EDP Series, No. 4

MINICOMPUTERS

AUERBACH TECHNOLOGY
EVALUATION SERVICE

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Philadelphia, Pennsylvania

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PREFACE

This is the fourth study report of the *AUERBACH Technology Evaluation Service: EDP Series.* This series is intended for analysts concerned with the impact of technological change on major commitments in electronic data processing as well as major computer users engaged in long range planning. Each study report covers a segment of the EDP industry. This issue analyzes the segment that produces low cost, stored-program, general-purpose minicomputers which are capable of performing an extensive range of control and computational functions.

Minicomputers have opened many new marketing areas which were previously unavailable to higher priced machines. Minicomputers have been used in a variety of dedicated applications such as the control of industrial processes, data acquisition systems, and communications systems. They have also been used as free-standing, general purpose systems for both business and scientific computation.

The minicomputer industry is only five years old. Its growth is paralleled by the dynamic changes in its structure and products. These changes are expected to continue and raise several significant questions. What effect will developing MSI/LSI technology have on system prices and architecture? How will continued price erosions affect the growth in shipments and total sales? How will the industry structure change with the evolving products and market needs? What will be required to succeed in this highly competitive market? What will be the market potential for minicomputers by application areas. What factors will limit penetration in each area? Where are the potential markets located by industrial segment?

This study analyzes the underlying financial, technological and marketing factors that determine the answers to these questions. It reviews the current status of the minicomputer industry, describes current trends, analyzes the fundamental forces controlling the prospects for the industry, and predicts future directions.

The information in this report was obtained from both manufacturers and users. Users were surveyed in person and by telephone. In-person interview discussions were conducted with manufacturers representing 75 percent of the installed base. The remaining manufacturers were surveyed by telephone and mail inquiries. This study reports the findings of these inquiries and the conclusions of our analysts. The results obtained from analysis of this information as well as independent secondary sources are contained herein.

Chapter I presents an overview of the minicomputer industry, describes how the industry emerged, identifies its products and markets, and defines the industry structure. Chapter II categorizes the minicomputer product line, its distinguishing characteristics, and the associated technologies. Chapter III analyzes the market for minicomputers and presents our market forecast. Chapter IV presents our overall evaluation of the minicomputer industry. The Appendices contain information on minicomputer product characteristics, supporting data for our market analysis, user experience case histories, and additional information on principal minicomputer manufacturers.

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SUMMARY

Minicomputers are small, stored-program binary computers costing under $25,000. They evolved as the need for small processors was recognized and as technological developments provided cost and size reductions. Due to their flexibility, minicomputers are used in a variety of industries and applications. They function as controllers for processes, devices and communication systems and fill a basic need for low cost computation.

The minicomputer industry experienced rapid growth between 1967 and 1970 when industry sales spiralled from $65 million to $210 million. This growth was accomplished despite the depressed state of the general economy in 1970 when the total computer industry experienced a decline. In 1970, the minicomputer industry achieved a 25 percent growth and demonstrated the strength of the market interest and the product demand for machines in the minicomputer price range.

The relatively low price of minicomputers as compared to larger general-purpose computers is achieved as a result of shorter word lengths, simpler instruction sets, smaller memories, less elaborate input/output capabilities, smaller peripheral devices, less software, and less market support. Due principally to progress in semiconductor technology, minicomputer prices have declined an average of 18 percent per year in the latter half of the 1960's. Further progress in semiconductor technology should produce additional price declines during the next five years resulting in basic configurations prices of 40 percent of current levels by the end of 1975. With continuing price declines and reductions in the number of separate packages in the central processor, minicomputers are rapidly approaching the status of a component of larger systems.

The potential domestic market for minicomputers is conservatively estimated to be well over 500,000 units. With a current installed base of only 21,500 units, it is clear that the industry has an opportunity for continued growth. The primary limiting factor to rapid growth will depend upon the ability of users to identify and implement new minicomputer applications. This will become more difficult as new areas and less sophisticated users are approached.

Successful penetration of potential markets and continued industry growth will also depend on the manufacturers' ability to simplify the application of minicomputers by providing greater support in software packages, education and training. Further, flexible systems are needed that use nearly identical hardware and software to solve many user prob-

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lems. Based on the projections of this study, shipments of minicomputers should grow from 9,000 units in 1970 to 41,000 units in 1975 for an average annual growth rate of 35 percent. Sales volume should grow from $210 million to $650 million during this period for an average annual growth rate of approximately 25 percent. The primary application area is expected to be industrial control systems, accounting for approximately 42 percent of sales.

The number of minicomputer manufacturers grew rapidly in the late 1960's. Currently, these companies include newly formed manufacturers dedicated to minicomputers, and large, diversified computer and electronics manufacturers. Continued growth in minicomputers offers many opportunities for these companies. However, several factors are expected to limit future success in the industry. These include high levels of competition, price declines in minicomputer systems and central processors, and the decline in value added in central processor manufacturing as machines are constructed from fewer semiconductor packages. The ultimate success of participating companies will be determined primarily by their ability to provide additional products and services such as diversifying into computer peripherals, providing software, and packaging complete systems to satisfy user problems. These factors are expected to be more important to a manufacturer's success than the ability to design and produce minicomputer central processors. Providing these services will require additional technical and financial resources which most current manufacturers will be unable to supply.

Two groups of companies are expected to predominate during the next five years — full range computer manufacturers who supply a broad spectrum of computer products and companies specializing in minicomputer systems. Both these groups will manufacture complete minicomputer based systems and will concentrate on the end user market.

I. THE MINICOMPUTER INDUSTRY

INTRODUCTION

In a large paper mill a computer completely controls the production of tons of paper. In the communications system of an international manufacturer, a computer network controls the flow of thousands of messages per day. In a high school, a student prepares his science lesson aided by a teletypewriter terminal communicating with a time-shared computer. So it seems that the giant computer complexes forecasted ten years ago, are indeed coming into being. Actually, however, in each of these three instances, the computers involved are the size of a desk drawer and cost little more than the average automobile. They are minicomputers or minis as illustrated in Figure 1.

Minicomputers represent one of the glamour industries of data processing—a $210 million industry that was born scarcely five years ago. It is an industry that some analysts predict will grow at least 50 percent per year and put a computer in every car and every home in the decade of the 70's.

This chapter reviews the scope of the minicomputer industry, the nature of its origin, the causes of its spectacular growth, its current status, its products and its markets.

EMERGENCE OF THE MINICOMPUTER INDUSTRY

Minicomputers are an outgrowth of the main computer industry which came into being in the late 1940's. Characterized by an initial period of slow growth, it was not until the early 1960's that the computer industry experienced an upsurge in growth. Initially, the low end of the product lines of the major computer manufacturers cost in the area of $100,000 thereby limiting their use to major organizations with large computational problems.

The key technological development that led to the emergence of the minicomputer was the wide-spread commercial availability of integrated circuits in the mid-1960's. The advent of this electronic development resulted in substantial progress in computer technology. It made feasible the manufacture of computers at substantially lower cost and enabled independent manufacturers to jump quickly into the computer market with a significantly new product.

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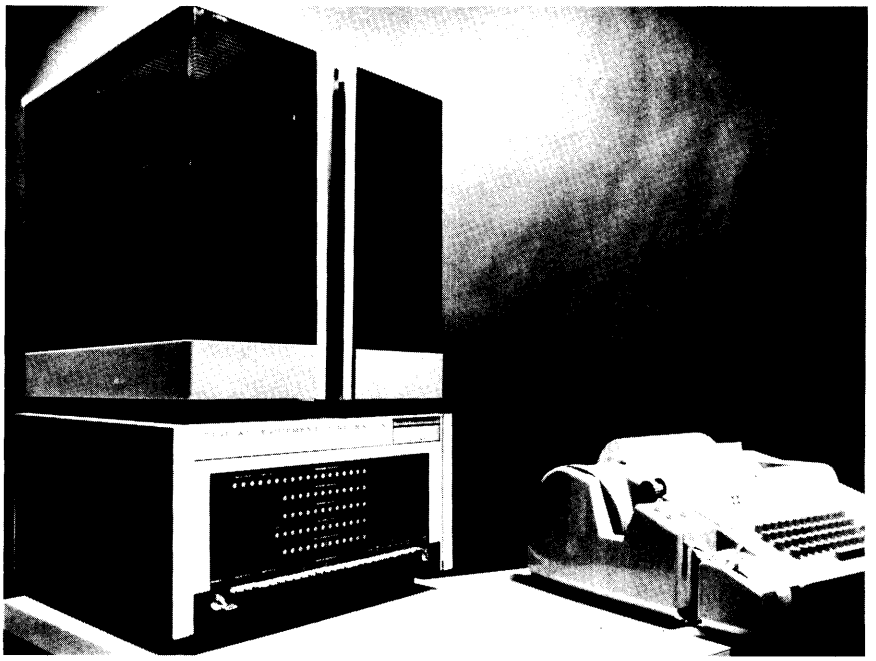

Figure 1. Basic PDP-8 Computer System

Industry Growth

In 1965, the minicomputer industry emerged with its first substantial sales of about $30 million. With rapid growth in sales, number of available machines and number of participating companies, the industry clearly established itself as a distinguishable segment of the computer industry. The phenomenal growth of the minicomputer industry is depicted graphically in Figure 2. In the last half of the 1960's annual sales have increased at an average rate of over 40 percent per year and, by the end of 1970, the installed base reached over 21,000 units.

Four factors were primarily responsible for the rapid growth of the minicomputer industry:

- The existence of a large market with a real and satisfiable need, due in significant measure to a maturing of user attitudes toward computers, and supported by general economic growth.

- Addressing this market by computer-experienced personnel who could exercise an unprecedented degree of freedom in product design to achieve major improvements in price and performance.

- Availability of resources to capitalize on this market opportunity, including experienced people, ready availability of funds, and readily usable technology.

- Availability of many off-the-shelf components for use in producing a reliable low-cost product.

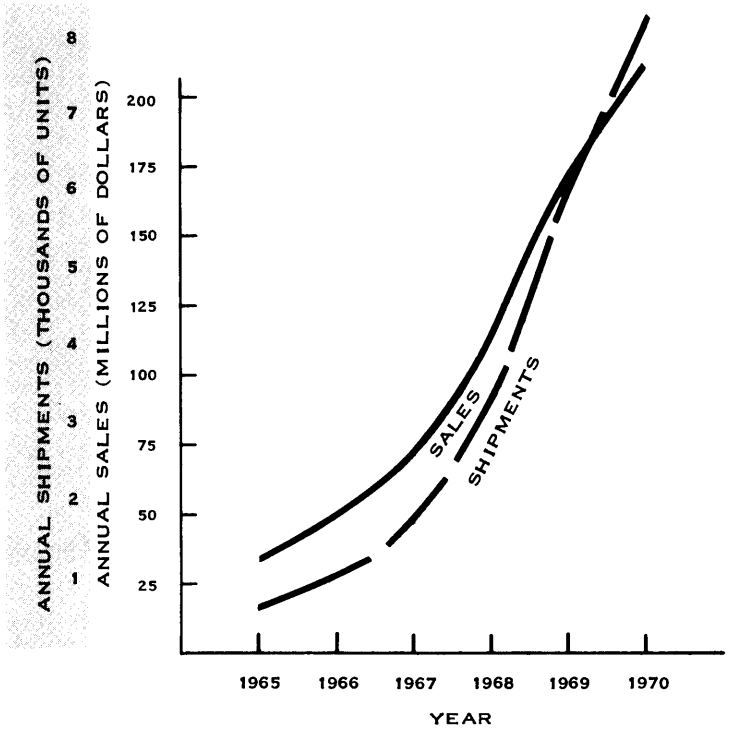

Figure 2. Growth of the Minicomputer Industry

The minicomputer has accomplished its growth both by making great strides in brand new territory as well as by invasion of existing markets commonly addressed by the big computer installations. It has not been restricted either by the kind of business or by the type of application. Its successes have been evident wherever people have recognized its ability to provide a special capability at a sharply lower cost, thereby producing a dramatic overall improvement in price versus performance ratios.

While the minicomputer industry achieved annual sales of approximately $210 million in 1970, the growth rate had clearly slowed compared to previous years. The national economic condition was a major contributing factor. Of further significance was the decline in the average system selling price which had fallen to approximately $23,000 in 1970 with a range of prices for minimum configurations reaching below $3,000.

Growth in Manufacturers

The rapid growth of the minicomputer industry also manifested itself in the number of companies involved. In 1970, the number of minicomputer manufacturers had grown to more than 60 of which more than half were newly incorporated within the last ten years. (See Figure 3.)

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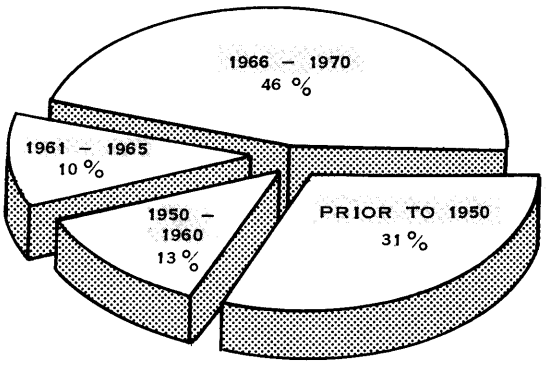

Figure 3. Distribution of Minicomputer Manufacturers by Year of Formation

Most of the manufacturers participating in this industry shared a number of important characteristics.

- They were formed by a small group of people with extensive technical and marketing experience within the computer industry.
- They generally enjoyed an abundance of financing, both through venture capital as well as through an overwhelming reception by the public for new stock offerings in computer-related firms.
- They were innovative and developed an internal ability to design, assemble and bring to the market quickly a product made primarily from purchased and readily available component parts.

THE MINICOMPUTER DEFINED

The word minicomputer probably originated in a presentation made at the Fall Joint Computer Conference in 1968 entitled "The Mini-Computer — A new Approach to Computer Design"[1]. The paper described a small experimental computer designed by IBM, which was called MINI. It contained only eight program instructions and 512 bytes of memory. Subsequently during 1969, the word minicomputer gained popularity and was used to categorize many small computers that were introduced to satisfy the demands of the scientific, data communications, and control-computer markets for a low-cost machine.

A minicomputer cannot be defined rigidly because of the dynamic nature of the industry. Any definition must necessarily be flexible—and subject to change as the minicomputer

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[1]D. C. Hitt, G. H. Ottaway, and R. W. Shirk, *AFIPS Conference Proceedings*, Volume 33, Part 1, 1968.

industry responds to technological developments in functional and innovative ways. The following definition, however, as used in this study, characterizes a distinguishable segment of the data processing industry and corresponds to general industry usage:

- A physically small, stored-program digital computer, which can be programmed
- Has a selling price less than $25,000 for a minimum stand-alone configuration that includes a central processing unit, a memory, input/output equipment, and systems software
- Contains a memory of at least 4,000 eight-bit words
- Performs normal computer functions (data input, transfer, storage, processing/-computational/logical operation, and data output) under stored-program control
- Programmable in an assembly or higher-level language, by the end user
- Usable in a broad range of applications.

In summary, a minicomputer is a small, stored-program computer priced under $25,000.

OVERVIEW OF THE INDUSTRY

An overview of the minicomputer industry is provided in the following paragraphs by examining the minicomputer from three perspectives. (1) its product, (2) its present and future markets, and (3) its manufacturers.

Products

Minicomputers are functionally similar to their larger counterparts. The implication of the description "mini" should not be misinterpreted. They are powerful machines with speeds as fast as, or even faster than some larger computers. The price advantage achieved in minicomputers relative to larger computers results from:

- Simpler instructions sets — both in the absolute number and the power of instructions provided.
- Smaller memories — prices under $5000 for minicomputers are for minimal configuration systems, typically with 4,000 words of memory. For larger systems, memory prices rapidly overwhelm the central processor cost.
- Shorter word lengths which permit internal economies in the central processor electronics.
- Less elaborate input/output control capabilities.

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- Minimal software which reduces the manufacturer's development cost.
- Elimination of such features as real-time clocks and parity checking from the basic system.
- Less powerful peripheral devices.
- Lower marketing costs due to minimal system engineering support.

While limited software, instruction sets, memories and word lengths represent significant economies, they also contribute to the major disadvantages of minicomputers; i. e., programming difficulty and increased program execution times. These difficulties arise from the limited addressing capabilities provided by short word lengths, longer instruction sequences necessitated by the limited instruction sets, a larger number of memory accesses required per instruction, and the difficulty of implementing programs due to the limited memory capacity. The simpler instruction sets also limit the flexibility of each individual machine to address the requirements of different applications.

Rapid Growth in Available Machines. The growth in the population of available minicomputers has paralleled the growth in manufacturers. Between 1965 and 1970, approximately 100 new models were installed — most of them in 1969 and 1970 (Figure 4).

Recent Price Trends. Since 1965, basic system prices for minicomputers have declined over three-fold, with some models now priced as low as $3,000. In 1970, many manufacturers reduced their selling prices 20 to 40 percent. This price decline was influenced by lower component costs, larger customer bases and increasing pressure in the marketplace. Manufacturing cost reductions were achieved in a number of ways:

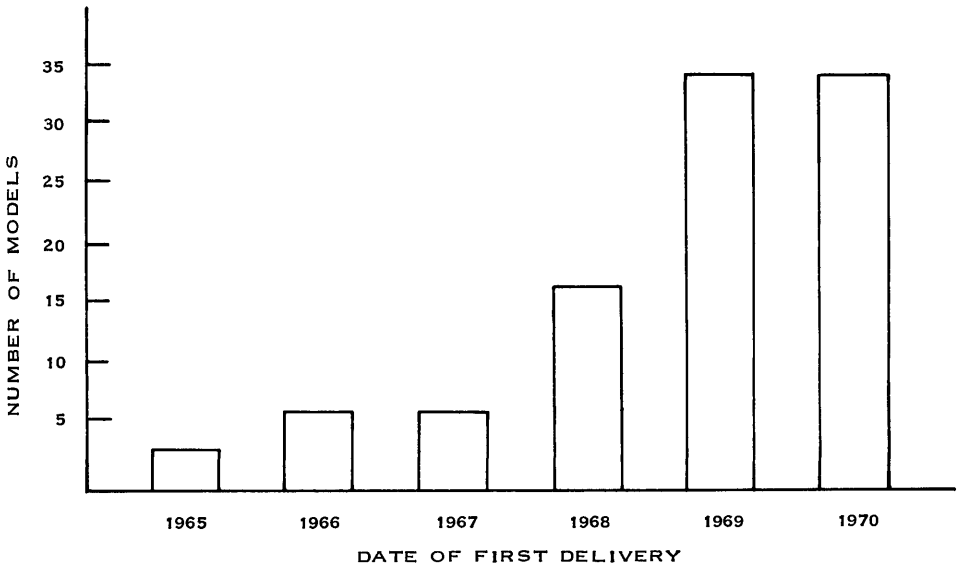

Figure 4. Number of New Minicomputer Models

- Production improvements notably in the manufacture of memories
- Lower material cost, especially for integrated circuits
- Lower labor costs due to greater component densities which yield fewer parts
- Improved production reliability, yielding lower re-work costs
- Increasing volume, yielding production economies
- Expanding product lines, spreading the base for recovery of product development costs.

Not all of these price cuts, which amount to as much as 40 percent, are entirely attributable to manufacturing efficiencies. The combination of decreased demand due to the national economy and increased competition has led to more aggressive sales policies. Substantial discounts below list prices are common. Another price cutting method is to introduce new models essentially comparable to earlier modes but with reduced price tags. The obvious result is greater pressures on profit margins.

Design Flexibility. Minicomputer designs emphasize flexibility to satisfy a broad range of application requirements. They are typically designed around a minimum stand-alone system composed of a small core memory of 4,000 bytes and a teletype keyboard with a paper tape input/output. The basic system usually includes as little standard hardware as possible but can accommodate a variety of optional hardware modules which can produce a system to match a user's specific requirements. These options include: internal hardware such as multiply/divide and peripheral devices such as card readers/punches, disks, tapes, line printers, serial printers, plotters, CRT terminals, and analog/digital/analog conversion equipment. Minicomputers are not so "mini" when a number of optional features are included.

Early minicomputer manufacturers avoided expensive outlays on software development. This was possible because the specialized programming needs of dedicated applications did not require extensive system software. Typical software provided with an early minicomputer system included a compiler (FORTRAN, BASIC or ALGOL), an assembler, a small set of utilities and a modest operating system. However, as broader markets, such as business applications are approached, marketing success will increasingly depend on software products.

Markets

Despite the minicomputer's relatively short history, they have been utilized over a wide range of applications. They are used as stand-alone general-purpose systems, as well as in very narrow applications in which the mini performs a dedicated function.

Scope of Present Markets. Minicomputers are sold extensively to original equipment manufacturers (OEM's) and incorporated within a larger system for distribution to end

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users. They are commonly used as the main component of a system for a process control, as well as a component of large computer systems such as a front-end communications processor. They have penetrated existing markets such as time sharing, and entered new markets such as that or laboratory experiment monitoring. Despite this broad view of the minicomputer marketplace, the majority of minis are installed in dedicated applications, sold to OEM's, or are used in new market segments not previously penetrated by larger computers.

Marketplace Utilization. The minicomputer, like the large computer, is used for two basic types of functions — as a controller and as a calculator/data processor. As a controller, minicomputers control:

- *processes* such as those encountered in a chemical production plant or an experimental laboratory,
- *devices* such as typesetting machines or Optical Character Readers,
- *data* as in a data communication network.

As a calculating machine, minicomputers are used to solve complex scientific problems, perform business data processing, and solve student homework problems. Minicomputer uses are best characterized by their variety, limited mainly by the creativity and ingenuity of users and manufacturers.

General Applications Areas. In this report, minicomputer applications are grouped into five general areas (Table 1-2). These application areas possess distinguishing characteristics relating to the type of function performed by the mini, the design requirements of the mini and the marketing approach required to successfully penetrate the area. Both the minicomputer market analysis and the market forecasts presented in later sections of the report are based on these application areas.

INDUSTRY STRUCTURE

Minicomputer manufacturers encompass a broad spectrum of companies, from the very small newly formed companies, to the very large and diversified manufacturers. This spectrum is defined by the following five classifications.

- *Large computer manufacturers* — such as Digital Equipment Corporation, Honeywell and IBM
- *Dedicated minicomputer manufacturers* — such as Data General and Interdata
- *Diversified electronics manufacturers* — such as Hewlett-Packard and Varian
- *Semi conductor manufacturers* — such as Texas Instruments and Motorola
- *Diversified manufacturers* — such as Lockheed, Westinghouse, and Xerox Data Systems

Nearly all of the companies in the minicomputer industry are exclusively assemblers of purchased parts, with only the degree of assembly varying among companies. For example, companies can either make or buy such system components as printed circuit boards, core

Table 1. Application Area Sales Distribution and Description

Application Area	1970 Sales (Percent)	Functional Description
Industrial Control	45	Controls continuous industrial process in the chemical, petroleum, food processing, utility, and other industries. Controls the operation of numerically controlled machine tools. Controls a variety of special industrial operations like typesetting in the publishing industry or automatic system testing in the electronics industry.
Peripheral Control	3	Controls the operation of other equipment, such as Computer Output Microfilm (COM), Optical Character readers (OCR), key-to-tape and key-to-disc computer input systems, digital plotters, line printers, magnetic tape units, magnetic disc units and intelligent terminals.
Communications	20	Controls the concentration of data from several low-speed communications lines onto one high speed line Controls the flow of messages in message switching systems. Controls the transfer of data between a large computer and communication lines connected to remote terminals.
Computations	10	Used as the central processor in a free-standing computer system performing general business data processing functions. Used as the central processor in a free-standing computer system performing scientific computations. Used as the central processor in small in-house time-sharing systems.
Data Acquisition	22	Controls the operation of scientific experiments and instruments. Monitors various types of experiments or operations to accumulate performance data.
TOTAL	100	

memories, mechanical housings, peripheral devices and software. Naturally, the greater the degree of in-house fabrication, the greater the value added and the greater the prospects for profitability. The primary contributions of the minicomputer manufacturer are his ability to design a high-performing system that can be manufactured with high production efficiency, and his ability to market these products to sophisticated users.

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Concentration of Manufacturing Capacity

The population of minicomputer manufacturers increased at a rapid pace late in the 1960's and totaled over 60 by the end of 1970. Currently, however, the number is declining due to the financial difficulties experienced by many new companies.

Despite the large number of minicomputer manufacturers, a high percentage of the installation base is concentrated in relatively few companies. The installed minicomputer base and the distribution among the major manufacturers is indicated in Table 2. Of the

Table 2. Installed Minicomputers

Company	Principal Minicomputers	Number of Minicomputer Installations (1/1/71)	Percent of Total
Digital Equipment Corp.	PDP-8 Series PDP-9/15 PDP-11 PDP-12	10,000	46.5
Hewlett-Packard	2007-A 2114-A 2114-B 2115 2116-A 2116-B	2,000	9
Honeywell	316 416 516	1,800	8.5
Varian	520 620 (Series)	1,800	8.5
Data General	Nova Supernova Nova 1200 Nova 800 Supernova SC	850	4
General Automation	SPC-12 SPC-16 GA-18/30	800	4
Interdata	1, 2, 3, 4, 5, 15	550	2.5
Systems Engineering	810	450	2
Computer Automation	208, 808, 216, 816	400	2
All Others		2,850	13
Total		21,500	100

21,500 installations at the end of 1970, approximately 87 percent is accounted for by the nine largest companies.

Except for the largest suppliers of minicomputers, most companies have concentrated on either OEM sales or end user sales. Most companies have preferred the OEM segment, principally because of minimal sales expenses and software development. Furthermore, this segment provides the most rapid avenue for increasing an installed base and generating cash flow.

The Major Industry Segments

In order to present a true perspective of the relative influence of minicomputer manufacturers on the industry, it should be described as being composed of the following four segments.

