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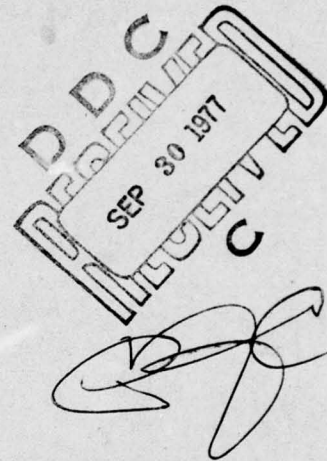
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# MINICOMPUTER SYSTEM STUDY

Mark E. Barkley

July 1977

Final Report



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U.S. ARMY AVIATION SYSTEMS COMMAND  
Systems Analysis Office  
Advanced Methodology Division  
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Minicomputers were observed in light of United States Army Aviation Systems Command (AVSCOM), Systems Analysis Office (SAO), Scientific and Engineering (S&E) current and forecasted computer requirements.  The SAO computer requirements were isolated based on its present and programmed work load. Commensurate with those computer requirements and the SAO work load, compelling considerations in selecting a minicomputer were amassed and			

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20. ABSTRACT

analyzed. That analysis resulted in criteria and a method for selecting the appropriate minicomputer to provide generalized S&E computer support to the United States Army Aviation Research and Development Command (AVRADCOM), and in particular the AVRADCOM Directorate for Plans and Analysis, Systems and Cost Analysis Division.

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## 1. INTRODUCTION

### 1.1 Background

In the past decade or so, the computer-user community witnessed the emergence of low-cost computers, specifically, the so-called minicomputers. They are the computers within the computer industry which incurred the most significant growth during the cited time period. (Historical sales statistics add some credence to the statement.)

Calendar Year (CY) 1962 can be thought of as the first time of noteworthy publicity for the application of minicomputers to the solution of a special class of real-time problems. That publicity disclosed that minicomputers were being (or could be) used to perform a whole host of specialized tasks (especially in dedicated real-time type applications), for example, to obtain solutions to a certain class of aerospace problems, for recording the results of certain experiments, for controlling certain precision scientific equipment, and as traffic light controllers.

### 1.2 Problem

The United States (U.S.) Army Troop Support and Aviation Materiel Readiness Command (TSARCOM) has two IBM System 360-65 computers which are dedicated to scientific and engineering (S&E) applications. These computers represent the hardware for the U.S. Army Materiel Development and Readiness Command (DARCOM) Midwest Regional S&E Computer Center, located in St. Louis, Missouri. Being the DARCOM Midwest Regional S&E Computer Center, it has many retail customers. Among them are the U.S. Army Armament Research and Development Command (ARRCOM), Rodman Laboratory, and U.S. Army Management Engineering Training Agency (AMETA), Rock Island, Illinois; U.S. Army Air Mobility Research and Development Laboratory, Ft. Eustis, Virginia; Materiel Testing Directorate, Aberdeen Proving Ground, Maryland; U.S. Army Bell Plant Activity, Ft. Worth, Texas; ARRCOM Product/Project Managers (PMs), St. Louis, Missouri; and U.S. Army Aviation Research and Development Command (AVRADCOM), St. Louis, Missouri.

Note that the retail customer concept for computer resources suggests a sharing of the computer (as well as computer time) on the part of these customers. Additionally, it suggests that S&E computer users purchase a block of computer time from TSARCOM. As a matter of fact, this is how the concept was implemented and is maintained. The amount a retail customer pays for computer resources is principally contingent upon the amount of computer time he (she) uses.

