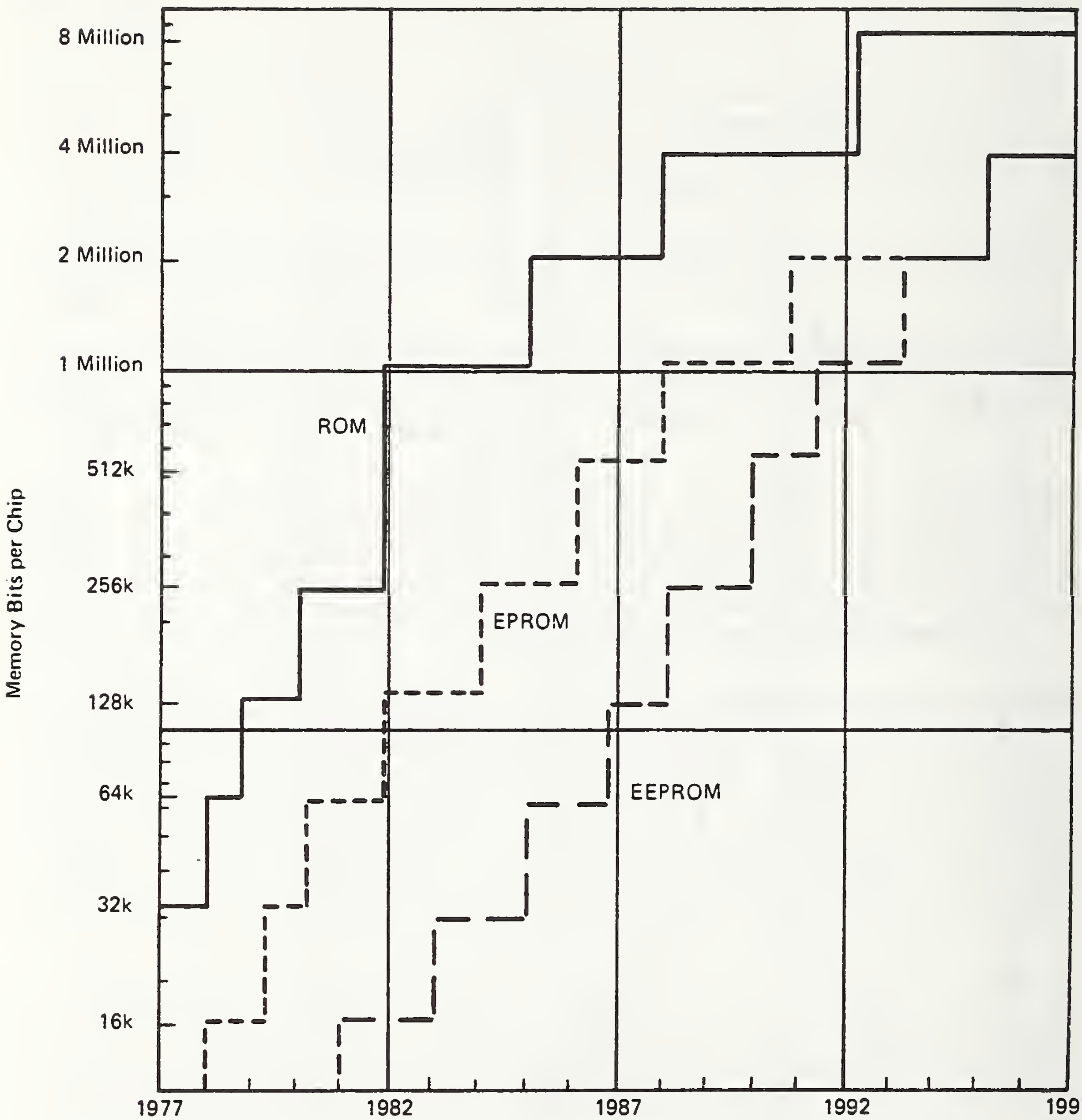
Non-volatile electrically rewritable semiconductor memories (electrically programmable, electrically erasable and programmable, and electrically alterable read-only memories, respectively abbreviated EPROM, EEPROM and EAROM), use either ultraviolet light, or now, electrical signals for erasure. Though these cost 2-5 times as much as the lowest cost memory, their use is economical where occasional revision and non-volatile content are desirable. Access time is similar to slow-speed memory but writing time is two orders of magnitude longer.

In 1997, both logic and memory using silicon devices will still be improving, though at a slower rate. Among the four determining factors (cell size, chip size, wafer size and defect density), at least one or two should still be capable of further improvement. Gallium arsenide will see use for very high-speed logic, but ultimately will not greatly exceed the speed of silicon-based semiconductor devices at room temperature. However, by cooling gallium arsenide with liquid nitrogen, still higher logic speeds may be attained.



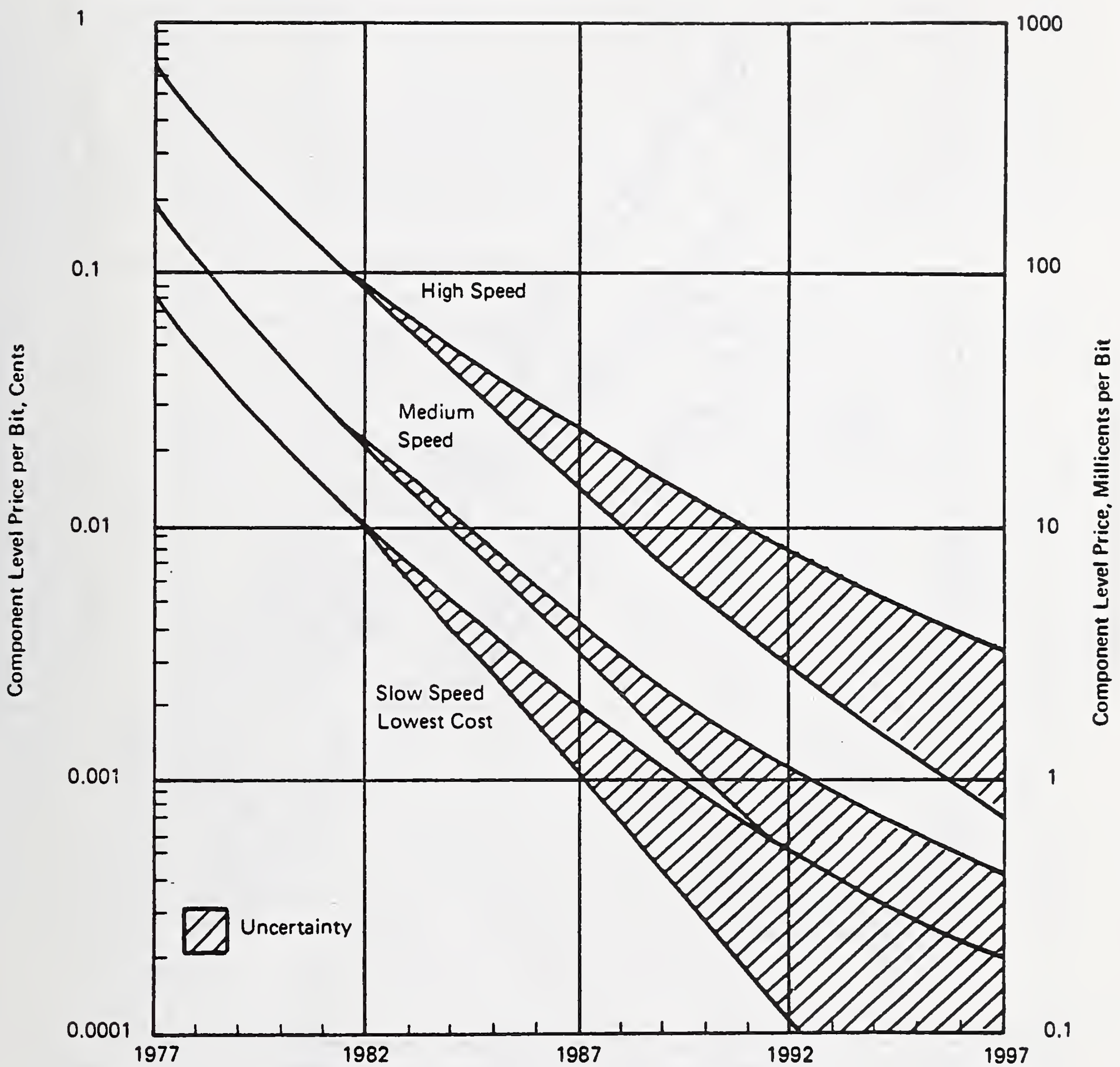
Source: Arthur D. Little, Inc., estimates.

FIGURE 2.8 COMPLEXITY (BIT SIZE) OF SEMICONDUCTOR MEMORY: RAM (RANDOM ACCESS) FAMILY, STATIC AND DYNAMIC, BY SPEED CLASS



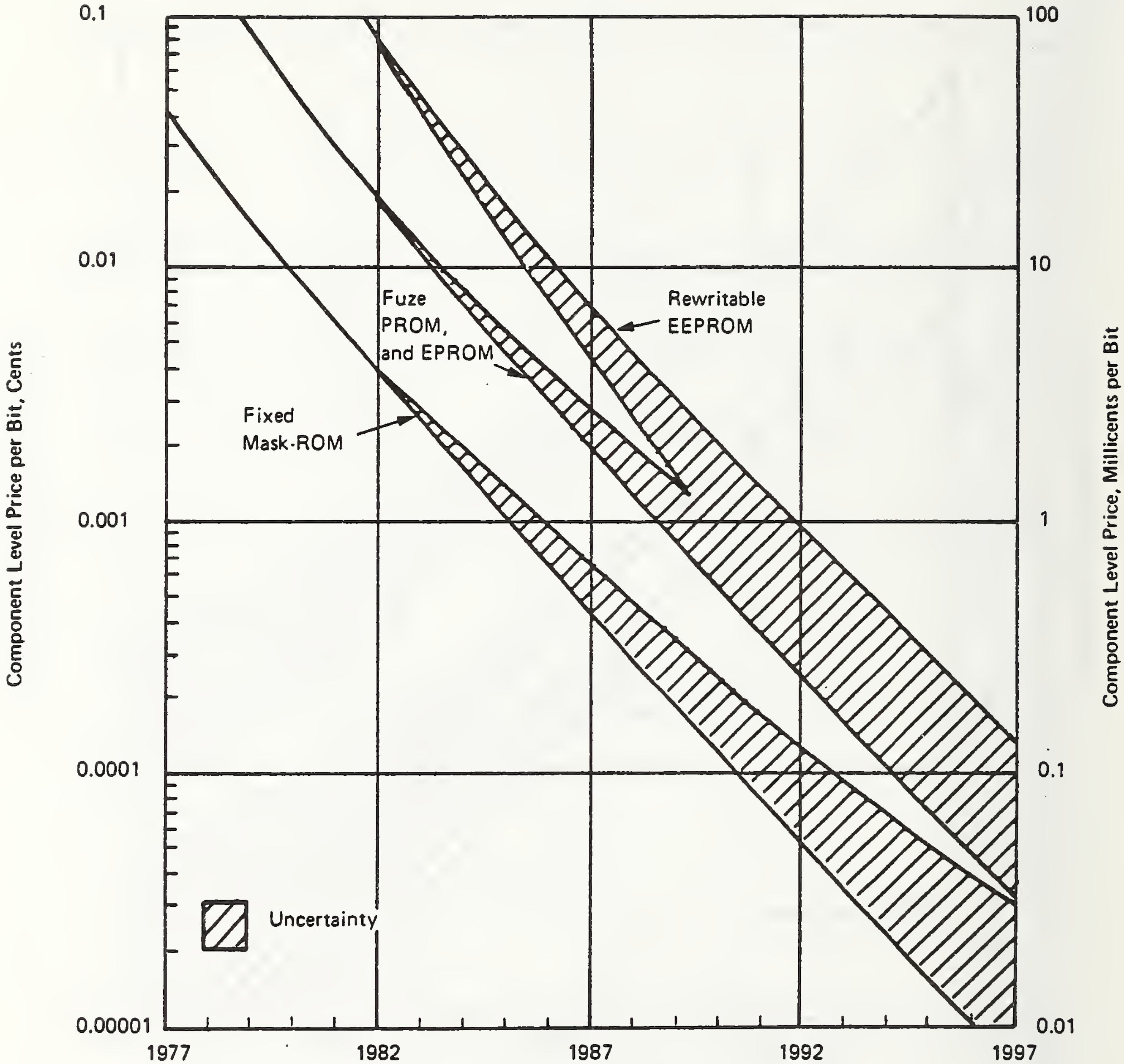
Source: Arthur D. Little, Inc., estimates.

FIGURE 2.9 COMPLEXITY (BIT SIZE) OF SEMICONDUCTOR MEMORY: ROM (READ-ONLY) VS YEAR OF INTRODUCTION



Source: Arthur D. Little, Inc. estimates.

FIGURE 2.10 SEMICONDUCTOR MEMORY COMPONENT PRICES (PER BIT): RAM (RANDOM ACCESS) BY SPEED CLASS



Source: Arthur D. Little, Inc., estimates.

FIGURE 2.11 READ-ONLY SEMICONDUCTOR MEMORY COMPONENT PRICES (PER BIT) BY TYPE

2.2.3 Other Logic and Memory Technologies

2.2.3.1 Charge-coupled Devices (CCD)

CCD technology has been developed intensively since 1971 and has benefitted from some of the general advances in the fabrication of silicon devices.

However, CCDs have not been used in large numbers because they have suffered from yield and reliability problems and have no cost advantage over serially-accessed RAM. CCD devices are not likely to capture a significant share of the serial memory market in the future unless their cost per bit drops to less than half that of conventional semiconductors. Little use of CCDs is expected except in optical processing (for digitizing and storing images) and digital filtering.

2.2.3.2 Cryogenic (Josephson Junctions)

A completely new technology, with considerable but distant promise, is that associated with the superconductive tunnel junction. Certain devices, when cooled to near absolute zero -- the temperature at which many materials become superconductive -- can be switched between the superconducting and normal states by small changes in the local magnetic field. These changes can be provided by an adjacent superconducting control circuit. When this change is observed in a superconductive tunneling function, this is the so-called Josephson effect. It can be employed to make memory and logic circuits which consume less power and occupy less space than conventional circuits while operating at very much higher speeds. However, many theoretical and practical problems remain to be investigated and overcome before such devices could become practicable. One major constraint on their application is that they would have to operate in a cryogenic environment (near absolute zero), with its associated cooling apparatus and its added cost and space requirements.

Laboratory devices and computer modules have been demonstrated with switching speeds of about four picoseconds and a power delay product 1,000 or more times better than that of semiconductor circuits. Memory access times of one nanosecond or even less appear possible. This technology offers an improvement in computing speed exceeding an order of magnitude.

Cryogenic technology is the only known alternative to semiconductor technology that offers significantly increased speed for data processing (optical logic appears applicable to high-speed signal processing, but signal processing as such is outside the scope of this report). It is therefore likely to be pursued for supercomputers and perhaps for the most demanding signal processing applications. Work continues on cryogenic computers, especially at IBM, and some systems may be in use by the late 1980's (as indicated in figure 2.3). However, we doubt that cryogenics will ever see general data processing use. The improvement potential of conventional silicon and gallium arsenide-based electronics is so great that it should meet virtually all needs at low cost except those for the highest speeds, without requiring expensive investments by users and manufacturers alike in exotic technology and elaborate mechanical cryogenic refrigerators.

2.2.3.3 Magnetic Bubble

Magnetic bubble memory systems offer several advantages over conventional technologies for non-mechanical magnetic storage:

- non-volatility (data is retained when power is turned off);
- high bit-packing density up to 10 million bits per square inch has been achieved and 100 million bits per square inch is possible;
- low power consumption since one rotating in-place drive field can move many millions of bubbles;
- the ruggedness and small size of the all solid state system; and
- an excellent error rate (better than one in ten billion has been demonstrated).

Bubble technology has two intrinsic disadvantages: it is more difficult to fabricate and it is slower than semiconductor technology by about two orders of magnitude, if the bubble memory is organized to minimize cost (in long shift registers). Different architectures and organizations can provide an order of magnitude difference in access time and cost. Redundancy techniques are essential to minimize the influence of manufacturing defects.

Most manufacturers of bubbles believe they must achieve a chip capacity of at least one million bits and a device price level of 0.01 cents per bit before their products will be viable. This price target is being approached, and chip capacities reached one million bits in 1980. A 4-megabit chip is now under development. Bubble memory component kits are offered to users in 1982 at costs of about 40 millicents per bit, including the peripheral devices. Prices will decline slowly toward those of semiconductors through the 1980's and then level off because of minimum bubble diameter limits; device price per bit should be below 5 millicents in the early 1990's, varying widely with chip designs and access time, but approaching the price of the cheapest semiconductor memory.

Magnetic bubble technology will be applied selectively, particularly in terminals and small, portable devices of selected kinds, offering as it does small size, light weight and information survivability (and where its slow speed is no impediment). In other applications, higher-priced erasable rewritable EEPROM or lower-priced serially-accessed semiconductor RAM will be used.

2.2.3.4 Semiconductor Serial Store (Disk)

The rapidly decreasing cost of semiconductor memory has led to the use of RAM chips in a serially-accessed architecture to replace magnetic drum or disks used as cache or buffer store for large disk stores. Such semiconductor serial store -- so-called solid state disk -- costs no more than semiconductor main memory but can be programmed and controlled for paging and lookahead. Access time can be very short compared to magnetic media. It depends on the semiconductor devices and cable lengths used but typically can be less than one microsecond multiplied by the bit length of the data stream sector. Very short latency can thus be obtained. These systems cost less with faster performance than drum buffer storage and are now near $6,000 per megabyte. Costs will decrease further with the lower RAM prices.

2.2.3.5 Other Storage Technologies

Research work continues on other technologies that may eventually yield cost-effective alternatives for information storage. Several areas receive attention, but to date no technically feasible and/or economically viable products are in sight.

Efforts continue to develop large capacity storage capability through holographic interference patterns, notably in France, Germany, and the United Kingdom. Realization of a workable system with the hoped-for storage density 10,000 times that of magnetic media appears to be held off by the lack of an appropriate substance having satisfactory reliability in repeated write/read/erase processes.

Other efforts explore low-voltage electrophotographic materials. Such materials, in crystalline form, are considered for their potential to maintain a very high charge density, allowing for the storage of a great amount of information. Based on the number of crystallites and the electron levels per crystallite, theoretical information capacity projections made are in the order of one trillion bits/cm squared.

Work is also continuing on the development of megabit memories using wafer-scale integration (WSI), based on single unbroken four or five inch metal-nitride-oxide-semiconductor (MNOS) wafers. Adaptive WSI, integrating storage with processing in an array structure on a single wafer, is expected to combine speed with reliability, nonvolatility, and low heat dissipation. While efforts in this direction have been exerted for several years, there is no indication that a commercial product is near. However, for memory, this concept has been successfully used in the laboratory to build very large stores for use as character generators for Kanji characters and digital facsimile image processing.

2.2.4 Mass Storage Technologies

2.2.4.1 Magnetic Disks

Magnetic disk storage devices continue to show improvements in capacity and cost, as the technologies advance in the read/write head designs and arrangements, and in the recording surface structure.

Since the arrival of sealed storage modules with their internal filtering devices, dust particles have been removed to a high degree and reliability has been increased considerably. This cleaner environment, together with the replacement of the previously used ferrite magnetic head technology with thin film heads of special aerodynamic design, has allowed heads to be spaced much closer to the surface (in the order of 20 microinches) allowing higher density of recording and reduced track width. As a result, the linear recording density of about 15,000 bits per inch used in some recently announced products and the increased track density result in an area density of approximately 11 million bits per square inch, more than double that provided in predecessor products, and permitting a reduction in the cost to the user by one half, to 0.4 millicent per bit.

The largest capacity disk drive now available combines two sealed head/disk assemblies of 1.26 gigabytes each, for a total of 2.52 gigabytes per drive. As a result of its increased linear recording density, it has a data transfer rate of three megabytes per second. Using two sets of actuators in each head/disk assembly effectively cuts the average seek time in half to 16 milliseconds.

Slightly lower levels of technology have been applied to small disk drives for small computers and office products. Reduction of disk size (for rigid mini-disks to 5 1/4 inch diameter with 3 1/2 inch diameter recently offered), as well as a recent 50 percent reduction in the height of drive mechanisms has led to an increasing use of mini-disk systems. This trend will continue as improvements in the recording density continue and the cost of devices decreases.

Flexible (or "floppy") disks are also in widespread use for both information storage and information transfer. Low-performance, flexible-disk drives for the standard 5-1/4" disks are very inexpensive and the more recent 3" disk drives may do even better. The technology of flexible disks is behind that of rigid disks, but is improving. **[STAFF COMMENT 1]**

Thin film heads and thin film media should provide densities of about 25,000 bits per inch and 2,000 tracks per inch in production-run high end fixed disks in 1987. The resulting density of 50 million bits per square inch could rise to 180 million bits per square inch in 1992, by a combination of thin film heads, thin film media, and vertical recording.

In vertical recording, the magnetized domains are stacked perpendicular to the surface of the substrate (rather than horizontally, as is the case in the present mode). Vertical recording at 100,000 bits per inch density has already been demonstrated in the laboratory and ultimate linear densities of over 400,000 bits per inch are considered possible.

While uncertainties remain about the degree and timing of these improvements, we expect that continuing improvements could lead to densities of 400 million bits per square inch in 1997. To achieve these results, the electromechanical assemblies will require considerable refinement since head-to-medium clearances and track positioning accuracies will become increasingly difficult to achieve and to maintain and will finally become limiting, at least in present configurations.

The above refinements in heads, media, and mechanics will lead to higher cost drives but the cost per bit stored falls, nevertheless, because of the great increase in storage density. Our cost forecasts are shown in table 2.1.

In conclusion, except for relatively small applications where semiconductor or magnetic bubble technology will be used, moving head disk storage systems will continue to offer a significant cost advantage over other storage technologies throughout the 1982-1997 time period. However, this cost advantage will often be partly offset by the use of the buffered approach to reduce effective access time. Storage densities will increase more than tenfold to provide capacities in the tens of gigabytes per drive.

2.2.4.2 Magnetic Tape

Magnetic tape, the earliest secondary data storage medium, lost importance as the magnetic disk became available. The disk's better accessibility of data and related improvement in sorting ability over the serial operating mode of the magnetic tape relegated the tape to a medium for archival storage.

Increased recording densities on magnetic tape, from 800 bpi to 1600 bpi and 6250 bpi, combined with higher tape transport speed (up to 200 inches/sec) provided data rates usable for data dumps of large disk files. The continuing need for higher capacity and data transfer rates to satisfy backup requirements of emerging new disk storage products is expected to be satisfied by future magnetic tape systems. We expect solutions to this need to come from two directions: first, increases in linear recording density similar to that on magnetic disk devices; second, increased width of the magnetic tape to dimensions wider than the customary 1/2 inch. Both actions would serve to provide the data rates required for archival backup of information maintained on the new disk systems.

In any case, the technology is at hand for high density recording. Tape media may change to smaller and oriented particulates, and higher coercive materials. Vertical recording may also be used with possible lineal densities in excess of 100,000 bits per inch. Heads, to allow the very high densities, will go to thin film design.

Other efforts to develop ultra-high density recording capabilities include a microgap head arrangement. In conjunction with chromium-oxide tape, it is reported to have permitted recording densities of 120,000 bits/inch. Extremely high densities of recording are possible with very small record gaps and unoriented tapes with small particles. Recording densities of 40 million bits/square inch at error rates of 10 to the minus 12 power to 10 to the minus 15 power appear practicable.

To improve performance and reliability and to reduce costs, microprocessors are used to control the rate of change of tape drive motor current and to reduce starting current in order to attain accurate tape speed control. This is translated into very low access times while meeting velocity standards. As a result, prices for tape drives applying improved versions of existing technology are likely to remain at existing levels, resulting in an effective two- to four-fold price-performance improvement per bit stored.

As the standard reels of such tape have several orders of magnitude more capacity than the cartridges used with some mass storage systems, and as the capacities of disk drives (including video discs -- see below) become very large, we see the cartridge-type mass storage systems being phased out for most applications.

Quarter-inch magnetic tape cassettes continue to hold their position as backup media to the smaller fixed disk systems in the small business system, minicomputer, and text processor environments, but their usage growth may be affected by the increasing price-performance and physical size reduction of mini-disk units.

Optical recording tape as reported under development at Drexler Technology, may become a new alternative if it can realize its expected capacity of 1.6 trillion bits per 2,400 foot reel, 1,000 times that of present high density magnetic tapes.

2.2.4.3 Video Disc

The video disc*, developed for and initially applied to the recording and replay of TV programs, movies, and other visual information in the entertainment and training fields, is receiv-

*Ed. note: The vocabulary and spelling used in this field is still in flux. In this report, the term "video disc" is used in the broadest sense, denoting general information storage technology and is not limited to home entertainment technology.

ing increasing attention in the data processing/information handling areas for its large storage capacity, small size, and relatively low cost.

In the form of a 12" removable plastic disc, it can be encoded by a laser beam which "burns" small pits, each representing a bit of information, along a continuous groove. It is able to store a 30 minute TV program (about 54,000 color TV frames) or approximately 100,000 pages of 8 1/2" x 11" black and white documents. The potential digital image storage capacity by single or dual sided recording methods presently is in the one to 10 gigabyte range. **[STAFF COMMENT 2]**

With an estimated mass production cost of prerecorded video discs at the $10 level, competition for the entertainment/educational market is intense among RCA, Philips, MCA, Magnavox, Sony, and others, with playback equipment prices down to the $300-$1,000 level.

Parallel to this, RCA, Philips, Toshiba, IBM, STC, CDC, and others are working to apply this technology to the field of digital information storage. Recording the scanned image of a document in the form of a bit-stream and reconstructing it for replay, they could serve as electronic document filing systems, with initial cost projections in the $20,00-$50,000 range. Maturing of these products and low prices will open the way to many uses in the office environment. A novel approach is already being taken by several personal computer and personal computer accessory vendors who are supplying systems by which personal computers can be converted to, and can control commercial video disc players for educational, advertising, and training markets. These types of systems are expected to proliferate over the next several years.

The process of recording information by burning pits into the surface of the video disc with a laser beam and the retrieval of such information, is subject to a raw error rate (in the range of 10 to the minus 5 power to 10 to the minus 8 power) which is several orders of magnitude higher than the error rate experienced with presently used magnetic storage devices. While this error rate may be acceptable for the recording and retrieval of digitally stored images due to the redundancies inherent in such images, it is generally not acceptable for the recording and retrieval of data. Methods for the reduction or compensation of the existing raw error rate under consideration generally lead to a significant trade off reduction of usable storage capacity. As a result, the estimated available capacity of video discs for the storage of data is much less than the capacity applicable to image storage.

For the laser hole-burning approach, conservative estimates for the storage of digital data expect a capacity of 500 megabytes to one gigabyte for a 12" disc. With the added complexity of the error control logic and indexing in the digital data environment, the cost estimates for single drive systems vary between $25,000 and \$120,000. While Toshiba has announced the availability of an initial product, volume availability and acceptance still appears to be three to five years away.

With the anticipated price for a recordable hole-burning type video disc of \$150, multi-disc arrangements for shelf storage in "jukebox" format could permit a storage capacity of 10 trillion bits per system at a potential cost of .003 millicent per bit. Access times are likely to range from about 0.1 second to a single disc to about 3 seconds to a "jukebox" of multiple discs. Little effort is seen to reduce access times since the video disc will be used in a storage mode; cost, capacity, and reliability will be the critical variables.

Driven by the need to improve reliability and to increase capacity, the search for ways to enhance electro-optical storage capabilities continues. A new recording technique developed by 3M takes the approach of using a laser beam to heat a base material on the disc and create bubbles or bumps in the surface covering material. Reportedly this playback system can more readily differentiate a blister than other techniques can distinguish a hole in a flat surface.

Another process of considerable promise is reported under development at the IBM research laboratories in San Jose. Called frequency domain storage or photochemical hole burning, it has the potential of storing many bits of information in a single spatial spot. To achieve this effect, a very low temperature environment is required.

Efforts are also directed to determine the potential of electrophotographic material for high density recording of digital information.

There are also efforts underway to develop technologies which provide erasable optical storage media. One of them has resulted in the development of a prototype disc by Japan Broadcasting Corporation. Using the thermomagnetic characteristics of a gadolinium-cobalt thin film, it is reported to permit selective erasure as well as erasure of the whole disc by a strong magnetic head.

No firm data on the storage life of video disc storage exists as yet. Conservative projections, in view of unanswered questions of the possible vulnerability of protected recorded surfaces, anticipate a two-year minimum storage life. It is expected that it will become possible to extend the storage life of information recorded on video discs to ten years and more.

In view of the efforts still required to overcome the shortcomings of the video discs for data recording, it is not likely that they will play a major role in this field until the second half of the 1980's. The role of magnetic devices for the mass storage of data will remain predominant in the near term. Beyond the middle of the decade, however, new technologies now under development hold the promise of maturing to the application level and may supersede present mass storage technologies with dramatic effects.

At the present stage of development, video discs appear most attractive for their potential as electronic media for digitized text or image information, where the intrinsic error rate may be acceptable, and the high density and low price are especially important. [STAFF COMMENT 3]

2.2.5 Summary of Storage Component Performance and Cost

Since a variety of storage technologies will be used in information processing systems and the trade-offs between them will vary with time, to clarify the situation we present the following summary of the forecasts presented earlier.

Table 2.1 summarizes our forecasts of the cost per bit of the 10 major storage technologies presented earlier over the period 1982-1997. All are converted to the same measure, purchase cost to the user. (This conversion involves markups over manufacturing cost of about four times depending on expectations of system size, manufacturing technology, etc. Note that figures 2.10 and 2.11 show costs from the device manufacturer.)

TABLE 2.1

COST COMPARISONS OF STORAGE TECHNOLOGIES
(user cost in millicents per bit)

Type	1982	1987	1992	1997
Random Access				
Fast Semiconductor (RAM)	300	70-100	20-40	5-10
Medium Speed Semicond. (RAM)	100	20-30	7-12	1.5-3
Slow Semiconductor (RAM)	25	7-10	2-4	0.5-1
Fixed, Non-Volatile Semiconductor (ROM)	20	5-7	1.5-3	0.5-1
Fuze, Non-Volatile Semiconductor (PROM)	300	50-100	10-30	2-5
Rewritable, Non-Volatile Semic. (EEPROM)	300	50-70	10-20	3-5
Serial Access				
Serial Semiconductor	75	10-15	2-4	0.3-0.5
Bubble	100	20-30	5-10	3-5
Magnetic Disk	0.4	0.12	0.03-0.06	0.01-0.03
Video Disc	---	0.05-0.1	0.01-0.02	0.001-0.003

Table 2.2 summarizes our estimates of access time (complete read cycle) in a corresponding manner. As the tables make clear, the improvement potentials for semiconductor memory are so great that, given the large investments in existing technology, it will continue to dominate all high-speed memory applications. Semiconductor technology also offers a wide range of speed-cost

alternatives. These technologies will continue to be used in user-transparent hierarchies, as they are now.

TABLE 2.2

AVERAGE ACCESS TIMES OF STORAGE TECHNOLOGIES

Type	1982	1987	1992	1997
Random Access				
Fast Semiconductor (RAM)	12 nsec	8 nsec	5 nsec	4 nsec
Medium Speed Semicond. (RAM)	60 nsec	40 nsec	25 nsec	15 nsec
Slow Semicond. (RAM)	250 nsec	150 nsec	80 nsec	60 nsec
Fixed, Non-Volatile Semic. (ROM)	350 nsec	150 nsec	80 nsec	60 nsec
Fuze, Non-Volatile Semic. (PROM)	70 nsec	50 nsec	30 nsec	20 nsec
Rewritable, Non-Volatile Semic. (EEPROM)	250 nsec	150 nsec	80 nsec	60 nsec
Serial Access (Latency)				
Serial Semiconductor	0.4 msec	0.25 msec	0.15 msec	0.1 msec
Bubble	2 msec	1 msec	0.7 msec	0.5 msec
Magnetic	25 msec	20 msec	15 msec	10 msec
Video Disc		0.1-3 sec	0.05-3 sec	0.02-2 sec

Storage capacity (the third major variable besides cost and access time) is not shown in the tables because most storage systems are highly modular and available in a wide range of capacities.

Most semiconductors are volatile, which is not necessarily a disadvantage in most computer systems where magnetic storage backup and virtual memory-file techniques are generally used. However, in smaller devices (terminals, portable, and desk-top systems) magnetic bubble technology may be preferred because it is non-volatile, because its slower access time will usually be acceptable, and because for small systems of a few million bytes, its size, power consumption, and overall cost may make it superior to a semiconductor-magnetic hierarchy.

Magnetic disks are expected to retain their cost per bit advantage over solid-state alternatives throughout the period, though their access times will not improve much. They will, therefore, continue to be used for large files.

As discussed more fully in section 2.1 buffered disks are likely to be applied in large systems with large files and high activity. Using a faster technology (perhaps semiconductor or bubble) as a buffer, most of the cost advantage of the disk can be retained while a reference rate of 1,000-1,500 per second is supported. The cost and average access time of buffered disk systems are determined by a trade-off between buffer size and disk size.

These tables do not depict the fact that logic and storage components will increasingly be combined on ever-larger semiconductor chips that will make new processor organizations and applications possible. Such combinations, discussed more fully earlier, may have more impact on data processing users than the simple improvements in price-performance summarized here.

The pace of improvement of semiconductor manufacturing is very rapid. The above forecasts are considered conservative and it is possible that the forecasted cost and complexity levels may be achieved at significantly earlier dates.

2.3 INPUT/OUTPUT TECHNOLOGIES

Since the technologies discussed in this section evolve relatively slowly and at varying rates, the discussion is not divided into five-year periods. However, dates of expected first availability of commercial products are shown where possible.

2.3.1 Status and Trends

Input technologies have changed very slowly and not much change is anticipated for the next five years or so. The dominant mode remains the operator keying in the information, with the keyboard of the terminal replacing the previous card keypunching process.

Optical character recognition effectively remains limited to discrete characters with stylized shapes; voice recognition similarly has been applied effectively only to individual word recognition in a small vocabulary environment. Most present efforts are directed at improving performance of existing vocabulary levels and reducing cost. Major vocabulary expansion and continuous speech recognition remain difficult.

Improved keyboards are appearing in which numerical key fields and special control keys (e.g., cursor control) complement the traditional alphanumeric key arrangement. These increase productivity and operator comfort.

As a new variant to the touch-entry process, touch screen capabilities are being provided, facilitating the man-machine interface with minimum training requirements.

Voice and image signals are increasingly being digitized into bit-streams and intermixed with encoded text and data. The digitized speech and imagery cannot be recognized and processed like the encoded material but it can share the same communications, storage, and display resources. This intermixing of bit-stream and encoded information is likely to improve the cost-effectiveness of office information systems.

In the field of output, innovation and change occur at an accelerating pace. Visual displays with color options and greater resolution have become available. Flat-panel displays are coming into use in situations where their convenience of shape and weight offset their cost and resolution disadvantages. Voice output has gained in vocabulary range and cost effectiveness as semiconductor-based synthesizers enter the market. Hard-copy output capability has broadened in scope and quality with the application of laser beam, fiber optic, and magnetic technologies to the xerographic process of image formation. Matrix formation of characters and images has permitted low cost output creation for new office or home applications, using either non-impact or impact means of creating the image.

Simplified designs have emerged which reduce the cost of hard-copy output devices, especially at the low-speed end. They offer good quality of copy and can be expected to offer color capabilities.

2.3.2 Display Technology

The display field continues to be dominated by the cathode ray tube (CRT). Efforts to compete against or complement the CRT center are attempts to develop acceptable flat-panel displays at competitive prices.

While basic technology for large flat-panel plasma displays has been around for some time, high cost (typically $7 per square inch of screen), bulky driver electronics, and limited color capability have restricted their usage to small- to medium-size displays with up to 500 character capacity. Special panels with high resolution have been developed, such as 8.5-inch square displays with 512 x 512 pixels, and 12-inch square displays with 1,024 x 1,024 pixels. Larger panels (40 x 25 inches with a resolution of 2,500 pixels per square inch) are available, but they cost in the range of $50,000 to $80,000, depending on the quantity. The production of large size flat-panel displays at acceptable cost depends on the progress of thick-film and thin-film technology.

Cathode ray tubes are expected to maintain their dominance in the display field for some time. With resolution of 512 x 512 elements and tube sizes ranging from 12" to 30", the cost of standard tubes during the next few years is expected to be in the $50 to $100 range. Color options and high resolution (to 7,000 x 7,000 elements) will lead to special tube prices in the $1,500 to $2,000 range by 1985.

Traditional manufacturers will continue to improve CRTs in the face of impending challenges from flat-panel display technologies. Large flat-panel CRTs may be a reality toward the end of the eighties.

Color display CRTs have increasingly come into use in applications such as computer system status, management

Color display CRTs have increasingly come into use in applications such as computer system status, management information systems, and process control, where color facilitates the separation of the information displayed into content categories.

Another means of separating displayed information according to content is through multiple bit-planes (e.g., a background map or form with one or more levels of varying information in the foreground, usually in a contrasting color). Two bit-planes are generally available in terminals used for real-time situation display and more can be obtained. Electronics cost is the limiting factor: as it declines, display terminals with as many as four bit-planes will become available at reasonable prices by 1986.

The growing interest in graphic display for computer-aided design and animation has led to an increasing interest in the creation of three-dimensional perspective images, mostly through improvements in software for providing shading, etc. However, progress toward true three-dimensional displays (where a different image is provided for each eye) is much slower. Considerable research and development work on this subject is being carried out in Japan but the complexity involved and the volume of information required in the recording, storage, transmission, and reproduction of three-dimensional images has, to date, not permitted practical solutions. While no breakthrough appears likely in the near term, the market potential for three-dimensional imaging will lead to further development efforts and possible products in the 1990's.

Large area (8 x 10 square inches or larger) flat-panel displays based on technologies such as electroluminescence, liquid crystal, electrochromic, etc. (in addition to plasma panels previously described) will be commercially available before 1987 at prices in the $200 to $300 range. CRT technology may lose its position in the less-than-2,000 character display market. Toward the end of the eighties and into the nineties, flat-panel displays are likely to come into general use in wall television sets, telecommunication terminals, and home entertainment terminals. Greater acceptability and improved performance will increase the use of flat-panel displays in all areas.

2.3.3 Hard-copy Output Technology

Impact printers have improved significantly in recent years, particularly at the low-speed, low-price end of the spectrum. Electronics has been substituted for mechanical controls, lightweight plastic parts have been substituted for metal, and matrix character production has been exploited. Further improvements in print quality, cost, and color capability are expected, mostly in low-speed, low-cost printers. However, new developments are occurring mostly in the various non-impact technologies which are discussed below.

2.3.3.1 Xerographic Technology

To date, xerographic technology has been applied at the high- and medium-speed ranges of the printing spectrum.

At the high end, laser printing/imaging systems costing several hundred thousand dollars each are able to produce up to 10,000 sheets of output hard copy hourly and to feed, cut, and collate the stream of pages produced.

As more cost-effective technologies come into use, the price of these systems continues to drop considerably. Semiconductor lasers replace gas lasers and simplified beam deflection techniques like Xerox' Hologon supersede the rotating mirror. The Xerox 2700 system, directed at the office environment, was announced with a price below $20,000; the trend continues.

Another image-output approach is taken in a product recently announced by Delphax Systems. It offers a lower-cost alternative to laser xerography by an ion-deposition imaging process. The Delphax 2460 operates at 60 pages per minute with an expected end-user cost at the $30,000 level.

As the cost of hardcopy output image forming stations continues to decline, it becomes economically feasible to combine several in one unit, providing multicolor capabilities. Color non-impact printers are likely to be in increasing demand to complement the increasing use of color displays and be generally available by 1987.

2.3.3.2 Ink-Jet Technology

The technology of using a fine stream of ink droplets to create alphanumeric or image output has been applied to several commercial products, at both ends of the speed spectrum. At the low end, modification of the Siemens PT-80 ink-jet printer by Printa Color and ACT provide color printing models at prices below $10,000.

At the other end of the spectrum, high-speed ink-jet customized printers are used for special jobs such as address label printing. One such printer produces up to 80,000 limited width address lines per minute. For other special applications such as geographical or medical plotting, special ink-jet control remains complex and the related cost and operational problems continue to limit its application but high-speed systems will continue to improve.

2.3.3.3 Other Technologies

Character generation by a magnetic process has been pursued by several companies, with the intent to provide line printing capabilities of 6,000 to 8,000 lpm. To date, however, no product of acceptable quality and reliability has appeared.

A novel approach to improved print/image quality in matrix based output systems uses a slight repositioning of the image-creating head and repeated character or image formation runs. The slight overlapping provides improved resolution. While this occurs at a reduction in output speed, single-pass output creation at full system speed can serve many applications (such as internal reports or drafts) where speed takes precedence over output quality, followed by later high-quality runs at slower speed.

Another novel approach to low-cost color output is followed in the Sony Mavigraph printer, intended for the creation of color prints for Sony's electronic Mavica camera. This printer uses a thermal print head, whose tiny pins in successive passes over yellow, cyan, magenta and black carrier sheets transfer the dye to the paper and blend it to form a hard copy color image.

Another field of high-speed non-impact output imaging is the creation of computer output micro-images, with devices capable of recording up to 130 output pages per minute in micro-image form. Micro-image output is particularly useful in the growing field of computer-assisted design and image processing in general. It also works well with off-line film-based information retrieval and photocomposition systems. This technology is likely to be complemented by computer output video disc technology which would make possible new forms of information dissemination.