- *Digital Equipment Corporation* — the single most successful company in the industry, with 46.5 percent of the installed base
- *Three large electronics and computers manufacturers* — Hewlett-Packard, Honeywell and Varian, with 26 percent of the installed base
- *Five young minicomputer manufacturers* — General Automation, Data General, Interdata, Computer Automation, and Systems Engineering, with 16.5 percent of the installed base
- *Over fifty remaining companies* — with approximately 13 percent of the installed base

Digital Equipment Corporation (DEC). DEC was formed in 1957 to design and manufacture electronic logic modules but has emerged as the giant of the minicomputer industry with 46.5 percent of the installed base. It has used its successes in the minicomputer field to expand into broad product lines. This expansion includes larger machines which compete directly with larger computer systems and the manufacture of a wide range of peripherals for minicomputer systems. DEC's strengths in the industry include an extensive market penetration, an extensive product line, a well-established image and marketing force, and a profitable mode of operation.

Three Large Electronics and Computer Manufacturers. A group of three diversified electronics manufacturers, Hewlett-Packard, Honeywell and Varian, each accounted for $15 - $25 million in minicomputer sales in 1970. In each case, minicomputer sales represented a relatively small part of the company's total revenues.

Hewlett-Packard (HP) has capitalized on its exceptionally good reputation in instrumentation to penetrate the minicomputer market. It emphasizes sales for process control and other applications which utilize its extensive instrumentation experience and has in addition, been successful in reaching the in-house time-sharing market. HP's strength is based on its financial durability and established marketing organization.

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Honeywell entered the minicomputer field via its acquisition of Computer Control Corporation, which has become its CCD Division. Minicomputers represent only one segment of the broad spectrum of computer systems it offers. Honeywell concentrates on the communications, in-house time-sharing and industrial control segments of the minicomputer market. Its strength is based upon the diversification of its product line, extensive marketing force and general reputation as a computer manufacturer.

Varian's principal business has been in the area of microwave tubes and electronic devices. The minicomputer division, founded in 1960 as an independent company, was purchased in 1967 and later became known as Varian Data Machines. Varian emphasizes OEM sales and concentrates on the communications, peripheral control, data acquisition and scientific computation application areas..

Five Young Minicomputer Manufacturers. Five aggressive minicomputer manufacturers, General Automation, Data General, Interdata, Computer Automation and Systems Engineering, represent the third segment of the industry. Each controls 2 to 5 percent of the market. The first four companies listed are dedicated to minicomputer manufacture. Formed in the latter half of the 1960's, they each grossed less than $10 million sales in 1970 while operating with only a few hundred employees. These companies concentrate on the OEM market and aggressiveness in product development and marketing approach. For example, Data General is the first minicomputer manufacturer to announce a semiconductor memory in its product line, and Interdata made extensive use of firmware, i.e., the hardware implementation of routines and algorithms normally performed with software.

Over Fifty Remaining Companies. The fourth segment of the industry, which consists of more than 50 remaining companies, includes several manufacturers which illustrate special aspects of the minicomputer industry. IBM, the giant of the computer industry, entered the minicomputer field in 1970 with its System/7. With it came the spectre of a broad-scale invasion of the minicomputer marketplace by the industry giant and the potential impact on the smaller companies. Furthermore this move portended the potential entry of the major computer manufacturers into the minicomputer field.

Texas Instruments (TI) and Motorola used their expertise in semiconductor technology to enter the minicomputer field. Minicomputer price and performance have benefited primarily from the improvements in semiconductor technology. This technology continues to be a key element in the future success of minicomputer companies, so that TI and Motorola possess a unique advantage in one aspect of the industry.

Included within the fourth industry segment are a number of companies which are minicomputer manufacturers only in a peripheral sense. They manufacture minicomputers, but only as one subsystem of a larger, special-purpose system. Four Phase Systems, Inc., which manufactures a display processing system, and Foto-Mem, which manufactures an information storage and retrieval system, represent examples of these companies.

Japanese manufacturers have not been a significant factor in the American market. Six Japanese companies are in various stages of developing and introducing their own minicomputers. *The potential for invasion of the domestic and worldwide minicomputer markets*

by these companies is clearly present in a manner similar to that of the calculating machine market.

The well-publicized fall-out of minicomputer manufacturers during the last several months has left its mark upon the industry makeup. Financial difficulties have beset a number of firms, especially the smaller and poorly financed ones. Such financial difficulties have recently taken their toll among such names as BIT, Viatron, Scientific Control Corporation and Foto-Mem. Fairchild announced at the Spring Joint Computer Conference in 1970 that it was introducing a minicomputer family, but reversed its stand in the Fall of 1970 by completely withdrawing the program. Other firms sought support through merger with larger organizations such as the purchase of Tempo Computer by General Telephone and Electronics. In January of 1971 with no relief in sight for the financial difficulties of most members of the minicomputer industry, the roster of minicomputer firms continued at a highly fluid rate.

* * * *

In this chapter, we have reviewed the formation of the minicomputer industry, outlined its products and technology and identified the functions and applications which have provided the opportunity for its outstanding sales growth. The next chapter examines the industry's products in greater depth and the technology behind these products.

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II. PRODUCTS AND TECHNOLOGY

THE MINICOMPUTER SYSTEM

Just as the minicomputer industry has evolved from the larger EDP industry, so minicomputer design has evolved from that of larger computers. Conceptually, minicomputer systems are similar to bigger systems. Their components can be similarly divided into the central processor unit (CPU), peripheral equipment, and software. A block diagram illustrating the hardware components of the system is shown in Figure 5. The major components are discussed separately in the following paragraphs.

Central Processor Unit

The central processor or main frame of a minicomputer system contains the basic computational logic, internal memory, and control capabilities. Specific units of the central processor include the following:

- *The Arithmetic Unit* — performs the computation and logic required for the execution of machine instructions.
- *Control Unit* — coordinates the actions of the arithmetic unit, memory, and the input/output devices.
- *Main Memory* — holds instructions and data in the form of binary numbers.
- *Input/Output Control* — provides communication between the computer and input/output devices as determined by instructions decoded in the control unit and signals sent to the computer from external peripheral devices.

Peripheral Equipment

Peripheral equipment consists of devices which are external to the computer but communicate with it directly. They can be classified as follows:

- *Man-machine devices* — provide direct communication between the computer and a human operator; communication may be via a keyboard (as in a teletypewriter), paper tape, cards, printed output, or a cathode-ray tube display.

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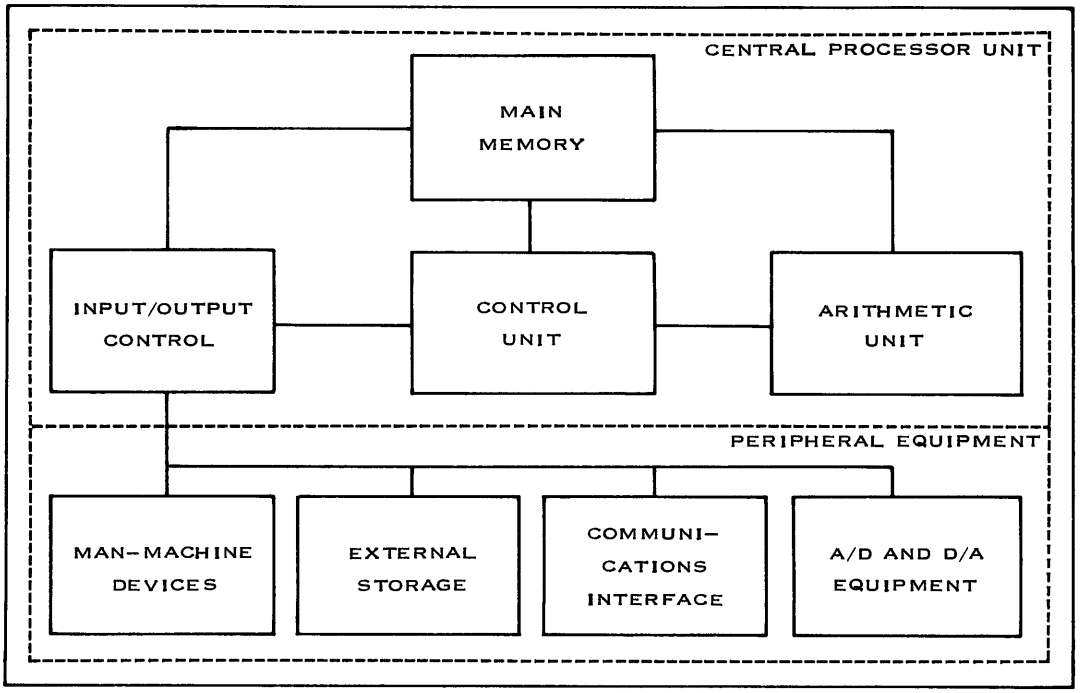

Figure 5. Block Diagram of Hardware Components of Minicomputer System

- *External storage* — provides economic storage for large quantities of data for access and alteration by the computer; devices in this category include magnetic tape units, drums and disks.

- *Communications interface* — provides external communication either with other computers or with remote terminals; frequently a communications controller is provided to allow connection of the minicomputer to a number of telephone lines.

- *Analog to digital, and digital to analog equipment* — provides communication between the computer and its external environment in such applications as process control. Digital to analog equipment allows the setting of external controls and indicators by the computer while analog to digital equipment allows the computer to read such external devices as thermometers or voltmeters.

Software

The software for a computer system consists of sets of specific instructions (programs) to control its operation. There are two basic kinds of software. (1) system software — concerned primarily with the basic operation and programming of the computer, and (2) applications software — dedicated to a particular application.

System software is usually provided by the computer manufacturer and ranges in complexity from the minimum required for operation of the machine to sophisticated multi-

programming or time sharing operating systems. Applications software is usually provided by the computer user. Its production is facilitated by the provision of standard subroutines and language compilers within the system software. In some cases, the manufacturer sells a minicomputer as a complete free-standing unit for some particular application such as typesetting, time sharing, numerical control of machine tools or digital circuit testing. In such cases the manufacturer generally supplies all the software required for that particular application.

PRODUCT AND PERFORMANCE PROFILES

The product ranges represented by the large number of minicomputers currently on the market can be understood by analyzing the various types of minicomputer systems and the ways in which performance characteristics have developed over the last few years. This section categorizes the available and recently announced minicomputers and discusses the ways in which their prices and performance characteristics have developed. In addition, a perspective of minicomputer capabilities and prices is presented by comparing them with those of some larger computers.

Product Classification

The most fundamental classification of minicomputers is in terms of word length—the number of bits of data available by a single access to the computer's memory. The designer's choice of word length is a compromise between a number of conflicting factors. For example, the main advantage of short word length is that the central processor is potentially less expensive since the number of bits in a memory word largely determines the number of the data paths and the size of logic circuits (such as special registers, adders, etc.) within the arithmetic unit. However, a short word length has the disadvantages of programming difficulty and reduced operating speed. These disadvantages develop because:

- Several words are frequently required to retain a single data item (with a consequent need for the elaborate programming of arithmetic operations).

- The instructions themselves are too short to permit the direct addressing of much of the memory, therefore time-consuming addressing techniques must be used.

Sixteen-bit minicomputers represent a reasonable compromise on word length and are rapidly becoming an industry standard. The 16-bit word provides a reasonable balance between the factors mentioned. It also has the further advantage of holding two standard 8-bit bytes of data. Table 3 presents the distribution of minicomputers by their word lengths and year of first delivery. It indicates both the large increase in the number of machines available and the preponderance of 16- or 18-bit machines. (Of the seventy 16/18-bit machines listed in the table, 64 are 16-bit and 6 are 18-bit machines.)

Price Profiles

Minicomputer prices have declined rapidly in the last several years. A discussion of price must be qualified by such factors as the marketing strategies of manufacturers and the

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Table 3. Distribution of Minicomputers by Word Length and Year of First Delivery

First Delivery	Word length				
	8-bit	12-bit	16/18-bit	24-bit	Total
1965		1	2		3
1966	1	1	4		6
1967		1	5		6
1968	5	3	9		17
1969	5	2	26	1	34
1970	7	2	24	1	34
TOTALS	18	10	70	2	100

architectural peculiarities of particular machines. The general trend in prices however, is shown in Figure 6. This figure shows the representative price ranges by year of first delivery for standard configurations of 8- and 16-bit minicomputers. It indicates the general price differentiation between the 8-bit and 16-bit machines and demonstrates a similar price decline for both product categories. The trend line indicates a typical decline by a factor of

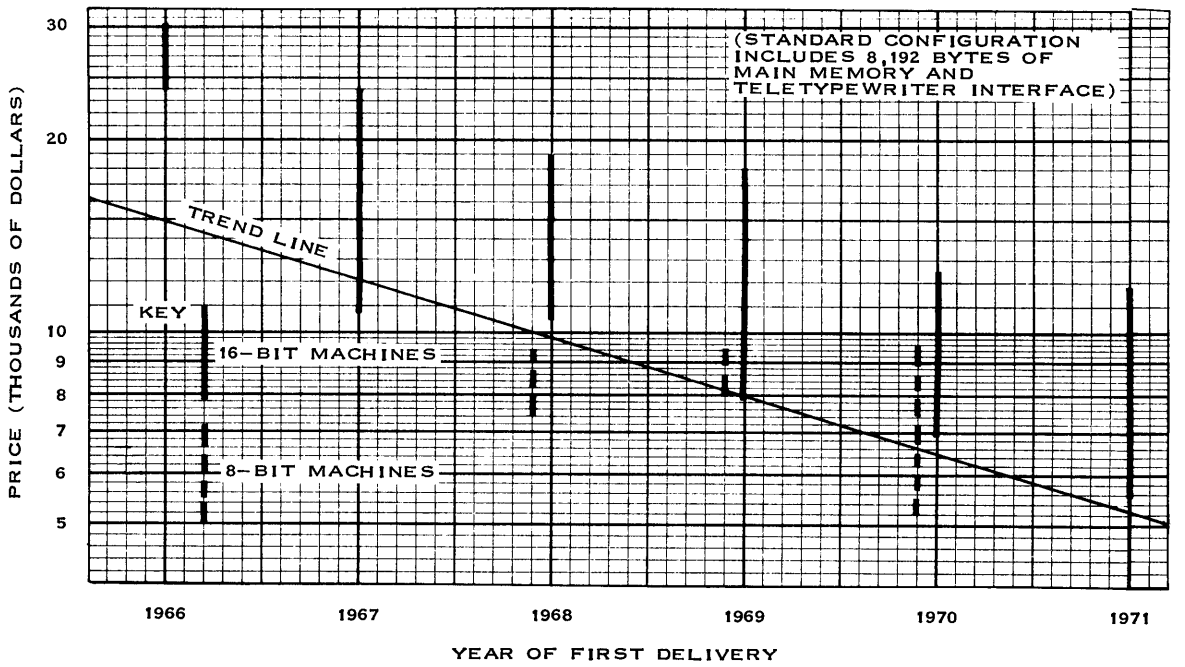

Figure 6. Standard Configuration Price Ranges

almost 3 over a 5-year period, or approximately 18 percent per year. The general decline in prices can be attributed to:

- Lower component costs in both the central processor and main memory.
- Changes in marketing strategies as competition intensified
- Economies in large-scale production as the size of the minicomputer market increased

Recent examples of the way in which competition and the prospects for mass production have encouraged manufacturers to reduce their manufacturing cost include Digital Equipment Corporation's automated PDP-8/e production line and Interdata's fabrication of core memories in Barbados (for economies in labor costs).

Performance Profiles

Care must be used in evaluating the improvements in minicomputer price/performance ratios. The improvements in the price portion of the ratio have been shown. The performance portion, however, is less obvious. Many factors determine the capabilities of a minicomputer; cycle time, memory capacity, word length, instruction repertoire, interrupt procedures, and addressing schemes interact in complex ways so that absolute performance measures are difficult. Furthermore, these factors combine differently for particular applications.

Table 4 presents the trends in several minicomputer performance parameters. The data illustrates the fact that several parameters have provided modest improvements in performance while other parameters have remained relatively stable.

Memory Cycle Time. A key indicator of internal performance is memory cycle time. The median value of minicomputer cycle times has declined 31.2 percent from 1.75 to 1.2 microseconds between 1967 and 1971. Cycle times for the fastest machines, however, remained in a narrow range of 0.75 to 0.9 microsecond between 1967 and 1970. The first significant increase in speed in several years has been provided by newly announced minicomputers with semiconductor memories which are scheduled for 1971 delivery.

Instruction Execution Time. The trend in instruction execution times is indicated by the program sequence of adding two numbers from memory and storing the sum in a third location (i.e., c = a + b). Table 4 presents for 16-bit machines the actual times for c = a + b as well as the time normalized by memory cycle time which yields the number of memory cycles required for the program sequence. The median value for normalized c = a + b has remained constant indicating stability in instruction execution logic. The median value of actual time for c = a + b has declined by 30.4 percent from 10.2 to 7.1 microseconds — a reflection of the improvement in memory cycle time.

Internal Registers. The availability of internal registers has also produced improved performance. General purpose registers can reduce the number of memory references

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Table 4. Trend in Minicomputer Performance Parameters

Parameters	Year of First Delivery				
	1967	1968	1969	1970	1971
Memory Cycle Time					
Range (microsec)	0.96-3.0	0.75-8.0	0.8-8.0	0.75-1.75	0.3-1.76
Mean (microsec)	1.69	2.68	1.87	0.98	1.16
Median (microsec)	1.75	1.50	1.55	0.98	1.2
c=a+b (16-bit machines)					
Mean (microsec)	25.7	18.5	13.6	6.5	6.4
Median (microsec)	10.2	12.0	11.2	6.0	7.1
Normalized c=a+b (16-bit machines)					
Mean (no. cycles)	17.1	8.8	6.9	6.7	7.6
Median (no cycles)	6.0	6.0	6.0	6.0	6.0
Number of General Purpose Registers					
Mean	3.6	3.4	3.1	6.5	4.0
Median	2	2	1	4	3
Number of Index Registers					
Mean	3.0	3.5	1.7	2.5	3.1
Median	1	1	1	1	1
Standard Interrupt Problem					
Mean (microsec)	18.4	18.1	22.4	17.8	19.7
Median (microsec)	9.5	11.6	11.2	7.0	11.2
Interrupt Lines & Levels					
Median Number Lines	1	4	4	4	1
Median Number Levels	15	6	16	8	16

during program execution. The median number of these registers per machine has increased from 2 to 3 between 1967 and 1971. Conversely, the median number of index registers has remained constant during this period.

Interrupt Structure. The interrupt structure is a further influence on performance. Table 4 presents the timing for a standard interrupt problem which measures the overhead for storing all processor registers at the beginning of an interrupt servicing sequence as well as for re-storing them again at the end of the sequence. Also shown in the table are the number of available interrupt lines and levels. Examination of this data does not reveal any discernible trend toward improved performance within these particular parameters.

Other Factors. Several other factors have contributed to improved minicomputer performance. These include:

- Interrupt systems which permit faster identification of the source of an interrupt
- Use of firmware; i.e., hardware implementation of complex routines normally accomplished via many program instructions

- New bus concepts which contribute flexibility in peripheral to peripheral data transfers
- Availability of high performance disk pack systems
- Increased availability of software to ease programming

In summary, many factors have contributed modest increments to better performance yielding a total improvement that is difficult to quantify. It should be noted that minicomputer capabilities are more than adequate to satisfy most application requirements. Improved performance, therefore, is not necessary for reaching the bulk of the minicomputer market.

Price/Performance Profiles

One parameter which approximates the combined effects of price and performance in minicomputers is the quantity.

$$\frac{\text{word length}}{(\text{cycle time})\ (\text{standard configuration price})}$$

This parameter is a consistent measure of price/performance since it improves as the word length increases, and as cycle time and price decrease. The mean value of this price/performance ratio for minicomputers by year of the first delivery is plotted in Figure 7. The

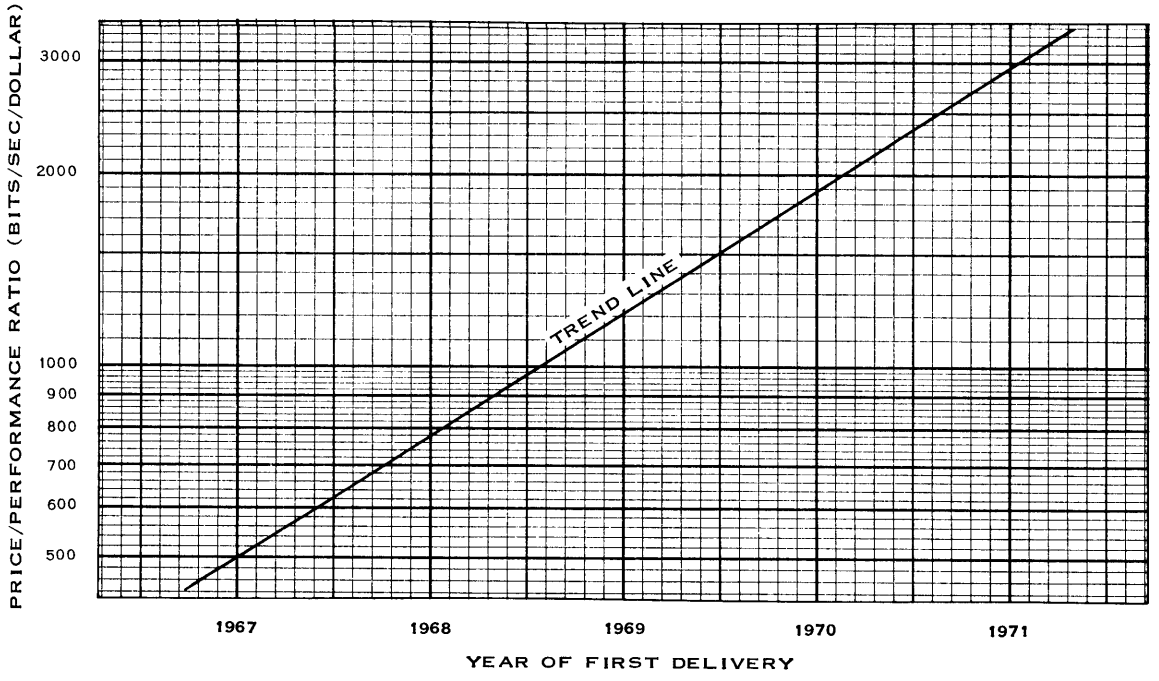

Figure 7. Trend in Price/Performance Ratio

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approximate trend line shows an improvement by a factor of 6 over a 4-year period which represents an average gain of over 50 percent per year.

Comparison of Minicomputers with Larger Computers

A perspective of the relationship between minicomputers and the spectrum of general purpose computers is provided by comparing the minicomputer with other modestly-priced computers such as the IBM System/3 and the smaller models of the System/360 line. Table 5 presents a comparison of representative 16-bit minicomputers and small business computers, and Figure 8 presents their price ranges versus main memory capacity. This figure illustrates that minicomputers have basic configurations which are less expensive than the basic configurations of small business machines, and that the cost of main memory is an important component of the total main frame cost for either type of system. The data given in Table 5 also indicates that minicomputers and small business computers are similar in many of their performance capabilities.

The differences between minicomputers and small business computers arise primarily from the divergent markets which they address. Minicomputers are generally sold to sophisticated computer users for applications in which arithmetic speeds and rapid response to external signals are important. Conversely, business computers are generally sold to comparatively unsophisticated users for input/output dominated applications where ease of programming is more important than arithmetic speeds. Application requirements therefore determine the following general differences between minicomputers and small business computers.

- The instruction sets of minicomputers tend to consist of rapid instructions for elementary operations such as fixed-point arithmetic and logical operations; instructions in small business computers are, in general, slower but include more elaborate instructions for such operations as character handling and decimal arithmetic.

- Input/output control requires more programming and consumes more computer time in minicomputers; autonomous input/output transfers (requiring minimal instruction execution) are generally provided on a limited scale as optional features for minicomputers; in small business computers this mode of input/output is the norm and more sophisticated features such as command chaining (i.e., the execution of a sequence of input/output operations with a single instruction, are usually included as well).

- The pricing of small business computers compared to that of minicomputers necessarily reflects the manufacturer's increased marketing costs, associated with sales and support needs of unsophisticated users.