When a computer user determines that he (she) really needs computer support, he (she) should first evaluate the available alternatives. The following is a partial listing of the questions that should be answered before he (she) proceeds:

a. What level of S&E computer support does my organization require? (Things to be considered are: Who is to prepare, operate, and maintain the S&E computer system, computer programs, and data files? What size computer is needed to satisfy my organization's S&E computer requirements? When will my organization receive the appropriate output--turnaround time with respect to needs?)

b. What is the most cost-effective means of providing S&E computer support to my organization?

c. How do the regular and nonregular duty hours of my organization differ from those of the organization(s) which are to provide S&E computer support?

d. Which S&E computer software packages will my organization have access to?

e. Is my organization's present computer hardware compatible with that of S&E computer retailers on my candidate list?

f. Does my organization's present computer hardware allow for growth and upward compatibility? (Are my organization's computer support needs expected to remain virtually constant?)

In view of the above and because of austere funding, the Systems Analysis Office (SAO), U.S. Army Aviation Systems Command (AVSCOM), initiated the Minicomputer System Study. The purpose was to determine the projected minicomputer/microcomputer hardware and software requirements for the Directorate for Plans and Analysis, AVRADCOM, develop a procedure for selecting a minicomputer/microcomputer system which satisfies these requirements, and derive an estimate of the benefits that could accrue from procuring and implementing the appropriate minicomputer/microcomputer system within the Directorate for Plans and Analysis, AVRADCOM.

### 1.3 Characteristics

Table 1 shows a range of the typical characteristics of a minicomputer/microcomputer from a minimal through a fairly sophisticated piece of hardware. (Note these before proceeding.)

TABLE 1

## TYPICAL MINICOMPUTER/MICROCOMPUTER CHARACTERISTICS AND FEATURES

CHARACTERISTICS	FEATURES AVAILABLE		
	MINIMUM	AVERAGE	MAXIMUM
<b>MEMORY</b>			
Word Length (Bits)	8	8 or 16	32
Size (Words)	1,024 to 4K	4K to 32K	4K to 256K
Increment Size (Words)	1,024	4,096	8,192
Cycle Rate (KHz)	125	571 to 1,000	2,000
(Cycle Time, $\mu$ Sec)	8	1 to 1.75	0.5
Parity Check	No	Optional	Standard
Memory Protect	No	Optional	Standard
Direct Addressing (Words)	256	256 to 4,096	All of Core
Indirect Addressing	No	Single/Multilevel	Multilevel
<b>CENTRAL PROCESSOR</b>			
General-Purpose Registers	1	1, 2, 3, or 4	12
Index Registers	0	1	15
Hardware Multiply/Divide	No	Optional	Standard
Immediate Instructions	No	Half yes	Yes
Double-Word Instruct	No	Mostly yes	Yes
Byte Processing	No	Half yes	Yes
<b>INPUT/OUTPUT (I/O)</b>			
Programmed I/O Channel	1	1	1
I/O Word Size (Bits)	8	8 or 16	32
Priority Interrupt Lines	1	1 Standard to 64 Optional	2 Standard to 256 Optional
Direct Memory Access (DMA)	No	Optional	Optional
I/O Maximum Transfer Rate (DMA)	125,000	400,000 to 600,000	1,000,000
<b>OTHER FEATURES</b>			
Realtime Clock	No	Optional	Standard
Power Fail/Restart	Optional	Optional	Standard
Largest Disk (Megabits)	No	2.1 to 9	183.6
Assembler	Yes	Yes	Yes
Interpreter	No	Basic, FORTRAN, PLM	Basic, FORTRAN, ALGOL, APL, PLM
Compiler	No	Basic, FORTRAN, PLM	Basic, FORTRAN, ALGOL, APL, PLM
Operating System	No	No	Real-Time, Background, Foreground

Minicomputers typically possess fast processing (core cycle times and peripheral transfer) rates, relatively short word lengths, and adaptable input/output (I/O) structures. The price of one of these appears to be based on such attributes as the word length, scope of the instruction set, and adaptability of the I/O structure.

The central processor units (CPUs) of minicomputers or microcomputers are generally single-address binary processor units with negative numbers expressed as two's complements. However, there are distinguishing characteristics among them. The principal ones are the following: number of accumulators provided; instruction decoding; and interrupt handling capability. Typical CPUs possess an instruction set from 60 to 100 instructions. However, it is possible to find CPUs which possess more than 200 instruction sets.