Non-impact printing is also well adapted to the production of computer-readable media using either special fonts or bar codes. These can be applied both to documents and to objects; applications are likely to expand steadily. [STAFF COMMENT 4]

2.3.3.4 Forecast

The non-impact technologies will continue to improve steadily in resolution and cost throughout our forecast period. None are likely to be lower in unit cost than impact printers, however. The result will be that at all price levels users will be offered increasing options of resolution, speed, graphics, and color. Few users will be paying less for printers than they do now; most will instead be evolving their information systems to take advantage of the new printers' capabilities to provide more customized and management-oriented images, and to support increasingly versatile office systems.

2.3.4 Image Recognition

Success in image recognition to date has been limited to constrained applications. Little progress has been made in the development of generalized systems capable of a wide range of variations. Successful applications include optical character recognition of typewritten or printed fonts, Universal Product Code, and handwritten characters produced in conformance with specific rules. Commercial applications implemented include reading of utility turn-around billing forms, bank check reading, and retail check-out counter product code reading. These applications are becoming more widespread as the cost of the reading devices decline.

Patterns with greater degrees of freedom, higher content complexity, and noise factors continue to present such problems that progress in generalized image recognition have been very slow. Limitations both in processing power available and in the resolvability of ambiguities have hampered progress.

Hybrid systems combining computer throughput power with human analysis capabilities have had some degree of success, as exemplified in the fingerprint recognition area. In most fingerprint identification systems, fingerprint images are scanned; ridges, ridge endings, and bifurcations are detected, and their relative positions and orientations recorded. This information is used to match a search fingerprint against a file. A very small list of candidates is identified and a human performs the final identification.

Further improvements of image recognition systems will depend less on the increase of processing power than on the development of analytical software able to apply classification criteria via decision-tree algorithms. Progress in these procedures, utilizing increasing capacity and cost effectiveness of enhanced storage technology, is likely to be applied to interactive schemes with two levels of capability:

- a screening facility, that will alert an operator to a possible occurrence of an interesting pattern, and

- a manipulative capability, as mentioned above, to assist the human decision.

Fully automatic image processing is not expected to be possible any time in our forecast period except for image sets predesigned to facilitate recognition (e.g., Optical Character Recognition (OCR) character sets). However, knowledge-based systems with which human interaction is necessary only for final and subtle decisions may be in use in the 1990's.

2.3.5 Voice Recognition

2.3.5.1 Discrete Words and Phrases

The most successful voice recognition systems to date are those that deal with discrete words, a small vocabulary and one or a few persons. Systems capable of handling from 16 to a few hundred discrete words are readily available. Systems costing from $30,000 to $75,000 may also incorporate host processors that may also perform other functions in addition to speech recognition (typically speech synthesis in man-machine dialog). These larger systems also incorporate connected word and/or speaker independent recognition capabilities. Lower cost systems, typically at the $2,500 price level for a broad-level recognition product, provide slightly inferior recognition performance with more severe constraints on the degree to which the words are spoken as discrete (unconnected) utterances, and with less sophisticated algorithmic methods to handle speaker idiosyncracies and varying background noise conditions. Neither recognition accuracy nor vocabulary size are directly correlated with price; they are indirectly related along with a large number of other features. "Recognition accuracy" per se is a meaningless term in the absence of standardized databases and guidelines and procedures for performance assessment. Most manufacturers, trying to expand the market for word recognition systems, presently focus on improvement of recognition rates in low-cost systems with small vocabularies, using increasingly cost-effective components.

The recognition of longer patterns, as they are found in phrases made up of several words, requires increased storage capacity for the voice patterns to be compared and calls for greater processing power to perform the analytical operations. One problem encountered in the attempt to develop systems capable of recognizing connected speech is the difficulty of determining where one word ends and the next begins. This problem is complicated by the variability of the acoustic characteristics of sounds and words in connected speech. It has been greatly assisted by use of dynamic time warping algorithms. The use of clustering methods in template formation has provided procedures to accommodate speaker independent input for larger vocabularies without severely degraded performance, while accommodating the variability in the acoustic characteristics of sounds and words in connected speech. Recent work at Bell Laboratories (*J. Acoust. Soc. Am.* *72* (2), 390-396, August 1982) as well as elsewhere has demonstrated speaker-independent recognition accuracies for 129 word vocabularies that are comparable to those obtained on the same vocabularies with speaker trained reference patterns.

The segmentation of continuous speech into discrete, phonetically significant intervals and the matching of these intervals with stored phonemes requires carefully constructed similarity measures and extensive tree search algorithms. Connected speech recognition systems must be able to handle not only characteristics of sounds and variations in pronunciations (as the word recognition systems do for discrete words), but also the grammatical structure of the language. Even with simple vocabularies of less than 250 words and using large computer systems executing millions of instructions per second of speech, the achievable accuracy rates are much lower than those of discrete word recognition systems. Certain procedures such as dynamic time alignment and statistical clustering offer promising ways of dealing with the connected speech and speaker variability issues, and of reducing processing requirements. Efforts in this direction continue, but the power of available resources sets limits even in this relatively simple environment.

We expect that efforts to recognize strings of words will show increasing success in environments which permit limitation of the permutations that must be covered by the analysis through limitation of the choices of words at specific points in the strings. The NEC DP-100 system is an example of a system operating successfully within the constraints of limited vocabulary, tuned to a specific speaker and a limited size string of words. By applying two matching steps, one for each word and one for an entire group of words, it allows the recognition of a continuous string of up to five words out of a vocabulary of 100 words spoken by a speaker whose pattern of speech for each of these words has been prestored. Such a system might be termed a "command recognition system". Considering the processing power needed to perform the analysis, it is expected that such systems will not be economically justifiable for the commercial environment until the next generation of component technology can be applied. Beyond 1985, command recognition systems for entering operating instructions to computer-based devices, as well as for highly restricted voice data entry applications, may become practical. [STAFF COMMENTS 5 and 6]

2.3.5.2 Continuous Unrestricted Speech

The most complex level, that of recognizing continuous unrestricted speech, requires not only definition of the structure of an utterance but also comprehension of specific meanings which depend on knowledge of context and semantics. The processing power of present computers is several orders of magnitude lower than necessary to deal with the problem in real time and it remains doubtful that even with availability of sufficient processing power the problem may be solved in its entirety. Unconstrained continuous speech recognition systems are not expected during this decade and remain in doubt even for the next decade. When they appear, they will probably be available first for the Japanese language which is well adapted to phonetic feature-based recognition algorithms. [STAFF COMMENT 7]

2.3.6 Voice Synthesis

With the continuing rapid advance of semiconductor circuit technology, voice output systems have made considerable progress. Replacing the need to store output voice vocabularies with the capability of creating the individual sound elements of speech resulted in a reduction of the complexity and cost of voice output systems. Voice synthesizer chips are already used in many low-priced products.

Replacing vocabularies of stored voice with semiconductor voice synthesizers contributed to the reduction in cost of systems from the hundred thousand dollar level to several thousands (and down below $20 at the component chip level). With rising interest in voice output at the new price level, application of voice synthesis in control and warning systems is expected to grow. Applications in industrial process control and warning, home appliance operations monitoring, and even computer assisted training routines are under consideration. Chip prices are expected to decrease further to the single digit dollar level soon. We expect that these chips, complemented by the implementation of advanced algorithms for producing well-intoned continuous synthetic speech, will find considerable usage in quality answer-back systems costing at most several hundred dollars each. **[STAFF COMMENT 8]**

Voice synthesis, then, will be generally available as a computer output medium by 1985. Since visual display is generally preferable for most purposes, however, voice output for computer systems will ordinarily play a secondary role (e.g., warning of exceptional conditions).

Voice synthesis appears promising for use both as a means of providing informative audible prompt and system status messages and as a means of facilitating voice mail systems. The classic trade-offs in system design will continue to be flexibility, intelligibility, and storage requirements.

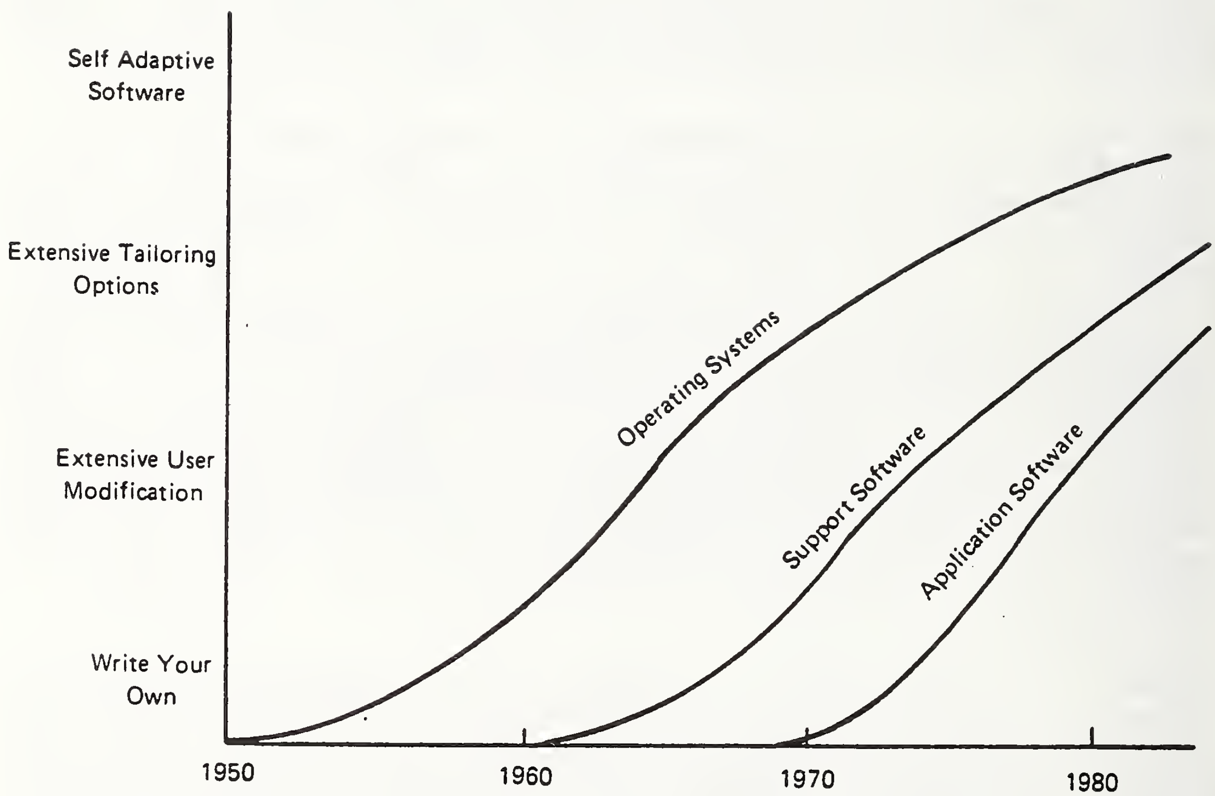
Requirements for systems that are sufficiently compatible with one another to permit the exchange of software, data, and/or voice messages may require the evolution of standardized procedures for phonemic and bandwidth compressed synthetic speech.

Voice mail systems, capable of storing and forwarding voice messages (without any recognition process involved), have been announced by IBM, Wang, and several others. While their acceptance is still limited due to the extensive storage requirement (about 250,000 bytes per minute of speech), the application of data compression algorithms and the dropping cost of magnetic disk storage may lead to increasing use of voice mail in office systems in the latter part of the decade.

2.4 SOFTWARE

Software has evolved more slowly than hardware, inhibiting potential market growth. Nevertheless, evolution has been occurring. Figure 2.12 depicts a trend which we believe has been slowly affecting all types of software. Over time, the three major classes of software have been undergoing an evolution from "home grown" systems to vendor-produced systems that can be adapted with increasing ease to varied user needs. In the increasingly likely event that a vendor-produced product can be adapted to an organization's needs, this evolution permits users to obtain increased value per dollar of software investment.

This trend to adaptable vendor-provided software has led to the largest improvement in programmer productivity of any of the software technological trends over the past ten years. Increased use of vendor-supplied software permits internal programming



Source: Arthur D. Little, Inc.

FIGURE 2.12 SOFTWARE EVOLUTION

staffs to concentrate their efforts on the diminishing proportion of application programs which must be specifically tailored for their individual organizations.

In the following paragraphs we separately discuss the trends in the three main software categories of the forecast period.

2.4.1 Operating Systems

2.4.1.1 State-of-the-Art

At the present time, the operating systems produced by the major computer manufacturers are undergoing a long-term, gradual transition from completely bundled, easily identified, integrated collections of software to almost completely unbundled, very modular, software and microcode-implemented sets of elementary functions whose major purpose is to allocate and control resources on a millisecond-by-millisecond basis. Since the users and their application software are far more sensitive to changes in the operating system than they are to changes in the hardware, this transition is by necessity a very long and gradual one where major discontinuities or conversions are avoided whenever possible.

At the present time, we are only part-way through this process which is expected to last through the early to mid-1990's. Today's operating systems still have many clearly definable functions above and beyond basic resource management. However, each announcement of a new operating system release generally includes a reduction of the scope of the operating system functions and incorporation of the functions deleted from the operating system into one or more of the associated software systems, such as the database management system, the job entry and sequencing systems (such as IBM's JES), and the various telecommunications monitors.

Most manufacturers are charging for at least part of their operating system software and are gradually increasing the charges and the portion of software for which a charge is made once or twice a year. Microcode assists have started to appear primarily as throughput enhancement mechanisms. Although many of these assists are, at present, not required in order to operate the system, a trend towards making the assists a prerequisite for higher level software is beginning.

The operating system interfaces are beginning to disappear from the user's view, being replaced by easier-to-use, more logical interfaces in the higher level support software systems.

Security is becoming a more important issue for many of the manufacturers, some of whom offer to repair, at no cost, any breach in the operating system security mechanisms found by the users during normal use.

For smaller minicomputer and small business systems the trend is somewhat different. Ease of use is judged more important than a wide variety of options; therefore, integral, semi-automatic operating system packages are being developed.

Early microcomputer-based systems (MBS) used software control systems which were too small to be considered operating systems. These control systems were generally classified as monitors.

This class of system is undergoing a rapid evolution. For 8-bit MBS's there are several manufacturer-specific systems as well as a single system, CP/M, which is used by most of the smaller manufacturers and offered by the larger manufacturers as an option. This situation is not expected to change in the foreseeable future.

There is intense competition among the suppliers of the newly emerging 16-bit MBS's to develop a generally accepted de facto standard monitor. The leading candidates are evolved versions of CP/M (MP/M, CP/M-86, etc.) and versions of the UNIX operating system (UNIX, XENIX, etc.). In addition, a language-specific monitor (Pascal) is also being used as a secondary standard for many systems.

We forecast that all of the systems mentioned above will survive throughout the forecast period. Each one will find a specific market niche in which it is preferred and will maintain a slow evolution towards operating system capabilities for the foreseeable future. This subject is discussed further in section 4.2.

2.4.1.2 1982-1987

Almost all the manufacturers will be attempting to obtain more revenue from their operating systems than they currently do. Those whose operating systems are now in the public domain will use various mechanisms such as renaming, redistributing the functions, rewriting major sections, and implementing microcode to insure that almost all customers will have to pay some license charges for their operating systems. Also, in preparation for the more modular machines of the future, the manufacturers will continue to reduce the functionality of the basic operating system. These functions will be taken over by such systems as storage hierarchy management software systems, database management software systems, communications management software systems, and job entry and scheduling software systems. Such software systems will also be separately priced and be sufficiently interrelated that most users will be required to purchase a large number of the systems.

By the mid-1980's, 30 percent to 50 percent of most operating systems will be implemented in some form of microcode, either plug-in ROM modules for smaller machines or electrically alterable control storage for the larger machines. Large virtual address spaces will continue to be supported and, in many cases, multiple address space capability will be required in the operating system to facilitate testing of new system and application software and conversion of older systems.

2.4.1.3 1987-1992

The trends discussed in the previous section will continue to maturity.

Except for those few users still programming in assembly language, all of the operating systems' visible interfaces will have been subsumed by the higher levels of system software such as the job scheduling systems, language compilers, database management systems, query languages, etc.

The operating system itself will have been reduced to its basic millisecond-to-millisecond resource management functions as well as basic error detection, correction, and recovery functions. Additional resources beyond those currently envisioned will have to be managed. Microcode supporting the database management systems and the code generated by the various compilers will be dynamically moved in and out of the larger processors under the control of the basic operating system. In addition, the handling of messages on the high-speed bus which connects the various parts of the modular bus-oriented processors (which will predominate during this period) will also be controlled by the operating system, enabling a coordinated control over the various modules which make up a computer system. The operating system itself will be distributed among various modules with at least a communications, coordination, and low level resource management function existing in each hardware module. The supervisory processor in these modular bus-oriented systems will contain the job scheduling, security, and error recovery and restart functions of the software which have been removed from the operating system.

By 1987, the operating system will lease for between 10 and 20 percent of the lease costs of its associated processor and memory.

The operating system during this period will also be the supervisor of the security mechanism. Such functions as address space protection and protection of the other objects such as programs, read-only data, and specific system facilities will be handled by the microcode (and hardware) on a millisecond-to-millisecond basis. However, the major security mechanisms such as access permission to the system as a whole will be implemented in higher levels of system software coordinated by a single centralized security mechanism which may be resident in the supervisory processor. The supervisory processor will provide the necessary controls to isolate the applications from each other, and the application processors will control end-user access, authorization, and sharing.

Operator interaction with the system during normal operations will tend to revolve mainly around the mounting and dismounting of removable printing and storage media. Other interactions will only take place in the event of very unusual situations such as the failure of one or more of the major components of the system. It is likely during this period that most operators, except those involved with physical media, will not be in the computer area but located in an operations control center from which the operations of the system (including its communication facilities) are controlled.

The easy-to-use operating systems for small computers will have incorporated facilities for multi-media file management by 1992. [STAFF COMMENT 9]

2.4.1.4 1992-1997

Most computer systems will be integral parts of larger systems which handle distributed processing and office automation functions as well as complex telecommunication functions. The operating systems of the computer will be completely self-sufficient, operating the computer systems without requirement for human intervention except for management-level priority setting. The portions of the operating system within the computers will be almost completely implemented in microcode of one type or another and will be completely controlled by the computer manufacturer. The remaining software will function primarily at the supervisory level. Any modifications to the operating system will probably void any system warranties.

The functions of the operating system will not have noticeably changed from those described for the 1987-1992 time period. There will perhaps be more error recovery and system performance optimization features included in the operating system itself or supported by functions provided by the operating system.

Most manufacturers will have migrated all of the current operating systems into a single operating system per manufacturer with the differences in facilities available in various size systems being handled by different versions of the support software (see sections 2.4.2 and 2.4.3). The operating system will have been effectively rebundled into the cost of the system, although specific charges will continue to be made for other software. The basic hardware will be inoperable without the operating system and will be so complex that generation of a user's own operating system will be impossible except under some extremely unusual sets of circumstances.

During this period integrated operating systems for small systems will develop automatic image and voice handling facilities as well as data and text handling facilities.

2.4.2 Support Software

This section deals with that level of software which resides between the operating system and the application level programs (either user-generated or manufacturer-supplied). Some examples of support software are the file management systems, the database management systems, the communications management systems, and the transaction process monitors which exist in most general-purpose computer systems.

2.4.2.1 State-of-the-Art

At the present time, manufacturers offer a wide variety of system support software which is usually separately priced and can be classified in one of the following categories:

- o database management system,
- o data dictionary,
- o communications monitor,
- o transaction processing monitor,
- o remote and local job entry systems,
- o job scheduling system,
- o input/output scheduling system,
- o file management system,
- o time sharing monitor,
- o resource utilization measurement and optimization system, and
- o storage hierarchy control system.

One major manufacturer has already announced that future enhancements to its system software will be made in these support systems rather than in the basic operating system itself. Other manufacturers are expected to follow this lead within the next few years as operating system technology matures.

As can be seen from the above list, most of the user interfaces with the system software are with one or more of these packages. The major interfaces with the operating system (the control language and the operating system supervisor calls) have disappeared or are quickly disappearing from the user's view, being masked by the high-level language and by the control languages of these various support systems.

2.4.2.2 1982-1987

We expect the systems at this level of software to become more distinct and more comprehensive. Their functionality will increase as functions are removed from the operating system and their separate identities will become more firmly established. Groupings of the systems will become more pronounced as the functionality of the various special-purpose processors is increased. We foresee three major groupings of systems:

- macro resource management,
- storage management (including database management), and
- communications management.

The macro resource management systems will be the outgrowth of today's job scheduling, job entry, spooling, resource measurement and optimization, and error recovery and restart routines. These systems will have overall management control of the entire computer system (and generally will run in the supervisory processor). The user interfaces to these systems will be greatly simplified so that only a few statements on the user's part will be required to let the system know what is desired. The interfaces between these systems and system operators will be made more comprehensive, providing an integrated interface for control of the overall operation of the system. For those manufacturers who now support several operating systems for the same product line, the differences between the external interfaces of those systems will begin to disappear as the management level interfaces become more compatible among the various systems.

Each of the packages will be separately priced, with several levels of functionality being available for various size machines. Major enhancements during this period will be in the area of security control and restart and recovery features. These functions will be integrated in such a way that the system will be able to be restarted or recover in the event of any type of failure with little operator intervention and with little or no loss of data. When the system recovers it will inform the affected users of the loss of any transactions and the corresponding need to re-enter these transactions. The major progress in this area will take place toward the end of the period, with the larger systems having complete facilities first.

The storage management class of routines will include such functions as storage hierarchy management, file management, data dictionary, and database management. Each of these routines will be separately priced and separately identified, though they will form a type of hierarchy in that the database management system will not operate without file management routines, but the data dictionary will be useful with conventional files as well as databases.

Extract database managers will also appear for the support of analytic, decision support, and modeling activities. Automatically fed from operational databases, these will generally contain summarized data from multiple sources and will emphasize versatility of access and retrieval.

Database management systems will become more capable. They will be able to be integrated into distributed database systems in which data is either geographically segmented or, if there is any data duplication, centrally updated. One of the database management systems will periodically update the master copy of each class of data, and other systems will contain zero or more slave copies of the same data. (In distributed systems, use of the "memo posting" technique of performing updates on-line in a tentative or memo form, with designated control processors doing the final updating of the master copy periodically, will be the most prevalent technique.)

The current debate about the various database management models (hierarchical, network, or relational) has begun to subside and will have virtually disappeared by the late 1980's. At least the large database management systems will be able to give the appearance and effect of using all three of these models using a single (invisible) data storage model. Text, voice, and graphic data will be associated with the databases of computational data with unique query, search, and report generation routines to account for the special characteristics of the information being processed. Associative processors will also be extensively used to manipulate text as well as computational data. This type of processor will be mainly used on larger systems and will be made invisible to the end-user. However, logical distinctions among data models (as distinct from physical models) are application-related and will continue to exist.

Storage hierarchy software control systems will appear as uniquely identifiable software packages. These system will control the movement of data between the various levels of the storage hierarchy and will have the capability of automatically making duplicate copies of data for backup and recovery purposes. In those systems where software database management systems are utilized, it is likely that the parts of the database management system which have to do with the physical storage of data will be included in the storage hierarchy software systems, as will the physical data handling parts of file management systems.

The communications-oriented software (which includes transaction processing monitors, time sharing monitors, and communication access methods) will become increasingly important. All manufacturers will have developed and implemented their own network architectures. These architectures will all be somewhat incompatible, especially at the more application-dependent levels of the architecture, but will all be able to communicate with each other via ANSI X.25-like protocols. Special hardware-software protocol translators may be required for communication between processors of different manufacturers. (Even though basic communication will be possible, the manufacturers will still exercise lock-in through the higher levels of the software. Throughout the period, inter-manufacturer CPU communication will generally only be possible in a master-slave mode in which one of the processors appears to the other as a relatively simple remote terminal.)

Within one manufacturer's product line, however, complex, highly functional communications between various types of processors and terminals in complex network configurations will be possible. The software will absorb more of the network management, diagnosis, and error recovery functions which must now be handled either manually or with specialized equipment. Many different types of equipment will be able to be connected to these networks: primarily text processing and data processing equipment at the beginning, expanding toward the end of the period to include various types of image and voice processing equipment.

The system software will be able to handle non-coded transmission (in digital form) leading to electronic mail-like services in which facsimiles of documents which contain not only text but graphics will be transmitted, stored, and retrieved easily without special user application programs. Toward the end of the period, communication software routines will be able to handle digitized voice messages. However, it is expected that this type of software with its associated hardware will still be relatively expensive and will not become generally available until the mid-to-late 1980's.

As operating systems become more self-adaptive and on-line computing becomes the dominant mode, the nature and operation of measurement software tools will slowly change. Emphasis will be placed on terminal response time measurements and measurements of machine peak loading conditions (memory utilization, paging rates, I/O rates, etc.). Continuous on-line data gathering systems combined with batch summarization systems will gradually be phased out. They will be replaced by on-demand routines which are automatically triggered by heavy use of specific central resources, combined with batch data reduction routines which produce output in more useable forms such as graphs, charts, and histograms.

2.4.2.3 1987-1992

The appearance of specialized processors will accentuate the division of the various system software functions. By this time, the communications functions will run only in the communication processor; the file processing functions will run only in the storage hierarchy processor, the task management functions will be distributed among the various application processors; and only the overall system monitoring and configuring functions will remain central.

In general, trained communications and database management operational personnel will not be required except for the largest, most complex systems where high levels of system tuning are required to meet the users' needs. The system software will handle all normal operational tasks and integrated system recovery from any single hardware or software failure (including a power failure which shuts down the entire system). This software will permit the deployment of large distributed systems where trained personnel exist only at one or at most a few central sites to handle the overall system management functions. End-users will be expected to have little training in data processing and will be shielded from the intricacies of complex operational modes by the automatic operational capabilities of the system software and the higher level application software (discussed in section 2.4.2.4).

Hardware assists will become common for database management systems, thereby simplifying the software and firmware required, reducing the size of the systems, and generally increasing their functionality. By the end of the period, data dictionaries will be mandatory for almost all systems, and very few database management systems will operate without an integral data dictionary.

The user will be shielded from the actual data model used in the database, and will deal with the operational or extract database at the query language level (discussed in section 2.4.2.4) whose software will have evolved from today's query languages and report generation routines. **[STAFF COMMENT 10]**

A new level of system control software will be coming into use during this period. It will control a distributed information processing system which is geographically dispersed (possibly on a world-wide basis) but operates as a single unit. Overall system control and resource balancing will be controlled from a single location. Independent operation of the various parts of the system will be possible in the case of a failure or when integrated system operation is not required. The setting of the policies which govern the operation of the overall system will still be a human function requiring personnel trained in system management but not necessarily in the technological details of computer system operation. Once these policies are set and communicated to the system control software, the system will be able to carry out normal control functions on a day-to-day basis without human intervention.

Error recovery facilities will also be automatic, including the shifting of work from a failed processor to another processor in the network. However, human pre-planning in distributing backup copies of programs and databases will be required prior to any failure, so that backup systems will have appropriate resources.

Automatic connection to a vendor's diagnostic facilities will be possible for failed equipment. The vendor's highly trained maintenance personnel will be alerted automatically and will remotely diagnose the failure in order to provide rapid repair. However, users' security requirements will sometimes force them to forego this service.

The communications network resources available to the system will be treated in much the same way as the processing resources of the system, permitting dynamic reallocation of network resources as required. Digitized voice, facsimile, video, as well as coded data and text will be handled simultaneously on the same network facilities. All terminals will be able to communicate with all application subsystems, with the system software handling whatever high level protocol translations are required to make the communication possible. (Naturally, when the terminal is not physically able to handle a given type of data, this will not be possible.) Multiple levels of encryption will be possible, handled automatically by the security control software in those systems where this is deemed important.

Distributed processing networks using equipment from different manufacturers will be possible. However, none of the participating manufacturers will take responsibility for the entire network. Careful coordination by the user of the applications on the different manufacturers' types of equipment will be required in order to insure the appropriate levels of compatibility. Most differences will be in the higher level application-dependent functions; vendor-provided application software will be developed in such a way as to try to lock a user into the vendor's product line.

Measurement software tools will continue their slow evolution. Increasing amounts of self-measurement software and firmware will be built into the operating system and control processors of the bus oriented systems which are expected to be common during this period. This code will build an historical database of usage information which will be analyzed periodically by batch data reduction routines. These routines will utilize the historical data not only to report on current resource utilization but also to generate forecasts of additional resource requirements.

Multiple options for most types of software will be offered, each independently priced. For many systems the price of software is apt to be greater than 50 percent of the price of the hardware.

2.4.2.4 1992-1997

By this time we expect data processing functions to be only one aspect of the processing that an integrated information processing system is expected to perform. The intermediate levels of system software will have grown enormously in size and complexity.

Completely automated operation of world-wide, distributed information processing systems will be made possible by this intermediate level of system software. Adaptive or experience-based load balancing, error recovery, and system optimization will be standard features of most manufacturers' software. The software catalogs of the period will approximate today's hardware catalogs.

There will be large functional systems of software with multiple optional features, all at separate prices. Users will choose specific options for their systems, and the software systems will be pre-integrated, tested, and installed by the manufacturer. System generation, as we now know it, will have almost disappeared.

Information processing networks which contain equipment and software from multiple vendors will be common. The manufacturers will still attempt various types of lock-in by providing special features for their subsystems, but the emphasis will have changed from attempting to lock a user into an entire system of a single vendors' equipment to maximizing the amount of the vendors' equipment that is contained within the subsystems making it up. In other words, interconnection of products from multiple vendors will generally be possible, but functional integration of products in subsystems will remain more vendor-specific.

Limited amounts of artificial intelligence will be built into the software by this time. It will primarily be used to handle the dynamic load balancing and optimization of the system as well as some of the more important security aspects of the system. Also, extract databases for support of modeling, decision support, and analytic activities are likely to be able to adapt to individual users' interests and needs, evolving into knowledge-based personal assistants.

2.4.3 Application Level Software

This section deals with the level of software that directly interfaces with the end-user and carries out the processing requested by the end-user. The software at this level can be divided into two categories: tools used by the end-user to carry out various processing activities and application software for repetitive, production use prepared either by the end-users or by trained programmers.

2.4.3.1 State-of-the-Art

At the present time, we are observing the maturation of the procedure-oriented software development tools which have been slowly evolving over the past thirty years. The number of general-purpose programming languages in widespread use has been stabilizing with few, if any, completely new languages being introduced in the past five years. In addition to the standard languages (COBOL, BASIC, and FORTRAN) such languages as PL/1, APL, and Pascal (and C, for systems programming) are slowly replacing assembly language programming.

A new language, Ada (Ada is a trademark of the Department of Defense), may replace some of the other general-purpose languages for major system development projects due to its structuring and code reusability capabilities. Ada is under the control of the U.S. Department of Defense and is primarily intended for use in real time applications as a part of weapons systems. It remains to be seen whether it will become a major factor for the non-real time general-purpose market. Slow growth is also likely in the use of very high-level languages for system specification and design, especially in the context of large projects.

All these languages are undergoing a slow, steady evolution which is making them more powerful and more easily able to handle interactive and non-coded data environments. The slow rate of evolution is primarily due to the large volume of pre-existing applications which have been written in the major languages and which form a base for additional applications, and the large investment which has been made by the industry in training professionals to be proficient in these major languages. These factors represent investments worth billions of dollars. This enormous investment actively discourages development of any new techniques which would tend to reduce its value. [STAFF COMMENT 11]

At the same time that procedurally-oriented software development tools have been maturing, the number and variety of non-procedural tools has been increasing at an accelerating rate. Most of these new tools are either data-oriented or are oriented toward the new man-machine interfaces such as graphic terminals which have started to appear in great numbers over the past several years. The major classes of tools which have appeared include:

- report generators,
- query languages,
- graphic language processors, and
- specialized non-procedural analysis tools.

All of these tools are interactively oriented and many are intended for users who are non-data processing trained professionals. Most of these tools are (to at least an extent) menu-oriented, with many assists for the users and with protections against the user unintentionally doing harm to essential system data or even to their own programs and databases.

Increasingly adaptable application packages are spreading at an accelerating rate as a substitute for in-house programming.

2.4.3.2 1982-1987

During the early to mid-1980's, only relatively minor enhancements are expected in the various procedure-oriented, high level languages which are offered by the various manufacturers. Most development effort will be expended on completing the conversion of the various language systems from batch orientation to full interactive orientation. In addition, new constructs will be implemented which permit the languages to make full use of the various database and communications-oriented facilities being developed at the support software level. Such enhancements as the automatic transcription of the data schemas into the data divisions of COBOL programs and the common definitions of FORTRAN programs are expected toward the end of the period.

A great deal of progress is expected to be made in this period in non-procedural tools. Special emphasis will be placed on making use of some of the new non-keyboard input/output mechanisms which will be marketed during this period. Such devices as color graphic CRTs, touch video screens, light pens, voice input/output mechanisms, and specialized handwriting recognition mechanisms will be employed. Most of the tools will be menu-oriented and will have, at least as an option, the ability to output data in the form of scatter charts, bar charts, histograms, etc., whenever that makes sense. The use of color graphic output will become increasingly important during the period, with most tools having the ability to effectively utilize color graphic CRTs by the end of the period.

As figure 2.12 indicates, we believe that application software is rapidly evolving from "do your own" toward vendor-supplied, user-tailorable packages. Progress varies widely between application areas, with the most mature, such as general ledger and payroll, being the areas most completely penetrated. During the entire forecast period application software packages will continue to evolve in generality and adaptability within existing applications as well as into new applications.

Progress will be slower on such often-mentioned items as artificial intelligence-based problem solvers and generalized computer-assisted instruction programs. Such progress as has been made has been isolated in particular application or problem areas. For instance, some applications of specialized "knowledge-based" artificial intelligence systems have been demonstrated in medical diagnosis, mineral exploration, and oil well log processing. We expect this pattern to continue, i.e., slow evolution in the application of artificial intelligence to discrete problems, with a body of experience being collected that can gradually be generalized.

2.4.3.3 1987-1992

The development of specialized processors in the database management and image processing areas will lead to major enhancements in query languages and image processing languages. During this period relatively untrained users will become able to generate graphics (line charts, animation, maps, histograms, etc.) on-line with the system in full color. Due to the speed and power of the processors, multiple analyses and many variations of hypotheses will be able to be tested very rapidly with the results of tests shown in easily interpreted form. As analysts accumulate results and preferred procedures in their systems, knowledge-based services of a more general nature will begin to emerge.

Some of the animation and three-dimensional image generation techniques being developed in the early 1980's will begin to be utilized to provide analysts with three-dimensional simulations of the behavior of models or images under investigation. Using these techniques (available primarily on specialized systems), long range trends can be dynamically portrayed on maps and moving three-dimensional views of objects being investigated can be readily shown.

Major enhancements are expected to occur in the program development process. High-level specification languages are likely to see increasing use. For both conventional and new languages, such as Pascal and Ada, tools which assist programmers will be perfected. These will include compilers, syntax checkers, text editors, project management tools, databases, and data dictionaries in a single integrated environment. These tools will operate with multiple programming languages (in fact, they will allow systems of programs to be developed using multiple languages but all based on the same definitions of the data to be used). Constraints of the interoperability will constrain the languages used however. Each organization will implement only the languages it uses in its programming environment. By 1987, such environments will be implemented on large machines with individual programmer terminals connected to them via high-level network protocols. By 1992, the large machines will only be used to store the major databases, and the programmers will each have their own small systems which will carry out most, if not all, of the processing in an individualized fashion independent of the main system. This will allow geographically dispersed programming teams to cooperate on the development of complex data processing software without the need for large timesharing networks to support the effort. Information analysts will use similar tools; there will be little distinction between them and programmers. Languages suitable for the development of knowledge-based systems, generally derived from the LISP family, will probably become richer and more diverse as more development effort is applied to such systems. **[STAFF COMMENT 12]**

Much written documentation and instructional material will have been replaced by audio-visual material stored on video discs. Programming documentation will be presented in the form of structured walk-throughs of the program. User manuals will be in the form of tutorial audio-visual programs stored on video discs. They will be keyed to the data dictionaries used to support the program development and supported by other cross-referencing tools. Most software will be provided with multiple levels of on-line assistance routines, which will allow complex software systems to be utilized by non-data processing trained personnel both for clerical-like functions and for decision support-type functions.

Various types of office automation will also be provided by these systems including electronic message handling with messages in voice, audio-visual, facsimile, and coded digital form. Decision support systems will be common, allowing many types of models to be developed and exercised by non-trained personnel. The modeling languages will be interactively oriented and experience with them will contribute to the development of knowledge-based systems.

2.4.3.4 1992-1997

During this period the use of higher level procedure-oriented languages will begin to decrease as the evolved query languages and other database support routines substitute for some large data processing programs. Limited voice input/output for commands will be common, and the ability to handle various types of graphic data processing, image processing, and character recognition hardware will reduce the use of keyboards at the man-machine interface.

By the early 1990's fairly generalized types of knowledge-based systems are likely to become commercially important. Each type will apply only to a specific kind of analysis, modeling, or forecasting to which a limited range of expert knowledge can be applied. By 1997, however, ten years or more of software development will have been invested in some of the application areas and substantial progress is likely. Specialized hardware (such as that presently existing to optimize the processing of INTERLISP) may well be used and interfaces with individually personalized extract databases will be intimate. To the degree that these knowledge-based systems are specialized hardware-software complexes, they will probably appear as modules interoperating with more conventional types of modules in the bus-oriented systems which will, by then, be in universal use.

Most other enhancements which will occur during the early 1990's are likely to be incremental. During the 1980's many new capabilities will have been introduced and it will probably be necessary to spend several years thereafter perfecting them by eliminating bugs, integrating them, making them easier to use and more general, and implementing them on smaller machines at lower cost. Some artificial intelligence capabilities may appear for the large database processors that will have become firmly a part of computer architectures of the 1980's. Beyond this, the new features of the 1990's will evolve from the commercially important applications of the time which are not easily predicted now.

Figure 2.13 summarizes the forecasts in this section, showing the advances expected in large and small operating systems, support software, and application-level software.

	1982–1987	1987–1992	1992–1997
General-Purpose Operating Systems	Decomposition into separately priced, partly microcoded modules	High level command language, improved security	Integration into multi-medium modules, common throughout product lines
Small Computer Operating Systems	Integral, semi-automatic systems for data and text processing	Multi-media file management added	Image, voice processing added
Support Software	Separation into distinct modular functions	Hardware-software modules for distributed data-base management	Automatic multi-media network control, adaptation to users
Application Software	Rapid growth of Pascal family; data orientation to COBOL; package evolution	Programmer workbenches, interactive dialogs; package evolution	Multi-media direct interaction with end users; graphics; knowledge-based systems

1982 1987 1992 1997

Source: Arthur D. Little, Inc.

FIGURE 2.13 SUMMARY OF SOFTWARE FORECASTS

3. CHANGES IN THE INFORMATION INDUSTRY AND MARKET

3.1 INTRODUCTION

The purpose of this chapter is to review the changes that are occurring in the structure of the information processing industry and in the markets it serves because they affect the availability of the products and systems which are forecast in chapter 4.

Table 3.1 lists the major segments of the U.S. information processing market and the revenues provided by each segment. All of these segments are changing. (Our report of September 1981 used a broader definition of the industry and the data reported therein is therefore not comparable to the data presented here. The earlier report included worldwide rather than just U.S. revenues and also encompassed all categories of publishing. We believe the new, limited definition is more meaningful.)

TABLE 3.1

THE PRESENT INFORMATION PROCESSING MARKET

Segment	Approximate 1981 Revenue from U.S. Market
Data Processing	$41 billion (1)
Mainframes	
Minicomputers	
Peripheral equipment and terminals	
Personal computers	
Software and services	
Media and supplies	
Office Equipment	$10 billion (1)
Typewriters and word processors	
Copiers	
Micro-image systems	
Facsimile equipment	
Communications	$69 billion (2)
Telephone service	
Telex and data services	
Customer premise equipment	
Information Dissemination	$30 billion (2)
Newspaper and magazine publishing	
TV and radio broadcasting	

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(1) Arthur D. Little, Inc., estimates.
(2) 1982 U.S. Industrial Outlook, Bureau of Industrial Economics, U.S. Department of Commerce.

Distinctions among segments of the data processing market are becoming obscure as the products become more modular at all levels, incoporating microprocessors and minicomputers with embedded software as components in larger, distributed systems.

The office equipment market segments are becoming indistinguishable from segments of the data processing market. Microprocessors make typewriters into word processors which, in turn, have become capable of functioning as data terminals and personal computers. Copiers and facsimile machines are becoming digitally controlled and capable of functioning as computer and word processor peripheral printers. Even micro-image systems are subject to change and integration with other market segments through the incorporation of video disc technology.

The segments of the communications market are changing as voice and data services become intermixed in all-digital networks and as local area nets evolve to interconnect the computer-based office and data processing modules.

The information dissemination market is changing as attempts are made to exploit new computer-based technology, both to take advantage of new market opportunities and to counter new competition in traditional markets.

The consumer electronics market is changing as digital electronics begins to pervade entertainment products and as the markets for home computers and information services grow.

All of these market changes are accompanied by changes in the structure of the industries providing the products and services. Companies are merging, diversifying, innovating, and entering new markets. This chapter reviews the forcing factors that serve to both accelerate and constrain these structural changes (section 3.2), reviews the pattern of recent acquisitions and joint ventures (section 3.3), and presents an overall forecast of the emerging structure of the information processing industry (section 3.4).

3.2 FORCING FACTORS

We believe the following are the major factors causing the changes. We discuss first the factors tending to accelerate structural changes, then the factors tending to slow the rate of change.