MINICOMPUTER TECHNOLOGY

This section evaluates the current state of minicomputer technology. The emphasis in this section is upon those technology features which are representative of all the currently

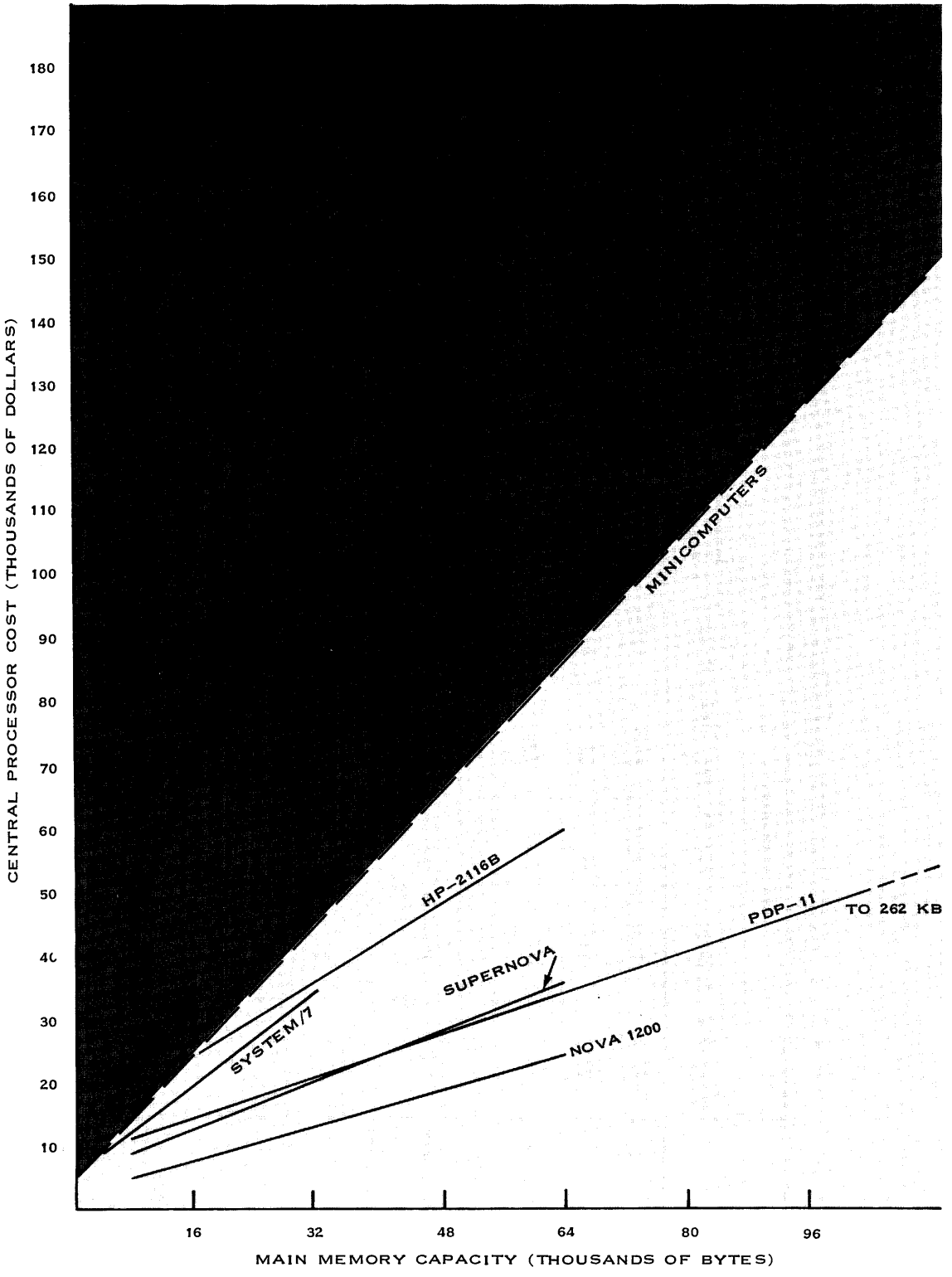

Figure 8. Central Processor Costs of Minicomputers and Small Business Computers

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Table 5. Comparison of Minicomputers and Small Business Computers

		Minicomputers				Small business computers				
Machine	Nova 1200	Supernova	PDP-11	HP 2116B	System/7	System/3 Mod 10	360/20 Mod 3	360/20 Mod 5	360/25	360/30
First Delivery	2/71	4/70	4/70	7/68	11/71	11/70	11/68	5/69	1/69	5/65
No. Instructions	28	28	45	51	39	28	37	37	87	87
Cycle Time (microsec)	1.2	0.8	1.2	1.6	0.4	1.52	3.6	2.0	1.8	
Memory Range, (Kb)	4-65	4-65	4-262	16-65	4-32	8-32	4-16	8-32	16-49	8-65
Bits Accessed Per Cycle	16	16	16	16	16	8	8	16	16	8
No. Decimal Arithmetic Operations	0	0	0	0	0	All instructions character or decimal oriented	5 (+ character handling)	5 (+ character handling)	0	8 (opt.)
No. Floating Point Operations	0	0	0	0	0	0	0	0	44 (opt.)	44 (opt.)

available minicomputers rather than on the specific features of any particular machine. Technology issues relevant to main frame architecture, semiconductors, peripheral equipment, and software are discussed separately in the following paragraphs.

Main Frame Architecture

Main frame architecture represents the fundamental internal design feature of the machine. The characteristics of main frame architecture include addressing schemes, interrupt schemes, control logic, input/output control, and internal memory.

Addressing Schemes. The limited word size in minicomputers restricts the number of binary bits in its instruction which can be used to specify the location of an operand in main memory. Generally, this means that not all the locations can be addressed directly. Various techniques have been devised to overcome this shortcoming. They are collectively referred to as addressing schemes and are summarized in Table 6. The limitations of each method as indicated in the table are not always apparent to the programmer because the system software (assemblers, loaders, and language compilers) frequently allows the programmer to write instructions as if the whole of main memory were directly addressable from every memory reference instruction. In any particular minicomputer, the addressing techniques are usually a combination of several of the methods listed in the table. For example, the Data General Nova has direct, multi-level indirect, and indexed addressing capabilities.

Interrupt Schemes. An interrupt in a computer is a signal which causes it to stop the execution of instructions of lesser importance and branch to a specified set of instructions to deal with the interrupting conditions. When processing of the interrupt is complete, processing of the less important task is resumed.

Interrupt handling is important in many minicomputer applications, particularly, process control and data communication where the computer must respond quickly to external conditions. Interrupt can be handled in various ways, but basically the two types of interrupt structures are single-level and multi-level.

In a single-level interrupt structure, all interrupts, regardless of their cause, transfer control to a standard software routine that determines the cause and branches to a set of instructions to process the condition. While the interrupt is being processed, no other interrupts can be serviced although there may be some queuing arrangement in the computer hardware. The advantage of a single-level interrupt system is its low cost due to its simplicity; however, the overhead time required to identify the cause of each interrupt, and the possibility of losing other interrupts while this function is being performed, are disadvantages.

In a multi-level interrupt system, the interrupts are arranged on several priority levels. Each priority level passes control to a separate memory location which eliminates the need for software identification of the level. Some minicomputers provide enough levels (usually as options) to allocate a different level for each interrupt cause. The main advantages of

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Table 6. Minicomputer Main Memory Addressing Methods

Method	Description	Problems/Limitations
Direct Addressing	Instruction format includes field large enough to address any main memory location.	Number of required bits either curtails main memory size too severely or the instruction length slows execution time, and makes logic expensive, (because instruction extends over several words)
Indirect Addressing	Address in instruction specifies a memory word that contains the operand address (multilevel indirect addressing is sometimes permitted)	Time consuming due to extra memory cycle required to fetch address word.
Paging	Memory divided into sections called "pages", typically 256 words. Address in the instruction refers to address within the current or base page. Usually the base page is accessible by any instruction.	Overhead required to specify page. Constraints on organization of program to be met by programmer or software
Relative Addressing	Operand address interpreted as a displacement from address of instruction using it.	Constraints on program organization leads to problems when instructions are added or removed from an existing program
Indexing	Address specified in instruction is added to contents of an index register to obtain effective address	Overhead associated with setting up index register contents. Time consuming if index register implemented as a main memory location.

multi-level interrupt systems are the reduction of the software overhead for interrupt identification and the ability to nest interrupts; i.e., a high-priority interrupt can disrupt the processing of one of lower priority.

Both single and multi-level interrupt systems must provide for protecting the contents of the program-addressable hardware registers, such as index registers. The content of these registers must be saved before processing an interrupt and then restored to their orginal state in order to resume execution of the interrupted program. Some minicomputer designs require that each interrupt processing routine start and finish with standard sequences for storing and restoring the contents of hardware registers. In other cases, multiple sets of registers are available or the necessary storing and restoring is performed automatically by hardware. In any case, while assessing the performance of a given interrupt system, some attention

must be paid to the details of the hardware registers of the machine as well as to the number of hardware interrupt levels.

Control Logic. The control logic coordinates the functions of all the system components, is responsible for the decoding and execution of the computer instructions, and determines the exact sequence of events following an interrupt. Functionally, it determines what actions the machine should perform and generates electrical signals to implement this action. There are two fundamental approaches to the implementation of control logic — special logic and microprogramming.

- *Special logic* — the conventional approach is by special logic. In this case, all the control logic is a part of the basic machine hardware and consists of logic gates and timing circuits which recognize certain conditions and generate the required control signals.

- *Microprogramming* — in a microprogrammed approach the hardwired machine can perform only simple functions on microinstructions. The control logic consists of a high-speed memory containing sequences of microinstructions for each available machine instruction and relatively simple logic to execute the microinstructions. Typically, the microinstructions are stored in a special-purpose, read-only memory. This approach is becoming more attractive with the availability of high-speed semiconductor read-only memories. Three advantages of microprogramming are:

  1. The read-only memory can take advantage of standardized MSI/LSI circuits while maintaining flexibility in the manufacturer's control logic;

  2. Microprogramming provides flexibility which permits the same basic machine to be tailored to different requirements;

  3. Microprogramming can improve performance by incorporating special-purpose instructions—such as a push-down list or character manipulation.

Disadvantages of microprogrammed machines are that system software cannot be used if a special purpose instruction set is provided and they are usually slower and more expensive than special logic machines. The flexibility of microprogramming, however, is useful in such applications as communications control, where specially tailored instructions can offset slowness in the execution of the standard instruction set.

The development of special-purpose microprograms to implement machine functions appropriate to particular applications is emerging as a discipline somewhat unlike either hardware or software design. The term firmware has been coined to denote the microprogramming for these machines. A firmware routine must be placed in a read-only memory module by the computer manufacturer. Some manufacturers however, provide software facilities to allow users to develop their own firmware, which is returned to the main frame manufacturer for incorporation into the read-only memory.

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Input/Output Control. The passage of data between the main memory of a minicomputer and the external peripheral devices is accomplished by the input/output sections of the control logic, under the direction of programmed instructions. There are two methods for I/O transfers.

- *Programmed input/output*—a computer instruction is executed each time a data word is transferred.

- *Autonomous block transfers*—a single instruction initiates the transfer of a block of data.

In both cases, the processor is free to perform other functions while the data transfer is in process and an interrupt signals the completion of the requested transfer.

Programmed Input/Output is basic to all minicomputers. In this method, an instruction is executed to transfer each word of data between the main memory (or an accumulator) and the peripheral device. An interrupt is received at the end of the word transfer. The usual practice is to program the transfer of another word as part of the interrupt processing in order to effect multiple word transfers simultaneously with computing. This method of input/output has the advantage of low cost, but it is time consuming because of the interrupt servicing required. Typical minicomputers have maximum data transfer rates of approximately 50,000 bytes per second with this method.

Once initiated, autonomous block transfers proceed independently of any stored program. Special hardware controls the transfer by means of registers containing the addresses of the first and last main memory locations involved in the transfer (or equivalent information), and a pointer to the memory location currently involved (or, equivalently, a counter of the number of words already transferred). The controller terminates the transfer and generates an interrupt when the specified transfer is completed. Two kinds of autonomous block transfer capabilities may be provided. The Direct Memory Access (DMA) feature uses special hardware registers within the controller to control the transfers. The data-break or multiplexer feature uses dedicated main memory locations for this purpose. Of the two types, the Direct Memory Access feature is more expensive (because of the cost of the special-purpose registers) but faster, being limited in speed only by the rate at which data can be transferred between the data channel and the computer main memory. The data break or multiplexer approach is slower than a DMA channel because it requires several memory accesses for each data word transferred to update memory locations and to compare the progress of the transfer with the finishing state.

The ways in which the special channels are assigned to devices vary from one minicomputer to another. An optional DMA channel can be hard-wired to a particular device controller or can be assigned to a device by the program. The recent DEC PDP-11 for example, has an input/output structure in which DMA channel logic is included in the de-

vice controller of any device fast enough to warrant DMA. This approach means that transfers can be arranged between peripheral devices independently of the processor. As hardware logic and special registers decline in price, this approach seems likely to become more and more attractive.

Internal Memory. The memory can be the most costly single component of a minicomputer main frame. The most common form of main memory is core storage, which typically ranges in capacity from 1,024 to 65,526 words and in cycle time from 0.8 to 2.0 microseconds. Core memory prices have significantly contributed to minicomputer price declines. Figure 9, which presents the cost per bit of core memory in minicomputers with cycle times between 0.8 and 1.2 microseconds, shows that core memory prices have declined 20% annually during the last five years.

Semiconductor memories have been incorporated in some recently-announced machines. While faster than core memory, with cycle times around 0.3 to 0.4 microseconds, they are more expensive. One feature of semiconductor memory which may be disadvantageous in some applications is its volatility, i.e., if power is interrupted, then the information it contains is lost. While this problem can require a back-up battery system in certain applications, volatility does not pose a serious limitation in most cases. This is demonstrated by the fact that most computer operators reset the machine after power failure, thus losing prior information anyway.

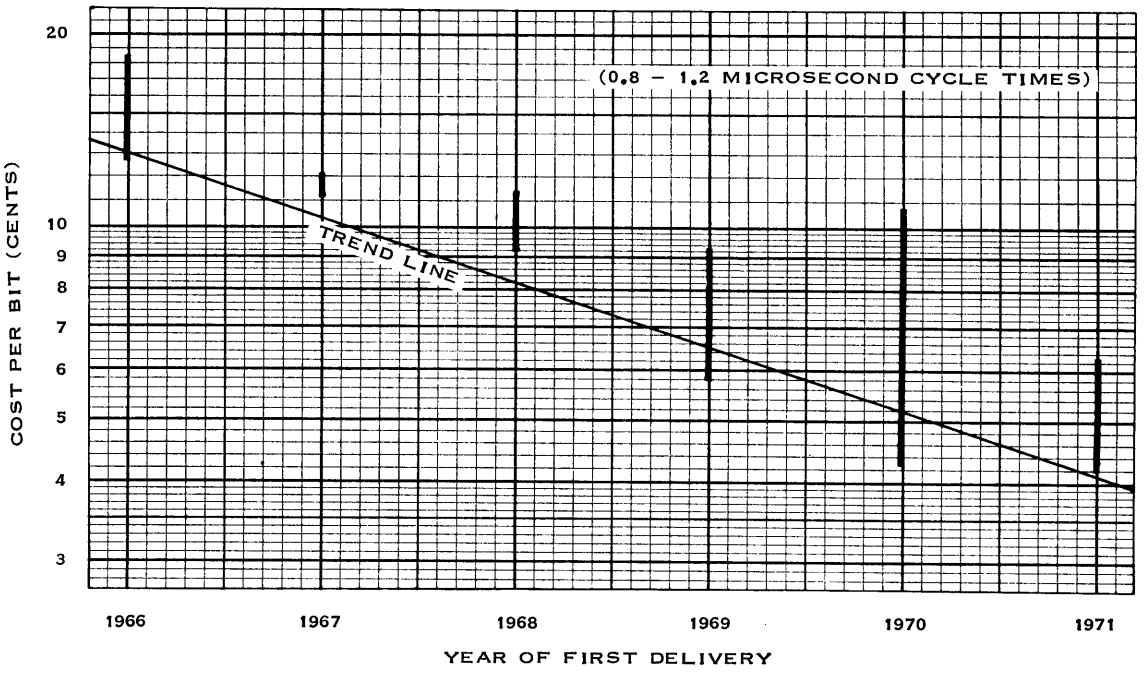

Figure 9. Representative Minicomputer Main Memory Prices*

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MINICOMPUTERS

In discussing the overall performance of minicomputer systems, the speed of the main memory is nearly always the limiting factor. It determines the instruction execution speed and maximum data transfer rate between peripheral devices and the computer. On some large computers, several independent simultaneous accesses can be made to memory, but this has not been a general feature of minicomputers.

Besides the random-access main memory, other types of minicomputer memory systems are read-only memories (ROM) and scratch-pads. Read-only memories can store microinstructions for microprogrammed machines, or can store as a part of the main memory programs that must be protected. A ROM usually decreases execution time for protected programs since the ROM is frequently faster than core memory.

Scratch pads are small, high-speed memories used for accumulators, index-registers and general purpose registers. The recent availability of faster scratch-pad memories has led to their use in larger computers for such purposes as the buffer between the main memory and the control logic in the IBM System/370 computers. Currently, this type of use is not encountered in minicomputers. The availability of these memories, however, should lead to an increase in the number of hardware registers in future minicomputers, with consequent improvements in performance.

Semiconductor Technology

Contribution to Improved Price/Performance. Minicomputers consist of an assembly of many types of electronic, magnetic and mechanical components or building blocks. The manufacturers are basically equipment assemblers — buying the basic components and assembling them into complete systems.

In first and second generation computers, the electronic components were discrete components, such as diodes, transistors, resistors and capacitors. These individual components were wired to circuit boards to build functional circuits, such as gates and flip-flops to perform the computer's internal logic. The typical central processor requires several thousand such circuits. The development of the integrated circuit in the 1960's led to the so-called third generation of computers and stimulated the emergence of the minicomputer.

In an integrated circuit the individual discrete components lose their external identity. All the components required to build a functional circuit and their interconnections are fabricated in the same manufacturing process and encapsulated in the same package. The process consists of many stages of oxidation, masking, etching, and diffusion and the result is an inseparable assembly of semiconductor elements in a chip of silicon which performs one or more logic functions.

Integrated circuits (IC's) have many advantages.

- *Lower assembly costs*—the number of separate components connected to circuit boards is reduced 10 to 100 fold, thus reducing the labor required to manufacture the minicomputer.

- *Lower component costs* — the logic circuits, which represent approximately 25 percent of the manufacturing cost, have dropped rapidly in price. Circuit costs dropped by a factor of 10 from the second generation computers using transistors to the third generation systems available in the mid-sixties. The average selling price of digital integrated circuits has declined from $65.00 in 1962 to $7.25 in 1965 to $1.56 in 1969. The 1969 decrease alone was 27 percent when compared to the previous year.

- *Higher Reliability*—most failures in electronic systems occur in the component interconnections. Most system interconnections are completed in the manufacture of the IC under closely controlled conditions. Systems using IC's have demonstrated failure rates one-to-two orders of magnitude lower than for comparable systems using discrete components. Higher reliability has been essential to the acceptance of minicomputers in many real-time applications such as communications and process control.

- *Lower maintenance costs* — higher reliability reduces the frequency of repairs. Furthermore, faulty circuits can be detected easier than faulty components resulting in less time for fault isolation.

- *Higher speeds*—the high density of components in IC's reduces electrical propagation delays and allows high speed circuits to be built.

- *Lower power consumption* — lower power consumption of IC's reduces the cooling problem.

- *Smaller size and weight* — fewer separate packages and higher densities reduce size and weight.

Medium-Scale and Large-Scale Integration (MSI/LSI). The next revolution in semiconductor technology is MSI/LSI which is now emerging. The technology is developing rapidly and many new products are available. MSI/LSI is an extension of integrated circuit technology in which higher densities and larger chip areas yield a larger number of circuit functions per chip. No hard definitions of IC, MSI and LSI have been established. However, generally accepted industry definitions are based upon the number of gates per chip.

Integrated Circuits — less than 10 gates per chip

Medium-scale Integration — 10 to 100 gates per chip

Large-scale Integration — over 100 gates per chip

There are no discrete boundaries or sudden changes from one technology to another. The same technologies used to fabricate IC's extend well into the MSI region. Similarly, MSI technologies extend well into the LSI region.

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MINICOMPUTERS

MSI/LSI further extends the price/performance advantages of integrated circuits with lower assembly costs, higher reliability, etc. Increasing the number of circuits per chip yields lower circuit costs for several basic reasons.

- *Lower manufacturing cost per circuit* — manufacturing costs are directly related to the number of steps involved and less to the density of circuits per chip. Therefore, higher densities per chip yield significant cost reductions per circuit.

- *Lower packaging cost per circuit* — packaging costs, which represent approximately half the cost of simple IC's, is essentially independent of the circuit densities. Therefore, higher densities per chip yield reductions in per circuit packaging costs.

- *Less bonding area per gate* — bonding pads to terminate connecting wires from the package leading to the chip require a large fraction of the chip area in an IC. Additional circuits per chip to not increase the bonding-pad area, resulting in more efficient use of the chip area and therefore in lower cost per gate.

An important result of the development of MSI/LSI is the extension of semiconductors from the internal logic functions to the memory functions in the minicomputer. The memory, which represents about half the processor cost in a 4 K-byte minicomputer, has primarily used magnetic cores. Memories consist of a large number of identical functions which are ideally suited to MSI/LSI manufacturing techniques. As a result of lower costs and higher packaging densities, semiconductors have been used for special purpose memories like scratchpads and read-only memories (ROM's) and are now beginning to be used for main memories.

Two Basic Technologies — Bipolar and MOS. Two distinct technologies, each with several variations, have been used in the production of semiconductors — bipolar and Metal-Oxide-Semiconductor (MOS). Bipolar is the original type of semiconductor which depends on the diffusion of holes and electrons (positive and negative charges) between areas of the semiconductor. MOS is a newer, rapidly developing approach, which depends on propagation of electric fields across an insulating layer. In general, MOS provides an easier fabrication process, lower power consumption, higher yields (percentage of good chips), higher densities (3 to 10 times more circuits per chip) and lower cost per chip. The main advantages of the bipolar approach are its higher speed and fewer problems resulting from a longer history of use. Table 7 compares the range of typical performance values for bipolar and MOS circuits available in random access memories.

Table 7. Characteristics of Semiconductor RAM's

Characteristic	MOS	Bipolar
Access Time (nanoseconds)	100-1,500	15-250
Cost per bit (cents)	5-20	10-15

Due to the different advantages offered by each technology both will continue to be used in minicomputer systems. For example, currently available hybrid semi-conductor memories use MOS storage elements for their high density and low cost, and bipolar drivers, sense amplifiers and decoding circuits for their speed.

Peripheral Equipment

The importance of minicomputer peripherals is demonstrated by the fact that peripherals comprise 60 percent of the average system price. In the last few years, minicomputer peripherals have declined in price and more devices have become available. Although peripherals for a minicomputer system are usually purchased with the main frame from the main frame manufacturer, few minicomputer manufacturers make any of their peripherals. The standard practice is for the minicomputer manufacturer to buy his peripherals from an independent supplier and add his own control electronics, software and servicing arrangements to the package offered to the minicomputer user. The cost of the control electronics can approach that of the device itself. Typical ranges for the percentage of total cost of minimum capacity disc and tape systems represented by the controller are 35-40 percent and 30-35 percent respectively. The extensive additions made by the main frame manufacturer to the device supplied by the OEM supplier means that profit margins on minicomputer peripherals can run as high for the main frame manufacturer as they do on the main frame itself. Furthermore, the control electronics should benefit from declining prices of integrated circuits and should yield price reductions in mini-peripherals.

The OEM peripherals market is a very competitive one, and minicomputer main frame manufacturers frequently change their suppliers, as first one and then another appears to offer advantages in price, performance or reliability. This changing of suppliers means that minicomputers introduced by different manufacturers at about the same time tend to have peripherals with similar specifications. There is some variation in price however, due to different marketing approaches.

Random Access Storage. Most minicomputers offer a disc and/or drum for large capacity storage. Disc devices available for the PDP-11, shown in Table 8, are representative of the devices available with minicomputers. The table also presents the characteristics of the lowest cost random access devices available with the IBM System/360. The comparison demonstrates the most significant characteristics of mini-discs — lower total cost and capacity but higher cost per byte of storage. For example, a disc pack system is available with the PDP-11 for 26 percent of the cost of the least expensive System/360 disc-pack, and random access storage is available in the model RS-64 at only 14 percent of that cost. The availability of low-cost fixed head discs with fast access times for minicomputers has improved the price/performance capabilities of minicomputer systems. They have provided large storage capacity for operating systems and large data bases at prices consistent with small scale minicomputer systems. As a result they have expanded the flexibility of minicomputers to satisfy many applications in communications, business data processing, industrial control, and time sharing systems.

Magnetic Tape. Most minicomputers offer industry standard 7 and 9 track IBM compatible tape systems. Like their random access counterparts, mini-tapes are generally lower in price and have lower performance (transfer rates and capacity) than tapes offered with larger computer systems. Even so, these tape systems cost as much as the central processors

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Table 8. Typical Minicomputer Disc Systems

Type Device	Fixed Head Disk	Fixed Head Disk	Removable Disk	Removable Disk	Removable Disk
Model Number	RS-11	RS-64	RK02	2311	2314-B1
System	DEC PDP-11	DEC PDP-11	DEC PDP-11	IBM System/360	IBM System/360
Capacity (millions of bytes)	0.512-4.096	0.128-0.512	1.2-4.8	7.25-58	87-233
Average Access (msec)	17	16	80	75	60
Transfer Rate (bytes/sec)	125,000	125,000	90,400	156,000	312,000
Purchase Price ($)					
Min.	14,000	6,950	12,900	50,380	111,385
Max.	77,000	20,450	33,900	223,595	201,385
Cost Per Byte ($)					
Min.	0.0274	0.0543	0.0107	0.00695	0.00128
Max.	0.0189	0.04	0.00705	0.00389	0.000865

themselves. For example, single transport tape systems for the PDP series and Nova minicomputers cost $9,950 and $11,000, as compared to basic central processor prices of $9,300 and $7,600 respectively. OEM suppliers have made available very low cost, large storage capacity in cassette-cartridge transports for several minicomputer systems. These transports operate with a tape which has been previously loaded in a container. In the way of explanation, a cassette container is one which uses two reels with the tape alternately transferred between reels. A cartridge uses an endless loop of tape on a single reel with the tape drawn from the center of the reel past the read/write heads and rewound on the outside of the reel. These transports offer lower performance than standard tape systems but their cost makes them compatible with low cost minicomputers. The price/performance distinctions between the cassette-cartridge and standard tape systems are indicated in Table 9.

Printers. Most minicomputer systems offer a standard medium speed line printer operating in the range of 200-400 lines per minute. A few systems offer high speed line printers operating in the range of 1,000 lines per minute. Line printers can exceed the cost of the minicomputer central processor. For example, for the DEC PDP-11 the LP-11JA (300 lpm, 132 columns) line printer costs $17,500 as compared to the basic processor cost of approximately $9,300. Serial printers are now available which provide minicomputer systems with moderate speed print capability and low cost. A typical model is the DEC LA30 which costs $2,500 and operates at 30 characters per second. These printers are

Table 9. Comparison Between Cassette-Cartridge and Standard Tape Systems

Characteristic	Cassette-Cartridge Systems	Standard Tape Systems
Max. On-Line Storage (Millions of bits)	1-10	1,200
Data Transfer Rate (Thousands of bits/sec.)	2-10	300
Price (with computer interface)	$2,000-$6,500	$10,000

ideally suited to small business applications and will be used in minicomputer systems which can satisfy the needs of this market segment.