At one time, the principal role of a minicomputer or microcomputer was that of performing management control, data acquisition, and display functions. They were then dedicated to performing the following kinds of tasks: monitoring and controlling specified processes; monitoring specified processes and displaying prescribed output; data acquisition; data reduction and analysis; and communication.

To distinguish a minicomputer from a microcomputer, Barden<sup>1</sup> offered the following statement (the statement below is a paraphrase): A minicomputer is an inexpensive (costing up to a few thousand dollars) physically small, general-purpose computer, while a microcomputer is a minicomputer possessing a microprocessor chip or chips as its CPU. Observe that, from the previous statement, one could not obtain a crystal clear distinction between a minicomputer and a microcomputer. Not enough facts were offered, to have done so would have been an horrendous task, and certainly not worth the effort.

In view of the discussion presented above, any rationale offered in the future for a minicomputer will also apply to a microcomputer. (Appendix A shows a select list of minicomputers/microcomputers and their manufacturers.)

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<sup>1</sup>William Barden, Jr., How to Buy Minicomputers and Microcomputers (Indianapolis, IN: Howard W. Sams and Company, 1977), P. 11.

#### 1.4 Literature Search

References 1, 7, and 12 disclose that minicomputers/microcomputers are available in numerous configurations and are highly suited for two basic kinds of processing, batch and time-sharing. Additionally, they show that minicomputers/microcomputers are being used to aid in the performance of many (as well as different kinds of) tasks, with few exceptions. Several of these applications were cited above, under Characteristics. Needless to say, a given manufacturer's literature (Reference 16) makes assertions about how useful and versatile its product would be in enhancing solutions to specific user type problems.

References 2 through 6, 8 through 11, and 13 through 15 disclose that when a potential user commences a search for a minicomputer/microcomputer, he (she) should identify his (her) particular requirements and then concentrate on obtaining the computer configuration which best meets his (her) needs. Additionally, special consideration should be given to on-line storage, peripherals, software, monitors, language processors, editors, and operations.

## 2. REQUIREMENTS

### 2.1 General

The scope of this study was limited to AVRADCOM's S&E and data management computer requirements. This action was taken because of the thrust of the potential work load (research and development oriented) and since many of the operations research and cost analysis projects can be properly accomplished only through the use of a computer as a tool.

The following is a partial listing of the kinds of programmed assignments which are required to support AVRADCOM functional offices and resident DARCOM Project/Product Managers (PMs): system/end-item life cycle cost modeling, system/end-item survivability and vulnerability modeling, support computer graphics--network, schedule and risk analysis modeling, organization force structure modeling, routine cost and system analyses, and implementation and maintenance of the Modernized Army Research and Development Information System (MARDIS) and of the Second Generation Comprehensive Helicopter Analysis System (SGHAS).

AVRADCOM and resident DARCOM PM personnel programmed to use the S&E computer system consist principally of scientists and engineers (specifically operations research analysts, various kinds of engineers, mathematicians, and mathematical-statisticians), but also others who are not necessarily trained or experienced computer scientists or computer programmers. These personnel are expected to develop their own applications software or exercise applications software which are designed for them by others to satisfy their specific S&E and data management requirements.

### 2.2 Hardware

One of the principal concerns of AVRADCOM is to accomplish its mission. To efficiently and effectively attain this goal, it is mandatory that the proper resources (personnel and hardware) be readily available and accessible to AVRADCOM for employment at all times. The resource of interest here is computer hardware (a CPU, main memory--core, solid state electronic or bubble storage, input/output (I/O) devices, and external storage devices), in particular, a general purpose minicomputer/microcomputer for direct support of AVRADCOM's S&E and data management requirements. AVRADCOM offices, particularly the Directorate for Plans and Analysis, Systems and Cost Analysis Division, need access to computer hardware which has the capability to support their S&E and data management requirements. This computer hardware may be internal or external to AVRADCOM's on-site facilities. (See Table 2 for a possible configuration of minicomputer/microcomputer hardware.)