3.2.1 Improving Technologies

The structural changes in the industry are mainly technology-driven. New markets have developed for previously unknown products (word processors, digital watches, pocket calculators, games). Other products have declined in cost so greatly that entirely new markets for them have emerged. The market for personal computers in the home, for example, is a new one made possible by the dramatically declining cost of microprocessors and memory.

Microprocessors have increasingly been used instead of custom-designed integrated circuits in order to save design cost. Modern data terminals, word processors, and personal computers all use standard microprocessors. Software for a wide variety of applications is available from many sources for these standard microprocessors. As a result, modern data terminals, word processors, and personal computers are all capable of running the same wide variety of application programs. Thus, these three product categories are merging and manufacturers offering any one of the three must also offer the other two whether they want to or not. Similar, standard microprocessors are appearing in consumer products as well (video games, video recording systems) and the consumer electronics market appears to be converging with the other three. Apparently, an industry offering modular information appliances for individual use is emerging, with only degrees of difference existing between information appliances intended for consumer, corporate, small business, or professional use.

Consumer products are substantially less expensive then those designed for business and professional use. This price differentiation is likely to widen during the next few years as the business desktop computers and office automation products become more capable and (on the average) more costly. In the late 1980's and 1990's, however, the continuing decline in component costs should cause the price gap between consumer information appliances and business and professional ones to narrow.

Technology sometimes advances faster than markets do. As of 1982, for example, data terminals, word processors, and personal computers are likely to be operated by different people within an office. Roles must change before market demand for multi-function devices exceeds that for single-function ones. Changes in the roles of office workers are in fact occurring, however, and by the late 1980's, the multi-function devices are likely to dominate.

Improving technology is also forcing changes in the component and subsystem manufacturing structure of the information processing industry. Semiconductor line widths are becoming narrower and device densities on chips are increasing; as they do, the levels of skill and equipment required to design and manufacture competitive semiconductor products increase. Packing densities are increasing in magnetic disk devices of all sizes, with a similar result. Low-speed printers have become mass-production items with very large production volumes required to attain competitive manufacturing cost. Non-impact technologies are becoming more prevalent among high-speed printers; design and manufacturing of non-impact printers require a broader mix of skills than for impact printers. The effect of all these changes is the same:

- System manufacturers tend to give up efforts to design and manufacture components and specialized subsystems themselves, and turn to outside suppliers.

- The outside suppliers tend to merge and consolidate in order to obtain economies of scale.

- The resulting large suppliers of components and subsystems seek worldwide markets in order to obtain adequate production volumes.

3.2.2 Improving Communications Services

Past cost and technical limitations of high-speed communications have constrained the growth of data and text processing networks, and virtually precluded both high-speed image networks (teleconferencing and facsimile) and interactive consumer services. This cost is dropping for several reasons. Most importantly, common carrier organizations all over the world are upgrading their facilities, a process that will take many more years. Progress has been accelerated for specific services by incorporating more hardware and software "intelligence" in the devices that send and receive data. For example, facsimile transmission becomes faster as more advanced bandwidth compression logic is incorporated in transmitters and receivers, and both TV and FM broadcast stations can transmit data in unused time slots to suitably equipped receivers. Finally, satellite communications can provide point-to-point high volume communications via synchronous satellites. The costs are still high but will come down as volumes rise. Numerous large corporations now use satellite communications occasionally or regularly and a small, but growing, number of homes are equipped with satellite receivers. Cable television services for consumers are widespread and they are likely to come into existence for businesses as well.

Often buildings must be rewired at considerable cost to provide for the local distribution of new communications services. The cost of this rewiring will not decline, and will inhibit users' adoption of the new services.

The slow but steady improvement in communications services is fostering the expansion of markets for many kinds of information processing modules. It is also having structural effects in the information processing industry as the producers of material (newspaper publishers and the like) attempt to take advantage of the new services.

3.2.3 Economic and Demographic Pressures

The structure of the information processing industry will be affected by many external factors: political, social, economic, and demographic. It is not within the scope of this report to examine them in any depth. A few stand out so clearly, however, that it is appropriate to mention them.

Productivity improvement is more than just a popular phrase; it is a firm objective of the managements of many organizations. Assuming that inflation will continue, they believe that competitive survival depends on improving operational productivity.

- For energy and raw materials, many anticipate shortages as well as soaring prices. As a result the use of computer-based systems to manage inventories and resource usage ever more tightly is of continuing interest.

- For manufacturing labor, many anticipate increasing benefit and employment commitment costs in addition to salary inflation. This has led to a surge of interest in robotics and increasingly automated manufacturing processes, and the appearance of an additional group of companies in the information processing field.

- For engineers and product developers (including computer programmers), the provision of dedicated computer power and appropriate software tools is expected not only to improve productivity by reducing elapsed time, but to produce more optimized designs.

- For clerical labor, the present poor level of productivity combines with inflationary expectations to enhance interest in office automation.

Indirect inflationary effects are also felt, exemplified by the increasing cost and decreasing convenience of air travel. There are signs that this will lead to increased use of teleconferencing (which provides another instance of previously uninvolved firms being brought into information processing--in this case, providers of TV and audio equipment).

Combining with these economic perceptions is a widespread understanding that the declining birth rate will result in a scarcity of younger workers. Young people (ages 15-24) provide the main pool of new entrants into the labor force. In 1976, there were 51.6 million young people in the U.S., consituting 24 percent of the population. In 1987, there will be 37.2 million of them, 16 percent of the population (3). The situation in most other developed countries will be similar.

The effect of these factors has been to produce a positive attitude in the minds of managers toward the use of information processing to improve productivity. This attitude is very widespread in all developed countries and increases the market opportunities for competitive firms.

3.2.4 Cost and Profit Pressures

Costs have risen at an unprecedented rate for companies in the information processing industry. The rate of price increase has been constrained by competitive forces and, as a result, selective profit declines have occurred that have structural implications.

Capital investments in new manufacturing facilities are required as technologies improve. Each new level of technology requires more expensive equipment than the level before and the cost of money is high.

People costs for software development, marketing, customer support, and maintenance are increasing faster than the average rate of salary inflation. (As the industry grows, competition for a slower-growing pool of trained people forces salaries up.) Since these people-related components of product cost have increased relative to hardware cost, product costs have become more tied to the rate of salary inflation.

The cost of money required to finance all manufacturers' growing working capital needs remains extremely high. The prevalence of leasing in the information industry intensifies the problem.

Manufacturers should be expected to pass these costs on to customers in the usual inflationary cycle and, in part, they have. However, competitive pressures have constrained the rate of price increase. These pressures have been intensified by the fact that large companies outside the information processing industry with strong financial resources have been moving into high-growth areas of the industry directly or through subsidiaries. Anxious to establish strong market positions, they price products aggressively.

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(3) Bureau of the Census. Projections of the Population of the United States, July 1977.

Companies are introducing new products and policies designed to alleviate this profit pressure. Briefly summarized, the major directions are these:

- *Separate pricing of software.* A separately priced software product offers the vendor potentially high profits if it becomes widely adopted, since software has a negligible unit manufacturing cost. However, such profits develop only gradually over time. Any new software product must be attractive enough to induce users to abandon presently used software and to undergo the necessary conversion. Software revenues to the industry have nevertheless been rising steadily. Arthur D. Little, Inc. estimates that U.S. computer users paid $3 billion for separately priced software in 1981 and that payments will rise to between $9 billion and $11 billion in 1986, and to between $22 billion and $25 billion in 1991. (4)

- *More maintainable machines.* All manufacturers, facing escalating costs for field engineering personnel and for financing parts inventories, have been designing their new products to have a low probability of failure and to permit more rapid repair. Recent concentration on more maintainable designs has produced encouraging results for all manufacturers. For example, the contract maintenance price for one recently announced computer is about 80 percent below the corresponding charge for computers of similar power announced previously. When the industry's installed base becomes made up largely of these more maintainable machines, maintenance cost pressures should be greatly alleviated. However, a number of years will pass before a large part of the present installed base is turned over.

- *Remote customer support.* Several manufacturers are establishing customer support centers both to diagnose equipment malfunctions and to solve software problems. Working by telephone, instead of by in-person calls, support center technical staffs should be able to spend substantially less time (and reduce escalating travel costs) per problem solved. However, new procedures must be developed, hardware and software must be redesigned in some instances, and customer doubts about the efficacy of remote service must be overcome. Early reports on the success of remote customer support centers are encouraging; these centers are likely to become a significant factor in reducing cost pressures.

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(4) World Markets for Information Processing Products to 1991, Arthur D. Little, Inc., April 1982.

- *New marketing structures.* Associated with the effort to provide expert services remotely is a widespread experimentation with ways of reducing marketing costs. Some products that used to be sold directly by their manufacturers via personal calls on prospective customers are now offered through electronic equipment distributors. Retail outlets of several kinds are also being used, including:

  - independent computer dealers that handle competing manufacturers' products,
  - manufacturer-owned retail stores,
  - office supply stores, and
  - established department store chains.

  The general hope is that use of retail-type distribution will lower both the time and expertise required to make a sale. However, the manufacturers' experiments with retail distribution are not proving uniformly successful and presumably further evolution will occur. Whatever the outcome, the structure of the industry will be permanently affected.

- *New system designs.* The trend is away from unique circuit designs and toward the use of multiple microprocessors in information appliances of all kinds. Incorporating modular designs with module functions determined by combinations of microcode and software that change only slowly, these machines should be more economical to manufacture, easier for the customer to use, and less costly to maintain.

3.2.5 Evolving Interconnect Standards

Almost every aspect of the information processing industry is becoming more communications-oriented:

- Computer users shift from batch processing to transaction processing, installing terminal networks as they do.
- Word processing users shift to inter-office mail, often via hierarchical computer networks.
- Information dissemination is evolving from mail and broadcast media to selective, on-line networks wherever market demand justifies it.
- Teleconferencing and communicating copiers are beginning to appear.

Large computer users already wish to integrate their application-specific networks, to add intra-company mail services, and generally to use remote terminals for multiple purposes. They are impeded by the lack of interconnect standards at every level from the basic message protocol to the network control aspects of the mainframe access methods. Most interconnect standards in existing networks are proprietary ones of limited generality developed in the past by large computer manufacturers. The smaller manufacturers have had to adopt the network architecture standards of the large ones, thereby limiting available markets and failing to meet the users' demands for a broad range of interoperability. Therefore, the rate of the market's growth is constrained by the lack of vendor-independent interconnect standards, particularly when media are to be intermixed. Fortunately, the rate of acceptance of interconnect standards is accelerating, as discussed below, but the process is necessarily slow.

The efforts of ICST are helping to produce this accelerated acceptance within the Federal government and to a lesser degree, globally. These efforts are important, because even a little progress toward standardization can produce major long-term savings for users.

3.2.6 Regulation and Litigation

Regulation (particularly of communications carriers) and litigation (particularly in the form of antitrust lawsuits in the U.S.) have been significant forces throughout the history of the information industry, and they will continue to be. However, a significant change in the direction of the forces seems to be taking place.

Regulation of the broadcast spectrum and of telephone interconnect standards through voluntary multi-national bodies and national legislation has been nearly universal for many years and, by and large, it has worked very well. The process of standard-setting is slow, but unsatisfactory standards rarely either make it through the process or live long, and the process tends to ensure general conformance to the standards when they become effective. Versions of this standard-setting process are being applied with increasing success to video and other wide-band communications, as well as to interchange of encoded information (data, text imagery). In the past, some equipment manufacturers and national governments have felt that proprietary network architectures and interface standards produced competitive advantage. This attitude seems to have largely disappeared: all parties appear to believe that manufacturer-independent information interchange standards are in the general interest. Every computer manufacturer in the world, for example, now supports the ISO data interchange standards to some degree. (The larger manufacturers facing conversion costs and potential market share losses tend to show less enthusiasm than the smaller ones, but all are officially supportive.) At the same time, the parties involved in the standards setting process (including in the U.S., the ANSI committees and ICST) appear to have become more proficient.

We conclude that in the standards area, semi-voluntary regulation of the information industry is an increasingly positive and significant force. Its structural effects will be to foster both multi-national competition among suppliers of products and services, and overall market growth.

Regulation of the behavior of companies by national governments may prove a more negative force. In the U.S., the trend is toward less regulation of large companies. However, implementation of this trend (e.g., the deregulation of part of AT&T and changes in the Foreign Corrupt Practices Act) tends to be slow. Other potentially restrictive forces may be increasing; for example, a legitimate national security concern about the transfer of sensitive technology. If poorly conceived, restrictions on technology transfer can do more to harm the national interest than to help it. In some other countries (e.g., France, Mexico), constraints on the presence of foreign competitors are on the rise. Past experience in countries where such constraints have been strong (e.g., India, Brazil) shows that they can impede the development of local information industries and markets, although there may be offsetting social gains. National constraints on foreign competition that are intelligently applied, permitting economically viable joint ventures, regional manufacturing, and the like, may serve national interests adequately without suppressing desirable growth. Economic nationalism is on the rise, however, and there can be no certainty that it will always be intelligently applied.

The focus of litigation in the information industries also appears to be changing. The popularity of antitrust lawsuits in the U.S. (mainly against IBM and AT&T) is waning, partly because the litigants rarely won anything and partly because of changes in both the popular and government attitudes, although an EEC investigation of IBM policies continues. Not much litigation of this sort exists outside the U.S. nor does any appear to be coming.

The trend of new litigation seems to be toward alleged theft of trade secrets. The recent allegations that Hitachi and Mitsubishi obtained IBM trade secrets illegally are only exceptionally visible examples of a growing trend. The main problem is that no existing laws adequately protect proprietary rights in software, and copying of software (especially for personal computers) is rising as software markets grow.

In summary, increases in economic nationalism and in litigation about trade secrets may impede growth and structural change in the industry; improvements in standards and reductions in useless antitrust lawsuits should foster it. It is difficult to foresee the exact results, but some of the probable structural effects are considered below.

3.3 RECENT ACQUISITIONS AND JOINT VENTURES

There has for several years been a steady flow of mergers, acquisitions and joint ventures among the competitors in the information industry; study of this pattern provides further indications of the trends.

Table 3.2 lists some examples of affiliations among companies in the industry that have occurred during the last three years. There have been many more, including literally hundreds involving small software firms and service bureaus. The examples in the table have been selected both because large companies are involved and also to illustrate the diversity of the affiliations.

There are three distinct patterns among these affiliations: concentration, product diversification and geographic diversification.

Concentration is occurring as smaller companies sell out to larger ones. Faced by the increased intensity of competition from large mainframe manufacturers and by profit pressures, many highly competent companies have accepted acquisition (Memorex, Four-Phase Systems, Logicon, SEL, Centronics, Calma).

This concentration is particularly prevalent in the software and data services subindustry, with the large firms steadily buying out smaller ones. Automatic Data Processing has recently acquired five smaller firms, Electronic Data Systems four, Informatics four, and several others two each. General Electric has acquired seven, most (along with the acquisition of Calma) apparently associated with an expansion of its position in manufacturing automation. (These are not listed in table 3.2 because they are too numerous.)

Continued economic pressures are likely to cause concentration to continue. However, the number of new starts may equal or exceed the acquisitions as new firms spring up in the more novel areas of the industry such as robotics and personal computers. The process of company formation, growth, and acquisition is likely to continue.

Product diversification is occurring as large, cash-rich companies in mature industries seek to participate through acquisition in the growth opportunities described earlier. Bell & Howell and Eastman Kodak are recent examples. The pace of such diversification appears to have slowed somewhat, however; some earlier acquirers (Exxon, Citicorp) have recently been selling some of their acquired companies, apparently finding that growth and profitability can be elusive in this industry.

An area of product diversification that continues to be particularly active is the affiliation between information producers and distributors: both diversify through mutual association. Twelve of the affiliations listed in table 3.2

involve combinations of publishing firms and communications companies, four of them quite recent (Dow Jones, MCI, United Telecommunications, Ziff). Conventional paper-based distribution media (newspapers, magazines, books) are becoming less profitable except in selected markets. At the same time, electronic distribution systems including broadcast, cable TV, and interactive computer networks require multi-media capabilities and the largest possible libraries of attractive material in order to justify their large capital investments.

TABLE 3.2

EXAMPLES OF AFFILIATIONS

Agfa-Gevaert - Compugraphics
Amdahl - Tran Communications
American Broadcasting - MacMillan
American Express - Warner Cable (Warner Communications)
Bell & Howell - Applied Dynamics
Burroughs - Redactron; Context; System Development; Memorex
CAP Gemini - DASD Corp.
Computer Peripherals (Control Data, NCR, ICL) - Centronics
Continental Telephone - Executone; World Cablevision; American Satellite
Datapoint - nine foreign distributors
Dow Jones - Continental Cablevision
Dun & Bradstreet - National CSS
Eastman Kodak - Atex
Fujitsu - TRW, ICL
GE - Intersil, Calma
GTE - Telenet
Gould-SEL - DeAnza
Harris - Farinon, Logicon
IBM - British Aerospace
MCI - WUI
McDonnell Douglas Automation - Microdata, Excalibur, Bradford National
McGraw Hill - DRI
Motorola - Four-Phase Systems
NCR - Comten; Applied Digital Data
Olivetti - Compuscan, Data Terminal Systems, Hermes (Swiss)
Racal Electronics - Redac
Rockwell - Wescom
Schlumberger - Fairchild, Applicon, Manufacturing Data Systems
Sun Co. - Communications Group
Thomson-CSF - Fourtune Systems
Time - American Telephone & Communications
United Telecommunications - North Supply; United Computing; Insurance Systems
Viacom International - Sonderling Broadcasting
Wang Laboratories - Computer Resources
Ziff - Wharton Econometric Associates

Examples of geographic diversification have been particularly numerous recently.

The majority of instances involve European firms establishing or adding to their United States positions via acquisition (Olivetti, CAP Gemini, Raca , Schlumberger, Thomson-CSF, Agfa-Gevaert).

In several cases (Wang, IBM, Datapoint), however, the geographic diversification is the other way; U.S. companies are either acquiring European outlets or setting up joint ventures in new market areas.

Japanese companies have rarely been involved recently in acquisitions or joint ventures in the U.S., although there have been several instances of joint marketing organizations being established between small U.S. companies and large Japanese ones in order to market the U.S. firms' products in Asia. Each of the large Japanese companies selling information processing products already has a U.S. presence, either under its own name or with a partner. The Japanese companies are now attempting to increase their exports to the U.S. market through their existing outlets, in most cases selling subsystems (printers, storage devices, CRT display assemblies) to U.S. system manufacturers for incorporation in their products. The Japanese companies have also been active recently in establishing joint ventures in other countries (e.g., Fujitsu-ICL in the U.K.).

Japanese products have to date demonstrated excellent hardware price-performance and reliability, but Japanese software (while reliable) has tended to lag behind the state-of-the-art. If Japanese software innovation accelerates (as the fifth-generation project would require, for example), Japanese products will become still more competitive worldwide.

3.4 THE EMERGING STRUCTURE OF THE INFORMATION INDUSTRY

Taking these trends in inter-company affiliations as indicators, and considering the forcing factors discussed in section 3.2, the future structure of the information industry should include the following:

1. A new expanded set of retail-type organizations providing workstation hardware and software interchangeably to consumers, professionals and business people.

2. Expanded roles for network service providers offering extensive hardware and software as well as communications services.

3. A relatively diminished role for corporate system providers (the traditional mainframe computer manu-

facturers). The companies involved will be trying to increase their participation in the first two areas.

4. A rich substructure of specialists offering hardware subsystems, software, and data services to these three kinds of end-user providers (and sometimes directly to end-users via specialty channels and mail order). The hardware subsystem suppliers will generally be multi-national; the software and data service suppliers will generally work within national language and cultural frameworks.

The end-user (as an employee and as a private consumer) is the eventual consumer of all the information industry's products and services. This has always been true, but usually in an indirect way. An employee has usually interacted with his or her employer's data processing function via paper reports, with little or no influence over their content. As a consumer, the employee has purchased electronic products and telephone service, each of which serves a single purpose.

In the future, most end-users will have information appliances ("multifunction workstations" in business versions, "information centers" in consumer versions) that will combine standard and individualized capabilities. The individualized capabilities will include optional processing modules and peripheral devices on the hardware side and programs, public reference information, and consumer software products (entertainment, instructional, etc.) on the software side. There will be many of these, provided both by small, specialized companies and by large, full-line ones. The end-user will procure these individualized capabilities from a retail distribution structure not exactly like any that exists today, since business, professional, and consumer products and their support requirements will overlap in an unprecedented way. The need for a new form of retail structure will impede the appearance of new capabilities in workstations.

Suppliers of individualized software and hardware modules appropriate to this new retail distribution structure will offer their products directly through it. The largest suppliers may own some or all of their retail outlets, though the competitive desirability of handling many suppliers' products should favor independent retail organizations. Similarly, some of the suppliers will be able to deal directly with the end-user via specialty stores or direct mail.

This user workstation market will be almost completely multinational, since interface standards will be in general use and since relatively few of the modules will be specific to languages or cultures.

In their roles as employees, the end-users will usually be provided with the corporate standard products and services. These will include both basic workstation hardware which is compliant with the corporate interface standards, the corporate communications services, the corporate databases, and the corporate processing programs as well as with services not suitable for incorporation in the workstation. In many instances the corporation will also provide most or all of the individualized modules desired by the end-users. Many organizations will want the corporate people to have virtually complete control in order to constrain proliferation, guarantee interoperability, verify vendor credibility, foster sharing, and obtain quantity discounts. Therefore, it will be necessary for the larger retail distribution firms to have corporate marketing capabilities as well as retail outlets.

Vendors of corporate systems will sell their products to the corporate information system managers, as they do now. These products will (in general) include the larger general- and special-purpose computers, communications controllers, large peripheral devices, and corporate application, data and system management software. The corporate system vendors will also (of course) provide end-user workstations in competition with the specialized vendors. The existence of standard interfaces will render the competition more or less equal, but the corporate system vendors will attempt to sell interdependent high-level software for their systems that requires the customer to buy both their large computers and their end-user workstations. The smaller module vendors will have to respond and, therefore, will still face a degree of need to be plug-compatible.

The number of corporate system vendors will be far fewer than the number of vendors of workstations and optional modules. In fact, for many years they will probably be essentially the same companies as the thirteen or so now offering general-purpose computers worldwide. Considerations of capital and marketing cost will tend to keep this part of the industry concentrated. The present general-purpose computer manufacturers will be favored because of their existing bases of corporate customers who are committed to their software. All the corporate system vendors will attempt to expand their scope geographically, but change will be slow because of national government impediments to the entry of foreigners and because corporate customers everywhere will be reluctant to abandon existing software investments. The requirement for backward compatibility will impede the appearance of new functions in corporate systems.

Network service providers will provide communications services to both corporate and individual customers. They will often own the information utilities and producers of the information they distribute. At present, their number is increasing as specialized carriers come into existence, but in the long range we think relatively few will survive, each offering a wider variety of services than today's common carriers do. This eventual convergence will come about for two reasons. First, the large capital investment required to build any independent network service will force smaller competitors to combine with larger ones, as happened in the past among telephone companies. Second, in most of the world, national governments own the domestic common carriers, and as new network services become viable they are likely to be offered preferentially by the national services. These factors will impede the appearance of new technology in network services.

Each of these three types of organizations will have to offer an increasingly broad line of hardware and software products if they are to remain competitive. Each will also have to invest in software interfaces so that new products can interoperate with its existing and past products. Each, therefore, will be less and less able to sustain internal development and manufacture of all the subsystems and minor hardware and software products it requires. The trend at all levels will be for the marketing-oriented vendors to procure subsystems from specialists. Intense competition in the sale of standardized subsystems to broad-line marketers will foster continued improvements in the cost-effectiveness of information processing products, but will impede rapid changes in their capabilities and functions.

As noted earlier, the hardware subsystem market is already nearly independent of national boundaries. Continuation of the trend should lead to a true worldwide industry though local marketers' names may often appear on the finished systems for nationalistic reasons. The vendors of software and data services are more likely to operate nationally, however, because their products must reflect national languages, cultures, and business patterns. **[STAFF COMMENT 13]**

If the information industry evolves along these lines, there will be winners and losers.

Major winners will be the companies (whoever they may be) that prove most competent in selling user workstations to the overlapping corporate, professional, and consumer markets of the future.

The relatively few surviving network service providers will also be major winners, sharing a much larger market among them and often owning the production sources of the material they distribute. (Regulation may moderate the degree of ownership.)

Both winners and losers will continue to be found among the software and data service providers, the user workstation providers, and the subsystem specialists. Their markets are heterogeneous and often subject to rapid technological change. Many of them will also be at the mercy of the larger system and marketing firms on which they depend. The more successful ones will probably be the best ones at establishing worldwide economies of scale (i.e., those most clever at exploiting nationalistic forces in their interests), and those most successful at integrating forward and controlling their own marketing.

Losers will be the conventional corporate system providers, beset with increasing competition from above and below, made increasingly vulnerable by the spread of interface standards, and constrained in their ability to change by their customers' software investments. The companies which have been primarily corporate system providers are already moving vigorously into the other areas. Time will tell whether they, the incumbents, or new companies prevail. One thing is certain, however: the profile of any "information industry giant" of the year 2000 will be far different from what it was in 1970.

4. FORECASTS OF FUTURE PRODUCTS AND SYSTEMS

This chapter integrates the forecasts of underlying technologies and industry change into forecasts of the overall nature of future information processing products and systems. Many specific products (e.g., input/output equipment, mass storage systems) were covered in chapter 2; the forecasts are not repeated here. The emphasis in this section is on general-purpose systems of the future and their implications for users.

Since systems evolve incrementally rather than in discrete steps, point forecasts are not provided as they were in chapter 2. However, ranges of expected availability dates are provided.

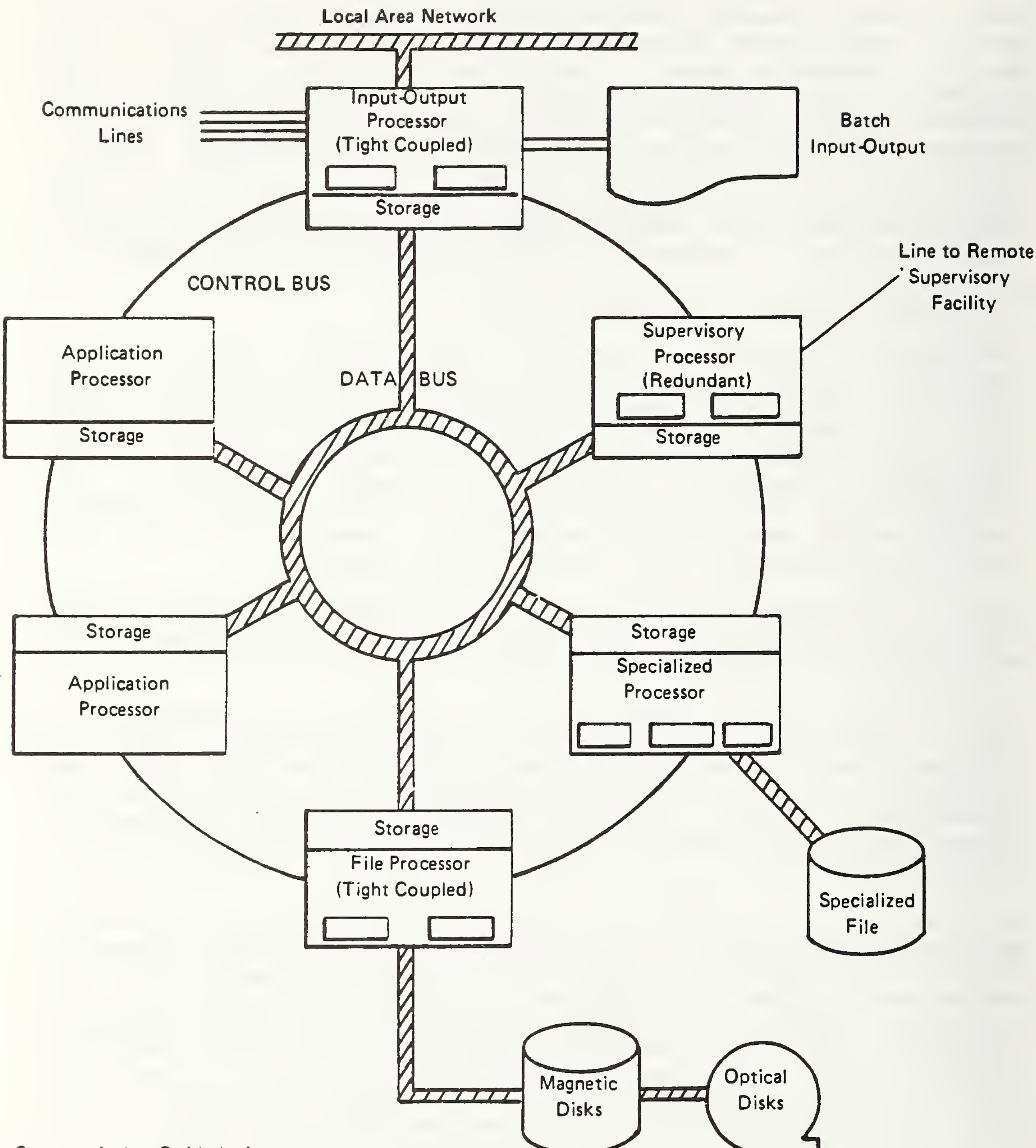
4.1 GENERAL-PURPOSE COMPUTER SYSTEMS

Centralized processing methods using large general-purpose computers (batch, time sharing transaction processing) are expected to remain the most cost-effective for many applications. This is especially true in those applications where a large number of trained data processing personnel is required to support the system, either for software development and maintenance, or for the purely operational aspects of the system. Systems which require the use of large complex databases are especially appropriate for a centralized approach.

Figure 4.1 depicts the organization of a general-purpose computer system of the 1987-1992 time frame. We anticipate that it will incorporate the following principles:

It will be bus-oriented (a bus is a wide-band communications line). There will probably be two physically separate buses in most systems: a very high-speed bus for transmitting data and programs (probably a fiber optic bundle) and a control bus for transmitting brief control messages between processors. (Separation of the buses is desirable to ensure rapid delivery of control messages.)

It will contain multiple computers dedicated to specific functions of the system. The specific function of each processor (e.g., the programming language to be processed) will usually be determined by alterable microcode. The major types of functional processors likely to be used are described below. The processors will communicate with one another via messages and data blocks in standard form, regardless of whether the content is a program, data, or digitized text, imagery, or voice. They will also be able to back up one another in the event of the failure of any other one (fail-soft). Fault tolerance will be available both at the system level and at the device and component level to accommodate the increasing demands of the users for high system availability. Users will be able to choose degrees of increased cost to obtain increased levels of fault tolerance.



Source: Arthur D. Little, Inc.

FIGURE 4.1 FUTURE GENERAL-PURPOSE COMPUTER SYSTEM

There will no longer be a single, shared storage serving all the processors. Instead, storage will be dedicated to individual processors or clusters of processors, with the file processor as the central resource. Clustered processors (similar to today's tightly coupled multiprocessors) will be used where multiple processors should work on a single data stream, either to provide failure tolerance or to dynamically share workloads of varying priorities. Such clustered processors will typically be used for input/output processing, for file processing, and for specialized computing tasks where arrays of processors can be applied in parallel to tasks like image manipulation.

Under two special circumstances clustered processors will be able to share one another's storage:

- *When one processor wants to exchange data with another.* It will send a control message saying "read a block from location X in my storage" or "write your results into location Y in my storage" (virtual locations will be provided, not absolute).

- *When the supervisory processor detects a failure in a functional processor.* In this case the supervisory processor will direct another of the functional processors to read the contents of the failed one's storage so that the system's work may continue.

Such a modular computer system will be able to employ widely varying sets of functional processors.

A supervisory processor will always be present. Containing redundant small computers (to guard against internal failure), it will be responsible for measuring overall system performance and for sensing and diagnosing equipment failures. It will be capable of assigning processor and storage modules to overall classes of work in accordance with assigned priorities, and of reassigning them in the event of failure. It will have its own modest input/output capability for receiving and displaying supervisory information and for communicating with a remote diagnostic facility, when necessary.

An input/output processor will also be present. Its size and nature will vary widely, but it will usually be capable of controlling the attached communications lines and of switching messages between terminals (whether they contain data, text, or digitized imagery or voice). It will also control local batch input/output devices such as line printers.

A file processor will usually be present. (Many types of these will be available by 1987.) In small systems, it may be a single, small processor doing no more than managing a hierarchy of devices to protect data against loss. In large systems, the file processor will be performing access control, management, and retrieval functions. It will be redundant for reliability, and may incorporate associative and/or parallel processing capabilities for searching and retrieval. File processors will be available to handle data, text, and digitized imagery and voice (probably varying in design depending on the primary media. For example, a file processor for rapidly changing data is likely to employ magnetic media, while a file processor for less-rapidly changing but more voluminous text and imagery is likely to employ video discs).

Application processors will be dedicated to particular computational environments. Some will be oriented to direct execution of programs written in specific programming languages (COBOL, FORTRAN, etc.). Others will support problem-oriented languages (e.g., for simulation). Others will be oriented toward running the software of obsolete machines. The orientation of each application processor will be specified by alterable microcode. Within limits the processor orientations can be changed via the supervisory processor to meet changing workloads.

Specialized processors of various kinds are available now and will proliferate in the 1987-1992 period. These will include array and vector processors as well, perhaps, as others designed for voice and pattern recognition. Beyond 1992, specially designed hardware-software complexes for interactive knowledge-based decision support systems may form another class of specialized processors. Most supercomputers will also fall into the specialized processor class. They are discussed in chapter 2.

The constraints discussed in chapter 3 limit the computer manufacturers' rates of evolution toward modular systems of this type. Manufacturers of systems that have relatively limited capability and little or no requirement to be backward-compatible are able to innovate most freely. As a result, modern minicomputers and personal computers approach this architecture now, though not all the functional processor types have been developed yet. Larger general-purpose systems are evolving more slowly. Performance requirements are more stringent and the manufacturers are constrained by software investments (their own and their users') in older systems. Some of the latest types of distributed office systems also approach this architecture. By 1992 virtually all information systems will employ this type of architecture; in the interim the systems available will be of a transitional nature.

4.2 DISTRIBUTED PROCESSING SYSTEMS

The evolution of distributed processing systems is more constrained by market and industry readiness than by technical factors. Most distributed data processing systems are justified on the basis of a single application, which is generally transaction processing-oriented and dependent upon several geographically distributed but functionally integrated databases. It is generally found that once a distributed processing system is installed other local applications are added to the systems to increase the effectiveness of local management or operations. However, the successful distributed processing systems generally retain centralized control of the databases and programs which are essential to the operation of the main application for which the system was justified. Prudent users perform a careful analysis of each application on a case-by-case basis to determine whether an application is more effectively implemented using a distributed data processing solution, a batch centralized solultion, or an on-line transaction processing centralized solution. In a given user's network, there will be two main constraints governing the extent to which distributed processing is employed.

- *File Management and Control*

  If a file record is to be altered by more than one party, carefully-developed systems to assure identity of records at multiple locations must be employed. The distribution of files in a processing network must therefore be planned and controlled on a central basis if integrity is to be assured, along with the distribution of data entry, inquiry and processing functions associated with the files. Other constraints on file distribution include access control, security, backup and recoverability.

- *Non-standard Communication Protocols*

  There is no standard set of rules (protocols) by which information processing devices communicate with one another. Computer and office system manufacturers promote their own, hoping for competitive advantage. Users, forced to proceed with the implementation of network systems, develop their own protocols or select those of particular manufacturers. It seems likely that the ISO standards for message communication will eventually become universally supported, however. The work of ICST is an important influence in refining the ISO protocols and accelerating their acceptance.

Fortunately, conversions between specified protocols can often be made in the sending and receiving devices (or controllers) by combinations of software and microcode provided for the purpose. Equipment manufacturers are often willing to provide this protocol conversion software on contract or in their self-interest (some small manufacturers offer protocol converters now). If a restricted set of versatile protocols can be established for a given network as it evolves, and if the information processing devices used in it are equipped with enough processing power to perform protocol conversions, it seems likely that any individual future protocol support need can be met by retrofitting contracted software into the devices. No generalized, open-ended protocol converters are envisioned, however.

The primary local resource in distributed processing systems is the microprocessor-based system (MBS), implemented variously as a local controller for peripheral equipment and communications lines and as a personal or desktop computer. When the MBS is implemented as a local controller it often has multiple microprocessors, some of them dedicated to protocol conversions. When the MBS is implemented as a desktop computer it has one or two microprocessors.

The 1982 version of the MBS has an 8-bit microprocessor and 16,000 to 512,000 bytes of semiconductor high-speed storage. The 1982 version has a memory cycle time probably no faster than 1.8 microseconds, because it must use the cheapest circuits; by 1985, however, 200 nanoseconds will be standard for even the lowest-cost memory circuits. The program residence storage in 1982 is provided by one or two 5" diskette drives or their equivalent with 100,000 to 500,000 bytes, and magnetic bubble storage is sometimes used.

By 1983, 16-bit microprocessors will be standard in the MBS. Eight-bit systems will continue to be produced in high volume but the premier "state-of-the-art" systems will contain the 16-bit processors. Memory will range from 64,000 bytes to 1,000,000 bytes. The new smaller 5 1/4" Winchester hard disks and the 3" micro-floppy disks will have begun to replace the 5" floppy disk as the main mass storage medium.

By 1987, the 16-bit microprocessor will have been superseded in many cases by the 32-bit microprocessor. The MBS will have approximately three times the 1982 throughput. Its cost will have declined substantially even though its power and size have increased; we estimate that this processor with its memory and keyboard should cost in the $300-$700 range. The MBS will be of a generalized design suited to a broad range of applications, but the use of a particular MBS will be usually dedicated to a single functional area.

The struggle for operating system supremacy should continue throughout the period. We expect that there will be no clear winner with a dominant market share. None of the manufacturer-supplied systems is likely to spread beyond its specific systems. The three families of MBS operating systems (Pascal, UNIX, and CP/M) are each expected to find a specific niche in which it is widely used. In general we expect the CP/M family to remain the operating system with the largest market share. The other two operating systems are, however, expected to have a larger share of the market than they presently do.

All MBS operating systems are expected to evolve slowly over the period. The single user versions are expected to remain the most popular. A foreground-background capability is also expected to become standard for all systems. Some competition from the older microcomputer operating systems on the 16-bit based machines can also be expected.

For some applications, where multiple user capability and a high degree of resource sharing is warranted, a virtual memory operating system is likely to be available, permitting the simultaneous handling of inquiry and data entry tasks as well as simple batch processing. Spooled input/output will also be feasible. By the end of the period, multiple-indexed files and network capabilities for database reference are likely to be provided.

MBS's will be programmable at three levels. End-users will work with easy-to-use packages such as VISICALC for data processing, and others for text composition, critiquing and editing, graphics, and private database management. Programmers will work with appropriate languages such as Pascal or C. And when a large number of MBS's are required to work efficiently on a single corporate application, assembly language programming will be possible. The ability to run instruction sets developed earlier will facilitate this, as well as the availability of a wide range of specialized peripherals. Such use of MBS's in corporate applications will often be inhibited by security considerations, however; MBS's are not likely to become as secure as larger, central systems.

The incorporation of these powerful microprocessors into distributed processing systems will provide increased functionality through graphics capabilities, protocol conversions, and character set translations; will enhance security operations; will support user-assist software; and will improve maintenance features through self-diagnostics and error recovery. Improved maintainability will permit user installation and service which will reduce maintenance costs from vendors.

During the 1987-1992 period the use of 32-bit microprocessors will be standardized for all types of MBS's. Main memory sizes will grow to the millions of bytes range with 512K bytes probably being the minimum memory size for MBS's used in a business (as opposed to home or personal) context. Mass storage will continue to be largely on hard magnetic disk although most systems will be capable of accepting read-only video disc input for program loading, document storage, and audio-visual TV-like training aids.

All systems will be equipped for synchronous as well as asynchronous communications via telephone lines, and high-speed local area networks. Built-in emulation capabilities (supplied via a separate smaller microprocessor) will allow an MBS to be connected into a mainframe network. The MBS will be an integral part of the network with software in the mainframe and the MBS cooperating. This arrangement will permit full access to the mainframe operational and extract databases as well as to local databases.

The operating system battle will be refocused as the 16-bit to 32-bit processor transition occurs. The older MBS operating systems will face new competition from the evolved minicomputer and smaller mainframe operating systems. The strength of these latter systems will be their ability to offer utilization of the wealth of application software (both commercially and locally produced) which has been generated over the years. No generally accepted standards for operating systems are expected to be adopted.

During 1992-1997 the basic word length of the main microprocessor in the MBS is expected to stablize at 32 bits. The primary area of change will be in the number and functionality of the microprocessors which are contained in a specific MBS, as the typical MBS approaches the general-purpose architecture depicted in figure 4.1. Single chip-based floating-point processors, graphic processors, database processors, and communications processors are expected to be common in MBS's of the period.

It is likely that some fallout of the "fifth-generation" computer research will become apparent in MBS's of this period. Non-keyboard interfaces will be common and some specialized knowledge-based subsystems are likely to be widely used in specific decision support applications.

The software of the period will be a natural evolution of the software previously used. A sufficient inventory of vendor- and user-supplied software will exist to create a situation similar to that seen in the mainframe market today. Evolution of capabilities will be an absolute requirement. Software enhancements will have to be made without disturbing the user or application software interface in order to insure that software and behavioral investments are not prematurely obsoleted.