Software

The software provided for minicomputers can vary widely from one manufacturer to another. Some of the smaller companies that are concentrating on OEM sales provide only the minimum software required to develop programs for the machines, while the larger manufacturers provide extensive ranges of software comparable in scope to that provided for larger scientific computers. Software coverage is discussed separately, as (1) Systems Software and (2) Applications Software.

Systems Software. The most rudimentary form of systems software consists of an assembler and a selection of routines such as loaders and debugging routines for the development of assembly-code programs. More elaborate systems software includes a full range of operating systems.

Minicomputer systems software tends to be arranged in a hierarchy of operating systems with different hardware requirements. Typically, a system designed to run on a machine configuration of 4,096 16-bit words of core storage will offer a basic assembler supported by a range of utility routines and possibly a Basic or Fortran compiler. A system designed for 8,192 words of main memory will include a compiler and an assembler with a more comprehensive range of facilities (such as pseudo-operations) and automatic desectorizing, a facility which allows the programmer of a machine with paged addressing to write programs as if the whole of core store were directly addressable. For larger configurations, typical offerings include a time sharing operating system and a real-time operating system to permit the concurrent execution of real-time and batch-processing tasks. The recent availability of inexpensive disc storage units has led to an emphasis on disc operating systems for minicomputers. Typically a full disc operating system offering multiprogramming requires at least 16,384 16-bit words of main memory.

Applications Software. Minicomputer applications programming is generally the responsibility of the user, using system software aids such as language compilers and subrou-

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tine libraries. In some cases, however, a minicomputer manufacturer will develop particular applications packages as a marketing aid; these are generally for use of the minicomputer in dedicated applications, and are offered as a part of a standard package which includes the necessary hardware. Examples of minicomputer application packages include:

- Typesetting
- Data acquisition and control applications
- Numerical control of machine tools
- On-line testing of digital logic circuit boards
- Use of the minicomputer as a front end communications controller for a larger computer such as a member of the IBM System/360 Series

PRODUCT AND TECHNOLOGY FORECAST

This section presents the significant implications forecast for minicomputer products and technology. These implications are relative to the complexity of minicomputers, prices, system architecture and manufacturers' capabilities.

The Minicomputer as a Standard Component

The minicomputer main frame is expected to become a commodity product. This will occur because the manufacturing process is primarily one of assembly, and the increased growth of MSI/LSI technology will substantially reduce the assembly operations required. The nature of the MSI/LSI manufacturing process should also increase standardization of minicomputer components. The manufacturing process requires extensive initial design of circuit partitions (assignment of functions to chips), device locations, masks and interconnections. These fixed costs are a significant portion of the per circuit cost. Therefore, the lowest per circuit cost will be achieved by large production runs of standardized components. Semiconductor technology trends should also lead to a concentration of the manufacturing capacity of minicomputer components in relatively few firms which obtain the largest production runs and lowest unit costs.

Minicomputer systems and traditional general purpose computer systems are expected to continue their merging trends and the point of demarcation between them will soon disappear entirely. Minicomputer systems will be the low end on a continuous spectrum of computer products and cost will become more difficult to use as a criteria in defining minicomputers. Memory size, cycle time, and other frequently used performance measurements are even now vanishing in their usability as distinguishing factors between minicomputers and large general purpose systems.

Central Processor Prices

By the end of 1975 the cost per circuit function or cost per bit of memory is expected to decline by a factor of 5 to 10 over current prices. This will result in MOS RAM's for

1 cent per bit by the end of 1973 and a further reduction to 0.5 cents per bit by the end of 1975. For logic building blocks the cost per gate should decline from current levels of 10 cents to 20 cents per function to 5 to 10 cents per function by the end of 1973 and 2 to 5 cents by end of 1975. As a result of the lower circuit function costs and reduced labor in component assembly, manufacutring costs of central processors should decline to approximately 40 percent of current values, and minicomputer central processors with 1,000 bytes of memory, should become available for approximately $1,000 by 1975.

Minicomputer Architecture

The emergence of semiconductor memories will cause important changes in minicomputer architecture. Currently, semiconductor memories are less expensive (and faster) than cores for sizes under 10,000 bits or approximately 1,000 bytes. The breakeven point will move upward and semiconductor memories will make inroads on core memory for the smaller memories associated with minicomputers. Semiconductor main memories will yield faster machines but will require new internal designs with parallel options to take advantage of the available memory speed. Within the next five years greater use should be made of special purpose content-addressable (CAM) and read-only memories (ROM). These will be small high-speed memories used for storing microprograms, scratchpads, and implementing special functions (firmware) such as table lookups or push down stacks which are otherwise performed via software. Memories will be distributed throughout the minicomputer system performing special logic functions in the central processor and serving as buffers in peripheral devices.

Reduction in semiconductor prices will lead to increased use of general purpose hardware registers. These will be used as accumulators, index registers and temporary storage to improve system performance.

Microprogrammed machines should also become more prevalent. The control logic in a conventional computer is unique to each computer and consists of an irregular assembly of specially designed circuit functions which do not easily lend themselves to MSI/LSI. In a microprogrammed machine the control logic is embedded in a high-speed memory which reduces the amount of random logic in a processor and allows greater use of MSI/LSI. This approach allows high-volume production of nearly identical processors which can be tuned to a specific application by including a selected instruction set in the microprogram memory. The microprogrammed approach also provides flexibility to use existing software developed for earlier machines, thus reducing future software development costs.

Need For Semiconductor Expertise

The changes occurring in semiconductor technology will require increased expertise from the minicomputer manufacturers. The objective of system design will change to optimizing circuit densities as well as the interconnections between MSI/LSI arrays as opposed to minimizing circuit counts as in the case of discrete components and low density IC's. With a drop in the number of logic packages (to under 100) in the minicomputer, the partitioning functions into these packages is critical. Thus, optimum machine designs and production will require extensive knowledge of semiconductors by the manufacturer.

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We have reviewed the minicomputer system in this chapter. For each of the basic components, we have described its function, the alternate design approaches, and the advantages and disadvantages of each approach.

We have also described minicomputer technology and the trends in this technology. The chapter concluded with a forecast of how the developing technology will impact upon minicomputer products, prices, and architecture, and the effect on the required manufacturers' capabilities.

III. MARKET ANALYSIS AND FORECAST

This chapter discusses the characteristics of the diversified minicomputer marketplace from the viewpoint of OEM versus end users and for five major application areas. The potential market for minicomputers is developed, together with an appraisal of forces controlling the penetration of the market. The alternatives to the use of minicomputers are described and their impact on each application area is evaluated. Based on an analysis of these factors and the projected price trends a forecast is developed for minicomputer sales over the next five years.

MARKET CHARACTERISTICS

The minicomputer marketplace is a complex arena consisting of two segments — OEM and end user — which present individual opportunities, require special resources for successful penetration and respond to different marketing approaches. These segments are described followed by a discussion of the major application areas in which minicomputers are used.

OEM Versus End Users

The minicomputer manufacturer is confronted with two distinct market segments — (1) the original equipment manufacturers (OEM's) who purchase minicomputers as components of a larger system, and (2) the end users who purchase minicomputers directly for their own use. These market segments require different resources and marketing approaches from the manufacturers. The diverse requirements are a source of conflict to the manufacturer and limit his ability to fully impact upon both markets. The most important differences are summarized in Table 10.

OEM Market Segment. Nearly every minicomputer manufacturer competes in the OEM market. This segment of the marketplace accounted for 55 percent of industry sales in 1970. For the reasons indicated in the table this is the easiest market to enter especially for the new company with limited financial resources. Due to the high level of participation and the lack of product differentiation, the marketing emphasis in this segment is price with the resultant pressures on profit margins. Discounts of 20–40 percent below published list prices in multiple unit sales are common.

The OEM buyer is a sophisticated user who requires a minimum cost machine which meets his specifications. To successfully reach this market segment, the minicomputer manufacturer must emphasize flexibility in pricing policies, machine options, and delivery

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Table 10. Comparison of OEM and End User Market Segments

CHARACTERISTIC	OEM	END USER
Advantage for the Minicomputer Manufacturer	• Large quantity orders that readily increase sales volume and cash flow and reduce unit sales cost. • Emphasis on purchase which improves cash flow. • More uniform production workload. • Less customer education required. • Minimum software investment required. • Potential for follow-on orders.	• Large number of potential customers. • Higher profit margins. • Standardized products acceptable. • Diversified customer base yields greater stability. • More equipment supplied resulting in higher average system price. • Greater opportunity for value added.
Disadvantages for the Minicomputer Manufacturer	• Lower profit margins due to price sensitivity and high level of competition. • Vulnerable to loss of a single customer. • Customer demands for design changes. • Difficulty of establishing an image because product identity is lost in end product.	• High unit sales and advertising cost. • High administrative cost. • Extensive customer training required. • Difficulty of maintenance and service with geographically dispersed sales base. • Some preference toward leasing which requires greater financial resources. • Investment in extensive software is required.
Buyer's Most Important Selection Criteria	• Price and pricing policies. • Performance to satisfy minimum specifications without unnecessary excess capability. • Manufacturer's integrity, financial stability, and technical capabilities. • Product reliability.	• Price/performance ratio. • Reliability and field maintenance. • Applications orientation of the manufacturer.

schedules. He must orient himself toward the success of the OEM's end product and contribute to that success. The manufacturer's sales force should be technically oriented although its size can be relatively small.

End User Market Segment. The end user market is more readily accessible to the larger minicomputer manufacturers. This is due to the large investment required for sales support and software development. The end user market is oriented toward specific applications and is usually less sophisticated from a technical standpoint. To reach this market,

the manufacturer requires a large sales force to contact the numerous individual prospects. These salesmen must be trained in the specific application of interest to the customer. The manufacturer must also maintain substantial field support personnel such as systems engineers, programmers, and maintenance personnel.

In the long run the end user market is a more viable direction for the successful manufacturer. This market is less competitive, provides greater product differentiation and profit margins, and increases the opportunities for sales volume. Furthermore, it is less sensitive to price declines in minicomputer central processors. However, success in this market segment requires greater financial, personnel, and technical resources.

Functional Application Areas

The market for minicomputers falls into five major functional application areas — industrial control, peripheral control, communication, computation, and data acquisition. Minicomputer characteristics within each of these areas are summarized in Appendix A which shows the diversity of technical and marketing requirements imposed on the minicomputer manufacturers. For example:

- Minicomputers are used in large organizations to control multimillion dollar processes as well as in small colleges for educational purposes.
- Minicomputers serve both scientific machines (high computational and low I/O loads) and business machines (low computational and high I/O loads).
- Minicomputers represent resources ranging from a significant portion of the total system cost to an almost negligible component of cost.
- Software requirements vary from none at all to complete turnkey systems.

The implications of the diverse needs of the minicomputer marketplace are three-fold: (1) a flexible minicomputer system with an extensive range of options is needed to penetrate broad segments of the market, (2) manufacturers are limited in their ability to address the entire marketplace and (3) product and technological developments must be evaluated by application area to determine their effect on the minicomputer marketplace. A brief discussion of each major application area is provided in the following paragraphs.

Industrial Control. This market area comprises approximately 45 percent of sales volume of the minicomputer industry. In this application, minis are used to control various types of industrial processes and systems. They provide improved production efficiency and reduce labor costs. The central processor represents a small part of total cost to an end user in this application area since appreciable investment is required in sensor, interface, and external storage as well as extensive analysis and system design for each application. A large potential market continues to exist for industrial control systems throughout industry. In order to reach this market and facilitate the implementation of these systems, the manufacturers must supply services such as complete turnkey systems, extensive applications software and complete solutions to user problems.

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Peripheral Control. Approximately 3 percent sales volume is represented by this smallest segment of the minicomputer industry. In this application, minis are used to control both local and remotely located peripheral devices associated with data processing facilities. The mini provides a flexible controller that can operate with many different type devices. The peripheral control area is primarily an OEM market with the minicomputer manufacturer essentially providing a central processor. As a result, this application area is exposed to high competition, low profit margins and low dollar volume per installation. In terms of number of units, peripheral controllers provide the largest potential market for minicomputers. The principal limitation on minicomputer penetration of this area is price, especially for low-cost terminals.

Communications. Minicomputers are used as line concentrators in data communication networks, as controllers in message switching systems, and as front-end processors for large computers. The minicomputer central processor represents a small part of the total system cost (typically in the range of $40,000 to $120,000). These systems include many peripheral devices and require extensive software development. For these applications the minicomputer provides savings in communication line costs, serves as a low-cost controller for message switching, and improves the efficiency of large computers through elimination of overhead functions such as processing frequent interrupts, performing data editing, and data formatting.

Computation. Minicomputers are used as free-standing computer systems for scientific or business applications or as small in-house time sharing systems. The minicomputer offers users improved management information at prices comparable to large electronic accounting machines, improved response time for scientific applications, and cost advantages to large time sharing users. Systems used in this application typically sell for $20,000 and up. They often require extensive peripherals and system software thus making the central processor a small part of total system cost. While this application represented only 10 percent of 1970 sales volume, a large potential demand is represented by the more than 150,000 business establishments considered large enough (more than 50 employees) to have data processing requirements. In order to penetrate this market, the manufacturers must simplify the use of systems by supplying support services, system software, and application software which will facilitate system implementation for relatively inexperienced computer users.

Data Acquisition. Minicomputers are used to monitor real-time systems, record performance data, edit the data, and perform initial processing. The minicomputer offers a low-cost, flexible approach for a variety of systems. These systems usually require large storage devices and interface equipment, thus the central processor is only a small part of total equipment cost.

POTENTIAL MARKET

The flexibility and low cost of minicomputers in combination with the extensive need for controllers and computing devices suggest a promising future for minicomputers. To evaluate this total market, the following important factors related to market potential and constraints on market penetration are identified and analyzed separately: market potential

by application area, competing technologies, manufacturers growth capacity, and user absorption capacity.

Market Potential by Application Area

The estimated market potential for minicomputers has been developed by industry segment for each of the five application areas (Table 11). These estimates represent *existing user needs which can be realistically satisfied by minicomputers.* The data in Table 11 was derived by analyzing in detail the known potential minicomputer uses in each application area. (See Appendix B.) The following steps were taken in this analysis.

- A gross market size was estimated from Department of Commerce data and other published references
- An estimating factor based on the research for this study was applied to obtain a realistic market basis for each application area
- The market basis was then multiplied by the number (or range of numbers) of minicomputers that would be needed for each application site

Table 11. Minicomputer Market Potential
(In Thousands)

SIC Code Categories	Industrial Control	Peripheral Control	Communication	Computation	Data Acquisition	Total
Manufacturing	49-166	59-113	3-28	19-28	8-135	138-470
Utilities, Transportation, Communication	47-63	36-40	19-83	8-8	2-2	112-196
Wholesale & Retail	0-0	36-39	2-6	17-17	0-0	55-62
Financial, Insurance, Real Estate	0-0	60-157	29-33	14-14	0-0	103-204
Gov't. Services, Education	10-21	29-73	4-15	23-36	13-88	79-233
Total	106-250	220-442	57-165	81-103	23-225	487-1,165

Note: Excluded are military and most governmental applications. Estimates derived from current levels of each market basis.

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As an example in industrial control, the specific application of hospital operating room equipment control was estimated as follows: the gross market size was established as the total number of hospitals; an estimating factor of fifty percent was applied because only half of the total number of hospitals are expected to have a probable requirement for this specific application. Based on survey data concerning present applications, from one to four minicomputers are needed at each site. The number of sites times the number of minis per site yields the total market potential (expressed as a range for this specific application). This result becomes one component in the total for industrial control.

Because of the diverse minicomputer marketplace, the table does not represent an exhaustive enumeration of all potential applications. However, the analysis has been carried forward in sufficient detail to provide conservative estimates of the magnitude of the potential market and the relative distribution of the potential market among industries and application areas.

The results indicate an almost unlimited potential need which can be satisfied by minicomputers. From the analysis in Appendix B the gross market potential is estimated at over 500,000 units. This estimate is regarded as a practical boundary for minicomputer demand through 1975. Even so, these estimates are probably understated due to the omission of certain applications for which usable market data was not available. Compared to the present installed base of 21,500 units this market is still relatively untapped. *Thus, it is concluded that the growth in minicomputer sales will not be limited by the fundamental demand for these machines.*

While the total market potential is estimated to be very large, it is unrealistic to expect that this potential will be achieved within the next five years. Three factors are expected to limit minicomputer market penetration: (1) competition from competing alternatives, (2) manufacturers' growth capacity, and (3) absorption capacity of users.

Competing Alternatives

As with most product areas, potential minicomputer users are confronted with available alternatives. Three alternatives are competitive with minicomputers: wired logic, large computers and commercial time sharing (CTS). This section evaluates these alternatives relative to minicomputers in each of the five application areas.

Wired Logic. Wired logic is the use of hard-wired components and circuits designed to perform a specific pre-designed function and alterable only by physically re-connecting wired connections within the structure of the system. Wired logic, as an alternative to minicomputers, presents a tradeoff of a hardware approach versus a software approach. That is, wired-logic implements control in electronic circuits whereas minicomputers imbed control in a stored computer program.

Wired logic has two major advantages relative to minicomputers — lower cost, because only the minimum required functions are built into the systems, and greater speed. A relatively high proportion of its cost is in labor for design. Because labor costs are continually increasing while minicomputer prices are declining,

the cost advantage of wired-logic should decline with time. On the other hand, the availability of MSI/LSI circuits will provide economic benefits to wired-logic control for very high volume applications which require identical logic in each system. The primary weakness of wired-logic is its inflexibility. Any change whatsoever necessitates redesign and reconstruction of the system.

In some cases minicomputers differ little from wired logic because minicomputers can be built with fixed programs stored in Read Only Memory. This type of configuration can properly be classified as both a minicomputer and wired logic.

Large Computer. Relative to minicomputers a large computer is one which sells for more than $25,000 in its basic configuration. In this sense System/3 is a large computer. A large computer is an alternative to a minicomputer either as a direct displacement or as a shared machine. In a direct displacement the choice is relatively straightforward, i. e., the added cost of the large computer is justified only if the capacity requirements of the application cannot be satisfied by the minicomputer system. In a shared mode the capacity of the large computer is distributed over many applications, one or more of which can be performed by a separate minicomputer. For example, an engineering laboratory could use a dedicated stand-alone mini for scientific computation or it could use a central system performing all types of applications within the company. The choice between a shared computer and a mini reflects the problem of centralized computation versus distributed computation. Many variables, such as access to the computer, response time, computational capacity, memory capacity, the type of processing and intangible factors, all affect the decision in a particular application. General guidelines are difficult to produce; each application must be considered on its own merits.

Commercial Time Sharing. Commercial time-sharing (CTS) systems use a large centralized computing facility that services a multitude of remotely located terminals. These systems handle several remote users concurrently so that each user ideally appears to have complete use of the large centralized computer to himself at any given time. CTS has grown rapidly in the past few years. It has been used primarily for engineering and scientific computation but the suppliers are attempting to expand into business applications and special information systems such as financial data. CTS provides economic advantages to low volume users, better response times relative to batch-oriented systems, and access to very large computational and memory capacities. The primary weaknesses of CTS are its cost for high volume users, low input/output data rates, operational problems with the communication system, system reliability, potential degradation of response times in peak hours, and removal of operational control from the user.

Impact on Minicomputers by Application Area. The impact of the three competing alternatives on minicomputer prospects in each of the five application areas is outlined in Tables 12 to 14. Based on the factors indicated in these tables the following combined impact of competing alternatives on minicomputers by application area is expected.

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MINICOMPUTERS

- *Industrial Control* — small or negligible effect due to flexibility offered by minicomputers.
- *Peripheral Control* — large effect from wired logic, which will remain the most prevalent approach.
- *Communications* — moderate effect due to continued use of Time Division Multiplex (TDM) and Frequency Division Multiplex (FDM) switches and I/O controllers.
- *Computation* — moderate-to-large effect due to use of IBM's System/3, commercial time-sharing, larger computer systems and electronic accounting machines. Minicomputer manufacturers are limited by their ability to market to the potential users, as well as by their limited software and system support.
- *Data Acquisition* — small or negligible effect due to flexibility offered by minicomputers.

Table 12. Effect of Wired Logic on Minicomputer Penetration

Industrial Control	Minicomputer advantages are flexibility to modify control procedures and to adjust process parameters, greater analytical capabilities for decision making, and greater understanding of the process which results from the analysis associated with implementing the minicomputer system.
Peripheral Control	Wired logic is most frequent type of controller especially for low cost peripherals. Speed of wired logic is needed for applications with very high data rates. Minicomputer should gain favor with larger peripherals requiring flexible control. When used in remote terminals minicomputers provide several advantages such as: lower communication costs due to data reduction and high speed transmission; reduction in the transmission of erroneous data due to pre-editing; data editing is more efficient with a small computer rather than a large central computer.
Communication	Time division and frequency division switches are commonly used instead of minis for multiplexers. Special purpose I/O controllers are used instead of minis as front-end communication devices. Mini provides greater flexibility.
Computation	Wired logic is very limited in computational capabilities, and flexibility. Wired logic provides alternative only for very low computation loads as in desk calculators. There is limited effect on all three areas of minicomputer computational use—in-house time sharing, scientific computation and business data processing.
Data Acquisition	Wired logic is a potential alternative due to low cost. However, flexibility provided by minicomputer is strong advantage.

Manufacturers Growth Capacity

Rapid penetration of the large minicomputer market requires a sustained expansion rate by the manufacturers. Several practical considerations limit the expansion capacity:

- *Financial Requirements* — funds are required to expand production facilities, invest in product development, maintain technological capabilities, and increase the marketing and sales support staff. New financing is inhibited by general economic conditions and cash flow is retarded by price erosion.

- *Availability of Personnel* — capable personnel are needed for marketing, systems engineering, maintenance, customer training, production, and product development. While personnel availability is not currently a problem, the hiring of properly trained people, integrating them into a well organized staff, and properly managing a new staff can lead to many operational problems.

Table 13. Effect of Large Computers on Minicomputer Penetration

Industrial Control	The capacity of a dedicated large computer is usually not required. Sharing of a large computer with other tasks requires frequent monitoring of sensors and is generally an inefficient use of the large computer's capacity due to interrupt processing overhead. sufficient to satisfy requirements of real time processes.
Peripheral Control	Large computers are frequently used to control their on-line peripherals. Separate controllers are most desirable for high-speed devices, multiple low-speed devices, and in those cases requiring special data structuring or formatting functions.
Communication	A front-end minicomputer is usually a desirable subsystem in a communications oriented computer system. The line monitoring functions, which involve interrupt processing overhead, are more efficiently assigned to a low-cost communications processor rather than a large central computer.
Computation	The large computer is a definite alternative to the minicomputer in large organizations which already have central computer installation. However, it is not a serious alternative in a small organization. A large CPU offers advantages of: more computations per dollar, availability of large data base, and larger I/O capacity. The minicomputer offers advantages of: faster response time; greater accessibility, and more efficient execution of pre-processing tasks such as data editing, checking and formatting. The most significant impact in this area will come from IBM's System/3 which is a small system but not strictly a minicomputer. Due to IBM's marketing capability it is expected System/3 will gain the majority of small business applications.
Data Acquisition	The large computer is required for special, very high volume data transfer rates. However, minicomputers are capable of handling large majority of potential market at significantly lower costs.

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- *Production Capacity* — increasing production capacity will require new investment in plant and equipment, and in hiring, training and organizing of a production force. Simultaneously, price competition requires that production efficiency be maintained.

- *Need for Product Development* — the historical thrust of minicomputers sales has been directed to sophisticated users who required a minimum of software support. As new application areas are developed less sophisticated users will be encountered emphasizing greater need for application software. As a corollary, the manufacturers must also expand their expertise of user applications.

- *Size of Minicomputer Manufacturers* — several large organizations are minicomputer manufacturers. However, the majority are new, small companies with limited resources for sustained rapid expansion.

While these factors tend to limit industry growth, certain technological factors such as increased standardization and reduction in the number of individual components due to higher packaging densities are having the opposite effect. On balance, however, it would appear unrealistic to expect that the industry's unit growth capacity could be sustained above 50 percent annually over the next five years. This would, however, be an achievable growth

Table 14. Effect of Commercial Time Sharing (CTS) on Minicomputer Penetration

Industrial Control	CTS is not feasible because of unacceptable response times, low data rates, inadequate interfaces, and inadequate system reliability.
Peripheral Control	CTS is not appropriate for peripheral control.
Communication	CTS is a feasible alternative in only very limited situations, i.e., cases in which CTS service is used as a substitute for an in-house communications system.
Computation	CTS is the strongest competitor to minicomputers in this application area. CTS competes in all three areas of computational use—in-house time sharing, scientific computation, business data processing. CTS has been used most widely for scientific and engineering computation. Recently business applications services have been expanded by CTS companies. The tradeoff between CTS and a free-standing mini depends on the level of use—generally CTS will be more expensive for over 30-50 hours computer time per month. CTS offers the advantage of a large data base capability but presents problems with the communication systems, gaining access to the system in peak hours, response time in peak hours, security of information, and limited I/O capabilities due to limitations of available terminals. In-house time sharing is more cost-effective than CTS for a multiple terminal user with a small data base requirement.
Data Acquisition	CTS is not appropriate alternative.

rate in terms of manufacturers' capacity. A 50 percent growth rate would produce total shipments of 178,000 units during the next five years. It should be noted, however, that even this generous estimate is still well below the potential market.