TABLE 2  
MINICOMPUTER/MICROCOMPUTER HARDWARE

<u>ITEM</u>	<u>SPECIFICATION</u>
Central Processor Unit	
Main Memory	At least 32K bytes of storage
Floppy Disk Drive, or Diskette Drive	At least dual, with 250K bytes of storage/ floppy disk or diskette
Disk Drive	At least dual, with 10M bytes of storage/disk
High Speed Printer	At least 350 lines per minute (LPM)
Punch Card Reader, or	80 column card
Magnetic Tape Drive	Dual, with standard 7 or 9 channels, 800 or 1600 bytes per inch (BPI) tapes

Consider the case where computer hardware is external to AVRADCOM's on-site facilities. AVRADCOM would then be a user, as previously discussed, and consequently serviced by a computer retailer or wholesaler through batch, remote job entry (RJE), or time sharing option (TSO) terminal processing. (This assumes that the computer retailer or wholesaler will possess the computer hardware that satisfies AVRADCOM's total S&E and data management requirements.)

Reasonable sources for obtaining a listing (and even a comparative listing) of available computer hardware are:

- a. Manufacturers (IBM, UNIVAC, DEC, BURROUGHS, Interdata, Data General, PRIME, HP, etc.)
- b. DATAPRO Research Corporation -- a company that, among other things, compiles a comparative analysis of computer hardware.
- c. Auerbach Services -- a company that, among other things, provides information on particular manufacturers and their computer hardware.
- d. U.S. General Services Administration (GSA) Federal Supply Schedule.

Similarly, consider the case where computer hardware is internal to AVRADCOM. In this case, AVRADCOM has to acquire a set of computer hardware which is supposedly cost-effective and satisfies as a minimum the quick-response portion of its S&E and data management requirements. This computer hardware should possess the following:

- a. A CPU, main memory, input/output (I/O) devices -- card reader and high-speed printer, and mass storage devices -- direct access storage devices (DASDs), magnetic/paper tape drives, etc. which are only large enough to satisfy the user's total (or as a minimum his (her) quick-response) S&E and data management requirements.
- b. Compatibility with existing computer hardware, and permits upward compatibility and growth. (This case is assumed throughout the remainder of the paper.)

### 2.3 Software

Computer software in this paper includes the following: operating system (executive, supervisor/command, I/O logic, language processors-- assembler, cross-assembler, high level language compilers or interpreters (COBOL, FORTRAN, PASCAL, PLM, BASIC, APL, etc.), emulating packages, editors, support, and applications packages (See Table 3 for a minimum software requirements list.) A significant number of the minicomputer/

microcomputer manufacturers, software houses (INFORMATICS, DATAPRO Research Corporation, Management Science America, Inc. (MSA), etc.), original equipment manufacturers (OEMs), and service bureaus produce and market adequate computer software to support most user computer hardware systems. Consult the International Computer Program (ICP) Directory and other software directories for more information on software. (See the Glossary for a definition of peculiar terms.) An additional source of computer software is other computer users.

It behooves every potential software purchaser or user to be careful when he (she) takes inventory and evaluates his (her) organization's particular software requirements or seeks external software support. Otherwise, he (she) may not get what was originally bargained for.

Observe Table 3, two items of primary importance will be discussed in detail. They are operating system (OS) and system utilities.

First, the components of an OS:

a. Intertask communication permits one task or program to communicate with another.

b. Shared files permit several programs to access the same data concurrently.

c. Shared programs increase computer system efficiency and decrease the amount of memory required.

d. Multiprogramming permits more than one program to run on the computer system at one time.

e. Multitasking permits more than one task to run on the computer system at one time.

f. Batch gives a user the facility to run work in background. It is a noninteractive mode of operation.

g. Core dump gives a user the facility to obtain a snap shot of memory when a failure occurs.

h. Power failure/recovery routines protect a computer from losing its data when a power failure occurs.