By the 1990's, then, extremely high levels of computing power will exist in the microprocessor-based systems used in distributed processing systems, and they will have a broad range of capabilities. However, user and market constraints (primarily existing software, file management, and interoperability considerations) will slow down the evolution of users' systems and the acceptance rate of new products. By the 1990's a suitable retail distribution and service structure should have evolved for MBS's so its lack will no longer be a constraint, but this is not certain. The same considerations apply to the evolution of office systems, discussed below. [STAFF COMMENTS 14 and 15]

4.3 OFFICE SYSTEMS

Office systems are (from the technical viewpoint) supersets of distributed processing systems. Both incorporate microprocessor-based systems. Both serve end-users in their local offices. However, while distributed processing systems deal primarily with data processing, office systems deal equally with text, voice and image material as well as data. As noted above, many users of distributed data processing systems are already adding limited text and image processing capabilities to them. The objective of this section is to forecast the evolution of the full multi-media office systems.

Industry structural constraints are slowing the development of office systems. As chapter 3 points out, multi-media office systems require the skills formerly resident in four separate industry sectors: a vendor competent in any one of the four must acquire the skills of the other three before it can offer mature multi-media systems. It also appears that the modular information appliances for end-users in business and professional applications are converging with those in consumer electronics (a fifth sector), requiring a new form of retail distribution system. (Interactive video disc systems for corporate applications have their roots in consumer video disc technology, for example, but it seems unlikely that present consumer-oriented retailers can develop or sell such systems.)

We believe office systems will evolve gradually, then, with single-medium systems (e.g., word processors) slowly combining functions with other single-media systems (e.g., for distributed data processing and telephone service). Our observations of user behavior support this view: most organizations can assimilate only small office system changes without disrupting their activities, and require about one year between changes.

The following forecast reflects this view. During the 1982-1987 period user MBS's will be able to perform data entry and inquiry, text processing, stand-alone computing and image processing equally well via the use of optional software packages. There will be several limitations to their capabilities, however.

- Image processing applications will be limited by the display resolution available at a moderate price. Management graphics will be adequately supported, but graphic art and photographic quality will not be approached.

- The general-purpose user interfaces will not be ideal for all applications. Special, higher-cost devices will continue to be needed for production text processing (especially for printed reports), for engineering design, for photographic analysis, etc.

- The most important limitation will be availability of data. Appropriate extract databases to intervene between operational databases and personal computers used for decision support will evolve only slowly, and unstructured office file processors will only begin to be generally cost-effective toward the end of the period. Available files will usually be limited to rigorously indexed data and text files prepared from terminals within the user's system.

Electronic mail for structured, telex-like messages will become widespread, and this more than any other single factor will lead to proliferation of low-cost, lightly used terminals. With this proliferation will come a rapid spread of voice/data PABX's (local communications switches.)

Anticipated changes in the functionality of PABX's between 1982 and 1987 can be summarized as the integration of voice, data and office automation functions, thereby making the PABX an information-handling switch. While the user market is sure to evolve toward demands for increased functionality, we believe that implementation of such system features will happen gradually over the period, driven by developing user requirements and product feature availability. In 1982-1983 end-users who buy integrated voice/data switches are usually implementing them to carry voice only. The 1983-1984 time period will be characterized by the addition of the data handling capabilities and automated building management functions. However, it will not be before 1986-1987 that the full capability of the switch will be utilized through the implementation of office automation functions such as the transmission facility for communicating word processors, communicating laser printers, voice, voice and text messaging systems, etc.

At the present time the future is unclear as to the relative positions of Local Area Networks (LAN's) and PABX's in the emerging markets. Both types of systems aim to fill many of the same needs. PABX's have major advantages in the area of voice communication. LAN's have major advantages in the area of multimedia data communications especially where high bandwidth data is required. Both will be able to access files or central computers equally well through gateways at which security controls can be applied. (LAN's and PABX's themselves can do little to provide security.)

The situation is muddied even further by the ability of the large information processing system suppliers to develop and market both types of systems as integrated peripherals in an overall information processing system. The resulting confusion is leading to rapid technological development, but is impeding market development.

Confusion over interface standards for LAN's is also impeding market development. Hopefully a satisfactory set of standards for at least the low data-rate LAN's will be generally accepted by about 1985. A forcing factor will be increasing usage of communicating laser printers to share printing and copying functions within the office, and to serve as high-speed image transmitters and receivers. Their high data rates will require many users to consider installing LAN's of limited scope.

Other types of office systems will be evolving independently during this period.

Rapid growth is expected for interactive video disc based systems for training applications and for many information retrieval applications involving centrally prepared databases. (The lower-cost systems of this period will generally be read-only ones of limited graphic resolution.) These systems are expected to require only limited, dedicated communications facilities.

Teleconferencing systems will evolve slowly, constrained by the carriers' ability to offer wide-band communications at acceptable cost. Some users will invest in their own microwave and satellite facilities, and others will make do with increasingly capable versions of teleconferencing equipment that can operate within the band-widths of the carriers' offerings. However, general use of teleconferencing will have to await low-cost, wide-band service. Early teleconference centers will usually be equipped with their own dedicated wide-band lines.

Telephone service will change little in the absence of continuous speech recognition technology, but the use of voice commands as an option for data and text processing systems will grow. Also, the proliferation of lightly used terminals and voice/data PABX's will lead to incorporation of the telephone instrument into the housing of the general-purpose terminal. (Some early versions of these combined instruments are already being delivered.)

Some useful services such as telephone order entry and inquiry systems will also become possible, based on speech recognition technology.

During the 1987-1992 period user terminals (by then properly called multi-function workstations) will develop substantially improved capabilities, as noted in the above forecast of MBS's. They will offer high-resolution color graphic capabilities suitable for graphic arts work (though not approaching photographic quality). Accompanying software will lead to application of three-dimensional perspective views and animation to a widening spectrum of applications. The extensive computing and dedicated storage capacities of the workstations will lead many users to build libraries of their own information and procedural tools that evolve the workstations into "personal assistants."

In the 1987-1992 period, software evolution will permit integration of user workstations with the operational and extract databases residing on remote mainframes, and cost-effective office file processing systems ("file servers") should become generally usable.

Interactive text composition and edit software will become more versatile: it will also support electronic distribution of text and graphic material, and text critiquing by remotely-located individuals.

The market for integrated office systems will expand, and the focus of standards development will shift to the higher-level protocols for display and application level interoperability. Other shared local resources, especially communicating laser printers ("print servers"), will also become highly cost-effective and will see widespread use. These developments will increase the need for high-speed communications in the office.

Video disc technology should become widely used in office file servers. By the late 1980's local input capability (electronic cameras and converters for encoded material) should be in general use, and mixed-media storage systems (with document images in the form of bit streams, and encoded information in the form of file records) will be in delivery. The present rapid convergence of the data processing and office equipment industries will facilitate the evolution of these systems. These mixed-media storage systems will require high data rates for the communication of image material.

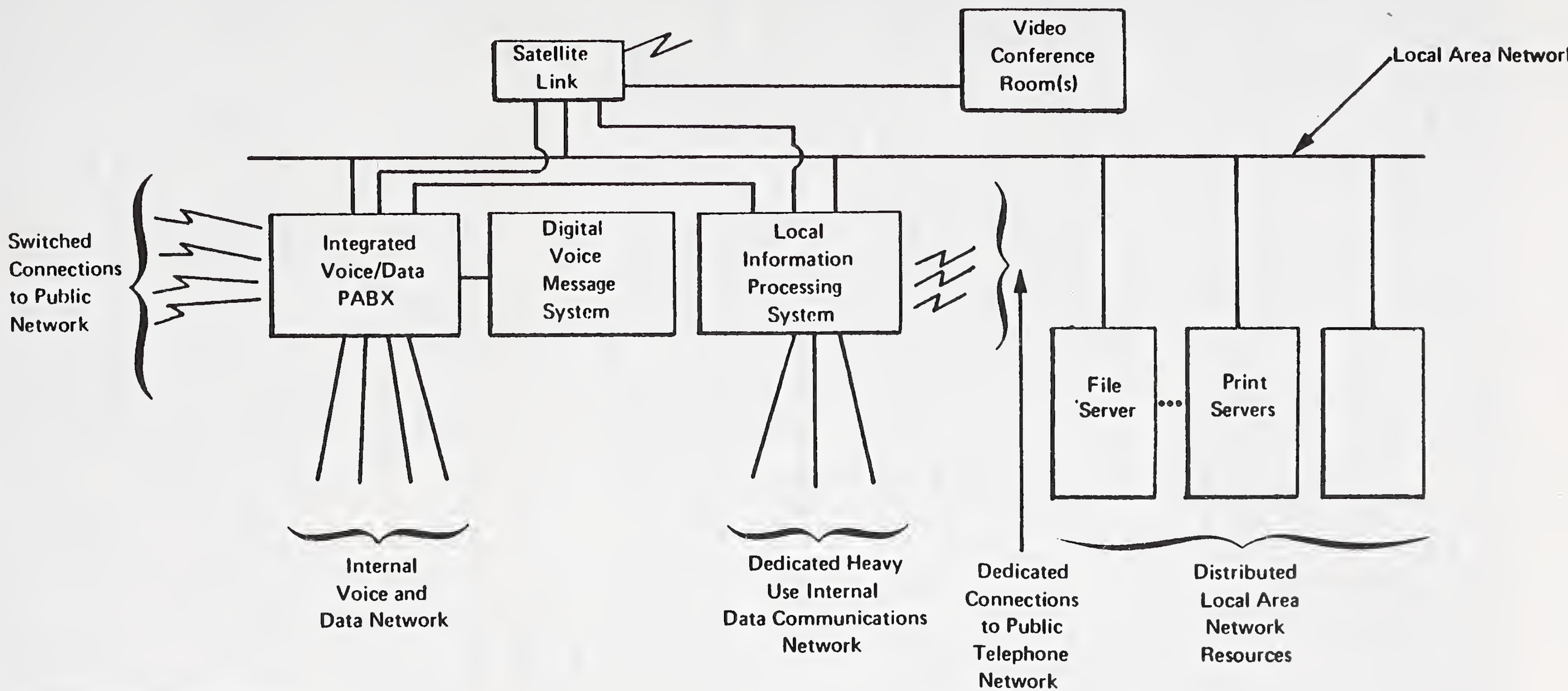
Teleconferencing using high-speed video links will expand, but will continue to be constrained by the communications carriers' ability to install cost-effective facilities for occasional public use. Video conference rooms will continue to be equipped with dedicated wide-band lines either to the user's satellite facility or to suitable wide-band public lines, where available.

Telephone service will continue to evolve slowly, in the absence of generally usable continuous speed recognition technology. Digital voice message systems may become commonplace, however, as well as the storage of digitized voice "documents" in the multi-media file servers.

Figure 4.2 depicts the local communications networks we believe will be installed by the large but cost-conscious user of 1987-1992. A LAN will be present to interconnect the local devices requiring high data rates (PABX, local data processing system, print and file servers, etc.). The LAN will also provide access to satellite or public wide-band lines. The individual users' telephones and lightly-used workstations, however, are likely to be connected to the local PABX using existing telephone lines (much less costly than wiring every telephone location to the LAN). Similarly, the heavily-used data and text processing terminals used for production applications are likely to be directly cabled to the local information processing system (as they are now), because switching is likely to impede their responsiveness without producing a cost reduction.

Office systems evolution in the 1992-1997 period is difficult to forecast because there are three embryonic areas in which rapid change could have nearly revolutionary effects.

1. *Continuous speech recognition* might come into general use in the mid-1990's. If it does, users' workstations, shared resources and (probably) local communications needs will be radically changed in ways that cannot be presently foreseen.



Source: Arthur D. Little, Inc.

FIGURE 4.2 LATE 1980's LOCAL COMMUNICATIONS NETWORK

2. *Knowledge-based systems* will be in use in the early 1990's. They will be combinations of workstations and files that provide personal assistance for various analytic and decision support activities. If these prove difficult to generalize from one user to another, and/or if they turn out to use conventional resources, they will not have a major impact on office systems. On the other hand, it is conceivable that a widespread market for knowledge-based systems could develop that involves shared usage of associative or fifth-generation super-computers, or some other kind of novel resource.

3. *Switched fiber optic communications service* will be installed by degrees by the communications carriers. If the rate of installation is slow (as it will be for the immediate future), office systems of the 1990's will still be constrained by the availability of low-cost, high-speed communications. The rate of installation could accelerate, however, given such factors as high demand, lower cost of capital and deregulation. If switched fiber optic communications service becomes generally available in metropolitan and high-density industrial areas by the mid-1990's, the users' office systems could change rapidly as they take advantage of switched video and very-high data rate services.

If none of these three embryonic areas evolves rapidly, the office systems in general use in the 1992-1997 period may still resemble that depicted in figure 4.2. Revolutionary change is possible in the 1990's, however, if rapid development occurs in one of these areas or in some other of equal importance which we have not foreseen.

4.4 SYSTEM COSTS

Most users' expenditures for information industry products and services will be rising steadily through the 1980's on a constant-dollar basis. This seems surprising, because our technology forecasts in chapter 2 show the costs of most hardware components dropping by a factor of ten or more. Our reasoning is:

- Office systems will generally be new ones with new, additional costs. Present budgets for telephone service, copiers, word processors, etc. are not nearly enough to pay for multi-media office network systems such as we depict in figure 4.2.

- Most users want to do more complex and sophisticated data processing. There will be more interactive processing (as opposed to batch); more "browsing" in databases; more incorporation of text, image and even voice processing into data processing systems.

- Most systems will be equipped with software tools that enable the user to obtain results directly without having to work through a professional programmer. Software tools that offer the required ease of use are becoming available, but they are inefficient; they use system resources poorly.

- Most users will be using more externally-provided application packages for their repetitive production applications. Payment for packages will therefore increase (through, hopefully, this increase will be more than offset by reduced in-house programming costs).

- The system vendors must be repaid for their increased personnel costs in marketing, support and software development. Some of these costs will be passed on as increased markups on hardware manufacturing cost, and some as separate charges for system programs (which are likely to approach 40 percent - 50 percent of hardware payments for many users). Where local retail outlets provide marketing and service, the increased cost to the user will appear in the retailer's markup.

Users wanting simpler systems (e.g., stand-alone word processors or batch processing computers) should find their costs reduced; electronic modules (computers and controllers) may cost as much as 75 percent less for a given level of throughput in the late 1980's than they do now (in constant dollars). We think relatively few users will want simple systems, though, because the ease-of-use features of the newer systems will reduce programming cost for small, interactive programs by at least 20 percent and as much as 80 percent in some cases. Cost of programmer salaries will matter much more to most users than cost of equipment.

In the 1990's, expenditures may stabilize or decline for many users.

- Electronic component costs will continue to decline.

- Many office and interactive data processing systems will mature: usage levels will stabilize and equipment procurements will be for replacement rather than new installation. Most users' batch data processing applications have already matured in this sense.

- Providers of communications network services will be offering integrated high-speed nets, consisting (at least in part) of switched optical fiber lines. Users should be able to combine their communication requirements in these nets, and take advantage of lower unit communication costs.

- The changes in the information industry structure discussed in chapter 3 should be largely complete in the 1990's. The surviving competitors should be the most efficient ones, and users should receive the benefit of continued competition among them.

On the other hand, we cannot clearly foresee the user costs associated with embryonic products that will not mature until the 1990's. These include supercomputers with novel architectures and processing power of one hundred thousand MFLOPS or more; systems incorporating "fifth-generation" characteristics, particularly continuous speech recognition; and knowledge-based systems operating as personal assistants for decision support and analysis. We cannot tell how successful these will be. It may be that some of these novel products will prove so broadly popular that increased user expenditures for them will offset the maturing of the new applications of the 1980's.

However this turns out, the modularity of future systems may have the greatest impact on cost-effectiveness. Systems employing modular computers in distributed networks need never be replaced as a whole. They will be able to evolve, module by module, as users' needs change and as new capabilities become available. After 1990 it should never be necessary to replace information processing systems in their entirety, as was the case with past computers: life cycles will become indefinitely long. For this to be true the users' programs and databases must be machine-independent, however, capable of being moved from one module to another. This subject is discussed further in the following section.

4.5 COMPATIBILITY AND TRANSPORTABILITY OF SOFTWARE

The manufacturers' microcoded processors will be able to run a variety of instruction sets (many already can). It will therefore be possible for users to obtain new processors that run programs written for obsolete machines. Such programs will not be able to take advantage of the new systems' capabilities (mass storage processors, special processors, etc.) because the old programs did not envision their existence. The users will therefore have two options.

- They can use the old programs as they are, obtaining a suitably microcoded new machine. Manufacturers will provide suitable microcodes for the most widely used obsolete machines; other microcodes can be obtained by special contract. The disadvantages of this approach are that all the deficiencies of the old programs remain, and that the new systems' capabilities are not exploited.

- They can convert their old programs. Poorly prepared programs, especially those written in assembly language with no discipline in regard to data typing and no use of structured programming rules, are impossible to convert short of a rewrite. A user organization with a set of poorly prepared programs must face an onerous conversion (or reimplementation) of its applications sooner or later.

Transportability of programs within a line of compatible modules will be relatively easy by 1985. Taking advantage of reduced electronic component costs, most manufacturers have recently introduced computers in the medium price range ($50,000-$200,000) that have enough capacity to run versions of the entire software environments developed for their large systems. User organizations are already responding by establishing standard configurations of hardware and system programs that can be distributed through their networks and operated by end-users unaware of their technical complexity. Transportability of software is enhanced by the use of such standard configurations. (It is easier to establish standards for new applications than to retrofit them to existing ones. In many organizations, old, non-standard applications will be running for many years alongside new ones, until it becomes cost-effective to replace the old application with a new one or a commercial package.)

Users would also like to be able to transport their programs across product lines; to be able to select among competitive vendors' offerings for every system module without having to reprogram existing software. Vendor independence cannot be guaranteed unless a comprehensive set of universally supported standards exists. Some standards exist now and others are slowly emerging, but the process is slow because of its inherent complexity and manufacturer self-interest.

After 1990, we believe standards will be supported by all vendors for a variety of data representations, languages (both procedural and interactive) and for communications at the message level. Vendors will remain non-standard in offering distributed application functions, however. For example, one vendor may offer a complete data capture, communication, storage and analysis function. This function may require the use of terminals, communications processors and file processors, each containing software uniquely prepared for the function and presuming the existence of the others. If the software can be protected as a trade secret, it would be difficult for a competitor to offer any one of the modules. A user desiring the application function would be effectively tied to its originator for all of the system modules needed. To avoid such a vendor lock-in a user must forego the use of such interdependent distributed applications.

Markets for high-speed services (e.g., broad-band local area networks and video teleconferencing) are in their infancy, and until functional requirements are clarified in the marketplace it is difficult to forecast the development of standards. However, we believe that the satisfactory standards for high-speed services can be derived from standards that will already be in existence. For encoded information, we believe the standards now evolving within the ISO framework for low-speed services should generally be extendable to high-speed ones. For analog and bit-stream information, standards for interconnection, propagation and storage developed by the television broadcast industry should be applicable. After 1990, then, we believe that widely-supported standards for high-speed services will also exist (though the appearance of novel functional requirements could delay their development).

A user wanting to remain as vendor-independent as possible should observe the following four guidelines in preparing new systems:

- Programming should be in standard high-level languages.

- Programs should be modular. In particular, input/output and file processing functions should be separated from computational ones.

- Inter-system communications should be conducted according to ISO standards, which will probably be supported by all vendors at this level.

- Hardware modules that are to be retained as the information systems evolve (terminals, communications controllers, processors) should as far as possible have their specific functions and interfaces established by microcode and software, rather than by fixed wiring. Within limits microcode and software can be changed to accommodate new requirements (e.g., for exchanging messages over a data bus). In some instances manufacturers will provide these changes in their self-interest. In others it should be possible to contract for them. The ease of making changes (and the need for them) will be minimized if the communications between modules are kept in the form of standard messages. To the degree that modules share an application function via interdependent software, their intercommunication will be non-standard and vendor-dependent.

4.6 INFORMATION CONTROL AND SECURITY

Commercial requirements for access control and data security are generally less stringent than those of military security. This discussion will be confined to commercially available products and techniques.

For the relatively few commercial users desiring data encryption, the ICST standard will be satisfactory. We envision no major effort to improve the level of security provided, though device costs have already begun to decline. The use of DES (Data Encryption Standard) may very well increase if and when encryption devices are incorporated in terminals and workstations so that the use of encryption is transparent to the user and is performed at little or no additional cost. Encryption will often be applied to data in files as well as to data being communicated especially when the storage media is transportable (e.g., floppy disks). It may also be applied to personal key encryption, data integrity and message authentication. User demand for encryption may decline somewhat in the 1990's as optical fiber communication lines come into widespread use, because signals in optical fibers are less vulnerable to interception than electrical signals are. However, increased use of satellite communications may affect this. In any case, more widespread use of existing cryptographic tools for protecting data, user passwords and programs, and for providing authentication, will occur as costs decline.

Physical access to terminals and machine spaces is currently controlled by passwords, identity cards, terminal identifiers and the like. Promising work is under way on signature dynamics and fingerprint and hand profile pattern matching. If these techniques are restricted to the matching of small sets of properly prepared patterns (as is the case in access control) rather than to open-ended searching of large files, they should prove effective for most commercial requirements by 1990.

Logical access to computer software and databases will also be subject to improved control. The virtual machine concept can make it impossible for a user limited to one machine environment and data set to enter the supervisor state and reach another machine environment. Even if the user does so, he will then encounter the system access barriers mentioned above that operate at the supervisory level. By 1985, access controls in mass storage system controllers will guarantee compliance with all specified procedures, particularly if associative look-up tables are used that can be changed only in a controlled manner.

However, mass storage system controllers operate at a physical access level. Mappings from the logical to the physical level must still be performed by trusted processes with hardware support (i.e., the associative look-up tables must be set up correctly and must be tamper-proof).

It appears likely that by 1990 all mass storage systems will be equipped with automatic journal facilities, inaccessible to users, that record all changes and/or all references to a database at a logical level. Primarily designed to permit recovery from error, these will also be useful for monitoring accesses.

Finally, the use of write-once video disc technology (which we believe is likely at the shelf storage level in database systems and in multi-media office files) will also have an incidental security benefit: it will be impossible to alter file records without destroying them.

4.7 PERSONNEL AND MAINTENANCE IMPLICATIONS

After 1985, the end-users of the new systems will do much of their own programming via interactive dialogs with easy-to-use software, so they will no longer need to work through application programmers. However, user organizations will need central groups of highly-trained technicians to establish the environment in which the end-users work: to select the hardware and systems programs, to establish the standards, to define the software tools available to the users, and to perform information resource management functions. The emphasis will be on personnel quality rather than quantity. A cadre of experts will be required whose technical knowledge may be greater than presently needed. (After 1990, this requirement for technical expertise may relax as the system modules become more and more automatic.) Application programmers will still be needed for the organization's production applications, perhaps as many as are now employed in many. However, their numbers will not rise proportionately to the total amount of programming done in the organization.

A training requirement for the end-users is implied, if they are to do their own programming. This requirement should usually be met by short (one-half to three day) courses, since the interactive software selected will probably include self-teaching and assistance facilities. As information processing systems are used by more personnel within an organization, the manufacturers will be concentrating on reducing the training time required to make effective use of the equipment and on making the systems easier to use by those personnel for whom the system is only an aid for carrying out their main functions. As more analysts, engineers, managers, and clerical personnel make use of the system part of the time, the manufacturers' emphasis will move from the data entry, data retrieval types of applications to the database-oriented, office automation, and personal computation type of applications which will be needed by these new users. Thus, major changes in both the training aids and the on-line system hardware and software supporting elements will be appearing.

The application programmers remaining in user organizations will be equipped with improved tools to help them, often resident in their versions of the multifunction workstation (the "programmer's workbench"). Paradoxically, however, the productivitiy of the developmental programming function itself is not likely to be enhanced much. Developmental programming is the most intricate, the most skilled and the most highly variable of the components of data processing system development; hence, it is the least likely to be automated.

The new software development aids should primarily be considered as tools for developing bigger systems better. The paybacks will be found in areas other than programmer productivity, such as documentation, maintenance, end-user training, and faster response to small problems.

Effective use of new software development aids will not be possible in the absence of good program design practices. If organizations indefinitely attempt to continue maintaining poorly designed programs, especially those written in assembly language with no discipline in regard to data typing and no use of structured programming rules, the problem will eventually become insuperable. The vendors' evolving system environments will make such maintenance increasingly difficult, and the supply of programmers with obsolete skills will decline. Organizations whose applications follow good software engineering principles and fit the vendors' modular system architectures will find maintenance much easier. For them software maintenance problems should decline in severity but will never disappear.

The trend to end-user programming of MBS's is cause for concern: for each degree of improvement in the software engineering expertise of professional designers, there will apparently be added numbers of less expert end-user designers. Many organizations may limit end-user freedom to design software in the interest of maintaining quality control.

Operations personnel requirements should slowly decline: system modules of all types should become increasingly automatic in operation, requiring less loading of programs, scheduling, changing of media, etc. After 1990, users of information systems will in most cases communicate with them directly to specify their needs and receive results, rather than through operators. This will be true whether the need is for an answer to a question, for a routine batch processing run, or for entry of data or messages. By the early 1990's it is reasonable to expect that network systems will be available that can handle voice and digitized image material as well as data and text, that can assist the users in discovering and using system resources, and that can control themselves within the bounds of normal operations:

- compensating for equipment failures;
- optimizing service levels to meet fluctuating demand in accordance with established priorities;
- supporting multiple levels of security and access control; and
- measuring the use of system resources and identifying bottlenecks.

Maintenance of electronic modules will become much easier and less costly:

- Failure rates will decline as the level of circuit integration and automated manufacturing rises;
- Failure tolerance through redundancy of modules, communication paths, etc., will reduce the urgency of maintenance; and
- Self-diagnostic facilities in the systems will reduce the level of expertise required in the field.

Unfortunately, the reliability and maintainability of electromechanical peripheral devices (disk drives, printers, etc.) will not increase so much. Electromechanical devices will therefore be used less (e.g., magnetic bubble technology will be used instead of magnetic disk for smaller files), but many of them will still be needed. Combining this fact with a probable proliferation of information system modules in relatively inaccessible field locations, the result may be that overall cost and quality problems of system maintenance will remain at approximately their present level.

5. SUMMARY

5.1 INTRODUCTION

Figure 5.1, at the end of chapter 5, summarizes the major findings in chapters 2-4. Summaries of the component technology forecasts are presented in chapter 2 and are not repeated here, but the summaries of product-related forecasts are included.

The leftmost column lists the technology areas most important to the development of future information industry products. The technology areas are listed next to the products on which they have greatest impact, but this association is not precise: obviously "improved semiconductor electronics" affects categories other than general-purpose computers, and "easy-to-use interactive software" affects categories other than intelligent terminals and desktop computers. This broad overview does not attempt to be precise.

The second column identifies the nine product categories that are individually forecast. They are defined below.

The third column introduces aspects of the information processing industry's structure that are likely to either advance or retard the evolution of each product category.

The remaining three columns summarize our forecasts for each product category during the next three five-year periods: 1982-1987, 1987-1992, and 1992-1997. We forecast the general availability of mature, robust products: in many instances embryonic versions of the products appear in the market as much as five years earlier.

The next section of this chapter comments on the product category forecasts summarized in figure 5.1, and the concluding section contains a brief overview of the implications for users.

5.2 FORECASTS BY PRODUCT CATEGORY

General-purpose computers are of any size and price, but by definition they are capable of operating simultaneously in all the modes of use required by the bulk of customers in a given time period: currently the batch, on-line and time-shared modes with integrated database and communications management. Therefore they are generally relatively large and costly.

The evolution of general-purpose computers will be limited to a series of individually minor changes to minimize the software conversions required by both user and vendor. Nevertheless the systems are partway through a period of transition from monolithic mainframes to bus-oriented architectures in which a mix of modules is selected by the user. This transition should be complete by 1987: at that time the processing modules should have absorbed most of the system management functions presently performed by operating systems. After 1987 module types should proliferate, some containing application-oriented software sets, others oriented to the processing of text, image and voice media in addition to data. The modular architecture is relatively inefficient because much redundant hardware is included, so user costs for systems will not decline as much as the costs of the electronic components will.

Supercomputers are oriented toward mathematical computation and offer processing speeds substantially higher than those of the general-purpose systems available at a given time. Their evolution is advanced by the trend in the industry toward vendor specialization interoperable subsystems, but retarded by a need for software compatibility. Even in this specialized area users' investments in application programs are a strong constraint.

However, research in both computational algorithms and machine architectures is slowly permitting a higher degree of parallelism to be employed in many applications. Our forecasts for supercomputer performance in the 1990's anticipate a high degree of success in this research. All state-of-the-art supercomputers provide two modes of operation, scalar and vector. Scalar rates typically govern the overall performance of a supercomputer and, unfortunately, are particularly subject to the physical limitations just mentioned.

Two avenues of developing technology offer potential for significant improvement to scalar-processing rates, faster componentry, and parallel processing. Advances in very large scale integration (VLSI technology), will probably improve scalar processing rates by a factor of about three, relative to the Cray-1, by 1985. Use of gallium arsenide devices and other forms of high-speed logic, may provide an additional factor of three or four by 1990. A second avenue for increasing overall scalar performance is to use parallel processing systems, i.e., several processors collaborate in the execution of a common task. As expected, the first such systems were announced this year and should become operational in 1983-84. These systems typically offer two or four processors. By the end of the decade systems with eight and possibly sixteen processors are likely to be available. Speedup from these devices cannot be expected to be linear in the number of processors due to overhead incurred from synchronization of them and potential delays in data communications between them. Preliminary research indicates that systems with up to eight processors will offer attractive increases in overall performance.

Memory size for supercomputers will continue to reflect advances in VLSI of memory chips. Thus, by the end of the decade, we are likely to see memories with 100 million words (64 bits per word).

From 1982 to about 1992 we expect the main path of evolution to be in vector and array processors. Maximum speeds should advance from about 100 million floating-point operations per second (MFLOPS) now to about 1000 MFLOPS. Also during the period software-limited advances should be made in new types of architectures, particularly the data-flow type, which may permit a much higher degree of parallelism to be applied to certain kinds of applications. It is possible that by 1997 equivalent speeds on the order of 100,000 MFLOPS may be reached in some applications.

Other types of special-purpose computers will also be appearing, advanced by the industry trend toward subsystem specialization. Besides file processors (considered separately below) these will include by 1987 limited protocol translators, which will permit interoperation of specific sets of non-compatible products for individual organizations, and small array processors to operate as part of general-purpose systems. In the 1987-1992 period we expect specialized processors for image or graphic material to become generally available. In 1992-1997 we may also see specialized knowledge-based processors become available, incorporating artificial intelligence techniques and special architectures to provide personalized assistance to groups of designers or analysts sharing a degree of common experience and methodology.

File processors are expected to evolve steadily throughout the period, advanced by the trend to specialization (and by strong market demand) but retarded by a need to maintain compatibility with existing programs and data set representations. By 1987 we expect four related but distinct kinds of products to become generally available:

- Database management software that provides extracts of operational databases for decision support and multiple user views of data.

- Associative file searchers for limited collections of data and text.

- Storage hierarchy managers that provide access and control for large databases resident in multi-level hardware hierarchies.

- Read-only systems incorporating optoelectronic (video) discs to provide text and image material for retrieval and training applications.

In the 1987-1997 period we expect these products to converge by degrees toward multi-purpose file processing systems that combine the handling of encoded data, text and imagery with bit-stream representations of speech and imagery. The convergence of video disc-based office file systems (oriented toward bit-stream material) with encoded file processors is not likely until late in the period. In fact, there will probably be a family of such systems designed to optimize various combinations of capacity, speed, versatility and mix of media: user organizations are likely to incorporate several types in their networks.

Intelligent terminals and desktop computers are considered together, because modern designs of such products are nearly identical whether their primary application is as data terminals, word processors or desktop computers. Very large market demand coupled with the evolution of message interface standards is causing rapid evolution of the products. However, few vendors have experience in all three of the markets served (data processing, office equipment and communications) and the lack of a completely suitable retail distribution and service industry also retards progress.

By 1987 we expect to see a complete integration of most terminal, word processor and desktop computer types (though specialized versions for focussed production applications will remain), and typical devices will incorporate relatively high resolution color graphics capability and read-only video discs. The prices of simpler models will decline to $300-$700 (constant dollars), but models with high resolution displays and costly peripherals will still cost several thousand dollars.

In the 1987-1992 period these devices will have become highly modular multifunction workstations, configurable for a wide variety of business, professional and consumer applications. High resolution, flat color displays should be available. Also, the processors described above, and developments in high-level interface standards and communications, should permit these workstations to interoperate with a wide range of dedicated and public networks.

After 1992 developments in knowledge-based systems may enable versions of these workstations to serve as "personal assistants" to professionals sharing a common knowledge base. It is not clear where such capabilities will reside in the networks of the 1990's (or to what degree they will exist). **[STAFF COMMENT 16]**

The evolution of voice processors will be slow. Speech recognition technology is advancing slowly; investments in existing telephone wiring and switching equipment will not be abandoned rapidly; and existing suppliers of telephone, data processing and office equipment must all learn about the others' markets. In the meantime, the development of limited command recognition systems is likely to permit a number of useful applications to emerge (e.g., for order entry or inquiry systems). **[STAFF COMMENTS 17 and 18]**

In the 1982-1987 period many organizations will install digital PABX's to switch data and voice traffic, and many will install digital voice message systems as accessories. In 1987-1992 systems should become available that can recognize limited-vocabulary voice commands, and bit-stream voice messages should be integrated with other media in office file systems. Finally, in the 1992-1997 period specialized processors for continuous speech recognition may also become available for integration into fully multi-media networks.

Automatic document processing systems convert images on paper to electronic form and produce paper images from electronic signals (either encoded or bit-stream). Many early versions of such systems exist (e.g., facsimile machines and laser printers), but none yet combine all the desired functions:

- o input (optical character recognition) with output;
- o text, data and graphic media in monochrome and color;
- o bit-stream and encoded information.

Market demand is strong and the evolution of interface standards is enhancing product development. However, applications cross over data processing, office copying, communications and printing industries with which no single vendor is familiar.

Software to meet the disparate needs of these applications is evolving slowly, so in the 1982-1987 period we forecast separate development of "communicating copiers" for offices, of OCR page readers, and of high-speed data processing and printing devices for production applications. In the 1987-1992 period these devices should converge into a family of modular document handling systems serving as nodes in users' networks. Even low-cost versions should have color capability. Maturity should be reached in the 1992-1997 period, but systems of that time should be able to deal with a full range of data, text, image and perhaps even voice media.

Videoconferencing is growing slowly, retarded by the lack of low-cost, high-speed switched service from the carriers. Such service will slowly increase in availability over many years as the carriers invest in fiber optic cables. By 1997 multi-media, high resolution services will be available, but continuing high equipment costs will cause most users to install them only in specially-equipped videoconference rooms with dedicated lines to the local carrier's switch.

Network technology is advancing rapidly as increasing numbers of vendors concentrate on the area and as interface standards evolve. Users and vendors alike, however, are constrained by existing investments in hardware and software.

By 1987 local area nets should be technically mature and widespread in user facilities (though digital PABX's will be effective competitors). Electronic mail will be widespread within and among user organizations, and the vendors of network services should be offering a variety of multi-protocol packet switched services.

In the 1987-1997 period the communication carriers and network service vendors should become increasingly able to offer custom-tailored, multi-media services to their customers. By 1997 most user organizations should be able to contract with them for their entire communications needs: it should no longer be necessary to separately procure and manage leased lines, packet and switched services, controllers, etc.

5.3 IMPLICATIONS FOR USERS

Most users' expenditures for information industry products and services will be rising steadily through the 1980's on a constant-dollar basis, even though the cost of electronic components will continue declining. Automated office systems will generally represent new, added costs. New services to end-users (easy-to-use interactive programming tools, direct access to databases) are generally wasteful of computing resources. The modular architectures of modern equipment are themselves wasteful, because the computer and memory in a particular processing module are idle when its function is not required. Finally, user expenditures for externally-provided software will be increasing: for system and support programs, and usually also for application packages.

In the 1990's users' expenditures may stabilize or decline as the new types of systems mature and the cost of components continues to decline. However, there may be new costs associated with products and services that are presently embryonic. These include extremely fast, application-dedicated supercomputers; knowledge-based systems; continuous speech recognition systems; and image processing systems with the accompanying high-speed communications services.

However this turns out, the modularity of future systems may have the greatest impact on cost-effectiveness. Systems employing modular processors in distributed networks need never be replaced as a whole. They will be able to evolve, module by module, as users' needs change and as new capabilities become available. After 1990 it should never be necessary to replace information processing systems in their entirety, as was the case with past computers: life cycles will become indefinitely long. For this to be true the users' programs and databases must be machine-independent, however, capable of being moved from one module to another.

Lack of industry-wide standards will continue to impede this; vendors offering integrated systems will prefer that they remain unique.

The mix and number of information processing specialists employed by users will change steadily.

Relative requirements for application programmers should decline as end-users do more and more of their own programming, as programmer productivity increases, and as externally-provided application packages see increasing use. However, during the 1980's many user organizations face conversions of their continuing production applications into the new modular environment; any decline in application programmers will have to await the completion of such conversions.

Central system planning groups will need increased expertise. More and better system architecture specialists will be needed. These people will identify needs and potentials for productivity and other improvements through the use of such techniques as organization and data modeling. The use of database administrators will spread, as more organizations create the large, integrated databases of multi-media material that the technology of the late 1980's will permit. Large, self-optimizing systems will require careful performance measurement, using the best techniques available: performance measurement specialists will be needed. Central system planning groups will also have to apply software engineering methodology more professionally. They must establish the standards (as ICST is doing for the Federal government), evaluate and select the modules, and monitor the cost-effectiveness of the whole. This will be a complex problem for systems integrating data, text, image and voice processing, and working in a highly interactive and dynamic manner. However, in the 1990's the need for expertise in central system planning groups may decline again, as the modules in the users' networks become increasingly automatic and as the providers of network services become increasingly able to assume the role of communications network manager for the user organization. At the same time, in the 1990's the procurement of software and services for the user organization will be a much more extensive job than it is now. Application packages, video disc-based training materials, database services, videoconference services and knowledge-based systems are examples of areas likely to need increasing central planning and procurement. Perhaps the focus of many central system planning groups will shift from technology to software and services.

Effects on end-user personnel are beyond the scope of this report. However, the focus of most information processing technology and industry evolution during the 1980's will be on end-users. Clerical and production workers, professionals and managers of every kind will be offered new tools to enhance productivity, improve the quality of work and improve communications. The effects on them will be many and varied, but will rarely be revolutionary. The main constraint on information technology's evolution will be the ability and willingness of end-users to alter their behavior to accommodate the new tools, without interrupting their daily work.

Contributing Technologies	Product Class	Effect of Industry Structure on Product Evolution	Products by Time Period of General Availability: 1982 - 1987	1987 - 1992	1992 - 1997
• System Architecture • Programming Language Evolution • Modular, Microcoded Operating Systems • Improved Semiconductor Electronics • Gallium Arsenide and Superconductor Logic • Novel Processor Architectures	General-Purpose Computers	• Retarded by requirement for software compatibility	• In transition to modular, bus-oriented architecture • Modules absorb software functions	• Modular architecture mature • Module operating system functions embedded and automatic • Preconfigured application modules	• Proliferation of module types • Integration of bit-stream and encoded data, text, voice and images
	Supercomputers	• Advanced by trend toward specialized subsystem vendors • Retarded by requirement for software compatibility	• Vector and array processors achieve 1,000 MFLOPS speed • MIMD and Data Driven Processors in early delivery	• Vector and array processors achieve 5,000 MFLOPS speed • Software to tailor novel architectures to applications evolves	• Best application-tailored systems achieve 100,000 MFLOPS equivalent (?)
	Other Special-Purpose Computers	• Advanced by trend toward specialized subsystem vendors	• Limited protocol translators • Small array processor subsystems	• Image processors	• Knowledge-based processors (?)
• Opto-electronic Recording • Improved Magnetic Recording • Extract DBMS with Multiple User Views	File Processors	• Advanced by trend toward specialized subsystem vendors • Retarded by requirement for software and data set compatibility	• Extract and multiple-view DBMS • Associative file searchers • Storage hierarchy management systems • Read-only and archival video disk systems	• Multiple-view data base machines for text and data • Video disk-based office file systems	• File processing systems integrating bit-stream and encoded data, text, voice and images
• Easy-To-Use Interactive Software • Graphic and Image Processing Software • High-Resolution Flat Displays	Intelligent-Terminals and Desktop Computers	• Advanced by evolution of interface standards • Retarded by vendor need to master multiple industry areas • Retarded by lack of suitable retail distribution structure	• Integration of most terminal, word processor and desktop computer types • Addition of high-resolution color graphics capability and video disk	• Modular multi-function workstations integrated with networks	• Incorporation of knowledge-based techniques to provide "personal assistant" capabilities(?)
• Speech Recognition	Voice Processors	• Retarded by capital investment requirement • Retarded by vendor need to master multiple industry areas	• Digital voice-data PABX's proliferate • Digital voice message systems	• Digitized voice message systems with voice commands • Integration of voice storage with office file systems	• Limited continuous speech recognition systems(?) • Integration into multi-media networks
• Optical Character and Image Recognition • Non-Impact Printing	Automatic Document Processing Systems	• Retarded by vendor need to master multiple industry areas • Advanced by evolution of interface standards	• Non-Impact printers with communicating capability • Inexpensive OCR page readers	• Integration with report production and office file systems • Color hard copy imaging	• Integration into multi-media networks
• Fiber Optics	Videoconferencing	• Retarded by capital investment requirement	• Limited growth of intra-company dedicated links • Public centers in major cities	• Switched video lines available in major cities	• High-resolution, multiple-media service on dedicated links • General availability of switched video lines(?)
• Local Area Networks	Networks	• Advanced by combining of information producers and distributors • Advanced by evolution of interface standards • Retarded by capital investment requirement	• Local area nets mature • Electronic mail becomes general • Limited multi-protocol services proliferate	• Evolution of multi-media narrow-band services; dedicated to customer by carrier • Local area nets combine with digital PABX	• Automatic world-wide network management for customer by carrier

Source: Arthur D. Little, Inc.