End User Absorption Potential

The single most important factor which we expect will limit the growth of minicomputer sales is the ability of the user to absorb the minicomputer systems which are offered him. No matter what the minicomputer capabilities might be or how attractive the price, the sale would be impractical if the user does not have the necessary personnel resources to implement the system. One way to bound the end user absorption potential is to identify personnel limitations. To put this in perspective it is noted that in the United States there are approximately 400,000 programmers and analysts in computer sites and possibly an equal number trained in computers outside these sites. An upper bound on the penetration of the potential market would be reached as the number of minicomputers approached the number of programmers and analysts available for minicomputer applications. If 20 percent of the 800,000 were available for minicomputer applications (considered a high estimate), the total penetration would be limited to 160,000.

Many other factors influence the end user absorption capability, any one of which could eliminate a potential user as a buyer. The most important of these factors include:

- *National Economy* — the uncertainty created by the national economy has delayed final closing of many minicomputer sales in 1970.

- *System Cost* — while minicomputer main frame prices are relatively low and declining total system cost could be extensive when peripherals, system design and programming are all considered. Furthermore, the anticipated declines in minicomputer prices will not necessarily open new markets since total system costs including all other equipment and personnel will not decline at the same rate as minicomputers.

- *Availability of Personnel* — successful application of a minicomputer requires knowledge of the minicomputer's capability to perform a required function, system design, program design, and program implementation all of which require trained personnel who are not always available.

- *Computer Justification* — application of a minicomputer requires feasibility analysis and justification which can be time consuming and thus serve as a constraining influence.

- *User Acceptance* — a potential user must learn to accept minicomputers as a reasonable alternative to be considered for his application in order for serious evaluation to be initiated.

An evaluation of the growth rate in the absorption capacity by application area is summarized in the following paragraphs.

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Industrial Control. The basic limitation on growth rate in this area is the extensive personnel effort required to propose and implement an application. This includes the requirement to analyze the process, complete feasibility studies, specify the hardware configuration, and design and implement the software. However, these factors are partially offset by the strong basic need for minicomputers in these applications, the relative ease of justifying the minicomputer's cost, the trend toward development of application software by the manufacturers which will reduce programming costs and ease system implementation, and the growing acceptance of minicomputers in these applications.

Peripheral Control. Users in this application area are primarily OEM's with extensive hardware and software capabilities. The same basic minicomputer software is used for all installations of a given peripheral device which reduces software development per unit. For these reasons there are few constraints to growth in this area. In addition, this application is price elastic so that minicomputer price declines should significantly help economic justification. These price trends, however, will limit the growth in dollar volume.

Communications. Communications oriented computer systems are expected to grow rapidly in the 1970's. Data communications volume expanded rapidly in the 1960's and continued growth between 30 and 40 percent annually is expected during the next decade. These trends together with the economic advantages provided by minicomputers in communications applications should generate strong growth in the basic need for the minicomputer. The extensive software required for most applications in this area will be a constraint but this problem is partially overcome by the similarity of software requirements among applications.

Computation. Growth in this area has been restricted by the limited knowledge of computers in small organizations, the difficulty of economically justifying a minicomputer system, the reluctance to displace existing people and procedures and required software development. However, many of these restrictions are becoming less serious. Users are gaining computer knowledge; the use of computers in small business has gained wider acceptance with the introduction of the IBM System/3; and manufacturers are providing increasing numbers of application packages for business systems use. The result should be a rapid growth in user absorption capacity.

Data Acquisition. User acceptance in this area will be limited by the requirement for special software for each installation and economic tightness in the scientific and engineering environment. Further, the potential market in this application is significantly smaller than in other areas.

MARKET FORECAST

Unit shipments of minicomputers are expected to increase during the next five years from a level of 9,000 in 1970 to that of 41,000 in 1975 with annual sales increasing during the same period from $210 million to approximately $650 million. (Table 15). These pro-

Table 15. Projected Shipments 1971 – 1975

Year	Unit Shipments	Shipment Value ($ Millions)
1970*	9,000	210
1971	11,790	259
1972	16,650	340
1973	22,860	433
1974	30,870	538
1975	41,040	651

*Estimated From Industry Survey

jections through 1975 were developed in two stages. First the probable growth rates in system or unit sales were estimated for the five primary application areas and second, a projected decline in average selling price over the five year period was applied to obtain an annual sales forecast.

The practical limitations on minicomputer growth have been discussed in the preceding section. The earlier sections concerning the potential market indicate that growth in unit shipments will not be limited by the potential demand for minicomputer products, since this demand exceeds by a wide margin their practical penetration rates. Our study findings indicate that the competing alternatives will have varying effects on potential demand depending on the application area involved.

The primary constraints on minicomputer sales are expected to be the ability of potential users to recognize cost justifiable applications and to effectively plan for and implement these applications. In the short term this limitation on industry absorption capacity will be the availability of trained personnel. These considerations are reflected in the estimated growth rates for system or unit shipments shown in Table 16. The following is a discussion of these growth rates for the primary minicomputer application areas.

- *Industrial Control* — annual unit growth of 35 percent is projected for 1971, increasing to a high of 40 percent in 1972, and then declining to 25 percent by 1975. This estimate reflects a continuation of earlier growth based on strong need for these systems, a large potential market, the increasing availability of standard systems and the limited effect of competing alternatives. The gradual decline in growth rate reflects the increasing base in later years and greater difficulty in penetrating new markets in which users are less oriented towards computers.

- *Peripheral Control* — a constant unit growth is projected over the five-year period. The large growth rate in the early part of the period reflects the small base in this application. The large growth rate in the latter part of the period reflects the large potential number of units in this application and a more competitive cost situation as the price of minicomputer central processors declines.

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Table 16. Estimated Yearly Growth Rate in Number of Systems or Unit Sales

Application Area	Limitations on growth Due to Competing Alternatives	Growth of User Absorption Capacity	Yearly Growth Rate (Percent)				
			1971	1972	1973	1974	1975
Industrial Control	Small	Rapid growth due to need, general acceptance and increased availability of standard systems. Limited partially by system design requirements	35	40	35	30	25
Peripheral	Large. Wired logic will still be most prevalent approach	Should grow rapidly with declining prices due to large number of potential units	75	75	75	75	75
Communications	Moderate. TDM, FDM, and I/O controllers still important	Rapid growth as number of users and traffic volume increases	35	40	35	30	25
Computation	Moderate-to-large. Electronic accounting machines competitive to business applications, commercial time-sharing competitive to scientific applications and in-house time-sharing, small business computers highly competitive due to marketing strength of large manufacturers.	Good growth due to greater user acceptance and increased availability of software.	35	70	65	60	55
Data Acquisition	Small	Modest growth due to limited market size and fund limitations	15	20	15	12.5	10

- *Communications* — the projected growth pattern is based on estimates for the growth in data communications volume in the 1970's which is forecast between 30 and 40 percent annually, and the moderate impact of competing alternatives.

- *Computation* — the projected growth rate in this area is primarily a reflection of the following two factors: (1) growth in 1971 should be modest due to the general state of the economy, and (2) large annual growth rates are projected thereafter because of the small base and the large number of potential users.

- *Data Acquisition* — a modest growth rate is projected because of the relatively small market size and tight money conditions in most engineering and scientific areas.

In Table 17 the forecasted unit growth rates are applied to 1970 sales revenue in each application area to yield annual sales unadjusted for price changes in minicomputer systems. The total projected growth in unit shipments is developed from the unadjusted sales forecast in each year compared to 1970 sales of $210 million and 9,000 shipments. This yields an average annual growth rate in unit or systems shipped of 35 percent to approximately 41,000 units in 1975.

Table 17. Unadjusted Annual Sales

Application Area	Percentage of 1970 Sales	Sales in 1970 (millions of dollars)	Unadjusted Sales (millions of dollars)				
			1971	1972	1973	1974	1975
Industrial Control	45	94.5	127.6	178.6	241.1	313.4	391.8
Peripheral Control	3	6.3	11.0	19.3	33.8	59.2	103.6
Communication	20	42.0	56.7	79.4	107.2	139.4	174.3
Computation	10	21.0	28.4	48.3	79.7	127.5	197.6
Data Acquisition	22	46.2	53.1	63.7	73.3	82.5	90.8
Total	–	210.0	276.8	389.3	535.1	722.0	958.1
Unadjusted Sales / 1970 Sales	–	1.0	1.31	1.85	2.54	3.43	4.56
Estimated Units Shipped	–	9,000	11,790	16,650	22,860	30,870	41,040
Percentage Increase	–	–	31	41	37	35	32

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The actual forecast sales for the minicomputer industry are developed in Table 18 by adjusting the estimates from Table 17 for projected declines in average system prices in each application area. The indicated price declines are based on our evaluation of:

- The estimated decline in main frame prices
- The estimated decline in peripheral prices
- The distribution of system prices between the main frame and peripherals in each application area
- The tendency for system expansion as more peripherals become available in a product line
- The required sales, marketing and support effort in each application area
- The software development costs in each application area

The final adjusted forecast (Figure 10) is for sales volume to increase to $650.8 million in 1975 reflecting an average annual growth rate of approximately 25 percent. By 1975 industrial control applications should account for 42 percent of sales with computation and communications applications accounting for 23 percent and 19 percent respectively.

Table 18. Adjusted Annual Sales

Application Area	Projected 5 year Decline in Average System Price	Forecasted Annual Sales (millions of dollars)				
		1971	1972	1973	1974	1975
Industrial Control	30%	119.9	157.2	197.7	238.2	274.3
Peripheral Control	50%	9.9	15.4	23.7	35.5	51.8
Communication	30%	53.3	69.9	87.9	105.9	122.0
Computation	25%	27.0	43.5	67.7	102.0	148.2
Data Acquisition	40%	48.9	53.5	55.7	56.1	54.5
Total		259.0	339.5	432.7	537.7	650.8

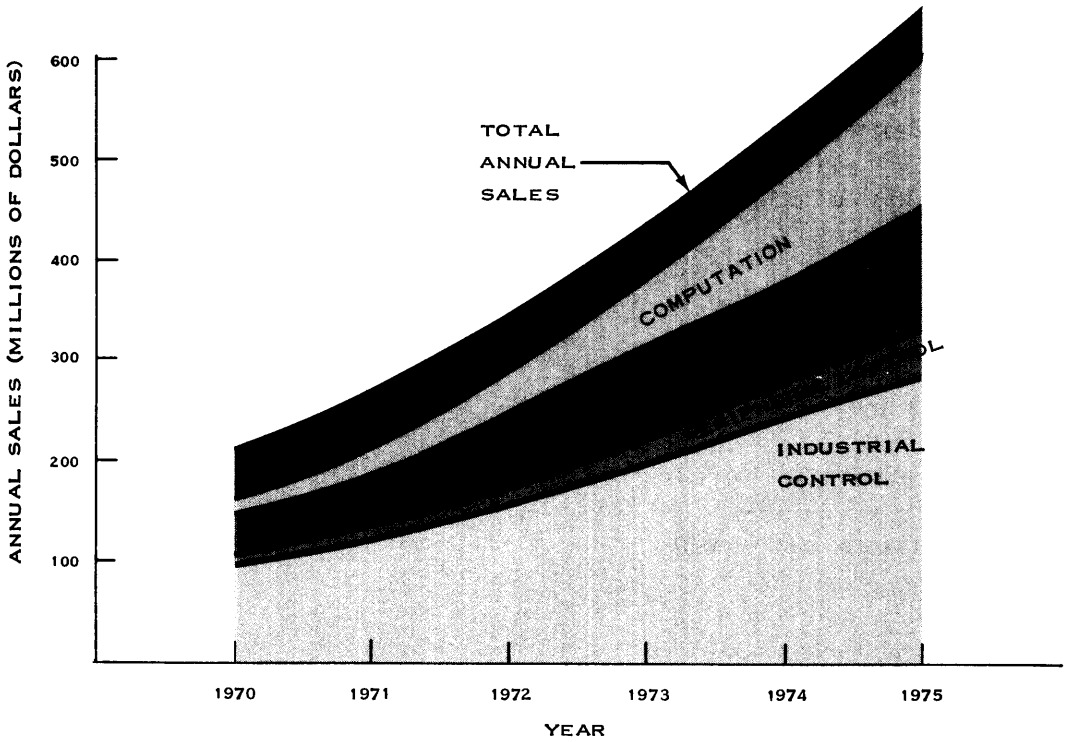

Figure 10. Forecasted Annual Sales by Application Area

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IV. THE MINICOMPUTER INDUSTRY OUTLOOK

Preceding chapters described the current status of the minicomputer industry—its present structure, products, and markets. Included in this coverage were technological developments that will affect the architecture and prices of future minicomputers, an analysis of the markets for these products, and a five-year forecast for unit and dollar sales of minicomputers. This chapter assesses how these changes in the minicomputer products and markets will alter the structure of the industry and how they will affect future prospects for the participating manufacturers.

PROFILE FOR FUTURE SUCCESS

As discussed in Chapter I, the minicomputer industry includes a variety of companies, ranging from very small new organizations to large diversified manufacturers. The value added by these companies is provided in the design and manufacture of the central processor and peripheral device electronics, as well as in applications expertise and systems integration.

The new minicomputer manufacturer has generally restricted his activities to the design and manufacture of the central processor itself and with the marketing of this basic unit to the OEM market.

Changes in minicomputer technology and the resources necessary to satisfy future markets will require a re-orientation in present marketing approaches with greater emphasis on systems and software services. Increased use of MSI/LSI circuitry will reduce the number of separate components and increase standardization of minicomputers. This will result in a reduction of the value added in the design and manufacture of minicomputers central processors. As the price of central processors declines, peripheral devices and associated software will represent an increasing percentage of the dollar volume of minicomputer systems.

Another factor contributing to the need for increased software development and support services is the continuing trend toward reaching new broader based markets with less sophisticated potential users who need complete system packages.

The pattern for future success seems to exclude low-volume manufacturers of minicomputer mainframes. For example, shipments of as few as 1000 units per year would be likely to generate less than $5 million total revenue. Such a manufacturer would have difficulty maintaining needed levels of technical expertise and he would not be able to generate production efficiencies being employed by the larger manufacturers. It is likely therefore

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that either his prices would be too high or his profit margins too low. Further, the assembly of components, representing the value added, will become less complex as the minicomputer is concentrated into fewer semiconductor chips.

We conclude that the survival of minicomputer manufacturers will require expansion — either in volume, products or services. For these reasons, their ultimate successes will be determined more by their ability to supply peripheral products, software, and support services than upon their ability to design and manufacture minicomputer central processors.

ALTERNATE PATHS TO SURVIVAL

Our analysis indicates that four alternate paths to survival are available to the minicomputer manufacturer:

- High-volume manufacturing of minicomputer main frames, directed primarily at the OEM market
- Full-range manufacturing, marketing primarily but not exclusively to end users and serving a broad market spectrum in several application areas; these manufacturers would provide a full range of services, an extensive line of computer capabilities, configurations and software, and an adequate marketing and field support staff
- Integrated manufacturing of complete minicomputer systems for selected applications to include the main frame, many peripherals, and application packages, and marketing these systems primarily to end users.
- Concentrating in the integration of subsystems including the minicomputer and peripherals to which the company would add their own software and application expertise and market these systems in specific special application areas.

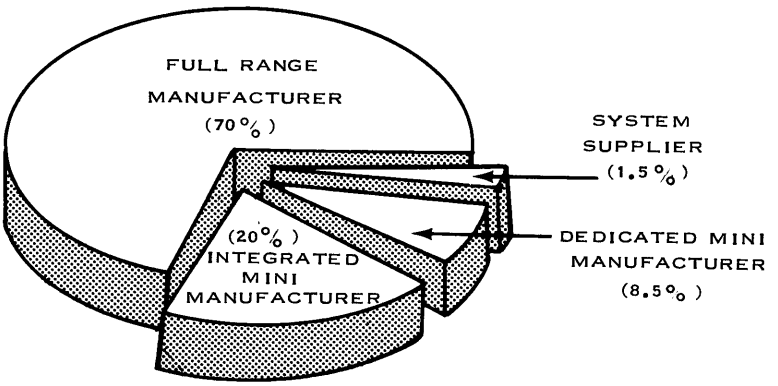

Figure 11. Forecasted Market Share by Industry Segment

These areas are specifically identified as: (1) dedicated minicomputer manufacturers, (2) full range computer manufacturers, (3) integrated minicomputer manufacturers, and (4) special systems suppliers. Anticipated industry market shares in 1975 are shown for each in Figure 11 and an additional discussion of each area is provided in the following paragraphs.

Dedicated Minicomputer Manufacturers

This group of companies would concentrate on manufacturing minicomputer main frames and marketing them in high volume to OEM's. This has been the traditional route by which new companies have entered the minicomputer field. The entrance fee has been relatively small due to the availability of technical expertise, the availability of required components off-the-shelf, and minimal investment in production capability since production is largely an assembly operation. As a result, the majority of minicomputer manufacturers currently function as this type of company. However, the number of competing firms in this group should decline sharply as continuing price declines squeeze out the marginal producers. The fading competition will generate further business in surviving companies. Higher production volumes will lead to lower unit prices and/or increased profitability in the remaining companies. These companies will offer standardized products with a minimum of such services as maintenance, software, and systems support. Their marketing force will be technically oriented of modest size and with a low level of marketing effort per unit sold. This group of companies should accrue approximately 8.5 percent of industry sales in 1975.

The basic requirements for success of individual manufacturers competing in this industry segment are:

- Emphasis on a marketing policy based on competitive pricing and fast delivery
- Investment in manufacturing automation to reduce labor cost to a minimum
- Production of a flexible, standardized product which can satisfy a wide range of market needs
- Manufacture only in large quantities to minimize unit costs
- Emphasis on large quantity sales to reduce unit marketing cost
- Provision of a highly reliable product which allows field maintenance via modular replacement
- Maintenance of a high skill level in important areas such as semiconductor technology
- Availability of financial resources to permit investment in plant and equipment

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The participants in this industry segment are expected from two sources: (1) the surviving newly created minicomputer manufacturers, and (2) present semiconductor manufacturers who have entered or are expected to enter the field.

The outlook for the dedicated minicomputer manufacturers is not especially encouraging. The total sales volume will be modest and little product differentiation among manufacturers is anticipated. Together with the emphasis on price and competition, these factors will limit the potential profitability of these companies.

Full Range Computer Manufacturers

The large, full range computer manufacturers are expected to be the dominant force in the minicomputer industry during the next five years with 70 percent of total industry sales. These companies will have extensive computer product lines including larger machines. They will manufacture many or all of their own peripherals and may even manufacture their own semiconductor components. These companies will have extensive marketing forces and will provide complete software support, systems support, maintenance, documentation, and user training. Marketing will be primarily to end users in several application areas and industrial groups. These companies will also participate as OEM suppliers but only as a secondary marketing effort.

These full-range capabilities could be obtained either through the major computer manufacturers expanding downward (internal expansion or acquisition) or through upward expansion of dedicated minicomputer manufacturers.

Major Computer Manufacturers. Honeywell Information Systems has already taken the acquisition path by acquiring Computer Control Corporation and has become one of the major companies in the industry. IBM, with its recent introduction of System/7 is the most significant example of internal expansion within a major manufacturer. Initially, IBM has set limited horizons for System/7 by concentrating on industrial process control. It is logical to expect that the System/7 product line will be expanded to other application areas and should include its use as a front end communications processor for its new System/370 product line. In this way IBM should become a major force within the total minicomputer industry, accumulating 15 to 20 percent of sales by 1975. With the availability of System/7, IBM is also expanding its current predominance in the central computer installation of a company by distributing processing capability throughout the organization.

Most of the major computer manufacturers are expected to enter the minicomputer market because it provides new avenues of growth and is a logical extension of existing product lines. From both product and marketing points of view, these companies will need the minicomputer capability to provide a full computer product line for the communications oriented systems of the 1970's.

Present Minicomputer Manufacturers. The most obvious example of minicomputer manufacturers expanding upward is Digital Equipment Corporation who has already made this transition with the introduction of larger computers (PDP-10), internal manufacturing of new peripherals, broadening of their minicomputers product lines, and increasing their

marketing staff and software development. DEC has achieved this transition from a minicomputer manufacturer through a combination of many factors, such as product leadership, excellence in reputation, and early recognition of the market. However, the likelihood of another mini manufacturer duplicating this transition appears to be remote.

Success for the full range manufacturers, relative to their participation in the minicomputer industry, will require the following strategies:

- Maintenance of a large marketing force with capability in many applications areas.
- Provision of an extensive product line which is highly modular and has configuration flexibility.
- Provision of extensive systems and application software.
- Emphasis on effective salesmanship, customer services, including maintenance system support, custom programming, education, documentation, and program libraries.
- Product design with ease of interfacing to the equipment of other manufacturers, especially IBM.
- Availability of large financial resources.
- Frequent adjustments to the product line and a flexible marketing approach to accommodate these changes.

Minicomputer systems should be a profitable business segment for these manufacturers. Large markets will exist, product differentiation will exist, and value will be added in the manufacturing of central processors and peripherals, as well as in the provision of software, application expertise, and customer support. These profit potentials exist for the small minicomputer manufacturer expanding into broader product lines. However, these companies will be exposed to new competitive pressures from the larger companies, especially IBM.

Integrated Minicomputer Manufacturers

The most promising alternative route for present minicomputer manufacturers is to concentrate on complete minicomputer based systems, including peripherals, for selected applications and to market these systems directly to end users. This approach would take advantage of two important characteristics of the industry:

- Peripherals already account for approximately 60 percent of total system costs and this percentage is expected to increase to approximately 75 percent by 1975.
- The end user market provides higher dollar volume per unit, higher profit margins, and the greatest opportunity to establish a company's niche in the marketplace.

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Applications which could be appropriate for this approach include in-house time sharing, message switching, educational training, business data processing, and various types of manufacturing control systems.

The primary requirements of a company participating in this industry segment are the following:

- Broad technical capabilities including semiconductors, electromechanical systems which are included in peripheral devices, and application knowledge.
- An applications oriented marketing staff.
- Internal manufacture of a broad range of peripheral devices and interface equipment.
- Emphasis on solutions to end user problems.
- Emphasis on the design of special systems modified for particular applications.

The integrated minicomputer manufacturers should obtain approximately 20 percent of industry sales during the next 5 years. In 1975 these manufacturers should account for approximately $130 million sales which should support at most 10-15 companies. This route offers the greatest opportunity for success for today's smaller minicomputer manufacturers. Value added will be supplied in manufacturing most of the hardware, integrating system components and solving specific user problems. Implementation of successful systems could establish a company's product in selected applications, leading to further penetration. However, these companies will be competing with the full range computer manufacturers, especially in high volume markets.

These companies are expected to compete in the OEM market as suppliers of central processors. However, this market is not likely to be successful since the more specialized dedicated minicomputer manufacturers should be capable of offering lower mainframe prices due to higher volume. For this reason, *the success of the integrated minicomputer manufacturer will depend more on his peripheral manufacturing and systems and marketing capabilities than on his capabilities as a minicomputer main frame manufacturer.*

Special Systems Suppliers

Another alternative available to the smaller minicomputer manufacturer is to depart from manufacturing per se and narrow his outlook and concentrate on one or two special applications. These companies would typically buy minicomputers as OEM's and integrate the minicomputer with purchased peripherals and systems software (purchased and/or self-developed) into complete systems for a dedicated application. These systems will be marketed exclusively to end users, most of them on a "turn key" basis. The value added by these companies will be derived from their systems integration function, systems and application software, and applications expertise. The products will be sold in low volume but with high profitability and product differentiation. Potential applications for these systems

include business data processing, hospital systems, information storage and retrieval, and computer-aided instruction.

Participation in this market segment may be derived from the existing minicomputer manufacturers, existing software companies, or new ventures by people with special application capability. This route will require the minimal marketing staff, minimal production facilities, and the smallest financial commitment.

Success in this market segment will require a participating company to concentrate on the following approaches:

- Selection of those applications and market with too low a volume to interest the larger companies.
- Development of a proprietary system (usually software) that provides a recognizable unique capability in the product sold.
- Establishment of a small sales force who are experts in the selected application.
- Manufacture of a non-standard product that will be difficult to replace by a competitor.

Most of the present minicomputer participants are expected to end up in this segment of the market as the financial, marketing and technical difficulties of the other alternatives become insurmountable. However, the growth prospects for such companies are limited. By 1975 the special systems suppliers are expected to have only about 1.5 percent of industry sales. The companies will require extensive marketing efforts per unit sale; they are especially vulnerable to technical obsolesence because of their narrow field of interest; they will be restricted in potential growth by the limited resources available for reaching a large sector of the market; they will have difficulty maintaining their installed systems; and they will be forced to concentrate on low volume markets which will be of minor interest to the full range manufacturers.

The ease of entry into this segment will generate a large number of participants and a high level of competition. Most important, these companies will face direct competition from the full range and integrated manufacturers that will be difficult to overcome. Some will survive with low levels of sales volume. Most will fail.

* * * *

Characteristics of the four industry segments discussed in the preceding paragraphs are summarized in Table 19. The long range view for these segments and the markets they represent are discussed in the next section.

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Table 19. Summary of Forecasted Industry Structure for 1975

	Dedicated Mini Manufacturers	Full Range Manufacturers	Integrated Mini Manufacturers	Special Systems Suppliers
Description	Manufacture mini central processors exclusively.	Manufacture broad range of computers and peripherals with extensive marketing and support staffs.	Manufacture complete mini based systems included CPU and peripherals.	Assembly and integrate special systems which include a mini and other components.
Forecasted 1975 Market Share (Percent)	8.5	70	20	1.5
Market Orientative	Exclusively OEM	Principally end users	Principally end users	Exclusively end users.
Recommended Strategies	• Competitive pricing • Fast delivery • Mfgr. automation • Flexible product • Large quantity mfgr. • Large quantity marketing • Reliable product • High semiconductor skills • Adequate financing	• Large marketing staff • Broad product line • Extensive software • Customer service • Compatible product • Large financial resources • Product line adaptability • Marketing adaptability	• Broad technical capabilities • Applications oriented marketing • Mfgr. many components • Solve user problems • Design special systems	• Selective applications • Proprietary system • Application oriented marketing force • Non-standard product
Success Potential	Modest due to price competition lack of product differentiation, and low dollar volume	Very good due to large market and value of complete systems.	Good depending primarily on peripheral manufacturing, systems and marketing capabilities.	Small.