Last, the components of system utilities:

a. A conversational editor permits the user to enter data programs into the computer.

b. A command language is the medium through which the user communicates with the computer system.

TABLE 3  
MINICOMPUTER/MICROCOMPUTER SOFTWARE

<u>ITEM</u>	<u>SPECIFICATIONS</u>
Operating System	Operational; maintainable
Intertask Communication	"
Shared Files Support	"
Shared Programs (Reentrant)	"
Multiprogramming	"
Multitasking	"
Batch	"
Core Dump	"
Power Failure/Recovery	"
Language	
FORTRAN Compiler/Interpreter	"
PL/I Compiler/Interpreter	"
APL Compiler/Interpreter	"
BASIC Compiler/Interpreter	"
Assembler	"
System Utility	
Conversational Editor/Text Editor	"
System Command Language	"
Stored Command Functions	"
Task Builder	"
File Transfer Programs	"
Sorts	"
On-line Debugging Tools	"
File Handling	"
Communication	"
Device Support	"
Statistical Package	"
Mathematical Programming Package	"
Emulation Package	"
Input/Output Logic or Circuitry	"

c. A set of stored command functions is a facility which permits the user to store command functions. This facility saves times and simplifies operations which may occur later.

d. A task builder produces tasks for later use so that a task or program can be exercised on the computer system.

e. File transfer programs facilitate data transfer between different peripheral devices.

f. A SORT routine arranges data in accordance with prescribed keys.

g. On-line debugging tools permit the user to debug (her) programs in a conversational mode.

#### 2.4 External Storage

External storage media in this paper is considered to mean principally mass storage, that is, direct access, magnetic tape or card, paper/mylar tape, and paper card. It may take any one of the following specific forms:

- a. DAS (drum, rigid disk, floppy disk, or diskette).
- b. Magnetic tape (various diameter and track sizes).
- c. Magnetic cassette tape (cartridge; standard and micro).
- d. Magnetic card.
- e. Paper or mylar tape.
- f. Paper card.

Hill offers a useful discussion on DAS; Hogg offers additional useful remarks on DAS, particularly floppy disks; and Boyle discusses some details of magnetic tape cassette storage.<sup>3, 10, 11</sup>

The advantages of external (mass) storage are ease of record handling, efficiency of repeated use, accuracy, and high volume storage performance.

Of the principal external storage media previously cited, one order of popularity is disk, floppy disk or diskette, magnetic tape, drum, magnetic cassette tape, punched paper card, and punched paper/mylar tape. This is partially due to the following attributes which each possess to some extent: speed, ease of data recovery, volatility, transportability, reliability, and economy.

The storage capability of the storage media listed below is estimated to be as shown:

<u>Storage Medium</u>	<u>Estimated Storage Capacity</u>
Drum	Open
Rigid or hard disk	About 10 $\bar{M}$ bytes and up
Floppy disk	About 250K bytes and up
Diskette	About 100K bytes and up
Magnetic tape (9 channel, 2400 feet, 1600 BPI, block size 20, 80 characters/record)	About 30.72M bytes and up
Magnetic cassette tape	About 125K bytes and up
Magnetic card	About 5K bytes and up
Punch paper or mylar tape (150 feet roll)	About 100K bytes and up
Punch paper card	80 characters
Magnetic stripe card	

Data may be recorded on each of these storage media under or without format control. In general, one may record more information on a medium when he (she) uses format control.

#### 2.5 Sources

Minicomputers/microcomputers can be acquired through many sources; among them are computer manufacturers, OEMs, and service bureaus. As previously mentioned, the GSA Federal Supply Schedule of computer hardware may be used as a source. Additionally, most computer manufacturers furnish assistance and information on the state-of-the-art and upcoming hardware and software.

#### 2.6 Analysis

Today's minicomputer/microcomputer hardware is reported to be state-of-the-art. Accordingly, almost any manufacturer can offer a potential purchaser or user a configuration of computer hardware that is reliable and which satisfies his (her) particular needs. (Mini-computer/microcomputer users who presented papers at the American Institute of Industrial Engineers (AIIE) Seminar entitled "Minicomputers: The Application Explosion," conducted by the AIIE, Chicago, Illinois, April 27-29, 1977, gave some credence to the previous statements.)