FIGURE 5-1 SUMMARY OF INFORMATION SYSTEM PRODUCT FORECASTS

PART II: FEDERAL STAFF COMMENTS

Edited by

Institute for Computer Sciences and Technology
and
Department of Energy

PREFACE

Part II is comprised of comments on the preceding Part of this report. The comments, which were submitted by members of ADP staffs from several Federal agencies, are keyed, by number, in their corresponding sections in Part I.

In September 1982, draft copies of A. D. Little's report "Future Information Processing Technologies", were sent to all of the Federal agencies. Staff members were asked to review and comment on the report. One or more staff members from each of 15 agencies returned substantive comments to ICST. Following receipt of the comments, a joint team from ICST, the Department of Energy, and A. D. Little "reviewed the reviews" and, when all of the team members agreed with an individual comment, that comment was included in the main body of the text that comprises Part I of this document.*

In a number of instances, one or more members of the team either did not concur with a given comment, felt that the comment was valid, but beyond the scope of the forecast, or thought that sufficient attention had already been given to the subject. In those cases, the author of the comment was consulted, by telephone or by letter, and invited to submit the comment for inclusion in this section.

The section notation preceding each staff comment denotes the section to which the comment refers.

STAFF COMMENTS

2.2.4.1

STAFF COMMENT 1

By 1985, for the home computer area, intelligent terminals, etc., a combination of small 5 1/4 inch Winchesters (capacity from 10 to 100 megabytes) plus floppies and mini-floppies will be the dominant storage.

The advantage of floppies is in their increased standardization in recording media, small physical size, common interface, data transfer rate, multi-source availability, and removable recording

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* Defense Mapping Agency, Department of Agriculture, Department of Defense, Department of Education, Department of Energy, Department of Health and Human Services, Department of Housing and Urban Development, Department of the Interior, Department of Justice, Department of the Treasury, Environmental Protection Agency, Institute for Computer Sciences and Technology, National Aeronautics and Space Administration, Securities and Exchange Commission, and Veterans Administration.

media. In this area, there will be continued improvement in size, cost, reliability and product standardization of mini-Winchester disk drives.

2.2.4.3

STAFF COMMENT 2

It is implied that TV-type scanning is adequate for document recording. This has misled many people. It takes at least twice the TV scanning resolution to record a typewritten page legibly and four to five times to record a typical technical typeset journal page.

STAFF COMMENT 3

This report does not really distinguish the great difference between the video disc, a recording device matching TV resolutions, with the much higher density optical digital data disk which really requires different techniques for recording.

2.3.3.3

STAFF COMMENT 4

Computer output microfilming (COM) is one of the fastest and largest volume computer printing techniques in both volume and dollars. COM for years has done engineering drawings and is, with CAD/CAM, becoming quite important. Computer Assisted Retrieval (CAR) from full text microfilm files is now big business as is computer driven photocomposition for producing printing plates.

Chapters 3 and 4 of Part 1 do mention these type of devices in a cursory way. The same goes for Optical Code Recognition (OCR) and bar code data entry. There are some very big users of both. Social Security and the Post Office are big users of multifont OCR readers, the grocery stores, also some parts of GSA and DOD (now has it mandatory), etc., are big bar code users.

2.3.5.1

STAFF COMMENT 5

Most audio I/O devices currently on the market are built around garden-variety microprocessors. Development of customized speech processors should result in noticeable performance improvements, especially in voice recognition.

2.3.5.1

STAFF COMMENT 6

Most connected speech recognition systems do not require modelling the grammatical structure of language, although this approach in some cases enhances performance.

Recognition accuracy rates for systems capable of handling continuous speech, when tested with databases developed for discrete word recognition systems, have shown performance superior to discrete word recognition systems. (*IEEE Spectrum* 26-32, September 1981; J. M. Baker in *Proceedings of Workshop on Standardization for Speech I/O Technology*, National Bureau of Standards, in press). For small vocabularies such as connected strings of digits, studies at SRI (D. W. Bell, numerous reports for United States Postal Service) have shown a number of encouraging results including rapid and accurate entry of digit strings with commercially-available connected word recognizers. The degraded performance suggested by recognition accuracy rates for connected speech recognition systems when tested with large vocabularies more properly ought to be interpreted as a measure of the increased difficulty of the recognition task than that the performance of the algorithm may be inferior.

Efforts to improve the power of connected speech recognition technology will necessarily include improved understanding of the acoustic-phonetic features to be extracted from the speech, better modelling of speech signals and language, and improvements in computational power and available memory.

Successful commercial exploitation of "command recognition systems" have been implemented in a number of applications (e.g., airline baggage sorting, parcel sorting, and military command-control operations in networking.) Many more applications are presently in development. The recent entry of major semiconductor manufacturers including Intel and Texas Instruments and the availability of developmental systems, suggest that more applications will become "economically justifiable" prior to 1985.

2.3.5.2

STAFF COMMENT 7

The need for completely unconstrained continuous speech recognition systems has not been well established. The imposition of a modest number of carefully-reasoned constraints (e.g., speaker-dependence, domain-specific grammars, interactive real-time error correction protocols, etc.) may sufficiently simplify the problem to make it within the state-of-the-art within this decade. Major advances will be required to make it affordable and a commercial success.

2.3.6

STAFF COMMENT 8

Voice synthesizers using a small vocabulary of pre-digitized human speech have become sufficiently inexpensive to begin to appear in all sorts of computer-related and consumer items. Text-to-speech devices are becoming good enough for use in computer-aided instruction.

2.4.1.3

STAFF COMMENT 9

Of particular interest during the 1986-1989 interval will be the work of the Microelectronics and Computer Enterprise Post von Neumann Computing Project. The project, which is designed to meet Japanese competition in the artifical intelligence area and to promote greater understanding of highly parallel and MIMD systems, should be in full swing at this time. It is anticipated that some results of this project will be incorporated in systems delivered to users before Fiscal Year 1989.

2.4.2.3

STAFF COMMENT 10

The need for staff members who understand data models will probably be greater than this section suggests. Query languages will be based on data models, and end-users will still have to know something about the structure of their data to use these languages effectively. Every organization will probably need some staff members who understand the mappings from logical user interfaces to physical storage structures. Performance tuning will be important and it will be up to database experts to shield the users from changes in physical storage. Large systems may need only a centralized staff of experts to accomplish this task, but even smaller systems will need someone -- either in-house staff or paid consultants -- unless they rely completely on default storage parameters with no physical restructuring flexibility.

2.4.3.1

STAFF COMMENT 11

The Pascal language now enjoys solid implementations on major equipment lines and is an especially significant language on smaller systems. Even though the language is typically implemented with different extensions on different hardware, a substantial common body exists. Large systems, up to 50,000 lines of source code, have been transported to several different machine types with very little recoding needed for each new environment. A number of operating systems for microcomputers has also been written almost entirely in Pascal and has been transported to different machines with modest effort. For these reasons I think Pascal will experience more rapid growth and more widespread use than A. D. Little predicts.

2.4.3.3

STAFF COMMENT 12

Program development environments will become available in large numbers during the forecast period. These systems, as noted in the A. D. Little report, contain a number of software tools that facilitate many phases of program development; however, there is a trend for these systems to be highly tailored for use with only one particular language. Since it is frequently desirable to develop systems using multiple languages, this is an undesirable feature. Here I disagree with the A. D. Little statement that "These tools will operate with multiple programming languages (in fact, they will allow systems of programs to be developed using multiple languages but all based on the same definitions of the data to be used)." It is my impression that these environments will not work well with several languages.

3.4

STAFF COMMENT 13

The statement that "The providers of software and data services are more likely [than are hardware vendors] to operate nationally...because their products must reflect national languages, cultures, and business patterns" is dubious. According to ADAPSO's 1981 annual industry survey, American companies with over $10 million in annual revenues were, collectively, exporting almost $3 billion in software. "Software" was broken down into four separate categories, i.e., integrated (or turnkey) systems which accounted for $267 million in exports, professional services with $428 million, remote processing with exports amounting to $1.127 billion, and software products (micro software, database management systems, system software, and applications software) which accounted for 1.141 billion export dollars. The last mentioned category is particularly interesting for two reasons. First, exports account for 22 percent of the industry's software product revenues whereas exports in all of the software categories together account for only 12 percent of the software industry's total revenues. Second, of the software categories "software products" intuitively would be the category most likely to be affected by language and cultural factors. That this is not so is surprising and bodes well for our future balance of trade IF we take care to protect our international markets.

It is important to note that the figures quoted are from 1981 and that they represent an increase in exports of 21 percent over 1980. In 1981, microprocessor software was just beginning to be marketed in the international arena and we can expect the export figure to jump significantly when newer data are available.

4.2

STAFF COMMENT 14

The incorporation of microprocessor based systems (MBS's) in the average office and laboratory will probably pass through three phases over the next decade, each phase determined not only by the level of sophistication of the hardware and software available, but to a large extent by the level of "computer sophistication" of the users. This is especially true since most MBS's will be used by people who have previously had little or no direct experience working with computers.

The initial phase is a time in which the relative expense of MBS's will limit their incorporation. They will primarily appear in offices of planners and supervisors and will consist of a relatively general purpose hardware system but will be used primarily to execute perhaps a half dozen or fewer software packages (word processing, spread sheet, personal data management, communications, etc.). The selection of hardware and software will be limited by the fact that most of the systems will be aimed for applications in which the MBS is the only computer available. Therefore, strong communication programs will not be available. This will not, however, be of great consequence to the average user initially.

In the second phase, communications between MBS's as well as between an MBS and a mainframe should take on an increasingly important role. This will probably coincide with the general acceptance of 16/32 bit MBS's which will have operating systems which are far more powerful than those typically used today. UNIX or one of its imitators or offshoots would seem to be the most likely candidate for such an operating system. This phase will also be marked by the incorporation of more specialized hardware, especially in the realm of human interface - bit mapped displays, voice communications, etc. Such diversion in hardware will ironically help in the widespread use of system independent operating systems, since one person may have to use a number of very different computers in any one project.

The third phase will be defined by the influx of computer knowledgeable people entering the job market at all levels. This influx coupled with the gradual decline in hardware prices will allow businesses to use MBS's in a wide range of areas. The greatest expense at this point will be employee training, which will add an increasing impetus toward the establishment of standard operating systems and application software.

During the initial phases, use of "turnkey" systems will have a dramatic affect on productivity since these will be systems which provide results without the need for a large number of programmers and engineers. As time progresses, and intercomputer communication becomes more widespread, productivity gains will be harder to measure (although they should be great).

At present, hardware selection should be made with some vision toward the near future. That is, 16 or 32 bit processors should be overwhelmingly selected over 8 bits and one should probably wait for the next generation of exotic peripherals. Both 8 bit MBS's and most of the newer peripherals will probably disappear or be replaced over the next 3-5 years. In the short run, choice of an operating system is less critical primarily because few users will have any interaction with the operating system. The choice will become increasingly important in the next few years, however, as the interaction of machines and the use of multiple computers by one individual becomes more common.

STAFF COMMENT 15

The integration of data processing equipment into networks offers opportunities for increased productivity by FY 1985. Word processors are now an accepted part of many oganizations. Personal computers are coming into extensive use. The potential advantages of connecting them into networks are that so doing makes it possible to share resources, big computers, big storage systems, specialized output printers or color film recorders; it can give the members of an organization access to a shared database; the collection of data at the point of a transaction with its immediate entry into the appropriate data collections becomes possible; and the provision of a new method of communication, electronic mail, between the members of an organization becomes possible.

The basic attraction of these networks for many people comes from the realization that much of what an engineer, scientist, purchasing agent, or manager does is collect, assemble, sort, and provide information. Going, for example, from the question "Should we put new air conditioning in the building?" to the purchase and installation of an air conditioning system may require hundreds of interactions between various members of the organization, collection of information about the existing conditions in the building, costs of air conditioning, future plans of the organization for the building in question, availability of money, and so on. This sort of thing is the daily work of many people. They work with information, factual data, opinions, decisions, schedules, and so on. Word processors, personal computers, and traditional data processing equipment are providing valuable assistance in performing this work. Connecting the equipment in networks will give users better access to the computing resouces and provide new channels of communication between the users.

Data networks providing many of these services already exist. But for the most part they are either in organizations that have developed them in-house over a period of many years or they are special purpose networks, such as airline reservation systems.

The development of data networks for general purpose use by organizations not specializing in computer use is in an early stage of development. There are several basic kinds of networks competing for consideration. Organizations have hardly begun to know how to make effective use of such networks. Two of the potentially biggest players, IBM and AT&T, have only begun to give hints of what they may do. There are very few standards so that it is often difficult to connect the products of several vendors together in a useful manner. And finally, much of what is described in the press, and in very handsome vendor brochures, is not tried and proven technology but represents completely new products from new companies, or is under development.

By FY 1985 your organization, if it is new to data networking and office automation, should have word processors in common use, personal computers in common use, and perhaps a small network, or perhaps more than one small network, performing useful services and providing your organization with experience in the use and benefits of data networks.

There are several rapidly developing kinds of network technology that are beginning to be put to productive use. They are the digital branch exchange, the baseband coaxial cable network, packet switched coaxial network, and the broadband coaxial cable network. Much development will have to take place before their potential can be fully utilized.

The digital branch exchange performs the functions of a traditional telephone exchange, connecting one subscriber's telephone to that of another. In addition, it allows the same kind of connection between personal computers or other kinds of computing equipment. Typical data speeds are 56 kilobits/per second. The signals are handled over ordinary twisted pair wires. The telephone signals are also handled digitally, the audio being converted from analog to digital form to make this possible. A major advantage of such a system is that in many instances the wiring installed for the existing telephone system can be used to provide both voice and data communication service.

The baseband coaxial cable network connects computing equipment by transmitting short bursts of data at very high speeds from one device to another. Typical data rates are in the range of 1 megabit/second to 10 megabits per second. Because of their high instantaneous data rate these networks allow a wide variety of devices to be connected to them effectively. They have another advantage, when a network is installed and operating new users can be connected simply by putting new taps on the existing cable. This is in sharp distinction to a telephone or digital exchange where new wires must be run from the central location to each new subscriber.

The broadband coaxial cable network performs the functions of the baseband coaxial cable network but it has several important advantages. It can handle several channels of video information in addition to the digital data, it can provide audio channels; it can provide effective communications for several times as many users as is practical for the baseband system; it readily transmits information over distances of five or ten miles with very inexpensive booster amplifiers; and it is designed so that many branch cables can be added to the original cable, allowing the network to develop as the organizations' use of it develops.

There is a networking technique that is not new that will surely continue to occupy an important place. It is the connection of terminals to a central computing resource using twisted pair wires. Such terminals can be made to perform in the same way as personal computers or word processors. In many cases they may prove to be the most economical way to provide service.

For data communications to reach its full potential, whole areas of equipment and technical expertise will have to be developed. The use of shared collections of data, for example, is an art that is still in the early stages of development. The uses of video transmitted to individual offices for education and communication are almost completely unexplored. The use of point of transaction collection of time card information, purchase requests, and other routine organizational data is in its infancy.

In view of all this, it seems apparent that organizations should not be precipitous in acquiring large networks. Those that have networks should continue to develop them. Those who forsee that networks can make a contribution to their work should certainly begin to develop them. But, in most cases, a staged development will be appropriate. Develop a plan, purchase part of the system and try it, and then, if necessary modify the plan.

All development of data communication networks should, of course, take into consideration the relationships between data communication, voice communication, and video communication.

Between FY 1986 - FY 1989, it is reasonable to expect considerable clearing of the data networking picture. We will know what services IBM, AT&T, and others offer. There may be useful standards. Many of the current small companies will have been integrated into larger companies, developed proven products, or failed.

It does appear likely that all of the networking techniques mentioned here, and others, will continue to find new markets and to develop rapidly between now and FY 1989. If one of the network technologies has fallen into disfavor it will probably be because some large vendor, or vendors, has pushed hard to support one that will have become popularly accepted because of that support, rather than because of its inherent technical properties.

5.2

STAFF COMMENT 16

The key message from the trade literature and computer hardware exhibitions during 1982 is that TERMINALS ARE BECOMING SMARTER; the days of the dumb terminal are limited. This year's shows and advertising are promoting the concept of the workstation and the different functions it can perform from word processing, financial management, remote communications, local area networks....

The majority of the workstations are designed around a bit mapped raster display with a local processor, memory, disks (hard or floppy); bit mapped graphics are available on many of the workstations. The early workstations were designed using the 8-bit micro processors but current announcements utilize the 16-bit micros.

The popular 16-bit micros are the 8Ø86, the 68ØØØ and the Z8ØØØ. The Z8ØØØ seems well entrenched in the video arcade games and a few professional applications; the 8Ø86 and the 68ØØØ are even competitors in the professional products.

For the 8-bit systems, the popular operating systems have been restricted to single vendor systems except for CP/M and UCSD Pascal. With the 16-bit systems, the contendors are CP/M-86, UCSD Pascal, Interlisp and Unix-like systems.

For the next five years, these bit mapped intelligent work-stations will dominate the market due to their price performance, size and the available applications software. The user interface will change radically as these units become consumer devices with friendly user interfaces utilizing menus or pictures (icons). Most of these systems will have graphics capability which will drive up the communication speeds necessary for communications with host computers by at least a magnitude for the same application compared to an alphanumeric implementation.

For 1982, the price range will be in the $11k-$25k range; for 1983 this should drop to $8k-$15k; for 1984, $3k-$1Øk; for 1985, $2k-$5k. All of these are 1982 dollars.

The other dominant theme during the next 5 years is the local area network which many of the workstations are supporting. This will allow many of these workstations to communicate at much higher speeds than with traditional hosts and users will demand and need better host communications.

The primary advantage of the 16-bit systems is the ability to address a much larger memory area than the 8-bit systems. For many applications, memory limitations have severely limited what the workstation could do and many of the 16-bit systems will support memory management in various ways including virtual memory systems.

In the 1985-1987 period, many 32-bit workstations will become available and may or may not displace the 16-bit systems. This depends entirely on price and application needs.

To date, within our agency, terminals have been purchased for their hardware capabilities or price performance. In the future, workstations will be purchased for what applications they can perform; local, remote and distributed. This will severly impact "centralized user organizations with highly trained technicians who establish and control the environment in which users work". Highly trained technicians who select the hardware and systems programs, establish the standards and define the software tools available to the users do not have the applications experience necessary to specify the users environment.

The administrative controls used for acquiring large computers are inappropriate for workstations. The users will want to control their own destiny. Mass marketing of these workstations will convince the users that they are capable of this and many organizations within DOE will have to adopt fundamental changes in the current way computing resources are provided users. The choice is not whether the user will have a workstation or what brand the workstation is but what are the general functions required of the workstation for it to complement the currently available larger computing resources at an installation.

[Ed. note: These last comments may be applicable to the scientific computing environment; they are not relevant to an environment such as that in an insurance company.]

STAFF COMMENT 17

To date, essentially all audio I/O development has been done by universities and small commercial entrepreneurs. Expect some of the larger computer companies to enter the picture within the next five years, probably by buying some of the small audio I/O manufacturers.

STAFF COMMENT 18

Fairly primitive, but useful, hardware/software is currently available in the areas of voice synthesis, discrete word recognition, and speaker recognition. With the development of specialized processors, progress in all of these areas will continue at a reasonable rate over the next decade.

PART III: TELECONFERENCE SUMMARY

Managed by

Kellogg Corporation

Contract NB82NAAM0773
Institute for Computer Sciences and Technology

PREFACE

In November 1982, ICST sponsored an audio teleconference for the purpose of having private industry representatives review a draft of Part I (the technology forecast) of this document. The Kellogg Corporation managed the logistics for the conference and, in consultation with ICST, selected and contacted the participants.

The mechanics of the teleconference were, in themselves, of interest-- sufficiently so to receive attention by the teleconference trade press. There were nineteen nodes on the network and for the first fifteen minutes the participants met in plenary session for the purpose of introductions, instructions by Kellogg's Virginia Ostendorf, and welcoming remarks by ICST's director, James Burrows. The conference then broke into four concurrent 30-minute discussion sessions. Staff members from ICST and the Department of Energy and Vice President Frederic Withington of A. D. Little, Inc. were available as "resource people", joining the individual groups when called upon. After half an hour, the participants reconvened in plenary session for 5-minute summaries of the respective group discussions.

The participants received review copies of Part I prior to the conference. After reading the document, each participant selected a discussion group from a menu of topics suggested by ICST. The four topics selected for discussion were: distributed processing, general-purpose computer systems, office systems, and compatability and transferability of software.

Part III contains the transcript of the summary session.

1. PARTICIPANTS

The following people participated in the teleconference:

Mr. Brett Berlin
Cray Research, Inc.

Mr. I. D. Brown
E. I. Dupont DeNemours Co., Inc.

Mr. Ed Christian
A. L. Roark & Assoc., Inc.

Mr. Mike Curran
Micro Industries

Mr. A. Ray Daniels
NCR Corporation

Mr. Glen Davidson
Custom Management Systems

Mr. Maris Graube
Tektronix, Inc.

Mr. Armin Gumerman
Northwestern Mutual Life Insurance Co.

Mr. Richard Hokaj
United Telecom Computer Group

Mr. Philip Huntley
Engineered Products, Inc.

Mr. Alan F. Lytle
Northern Telecom

Mr. Ed Mathews
Northern Telecom

Mr. John Davis
Bunker Ramo

Dr. Eldred Nelson
TRW

Mr. D. David Edison
Westinghouse Corp.

Mr. George Roberts
Boeing Computer Service Co.

Mr. David Smith
McDonnell Douglas Automation Co.

Mr. James Burrows
Institute for Computer Sciences and Technology

Ms. Virginia Ostendorf
Kellogg Corporation

Mr. Robert Carpenter
Institute for Computer Sciences and Technology

Mrs. Pat Powell
Institute for Computer Sciences and Technology

Mr. John Cavallini
Department of Energy

Mr. Tom Pyke
Institute for Computer Sciences and Technology

Mrs. Peg Kay
Institute for Computer Sciences and Technology

Ms. Cathy Thomas
Department of Energy

Ms. Joan Knoerdel
Institute for Computer Sciences and Technology

Mrs. Shirley Ward Watkins
Institute for Computer Sciences and Technology

Mr. Frederic G. Withington
Arthur D. Little, Inc.

2. SUMMARIES OF THE DISCUSSION GROUPS

Virginia Ostendorf: Peg, this is Gini Ostendorf in Denver. I think we're now ready to begin the small group discussion reports. If you would like to call on the group leaders for the summary of their comments, we have allowed about five minutes for each group to report.

Peg Kay: Alan Lytle, from Distributing Processing, could you sum up quickly what you've done?

Alan Lytle: We'll certainly try to. I apologize to the members if I miss any major points. First, a couple of social points came out. One, that distributing processing tends to have some major social implications in an organization or corporation, and requires a corporate management philosophy to succeed. Any discussion of distributed processing, we feel, should make an attempt to match the distributed processing to the organization of the entity trying to use it. Second point brought out is that the vendors of various equipment, and not just the computer but also telecommunications, software, etc., are and will be driving forces in the implementation of distributed data processing. In other words, we as users are not going to be able to solve all the problems and the vendors are going to, either de facto or with our guidance, take us into this world.

Next point is that the report dwells heavily on microprocessors and microcomputers to the point that one could get the impression that distributed data processing really relies on intelligent terminals. I think the general feeling of the group is that distributed processing is more than that. And we selectively have had some very large machines in what we would consider to be a distributed processing network, and these machines often tend to be functional in nature. As an example, a machine might be doing computer-aided design and it might be a large IBM main-frame, but we would consider that to be a distributed machine.

One comment or one phrase that was coined that I found useful was the idea of cooperative processing, rather than distributed processing. I think we have to give the credit for this to Eldred Nelson from TRW. But it seems to me the idea of cooperative processing very much sums up what we were thinking of in our group discussion.

Some of the problems we have right now and some of the things that have to be overcome - and again, we're not that good in putting time scales on it - number one would be the nonstandard protocols which while allowing machines to link up electrically and physically, would not allow the machines to link up from the data point of view. Second would be the distribution of control of the network so that we can move from having just one machine controling like an octopus a whole set of machines out in the real world. Another problem was the directory problem. It is great to have a network, but when somebody logs on they need some kind of mechanism to get to the end point. In other words, to get to the machine that the data is on. And that directory problem is going to be difficult. The major problem then is the distribution of data. And I think we felt that the report did not dwell on that particular subject, and if we're talking about distributed processing, we are essentially talking about distributed data, and that is a whole subject area missing in the report.

Quickly then to summarize, we think the report certainly dealt with the equipment technology - more can be done in the software and data technology. And as one of our members said, most of the systems we have start as individual islands which we then try and join together into distributed processing networks. So, therefore, a lot of the current protocols, a lot of the current database systems we're stuck with for quite a while to come. We won't be able to just implant a new distributed processing system on top of what we have today. Thank you. Those are the main points. I didn't have time to put them into a priority order, but I think if you go back to the recording, you might pick up a couple more. Thank you very much.

Peg Kay: Thank you Alan. Brett, can you take some time off from the sun in Honolulu to sum up your General-Purpose Computer Systems.

Brett Berlin: Peg, I've asked Don Brown from DuPont, who was our recorder, to give that summary.

Don Brown: We found in the General Purpose subcommittee, basic agreement with the report. There were several areas in which we felt the report was too conservative. One of them being that modular system nodes with half a channel is here now and not in the 1987 time frame as indicated in the report. We did not think the report dealt adequately with networking and networking protocols and, to agree with the first gentleman, with the distributed databases. It's a factor that we need to deal with. We felt that microcomputers are going to have a much larger impact than was indicated by the report. Database management system machines are not dealt with adequately. We feel that parallel processing software is going to be a deterrent to the rate at which we can use supercomputers, and we do not see a great demand for supercomputers. It's going to go at a much slower rate than the smaller computers. That, in general, was the summary of the General-Purpose Computer Systems Group.

Brett Berlin: Just dding one area to that which was brought up by the first report group also. We also saw more need in the area of protocols and the concept of the heterogeneous system where each system does start as an island. That makes it even more important to deal with the networking and the protocol problem. We are really, I think, in agreement with the distributed processing group in that as a limiting technology.

Peg Kay: Thank you. Armin Gumerman, can you sum up the deliberations of the Office Systems Group?

Armin Gumerman: Yes, I can. We also felt the area of the office systems of the report was too conservative. There's a general feeling that much of the technology covered in this section is here today, and it could actually be used much sooner than the report indicates. We felt that there was a need for education of the user community, however, to what is available and what needs to be done to use this.

Areas of particular concern were the local area network, integrated voice, and data PABX. There's a lot of technology here today and a lot of it being used, which is probably not given enough credit in the report. Some areas not in the report at all that we felt were fairly important was the whole area of user friendliness, which is very important to make this technology usable in the office. Also, the area of the integration of these technologies to make them an effective package. Another area that we feel is very important for the office area that did not get enough coverage was the area of security. A lot of our discussion also centered around the need for leadership in the development of standards in the areas where the technologies are proceeding down different paths, and the need for a leader is evident. Thank you.

Peg Kay: Thank you. Mike, can you talk about the compatability and transferability of software?

Mike Curran: Thanks, Peg. I think the general consensus of our group falls in line pretty much with everyone's discussion. We see a major divergence between large and small systems users in terms of their software utilizations. The utilization of software tends to be directed towards the machine the software is to be used on, and consequently discourages the transferability of software as it exists from one machine to another. This makes it very necessary for the industry to establish some degree of compatability which will allow one system to link with another to transfer information. The general consensus was that that transfer of basic applications of software in the foreseeable future would be very difficult. The transfer of data in itself is extremely difficult at this stage due to the variety of communications protocols that are available on the market.

The one thing that we did come to in looking at both large and small systems was the general feeling that in the small systems area, where there is a great deal of competition and you do not have any major dominant forces, the evolution of standards tends to be much more rapid and conformed to by both small and large manufacturers. In large equipment, software requirements are pretty much dictated by the customer requirements and tend to be tailored for specific pieces of hardware. And the compatability between large and small systems in the future I don't feel will be quite as idealistic as proposed by the report. Subsequently, that area is going to create a great deal of difficulty in the distribution of information and distribution of applications from one machine to the other.

Peg Kay: I think our agenda calls for some comments by ICST and Ted Withington of A. D. Little, and I think I'm going to pass this to Ted.

Ted Withington: These are very interesting comments. And very useful ones, I think. You're obviously a very "with it" group. I was just struck on hearing the very last point about the report being too idealistic in software compatability. Next to some earlier reports about, gee, technology is already here and it's going to be used faster, and the report says it's too conservative. This dichotomy of market readiness and commitment to isolated systems and protocols has to be mixed with the availability of technology, which is the very reason our industry is so confused today. It seems to me that the vendors, for one thing, would give a fig to know just where in-between the extremes of too idealistic and too conservative the actual market will turn out to be. That's about all. All of the points are very well taken. I have one feeble defense which is it says it's a technology forecast, not a management or data administration policy forecast. The points you raise are very well put. I think if we knew the answers, we'd probably put them in anyway.

Peg Kay: Thanks, Ted. From the ICST perspective, we certainly got out of this teleconference exactly what we wanted. I hope that the rest of the participants thought it as useful as we did.

Jim Burrows: I'd like to thank you very much for being with us this afternoon, and especially the leaders of the various groups. I think that we don't get as much comment in terms of conservative vs. too rash from our government people because they know that whatever you think is conservative, they think is too rash. We're not going to get there as fast as some of you. In DOD, we definitely do use the technologies to the full limit in areas where it's very clear what the payoff is. But in some of the support areas, it is very clear that the user and the Federal Government are a lot more conservative these days than they were in the '50s. I would like to continue keeping the communication lines open to all of you. I think all of you have things to tell us, and if there is anything we can tell you, we'd be grateful for the opportunity. Again, I just want to express our thanks for you being with us this afternoon. Thank you.

PART IV: ESTIMATES OF FUTURE SYSTEM COSTS

Developed by

Defense Intelligence Agency

and

Arthur D. Little

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Defense Intelligence Agency

PREFACE

The earlier parts of this document forecast the information technologies through 1997. This part, which deals with the costs of these future systems, is a companion-piece to be used for agency planning. Originally prepared for the Defense Intelligence Agency by A. D. Little, Inc., it is reprinted here in its entirety.

1. INTRODUCTION

These estimates of future system costs were developed by the Defense Intelligence Agency and A. D. Little. The cost estimates were derived by applying simplifying assumptions to the technology and product forecasts contained in Part I.

This Part provides cost estimates for computer systems, subsystems, and terminals for 1987, 1992, and 1997. The estimates are necessarily uncertain and will provide only overall totals for system costs, but they should be useful for long-range system planning.

Since computer systems procured after 1987 will be highly modular, cost estimates must be developed by selecting the set of modules likely to be needed in a given system. Section 2 explains the way this is done, using tables of module cost and capacity provided in sections 3 to 8.

Section 9 provides separate guidelines for estimating the cost of remote terminals and desktop computers. Since these product categories are converging, they are considered together.

Section 10 provides a guideline for estimating the cost of separately priced software, assuming that generally available commercial products are used. Specially contracted, application-unique software is not considered.

Finally, sections 11 and 12 provide estimates of system integration and maintenance costs to apply to all systems.

Costs of hardware (sections 3 to 9) are on a purchase basis, at the vendor's list price. Any anticipated discounts or lease arrangements can be factored in after the system purchase costs have been estimated. Software costs (section 10) are estimated as a percentage of hardware cost, assuming that software is procured on the basis of a single payment for paid-up license. System integration and maintenance costs (sections 11 and 12) are also estimated as percentages of total system cost.

All the estimates are of one-time costs at the time of acquisition, except for maintenance cost which is an annual recurring cost.

Estimates are based on constant 1982 dollars; there is no explicit allowance for inflation.

No cost estimates are provided for communications products and services (local area networks, PABX's, or carrier services). These are mentioned in the technology forecast because their evolution is related to that of information processing products, but coverage of them is otherwise outside the scope of this report.

The cost forecasts are for the full-function, state-of-the-art products of the time. For such products, market requirements for increased functionality and ease-of-use are expected to largely offset declining component costs. Simpler systems with fewer processors and less software will probably be available in the future at substantially lower prices than those estimated here; but if history is a guide, most users will prefer systems with state-of-the-art capabilities.

2. METHOD OF DEVELOPING COST ESTIMATES

First, the requisite number and power of general-purpose processors should be determined. The number is determined by the number of simultaneous processing environments expected. For example, if a system is to process both native-mode fast-response transactions and batch programs for an obsolete machine, one processor should be allowed for each. If, in addition, support is to be provided for programmers working in a given language, an additional processor should be provided for each language in major use (minor use of other languages can be accommodated in the same processor in the interpretive mode). If the total number of processors is only one or two, an additional one should probably be allowed to provide failure tolerance.

The power of each required processor should be estimated on the basis of millions of instructions per second (MIPS). (MIPS is a poor measure, but so far the industry has developed no better way.) Also, most system planners are aware of the MIPS ratings of the computers with which they are familiar and can, at least subjectively, relate the MIPS rating to a given level of required throughput.

With the number and power of general-purpose processors known, the planner should refer to section 3 to determine their estimated cost as a function of time.

For the planner interested in very large supercomputer systems for computation-intensive applications, cost and power estimates (expressed in millions of floating point operations per second or MFLOPS) for such systems are also included in section 3.

Second, the planner should determine whether any special-purpose computers are likely to be needed (for voice recognition, image processing, signal processing or vector computations). Section 4 provides cost estimates for them relative to those for general-purpose processors. Special-purpose file or database processors are separately considered in section 5, Step 3.

Third, the planner should estimate the overall on-line mass storage capacity needed and refer to section 5 for cost estimates (access time and other variables need not be estimated separately, as explained there). The estimates in section 5 also apply to the file processing systems likely to be used in future office automation networks. That is, networks which are connected to local area networks, but are otherwise stand-alone subsystems.

Fourth, the planner should refer to section 6 for the cost of the supervisory and input/output system needed to support the set of subsystems selected in the first three steps.

Fifth, the planner should determine whether the system is to be on-line to a communications network. If so, section 7 provides cost estimates for the necessary control unit (network front end).

Sixth, the planner should determine whether batch input/output devices are needed (high-speed printers and batch data entry). Section 8 provides cost estimates for these, whether local or remote. The estimates in section 8 also apply to the document processing systems likely to be used in future office automation networks.

These six steps complete the cost estimating process for the modules of a computer system.

Section 9 presents estimates for remote terminals and desktop computers (workstations). Given the number of workstations and their types (as defined in section 9), the planner can estimate their total cost whether they are to stand alone, connect to a local area network, or connect directly to a remote computer.

Section 10 presents estimates of the cost of separately priced software as a percentage of the total hardware cost derived in the preceding steps.

Finally, the resulting costs of both hardware and software should be increased by the system integration factors in section 11 and the annual maintenance factors in section 12.

3. GENERAL-PURPOSE PROCESSORS

Table 3.1 provides cost estimates for general-puprpose processors in five size classes for 1982, 1987, 1992, and 1997. In addition to cost, table 3.1 provides corresponding estimates of:

- Power storage. As explained in Part 1, future systems are likely to dedicate high-speed working storage to individual processors instead of having a common storage for all.

- Power in millions of instructions per second (MIPS). These processors will usually be microcoded and will not execute conventional instructions, so this measure of speed is not directly applicable. However as noted above, this measure is the only one in general use, and most planners are able to relate overall throughput to it.

- The largest supercomputers. For the convenience of planners interested only in this type of processor, they are shown in table 3.1 below the five categories of general-purpose application processors. They are shown here rather than in section 4 because the cost estimates in table 3.1 are sufficient to cover a complete supercomputer system if the input/output and file storage requirements of the supercomputer system are expected to be relatively modest.

The modular computer systems described in Part 1 are not deliverable in 1982. The corresponding estimates in table 3.1 (marked with an asterisk) are for conventional processor complexes which include supervisory and input/output capability. If a planner is preparing a cost estimate for one of these, step four in the above procedure should be omitted; no extra supervisory and input/output system is needed.

The five categories of general-purpose processors shown for 1982, become three in the later time periods. "Very small" application processors remain, but it seems likely that only two other levels of processor power will be needed in 1987 and beyond since customers will be able to mix levels and numbers of application processors in their systems.

TABLE 3.1

COST FORECASTS FOR GENERAL-PURPOSE APPLICATION PROCESSORS

<table>
<tr><th></th><th>1982*</th><th>1987</th><th>1992</th><th>1997</th></tr>
<tr><td>Very Small</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Cost ($Thousand)</td><td>12</td><td>8</td><td>5</td><td>3</td></tr>
<tr><td>Storage (Megabytes)</td><td>0.5</td><td>1</td><td>2</td><td>4</td></tr>
<tr><td>Speed (MIPS)</td><td>0.05</td><td>0.1</td><td>0.4</td><td>1</td></tr>
<tr><td>Small</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Cost</td><td>100</td><td rowspan="8">60
2
1.0</td><td rowspan="8">40
8
4</td><td rowspan="8">30
16
8</td></tr>
<tr><td>Storage</td><td>1</td></tr>
<tr><td>Speed</td><td>0.2</td></tr>
<tr><td>Medium</td><td></td></tr>
<tr><td>Cost</td><td>320</td></tr>
<tr><td>Storage</td><td>4</td></tr>
<tr><td>Speed</td><td>0.8</td></tr>
<tr><td>Large</td><td></td></tr>
<tr><td>Cost</td><td>1,400</td><td rowspan="8">600
16
8</td><td rowspan="8">400
48
24</td><td rowspan="8">200
75
50</td></tr>
<tr><td>Storage</td><td>8</td></tr>
<tr><td>Speed</td><td>4</td></tr>
<tr><td>Extra Large</td><td></td></tr>
<tr><td>Cost</td><td>4,700</td></tr>
<tr><td>Storage</td><td>16</td></tr>
<tr><td>Speed</td><td>14</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Largest Supercomputers</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Cost</td><td>10,000</td><td>10,000</td><td>20,000</td><td>30,000</td></tr>
<tr><td>Storage</td><td>20</td><td>100</td><td>500</td><td>5,000</td></tr>
<tr><td>Speed (MFLOPS)</td><td>100</td><td>1,000</td><td>5,000</td><td>100,000</td></tr>
</table>

*Conventional processor complexes. No supervisory and input/output system needed.

The increases in processor price-performance reflect the expected appearance of new technology. For example, new high-speed logic circuitry is expected to see general use in large processors by 1987, so the 1987-1992 power increase and accompanying memory size expansion are large and the price decrease relatively small. In particular, the largest supercomputers of 1992 and 1997 are expected to have very high prices and processing powers. This reflects the forecast that by then it will be possible to associate extremely large arrays of parallel processing elements with certain classes of problems. Most users with high computational workloads will find smaller specialized processors adequate; cost estimates for these are considered below in section 4.

4. SPECIAL-PURPOSE PROCESSORS

These are specialized computers designed for limited purposes such as voice recognition, image or signal processing, or vector arithmetic. File or database processors are not included (see section 5), but special-purpose processors will sometimes include specialized file or data set storage. They will be of many kinds, as discussed in Part 1. No effort has been made to differentiate the cost and power of each type. Instead, a gross simplification is suggested based on experience which indicates that, on the average, the cost of any special-purpose processor in a system tends to be equivalent to the combined costs of the general-purpose processors in the same system.

After completing step one of the estimating procedure, the planner should simply double the combined costs of the general-purpose processors to allow for special-purpose ones, if needed. If in a given instance the planner has specific information about the nature and cost of the special-purpose processor required, this information should be used to refine the estimate. This would be possible in the case of large supercomputers, for instance (see table 3.1).

5. MASS STORAGE SYSTEMS

These include a hierarchy of storage devices (disk and backup tape for the smallest systems, as many as four levels for the largest). They also include the typical controller and its software. Controllers range from an integral disk controller for today's small systems to sophisticated, associative mass storage processors for the large systems of the future. All mass storage systems after 1987 are assumed to have versions of such processors.

Table 5.1 shows the typical costs and capacities expected for these systems (in megabytes or gigabytes). Access times are not shown; in every instance the hierarchy of devices has been selected to provide the frequency of access typically required in a mass storage complex of the specified class. Office file systems based on video discs that have relatively slow access times and large capacities are likely to become available. These may cost less than the systems shown in table 5.1.

The expected improvements in price-performance of the magnetic disk storage units govern the cost for the configurations shown up to 20 gigabyte capacity.

Extra large file hierarchy configurations in 1982 are based on magnetic cartridge technology. Extra large configurations of 1987 and beyond as well as large ones of 1992 and beyond, are based on the use of new technology (the laser-based video disc) and the improvement in price-performance which is expected from it.

TABLE 5.1

COST FORECASTS FOR MASS STORAGE SYSTEMS

(Costs in $thousands, capacities in megabytes (MB) or gigabytes (GB))

	1982	1987	1992	1997
Small				
Capacity	50MB	500MB	2GB	4GB
Cost	10	25	45	40
Medium				
Capacity	1.66B	5GB	10GB	20GB
Cost	160	120	100	100
Large				
Capacity	5GB	15GB	200GB*	500-5,000GB*
Cost	260	300	500	500
Extra Large				
Capacity	250GB*	500GB*	1,000GB*	2,000-20,000GB*
Cost	1,500	1,200	700	700

*These systems incorporate a high-capacity archival store in addition to faster-access devices.