THE LONG-RANGE VIEW

From a long-range perspective (beyond 1975), minicomputers are expected to become less distinguishable as a separate product and to be considered more as an electronic component of other systems. Two industry groups will begin to predominate—the component manufacturer and the full range computer manufacturer.

The component manufacturer will possess the characteristics of today's semiconductor manufacturers. The participants in this segment will evolve from two sources—the OEM suppliers and the existing semiconductor manufacturers. Semiconductor manufacturers should become a more significant force in this segment as product standardization increases and high volume develops so that they will no longer need the special marketing and support staff now required for success in the minicomputer industry.

Success as a component manufacturer will depend more on the company's capabilities in semiconductor technology and production efficiency than in computer design expertise. This transition will be an evolutionary process as the semiconductor manufacturers make larger and larger portions of the CPU with MSI/LSI modules. Early evidence of this transition is expected by the period 1974-1975.

Since minis will lose their separate identity, they will be incorporated in the broad spectrum of computer based systems. In this environment, the full range manufacturers are expected to extend their dominance of the market beyond the mid-1970's. They will therefore impinge upon the market segments of the integrated manufacturers whose product and marketing opportunities should narrow into specialized areas. In this market the full range manufacturers will extend their full systems capabilities and concentrate on complete solutions to end user problems.

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V. APPENDICES

A. MINICOMPUTER APPLICATION AREAS

B. DEVELOPMENT OF MARKET POTENTIAL

C. PRODUCT COMPARISON CHARTS

D. COMPANY PROFILES

E. USER EXPERIENCE

F. GLOSSARY

APPENDIX A. MINICOMPU

Characteristics	AP		
	Industrial Control	**Peripheral Control**	**Quisition**
Use	Industrial testing (of components, systems, etc.), numerical control of machine tools, typesetting, control of open or closed loop continuous processes.	Controls operation of other equipment, such as terminals, subsystems connected to larger computers, or data entry systems.	Line ction of data, duce nigh rates sion lities, for transfocessing elsecontrors instrumessa netwc munic large c
Where Found	Throughout all types of industry-electronic component fabrication, chemical process control, navigation systems, aircraft checkout systems.	Associated with larger computer systems as a controller of local or remote peripheral devices.	High military, e.g. tion systems, reservations, satelquotang systems, messaospitals. compa
Application Requirements and Needs	Operation to be controlled or tested must be realistically definable by a mathematical analog; high reliability; must be capable of operating in a hostile environment; system design must have process orientation.	Efficient interface-high data rates, ability to handle wide range of signal requirements, software compatibility; special need to establish, and operate under worse-case conditions: system design must have task orientation.	Large sfer rates, to justh capacity chargeage; editing ing to g tasks, but of mesmple prolosing task.
Market Segment-OEM or End User	Both OEM and end user.	Principally OEM.	Both G user.
Customer Characteristics	Usually highly technical but frequently not experienced in computer systems.	Usually highly technical and with extensive experience in computer systems usage and design; highly price sensitive.	OEM'sal with exend uss capability softwærformance nomics.

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APPLICATION AREA			
Peripheral Control	**Communications**	**Computation**	**Data Acquisition**
Processes interrupt requests, or initiates action itself; outputs control signals to one or more peripheral devices which respond by taking the desired action; frequently involved with sequencing, data transfer, buffering, editing and formatting.	As a line concentrator, receives data on several low speed lines, interleaves characters and transmits data on one high speed line; in message switching, accept messages from multiple sources & coordinates their output on multiple output lines, logs transactions, and verifies transmission; as communications front end, processor performs on line monitoring, data editing and formatting.	Takes input from a variety of peripheral devices, processes data with prestored programs or compiles/assembles new programs being developed; outputs results to user via printer, display, etc.; in time sharing, handles multiple jobs concurrently without unacceptable degradation of service to any user.	Accepts input from one or multiple sources usually at high and variable rates; edits, formats, stores raw data, preprocesses data for later processing; logs selected data.
Input/output structure, interrupt structure, method of addressing, communication capabilities.	Byte oriented instructions, efficient interrupt structure, flexible I/O structure, input/output rate, memory cycle time, systems software, reliability.	Ease of operator use, systems & applications software, extensive instruction set, large memory capacity, easily learned languages and availability of wide range of peripheral devices.	Input/output rate & structure, large memory & storage capacity, cycle time.
Hard-wired controller or main computer.	Hard-wired devices or larger computer.	Manual computation or shared use of a centralized computer, in either a batch or a time sharing operation; electromechanical bookkeeping machines.	Hard-wired devices, large computer; often no other method is feasible.
Flexibility and adaptability to many type devices; improves performance of main processor.	Flexibility, and adaptability; lower cost through decentralized control, lower transmission costs, more efficient use of a large centralized computer.	Low cost, reduced total processing time; improved accessibility, to individual users; ease of operation; improved reports in business applications.	Flexibility, low cost, attractive price/performance; speed.

PPENDIX A.
ION AREAS

Characteristics	APl		
	Industrial Control	Peripheral Control	Cuisition
Mini's Disadvantages	Large start-up expense with long implementation period; potentially great loss if failure occurs; environmental sensitivity.	Expensive interfaces sometimes needed; more expensive than hard-wired logic; speed limitation in certain applications.	Additrfaces usually ble spd memory systerr liabilit ity.
Normal Systems Throughput Limitation	Peripheral units I/O transfer rates.	I/O transfer rates.	I/O trts or I/O trans-
Economics	Design, equipment, and total implementation costs all fairly high; of equipment costs, interface gear usually much more expensive than mini.	Equipment cost usually higher than design and programming costs; of equipment costs, interface gear usually comparable to mini.	Line cts usually stantiaan design or tem exosts; periphcosts fice gear more progra mini. menta gear ar compa
Software Requirements	FORTRAN, systems software, input/output handling routines, diagnostics, mathematical routines, applications software for special applications.	Usual modest-OEM's usually develop their own data handling routines, interrupt handling generally important.	Bit ma; needed; ity; opion capabilsembly macro
Roles of User and Supplier	Greatest burden on user process definition, interfacing, programming, maintenance; supplier provides technical capability, special design features, has relatively long involvement per unit sale.	Greatest burden on user to do all adaptation; must be strong technically; supplier provides system support, documentation, has relatively small involvement.	Supplicof most systechnicaces burden umenta system deprefersnentation; softwales system user of engineering nance ctle applicanical as user of system

NOTES TO APPENDIX A:

1. * - With optional equipment
2. (s) - Using subroutine
3. Kb - Thousands of bytes
4. KW - Thousands of words

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APPENDIX B. MINICOMPUTER MARKET POTENTIAL ESTIMATES

APPLICATION AREA: INDUSTRIAL CONTROL

TYPICAL POTENTIAL MARKETS	BASIS OF MARKET SIZE	SOURCE OF BASIS*	MARKET BASIS (No. of Sites)	GROSS MARKET SIZE (No. Minis)
Aerospace	No. firms	USDC	1,370	6,800-68,000
Paper mills	No. mills	USDC	794	800-3,200
Containers	No. firms	USDC	2,422	2,400-7,200
Auto traffic control	No. Cities > 100,000 People	DC/SA	130	130-650
Utilities	No. Plants	DC/SA	1,522	1,522-15,520
Elec. Component Testing	No. Estab. X 1/5	USDC	290	870-2,900
Aircraft Checkout (Com'l)	No. Major Airports	NYTA	50	500-1,000
Auto Checkout Diagnostic Ctrs.	No. Major Cities X 5	A/C	390	390-1,560
Typesetting	No. Newspapers + #Printers	DC/SA	5,884	5,900-11,800
Aircraft Navigation & Ctl.	No. Com'l & Military Aircraft	DC/SA	38,262	38,300-38,300
Ship Navigation	No. Com'l Ships X 1/3	NYTA	6,303	6,300-6,300
Elec. Component Fabrication	No. Plants= No. Estab. X 1/5	USDC	290	290-2,900
Com'l Building Control	No. Major (tall) Bldgs. X 10	NYTA	6,500	6,500-6,500
Hospital Oper. Room Eqpt. Ctl.	No. Hospitals X 1/2	DC/SA	3,575	3,575-14,300
Chem. Process Control and Allied Matl's.	No. Chem. Estab. X 1/3	DC/SA	3,935	3,935-19,675
Petroleum Process Control	No. Refinery Estab. X 1/2	DC/SA	219	660-4,400
Prim. Metals & Glass Process Control	No. Estab. X 1/3	DC/SA	5,844	5,840-11,680
Pipeline Flow Control	No. Gathering Lines X 1/10	DC/SA	4,800	4,800-4,800
Food Process Control	No. Establishments X 1/4	USDA	1,911	1,911-9,555
Numerical Control	No. Mach. tools shipped 70-75 X 1/100	DC/SA	13,500	13,500-13,500
Utilities-Trbl Shooting	No. Cities > 1/2M People X 5	DC/SA	350	350-1,750
Paper Process Control	No. Paper Mills	DC/SA	789	800-1,600
Electrical Sys. Testing	No. Elec. Sys. Estab. X 1/2	USDC	545	545-2,725
TOTAL				106,605-249,815

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MINICOMPUTERS

APPLICATION AREA: PERIPHERAL CONTROLLERS

TYPICAL POTENTIAL MARKETS	BASIS OF MARKET SIZE	SOURCE OF BASIS*	MARKET BASIS (No. of Sites)	GROSS MARKET SIZE (No. Minis)
COM	No. High resolution graphic art systems	ATES	500	500-500
OCR	No. Machines by 1975	ATES	8,000	8,000-8,000
Key-disk	No. Machines by 1975	ATES	3,300	3,300-3,300
Printer systems	No. Printers X 1/4	ATES	19,000	19,000-19,000
Terminal	No. Machines	ATES	122,500	122,500-122,500
Airport Baggage Handling Systems	No. Major Airports	NYTA	50	250-1,000
Cash Dispensing Machines	No. Bank Branches X 7/10	DC/SA	23,600	23,600-118,000
Mail Sorting/Handling	No. Post Offices X 1/3	NYTA	10,718	10,700-53,500
Matl's Handling-Mfg's	No. Mfgrs > $10M Assets	DC/SA	2,710	5,400-54,000
Key-Tape	No. Machines X 1/3	ATES	10,000	10,000-10,000
Text Editing	No. Publishers X 1/2 + Mfg > $25M No. + No. Advertising Firms X 1/3 + No. Radio Broad. X 1/3 + No. TV Br.	DC/SA	16,400	16,400-32,800
TOTAL				219,650-422,600

APPLICATION AREA: COMMUNICATIONS

Domestic Tel. & Tel.	No. Companies	USDC	1,876	1,900-37,500
Int'l Tel. & Tel.	No. Companies	USDC	8	160-1,600
TV Broadcasting	No. Stations	USDC	863	860-860
Radio Broadcasting	No. Stations	USDC	6,679	6,700-6,700
Time Sharing Companies	No. Companies	Modern Data Systems 2/70	94	940-9,400
Manufacturing	No. Cos. > $10M Assets	DC/SA	2,840	2,840-28,400
Wholesalers	No. Firms > $25M Assets	DC/SA	343	340-1,700
Airlines	No. Ticketing Sites	31 Airlines Served by ATC	1,550	1,550-3,100
Railroads	No. Firms	DC/SA	360	3,600-18,000
Credit Bureaus	No. Firms X 1/10	A/C	300	300-1,200
Retail Chains	No. Chains	A/C	200	1,000-4,000
Food Chains	No. Chains	A/C	50	250-500
Health, Life, Car Insurance	No. Firms > $1M Sales	A/C	20	400-4,000
Govt-Law Enforcement	No. Cities > 100,000	DC/SA	132	130-1,300
Utilities, (not tel.)	No. Establishment	DC/SA	1,552	4,550-15,500
Banks	No. Branches X 0.7	DC/SA	23,600	23,600-23,600
Brokerages	No. Branches	A/C	5,000	5,000-5,000
Air Traffic Control	No. Miles of Fed. Airways/500 + No. Com'l Planes	NYTA	2,640	2,640-2,640
TOTAL				56,760-165,000

APPLICATION AREA: COMPUTATION

TYPICAL POTENTIAL MARKETS	BASIS OF MARKET SIZE	SOURCE OF BASIS*	MARKET BASIS (No. of Sites)	GROSS MARKET SIZE (No. Minis)
Small Business	No. Establishments	ATES	67,000	67,000-67,000
Colleges & Universities	No. Colleges & Univ.	USDC	2,900	2,900-11,600
High Schools	No. High Schools X 1/3	USDC	4,400	4,400-4,400
Consultants	No. Firms; Arch. & Eng. > 1/2M; No. C.E. > 1/4M	DC/SA	1,151	1,150-1,150
Software Firms	No. Firms	A/C	500	500-5,000
In-House Time Sharing for Manufacturers	No. Mfgrs. > $10M Assets	DC/SA	2,710	2,710-10,840
Colleges & Universities	No. Number	NYTA	188	190-375
Utilities	No. Plants	DC/SA	1,552	1,550-1,550
Fin. Inst.	No. Firms > 250 People X 1/4	DC/SA	343	340-340
Services	No. Firms > 250 People X 1/10	DC/SA	412	410-410
TOTAL				81,150-102,665

APPLICATION AREA: DATA ACQUISITION

Medical Labs.	No. Establishments	DB	550	550-550
Patient Monitoring	No. Hospitals	DC/SA	7,137	7,140-71,400
Utilities	No. Firms	DC/SA	1,552	1,550-1,550
Commercial R & D	No. Firms	DB	2,000	2,000-10,000
Commercial Testing Labs.	No. Firms	DC/SA	1,253	1,250-3,750
Dental Labs.	No. Establishments	DB	1,962	1,962-1,962
Instrumentation	No. Mfgrs. > $10M Assets	DC/SA	2,710	8,120-135,000
TOTALS				22,572-224,212

*References to Sources

USDC -United States Industrial Outlook
DC/SA-Statistical Abstracts of the United States
NYTA-The New York Times Encyclopedic Almanac
A/C -AUERBACH Corporation Estimate
ATES -AUERBACH Technology Evaluation Service Study
DB -Dun and Bradstreet's File of Establishments

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APPENDIX C. PRODUCT COMPARISON CHARTS

Manufacturer	BIT, Inc.	Clary Datacomp Systems, Inc.	Compiler Systems, Inc.
Model Number	483	Datacomp 404	CSI-16
Word Length (Bits)	8 + 1	16	16
Cycle Time (microsec)	0.98	2.1	0.9
Memory Size Range (Kb)	1-65	65	8-65
No. Instructions	45	38	32
Add Time (microsec)	2.25	98 (Decimal)	1.8
Fixed Point c=a+b (microsec)	8.4	- -	6.0
Multiply Time (microsec)	2,700 (s)	183 to 2,427 (s)	8.5
Available Software & Languages	Assemblers (2) Fortran Utility & Debugging	Utilities, assembler, Executive, Timesharing Exec Basic, Cobol	Utilities, assembler, Fortran, Algol, Basic Full range op. Systems
Type I/O Equipment Available	TTY, Paper Tape, Printer, Mag Tape, Disc, Graphics, A/D, D/A Communications	TTY, Card, Printer, Mag Card, Tape Cassette, Communications, CRT	TTY, Paper Tape, Card Printer, Mag Tape, Disc, Graphics, A/D D/A, Communications
Max. I/O Transfer Rate (Kb/sec)	750 (in); 1.020 (out)	470	2,200
No. Priority Interrupts	8-32	Up to 256	4-256
1st Delivery	1/70	11/69	9/70
Standard Configuration Price CPU with 8Kb memory	9,600	12,000	12,350

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MINICOMPUTERS

Manufacturer	Computer Systems, Inc.		Computer Automation, Inc.
Model Number	CSI-24	PDC 208	PDC 216
Word Length (Bits)	24	8	16
Cycle Time (microsec)	0.9	2.67	2.67
Memory Size Range (Kb)	12-24,000	4-32	8-64
No. Instructions	32	76	160
Add Time (microsec)	1.8	7.01	5.34
Fixed Point c=a+b (microsec)	6.0	9.0	15.62
Multiply Time (microsec)	10.33	517 (s)	42 (s)
Available Software & Languages	Utilities, Assembler, Fortran, Algol Basic Full range of Op. Systems	Utilities, Assemblers	Utilities, Assembler, Fortran,
Type I/O Equipment Available	TTY, P. Tape, Card, Printers, Mag Tape, Disc, Graphics, A/D, D/A, Communications	TTY, P. Tape, Card, Printer, Mag Tape, Disc, Graphics, A/D, D/A, Communications	
Max. I/O Transfer Rate (Kb/sec)	3,300	68	134
No. Priority Interrupts	4-256	3-72	3-67
1st Delivery	9/70	7/69	8/69
Standard Configuration Price CPU with 8Kb memory	16,700 (12Kb)	9,650	8,700

Manufacturer	Computer Automation, Inc.		Computer Logic Systems, Inc.
Model Number	PDC 808	PDC 816	CLS-18
Word Length (Bits)	8	16	18
Cycle Time (microsec)	8.0	8.0	0.96
Memory Size Range (Kb)	4-16	8-32	4K-262K words
No. Instructions	73	160	112
Add Time (microsec)	24	1.6	1.9
Fixed Point c=a+b (microsec)	24	4.8	- -
Multiply Time (microsec)	1,552 (s)	128 (s)	7.04
Available Software & Languages	Utilities, Assembler	Utilities, Assemblers, Fortran	Utilities, Macro Assemblers
Type I/O Equipment Available	TTY, P Tape, Card, Printer, Mag Tape, Disc, Graphics, A/D, D/A, Communications	TTY, P Tape, Card, Printer Mag Tape, Disc, Drum, A/D, D/A Communications	TTY, P Tape, Printer Mag Tape, Disc, A/D
Max. I/O Transfer Rate (Kb/sec)	16	50	2,080
No. Priority Interrupts	3-72	3-67	8
1st Delivery	4-68	12/68	9/70
Standard Configuration Price CPU with 8Kb memory	9,500	11,500	10,470

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MINICOMPUTERS

Manufacturer	Control Data Corp.	Datamate Computer Systems, Inc.	
Model Number	CDCSC 1700	Datamate 16	Datamate 70
Word Length (Bits)	16 + 2	16	16
Cycle Time (microsec)	1.5	1.0	1.0
Memory Size Range (Kb)	8-65	8-65	8-65
No. Instructions	73 + 2*	115	144
Add Time (microsec)	3.0	2	1
Fixed Point c=a+b (microsec)	9.0	6.0	6.0
Multiply Time (microsec)	20.0	9	11.0
Available Software & Languages	Assembler, Fortran, Utilities, Applications packages, 3 operating systems	Main assembler, Fortran, Utilities	Assembler, Utilities
Type I/O Equipment Available	TTY, P Tape, Card, Printer, Mag Tape, Disc, Drum A/D, D/A, Communications	TTY, P Tape, Printer Mag Tape Disc, Drum A/D, D/A, Communi-cations	TTY, P Tape, Printer, Mag Tape, Disc, Drum, A/D, D/A, Communi-cations
Max. I/O Transfer Rate (Kb/sec)	1,332	1,000	1,000
No. Priority Interrupts	16	8-64	1-64
1st Delivery	10/69	10/69	Fall 1970
Standard Configuration Price CPU with 8Kb memory	15,900	15,300	8,900

Manufacturer	Data General Corp.				
Model Number	Nova	Nova 800	Nova 1,200	Supernova	Supernova SC
Word Length (Bits)	16	16	16	16	16
Cycle Time (microsec)	2.6	0.8	1.2	0.8	0.3
Memory Size Range (Kb)	4-65	4-65	4-65	8-65	4-65
No. Instructions	200	200	200	200	200
Add Time (microsec)	5.6	--	--	0.8	--
Fixed Point c=a+b (microsec)	21.8	4.6	7.05	5.6	3.3
Multiply Time (microsec)	11.0	--	--	--	--
Available Software & Languages	Assembler, Algol, Fortran, Disc operating, System, Utilities				
Type I/O Equipment Available	TTY, P Tape, Card, Printer, Mag Tape, Disc, A/D, D/A, Communication				
Max. I/O Transfer Rate (Kb/sec)	571	--	--	1,250	--
No. Priority Interrupts	16	16	16	16	16
1st Delivery	2/69	4/71	2/71	4/70	6/71
Standard Configuration Price CPU with 8Kb memory	7,950	6,950	5,450	9,600	11,900

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MINICOMPUTERS

Manufacturer	Digital Equipment Corp.			
Model Number	PDP-8	PDP-8/I	PDP-8/L	PDP-8C
Word Length (Bits)	12-bit	12-bit	12-bit	12-bit
Cycle Time (microsec)	8	1.5	1.6	1.2
Memory Size Range (Kb)	4-32 KW	4-32 KW	4-32 KW	4-32 KW
No. Instructions	29	29	29	29
Add Time (microsec)	3	3	3.2	2.6
Fixed Point c=a+b (microsec)	10.5	10.5	10.5	- -
Multiply Time (microsec)	9.21	7.2		7.4
Available Software & Languages				Assembler, Fortran, Focal, Disc System, Binder, Applications Packages
Type I/O Equipment Available				TTY, P Tape, Card, Printer, Mag Tape DECTape, Disc, Drum, A/D, D/A, Communication Graphics
Max. I/O Transfer Rate (Kb/sec)	148KW	500 KW	500KW	830KW
No. Priority Interrupts	0-1	0-1	0-1	0-4
1st Delivery	4/65	4/68	10/68	3/71
Standard Configuration Price CPU with 8Kb memory	16,700 (4Kw)	11,200 (4Kw)	7,200 (4Kw)	5,200 (4Kw)

Manufacturer	Digital Equipment Corp.		
Model Number	PDP-11	PDP-15	
Word Length (Bits)	16	18	
Cycle Time (microsec)	1.2	0.8	
Memory Size Range (Kb)	8-262	4-131 Kw	
No. Instructions	45	Over 90	
Add Time (microsec)	2.3	0.8	
Fixed Point c=a+b (microsec)	6.9	4.8	
Multiply Time (microsec)	120	7.4	
Available Software & Languages	Assembler, Utilities, Basic, Fortran	Basic, Fortran Focal, Assembler, Utilities	
Type I/O Equipment Available	TTY, P Tape, Card, Printer, Disc Mag Tape, A/D, D/A, Communications, Graphics (PDP-15 only)		
Max. I/O Transfer Rate (Kb/sec)	1,300	1,250 Kw	
No. Priority Interrupts	7	28	
1st Delivery	4/70	2/70	
Standard Configuration Price CPU with 8Kb memory	9,500	14,300	

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MINICOMPUTERS

Manufacturer	Digital Scientific Corp.		Electronic Associates, Inc.
Model Number	META 4		EAI-640
Word Length (Bits)	16		16 + 1
Cycle Time (microsec)	0.9		165
Memory Size Range (Kb)	4 to 65		16-65
No. Instructions	44		62
Add Time (microsec)	1.8		3.3
Fixed Point c=a+b (microsec)	- -		9.9
Multiply Time (microsec)	5.9		18.1
Available Software & Languages	Utility Assembler, Fortran		Utilities, Assembler, Fortran, Operating Systems
Type I/O Equipment Available	TTY, P Tape, Card, Printer, Mag Tape, Disk		TTY, P Tape, Card, Printer, Mag Tape, Disc
Max. I/O Transfer Rate (Kb/sec)	2,222		1,200
No. Priority Interrupts	Unlimited (added in groups of 12)		64
1st Delivery	3/70		4/67
Standard Configuration Price CPU with 8Kb memory	14,350		17,000 (est.)