For example, during the AIIE Seminar, Armstrong offered the following statement, "Because minicomputers grew up in a different world, they tend to be reliable to a degree those of us with large machine experience find unbelievable. The complexity of their systems is increasing, bringing with it some software reliability problems, but overall, you can expect a mean time between failures which large system owners can only dream about."<sup>1</sup>

One can infer from historical statistics that minicomputer/microcomputer CPUs are significantly more reliable than their large-scale big brothers. At the AIIE Seminar mentioned above, minicomputer/microcomputer users generally cited fewer than 24 hours of minicomputer downtime over a period of one year of operation. Minicomputer/microcomputer hardware system problems were reported to exist, but they were attendant with the mechanical moving parts of the peripheral equipment.

The price of a minicomputer/microcomputer hardware system from a given manufacturer is competitive with that from another. The price of the system, in addition to what was cited under Characteristics, is contingent upon the particular requirement of the minicomputer/microcomputer purchaser or user and the configuration of the hardware actually procured. New "chip" technology is permitting even further and more significant price reductions.

Note that select minicomputer/microcomputer manufacturers offer CPUs which may be linked with a variety of peripheral equipment, even those from different computer manufacturers. This capability should be one of the areas of primary concern when purchasing or seeking to use a minicomputer/microcomputer system. That is, such attributes as compatibility, upward compatibility and growth need to be an integral part of any minicomputer/microcomputer systems evaluation.

As noted earlier, select software for a minicomputer/microcomputer system can be obtained from most of the computer manufacturers. It can also be obtained from OEMs, service bureaus, software houses, and user organizations. However, there are inherent problems associated with some of these sources. For example, the OEMs, service bureaus and software houses may be dependants of the user organization because of the client-seller communications problem and bankruptcy--some of these institutions are underfinanced. (Check these institutions as you would any other for reputability, financial capability, and competence.) (Note that financial incapability does not necessarily imply incompetence.) Communications and

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<sup>1</sup>Jack C. Armstrong, "Minicomputer as Extension of Central Data Processing" (paper furnished to the American Institute of Industrial Engineers, Chicago, Illinois, April 27-29, 1977).

bankruptcy are purported to be the primary problems associated with software misunderstandings. Accordingly, a user would do well to ensure that there is a mutual understanding of the contract problems (particularly the detailed scope of work), and that the institution which is awarded a contract is financially capable of completing and maintaining the software it develops. On the other hand, if the applications software are not procured, the user organization is required to commit a significant share of its personnel resources to the task of developing and maintaining it, frequently a costly endeavor.

The DAS devices and media are superior external storage methods. (See the literature on each type relative to its merits.) However, if time and space are not of the essence, other external storage devices and media may satisfy your organization's external storage requirements. (Consider the bulk and frequency of the need of the data, etc. to be stored.)

## 2.7 Benefits

Procurement and implementation of an in-house minicomputer/microcomputer system within the user organization could result in the following benefits: improved responsiveness, increased user control, increased management control, absence of telecommunications costs, reduced overhead costs for use of a computer system -- no requirement to maintain a computer system which overfills the organization's needs, placing computing power where it is most used, reduced filing and storage costs, a more portable and reliable computer system, less space for placement of the computer system, reduced movement on the part of analysts and programmers, and increased efficiency from the computer hardware and personnel resources perspective. Observe, the previous statement was not meant to be an exhaustive delineation of the benefits of an in-house minicomputer/microcomputer system.

### 3. EVALUATION

#### 3.1 General

When a potential purchaser or user of a minicomputer/microcomputer system becomes serious about the selection and acquisition of a mini-computer/microcomputer system, he (she) should develop and establish a formal study plan. That study plan should as a minimum include the following: problem definition and data collection, data analysis, and decision.