6. SUPERVISORY AND INPUT/OUTPUT SYSTEM

The modular computer systems described in Part 1 employ central buses for intercommunication, supervisory processors, and tightly-coupled input/output processors. These may be separately priced and selected, but in most instances there is likely to be a typical combination of the bus bandwidth, supervisory processor power, and combined input/output rate needed to support a given set of processors and mass storage systems. Therefore, we combine the three elements into typical combined systems to simplify the cost estimating process.

Table 6.1 presents the cost estimates for these combined systems. The planner, having completed the first three estimating steps, will know how many and what size of processors (both general-purpose and specialized) and what size mass storage system are wanted. Reference to table 6.1 can determine which of the four supervisory complexes will be needed to support them, and the resulting cost. Table 6.1 has no entries for 1982. Processor complexes of the present type, that do not employ separate supervisory systems, remain dominant (as discussed above in section 3).

7. NETWORK FRONT END

These are the controllers necessary to connect computer systems to communications networks. Small systems today typically use integral line adapters costing about $3,000. Medium and large systems use controllers based on minicomputers, with fully configured costs of about $100,000. Extra large systems use larger minicomputer-based or redundant controllers, costing about $200,000.

In the future, their capabilities will expand to eventual combinations of data, image, and voice communication, all in digital mode, with expanded data rates and capabilities. These increasing capabilities will be derived from greater complements of hardware componentry and from a growing expense for supporting software. They will, in effect, serve to offset the declining cost per component, with the result that the user's cost for network front ends in each category will remain stable. As a result, table 7.1 shows a constant cost for each class of network front end throughout the period.

TABLE 6.1

COST ESTIMATES FOR SUPERVISORY
AND INPUT/OUTPUT SYSTEMS
($ thousand)

	1982	1987	1992	1997
Small (up to 4 very small processors and small storage system)	-	20	15	10
Medium (up to 4 medium processors and medium or small storage system)	-	150	100	80
Large (up to 8 processors, no more than 4 of them large, and large or smaller storage system)	-	500	400	300
Extra Large (up to 16 processors, no more than 4 of them extra large, and extra large or smaller storage system)	-	900	800	700

TABLE 7.1

COST ESTIMATES FOR NETWORK FRONT ENDS
($ thousand)

	1982-1997
Small Systems	3
Medium & Large Systems	100
Extra-Large Systems	200

8. BATCH INPUT/OUTPUT CLUSTER

We distinguish between the low volume/capability situation and the high volume/capability one. The first is served by a cluster consisting of a controller, a small diskette drive, and a 300 line-per-minute impact printer (which eventually is superseded by a low speed facsimile image output unit).

The high volume/capability cluster consists of a standard Winchester disk drive, and a high-speed line printer of 2,000 lines per minute (1982), which eventually is superseded by a medium-speed non-impact page printing device (1987 and beyond). Optional to the large cluster can be a high-speed laser print/image device of 10,000 lines per minute or more, for which the cost is shown in the bottom line of table 8.1.

The cost of input terminals for either cluster should be estimated according to section 9.

TABLE 8.1

COST ESTIMATES FOR BATCH
INPUT/OUTPUT CLUSTER
($ thousand)

	1982	1987	1992	1997
Low Volume	20	15	12	8
High Volume	80	60	40	25
Optional Very High Speed Laser Printer	350	200	120	80

The necessary device controllers are included, so the same cluster can be either local or remote from a processor system. These clusters can also serve as subsystems ("print servers") in office networks.

TEMPEST shielding, if required, will cost $20,000 for the low volume cluster, $40,000 for the high volume cluster, and $75,000 for the laser point.

9. TERMINALS AND DESKTOP COMPUTERS

The interfacing between user personnel and information handling systems is provided by a variety of terminals. The cost and hardware configurations of the more intelligent terminals and those of desktop computers are already nearly the same, so we have combined the two product categories. In table 9.1 we have grouped the terminals and desktop computers into three categories which we see as representative of the major variants. Included in the cost of each module are allowances for the cost of interconnect, shared control logic, printers, etc., as they are required for each category. Apportioning these costs directly to the module eliminates the need for separate consideration of cluster support control vs. stand-alone terminal intelligence, so the planner need only multiply the number of terminals needed by their unit costs. (When a specific system is being configured, the planner must take the limitations of the selected controller into account.)

TABLE 9.1

COST ESTIMATES FOR TERMINAL AND DESKTOP COMPUTERS
($ thousand)

	1982	1987	1992	1997
Data Entry/Basic Display	2.5-4.5	2.0	1.5	1.5
Intelligent/Desktop Computer	10	7	6	5
High Density/Desktop Computer	80	50	40	30

Three classes of terminals are specified:

The data entry basic display terminal provides local capabilities of formatting/editing of alphanumeric information in display and/or printout forms. Internal storage and computing capabilities are modest. Cost premiums for stand-alone computing capabilities will eventually disappear, as electronic intelligence levels of even the basic modules rise.

The intelligent terminal/desktop computer is characterized by a nominal 19-inch CRT with split screen capabilities, multiple font capabilities, 24 to 36 function keys, 0.5 megabyte of storage and 10 MB disk capacity. It is programmable and is capable of stand-alone computing. Each set of two terminals has one printer. It is expected to be complemented over the forecast period with graphic and voice input response capabilities. Considering the low cost of this intelligent terminal beyond 1987, it may largely replace the basic terminal.

The High Density (HD) terminal provides all the capabilities of the previous two categories plus a high resolution screen capability in excess of 1,000 lines. There is a printer and a good quality photo-plotter for every set of two terminals. Costs include modifications for emission control.

10. SEPARATELY-PRICED SOFTWARE

Users of future computer systems will increasingly obtain separately-priced software packages for system control, support, and application functions. The amounts paid will vary widely and the planner should use any specific information available. In the absence of such information, table 10.1 provides guidelines for the payments expected to be typical of an average of commercial users.

Having derived hardware cost estimates for all of the required equipment, the planner should refer to table 10.1 for the software cost percentage applicable at the planned installation date. Multiplying the total hardware cost by the applicable software cost percentage, the planner will obtain the cost of the separately-priced software likely to be needed (regardless of system size). This cost is on the basis of a one-time charge for a "paid-up license" for all the software, corresponding to the purchase basis assumed for the hardware.

This separately-priced software cost estimate does not include specially contracted software or in-house programming; only standard commercial products are included.

TABLE 10.1

COST ESTIMATES FOR SEPARATELY-PRICED SOFTWARE
(Paid-up License Basis)

	1982	1987	1992	1997
Percent of Total Hardware Cost	10	15	20	25

11. SYSTEM INTEGRATION COST

In addition to the modular costs, additional costs will be incurred for software tailored to the overall system configuration (e.g., for performance measurement), cabling, and floors. Table 11.1 shows the estimated allowances that should be made for these as a percentage of total system cost.

The integration cost factors for terminals and desktop computers are shown in the first line of table 11.1. Costs of these devices derived from section 9, plus their system costs, should be increased by the percentage shown to allow for system integration.

The integration cost factors for processing systems of four sizes are shown in the remaining lines of table 11.1. After a planner has completed the first six steps described in section 2, the estimated cost of a complete processing system will have been developed. The system will contain one of the four supervisory and input/output systems described in section 6. The system cost, plus software cost, should be increased by the factor shown in the corresponding line of table 11.1 to allow for system integration.

TABLE 11.1

SYSTEM INTEGRATION COST
(% of system cost)

	1982	1987	1992	1997
Terminals/Desktop Computers	20	20	25	25
Small	20	25	25	25
Medium	15	20	20	20
Large	10	15	15	15
Extra-Large	10	10	10	10

12. HARDWARE AND SOFTWARE MAINTENANCE PAYMENTS TO VENDORS

These will rise throughout the period as the software-intensity of all levels of system increases (an increasing use of vendor-supplied system control programs is assumed). They should be roughly the same for all systems, as a percentage of acquisition cost. The estimated annual allowances that should be made for these are shown in table 12.1.

TABLE 12.1

ESTIMATED ANNUAL HARDWARE AND SOFTWARE MAINTENANCE COST
(% of system cost)

1981	1985	1990	1995
15	18	20	22

PART V: THE IMPACT OF LAW AND REGULATION ON FEDERAL AUTOMATIC DATA PROCESSING

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Purchase Order AP5020
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PREFACE

In common with most large, private sector organizations, the Federal government formulates policies which guide the acquisition and use of automatic data processing equipment. In government and industry alike, this policy guidance strongly influences how and when new technologies are introduced into the organization and, within obvious limitations, at what cost. The policy formulation in the Federal government is, in one sense, typical of any large, moderately decentralized organization. That is, broad policy is formulated by central management, while interpretations of the policy and detailed implementation practice are the province of the decentralized units.

The Federal government differs from most private sector organizations in that the central policy formulation comes from a variety of sources: the Congress, the Executive's central management agencies, and even, on occasion, the Judiciary. As might be expected, this can lead to some confusion and to some unintended effects.

This Part, prepared by IDC, describes the current state of Federal ADP policy, discusses its impact on Federal ADP use, and draws a set of conclusions. Opinions expressed are those of the contractor and are not necessarily those of ICST.

1. LEGAL AND REGULATORY BACKGROUND

This nation of laws looks to the Congress for its legislative mandates and for the funds to operate the government. Absent congressional action, the courts, as in communications reform, may point the public way. Always, Executive action shapes and tones the thrust of law or justice.

Many do not view the congressional appropriations as laws, but in recent years the appropriations process has become a vehicle for legislative action on diverse topics ranging from abortion to Brooks Act exclusions. Most laws result in regulations by the Executive Branch of the government. The evolution of laws and their companion regulations traces the consensus at both ends of Pennsylvania Avenue. Seldom does any single law or regulation embody all that may be said on a topic.

The time and method of funds appropriation influence the executive agencies' method of administration, acquisition, and accounting. The Constitution precludes the withdrawal of public funds from the Treasury except pursuant to appropriations made by law. In addition, the Antideficiency Act establishes criminal penalties to assure that funds are not spent in the absence of sufficient appropriations. Recently, fiscal years have ended without enactment of specific appropriations or continuing resolutions. On April 25, 1980, the Attorney General issued a landmark opinion which concluded that, except for activities necessary to achieve an orderly shutdown, government operations must cease when appropriations lapse without the provision of new funding. As a result, the House Committee on Rules and Senate Committee on the Budget have undertaken hearings on improvements to the Congressional Budget and Impoundment Control Act of 1974. Comptroller General Bowsher has testified to both committees that:

1. A biennial budget cycle would be advantageous;

2. Investments in capital or physical assets should involve longer term decisions on programs and funding;

3. Greater stability for investment programs (such as major military weapons programs) is a necessary ingredient in program efficiency;

4. There should be a reduction of congressional "decision and detail overload" by focus on broad policy, such as the basic direction and general content of programs;

5. The recommendation of the Hoover Commission and the Commission on Budget Concepts which urged adoption of modern accrual accounting systems that permit cost-based budgeting should be acted upon.

The Office of Management and Budget (OMB) has indicated a simplification of the President's budget process by reducing the detail required from agencies by OMB Circular A-11, "Preparation and Submission of Budget Estimates."

In addition to the annual appropriations acts which influence the executive agencies' methods of administration, acquisition, and accounting, there have been a number of laws which specifically address information resource management; these are:

1965 Brooks Act

1974 Privacy Act

1975 Freedom of Information Act (streamlined)

1980 Paperwork Reduction Act

1981 Warner Amendment to Defense Authorization Act for FY 1982

1982 Federal Managers Financial Integrity Act.

2. LEGISLATIVE PROGRAMS

The Brooks Act was superseding legislation. It applied to all Federal agencies. It gave the General Services Administration (GSA) exclusive procurement jurisdiction over all general purpose, off-the-shelf, commercially available automatic data processing equipment (ADPE), irrespective of configuration or use. The Department of Commerce (Institute for Computer Sciences and Technology/National Bureau of Standards (ICST/NBS)) was assigned the ADPE technology assistance and standardization roles. OMB's Circular A-71, "Responsibility for the Administration and Management of Automatic Data Processing Activities," published in March 1965, anticipated the Brooks Act and assigned executive department responsibilities. The Brooks Act and Circular A-71 resulted in the creation of unique centralized management structures and acquisition procedures throughout the Federal agencies.

As technology advanced, general purpose computing device architectures and manufacturing techniques, traditional to ADPE, began to migrate into products marketed by the related fields of printing, office equipment, test equipment, and communications. This technology proliferation has progressively disrupted traditional product marketplaces and their Federal constituencies because of the emergence of common features and capabilities in previously unrelated products. Further, congressional attention to the emerging technological capability to establish Federal databases on all citizens resulted in the Privacy Act of 1974. The hearings which led to the Privacy Act highlighted the unique security risks of automated systems. The Act prompted OMB Circular A-108, "Responsibilities for the Maintenance of Records about Individuals by Federal Agencies" and Transmittal No. 1 to Circular A-71, "Security of Federal Automated Systems." From 1974 to 1980 product miniaturization and mass production reduced equipment price/performance cost. In the same period, the cost of software and data communications accelerated so that overall life cycle system costs (hardware and system software price and other factors) came to be recognized in the acquisition process.

The Congress addressed the merging of technologies into the "Information Age" by the Paperwork Reduction Act of 1980. The 1980 act recognized "Information Resource Management" (IRM) by calling for:

1. the OMB Office of Information and Regulatory Affairs (OIRA);

2. the designation of a senior (IRM) official in each agency;

3. the development of Federal five-year plans for ADP and telecommunications needs.

Seldom does the appointed senior official, required by the Paperwork Reduction Act, have exclusive IRM responsibilities or IRM background. Usually this results in the previously highly centralized "Brooks Act" functional managers expanding organizational control over additional functions such as communications, office automation, systems development staffs, libraries, printing, or publications. In some agencies, this organizational process appears to have resulted in a delegation of IRM responsibilities without the delegation of commensurate authority. As discussed later, the Brooks Act role of GSA has evolved since the Paperwork Reduction Act into more oversight and less control.

The 1980 Paperwork Reduction Act also recognized a perceived degrading of efficient and effective defense management which could result from central agency involvement with the acquisition of IRM resources. As a result, the 1980 act excluded from its purview ADP and telecommunications systems with intelligence and national security cryptologic, command and control, weapon system, or mission critical functions. In the following year, 1981, the so-called "Warner Amendment" to the Department of Defense (DoD) Authorization Act for FY 1982 made substantially identical exclusions to those in the Paperwork Reduction Act and applied them to the Brooks Act of 1965. The detailed procedure needed to implement these two DoD exclusions from central IRM management continues to evolve between DoD and OMB.

Within DoD, which received the Warner Amendment exclusions to the Brooks Act, IRM officials appear to pursue the same fundamental issues of organizational functional alignment, planning, and the low cost computer revolution as do their civil agency counterparts. The agency IRM organizations, including DoD's Army, Navy, and Air Force, generally plan to streamline their traditional "Brooks Act" centralization by granting bureaus or major commands increased autonomy based on review and approval of ADP and telecommunications plans. The Navy has announced no final decision, but indicates that it may exercise Warner Amendment authority to exclude selected activities, such as the Naval Laboratories, from central ADP planning and acquisition. The Air Force plans to retain central oversight and use common management practices for all commercial ADP plans and acquisitions, irrespective of the applicable procurement laws, unless the ADP is under the skin (embedded) in a weapon system. The Army plans to continue one management cycle for commercial ADP, but it also manages the unique "military computer family" program from the same Army staff.

It remains to be seen whether or not the DoD Warner Amendment authorities will accept only "fine tuning" of the centralized Brooks Act type ADP and telecommunications acquisition process. The traditional ADP acquisition process is perceived by some as a barrier to the flow of current technology directly into mainstream mission critical systems.

3. ROLE OF THE CENTRAL MANAGEMENT AGENCIES

3.1 OFFICE OF MANAGEMENT AND BUDGET (OMB)

In addition to the OMB regulations described earlier (i.e., Circulars A-11, A-71, and A-108), OMB has also regulated, directly or indirectly, the Federal IRM acquisition and management functions by the circulars outlined below:

- A-50 Executive Branch Action on GAO Reports
- A-76 Policies for Acquiring Commercial or Industrial Products and Services Needed by the Government
- A-94 Discount Rates to be Used in Evaluating Time Distributed Costs and Benefits
- A-109 Major Systems Acquisitions
- A-114 Management of Federal Audio Visual Activities
- A-119 Federal Participation in the Development and Use of Voluntary Standards
- A-120 Guidelines for the Use of Consulting Services
- A-121 Cost Accounting, Cost Recovery and Interagency Sharing of Data Processing Facilities
- A-123 Internal Control Systems.

Each of these circulars will be referenced later as their provisions impact IRM management issues.

3.2 OFFICE OF FEDERAL PROCUREMENT POLICY (OFPP)

In 1974 Public Law 93-400 established OFPP as a part of OMB in order to implement the recommendations of the Congressional Commission on Government Procurement (1970-72). Public Law 96-83 reauthorized OFPP for an additional four years until October 1983. Congress has made it clear that OFPP is to propose a comprehensive approach to a uniform Federal procurement system without regard to current barriers or statutory requirements.

Presidential Executive Order 12352, Federal Procurement Reforms, dated March 17, 1982, directed OFPP to resolve conflicting views among agencies (DoD, GSA, NASA) which currently have regulatory authority for government-wide or agency unique procurement regulations. DoD, GSA, and NASA reached joint agreement on August 2, 1982 to establish a Federal Acquisition Regulation (FAR) Council for development and maintenance of the FAR. They are working together to publish a single FAR by July 1, 1983 which is scheduled to be effective October 1, 1983. There are indications that these FAR schedules for publication and the effective date will each slip back six months or more. This massive transition of "all" procurement procedures contains many unresolved issues. As a result, it contains the potential to disrupt "all" Federal acquisitions, particularly high technology, high dollar value, and long system life requirements. For example, unless prompt action is taken with regard to current contracts, future cost type contract awards may result in the necessity to maintain two different sets of accounts after the FAR becomes effective.

In addition, OFPP and GSA agreed on February 26, 1982 (47 Federal Register 8384) that, due to GSA's unique Brooks Act procurement jurisdiction, GSA would continue to develop the FAR regulations governing the management, acquisition, and use of Brooks Act ADP and telecommunications. GSA plans to develop a FAR Part 39 entitled "Automatic Data Processing Equipment Contracting." GSA will place existing ADP and telecommunications Federal Property Management Regulation (FPMR) and Federal Procurement Regulation (FPR) provisions into the FAR structure with suitable formatting adjustments. Since FAR Part 39 will incorporate the existing ADP/telecommunications FPMR's and FPR's without substantive change, this FAR issuance may not be published for comments.

The merging of the FPR and FPMR provisions in Part 39 by GSA means that both management and acquisition (procurement and contracting) procedures will coexist in one set of regulations. It is GSA's plan that Part 39 will require ADP planners and ADP contracting officers to work together. If agencies, particularly DoD, attempt to assign both FAR Part 39 areas of responsibility to their contacting officers, some confusion and delay is likely. If confusion results from FAR Part 39, it will be a cumulative add-on to the predictable delays arising from implementation of the overall FAR. It appears that DoD's ADP requirements which fall under the Warner Amendment exclusions will be free to use Part 39 procedures or the basic FAR, at the option of the service conducting the acquisition.

3.3 THE GENERAL SERVICES ADMINISTRATION (GSA)

GSA elected to exercise its exclusive Brooks Act ADP procurement authority by drafting unique FPMR's and FPR's to cover only those matters of ADP management and acquisition in which the GSA's policies differed from the other government-wide and user agency acquisition policies. Thus, the ADP FPMR and FPR differences are a subset of the basic procurement regulations which govern all other aspects of every Federal acquisition, including those for ADP. The Brooks Act regulations take precedence only where they differ. GSA has published guidance, however, on OMB policy issues such as Circular A-94, "Discount Rates to be Used in Evaluating Time Distributed Costs and Benefits." The GSA guidance authorizes an evaluation tilt away from purchase and toward leasing when the real world of present value discount rates indicates that such action will result in the lowest overall cost.

GSA has also elected not to do all ADP procurements, or even to review all ADP acquisition cases. GSA's FPR's 1-4.1104 establishes blanket procurement authority dollar levels under which agencies may acquire ADP equipment, software, and maintenance services without prior GSA approval. For example, at present ADP acquisition is permitted of up to $300,000 by an order from a GSA schedule contract, up to $500,000 competitively, or up to $50,000 sole source. There are indications that GSA plans to substantially increase these thresholds in the near future. Above the FPR 1-4.1104 blanket procurement threshold, GSA has created a streamlined (alternate) case-by-case delegation process by FPR Temporary Regulation 64, March 2, 1982 (47 Federal Register 8774). This streamlined process builds upon the Paperwork Reduction Act of 1980. It places special responsibilities on the senior IRM official in each agency and provides that GSA may conduct periodic on-site reviews of user procurement actions authorized under the streamlined delegation procedure. GSA states that this simplified process has been successful. The acceptance by other agencies of GSA's on-site reviews indicates significant progress by GSA in its government-wide ADP management role. Many agencies believe GSA has improved understanding of their problems because of the on-site reviews.

Since the Paperwork Reduction Act of 1980, GSA has sought to establish a joint planning arrangement with several agencies. The reward was to have been an enlarged form of long-term delegation. GSA has suspended this attempt due to its conclusion that meaningful planning activities were not present. GSA is now considering the expansion of the 1-4.1104 blanket delegation thresholds for selected agency components which have achieved satisfactory on-site reviews by GSA. Conversely, GSA is also considering the reduction of the 1-4.1104 blanket delegation thresholds for agency components which received an unsatisfactory on-site review.

GSA's in-house contracting function has performed well in adapting procedures to permit timely award to the continued influx of vendors into the ADP market. The FY 1983 number of multiple award schedule contract (MASC) vendors is up to approximately 900 contracts--a 20 percent increase from FY 1982. GSA anticipates there will be 1000 MASC contracts for ADP during FY 1984. This MASC program will be optimized by GSA through interagency training for MASC use.

3.4 DEPARTMENT OF COMMERCE, INSTITUTE FOR COMPUTER SCIENCES AND TECHNOLOGY/NATIONAL BUREAU OF STANDARDS (ICST/NBS)

The NBS' Institute for Computer Sciences and Technology (ICST) mission is to develop standards for computers and networks, to provide technical advisory services to government agencies, and to perform computer and computer networking research. While ICST's "Brooks Act" mandate is directed toward ADP use within the Federal government, the agency believes that its mission is best achieved by ensuring that off-the-shelf products that meet the government's needs are available. This insurance is obtained by encouraging user-oriented standards development by the voluntary standards committees. ICST is, therefore, active in the work of those committees. It has representatives on more than sixty of these committees and chairs approximately a dozen of them. Very often ICST provides the only technically expert representative of computer users on these committees. By providing technical support to the committees in conjunction with the support offered by the manufacturers, it can frequently achieve the definition of standards leading to off-the-shelf products for government agencies as well as for the private sector ADP user.

International standardization activity is currently intense in the program areas of local area networks, high speed networks, data interchange, and interfaces. ICST, through its technical leadership, has assisted the American National Standards Institute (ANSI), Institute of Electrical and Electronic Engineers (IEEE), and the International Standards Organization (ISO). It has taken the lead in the development of technical specifications which are based on U.S. requirements and which are being accepted internationally as ISO standards.

In the international arena the ICST approach takes the following steps:

1. ICST assesses the requirements of the Federal government and private sector users and of U.S. computer vendors. This is done through direct relationships with design teams from the major agencies, particularly DoD, the major computer manufacturers, and through U.S. industry associations. These associations include the Network Users Association and the Association for Data Communications Users (ADCU) which is composed of 150 corporate ADP users.

2. ICST has been successful in having U.S. requirements accepted by ISO. The acceptance of ICST's requirements makes it the logical drafter of the technical specifications. ICST's specifications then become the draft international proposed standard.

3. These specifications are written in English and, because of the ambiguities and incompleteness of the language (and most other languages), products cannot be developed from those specifications. ICST has performed extensive research in formal description techniques which is then applied to the specifications and which is distributed to well over 100 companies in the computer industry.

4. Because these standards address new areas of computing and networking technology, there is not an associated testing methodology. ICST works in the

development of such testing methodologies and its laboratories are now able to test prototype implementations (which it also develops) for correctness and performance. These tests will later be used by industry for self-certification purposes. ICST has invited industry participation in the implementation and testing phases of the process. At this time, over 100 companies have volunteered their assistance in the program. The availability of ICST's laboratories for product testing ensures that the American products not only conform to the international standards but that the products work.

5. The final ICST step is a key one. It publishes the voluntary standard as a Federal Information Processing Standards Publication (FIPS PUB). The vendors themselves have been in favor of this because, at that point, they have a specification which they know they can implement and which they know will not be changed capriciously.

ICST also sponsors workshops that enable companies to meet together, without fear of anti-trust problems, for the purpose of discussing product development based on these draft proposed standards. This activity is extremely important if the U.S. is to maintain the lead over Japanese and European competitors. ICST predicts that several other program areas, within the next few years, will be the focus of intense international standardization activity. They are computer languages, database management, software quality, and microprocessor-based systems. ICST plans to position itself to assume the same degree of international technical leadership in these areas.

While the standards program will continue to be an important part of ICST's activities, the overall trend has been toward placing greater emphasis on non-mandatory guidelines and ADP management aids such as technology forecasting and the development of appropriate cost/benefit methodologies.

3.5 OFFICE OF PERSONNEL MANAGEMENT (OPM)

The proposed final classification and qualification standards for government employees in the contracting occupation has completed a formal "second review." The standards are predicted by user agencies to result in lowered contracting pay and professionalism, contrary to the spirit of Presidential Executive Order 12352. On the basis of an Office of Management and Budget recommendation, the Cabinet-level Management and Administration Council recently met to consider the proposed classification standards for procurement personnel developed by the OPM. As a result of the meeting, OPM was directed by the Council's chairman, Edwin Meese, to hold off the release of any standards.

Instead, OPM must convene an interagency team of higher level OPM and agency officials with a strong general management perspective "to reach a better accommodation of views." The team must strive to reach an agreement on the issues if possible, and, if not, to develop a list of issues and suggested options for Council review, giving particular consideration to "credentialism" and overgrading.

Taken together with the concurrent introduction of the new Federal Acquisition Regulations (FAR), any actual mass reductions in contracting occupation grades would lead to higher than normal employee turnover and government-wide delays.

4. MAJOR INFORMATION RESOURCE MANAGEMENT ISSUES

4.1 COMPETITION/COMPATIBILITY/CONVERSION

GSA's FPR's call for "maximum practicable competition" for requirements stated in the least restrictive terms possible without compromising the government's economy or efficiency. Award should be made to that vendor which offers the "lowest overall cost," price and other factors considered. On the cost side, users may include all identifiable and quantifiable costs which are directly related to the acquisition and use of the system. The cost of conducting the procurement and administrative costs are to be included. Taken literally this guidance makes requirements (taken in their broadest overall sense) the driving force. The degree of competition in a given case (ranging from sole source to the GSA-preferred fully competitive functional specifications) must be geared to the practicality of achieving competition while attaining the government's economy and efficiency.

GSA recognizes the value of user investments in software and data files. FPR 1-4.1109-12 states that "compatibility limited requirements tend to restrict competition and, therefore, shall not be made a mandatory requirement solely for reasons of economy and efficiency." This means that GSA expects software conversion studies to be made as required by 1-4.1109-13. The conversion study of any significant software library (significant in comparison to the cost of equipment to be acquired) normally will lead to a reasoned management judgment that it is impractical to consider conversion when a compatible alternative exists.

Thus, when there is a significant investment in software and data, the cost, risk and delay of conversion to a new architecture will be undertaken only for software which has no compatible migration path or when other "requirements" dictate that decision. This conversion policy has resulted in a de facto Federal "market share" for installed architectures so long as they continue to grow. New requirements appear to permit the unlimited competition of functional specifications, but in this case also there exist patterns of apparent user affinity for "application" architectures.

4.2 OBSOLESCENCE

The General Accounting Office (GAO) and GSA have recognized the loss of economy, efficiency, and effectiveness of obsolete computer systems. Obsolete systems can degrade operations, application development, and maintenance even though they may continue to perform up to their original design specification. There should be a case-by-case analysis, however, before replacement since technologically obsolete computers may still provide the least overall cost, price and other factors considered. GSA will approve "Technology Updates" with compatible equipment systems in order to preserve essential operations or to obtain the lowest overall cost. The "Technology

Update" replacement system is not to exceed 150 percent of capacity of the system being replaced and the system life is to be based on a replacement schedule (2 to 8 years) which should permit "maximum practical competition." GSA approved "Technology Updates" for economic obsolescence must result in overall economy based on a life cycle cost analysis. There is evidence that GSA is considering a new economic replacement program which would not contain the system life and capacity restrictions of the current "Technology Update" delegations.

The relative obsolescence of the Federal computer inventory by comparison with the age of U.S. computers in use by private commercial users remains a matter of debate. The first issue is the accuracy of GSA's ADP Management Information System (MIS) government-wide inventory which is used as the basis for those discussions.

GSA recently requested DoD to explore and explain the status of 407 central processing units (CPU's) which the ADP MIS reports were installed in DoD prior to 1966. The Office of the Secretary of Defense (OSD), Comptroller, has found the status of the 407 CPU's to be as follows:

	ADP MIS Report CPU's Installed Prior to 1966	Replaced or Excessed
Air Force	161	59
Army	80	23
Navy	147	100
Defense Logistics Agency	7	2
Defense Mapping Agency	12	12
	407	196

This ADP MIS inaccuracy dilutes the degree of actual obsolescence compared with that reported. It also highlights the need for a Federal inventory system which contains incentives for accurate reporting and processing.

The second issue in the obsolescence discussions is the requirement to maintain realism in the comparisons. Some studies have lumped all CPU's together by year, irrespective of the relative power or manufacturer of the units. Tables 2-12* provide a comparison of Federal government and non-government CPU's by date of installation, i.e., prior to 1976, prior to 1979 (including prior to 1976), 1979, 1980, 1981, and 1982. Table 1 describes the International Data Corporation (IDC) computer size class definitions and representative model assignments. The data in tables 2-12 reflect the CPU totals, by manufacturer, by computer IDC class size. The data also reflect the percent of CPU's by computer class size, installed in each time period.

*All tables are placed in Appendix B.

The data in tables 2-12 utilize the current GSA ADP MIS data for the Federal installed base. It has not been updated with the recent DoD review results. Tables 2-12 indicate that in Group A (large) size classes the Federal inventory installed prior to 1979 is proportionately older than non-government systems in Group A. There are relatively small numbers in the current Federal GSA ADP MIS inventory. If they are tempered by the approximately 50 percent inventory error in the DoD sample, they cease to be a meaningful indicator of Federal computer obsolescence. The age of Group B (minis) and Group C (small business) systems indicate that at this time, for those computer classes, there is no greater government rate of obsolescence than in private industry.

4.3 SECURITY/PRIVACY

In addition to the security and privacy provisions of OMB Circulars A-71 and A-108 presented earlier in connection with the Privacy Act of 1974, the current threat of computer fraud, waste, and abuse has resulted in additional law and regulation. As a result of a series of acts from 1977 through 1980, all Executive departments have new offices of Inspector General (IG).

The IG's have no program responsibility but conduct and supervise audits and investigations relating to the programs and operations. The IG's monitor compliance with OMB Circular A-50, "Executive Branch Action of GAO Reports." These new IG offices were complemented in 1982 by the Federal Managers' Financial Integrity Act. The 1982 act requires annual program evaluations of the adequacy of systems (normally automated) for internal accounting and administrative control by each Executive agency. These evaluations are to be conducted under GAO standards and OMB guidelines. The act calls for personal accountability for any false or misleading information given during the system evaluations. OMB Circular A-123, "Internal Control Systems," addresses these concerns.

The computer security requirements of GSA's 1-4.1109-20 and FPMR 101-35.17 address the traditional forms of automation and, therefore, do not fully consider the security issues produced by the flood of low-cost computer devices into the office. Office automation introduces the threat of privacy or mission security breaches by many employees. It will result in growing security related problems and a management reaction. As a result, OPM will receive unprecedented requests for security clearance of individuals. Use of the data encryption standard and personal identification techniques will accelerate. Suddenly, everyone must be trained in security.

4.4 OMB CIRCULAR A-121, COST ACCOUNTING, COST RECOVERY AND INTERAGENCY SHARING OF DATA PROCESSING FACILITIES

The government-wide implementation of A-121 has not been evaluated recently. The realism of its provisions, particularly those which call for the capitalization of software, has been questioned. Today, it faces an uncertain future. It is reported that the Assistant Secretaries for Management Group will formally request OMB to withdraw A-121. If that should occur, GSA may be requested to publish A-121-type guidelines.

By contrast, many of the emerging IRM managers believe that the true economics expressed by cost accounting and cost recovery are the only "common language" to be spoken between the frustrated users and providers of information (resources). IRM managers question how a meaningful five-year plan can be drafted as required by the Paperwork Reduction Act if it is not linked to the national priorities expressed in the President's budget and congressional appropriations. GAO and the Congress are also calling for program by program accounting of what has been achieved with the dollars spent, not just for an accounting of how much was spent.

4.5 LOW-COST COMPUTING (MICROCOMPUTERS)

The 1965 Brooks Act was forward looking legislation. The Act's legislative history recognized the accelerating pace of technology and assigned to OMB and GSA the task of determining, from time to time, which systems were then to be considered general purpose, commercially available ADP and, therefore, subject to its mandates. This essential flexibility has been difficult for GSA to maintain.

Merging technology has blurred not only traditional vendor product manufacturing and marketing practices, but also traditional Federal functional constituencies, both of which resist redefinition of ADP. This has been particularly true in the so-called "office automation" area. User frustration with all centralized automation support, whether or not associated with the Brooks Act, has led to the massive acquisition of low-dollar value devices. Frequently employees have voluntarily bought low cost systems at their own personal expense. These home computers, personal computers, desktop computers, standalone word processors, and smart typewriters have at least temporarily revolutionized the traditional organizational focus of user system development from top down to bottom up. The resulting threat to security and the integrity of corporate procedures and databases is just being appreciated, not solved.

Likewise, there is an about face in the selection approach to low-cost systems (equipment). The traditional, centralized Brooks Act system selection approach by user agencies has remained heavily hardware oriented in spite of the GAO and GSA policies to the contrary. These policies encourage, if not direct, that major consideration be given to user software and technical requirements in addition to the price of the equipment. By contrast, the users and ADP professionals agree that the acquisition of low-cost computing should be driven by first selecting the needed software application packages and, thereafter, selecting compatible operating systems and hardware.

GSA attempts to define low-cost general purpose, commercially available systems and software as Brooks Act within the framework of the Federal catalog and item classification system operated by the Defense Logistics Support Agency (DLSA). GSA's classification attempts have not kept pace with the movement of technology and product application. The result has been a confusing blend of GSA acquisition regulations and multiple award schedule contracts which tend to destabilize both vendor market approaches and user agency attempts to manage through procurement control. To date, GSA's in-house contract programs have focused more on low-cost hardware systems than on software packages for use on them. GSA is implementing plans (June, 1983) for a contractor-operated "computer store" which could offer contractual sources for software and hardware, plus user advice and integration services. GSA also plans to publish a catalog of low-cost computer systems and software packages plus evaluation of the user friendliness of the software packages. Prior Federal programs designed to publish relative evaluations of commercial products have generally been withdrawn.

The user is clearly "in charge" of low-cost automation at this time. Now that the low-cost genie is out of the bottle, most IRM management is scrambling to meet user demands. The ADP professionals are threatened by loss of control, and most realize it. Ultimately an embrace between agency central control (plans/budgets) and users must occur. The Army plans to capitalize on user experience by picking the user created flowers and burning the weeds.

The Congress and agency headquarters will demand to know what is going on. These demands will soon lead to "inventories" of low-cost devices and software. GSA's draft changes to the government-wide ADP Management Information System (MIS) states that no perpetual inventory of low-cost devices will be established. GSA proposes authority to demand such inventories with a 60-day notice period.

4.6 STANDARDS

ICST plans to continue to work through the voluntary standards development process to ensure that a broad consensus is achieved as a basis for Federal standards. This is in agreement with OMB Circular A-119, entitled "Federal Participation in the Development and Use of Voluntary Standards." OMB states that no future Federal ADP standard will be approved unless it is <u>cost justified</u>. This concept is generally in line with Circular A-71, but indicates a more vigorous test will be applied.

The Federal Information Processing Standards (FIPS) are enforced through the GSA procurement regulations at the time of acquisition as are the Federal Telecommunications Standards (FED-STD). The Paperwork Reduction Act provision for a standards enforcement program, particularly software standards, awaits further implementation in its application to software system development and maintenance. FIPS Publications (FIPS PUBs) are also used to publish ADP management guidelines.

DoD's draft order 5000.5X proposed Army, Navy, and Air Force standards based on an instruction set architecture.* The DoD objective was to evolve a family of DoD-wide standards. This proposal drew sharp criticism from segments of industry and Congress. The House Government Operations Committee has requested hard numbers to justify this approach. DoD is in the process of responding to Congress, but it is unlikely that any quantitative data can resolve the political uncertainties of this issue. Most likely, the proposal will remain a policy issue to be resolved in the appropriations process. For example, the Army's Military Computer Family (MCF) which embodies the 5000.5X concept could resolve some, if not all, of Army's problems with proliferation of unique hardware and software. The Army's MCF is proceeding with reduced funding during FY 1983. Three vendors are in competition. They are GE (teamed with TRW), RCA, and Raytheon. FY 1984 funding will be required in order to proceed with the MCF program. It is impossible to determine whether the controversy is being caused by the Army's operational policy to avoid Ada recompiles on the battlefield for back up compatibility, or if it is but a symptom of manufacturer unhappiness with the diminishing market for the traditional mainframe product lines.

4.7 AGENCY IRM ORGANIZATIONS

OMB Bulletin 81-21 provided agencies with guidance on designation of their senior officials, but provided sufficient flexibility for each agency to organize as it deemed appropriate. This permitted each agency to establish an IRM organization which was responsive to both the needs of the agency and the requirements of the Paperwork Reduction Act. OMB's report, "Improving Government Information Resources Management, March 1982, stated that the primary responsibility for information resources management rests with the head of each department and agency.

* Military Computers in Transition: Standards and Strategy, Louise B. Becker, Congressional Research Service, the Library of Congress, February 3, 1982: "A computer instruction set architecture can be described as the rules and procedures by which the hardware executes instructions or computer programs (software). (Source: conversations with Peter Fonash (DoD) and William Diet (Carnegie Mellon University).) It also may be defined as the structure of a computer that a programmer needs to know to write time-independent machine language that will run correctly on the computer. (Source: The Department of Defense.) These definitions, although not universally accepted, are included here to provide a basic understanding of the concept."

OMB plans, when necessary and possible, to provide IRM policy guidance and assistance tailored to the needs of the individual agency. OMB plans to publish additional government-wide IRM policies and regulations only when it determines that there is overwhelming evidence that such policies are necessary and will be effective. OMB experience indicates that general management policies are difficult to enforce, particularly if there is no effective feedback on agency implementation.

Voice and data telecommunications are IRM functions which are being considered for reorganization. Many civil agencies have merged them into the new IRM organization. DoD services appear to view telecommunications in a more traditional sense of being mission critical and, with the exception of the Air Force, may not integrate it with other IRM functions in the near future. Where telecommunications has been merged with other IRM functions, most automation managers are struck by the size and cost of the voice communications program compared to data costs. They believe that GSA was unprepared for the substantial Federal Telecommunications System (FTS) cost increase brought on by the end of the Telpak tariff. These same IRM managers state that the surge in FTS costs has also caught the attention of their user functional managers. There are agency telecommunications cost studies underway. Early indications are for a further substantial centrex* cost increase within the next two years under the court ordered divestiture of the Bell Operating Companies and as a result of AT&T's creation of an unregulated subsidiary, American Bell Inc., by order of the Federal Communications Commission. In this environment, GSA can expect agency requests to permit prompt recompetition of agency PBX installations and intercity digital communications outside the FTS, pending its common user digital availability. Some cost studies indicate that in local area networks, in addition to the reduction in voice costs with a competitively acquired digital PBX, data communications costs will also be reduced substantially.

Recent announcements from DoD communications personnel indicate that they also are entering the information management era. DoD communications planners now consider how large the communications pipe should be for the <u>required</u> communications, not just how big a demand is initially expressed by users.

* The centrex (central/exchange) concept is a complete communications system at a "package" rate. The centrex packages offer PABX features, plus additional features which give the stations the characteristics of both an individual line and a PABX line. Centrex-CO switching equipment is located in the central office while Centrex-CU switching equipment is located on the customer premises.

5. CONCLUSION AND RECOMMENDATIONS

1. If GSA's Brooks Act role ever was a significant obstacle in the acquisition and management of automation, few agencies find it to be an obstacle today.

2. Congressional oversight is and will continue to be a fact of life for all IRM executives. It will result in political uncertainty for Executive agencies through the IRM cycle from concept to implementation. The 1982 IRM targets of the House Committee on Government Operations and its subcommittees, Attachment A, could just as easily have been initiated by an aggressive chairman in either house of the Congress. A mature view of our political system should appreciate that fact, even if without joy. Management objectives should be uncertainty-tolerant (contain fall-back alternatives).

3. The entire OMB Circular A-1Ø9 ("Major Systems Acquisitions") thesis for competitive prototype demonstration contracts, such as the Air Force's Phase IV program (fly-before-you-buy), will be examined. There is a growing tendency to permit well-informed managers to take a properly calculated risk.