Manufacturer	Foto-Mem	Fujitsu, Ltd.	General Automation, Inc.
Model Number	Centaur	FACOM-R	SPC-12
Word Length (Bits)	8	16 + 1	8
Cycle Time (microsec)	0.98	1.5	2.16
Memory Size Range (Kb)	4-65	2-65	4-16
No. Instructions	78	28	52
Add Time (microsec)	3	6	4.32
Fixed Point c=a+b (microsec)	11.76	18	17.28
Multiply Time (microsec)	7	2,000	800
Available Software & Languages	Utilities, Assembler	Utilities, Assembler, Mini Fortran, Applications	Utilities, Conversational assembler, Real-Time Executive
Type I/O Equipment Available	TTY, P. Tape, Printer, Mag, Tape, Disc	TTY, P Tape, Printer, Mag Tape, Disc, Graphics, A/D, Communications	TTY, P Tape, Card, Drum, A/D, D/A
Max. I/O Transfer Rate (Kb/sec)	800	800	110
No. Priority Interrupts	4	4	3
1st Delivery	8/69	3/69	1/68
Standard Configuration Price CPU with 8Kb memory	7,950 (est.)	18,255	7,800

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MINICOMPUTERS

Manufacturer	General Automation, Inc.		
Model Number	SPC-16	SA 18/30	
Word Length (Bits)	16	18	
Cycle Time (microsec)	0.969	0.96	
Memory Size Range (Kb)	8-65	4-32Kw	
No. Instructions	90	36	
Add Time (microsec)	0.969	2.4	
Fixed Point c=a+b (microsec)	6.7	7.2	
Multiply Time (microsec)	4.0	12.0	
Available Software & Languages	Utilities, Conversational Assembler	Utilities, Assembler, Fortran	
Type I/O Equipment Available	TTY, P Tape, Card, Disc, A/D, D/A, Communications	TTY, P Tape, Card, Mag Tape, Disc, Drum, Graphics, A/D, D/A	
Max. I/O Transfer Rate (Kb/sec)	500	833 Kw	
No. Priority Interrupts	3	64	
1st Delivery	5/70	8/69	
Standard Configuration Price CPU with 8Kb memory	8,700	16,700	

Manufacturer	Hewlett-Packard, Co.		Honeywell Information Systems		
Model Number	2114B, 2115A	2116B	H316	DDP-416	DDP-516
Word Length (Bits)	16	16	16	16	16
Cycle Time (microsec)	2	1.6	1.6	0.96	0.96
Memory Size Range (Kb)	8-16	16-65	8-32	8-32	8-65
No. Instructions	70	70	72	30	72
Add Time (microsec)	4	3.2	3.2	1.92	1.92
Fixed Point c=a+b (microsec)	12	9.6	11.2	5.76	6.72
Multiply Time (microsec)	187	19.2	8.8*	--	5.28*
Available Software & Languages	Utilities, Fortran, Algol (2116), Basic, Disc Operating Systems		Utilities, Assembler, Fortran, SOLVE, TEACH, Applications Packages, Operating System		
Type I/O Equipment Available	TTY, P Tape, Card, Mag Tape, Disc, A/D, D/A		TTY, P Tape, Card Printer, Mag Tape, Disc, Drum A/D, D/A, Communications		
Max. I/O Transfer Rate (Kb/sec)	1,000	1,300	1,350	2,083	2,083
No. Priority Interrupts	8-40	8-40	16	16	16
1st Delivery	11/69 4/68	7/68	6/69	4/67	9/67
Standard Configuration Price CPU with 8Kb memory	8,500 14,500	--	8,400	15,700	23,800

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MINICOMPUTERS

Manufacturer	Interdata, Inc.			
Model Number	Interdata 1	Interdata 3	Interdata 4	Interdata 5
Word Length (Bits)	8	16	16	16
Cycle Time (microsec)	1.0	1.5	1.0	1.0
Memory Size Range (Kb)	2-16	4-65	4-65	8-65
No. Instructions	47	53	53	123
Add Time (microsec)	3	28	3.2	3.2
Fixed Point c=a+b (microsec)	- -	107	16.4	- -
Multiply Time (microsec)	- -	107*	24*	22.8
Available Software & Languages	Utility, Assembler	Utility, Assembler, Fortran, Operating Systems		
Type I/O Equipment Available	TTY, P Tape, Card, Printer, Mag Tape Disc, Drum, A/D, D/A, Communications	TTY, P Tape, Card Printer, Mag Tape, Disc, Drum A/D, D/A, Communications, Graphics		
Max. I/O Transfer Rate (Kb/sec)	500	750	900	500
No. Priority Interrupts	4-8	256	256	256
1st Delivery	11/70	5/67	8/68	8/70
Standard Configuration Price CPU with 8Kb memory	6,050	10,800	13,800	9,200

Manufacturer	Lockheed Electronics		Microdata Corp.
Model Number	MAC 16	MAC Jr	Micro 810
Word Length (Bits)	16		8
Cycle Time (microsec)	1.0		1.1
Memory Size Range (Kb)	8-131	8-16	1-32
No. Instructions	72		89
Add Time (microsec)	2		5.06
Fixed Point c=a+b (microsec)	6		15.18
Multiply Time (microsec)	437 (s) 10*		55.60
Available Software & Languages	Utilities, Assembler, Fortran Operating Systems		Utilities, Assembler
Type I/O Equipment Available	TTY, P Tape, Card, Printer, Mag Tape Drum, Communications		TTY, P Tape, Card, Disc, Communications
Max. I/O Transfer Rate (Kb/sec)	2,000		910
No. Priority Interrupts	4-64		8-64
1st Delivery	3/69	10/70	1/69
Standard Configuration Price CPU with 8Kb memory	11,100	7,900	19,400

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MINICOMPUTERS

Manufacturer	Monitor Data Corp.	Motorola, Inc.	Multidata, Inc.
Model Number	MD708	Motorola MDP-1000	Model A
Word Length (Bits)	8	8	16
Cycle Time (microsec)	1.6	2.16	0.8
Memory Size Range (Kb)	1-65	4-16	8-131
No. Instructions	101	56	163
Add Time (microsec)	1.6	4.32	4
Fixed Point c=a+b (microsec)	4.8	6.48	- -
Multiply Time (microsec)	- -	- -	195 (s), 10*
Available Software & Languages	Utilities Assembler	Utilities, Assembler, Monitor	Utilities, Assembler, Basic, Fortran
Type I/O Equipment Available	TTY, P Tape, Card, Mag Tape, Drum Communi-cations	Printer, Mag Tape, Drum, A/D, D/A, Communications	TTY, P Tape, Card, Printer, Mag Tape, Disc A/D, D/A, Graphics
Max. I/O Transfer Rate (Kb/sec)	625	46	2000
No. Priority Interrupts	1-8	1	0-384
1st Delivery	8/70	2/69	5/70
Standard Configuration Price CPU with 8Kb memory	5,200	9,000	

Manufacturer	Raytheon			Redcor Corp.
Model Number	703	704	706	RC70
Word Length (Bits)	16			16
Cycle Time (microsec)	1.75	1	0.9	1
Memory Size Range (Kb)	8-65			8.32
No. Instructions	74			74
Add Time (microsec)	3.5	2	1.8	2
Fixed Point c=a+b (microsec)	10.5	9.0	5.4	5.7
Multiply Time (microsec)	1225 to 17.5*	7*	6.3 to 9.0*	84 (s)*
Available Software & Languages	Utilities, Assemblers, Fortran, Real-Time Operating System			Utilities, Assembler Fortran, Operating System
Type I/O Equipment Available	TTY, P Tape, Card, Printer, Mag Tape, Disc, A/D, D/A, Graphics			TTY, P Tape, Card, Printer, Mag Tape, Disc, Graphics, A/D, D/A, Communications
Max. I/O Transfer Rate (Kb/sec)	1,142	2,000	2,222	2,200
No. Priority Interrupts	1-16			1-32
1st Delivery	10/67	4/70	3/69	3/69
Standard Configuration Price CPU with 8Kb memory	13,700	9,650	17,600	13,500

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MINICOMPUTERS

Manufacturer	Spiras Systems, Inc.	Systems Engineering Laboratories, Inc.	
Model Number	Spiras-65	SYSTEM 810A	810B
Word Length (Bits)	16	16	16
Cycle Time (microsec)	1.8	1.75	0.75
Memory Size Range (Kb)	4-131	8-65	8-65
No. Instructions	125	57	57
Add Time (microsec)	3.9	3.5	1.5
Fixed Point c=a+b (microsec)	16.2	10.5	1.5
Multiply Time (microsec)	22.0	7	4.5
Available Software & Languages	Utility, Assembler, Fortran	Utilities, Assembler, Fortran, Operating System	
Type I/O Equipment Available	TTY, P Tape, Card, Printer, Mag Tape Disc, Graphics, A/D, D/A, Communications	TTY, P Tape, Card, Printer, Mag Tape, Disc Drum, Graphics, A/D, D/A, Communications	
Max. I/O Transfer Rate (Kb/sec)		1,144	1,144
No. Priority Interrupts	1	96	96
1st Delivery	6/69	4/67	12/68
Standard Configuration Price CPU with 8Kb memory	9,800	16,700	- -

Manufacturer	Tempo Computers, Inc.	Unicom, Inc.	
Model Number	Tempo I	CP-8C	
Word Length (Bits)	16	8	
Cycle Time (microsec)	0.9	1.75	
Memory Size Range (Kb)	8-131	0.5-32	
No. Instructions	97	50	
Add Time (microsec)	1.8	3.5	
Fixed Point c=a+b (microsec)	5.4	10.5	
Multiply Time (microsec)	110 (s), 5.8*	300 (s)	
Available Software & Languages	Utilities, Assembler, Fortran	Utilities, Assembler	
Type I/O Equipment Available	TTY, P Tape, Card, Printer, Mag Tape, Disc, Drum, A/D, D/A, Communications	TTY, Printer, Graphics, Communications	
Max. I/O Transfer Rate (Kb/sec)	1400	143	
No. Priority Interrupts	4-16	4	
1st Delivery	9/69	4/70	
Standard Configuration Price CPU with 8Kb memory	14,700	7,400	

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MINICOMPUTERS

Manufacturer	Unicomp, Inc.		Varian
Model Number	COMP-16	COMP-18	520/i
Word Length (Bits)	16	18	8
Cycle Time (microsec)	0.9		1.5
Memory Size Range (Kb)	8-131	8-512	4-32
No. Instructions	31		Over 500
Add Time (microsec)	2.25	2.25	3
Fixed Point c=a+b (microsec)	--	--	19.5
Multiply Time (microsec)	290(s), 7.2*	340(s), 7.2*	190(s)
Available Software & Languages	Utilities, Assembler, Basic		Utilities, Assembler, Fortran
Type I/O Equipment Available	TTY, P Tape, Card, Printer, Mag Tape, Disc, Drum, (except Varian 520i), Graphics, A/D, D/A Communications		
Max. I/O Transfer Rate (Kb/sec)	2,200		660
No. Priority Interrupts	1-64		660
1st Delivery	7/70		9/68
Standard Configuration Price CPU with 8Kb memory	9,800	10,500	8,100

Manufacturer	Varian	Wang Laboratories, Inc.
Model Number	620/i	Wang 3300
Word Length (Bits)	16	8
Cycle Time (microsec)	1.8	1.6
Memory Size Range (Kb)	8-64	4-65
No. Instructions	107	72
Add Time (microsec)	5.4	6
Fixed Point c=a+b (microsec)	- -	18
Multiply Time (microsec)	- -	- -
Available Software & Languages	Utilities, Assembler, Fortran	Utilities, Assembler, Basic, Timesharing Operating System
Type I/O Equipment Available	TTY, P Tape, Card, Printer, Mag Tape, Disc, Drum, Graphics, A/D, D/A, Communications	TTY, P Tape, Disc, Graphics, Communi-cations
Max. I/O Transfer Rate (Kb/sec)	1160	300
No. Priority Interrupts	0-8	8
1st Delivery	6/67	9/70
Standard Configuration Price CPU with 8Kb memory	12,600	7,450

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MINICOMPUTERS

Manufacturer	Xerox Data Systems			
Model Number	CE16	CF16		
Word Length (Bits)	16			
Cycle Time (microsec)	3	2.67		
Memory Size Range (Kb)	8-32			
No. Instructions	126	126		
Add Time (microsec)	16	5.53		
Fixed Point c=a+b (microsec)	48	16.02		
Multiply Time (microsec)	126(s)			
Available Software & Languages	Utilities, Assembler			
Type I/O Equipment Available	TTY, P Tape, Card, A/D, D/A, Communications			
Max. I/O Transfer Rate (Kb/sec)				
No. Priority Interrupts				
1st Delivery	6/69	12/69		
Standard Configuration Price CPU with 8Kb memory	10,690*	8,700		

Notes:

* - With optional equipment
(s) - Using subroutine
Kb - Thousands of bytes
KW - Thousands of words

APPENDIX D. COMPANY PROFILES

IDENTITY	Atron 1256 Trapp Road St. Paul, Minnesota 55118		
TRADED	OTC		
BACKGROUND			
Principal Business	Manufacturer of minicomputers.		
Minicomputer Contribution	Dedicated to minicomputers.		
When Formed	November, 1968		
No. Employees (approx.)	190		
Minicomputer Experience	Company officers have technical backgrounds within the computer industry. First minicomputer delivered in 1969.		
ANNUAL SALES	$895,000		
MINICOMPUTER PRODUCTS			
Scope	2 models—501 is the basis for the Atron Terminal Family.		
Products, Approx. Price, First Delivery	501	$6,000	Sept., 1969
	601	$2,000	Apr., 1970
MARKETING			
Total Installed Units	115		
Approach	Emphasizes industrial control, peripheral control, and remote batch terminal systems for business computations. Concentrates on OEM sales (85% OEM, 15% end user). Maintains own sales staff (25 sales/support people).		
SPECIAL CONSIDERATIONS	Principally owned by Mohawk Data Sciences Corporation which has purchased 85-90 percent of its production.		

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MINICOMPUTERS

IDENTITY	Bit Inc. 5 Strathmore Road Natick, Mass. 01760		
TRADED	Privately held		
BACKGROUND			
Principal Business	Manufacturer of minicomputers		
Minicomputer Contribution	Dedicated to minicomputers		
When Formed	1964		
No. Employees (approx.)	14		
Minicomputer Experience	First minicomputer delivered in 1965		
ANNUAL SALES	$250,000		
MINICOMPUTER PRODUCTS			
Scope	2 models		
Products, Approx.	480,	$8,000	late 1965
Price, First Delivery	483,	$7,660	Jan., 1970
MARKETING			
Total Installed Units	165		
Approach	Emphasizes numerical control, process control, and data acquisition systems. Concentrates on OEM sales. (90% OEM, 10% end user). Marketing staff reorganized due to financial difficulties.		
SPECIAL CONSIDERATIONS	Have filed for bankruptcy under Chapter XI.		

IDENTITY	Computer Automation 895 West 16th Street Newport Beach, Calif. 92660
TRADED	Privately Held
BACKGROUND	
Principal Business	Manufacturer of Minicomputers
Minicomputer Contribution	Dedicated to Minicomputers
When Formed	1967
No. Employees (approx.)	60
Minicomputer Experience	Company officers have technical background within computer industry. First minicomputer delivered — 1968.
ANNUAL SALES	Not available
MINICOMPUTER PRODUCTS	
Scope	Several minicomputers

Products, Approx.	Price, First Delivery	
208	$5,990	July, 1969
216	7,990	Aug., 1969
808	4,990	June, 1968
816	9,980	Mar., 1969
108	3,000—3,500	—
116	3,450—5,400	—

MARKETING	
Total Installed Units	400
Approach	Concentrates on OEM sales (95% OEM, 5% End User) to Fortune 500. Plan to continue OEM orientation. Maintains own sales force (1 field manager and 6 salesmen). Uses CDC for maintenance.
SPECIAL CONSIDERATIONS	

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MINICOMPUTERS

IDENTITY	Data General Corporation Southboro, Mass. 01772
TRADED	OTC
BACKGROUND	
Principal Business	Manufacturer of Minicomputers
Minicomputer Contribution	Dedicated to minicomputers.
When Formed	1968
No. Employees (approx.)	300
Minicomputer Experience	Company officers have a technical background within the computer industry. First mincomputer delivered in 1969.
ANNUAL SALES	$7,035,000 (for the year ended Sept. 26, 1970)
MINICOMPUTER PRODUCTS	
Scope	Several minicomputer models

Products, Approx. Price, First Delivery		
Nova	$7,950	2/69
Supernova	9,600	4/70
Supernova SC	11,900	6/71
Nova 1200	5,450	2/71
Nova 800	6,950	4/71

MARKETING	
Total Installed Units	850
Approach	Emphasize industrial control, instrumentation, communications and computation systems. Concentrate on OEM sales (65% OEM, 35% end user). Maintains a sales force of 30 sales/support people.
SPECIAL CONSIDERATIONS	First to announce a completely semiconductor minicomputer main memory.

IDENTITY	Digital Equipment Corporation 146 Main Street Maynard, Mass. 01754
TRADED	NYSE
BACKGROUND	
Principal Business	Manufacturer of digital computers, electronic modules, and computer peripheral devices.
Minicomputer Contribution	Approximately 65% of company sales are represented by minicomputers
When Formed	1957
No. Employees (approx.)	5800
Minicomputer Experience	Manufactures the broadest line of minicomputer products. First computer delivery in 1960.
ANNUAL SALES	$135,408,000 (Year ending June 27, 1970)
MINICOMPUTER PRODUCTS	
Scope	Three families totaling 7 models.
Products, Approx. / Price, First Delivery	PDP-8, $4,990—$13,450, 1965 PDP-11, 10,800 1970 PDP-15 16,500 1970
MARKETING	
Total Installed Units	Over 10,000
Approach	Emphasizes industrial control, laboratory, communications, and computation systems. Sales are divided equally between OEM and end users. Maintain worldwide staff of 400 salesmen, 800 servicemen, and 200 support people.
SPECIAL CONSIDERATIONS	Possesses approximately 50% of the installed minicomputers. Expanding into larger general purpose computers with associated software and services and into the manufacture of peripherals.

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MINICOMPUTERS

IDENTITY	Digital Scientific Corporation 11455 Sorrento Valley Road San Diego, California 92121
TRADED	Privately held
BACKGROUND	
Principal Business	Manufacturer of small computers, controllers, special systems.
Minicomputer Contribution	Small computer is the primary product.
When Formed	June 1967
No. Employees (approx.)	202
Minicomputer Experience	Company officers have technical and marketing background within the computer industry. First computer system was delivered in April 1970.
ANNUAL SALES	NA
MINICOMPUTER PRODUCTS	
Scope	One model.
Products, Approximate Price, First Delivery	META™ $70,000/System April 1970
MARKETING	
Total Installed Units	32
Approach	Marketing in all application areas, but with planned concentration in emulators, high-speed controllers, and communications. Sales are divided between OEM and end users. Marketing force consists of 15 salesmen and 4 support engineers.
SPECIAL CONSIDERATIONS	The META 4 computer is microprogrammed using read-only memory (ROM) as the control memory.

IDENTITY	FOTO-MEM 6 Strathmore Road Natick, Mass. 01760
TRADED	OTC
BACKGROUND	
Principal Business	Manufacturer of photo-optical random access memory systems for information storage and retrieval (IS&R).
Minicomputer Contribution	Approximately 20% of company sales represented by minicomputers.
When Formed	May, 1967
No. Employees (approx.)	67
Minicomputer Experience	First minicomputer delivered August, 1969
ANNUAL SALES	$72,000 (during first half of 1970)
MINICOMPUTER PRODUCTS	
Scope	1 model
Products, Approx. Price, First Delivery	Centaur, $7,500 Aug., 1969
MARKETING	
Total Installed Units	10
Approach	Concentrating on special IS&R system which uses minicomputer as a controller. Concentrates on end user sales. (10% OEM, 90% end user)
SPECIAL CONSIDERATIONS	

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IDENTITY	Four Phase Systems Inc. 10420 North Tantau Ave. Cupertino, Calif. 95014
TRADED	Privately held
BACKGROUND	
Principal Business	Manufacturer of a display processing system
Minicomputer Contribution	Minicomputer manufactured as part of basic display systems
When Formed	Incorporated 1969
No. Employees (approx.)	150
Minicomputer Experience	Staff has prior experience in solid state computer design and MOS/LSI production
ANNUAL SALES	Not available
MINICOMPUTER PRODUCTS	
Scope	Single machine
Products, Approx. Price, First Delivery	System IV/70, not available, Feb., 1971
MARKETING	
Total Installed Units	5
Approach	Marketing directed at CRT expansion and replacement, and small business data processing. Maintains own sales force (10 salesmen). Nationwide maintenance by Honeywell
SPECIAL CONSIDERATIONS	

IDENTITY	General Automation Inc. 1402 East Chestnut Ave. Santa Ana, Calif. 92701		
TRADED	OTC		
BACKGROUND			
Principal Business	Manufacturer of computer-based systems for industrial control		
Minicomputer Contribution	Minicomputers is primary product line.		
When Formed	May, 1967		
No. Employees (approx.)	400		
Minicomputer Experience	Company officers have technical and marketing background in computer industry. First minicomputer delivered in 1969		
ANNUAL SALES	$7,454,230 July, 1970		
MINICOMPUTER PRODUCTS			
Scope	Three models		
Products, Approx.	SPC-12	$3,900	Feb., 1969
Price, First Delivery	SPC-16	$9,200	Apr., 1970
	GA-18/30,	18,000	July, 1969
MARKETING			
Total Installed Units	800		
Approach	Have penetrated all application areas. Marketing directed primarily at industrial control and manufacturing automation. Sales volume divided equally between OEM and end user. Maintains own marketing staff with 25 salesmen.		
SPECIAL CONSIDERATIONS			

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MINICOMPUTERS

IDENTITY	GRI Computer Corp. 320 Needham Newton, Mass. 02164
TRADED	OTC
BACKGROUND	
Principal Business	Manufacturer of minicomputers.
Minicomputer Contribution	Dedicated to minicomputers.
When Formed	October 1967
No. Employees (approx.)	50
Minicomputer Experience	Company officers have technical background within the computer industry. First minicomputer delivered Jan. 1970
ANNUAL SALES	$500,000
MINICOMPUTER PRODUCTS	
Scope	4 models
Products, Approx. Price, First Delivery	909 (Series), $3,500-$7,800, Jan., 1970
MARKETING	
Total Installed Units	60
Approach	Marketing in all application areas without planned emphasis. Concentrates on OEM sales (OEM 95%, 5% end user) using dedicated computers as system controllers. Markets through 60 sales representatives.
SPECIAL CONSIDERATIONS	

IDENTITY	Hetra, Inc. P. O. Box 970 Melbourne, Florida 32901
TRADED	OTC
BACKGROUND	
Principal Business	Manufacturer of minicomputer based systems.
Minicomputer Contribution	Dedicated to minicomputers.
When Formed	October, 1968
No. Employees (approx.)	20
Minicomputer Experience	Company officers have technical and marketing background in computer industry. First minicomputer delivered in Sept., 1970.
ANNUAL SALES	Negligible
MINICOMPUTER PRODUCTS	
Scope	S&T series each consist of 3 models in a variety of configurations.
Products, Approx. Price, First Delivery	Universal Terminal, $30,000, Sept., 1970. Data Entry, $150,000, Jan., 1971
MARKETING	
Total Installed Units	6
Approach	Major emphasis in data communications and business data processing. Concentrates exclusively on end users. Marketing U. S., with 3 salesmen and 3 sales representatives.
SPECIAL CONSIDERATIONS	

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MINICOMPUTERS

IDENTITY	Hewlett Packard Cupertino Division 11,000 Wolfe Road Cupertino, Calif. 95014
TRADED	NYSE
BACKGROUND	
Principal Business	Manufacturer of diversified electronic and instrumentation products.
Minicomputer Contribution	Less than 10 percent of total sales is represented by minicomputers.
When Formed	1947
No. Employees (approx.)	600
Minicomputer Experience	First minicomputer delivered 1967
ANNUAL SALES	$347,949,000., 1970
MINICOMPUTER PRODUCTS	
Scope	Several models
Products, Approx. Price, First Delivery	2116 B $ 14,000 Sept., 1967 2116 C $ 14,000 Dec., 1970 2114 B $ 8,500 Nov., 1969
MARKETING	
Total Installed Units	2,000
Approach	Major emphasis on time sharing and instrumentation related processes. Sales equally divided between OEM and end user. Approximately half of OEM sales are in-house. Plans to concentrate on end user market. Maintains own sales force (50-60 salesmen)
SPECIAL CONSIDERATIONS	Emphasized sales in data acquisition, process control and other applications which can utilize its extensive instrumentation experience as world's largest manufacturer of electronic measuring instruments.

IDENTITY	Honeywell Information Systems, Inc. Computer Control Division Old Connecticut Park Framingham, Mass. 01701
TRADED	NYSE
BACKGROUND	
Principal Business	Manufacturer of full line of digital computers and automatic control equipment.
Minicomputer Contribution	Small
When Formed	1927
No. Employees (approx.)	50,000
Minicomputer Experience	One of the largest computer manufacturers. One of the first companies to manufacture a minicomputer.
ANNUAL SALES	$1,921,000
MINICOMPUTER PRODUCTS	
Scope	Several models
Products, Approx. Price, First Delivery	H112 $5,000 Nov., 1969 H316 $8,400 July, 1969 H516, 416 $23,000 June, 1965
MARKETING	
Total Installed Units	1,800 (minicomputers)
Approach	Major emphasis in data communications, industrial control and time sharing. Worldwide marketing sales force exceeding 6,000.
SPECIAL CONSIDERATIONS	Entered minicomputer field via acquisition of Computer Control Corporation in 1966.

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MINICOMPUTERS

IDENTITY	Interdata 2 Cresent Place Oceanport, New Jersey 07757
TRADED	OTC
BACKGROUND	
Principal Business	Manufacturer of minicomputers
Minicomputer Contribution	Dedicated to minicomputers
When Formed	1966
No. Employees (approx.)	300
Minicomputer Experience	Company officers have technical and marketing backgrounds within the computer industry. First minicomputer delivered in 1967
ANNUAL SALES	$6,458,400

MINICOMPUTER PRODUCTS

Scope

Products, Approx. Price, First Delivery			
	Model 1	$3,750	1970
	Model 4	$8,500	1967 - 1968
	Model 5	$10,500	1970
	14/15	$25,000	1969

MARKETING	
Total Installed Units	550
Approach	Emphasizes communications, industrial control and test applications. Concentrates on OEM (60% OEM, 40% end user). Maintains own domestic sales and support personnel with offices in England and Germany. Utilizes sales representatives in Japan, Canada and Scandinavia. Scandinavia.
SPECIAL CONSIDERATIONS	First to develop and apply firmware technology in minicomputers.

IDENTITY	IBM Armonk, New York 10504
TRADED	NYSE
BACKGROUND	
Principal Business	Manufacturer of full line of data processing equipment and office machines
Minicomputer Contribution	Small
When Formed	1911
No. Employees (approx.)	240,000
Minicomputer Experience	Largest manufacturer of computers
ANNUAL SALES	$7.5 billion
MINICOMPUTER PRODUCTS	
Scope	One model
Products, Approx. Price, First Delivery	System/7, $18,000 Nov. 1971
MARKETING	
Total Installed Units	0
Approach	System/7 directed at industrial control and data acquisition applications, and as a remote processor in distributed computer systems. Maintains largest marketing staff in the industry.
SPECIAL CONSIDERATIONS	System/7 represents IBM's first entry into the conventional minicomputer market. System/7 initially introduced with limited peripheral and software support.