4. Traditionally, control of ADP has resided centrally with ADP professionals -- a situation which has often frustrated the end-user. Low cost automation is user-controlled -- a situation which has caused many ADP professionals to feel threatened. The Department of Transportation's IRM project to "downsize" major systems applications to low-cost technology can serve as a pilot test "bridge" between the frustrated user and the threatened ADP professional. Its progress should be evaluated for interagency application.

5. The fundamental revolution which is underway emphasizes the following issues:

   a. The blending of traditional organizational segments which will integrate the converging technology;

   b. the major significance of telecommunications costs in IRM management;

   c. the benefits and threats of bottom up system development;

   d. the urgent need to distinguish between the management required for end-user computing which only facilitates a personal product and that which interacts with corporate databases or procedures.

INVESTIGATIONS FROM ACTIVITIES OF THE HOUSE COMMITTEE ON GOVERNMENT OPERATIONS, REPORT #97-994, DEC., 1982

INVESTIGATIONS RESULTING IN FORMAL REPORTS

1. *Continued Failure of Departments and Agencies to Take Effective Action on Audit Findings*, House Report No. 97-279, October 20, 1981, Eleventh Report by the Committee on Government Operations.

2. *Inadequate Control Over Government Material Furnished to Contractors*, House Report No. 97-381, December 10, 1981, Fourteenth Report by the Committee on Government Operations.

3. *NORAD Computer Systems are Dangerously Obsolete*, House Report No. 97-449, March 8, 1982, Twenty-third Report by the Committee on Government Operations.

4. *Mismanagement of SSA's Computer Systems Threatens Social Security Programs*, House Report No. 97-900, September 30, 1982, Twenty-third Report by the Committee on Government Operations.

5. *Statutory Offices of Inspector General (Leadership and Resources)*, House Report No. 97-211, July 30, 1981, Sixth Report by the Committee on Government Operations, Together with Additional Views.

6. *Air Force Control Computer Failures*, House Report No. 97-137, June 11, 1981, Third Report by the Committee on Government Operations.

7. *The Nine-Digit ZIP Code Investment: More Digits, Less Savings*, House Report No. 97-397, December 11, 1981, Nineteenth Report by the Committee on Government Operations.

8. *Direct Broadcast Satellites: International Representation and Domestic Regulation*, House Report No. 97-730, August 12, 1982, twenty-eighth Report by the Committee on Government Operations.

9. *Security Classification Policy and Executive Order 12356*, House Report No. 97-731, August 12, 1982, Twenty-ninth Report by the Committee on Government Operations.

10. *Postal Service Electronic Mail: The Price Isn't Right*, House Report No. 97-919, October 1, 1982, Forty-first Report by the Committee on Government Operations.

OTHER INVESTIGATIONS

1. Implementation of the Paperwork Reduction Act of 1980 (Public Law 96-511).

2. Review of Army's Automated Facilities Engineer Cost Accounting System.

3. Review of the Proposal for a Uniform Federal Procurement System.

4. Review of Discrepancies between GAO and the Summary Reports by the President's Council on Integrity and Efficiency of the Activities of Inspectors General.

5. Review of the Administration's Actions to Reduce Year end Spending Abuses.

6. Department of Energy Plans to Contract Out the Operations of the Forrestal Message Center and ADP Services.

7. Use of Internal Revenue Services Resources and Taxpayer Information for Draft Registration and Welfare Enforcement purposes.

8. Major problems with Small Business Administration's Section 8(a) Program for Disadvantaged Small Businesses.

9. Fraud, Waste, and Abuse at the General Services Administration.

10. Air Traffic Controllers' Strike--System Status in the Aftermath.

11. International Telecommunications and Information Policy: Management and Resources.

12. Federal Communications Commission Oversight.

13. Oversight of the National Archives and Records Service.

International Data Corporation's Computer Class Size Definitions and CPU Totals by Class Size

TABLE 1

COMPUTER SIZE CLASS DEFINITIONS
REPRESENTATIVE MODEL ASSIGNMENTS

Computer Size Class		IBM	HIS	UNIVAC	BURROUGHS	NCR	CDC	DEC	OTHER
GROUP D Desk Top		5100 5110 5150 (PC) System/23				7500 7900 Multivision		DDS 150 Rainbow 100 DECmate II Professional 325, 350	Apple II COMMODORE PET H-P 9825 87 Tandy TRS 80
GROUP C Small Business		System/32 System/34		BC-7	B20 B80, 800 B90, 900	8140 9020 9040		DDS 300 DDS 500	DE, CS/5, 10, 30 HP 250, 300 NIXDORF 8870 CADO SYSTEM 40 WANG 7200
GROUP B Minicomputers	1							PDP 11/03 LSI-11	DG MP100, 200 TI 990/4, 990/5
	2	Series/1	6/23 6/36	V77/200 V77-400			System 17 Cyber 18-20	PDP 8 PDP 11/04 PDP 11/34	DG NOVA 3/12 HP 2100 PRIME 200 TI 960
	3		6/43 6/47 6/57	V77-600 V77-700 V77-800			1700 Cyber 18-30	PDP 11/45 PDP 11/70	DG S/200 HP 3000-III PRIME 500
	4							VAX 11/730 VAX 11/750 VAX 11/780	DG MV/8000 PRIME 750 SYSTEMS 32/75

TABLE 1 (cont.)

COMPUTER SIZE CLASS DEFINITIONS
REPRESENTATIVE MODEL ASSIGNMENTS

Computer Size Class		IBM	HIS	UNIVAC	BURROUGHS	NCR	CDC	DEC	OTHER
GROUP A	2	System/ 38-3 System/ 3-4, 6, 8, 10	H-61/40 H-61/60	System 80-3 9200	B-1905 B-1815/20/ 30 B-1710	8270 8350 8410 Century 50, 75			
	3	System/ 38-5 System/ 3-12 370/115 4331-1	H-Level 62 H-2020 H-2030	System 80-5 90/30 9300	B-1955/85 B-1855 B-1860/70/ 80 B-1720	8370, 8430 8455, 8555 8450, 8550 Century 100 Century 151		2020	FUJITSU M140F FUJITSU M 130
	4	4331-2 4341-1, 10, 11 370/135, 138	DPS 8/20, 44 H-Level 64 H-2040 H-1200	90/40 90/60 9400/80	B-2900 B-3900 B-25/27/ 2800 B-35/37/ 3800	8565, 8575 8560, 8570 Century 200 Century 251	Omega 480-1 Cyber-71 3150 3200	2040, 2050 1040, 1050	IPL 4336-4446 Magnvson M80/31-42 Nat'l AS/3 HITACHI M 150 FUJITSU M 160F
	5	4341-2 370/145, 148	DPS 8/52 DPS 8/62 H-66/440 H-3200	90/80 1100/10, 20, 60	B-45/47/ 4800 B-5900 B-6800 B-6900	8550, 8585 Century 300	Omega 480-2 Cyber 170/ 720 Cyber 72 3300, 3500	2060 1060, 1070	Magnvson M80/43 Nat'l AS/4 HITACHI M 170 HITACHI M 240H
	6	3031, 3032 3033S 370/155, 158	DPS 8/70 H-66/60 H-8200	1100/40 1100/80, 81, 82 1106, 1107	B-65/6700	8650	Cyber 170/ 730 Cyber 170/ 750 Cyber 172, 173, 174 6400, 6500	1080, 1090	Amdahl 470 V/7C Nat'l AS/5
	7	3033N 3081 370/165, 168	H-66/80 H-68/80 H-68/DPS	1100/83 & 84 1108 1110	B-7700 B-7800	8670	Cyber 203, 205 Cyber 170/ 760 Cyber 74, 176 6600, 7600		Amdahl 470V/8 Nat'l AS/9000 HITACHI M 180 HITACHI M 200H FUJITSU M 380

TABLE 2

BURROUGHS CPU'S BY YEAR INSTALLED
Percent of Total

Group		CPU Total	<1976	<1979	1979	1980	1981	1982	Unknown
A-7	Fed. Govt.	4	50%	50%	50%	-	-	-	-
	Non-Govt.	113	10%	13%	11%	33%	14%	16%	1%
A-6	Fed. Govt.	13	46%	100%	-	-	-	-	-
	Non-Govt.	69	46%	94%	-	3%	3%	-	-
A-5	Fed. Govt.	23	17%	52%	13%	22%	13%	-	-
	Non-Govt.	682	17%	38%	16%	19%	17%	9%	1%
A-4	Fed. Govt.	129	81%	89%	4%	5%	1%	1%	-
	Non-Govt.	795	14%	35%	14%	15%	22%	11%	2%
A-3	Fed. Govt.	2	-	100%	-	-	-	-	-
	Non-Govt.	363	29%	51%	20%	14%	10%	5%	-
A-2	Fed. Govt.	62	3%	16%	3%	12%	68%	-	-
	Non-Govt.	1,082	10%	24%	20%	26%	21%	8%	2%
C	Fed. Govt.	7	57%	86%	-	14%	-	-	-
	Non-Govt.	1,208	20%	44%	12%	22%	17%	5%	1%
	Grand Total	4,556							

TABLE 3

CDC CPU'S BY YEAR INSTALLED
Percent of Total

Group		CPU Total	<1976	<1979	1979	980	1981	1982	Unknown
A-7	Fed. Govt.	72	78%	94%	6%	-	-	-	-
	Non-Govt.	81	56%	75%	12%	1%	4%	4%	5%
A-6	Fed. Govt.	63	81%	94%	-	3%	-	3%	-
	Non-Govt.	121	42%	61%	6%	13%	15%	5%	-
A-5	Fed. Govt.	60	92%	95%	3%	2%	-	-	-
	Non-Govt.	100	26%	34%	15%	24%	22%	4%	1%
A-4	Fed. Govt.	22	91%	100%	-	-	-	-	-
	Non-Govt.	52	25%	67%	19%	6%	6%	-	2%
B-3	Fed. Govt.	17	82%	94%	6%	-	-	-	-
	Non-Govt.	65	66%	89%	8%	3%	-	-	-
	Grand Total	766							

TABLE 4

DATA GENERAL CPU'S BY YEAR INSTALLED
Percent of Total

Group		CPU Total	<1976	<1979	1979	1980	1981	1982	Unknown
B-4	Fed. Govt.	39	79%	94%	3%	-	3%	-	-
	Non-Govt.	108	7%	7%	6%	2%	41%	40%	4%
B-3	Fed. Govt.	102	35%	77%	11%	8%	5%	-	-
	Non-Govt.	1,478	22%	53%	17%	15%	10%	5%	1%
B-2	Fed. Govt.	618	54%	88%	7%	3%	1%	-	1%
	Non-Govt.	2,398	35%	62%	11%	12%	13%	3%	1%
B-1	Fed. Govt.	2	-	50%	-	50%	-	-	-
	Non-Govt.	175	15%	29%	13%	26%	26%	5%	1%
C	Fed. Govt.	-	-	-	-	-	-	-	-
	Non-Govt.	287	9%	22%	22%	22%	28%	6%	-
	Grand Total	5,208							

TABLE 5

DEC CPU'S BY YEAR INSTALLED
Percent of Total

Group		CPU Total	<1976	<1979	1979	1980	1981	1982	Unknown
A-6	Fed. Govt.	1	-	-	-	100%	-	-	-
	Non-Govt.	87	20%	64%	10%	14%	6%	6%	1%
A-5	Fed. Govt.	-	-	-	-	-	-	-	-
	Non-Govt.	163	23%	45%	14%	16%	14%	8%	4%
A-4	Fed. Govt.	42	48%	74%	7%	19%	-	-	-
	Non-Govt.	250	43%	80%	5%	7%	4%	3%	1%
A-3	Fed. Govt.	4	-	-	25%	50%	25%	-	-
	Non-Govt.	68	6%	16%	37%	24%	12%	10%	1%
B-4	Fed. Govt.	29	-	-	31%	21%	41%	3%	4%
	Non-Govt.	1,090	15%	20%	7%	16%	26%	23%	7%
B-3	Fed. Govt.	352	36%	78%	11%	6%	4%	1%	-
	Non-Govt.	3,095	24%	56%	13%	13%	13%	5%	1%
B-2	Fed. Govt.	2,539	59%	87%	6%	4%	2%	1%	-
	Non-Govt.	7,026	52%	77%	9%	7%	4%	2%	1%
B-1	Fed. Govt.	171	1%	50%	20%	16%	12%	3%	-
	Non-Govt.	1,892	28%	52%	9%	15%	18%	6%	1%
C	Fed. Govt.	37	3%	100%	-	-	-	-	-
	Non-Govt.	373	17%	50%	15%	13%	16%	5%	1%
	Grand Total	17,238							

TABLE 6

HONEYWELL CPU'S BY YEAR INSTALLED
Percent of Total

Group		CPU Total	<1976	<1979	1979	1980	1981	1982	Unknown
A-7	Fed. Govt.	6	17%	84%	16%	-	-	-	-
	Non-Govt.	26	27%	62%	8%	8%	15%	8%	-
A-6	Fed. Govt.	41	66%	98%	2%	-	-	-	-
	Non-Govt.	229	27%	47%	16%	16%	17%	4%	-
A-5	Fed. Govt.	10	60%	90%	10%	-	-	-	-
	Non-Govt.	187	37%	75%	7%	7%	7%	3%	1%
A-4	Fed. Govt.	94	68%	80%	16%	2%	2%	-	-
	Non-Govt.	779	38%	63%	12%	10%	9%	5%	1%
A-3	Fed. Govt.	29	97%	97%	3%	-	-	-	-
	Non-Govt.	773	33%	76%	13%	7%	3%	1%	-
A-2	Fed. Govt.	-	-	-	-	-	-	-	-
	Non-Govt.	44	82%	93%	2%	-	5%	-	-
B-3	Fed. Govt.	-	-	-	-	-	-	-	-
	Non-Govt.	288	22%	39%	14%	17%	18%	12%	1%
B-2	Fed. Govt.	285	81%	96%	1%	2%	1%	-	-
	Non-Govt.	652	35%	45%	13%	16%	18%	5%	3%
C	Fed. Govt.	4	-	25%	-	50%	25%	-	-
	Non-Govt.	1	-	-	-	-	100%	-	-
	Grand Total	3,477							

TABLE 7

H-P CPU'S BY YEAR INSTALLED
Percent of Total

Group		CPU Total	<1976	<1979	1979	1980	1981	1982	Unknown
B-3	Fed. Govt.	31	10%	39%	16%	23%	19%	3%	-
	Non-Govt.	2,178	11%	33%	16%	19%	18%	12%	2%
B-2	Fed. Govt.	468	50%	76%	10%	9%	5%	-	-
	Non-Govt.	883	49%	67%	10%	11%	8%	3%	1%
B-1	Fed. Govt.	1	100%	-	-	-	-	-	-
	Non-Govt.	242	52%	90%	3%	3%	4%	-	-
C	Fed. Govt.	3	-	-	33%	67%	-	-	-
	Non-Govt.	108	10%	17%	14%	30%	30%	8%	2%
	Grand Total	3,917							

TABLE 8

IBM CPU'S BY YEAR INSTALLED
Percent of Total

Group		CPU Total	<1976	<1979	1979	1980	1981	1982	Unknown
A-7	Fed. Govt.	87	52%	73%	5%	10%	11%	1%	-
	Non-Govt.	1,974	13%	29%	19%	18%	16%	14%	4%
A-6	Fed. Govt.	109	71%	87%	7%	4%	2%	-	-
	Non-Govt.	2,209	18%	43%	26%	14%	8%	5%	4%
A-5	Fed. Govt.	77	69%	83%	4%	9%	4%	-	-
	Non-Govt.	1,946	13%	36%	9%	12%	22%	18%	3%
A-4	Fed. Govt.	139	67%	76%	4%	10%	9%	1%	-
	Non-Govt.	5,224	16%	28%	5%	19%	32%	12%	4%
A-3	Fed. Govt.	91	63%	76%	12%	8%	4%	-	-
	Non-Govt.	5,183	22%	50%	9%	19%	15%	5%	2%
A-2	Fed. Govt.	143	91%	99%	1%	-	-	-	-
	Non-Govt.	4,142	48%	55%	2%	7%	21%	10%	5%
B-2	Fed. Govt.	25	28%	52%	4%	32%	12%	-	-
	Non-Govt.	1,562	13%	27%	19%	24%	22%	7%	1%
C	Fed. Govt.	16	13%	64%	13%	19%	6%	-	-
	Non-Govt.	9,678	9%	32%	23%	26%	14%	4%	1%
	Grand Total	32,623							

TABLE 9

IBM PCMS CPU'S BY YEAR INSTALLED
Percent of Total

Group		CPU Total	<1976	<1979	1979	1980	1981	1982	Unknown
A-7	Fed. Govt.	7	14%	43%	-	57%	-	-	-
	Non-Govt.	306	21%	42%	12%	21%	14%	10%	1%
A-6	Fed. Govt.	15	-	67%	19%	7%	-	7%	-
	Non-Govt.	202	9%	39%	25%	18%	12%	4%	2%
A-5	Fed. Govt.	-	-	-	-	-	-	-	-
	Non-Govt.	59	2%	20%	22%	27%	17%	14%	-
A-4	Fed. Govt.	-	-	-	-	-	-	-	-
	Non-Govt.	218	11%	13%	7%	26%	38%	16%	-
	Grand Total	807							

TABLE 10

NCR CPU'S BY YEAR INSTALLED
Percent of Total

Group		CPU Total	<1976	<1979	1979	1980	1981	1982	Unknown
A-5	Fed. Govt.	-	-	-	-	-	-	-	-
	Non-Govt.	68	38%	56%	12%	18%	12%	1%	1%
A-4	Fed. Govt.	6	83%	100%	-	-	-	-	-
	Non-Govt.	417	27%	54%	10%	16%	10%	8%	2%
A-3	Fed. Govt.	1	-	-	-	-	100%	-	-
	Non-Govt.	1,169	25%	46%	14%	23%	13%	4%	-
A-2	Fed. Govt.	1	-	-	100%	-	-	-	-
	Non-Govt.	312	21%	30%	18%	28%	19%	5%	-
C	Fed. Govt.	11	-	-	27%	-	73%	-	-
	Non-Govt.	675	13%	41%	15%	12%	16%	13%	2%
	Grand Total	2,661							

TABLE 11

UNIVAC CPU'S BY YEAR INSTALLED
Percent of Total

Group		CPU Total	<1976	<1979	1979	1980	1981	1982	Unknown
A-7	Fed. Govt.	42	45%	60%	17%	21%	2%	-	-
	Non-Govt.	59	63%	85%	2%	8%	3%	-	2%
A-6	Fed. Govt.	62	84%	92%	6%	2%	-	-	-
	Non-Govt.	216	30%	45%	19%	18%	13%	4%	1%
A-5	Fed. Govt.	38	68%	82%	13%	5%	-	-	-
	Non-Govt.	384	15%	30%	11%	22%	27%	7%	3%
A-4	Fed. Govt.	79	92%	97%	3%	-	-	-	-
	Non-Govt.	299	42%	63%	17%	10%	6%	3%	1%
A-3	Fed. Govt.	123	66%	88%	11%	1%	-	-	-
	Non-Govt.	674	26%	76%	10%	7%	4%	2%	1%
A-2	Fed. Govt.	31	87%	100%	-	-	-	-	-
	Non-Govt.	284	48%	51%	2%	2%	29%	14%	2%
B-3	Fed. Govt.	70	30%	68%	22%	5%	5%	-	-
	Non-Govt.	235	37%	61%	11%	20%	4%	3%	1%
B-2	Fed. Govt.	107	79%	98%	2%	-	-	-	-
	Non-Govt.	263	90%	96%	2%	2%	-	-	-
B-1	Fed. Govt.	4	-	100%	-	-	-	-	-
	Non-Govt.	4	-	25%	-	50%	25%	-	-
C	Fed. Govt.	8	63%	87%	13%	-	-	-	-
	Non-Govt.	144	8%	42%	34%	15%	7%	1%	-
	Grand Total	3,152							

TABLE 12

WANG CPU'S BY YEAR INSTALLED
Percent of Total

Group		CPU Total	<1976	<1979	1979	1980	1981	1982	Unknown
C	Fed. Govt.	161	30%	81%	11%	6%	2%	-	-
	Non-Govt.	1,530	22%	43%	13%	18%	17%	8%	1%
	Grand Total	1,691							

PART VI: MANAGING END-USER COMPUTING

Prepared by

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Contract Number NB8Ø5BACAØ4Ø5
Institute for Computer Sciences
and Technology
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PREFACE

Following publication of the 1981 technology forecast, a poll of the Federal agencies elicited several requests to address, in this edition, management aspects of end-user computing. Part VI responds to those requests. The material contained in this Part builds on recent work done at the Environmental Protection Agency by EPA's Harvey Karch. The opinions presented in this Part, however, are those of the contractor and not necessarily those of either ICST or EPA.

End-user computing has, in a sense, "snuck up" on us, presenting both the public and private sectors with some completely unfamiliar situations. Researchers and managers in both sectors are only now beginning to recognize and describe the dynamics of those situations. This Part examines end-user computing from the organizational aspect, with particular emphasis on the management of change.

There are several critical end-user computing issues which are not addressed in this Part. Many of those issues are currently under study by ICST, GSA, OMB and others. OMB's Reform '88 initiative, for instance, is considering "action" proposals in these -- as well as other -- ADP issue areas which would help to define more clearly the appropriate roles of the central management agencies.

The host of issues involved in the interaction of microcomputers with larger machines are only touched on in this Part. That aspect of distributed processing is a candidate subject for examination in the next update of the technology forecast; telecommunication, from both technical and management perspectives, is another candidate. We would appreciate further suggestions for topics to be covered in subsequent editions.

Other publications relating to end-user computing are currently being prepared by ICST. The ICST Special Publication, Microcomputers: A Review of Federal Agency Experience is now available from GPO.

1. INTRODUCTION

Preceding Parts of this report have examined future information processing from three perspectives: the technological changes which are likely to occur through the 1990's; cost estimates of these future systems; and, with respect to the Federal government, the legal and regulatory environment in which these systems must operate. Part VI deals with information processing from still another perspective -- that of the management issues which are associated with the new technologies, especially those related to the introduction and widespread use of end-user computing in the Federal workplace.

End-user computing refers to a relationship between people and technology, in which individuals, located at their own work stations, interact directly with computers to process their own information. The term is deliberately very broad. It includes new technologies of office automation and personal computing which enable individuals to perform such functions as word processing and data analysis, thereby using and manipulating information directly and independently.

It is increasingly obvious that end-user computing is a rapidly growing phenomenon that will have a dramatic impact on the office environment, including that within the Federal government. The purpose of Part VI is to take a closer look at this phenomenon, specifically:

- o to identify major issues regarding management in an end-user computing environment;
- o to examine these issues in terms of their likely impact on the Federal workplace; and,
- o to suggest strategies to facilitate the transition to that environment.

The remainder of this Part consists of six chapters:

Chapter 2 defines the nature of the problem and examines the concept of information resource management.

Chapter 3 looks at the economic implications of end-user computing; focuses on two important aspects of the Federal government context which are related to and affected by end-user computing; identifies general management issues; and presents a candidate list of specific questions which a Federal agency might pose to itself in the process of implementing the new technologies.

Chapter 4 reviews the status of end-user computing in the private sector.

Chapter 5 reviews the status of end-user computing in the Federal government, examining both the roles and leadership approaches of the central management agencies and the approach and progress which some operating agencies have made to date.

Chapter 6 discusses principles of managing change and suggests ways to minimize the resistance to change.

Chapter 7 presents conclusions about the management aspects of end-user computing and suggests ways for the Federal government to approach the problem and to facilitate the transition.

A list of major references is provided following chapter 7, identifying source material which was used in preparing this Part of the document.

2. THE NATURE OF THE PROBLEM

2.1 END-USER COMPUTING WITHIN THE CONTEXT OF INFORMATION RESOURCE MANAGEMENT

While this Part of the report deals specifically with end-user computing, the basic principles of Information Resource Management (IRM) should be kept in mind since end-user computing is a particular area of focus within that larger concept. IRM is a management perspective that has been developing for many years. As an approach to managing the handling of information within an organization, it aims to improve both the efficiency of the systems which process the information and the effectiveness of the ways in which the information is actually used.

In the IRM framework, information is explicitly acknowledged to be an asset of an organization and a high-cost resource requiring specifically focussed managerial attention. In the broadest sense of the term:

- o Information resources include an organization's information and data, as well as the systems which relate to all aspects of handling the information, such as data processing, office automation, records management, and library services.

- o Management deals with the policies and procedures which an organization utilizes to oversee these resources and administer the information collection, processing and dissemination functions.

In many ways, IRM is a logical outgrowth of management information system concepts which have long been a part of the ADP environment. However, while IRM may have partly evolved from that tradition, managing information is not the same as managing data processing technology. The IRM environment of the 80's is different from the ADP environment of the 60's and 70's in two fundamental ways. These differences are at the root of the significant management challenge posed by end-user computing:

- o People are more expensive than technology. In the past, data processing hardware cost millions of dollars and required huge investments in money, space and facilities. Now, microcomputers are available at a fraction of the cost of one year of personnel time and are small enough to sit on an individual desk. Customized software can cost many times the price of the machine.

- o The new technology is increasingly user-friendly. Data processing specialists are less necessary than they were in the past for retrieving and analyzing information. More and more users will interface directly with their own data.

As the Federal government considers how to cope with those differences, it would do well to put them in the context of IRM.

2.2 MANAGING CHANGE: THE BASIC PROBLEM CONCERNING END-USER COMPUTING

The essence of the management problem with respect to end-user computing, especially in the short term, is that of managing change. What is changing is the information handling environment: that set of policies and procedures, roles and responsibilities, which characterize the way offices use information to perform their work.

A transition is being made from an environment in which information is collected, processed, and distributed by ADP specialists for use by others, to one in which the users themselves interact directly with their own information. This is not merely a question of introducing faster typewriters, replacing mechanical adding machines with electronic calculators, or even upgrading a computer mainframe installation from, say, an IBM 7090 to a system 370. The transition is not merely one of improved speed or efficiency in the usual sense of those words. Rather, it is a qualitative transition, involving serious changes in the patterns of work which characterize most of the white collar world and which will have impact on the most basic office relationships: between people and technology; between people and information; and between people and other people.

To formulate a meaningful and effective managerial response, it is necessary to be aware of what these changes will entail. Those in charge of the transition process need to understand the management issues which they will face, and the characteristics of the workplace in which the changes will occur. Managers need to know what the work patterns are now and what they are likely to be in the future. Equally important, since the way the transition process is handled will be a critical factor in determining whether it is a positive or disruptive experience, managers need some insight into the dynamics of the change process itself.

Thus, with respect to the management of end-user computing in the Federal government, what is necessary is a conscious, planned, process to enable Federal government managers to exploit the new technologies in ways which will maximize the efficiency, effectiveness, and overall health of their agencies. Accomplishing this requires that the following questions be addressed: [1]

- Where are we?
- Where do we want to be?
- How do we get from where we are to where we want to be?

3. MANAGEMENT ISSUES

3.1 ECONOMIC IMPACT OF END-USER COMPUTING

End-user computing is sometimes referred to as "low cost technology". Generally, what is meant is that small, desk-top, "personal" computers and accompanying packaged software are inexpensive compared to large, centrally operated, mainframe installations. Moreover, these systems, which cost only a few thousand dollars, can be used virtually from the first day, by people with no data processing experience whatsoever, and have the memory and capacity of large computers, which only a few years ago cost millions of dollars, and still require large staffs and specialized programming to utilize.

Unfortunately, that comparison is misleading because it is incomplete. The fact is, the total cost of any system includes much more than the costs of the hardware and software. There are at least three categories of expense which are of great significance to any organization: the aggregate cost of the technological investment; the cost of the personnel time necessary to utilize that investment; and the opportunity cost to the organization incurred by utilizing the investment. In order to understand the economic implications of widespread use of end-user computing, a relevant point of comparison is the telephone.

The telephone was the first and still remains the most familiar piece of user-friendly technology. It is an input/output information-handling device; the cost of each individual instrument is low: well under $100 in most cases.

What is not low are other categories of telephone-related expenses: e.g., the expense of sending messages along the multi-million mile network and the cost of the time spent by workers who use the telephone system. In fact, use of the telephone consumes a vast amount of the on-the-job time of many office workers. Thus, it isn't the cost of each individual instrument that is significant; rather it is the totality of the impact that the telephone has on the working styles and use of time of the office personnel, particularly those in professional and managerial positions.

The telephone system exists in its current size and complexity because, over the years, numerous judgments and decisions have been made which fostered the growth of the system. Society's economic and social values encouraged and supported this kind of technological development. Elaborate, sophisticated communications which non-technical people are able to utilize have always been considered desirable, as much for quality-of-life reasons as for purposes of efficiency, effectiveness and productivity improvement. End-user computing is a natural product of this development history.

However, viewed from this perspective, end-user computing is far from low cost. While each individual microcomputer may be cheap, the aggregate amount of the investment is huge. And, as the number of small computers in use grows, the cost of personnel time spent using those machines, including professional and managerial time, will grow accordingly. Moreover, the additional factor of opportunity cost--the time spent doing analysis or word processing on one's "own" computer (work that in the past was done by ADP specialists or secretarial staff) could be used to do other tasks.

It is true that not all the time spent using microcomputers is incremental. Micros are tools which people should be able to utilize to do their regular work better. Thus, writers may compose their copy directly on a word processor and executives can use decision support systems to help them select appropriate alternatives. Still, the power of the technology often defines the scope of the work (Is there more or less paper in offices since the invention of the Xerox?). The availability of the technology can create its own demand, particularly for such things as customized software and elaborately formatted documents.

Finally, especially in the case of the Federal government, there is the additional cost of oversight. Government procurement regulations tend to be complex, and even if they are simplified vis-a-vis the acquisition of microcomputers and similar technology, there will still be costs associated with those acquisitions.

Similar factors comprise the total cost of traditional ADP systems. However, although the cost of the hardware was high--many millions of dollars--much of that is sunk cost, the investment having already been made. Now the big expenses are often those of software development, operations, and maintenance and the expense of large numbers of specialized data processing personnel to develop, utilize and modify existing systems. The opportunity cost question also applies. Time spent patching and running old, sometimes inefficient, or even obsolete systems cannot be used to meet new requirements and respond to growing needs. This is a major cause of the user frustration, a common sentiment among non-DP personnel. There are the other costs as well: space and utilities, for example.

Much as the telephone grew in the complexity and sophistication of its network, we expect similar growth related to end-user computing. We are already seeing the need for interfaces between microcomputers and other micros, and between micros, minis and large central systems. Hence, when all the costs of development, support, and maintenance of an end-user computing environment are taken into account, the cost of the desk-top unit itself is the least significant component of the total.

This is not to suggest that no more investment in large mainframe systems will be made. These systems will certainly be around for quite a while, although they will tend to be used for the narrower range of tasks for which they are extremely efficient, scientific computing and those large batch processing systems especially suited to central control, for example. Part of the management challenge is to strike a balance between utilizing old systems, enhancing them in many cases, and converting others to an end-user focus. Many of the biggest savings in administrative streamlining have already been realized because the early development of large ADP systems was clerically and administratively oriented. The new end-user technology focusses on a different aspect of office work--that which is more related to professional analysis and managerial decisionmaking. In these areas, work products are much less tangible, and cost-effectiveness and productivity are far more difficult to measure.

Thus, economic issues regarding the new technology are more those of resource management than simple cost cutting. Ultimately, decisions about the use of the new technology will be more a question of reallocating resources than simply saving dollars.

3.2 THE FEDERAL GOVERNMENT CONTEXT

3.2.1 The Paperwork Reduction Act

In terms of information resource management, the Paperwork Reduction Act (PRA) of 1980 has had a major impact on the Federal government. The purposes of the Act are to minimize the Federal paperwork burden on the public; to minimize the cost to the Federal government of collecting, maintaining, using, and disseminating information; to maximize the usefulness of the information; and to coordinate Federal information policies and practices. Among the areas covered are information collection requests directed to the public; Federal statistical activities; records management activites; privacy of records; interagency sharing of information; and the acquisition and use of ADP and telecommunications technology. The scope of the PRA covers virtually all aspects of end-user computer use and technology.

Among the provisions of the PRA, the following are of particular significance to the management of end-user computing:

- Each agency must designate a senior official, who reports directly to the head of the agency, to carry out the agency's responsibilities under the Act.

- The Office of Management and Budget is at the top of the Federal organizational hierarchy to manage Federal information resources.

The PRA has had the effect of raising the level of awareness of many Federal managers as to the importance of IRM and the value of agency resources that are involved in collecting, processing, and disseminating information. But, there are problems too. The PRA emphasizes central consolidation and management of information; yet the GAO has observed that it may be desirable that IRM policy and oversight functions be separate from the direct management of agency computer and related operations.[2] Agencies need to consider this point when setting up their internal IRM structures. The decentralized nature of end-user computing will also make central control difficult. Problems of redundancy and quality of information, two important areas of PRA concern, are not likely to be easily addressed through management approaches that emphasize strong central control.

Finally, while the PRA greatly strengthens the role of OMB in terms of Federal information resources oversight, OMB, in turn, has prepared little guidance to the agencies for implementing the Act's provisions. Thus, great variation exists among Federal agencies in the nature and effectiveness of their approach to IRM and PRA compliance.

3.2.2 Federal Management Roles

The responsibility for managing Federal information resources rests in a number of different positions in the Federal workplace. Figure 3.1 identifies key Federal management positions, with respect to end-user computing and summarizes their corresponding roles and responsibilities.[3]

3.3 MICROPROCESSING ISSUES

This section describes the major management issues related to end-user computing in the Federal government. In a conceptual paper prepared for the Department of Defense, Arthur Young and Company highlighted the following six management issues especially related to microprocessing.[4]

3.3.1 Control of Acquisition and Use

The issue of control begins with the fundamental question of whether control over the acquisition and use of microcomputer systems is desirable, or whether it will serve only to obstruct the initiative of managers to find innovative, cost-effective applications for the new technology. If control is desirable, the most appropriate level for control needs to be identified.

Ultimately, some degree of control is necessary to ensure compatibility of resources and to promote sharing through networking or integration with mainframe systems and to ensure compliance with data security and privacy laws and with applicable Federal procurement regulations and the PRA.

Type of Manager	Significance and Implications of Role	Future Opportunities
• Executive Managers: Political appointees, typically the Assistant Secretary for Management or Administration.	• Most influential government officials with respect to the future of office technologies; but, they often have limited experience in managing technology and can't always get good advice. • Short-term tenure (usually 18-24 months) encouraging search for short-term solutions.	• Need to create the proper environment for new technology--neither forcing nor constraining. Policies and procedures should be comprehensive and Agencywide in application. • Used to ensure that help is provided to functional managers making technological decisions.
• Oversight Managers: Staff personnel in IRM technology who establish policy; prepare directives and guidelines; review, audit, and approve IRM-related plans and activities. Most oversight officials are control oriented.	• Current oversight policies were developed for large, central computing facilities--small number of cases to review, each representing very large dollar investment. End user systems are smaller and more numerous, with dollar costs generally below oversight purview. • Pace of new technology development is often faster than time it takes for the government to develop new policies relating to that technology.	• Procurement processes and guidelines need to be simplified, to be able to keep up with the pace of development. • Oversight managers will need assistance to make a transition to a role which emphasizes leadership through incentives and service more than the exercise of control.
• Functional Managers: End-users; government line managers such as comptrollers, tax policy analysts, personnel managers, customs inspectors.	• In the past, they have relied on ADP specialists regarding use of technology. Have often been frustrated by backlogs and latter's inability to respond quickly to new requirements. • Are now beginning to make their own decisions about systems for their own use. They are inundated with technological information, which they are not equipped to evaluate, and are often overwhelmed by procurement requirements.	• As the focal point of end-user computing, this group needs the most help in order for their agencies to achieve maximum benefit from the new technologies.

FEDERAL MANAGEMENT ROLES AND END-USER COMPUTING
Figure 3.1

Type of Manager	Significance and Implications of Role	Future Opportunities
• Technical Managers: Senior ADP managers, who traditionally have controlled most resources and decisions concerning the allocation of information systems resources.	• Traditional ADP utilizes center control; end-user computing emphasizes decentralized technology and decision making. • Are responsible for most of the progress made in the last 20 years in streamlining government operations and administration. Much effort is devoted to maintaining these large, central systems. • Functional managers will probably soon want to link their own systems with the central systems. Interface may be difficult or impossible because technical managers were not involved when end user systems were procured.	• Will still have a role in managing and controlling large complex systems and technology. • Need to develop a more service-oriented, rather than control-oriented approach to make an effective contribution in an end-user environment.
• Information Resources Managers: New management position, embodied in the Paperwork Reduction Act, intended to provide a unifying focus for the management of all information-related resources.	• IRM is based on the concept that information is not free and needs to be managed like any other organizational resource. • End-user computing is one function under IRM.	• Need to find ways to satisfy information needs at any acceptable cost, while exploiting new technology. • Need to develop policies and procedures which integrate end-user computing into an overall information management structure.

Source: "Managing End-User Computing in the Federal Government." [3]

FEDERAL MANAGEMENT ROLES AND END-USER COMPUTING
Figure 3.1 (continued)

3.3.2 *The Role of Microcomputers in Relation to Mainframes and Minicomputers*

ADP professionals will need to develop expertise in the process of identifying which functions are most appropriately handled on a mainframe, a minicomputer or a microcomputer. For example, options for micros include using them as standalone processors and as remote terminals to provide decentralized access to centralized systems. In addition to calling for considerable technical expertise, the clarification of micro roles will require a senior management perspective on organizational and personnel issues.

3.3.3 *Application Areas and Sequence for Introduction*

Microcomputers have numerous potential applications, from enhancing word processing to supporting management decision-making. The management issue is in identifying where the systems can be used most effectively and determining the sequence for introducing the applications. A period of experimentation and use of prototype installations may be useful.

3.3.4 *Pace for Introduction and Integration*

Too rapid a pace involving a large number of applications over a broad range of user groups could cause failures, widespread disillusionment, and implementation of incompatible systems. On the other hand, an extremely slow pace could cause dissatisfaction among users who are eager to install the systems immediately and could cause a delay in achieving higher degrees of cost-effectiveness. Here again, the selection of pilot sites may be useful.

3.3.5 *Roles and Responsibilities of Users, ADP, and Word Processing Professionals*

The development of new roles and responsibilities is perhaps the most demanding management issue, as the traditional division of duties changes with the introduction of the new technology. In addition, there is a critical need to identify changing organizational structure requirements, to define and assign responsibilities for activities as they relate to microcomputers. These activities include planning; acquisition; application system development; system operation; hardware and software maintenance; training; and compliance reviews. The definition and assignment of these responsibilities may have significant impacts on organizational structures, job descriptions, hiring goals and training needs for technical and user personnel.

3.3.6 *Support Structure*

An important management question is how will microcomputer systems be acquired, maintained, and operated? One issue is whether a central acquisition support structure can foster increased compatibility by acquiring these units at volume discounts, without "locking out" new products and and possibly "locking in" to older technology. The support question also includes issues relating to software development and maintenance techniques and practices for large quantities of microcomputers.

With the above issues in mind, as the Federal agencies begin to formulate their end-user computing policies, they should assemble a checklist of questions to be addressed. An exemplar list follows.

- What management decisions are to be made, using information processed by micros.

- In an end-user computing environment, who would "own" the information on which institutional decisions are based?

- How much leeway should program managers have regarding the acquisition and use of microcomputers?

- In the future, professional staff are likely to have more direct access to the information they need and use. How will this affect supervisory patterns? How will this affect the roles of the traditional ADP staff?

- Should we maintain an in-house capability to train our staff in the new technologies?

- Should we require some type of computer training for all staff? For certain categories of staff?

- What tasks should we automate and what tasks are better done manually?

- If our agency were to establish a central support group for end-users, how should it be funded? Should end-users be required to use the group or should they be able to use services outside the agency?

4. END-USER COMPUTING IN THE PRIVATE SECTOR

4.1 CORPORATE SURVEY

Occasional articles in the business and trade literature recount how well the private sector is utilizing the new technology. Readers are often left with the impression that private industries have made an easy transition to an end-user computing environment and that they are rising to the technological and management challenge with an orderly, well planned, rational approach. The results of a corporate survey, based on replies from 250 respondents, published in *Datamation* in November 1982 provides some interesting information about use of "personal business computers" (PBC's) in private sector companies.[5] Following are some highlights from that survey:

- Most companies do not know with absolute certainty the actual number of PBC's they have paid for, let alone the users or uses to which they are applied.

- Only eight percent of the corporate respondents indicated that firm guidelines governing the acquisition of PBC's were in place. Only 24 percent reported that informal rules were being applied toward the purchase on an experimental basis, leaving about 67 percent with no guidelines or procedures in place. Of the latter, only 36 percent stated intentions to implement guidelines.

- With respect to approval authority, nearly 55 percent stated that the DP department was involved in the cycle, and in about one-third of the companies, the DP department had absolute approval or veto power over PBC acquisition. User departments approved acquisitions in 43 percent of the firms while purchasing departments had such authority in only 14 percent.

- The survey indicated a degree of confusion about setting policies, as well as a lack of planning, strategic or otherwise, in the implementation of PBC's as part of an overall information system.

4.2 CENTRAL INFORMATION SYSTEMS SUPPORT

Some companies have identified and taken specific steps to manage the new technology. One approach, in particular, may hold some lessons for the Federal government. It is the establishment of a central group, within an organization, to provide information systems support to all levels of users throughout the organization. The structure seems to provide a mechanism for an organization to maintain central control, while still providing non-ADP personnel with the advice and help they require to utilize the new technologies.