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MINICOMPUTERS

IDENTITY	Lockheed Electronics, Data Product Division 6201 E. Randolph Street Los Angeles, Calif. 90022
TRADED	NYSE
BACKGROUND	
Principal Business	Manufacturer of circuit boards, memory systems, computers
Minicomputer Contribution	Small
When Formed	1932
No. Employees (approx.)	1,000 at Data Products Division.
Minicomputer Experience	First minicomputer delivered 1969
ANNUAL SALES	$1,745,000,000 - 9 mo. to Sept., 1970
MINICOMPUTER PRODUCTS	
Scope	2 models
Products, Approx.	MAC 16, $11,200 Mar., 1969
Price, First Delivery	MAC JR. 7,900 Oct., 1970
MARKETING	
Total Installed Units	270
Approach	Emphasizes industrial process control. Concentrates on OEM sales (85% OEM, 15% end user). Maintains own sales force (3 administrative, 12 salesmen, 11 servicemen, and 10 support people).
SPECIAL CONSIDERATIONS	

IDENTITY	Microdata Corp. 644 E. Young Street Santa Ana, Calif. 92705
TRADED	Privately held
BACKGROUND	
Principal Business	Manufacturer of Minicomputers
Minicomputer Contribution	Dedicated to minicomputers.
When Formed	July, 1967
No. Employees (approx.)	85
Minicomputer Experience	Company officers have technical background in electronics industry. First minicomputer delivered in 1969
ANNUAL SALES	Not available
MINICOMPUTER PRODUCTS	
Scope	5 models

Products, Approx.	Price, First Delivery	
400	$2700	Jan. 1971
800	2550	Jan. 1969
810	4650	June, 1969
812	7850	Nov., 1969
820	4525	Oct., 1970

MARKETING	
Total Installed Units	336
Approach	Emphasizes data acquisition, instrumentation, and communication systems. Concentrates on OEM sales (95% OEM, 5% end user). Maintains own sales force (4 salesmen).
SPECIAL CONSIDERATIONS	Purchased Monitor Data in 1970.

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MINICOMPUTERS

IDENTITY	Qantel Corp. 3474 Investment Blvd. Hayward, Calif. 94545
TRADED	Privately held
BACKGROUND	
Principal Business	Manufacturer of minicomputer systems
Minicomputer Contribution	Dedicated to minicomputers
When Formed	January, 1969
No. Employees (approx.)	75
Minicomputer Experience	First minicomputer delivered March, 1970.
ANNUAL SALES	Not available
MINICOMPUTER PRODUCTS	
Scope	1 model
Products, Approx. Price, First Delivery	Qantel V, $14,550 March, 1970
MARKETING	
Total Installed Units	40
Approach	Concentrating on business data processing application. Marketing exclusively to end users. Marketing through own sales force (10 salesmen) on west coast and through representatives in other areas of the United States.
SPECIAL CONSIDERATIONS	

IDENTITY	Rolm Corp. 10300 N. Tantau Ave. Cupertino, Calif.
TRADED	Privately held
BACKGROUND	
Principal Business	Manufacturer of minicomputers for severe environmental applications.
Minicomputer Contribution	Dedicated to minicomputers
When Formed	February, 1969
No. Employees (approx.)	35
Minicomputer Experience	Company officers have extensive backgrounds in the electronics industry. First minicomputer delivered in 1970.
ANNUAL SALES	$300,000
MINICOMPUTER PRODUCTS	
Scope	1 model
Products, Approx. Price, First Delivery	1601 $20,000 March, 1970
MARKETING	
Total Installed Units	22
Approach	Emphasizes industrial process control, communications, and data acquisition systems. Concentrates on OEM sales (90% OEM, 10% end users). Maintains own sales force (5 engineer/salesmen).
SPECIAL CONSIDERATIONS	The 1601 is basically a Nova minicomputer purchased from Data General.

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MINICOMPUTERS

IDENTITY	Spiras Systems, Inc. 332 Second Avenue Waltham, Mass. 20154
TRADED	Privately held (Affiliate of USM Corporation)
BACKGROUND	
Principal Business	Manufacturer of digital computing systems and related products
Minicomputer Contribution	Approximately 75% of company sales represented by minicomputers
When Formed	August, 1967
No. Employees (approx.)	70
Minicomputer Experience	First minicomputer delivered June 1969.
ANNUAL SALES	$1,000,000
MINICOMPUTER PRODUCTS	
Scope	1 model
Products, Approx.	SP65, $9,800 June, 1969
Price, First Delivery	
MARKETING	
Total Installed Units	20
Approach	Concentrating on direct numerical control, data acquisition and factory data retrieval systems. Concentrates exclusively on end user sales. Maintains 3 sales engineers.
SPECIAL CONSIDERATIONS	

IDENTITY	Systems Engineering Laboratories Inc. 6901 W. Sunrise Blvd. Ft. Lauderdale, Fla. 33313		
TRADED	ASE		
BACKGROUND			
Principal Business	Manufacturer of computers, peripherals, a broad line of digital computers, and related products.		
Minicomputer Contribution	Approx. 50% of company sales are represented by minicomputers.		
When Formed	January, 1961		
No. Employees (approx.)	1,000		
Minicomputer Experience	First minicomputer delivered in 1965		
ANNUAL SALES	$21,153,000	June, 1970	
MINICOMPUTER PRODUCTS			
Scope	Several models		
Products, Approx.	System 810 B	$31,000	Dec., 1968
Price, First Delivery	System 72	19,000	Oct., 1970
	System 82	11,000	—
	System 810 A	23,000	Aug., 1965
MARKETING			
Total Installed Units	450		
Approach	Emphasizes data acquisition, industrial control, communications, and peripheral control systems. Concentrates on end user sales (25% OEM, 75% end user). Maintains own sales force (35 sales engineers).		
SPECIAL CONSIDERATIONS			

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MINICOMPUTERS

IDENTITY	Tempo Computers Inc. 4005 W. Artesia Fullerton, Calif. 92663
TRADED	Privately held (purchased by General Telephone and Electronics)
BACKGROUND	
Principal Business	Manufacturer of minicomputers
Minicomputer Contribution	Dedicated to minicomputer
When Formed	December, 1968
No. Employees (approx.)	90
Minicomputer Experience	Company officers have technical and marketing backgrounds in the computer industry. First minicomputer delivered in 1969.
ANNUAL SALES	$1,000,000
MINICOMPUTER PRODUCTS	
Scope	1 model in several configurations
Products, Approx. Price, First Delivery	TEMPO I, $13,800 - $500,000 Sept., 1969
MARKETING	
Total Installed Units	24
Approach	Concentrating on data communications and special minicomputer based systems. Concentrating exclusively on end users but expect some OEM sales in future. Maintains 15 salesmen.
SPECIAL CONSIDERATIONS	

IDENTITY	Texas Instruments P. O. Box 5474 Dallas, Texas 75222		
TRADED	NYSE		
BACKGROUND			
Principal Business	Manufacturer of semiconductors and related products.		
Minicomputer Contribution	Small		
When Formed	1938		
No. Employees (approx.)	59,000		
Minicomputer Experience	First minicomputer delivered May, 1970		
ANNUAL SALES	$632,448,000 - 9 mos. - to Sept., 1970		
MINICOMPUTER PRODUCTS			
Scope	Two models		
Products, Approx.	960,	$14,500,	May, 1970
Price, First Delivery	980,	$16,700	Aug., 1970
MARKETING			
Total Installed Units	Approximately 10		
Approach	Not specified		
SPECIAL CONSIDERATIONS	Extensive semiconductor knowledge and production capacity provides important technological capability in minicomputer industry.		

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MINICOMPUTERS

IDENTITY	UniComp Inc. 18219 Parthenia Street Northridge, Calif. 91324		
TRADED	Privately held		
BACKGROUND			
Principal Business	Manufacturer of minicomputers		
Minicomputer Contribution	Dedicated to minicomputer systems		
When Formed	August, 1969		
No. Employees (approx.)	20		
Minicomputer Experience	First minicomputer delivered in June, 1970		
ANNUAL SALES	$750,000		
MINICOMPUTER PRODUCTS			
Scope	2 models		
Products, Approx.	16-001	$18,000	June, 1970
Price, First Delivery	18-001	17,000	June, 1970
MARKETING			
Total Installed Units	15		
Approach	Emphasizes laboratory systems, data communications, and peripheral control. Concentrates exclusively on end users, although future marketing strategy includes OEM. Markets nationwide using sales representatives.		
SPECIAL CONSIDERATIONS			

IDENTITY	Varian Associates 611 Hansen Way Palo Alto, Calif. 94303		
TRADED	NYSE		
BACKGROUND			
Principal Business	Manufacturer of electron tubes, instruments, electronic equipment, minicomputers.		
Minicomputer Contribution	Approximately 10% of total sales		
When Formed	1948		
No. Employees (approx.)	Approx. 10,000; 600 employed by Varian Data Machines		
Minicomputer Experience	First minicomputer installed in 1964		
ANNUAL SALES	$195,960,000 - Sept., 1970		
MINICOMPUTER PRODUCTS			
Scope	Several models		
Products, Approx. Price, First Delivery	520/i	$7,500	Aug., 1968
	620/i	11,000	June, 1967
	620/f	10,500	Nov., 1970
	620/l	5,400	June, 1971
MARKETING			
Total Installed Units	1800		
Approach	Emphasis in data communications, peripheral control, instrumentation and data acquisition. Concentrates on OEM sales (90% OEM, 10% end user). Markets domestically through own sales force, internationally through representatives. Approximately 30 salesmen.		
SPECIAL CONSIDERATIONS			

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MINICOMPUTERS

IDENTITY	Westinghouse Electric Corp. 200 Beta Drive Pittsburgh, Pennsylvania 15238		
TRADED	NYSE		
BACKGROUND			
Principal Business	Manufacturer of diversified electrical products.		
Minicomputer Contribution	Small		
When Formed	1892		
No. Employees (approx.)	142,000		
Minicomputer Experience	Manufactures a variety of computer products. First minicomputer delivered 1965.		
ANNUAL SALES	9 mo. - to Sept. 30, 1970		$3,509,153,214
MINICOMPUTER PRODUCTS			
Scope	3 models		
Products, Approx.	P-50	$16,000	Mar., 1965
Price, First Delivery	P-2000	10,000	July, 1969
	P-2500	9,950	Feb., 1971
MARKETING			
Total Installed Units	413		
Approach	All applications are in the industrial control area. Concentrates on end user sales (10% OEM, 95% end user). Maintains 100 salesmen within the division, supplemented by 2000 salesmen in other divisions.		
SPECIAL CONSIDERATIONS			

APPENDIX E. USER EXPERIENCE

This appendix summarizes the experience of five minicomputers users. One user was selected in each of the five major application areas. Two of the users are OEM's while the remainder are end users. Each summary is structured so as to provide a brief outline of the company, a general description of the application, the function of the minicomputer in this application, and the method by which the minicomputer was selected.

Application Area — *Industrial Control*

Company A is an OEM that buys minicomputers outside and sells a complete process control system to end users, often on a "turnkey" basis. Company A has 130 people, was founded three years ago, and was established initially to sell to one specific segment of the process industries, branching to broader markets at a later time.

This firm uses the minicomputer as the main processor in its process control system. Together with special interface gear, process instrumentation (which it makes mostly itself), and computer peripheral equipment including terminals and displays, this firm provides software, custom design, and installation as a total package. The resulting system, while modular in design, is structured to meet the needs unique to a specific end user. The minicomputer obtains signals from several hundred process sensors, applies them to a computer-stored mathematical analog of the process, and outputs corrective signals to process controllers. Certain data is logged and displayed for purposes of monitoring by the process operators, for further refinement of the process and its associated control systems, and as the basis for production reporting. A clear-cut need for flexibility at modest cost makes alternatives other than a minicomputer unrealistic for this firm.

Approximately 10 man-years to date have been invested by this company in software development. In selecting a minicomputer manufacturer, the six largest vendors were initially considered but a final choice was made on the basis of reliability, quality, manufacturer reputation, software support, and service.

Company A also uses minicomputers in-house for engineering analysis, production control, gauge inspection, and components checkout.

Application Area — *Peripheral Control*

Company B manufactures computer disc storage drives, displays, and specialized computer systems.

The company is an OEM which buys minicomputers primarily as controllers for the peripheral equipment it manufactures. Systems are sold to end users and other OEM's are highly variable but are likely to include some form of data input/output, storage, interface, and communications devices. The minicomputer is often connected to a larger main com-

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puter at the customer's site. The mini allows easy access to the main computer, provides block data transfers, editing, etc., and takes some load off the main computer. Only modest systems-oriented software is generally supplied by the company.

Company B has ruled out the use of the large computer as an alternative to using a mini, because large computers (such as a System/360) do not have the proper software to drive its display system. From an economic standpoint, the reduced overhead on the main computer more than recovers the price of the mini. Hard-wired equipment was tried in a testing environment but the lack of flexibility made it unacceptable.

Formal analysis was used for minicomputer selection. The analysis considered hardware specifications, price/performance, and pricing policies as the most important criteria, followed by reliability, service, and field maintenance capability.

The company also uses minicomputers in-house for some of its manufacturing applications, including check-out of disc units and complete systems.

Application Area — *Communications*

Company C is one of the larger commercial time sharing firms in the United States. Its nationwide time sharing systems provide computational capability for many users in a variety of scientific and business applications. As an end user, the company has purchased approximately 60 minicomputers within the past 3 years for use in its timesharing network. These minis are used in a communications application and perform several functions including error detection/retransmission, editing, formatting, and adjusting for code and speed differences between the remote terminals, communications lines, and the central timesharing computers.

According to the company, no acceptable alternatives of minicomputers exist. Without minis, the central computers would be overburdened leading to a drop in the number of users served and a corresponding drop in revenue. Flexibility would be severely reduced, affecting the types and number of terminals available, transmission speeds, accuracy of data transmission, and line costs. The company prefers to do its own software development and has a large, highly qualified staff for this purpose. Several man-years have already been invested in a continuing software development program.

Its original list of minicomputer manufactures included 5 of the largest firms. Final selection criteria placed greatest emphasis upon cost, reliability, equipment architecture, word length, and delivery. The company performs a 30 day "burn-in" on each new mini to establish reliability, and has trained personnel who do circuit design and fabrication in-house to produce custom-made interfaces and engineering changes to its minicomputer communications systems.

Application Area — *Computation*

Gavilan College is a small liberal arts college that installed a minicomputer approximately two years ago for education purposes only. It is a leased computer system including a mark sense card reader, an ASR 33 teletype, and a minicomputer central processor with 12,000 words of memory plus necessary interfaces. Purchase price of this system is approximately $23,000.

This system is used 6 or 7 hours per day for student instruction. It assembles and executes student-written programs of a diverse nature. All software was supplied by the manufacturer so essentially 100 percent of Gavilan's total system cost was in the equipment

leased from the manufacturer. When demand becomes substantially greater on this computational system, Gavilan will consider a commercial timesharing service, but this will be substantially more expensive at the present time, as would a "big computer."

In selecting a minicomputer manufacturer, several of the larger firms were considered; manufacturer reputation and financial stability were the significant factors. Price/performance, reliability, freedom from being locked-in to future equipment purchases, software support, sales support, and geographical location were the most important selection criteria. Another important fact that influenced their decision was that the selected manufacturer has a group devoted specifically to the educational field and convincingly presented itself as willing and able to give strong support to their customers in this area.

Their experience has influenced at least one other similar institution, De Anza College, Cupertino, California, to install a comparable system for the same purposes.

Application Area — *Data Acquisition*

The Stanford Linear Accelerator Center (SLAC) is a joint venture by Stanford University and the Atomic Energy Commission of the United States Government. Its principal function is to operate a 2-mile long atomic particle accelerator for a variety of research experiments in the field of atomic physics. It has a permanent staff of 1000 people. SLAC's main computer center is very large and includes a large scale System/360 and 8 medium-sized computers via used to process great volumes of data highly complex computations.

Of the several minicomputers used at the site, 4 are involved in on-line data acquisition. Configured and adapted to successive experiments, these systems gather and store data at high speeds and in substantial quantity for later processing at the main computer center. Individual experiments are generally of short duration (a few days to a few weeks) and require a maximum of one man-month per experiment for programming a problem unique to the particular experiment. SLAC has a large, well qualified in-house staff for software development.

Time sharing is unsatisfactory for SLAC at this time due to the far greater expense involved. Hardwiring would eliminate the flexibility required to adapt the data acquisition system to each successive experiment.

In selecting a minicomputer, SLAC considered only those major companies that had an established reputation (of at least 2 years). SLAC established its own system specification and then compared each vendor's product. The most important selection criteria were hardware specifications, price/performance, reliability, quality, and documentation.

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APPENDIX F. GLOSSARY

Accumulator — A register that holds one operand, with means for performing various arithmetic and/or logical operations involving that operand and (where appropriate) another operand; usually, the result of the operation, is formed in the accumulator, replacing the original operand. Note: Among computers currently in use, some have a single accumulator, others have multiple accumulators, and still others (especially those that use two-address or three-address instructions) have no accumulator as such; in the latter case, the results of arithmetic and logical results are usually formed in programmer-specified locations in the computer's main storage or in a general register.

Access Time — (1) The time interval between the instant at which data are requested from a storage device and the instant delivery is completed, i.e., the read time. (2) The time interval between the instant at which a request to store data is made and the instant at which storage is completed, i.e., the write time.

Arithmetic Unit — A computing system unit that contains the circuits to perform arithmetic operations.

Assembler — A computer program that assembles programs written in symbolic coding to produce machine language programs. Note: Assemblers are an important part of the basic software for most computers; their use can greatly reduce the human effort required to prepare and debug computer programs by enabling the coder to use a symbolic language that is simpler and more meaningful than the computer's machine language.

Batch Processing — A technique in which similar items to be processed are collected into groups (i.e., "batched") to permit convenient and efficient processing.

Bit — A binary digit; a digit (0 or 1) in the representation of a number in binary notation.

Byte — A group of adjacent bits operated upon as a unit and usually shorter than a word. Note: In a number of important current computer systems, the term "byte" has been assigned the more specific meaning of a group of eight adjacent bits, which can represent an alphanumeric character or two decimal digits.

Cassette Tape — A form of inexpensive magnetic tape storage in which the tape is housed in a removable plastic cassette.

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Central Processor — The unit of a computer system that includes the circuits to control the interpretation and execution of instructions. Synonymous with CPU (central processing unit) and main frame.

Command Chaining — A feature of the input/output control section of some computers to allow the execution of a sequence of input/output commands initiated by a single input/output instruction.

Compiler — A computer program that prepares a machine language program (or a program expressed in symbolic coding) from a program written in another programming language such as COBOL or FORTRAN. The compilation process usually involves examining and making use of the overall logic structure of the program, or generating more than one machine program instruction for each symbolic program statement, or both, as well as performing the function of an assembler.

Control Unit — (1) A section of a computer that effects the retrieval of instructions in the proper sequence, interprets each instruction, and stimulates the proper circuits to execute each instruction. (2) A device that controls the operation of one or more units of peripheral equipment under the overall direction of the central processor.

Cycle — (1) An interval of space or time required to complete one set of events or phenomena. (2) Any set of operations repeated regularly in the same sequence. The operations can be subject to variations on each repetition.

Cycle Time — The minimum time interval between the starts of successive accesses to a storage location. Contrast with access time. For example, if it takes 2 microseconds to read a word out of a core storage unit and 3 more microseconds to rewrite the word before another read operation can be initiated, then the unit has a read access time of 2 microseconds and a cycle time of 2 + 3 = 5 microseconds.

Data Break — A type of input/output control to permit the execution of autonomous block transfers, uses dedicated main memory locations as control registers for the transfer.

Decimal Arithmetic Features — The provision of computer instructions to operate directly upon decimal, rather than binary numbers.

Direct Memory Access — A type of input/output control permitting the execution of autonomous block transfers where registers used to control the transfer are special hardware registers within the controller. The only access required to main memory is for the actual transfer of data.

Firmware — Software that is stored in a fixed (wired-in) or "firm" way, usually in a read-only memory.

Flip-Flop — A circuit or device containing active elements that can assume either one of two stable states at a given time.

Floating-Point — Pertaining to a number system that represents each number by two numerals (i.e., two sets of digits), one represents the significant digits and the other (the exponent) indicates the position of the radix point. The number represented is equal to the fixed-point part multiplied by the radix raised to the power of the exponent. Algebraically, the relationship is: x = a(rb) where x is the number represented, a is the fraction, b is the exponent, and r is the radix (a positive integer not represented explicitly). Contrast with fixed-point. Note: Floating-point allows the representation of a wide range of numbers to a given precision using a limited number of digits. It is frequently used in scientific applications. Floating-point arithmetic operations can be implemented by means of either standard instructions, optional hardware facilities, or subroutines.

Gate — A device having one output channel and one or more input channels, such that the output channel state is completely determined by the input channel states, except during switiching transients.

Index Register — A register whose contents can be added to or subtracted from an address prior to or during the execution of an instruction. Note: Indexing (i.e., the use of index register) is the most ocmmon form of address modification used in stored-program computers. Indexing can greatly simplify programming by facilitating the handling of loops, arrays, and other repetitive processes. Some computers have many index registers, some have only one, and others have none.

Instruction — A statement that specifies an operation to be performed and the values or locations of one or more of its operands. Note: In this context, the term instruction is preferable to the terms command and order, which are sometimes used synonymously.

Instruction Set — The set of all the different instructions that can be executed by a particular computer.

Interrupt — To stop a process in such a way that it can be resumed.

Main Frame — Same as central processor. That portion of a computer system not considered peripheral equipment.

Memory — A device into which the data can be inserted and retained, and from which the data can be obtained at a later time.

Memory hierarchy — A set of memories with differing sizes and speeds and usually having different cost-performance ratios. A hierarchy might consist of a very-high-speed, small semiconductor memory, a medium speed core memory, and a large slow-speed core memory.

Microinstructions — The instructions which are used to define the basic actions of a microprogrammed computer.

Microprogramming — A method of operating the computer control unit by initiating the execution of a sequence of "microinstructions" at an elementary level. The Microinstructions

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are usually stored in a special read-only storage unit. Note: The instruction repetoire of a microprogrammed computer can be altered to suit particular requirements by simply changing the stored microinstructions.

Monolithic IC — An electrical circuit fabricated as an inseparable assembly of circuit elements in a single structure and cannot be divided without permanently destroying its intended electronic function.

Multiprogramming — A technique for handling two or more independent programs simultaneously by overlapping or inter-leaving their execution. The overlapping or interleaving is usually controlled by an operating system that attempts to optimize the overall performance of the computer system in accordance with the priority requirements of the various jobs.

Operating System — An organized collection of routines and procedures for operating a computer. These routines and procedures normally perform some or all of the following functions: (1) Scheduling, loading, initiating, and supervising the execution of programs. (2) Allocating storage, input-output units, and other facilities of the computer system. (3) Initiating and controlling input-output operations. (4) Handling errors and restarts. (5) Coordinating communications between the human operator and the computer system. (6) Maintaining a log of system operations. (7) Controlling operations in a multiprogramming, multiprocessing, or time-sharing mode. Note: Among the facilities frequently included within an operating system are an executive routine, a scheduler, an IOCS utility routine, and monitor routines.

Parity Bit — A binary digit appended to an array of bits to make the sum of all the bits always odd or always even.

Parity Check — A check that tests whether the number of bits in an array is either even ("even parity check") or odd ("odd parity check").

Peripheral Equipment — All of the input-output units and auxiliary storage units of a computer system.

Pushdown List — A set of items constructed and maintained in such a way that the next item retrieved is always the last item stored in the list; i.e., last in, first out (LIFO). Synonymous with stack.

Read-only Memory — A memory device into which data cannot be written by the computer with which it is used. Note: In some computers, portions of the core storage or drum storage can be made "read-only" by temporarily effecting manual or programmed write lockouts. Permanent read-only storage (ROS) is used in many current computers to implement microprogramming.

Real Time — (1) Pertaining to the actual time during which a physical process transpires. (2) Pertaining to the performance of a computation during the actual time that the related physical process transpires in order that results of the computation can be used in guiding the physical process.

Register — A device capable of storing a specified amount of data, such as one word usually for some special purpose. Note: Among the registers included in minicomputers are accumulators, index registers, instruction registers, and sequence counter. Each register can be implemented by special hardware or by a reserved location within a larger memory such as a reserved core storage location.

Scratch Pad — A small memory consisting of high-speed registers or memory locations.

Semiconductor Memory — A memory using a semiconductor circuit as the storage medium. Often used for high-speed buffer memories and for read-only memories.

Software — The collection of programs and routines associated with a computer. Includes system software assemblers, compilers, utility routines, and operating systems to facilitate the programming and operation of the computer, and application software which solves specific user problems.

Stored Program Computer — A digital computer that, under control of internally stored instructions, can synthesize, alter, and store instructions as though they were data and can subsequently execute these new instructions.

Substrate — The material on which an integrated circuit is fabricated. Its primary function is mechanical support, but it can also serve an electrical function.

Time-Sharing — (1) The use of a given device by a number of other devices, programs, or human users, one at a time in rapid succession. (2) A technique or system for furnishing computing services to multiple users simultaneously, while providing rapid responses to each of the users. Note: Time-sharing computer systems usually employ multiprogramming and/or multiprocessing techniques and are often capable of serving users at remote locations via a data communications network.

Utility Routine — A standard routine used to assist in the operation of a computer by performing some frequently-required process such as sorting, merging, report program generation, data transcription, file maintenance, etc. Synonymous with service routine. Note: Utility routines are important components of the software supplied by the manufacturers of most computers.

Word — A group of bits or characters treated as a unit and capable of being stored in one addressable main memory location.

Word Length — The number of bits or characters in a word.

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