As part of its work for the Department of Defense on the management of microcomputer technology, Arthur Young and Company studied nine large firms.[6] The companies had several characteristics that are similar to those of at least some government agencies: most are organized into autonomous service units, with their own management hierarchies; their work force encompasses most labor categories, including executives, managers, professionals, technicians and clerical workers; and the companies are strongly dependent on information processing to accomplish their work.

The study presented some interesting conclusions concerning management of the new technology:

- "A closer working relationship between end-users and data processing professionals will be required in order to plan for and use microcomputer technology successfully.

- There is an increased need for data processing support services to be provided outside the traditional data processing organization, directly within functional business segments of companies.

- An increasing concern over compatibility of information and software will replace the former concern with hardware standardization.

- Rapid advances in microcomputer technology and the frequency of new product offerings on the market have generated a requirement for large organizations to establish a method and structure for continuous monitoring and assessment of advanced technology.

- Through the continuous assessment process, equipment and software products of particular importance for the organization can be selected and processed before users have recognized the need. The products are then readily available for installation when the need is expressed.

- There is a significant increase in the need for education of end-users and data processing professionals in the application and management of the new, low cost technology."

The vehicle that the nine companies used to address these issues and to manage their new technologies is the central information systems support group. Because this concept appears to hold considerable potential and may provide a generic model that can be adapted by government agencies, it is explored here in some detail.

The central support groups of the nine firms revealed both similarities and differences in terms of their management philosophies as well as their modes of operation. (This information is summarized in table 4.1.) All of the central systems support groups, for example, provide the following services.

- monitoring technology trends,
- developing micro expertise,
- disseminating technology information,
- assisting users in system selection,
- trouble-shooting -- operation and maintenance,
- evaluating hardware vendors,
- evaluating software packages, and
- negotiating volume procurements.

On the other hand, the firms differ with regard to other services provided by their central support groups. The differences may be functions of the specific workplace demands in each firm, its over-all management philosophy or a combination of the two. The following services are provided by a subset of the nine firms.

- designing/delivering training (3 of the 9),
- building compatible architecture (3 of the 9),
- establishing a central demonstration room (2 of the 9),
- offering standard application systems (1 of the 9), and
- establishing an information center (none at present).

The concept of the central information systems support group continues to evolve, with several of the companies indicating their intention to expand the range of services they provide to users.

There are a number of functions that are necessary to the management, procurement, and use of ADP hardware and software, and the companies differed considerably in where they placed responsibility for each -- with the central group, the end-user, or shared between the two. These functions include:

- long-range planning,
- requirements analysis,
- hardware selection,

Table 4.1

OVERVIEW OF PRIVATE INDUSTRY LOW-COST COMPUTING STRATEGIES*

Company	Degree of Central Control	Strategic Goals of Management	Services Provided by Central Support Group: Monitor technology trends	Develop micro expertise	Disseminate technology information	Assist Users - System selection	Trouble-shoot (Oper. & Maint.)	Evaluate hardware vendors	Evaluate software packages	Negotiate volume procurements	Design/deliver training	Build compatible architecture (Micro/Mini/Maxi)	Establish central demo room	Offer standard appl. systems	Establish information center	Locus of Responsibility for Microcomputer Functions: Long-range planning	Requirements analysis	Hardware selection	Software package selection	Procurement negotiation	Application system development	Installation	Training	Operations	Maintenance	Post-installation review
1	High	Serve as mild inhibitor to user initiatives in acquiring micros while establishing place for the system in company network	✓	✓	✓	✓	✓	✓	✓	✓						S G	S	S G	S	S G	S G	S G	U	S G	S G	S G
2	High to Medium	Foster creative but cost effective use of micros, gauging the level of control needed by the systems' impact on the Co.	✓	✓	✓	✓	✓	✓	✓	✓						S G	U	U	U	S G	S	U	U	S	S	S G
3	High to Medium	Enhance the efficiency of operations through use of small computers as decision support mechanism	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		S G	S	S	S G	S G	S	U	S G	U	U	S G
4	Medium	Encourage & support appropriate use of micros & other office automation tools in micro mini maxi network	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓			S G	U	U	S	S	U	U	S	U	U	S G
5	Medium	Lead the inevitable advance of personal computers in the company through providing advice and support to users	✓	✓	✓	✓	✓	✓	✓	✓	✓					S G	U	S	S	S G	U	S	S G	U	U	S G/ U
6	Medium	Assist users in acquiring and using micros in a standalone operating mode & in avoiding systems problems	✓	✓	✓	✓	✓	✓	✓	✓						S G	U	S	S	S G	S	U	U	U	U	S G
7	Medium	Explore the value of micros as professional work stations by extensive pilot testing	✓	✓	✓	✓	✓	✓	✓	✓						S G	S	S G	U	S G	S	S G	U	U	S G	S G
8	Medium	Examine potential for improving productivity by using micros as professional work stations in pilot test	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				S G	U	S	S	S G	S	S G	S G	U	U	S G
9	Low	Encourage acquisition & use of micros as individual support tools, letting profit motive serve as control mechanism	✓	✓	✓	✓	✓	✓	✓	✓						S G	U	U	U	S	U	U	U	U	U	U

SG = Systems Group U = User S = Shared (by System Group and User)

*Based on data contained in "Low-Cost Computing Strategies: Analysis of Private Industry" [6]

- software package selection,
- procurement negotiation,
- application system development,
- installation,
- training,
- operations,
- maintenance, and
- post-installation review.

Table 4.1 illustrates that some of these functions, such as long-range planning and post-installation review, are almost always performed by the support group; others, such as requirements analysis and operations, commonly fall on the end-user. Still others, such as applications systems development, may frequently be shared between the central support group and the user. The range of approaches used by private industry to manage the new technology suggests that government policy-makers and managers need to give careful consideration to the various nuances of potential management strategies and make a deliberate selection from the range of possibilities.

In conclusion, the study looks toward an "integrated management organization" designed to optimize the productivity of the work force through information processing and to identify management requirements in four key areas:

- Education: With the advent of microcomputers, there is a need for education at all levels in the organization, from clerical workers through executives, and across all functional groups, including both end-users and data processing professionals.

- Information Management: The importance of managing information grows as technology advances into micros and hierarchical networks. Unless attention is paid to the information management issue, companies can expect widespread information discrepancies, costly duplication and non-comparability.

- Hardware - Software Compatibility: When micros are first introduced, the real need is for compatibility of information, not systems. However, in moving toward networks of micros with other micros and with minis and mainframes, system compatibility becomes critical.

- <u>Communication and Interaction among Users and Data Processing Professionals</u>: The creation of incentives for users to communicate with the information processing management structure becomes critical with micros. Management needs to know what users are doing, whether they have acquired systems and how they are using the systems, because this information may have a significant influence on the development of overall plans for automation throughout the company.

4.3 SUMMARY

It is evident that the private sector is aware of and feeling the impact of the new technological developments in information and data handling. While their responses may be uneven, companies giving thought to the problem seem to agree on two important points: management control can be better realized by emphasizing incentives over authority; and support for end-users will be a crucial factor in establishing and maintaining effective information management. As a result of this awareness, many organizations are paying a great deal of attention to the process by which they implement the new technologies.

The process is considered so important that one large corporation, a leader in the ADP and information field, has developed a comprehensive system to help organizations evaluate their information needs and put in place appropriate systems to meet those needs.[7] While the general planning concepts are not unique to this company's approach, the process does, both explicitly and implicitly, acknowledge some important principles:

- Data is a fundamental organizational resource, as important to an organization as personnel, cash or equipment.

- Both management commitment and user involvement are essential. The planning process stresses a "top-down" approach to gaining the commitment and to studying the business, and a "bottom-up" approach to implementation.

The most important objective of the process is to develop an information systems plan that both meets an organization's long- and short-term information needs, and is a consistent and integral part of the organization's overall business plan.

5. END-USER COMPUTING IN THE FEDERAL GOVERNMENT

5.1 THE CENTRAL MANAGEMENT AGENCIES

Management in the Federal government occurs at two levels: government wide, and at the level of individual executive branch agencies. At the government-wide level, there are five agencies with direct or indirect responsibilities for IRM and the management of related technologies: the Office of Management and Budget (OMB); the General Services Administration (GSA); the Institute for Computer Sciences and Technology (ICST); the Office of Personnel Management (OPM); and the General Accounting Office (GAO). The last, while not a management agency per se, is included here because of its influence on Federal government management.

The rapid growth in the new technologies caught these agencies relatively unprepared, just as it did most other public and private sector managers. A good example is the current situation with respect to the procurement of microcomputers, where there is minimal management, control, or attempt at standardization. Because micros are so inexpensive, they fall below GSA's thresholds for procurement control. As a result, no mechanism exists for ascertaining how many micros there are in government agencies, where they are, how they are used, or whether they are cost-effective.

However, there are now definite indications that these agencies are catching up. Most are addressing the problem and have begun to formulate approaches and take actions to deal with the kinds of management issues identified in chapter 3. This section describes some ways in which the central agencies are attempting to provide leadership, guidance, and support in the new technological environment.[8]

5.1.1 The Office of Management and Budget (OMB)

OMB is responsible for providing overall executive branch leadership and coordination, and for formulating fiscal and policy controls related to the acquisition and management of Federal ADP systems. Under the Paperwork Reduction Act (PRA), OMB is designated as the focal point for management responsibility of all Federal information resources.

To date, OMB has provided relatively little guidance in terms of IRM. In remarks made at the Information Resources Management Conference, in Gettysburg, Pennsylvania, in September 1982, OMB's Andrew Usher described that agency's role as follows.[9]

"OMB has made a conscious decision to adopt an implementation strategy based on the following perceptions:

1. The primary responsibility for implementation must rest with the head of each agency and the senior official designated by the agency for that purpose.

2. OMB would be primarily interested in results and not process. Each agency is generally free to choose its own methods as long as it achieves the objectives of the [Paperwork Reduction] Act.

3. The early emphasis would be on review responsibilities. This would permit the agency senior official and OMB to assess the current effectiveness with which Federal information resources are being managed and identify high priority problem areas whether agency-unique or government-wide.

4. OMB would issue government-wide policy and procedures where needed but only after there was a base of experience under the Act indicating clearly what the policy and procedures should be. However, the primary emphasis would be on the establishment of incentives which would encourage better management of information resources and serve as an alternative to traditional policy directives and regulations."

Consistent with the above policy, OMB has conducted PRA oversight mainly by exercising clearance control over agency information collection requests, approval of the annual information collection budget, and conducting periodic reviews of selected agencies' information activities. In addition, OMB sponsors a Departmental Level Working Group on IRM policy, which usually meets monthly.

5.1.2 The General Services Administration (GSA)

GSA has principal responsibility for developing regulations and guidance on procurement, implementation, and management of office automation systems. GSA tries to promote cost effective management and use of Federal information systems and technology by developing performance standards; helping agencies design and manage records and information management programs; and providing training. GSA also develops government-wide policy and plans for ADP and telecommunications equipment; establishes sources of supply for equipment and services for all Federal agencies and prescribes acquisition procedures promoting competition and economy; provides some technical assistance and has operated clearinghouse activities. The Paperwork Reduction Act basically reinforces GSA's operational responsibilities in information management, while shifting policy-making responsibility for records management to OMB.

GSA's response to IRM has been different than that of OMB, in that it proposes to take an active role to provide guidance and support. With respect to microprocessing, two recent proposals are especially pertinent:

- In a draft report, *Managing End-User Computing In The Federal Government*, February 1, 1983, GSA presents a Managed Innovation Program, which it describes as "a transitional program proposed to meet the needs of the government until the full implications of End User computing technologies are known".

- GSA is planning a computer store which will be operational in the near future. Run much like a commercial retail establishment where Federal agencies will be able to purchase brand name microcomputers and packaged software.

5.1.3 The Institute for Computer Sciences and Technology (ICST)

ICST is responsible for developing uniform Federal ADP standards and for providing scientific and technological advisory services to help Federal agencies acquire and use computer technology. ICST strives to promote hardware and software compatibility and interconnectedness by developing standards to achieve these goals in such technological areas as network protocols, formatting, and language.

Like GSA, ICST is taking an active approach to end-user computing issues. In addition to publishing technology forecasts (such as this document), and guidelines on microcomputer management and use, ICST is also taking the lead in developing and promoting the concept of information resource centers for Federal agencies. These centers would be end-user oriented support operations, which would provide information, technical assistance, and training to those individuals who will be utilizing computer technology, but who are not data processing professionals. The centers would address more than microprocessing; an important function would be to provide objective advice to end-users to help them identify and evaluate alternative ways to satisfy their requirements. ICST will be holding workshops on Information Resource Centers (the first, in June 1983) and is considering setting up a prototype Center at the Institute.

5.1.4 The Office of Personnel Management (OPM)

OPM is responsible for developing position classification standards and career tracks for executive branch staff and for providing or sponsoring government-wide training programs. OPM also deals with human factors issues.

OPM has been looking at the application of office automation as a way of improving Federal workforce performance and has recently begun to provide agency-specific training and technical assistance on office automation. It is also considering creating a new IRM job series and examining standards for computer specialists. However, OPM does not plan, in the near future, to address the problem of blurred personnel classification standards such as those for clerk/secretary/analyst job descriptions.

5.1.5 General Accounting Office (GAO)

GAO serves as an oversight agency for Congress. It directs its activities toward determining how effectively Executive Branch agencies carry out the laws and how effectively they use their appropriated funds.

With respect to IRM, GAO has found that, for the most part, the central management agencies have provided insufficient guidance, stating that this has been an important factor in the uneven progress that Executive Branch agencies have made in implementing the PRA. An exception is ICST whose "issuance in 1980 of a management guide specifically addressing integrated office automation systems has made a significant written contribution in guidance".[8] GAO also concluded that an important reason for the absence of leadership is that "a clear delineation of responsibilities and coordination among [the agencies] is lacking".[8]

The GAO has also reached some preliminary conclusions about the use of small computers in the Federal government. In a memo to David Stockman, dated March 8, 1983, L.D. Campbell states that "The Agencies' lack of planning and management has created a high potential for waste, duplication of effort, and general inefficient use of these resources."[10] The memo goes on to recommend several ways to improve the situation, including more active roles by OMB, GSA and ICST.

5.1.6 Summary

The above brief descriptions of the central management agencies make it clear that in terms of end-user computing the agencies' mandates make them very well suited to provide leadership in several important areas. Some of these are procurement of hardware and software; determination of performance and compatibility standards for hardware and software; justification of need; requirements analyses; software applications; information storage requirements, data security requirements, data quality control; budgeting; procurement of ADP support through grants and contracts; and personnel classification, job descriptions, and career path criteria.

It is significant that the above list corresponds very closely to the issues described in chapters 2 and 3.

What this means is the Federal government, at the central management level, has in place the necessary structure and mechanisms to address the important IRM and technological issues it faces, and to develop an appropriate response.

5.2 EXECUTIVE BRANCH AGENCIES

5.2.1 Overview

The lack of comprehensive, coordinated central direction or guidance at the government-wide level has created problems for the individual executive branch agencies and has led to considerable variation in the way they have responded to the issues. Not all of that variation is attributable to the differing needs of the agencies. For instance, while there is a requirement that each agency appoint an information resource manager, there is a good deal of confusion as to what this concept embodies -- in terms of both the background and function of the individual who fills it.

There is an awareness among managers in many government agencies that the new technology can present problems as well as opportunities unless managed properly. However, agencies are not making uniform progress in addressing the pertinent issues. At the one extreme are agencies that apparently will be surprised by the influx of microcomputers. At the other extreme are agencies that have undertaken management-oriented studies and/or have formulated systematic approaches or plans to address the new technology. Some agencies have elaborate organizational charts, reflecting the new IRM emphasis. However, it is not clear how, or even whether, the day-to-day management of information resources has, in fact, changed. Conversations with the staff of some of these agencies sometimes leave the impression that the management structure is more apparent than real, that the new organizational structure exists mainly "on paper", and that real organizational change is very slow in evolving. What does seem clear, though, is that in those cases where meaningful change has occured, to a great extent that change can be attributed to a single individual--a person who is both highly motivated and in a position to make a difference.

5.2.2 How User Agencies Are Addressing Small Computer Issues [10]

The GAO considers the management of small computers (mini and microcomputers) to be a serious potential problem. The GAO's view confirms points made by others in both the public and private sectors: that there has been a huge increase in the acquisition and use of small computers; that this trend is expected to continue; and that the management issues associated with the new technology are different from those pertaining to traditional ADP.

The GAO describes an "unmanaged system which can only worsen unless informed and systematic direction is introduced toward some predetermined agency goals". According to the GAO, the situation in the agencies is as follows.

- Little formal policy and guidance exist that relate to the unique aspects of justifying, acquiring, installing, and operating small computers.
- Agencies are not considering life-cycle costs when acquiring small computers and fail to realize the significance of the software costs.
- The accuracy of the data on small computers is receiving little or no verification.
- Some agencies do not know how many and what kind of small computers they have because they lack formal approval and accountability procedures. Little effort is being made to standardize hardware for compatibility.
- Few agencies have software and documentation standards for small computers.
- Agencies do not know what applications are on their small computers, which contributes to redundancy.
- Agencies have not justified the cost of purchasing small computers.
- Agencies have few procedures to provide security and backup to prevent loss of critical data.
- Agencies do not know to what extent their small computers are being utilized.
- Individual agencies are doing redundant studies of small computer issues.
- Few formal software libraries have been established to facilitate software exchange between user organizations.

5.2.3 Examples of Agency Approaches

By virtue of compliance with the PRA, most Executive Branch agencies are involved in some stage of IRM planning or implementation. Some have focussed on organizational change; others have tried to put in place some kind of support system to aid their staff in utilizing small computers. Below are some examples of how Federal agencies are approaching these management issues.

5.2.3.1 U.S. Geological Survey

In this agency, minicomputers are physically clustered in groups, which enhances security and lessens much of the burden of providing support for them. Microcomputers, on the other hand, are dispersed, but centralized support and maintenance is provided for them also. Services provided by the central systems group are billed, and the group is completely reimbursable. While the central group recommends make and model to users procuring equipment, it does not establish actual requirements. However, it does provide free and low-cost software, which tends to result in de facto standardization; it also supports users by maintaining systems which they design. The central group actively discourages languages unique to any particular machine, but it makes no attempt to restrict higher-level languages. Policy making is carried out through a Planning Council, composed of high-level managers who have the authority to formulate and implement policy.

5.2.3.2 Smithsonian Institution

The Smithsonian Office of Information Resource Management was established in April 1982 to identify the Institution's information priority needs and take action to meet those needs in an integrated and cost effective manner. Late in that year, the Institution utilized a consultant to review its policies with respect to electronic data processing and to identify objectives and policy decisions necessary for the Office to implement IRM. The result was a formal policy and planning document on the management of information resources.[11] As evidence of its commitment to carry out IRM, the Smithsonian hired the consultant as Assistant to the Director, Office of Information Resource Management, to implement the recommendations presented in the report.

The Smithsonian's approach is a comprehensive one which addresses most of the issues of concern. It also recognizes the potential of local area networks of microcomputers and attempts to maximize the benefits of communicating systems and shared databases.

The Smithsonian's information resource management strategy is designed around six issues:

- o centralized management of decentralized information handling capabilities,
- o institutional support for information resource expenditures,
- o planned acquisition of information handling capabilities,
- o educating Smithsonian staff for an automated future,

- a networking philosophy: institutional perspective on needs and resource, and

- reorganization of its Office of Information Resources Management (OIRM) along functional lines.

The Smithsonian is preparing a five-year plan for implementing IRM. Current areas of emphasis deal with data management implications, data modeling, applications analysis and planning in terms of management of data. An update of the original report is planned for the Fall of 1983.

5.2.3.3 U.S. Department of Agriculture

The USDA Information Technology Center opened in the Spring of 1983.[12] The facility offers information and training on the latest in applied computer technology, and provides USDA employees with the opportunity to obtain hands-on experience on selected microcomputer systems. The Center has a threefold purpose:

- to increase awareness of how small computer technology can enhance productivity;

- to promote greater self-sufficiency of users in the evaluation and application of computers; and,

- to facilitate department-wide information and resource sharing.

Operating expenses for the Center are covered by the USDA Office of Information Resources Management, as part of its technical services responsibilities.

5.2.3.4 U.S. Department of the Interior

The Department of the Interior was one of the first Federal agencies to implement the IRM concept, when in January 1980 it established the Office of Information Resources Management under the Assistant Secretary for Policy, Budget and Administration. Establishment of this Office involved the integration of several organizational entities encompassing "functional areas" such as ADP, telecommunications, library and information services, paperwork, and management analysis. Also included in this Office is the Program Development Division with responsibility for policy development and strategic planning. The staff of this Division is purposely drawn from the various information technology areas to provide an interdisciplinary IRM perspective.[13]

Interior has utilized a structured planning approach which utilizes four levels of planning detail. Ranging from general to specific, the formal IRM plan includes goals, subplans, major products/functional plans, and tasks. This system is applied at both the Department and Bureau level.

In the Department of the Interior, each Bureau plans for the management of its own functional areas, using its own 'language', to meet its own mission, and generally without regard to sharing common resources within the Department. The Department-wide IRM plan is intended to serve as a translation table between Bureau plans and to provide a comprehensive organizational bridge of IRM issues. Within this organizational structure, all Bureau information-related functional plans can be brought together without losing their identity. They can be compared to one another, and opportunities for resource sharing and/or other joint information-related efforts will be more apparent.

Interior has also identified three "interested parties", which although not mutually exclusive, represent different perspectives towards information and information resource management. They are the information user, management, and the information handling resources areas. Goals at the department-wide level are arranged in three groups, to support each of the "parties".

A complete description of the Department's plan is available from NTIS. It is a three volume report which includes an Executive Summary, a plan overview and discussion of the IRM environment, and a description of functional plans. The documents may be purchased either separately or as a set.

5.2.3.5 AFFIRM

AFFIRM is the acronym for the Association For Federal Information Resources Management. It is a membership association, not an agency, but it is included here because it is serving as a focal point for Federal IRM managers to address IRM and related technological issues.[14]

AFFIRM functions mainly as a vehicle for networking and information exchange. The objective of the Association is to improve the management of the information systems and resources of the Federal government. Its scope of interest includes virtually all aspects of IRM policies and processes including ADP, data communication, paperwork management, reports management, micrographics, word processing, publication and printing management, etc. AFFIRM's current major activities include the hosting of a monthly luncheon meeting, with guest speakers, and the publication of a monthly newsletter.

6. MANAGING CHANGE

6.1 OVERVIEW

The preceding chapters in Part VI have examined the impact of end-user computing. The major management issues have been identified and discussed; the Federal context has been described; and the status of end-user computing in both the private sector and the Federal government has been reviewed. Going back to the statement of the problem in chapter 2, the preceding chapters have dealt with "Where are we?" and have begun to imply some answers to "Where do we want to be?".

This chapter looks at the latter question from another perspective--that of the process of managing the transition to an end-user computing environment in the real-world context of the Federal government. First, general organizational factors which need to be considered are outlined. Second, some suggestions are presented as to how the change process might be facilitated. Going back again to the original problem statement, this section also begins to answer the question "How do we get from where we are to where we want to be?".[15]

6.2 EXAMINING THE ORGANIZATIONAL CONTEXT

Organizations have personalities, characteristic ways of approaching their missions and carrying out their activities. In determining the most effective way to facilitate the transition to an end-user computing environment, managers need to understand how their organizations work, in terms of several key factors: planning styles; power and leadership; interpersonal relationships; the pace of work; resources and costs; relationships with contractors and consultants; and performance criteria. Each of these is described, briefly, below.

6.2.1 Planning Styles

Some organizations rely on detailed plans with highly structured schedules and carefully defined staff assignments; others prefer a less structured approach, for example utilizing informal brainstorming in the development of 5-year plans.

The transition to end-user computing will be a complex process. The plans to accomplish this must be compatible with the planning styles of the Agency.

6.2.2 Power and Leadership

The distribution of power and the way leadership is exercised differs with organizations. At one extreme, all decisions are made at the top, with little or no input from subordinates. At the other extreme are organizations in which substantial authority has been delegated and decisionmaking responsibility is widely distributed.

End-user computing, by its nature, is in some conflict with strong central control. To achieve a smooth transition, agencies which tend to rely on unilateral decisionmaking should, in the future, expect to have to delegate more authority if a smooth transition is to be achieved.

6.2.3 Interpersonal Relationships

In some agencies relationships are formal and impersonal; in others, intra-agency relationships sometimes deal with personal, as well as work-related concerns.

Like any other change, the growth of end-user computing will threaten some individuals and benefit others. Management decisions regarding implementation need to be made with an understanding of the Agency's interpersonal patterns. This is important for at least two reasons.

First, the degree to which an office takes a "personal interest" in its staff should help determine the manner in which change is handled. Some agencies will need to provide many opportunities for personal discussions with employees about what effects the new technologies are likely to have on their jobs, careers, and on the office atmosphere in general. Other agencies will be able to handle the transition on a more formal and structured basis.

Second, what looks good on an organization chart may not work in reality. It is important to know which personnel work well together and which do not. This is one reason why user participation is important in implementing change; management and outside consultants may not always be aware of which combinations of people are more or less effective.

6.2.4 Pace of Work

Some organizations generate work at a fast pace. Turnaround time is rapid and results are immediate. These organizations are often able to handle rapid change. Other organizations operate in a more deliberate fashion, both physically and psychologically more slowly. In these offices, change is more evolutionary in character.

With the growing pressure to utilize the new technologies, some agencies may feel pressured to introduce widespread changes before they are really ready. Others may want to "study the problem" longer than is really necessary. Federal managers need to carefully consider the best pace to implement end-user computing, to ensure consistency with the general tempo of the work and to maximize their agency's ability to accomodate the changes.

6.2.5 Resources and Cost

The costs involved in implementing end-user computing fall into two main categories: direct expenses, such as the costs of hardware and software, salaries, consultants and contractors; and opportunity costs, the time spent creating and implementing the new technological environment, that might be spent for some other purpose. Agency resources are finite, and there are many competing demands on the time and money which are available.

The extent to which an Agency decides to implement end-user computing, the scope of its effort and the nature of its choices, will be affected by these contraints. Careful analysis of current and future available resources is essential and should be made as early as possible. Agency managers face a very large number of alternatives. Their choices need to take into account both the size of the initial investment and the ability of their agencies to maintain it in the future without undue burden.

6.2.6 Relationships with Contractors and Consultants

Some relationships with consultants are "client centered"; that is, the client retains primary responsibility for diagnosing the problem and determining the best course of action. In other client relationships, responsibilities rest almost entirely with the consultant, who is an expert.

With respect to end-user computing, government agencies will be working with vendors, contractors and consultants in the aquisition and utilization of new technology and systems. (Users working with their agency information resource centers will have a similar relationship.) Most Federal managers will lack the technical background to thoroughly evaluate the advice and information they receive, some of which is likely to be conflicting. Federal managers need ways to strengthen their ability to make informed choices in a complex technological arena. Responsibilities must be clarified and opportunities to blame "outside experts" for bad decisions must be minimized.

6.2.7 Nature of Performance Criteria

In the private sector, the most common way of measuring success is in terms of profit--how the innovation affects the "bottom line". While Federal managers need to adhere to a budget, and while it is desirable and may be possible to effect cost savings by following a particular course of action, such savings may not necessarily be the main criterion for judging the merits of the action.

The criteria for measuring the value of end-user computing are particularly ambiguous, since they involve intangibles such as quality of decisions, analytical effectiveness, and managerial productivity. These are notoriously difficult to measure. Federal managers should try to clarify their own expectations of end-user computing early in the transition process, to avoid disappointment and frustration over the results that the changes accomplish.

6.3 FACILITATING CHANGE

It is true that, on the whole, microcomputers are being acquired and their benefits are being anticipated with great enthusiasm. It is also true that the introduction of the new technology will effect important organizational changes in the Federal workplace. In fact, most of the major management issues that have been described in this report center around questions of control, authority, and other organizational considerations.

As figure 6.1 indicates, there are a number of possible ways for an individual to respond to organizational change. However, those attitudes depend to a great extent on how the change is managed. Those in charge of instituting change can facilitate the process and help to make the transition to end-user computing a positive experience for all concerned.

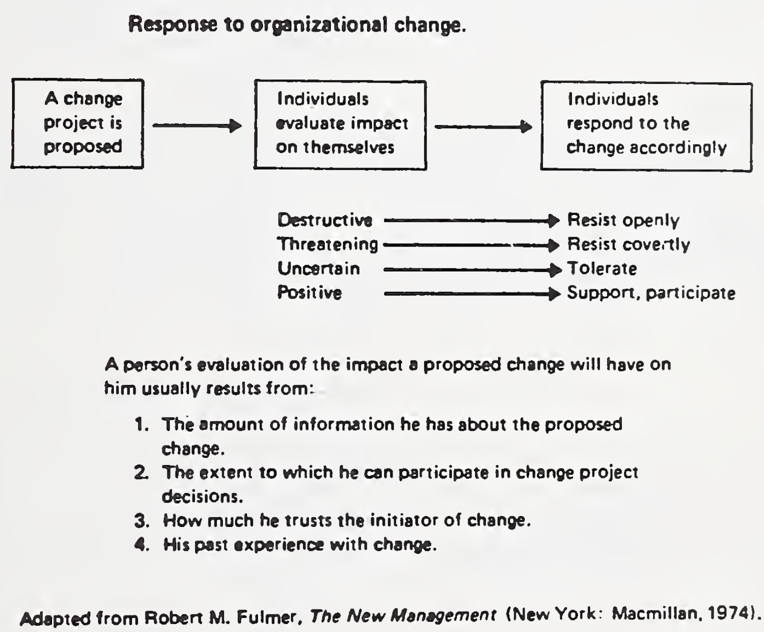

Figure 6.1 Response to Organizational Change

One of the most important ways of ensuring a positive outcome is for management to maintain good communications with all employees about the changes that are taking place. Included in the information that should be provided is:

- a review of the organization's history of change (to acknowledge past experience);

- a statement of the manager's motives and anticipated rewards (to foster trust);

- a review of the experience other organizations have had with the kinds of change proposed and a thorough explanation of the plan for this organization (to foster as thorough an understanding of expectations as possible); and,

- An explanation of everybody's roles and responsibilities including decisions for which they may provide input (to clarify the extent to which individuals can participate in change decisions).

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 OVERVIEW

The situation observed in government vis-a-vis the new technologies is not unique; private industry is also struggling to keep pace. But there are a number of aspects of the situation that are particularly characteristic of government.

First, government tends to lag behind private industry in addressing such issues. For one thing, private industry can often institute de facto management techniques which involve little formal reorganization, and where success can easily be determined by using the "bottom line" as the ultimate measure of the wisdom of decision making. Government cannot evaluate its decisions using profits and losses, and the relative costs and benefits as played out in such areas as worker productivity are exceedingly difficult to assess.

Secondly, government falls prey to problems in implementing and maintaining long-term management strategies because of frequent changes in high-level personnel having policy-making and senior management responsibilities. To the extent that policy-making and management relative to the new technologies are the responsibility of high level appointees, long-term planning and commitment to any particular management strategy become difficult.

7.2 CENTRAL MANAGEMENT AGENCIES

The central management agencies have several options in providing direction and oversight with respect to the new technologies. However, the success of their choices will depend on two factors: the coordination of management responsibilities across the agencies, and the continuity of any strategies over time.

On the issue of coordination, the GAO has described the ambiguity that exists concerning the respective roles and functions of each central agency. But even to the extent that roles are mutually understood, the allocation of related but different responsibilities across the agencies leaves open the possibility of a fragmented response unless deliberate efforts are undertaken to respond in an integrated way.

Lack of coordination could lead to several problems. For instance, the central agencies could develop incompatible objectives with respect to the new technology; or they could promulgate conflicting guidance for achieving similar objectives. Similarly, a strong approach by one of the central management agencies might be accompanied by a laissez-faire approach on the part of another--an inconsistency which could hinder an executive branch agency in its development of an effective agency-wide response. Having limited resources, operating agencies might have difficulty responding equally to different areas of central management emphasis (e.g., hardware compatibility as opposed to changing personnel requirements). Because the effects of the new technology are anticipated to be so pervasive throughout the Federal workforce, an integrated, coordinated set of strategies at the central management level would appear to be essential.

The issue of continuity over time is equally important. The procurement and management of large amounts of hardware and software, the creation of networks of microcomputers communicating with one another and with minis and mainframes and the dramatic changes that are occurring in the work environment cannot easily be managed effectively in a climate of the radically shifting winds of politics. Without a reasoned, steady, and consistent course that evolves in tandem with the expanding technology and the changing work environment, the Federal government will find it exceedingly difficult to catch up with and harness the new technology for its own benefit.

It is interesting that the Paper Reduction Act, which aims to foster and improve the management of Federal information, may in fact undermine continuity. That is because the Act requires that the individual responsible for IRM within an agency be a senior official who reports directly to the head of that agency. Since those positions are almost always political appointments, the result is that IRM leadership is virtually guaranteed to turn over every 18-24 months. In presidential election years, the effects can be dramatic, since new administrations often formulate policies very different from those of their predecessors.

Going beyond coordination and continuity, the central agencies need to determine appropriate levels of specificity at which they will manage the new technology and develop collateral management mechanisms for implementing those strategies. Four levels on which the central agencies might choose to exercise management are:

- goals (e.g., efficient and economic information processing),
- objectives (e.g., procurement of hardware and software at the lowest price),
- processes (e.g., providing training on evaluating microcomputer capabilities), and
- outcomes (e.g., requiring adherence to specific hardware or software standards).

Decisions as to which of the levels a management strategy will target need to be made with consideration of the management mechanisms that will be required to implement the strategy. In determining management mechanisms, both cost/budget issues and anticipated impact on the agencies need to be considered.

At one extreme, the establishment of general goals for the agencies would probably not require costly and burdensome reporting mechanisms; by the same token, such "management" would probably have little impact on what actually occurs within individual agencies. At the other extreme, attempts to regulate specific agency outcomes at the central management level would probably need to be accompanied by a set of clearance or reporting mechanisms, the costs of which would probably outweigh the potential benefits; whether or not such a strategy would even have the desired impact would probably depend on the vigor with which it was enforced and the ingenuity mustered in its circumvention. In the latter regard, private industry is showing a degree of leadership: e.g, in one company which adheres to rigorous central control over the procurement of microcomputers, an ingenious program manager ordered 5,000 reams of processor paper from a vendor who threw in a "free" microcomputer with the order.

It is clear that there is a real need for the central management agencies to define responsibilities and provide leadership and guidance for Executive Branch agencies. In fact, there are dangers in inaction. For one thing, the reluctance of the central agencies (particularly OMB) to articulate a policy may make individual agencies wary of going too far on their own. They may rightfully fear that any steps taken at this point will have to be "undone" if OMB chooses to act. Further, there is an important role for the central agencies in providing the information, direction, and support which the agencies require. The absence of this leadership will hamper or even prevent the agencies from implementing their own programs.

The central management agencies can provide leadership in several ways. Listed below are suggestions for policies and actions.

1. OPM. OPM needs to recognize that an evolution is taking place in the work environment, and that a changing combination of skills may become necessary or desirable within certain job series. For some professionals, such as budget analysts or scientists, the ability and willingness to use microcomputers may significantly enhance their performance and may in fact become increasingly necessary. For secretaries and clerical assistants, these abilities can expand the scope and nature of their work and enhance their value and contribution to the agency. But as data and word processing functions become increasingly intermeshed, clerks and secretaries are becoming capable of providing increasing administrative and/or research assistant type support; indeed, many are already being expected to perform such duties. Yet existing position classification standards build in no incentives for acquiring the necessary skills and taking on responsibilities for automated data input, retrieval, or manipulation. Without job-

classification standards that recognize the value of such expanded capabilities and responsibilities, employees in low grades in dead-end job series will simply take their newly acquired skills to private industry where they are more highly valued.

This is precisely what has happened in the area of word processing. OPM currently places no incremental value on the ability to do word processing above and beyond that for ordinary typing--in some cases, even down-grading the employee. Thus, clerk-typists often remain in government just long enough to learn word processing. Then, when faced with a ceiling on promotion opportunities, they leave for private industry where their skills are valued. In effect, the Federal government has become a training facility for the private sector. OPM needs to re-examine these issues and revise its position classification standards to reflect the realities of the current and projected work environment. However, interviews at OPM indicate that this may be a long time coming. Currently, OPM is working on revisions to the "Computer Specialist" classification and, in the view of some senior OPM managers, that should solve any personnel problems stemming from end-user computing.

2. ICST. ICST should continue to promote and support the information resource center concept for the agencies. It should help define functions which the Centers could provide, prepare guidance for the agencies on how to establish such a capability, and explain how this capability would help meet their needs, especially in the context of changing data processing roles and responsibilities. Furthermore, ICST should advocate that the Information Resource Center be headed by senior career civil servants. With their managers charged with long-term planning, this would help ensure continuity of information management, even in the face of frequently changing administrations and political appointees. Moreover, the information resource center concept could provide a realistic framework concerning the roles and functions of both ADP and non-ADP staff--a framework that could serve as a starting point for re-evaluation of position classification standards and other aspects of personnel policy.

3. OMB/GSA/ICST. One of these central management agencies should actively track on-going developments in the management of end-user computing and should institute a "pointer" system which agencies can use to find out where innovative management

techniques are being utilized and relevant training is being given. The Reform '88 initiative now underway at OMB would be an appropriate vehicle for examining the mechanics of a pointer system and determining who might best carry it out.

4. COORDINATION OF POLICIES AND PROGRAMS. There are many ways in which support from the central management agencies is needed. However, that support would be most useful if it reflected a coordinated central management outlook, a sharing of resources, and a consistent view of issues and appropriate solutions. Some specific suggestions are:

   - jointly sponsor meetings and workshops for user agency personnel, each central agency dealing with a particular aspect of IRM or microcomputer management;

   - develop planning guides for organizing for IRM;

   - provide training to user personnel in subjects of management agency expertise (e.g., cost-benefit analysis techniques);

   - conduct workshops on organizational development issues, specially focussed on the implications of end-user computing;

   - develop a set of incentives, applicable to most agencies, to minimize the necessity for strong central control of end-user computing. The aim is to minimize passive resistance and obtain compliance with policies, in the spirit as well as the letter of the law;

   - eliminate unnecessary obstacles to microcomputer utilization, such as overly complex approval procedures; and

   - establish networks among users, corresponding to the categories of users identified in figure 3.1.

7.3 EXECUTIVE BRANCH AGENCIES

Federal agencies differ in many ways: in size, styles of leadership, data processing sophistication, and, perhaps most importantly, in mission. A private company can decide to scrap a product or try to develop a different line of business. Not so for Federal agencies whose missions are established by legislation or executive order. Agency heads have little leeway in changing that, except to the extent such changes are an expression of the policy emphasis of the incumbent administration.

In terms of information handling, this means that decisions regarding allocation of information resources must enhance the agency's already established mission. Thus, for example, the Smithsonian can consider developing local area networks to link museums and other places of scholarly endeavor, while, on the other hand, regulatory agencies, like the EPA, must think in terms of systems which facilitate the carrying out of its enforcement responsibilities. To make the introduction and management of end-user computing a positive, rather than disruptive experience, the implementation process should be compatible with the organizational patterns which characterize the agency's functioning. Because of the variety that exists in this regard, the recommendations presented below are more those of considerations rather than recommendations for action.

1. Management approaches should be institutionalized to as great an extent as possible to minimize problems of continuity. For example, key IRM managers, such as the manager of an information resource center, should be career staff.

2. Don't be dazzled by packaged solutions to management problems. Working through the process is necessary to successful implementation; agencies need to do some things for themselves. What is not needed is an organizational chart developed elsewhere for use by another agency. While such a chart may be a handy starting point, don't expect to institute it in your own agency by fiat. A certain amount of reinventing the wheel is both necessary and desirable. The central management agencies should provide enough guidance to prevent the agencies from inventing flat tires.

3. User orientation means user participation. Maximize user involvement in all phases of implementation, especially in making decisions. An information resource center may be a good focal point for organizing along these lines.

4. Keep IRM policymaking responsibility separate from operational responsibilities. Users need to be able to obtain objective information about information processing alternatives in order to make good choices. In-house ADP should not be a mandated monopoly.

5. Establish and maintain both inter- and intra-agency networks. Organize meetings around problem solving, rather than show and tell. Stay in contact with counterparts in other agencies and in the

private sector. Electronic bulletin boards, such as the one run by ICST (telephone number: (301) 948-5718) can help put you in touch with user groups.

6. Pay attention to process. Consider utilizing some kind of team building approach which aims to improve working relationships and is structured enough to provide an orderly direction for future efforts.

7.4 CONCLUSION

Management issues pertaining to end-user computing in the Federal government deal not only with managing the new environment, but with managing the transition to that environment. There are approaches, some in particular for the central management agencies, which will make that transition easier and keep the disruptive effects to a minimum. Ultimately, the responsibility for implementation strategy will rest with the operating agencies.

There is good news. Part I of this Report covers the period from now through 1997. Technological changes will be introduced incrementally; offices are facing evolution, not revolution; new technologies can be incorporated into the workplace in an orderly way. There is still time to take full advantage of the opportunities offered by the new technologies if we use the time well.

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The document contains the 1983 Technical Forecast for the information processing industry through 1997. It consists of six parts. Part I forecasts the underlying technologies of hardware and software, contains a discussion of changes in the information industy and market, and forecasts products and systems of the future, e.g., general-purpose systems, distributed processing systems, office systems. Part II contains Federal agency staff comments on Part I. Part III summarizes a teleconference in which a number of industry ADP users and vendors reviewed Part I. Part IV provides cost estimates for computer systems, subsystems, and terminals through 1997. Part V discusses the current and potential rules and regulations of the Federal environment and how they may affect the Federal inventory of ADP equipment. Part VI discusses management strategies for the new information technologies with emphasis on microprocessors.

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