During problem definition and data collection, it is imperative that the potential purchaser or user of a minicomputer/microcomputer system delineate all potential problem and application areas in which it may be useful. (Refer to Exhibit 1 for a list of possible minicomputer/microcomputer application areas.) Additionally, he (she) should list such items as current and projected work load, the backgrounds of the current and potential purchaser or user employees, the suspense dates of the work load, file storage requirements, growth potential, manual and automated processes, existing computer system availability and capability, security considerations, backup and recovery procedures, etc.

During data analysis, the potential purchaser or user of a mini-computer/microcomputer system should delineate his (her) specific requirements (even if he (she) must obtain help), determine a possible set of vendors (by obtaining information from computer manufacturers, trade journals, and companies such as DATAPRO Research Corporation, Auerbach Services, etc.), and prepare and submit requests for proposals/quotes (RFPs/Qs) to the identified vendors.

During decision, the potential purchaser or user of a minicomputer/microcomputer system needs to follow a preestablished assessment procedure. That assessment procedure should reflect the potential purchaser's or user's previously established statement of the minimum hardware/software requirements, including a scheme for assigning the appropriate relative rating and weight for a given factor. (A proposed assessment procedure follows.)

EXHIBIT 1

MINICOMPUTER/MICROCOMPUTER APPLICATION AREAS

AREA

Process Control  
Numerical Control of Machine Tools  
Process Control: Security; Environmental Conditions  
Direct Control of Machines and Production Lines  
Automated Testing and Inspection  
Telemetry  
Data Acquisition and Logging  
Control and Analysis of Laboratory Experiments  
Analysis and Interpretation of Medical Tests  
Traffic Control  
Shipboard Navigation Control  
Message Switching  
Communications Controllers for Larger Computers  
Communications Line Concentrators  
Programmable Communications Terminals  
Peripheral Controllers for Larger Computers  
Control of Multistation Key-to-Tape/Disk Systems  
Display Control  
Computer-aided Design  
Typesetting and Photocomposition  
Computer-assisted Instruction  
Engineering and Scientific Computations  
Time-sharing Computational Services  
Business Data Processing  
Analog to Digital Conversion  
Text: Editing and Processing  
Transaction Systems: Point of Sale; Reservations; Attendance Reporting

### 3.2 Procedure

There are three components to the proposed assessment procedure for selecting and acquiring a computer system: purchaser/user requirements, factor analysis, and performance measurement.

The purchaser/user requirements, as previously mentioned, should be completely delineated to include the minimum constraints for each item placed on the technical requirements list. For example, consider several thresholds for a high-speed printer (HSP): A 132 character print line, 10 characters per inch, interchangeable print belts with 48, 64, or 96 EBCDIC character sets, and at least a 350 LPM for a 96 EBCDIC character set is required.

Exhibit 2 is a suggested factor analysis schedule. The weight and rating assigned to an entry in this schedule could be those which are shown in Tables 4 and 5, respectively. (However, it is recommended that the potential purchaser or user develop his (her) own weight and rating scheme.) Tables such as these should be used for assigning values to each item listed on the factor analysis schedule. A schedule should be prepared for each vendor/producer of a target hardware or software system to include calculating a composite vendor/manufacturer score.

The analysis of a target vendor/contractor, completion of the factor analysis schedule, and a comparison of the factor analysis schedules for the target vendors/contractors constitute the factor analysis. (Statistical theory and techniques may be used to facilitate the comparative analysis among the target vendors/contractors.)

Performance measurement can occur either when a prospective customer has selected and acquired a particular computer system or made contact with a current purchaser or user. In either case, performance measurement can result. A composite performance measurement score for a given vendor/manufacturer may be obtained in the same manner as the composite vendor/manufacturer score. Exhibit 3 is a suggested performance measurement schedule. Again, the weights and ratings from Tables 4 and 5 may be used. (Note that performance measurement assumes that there is experience with the computer system.)

EXHIBIT 2

WEIGHTED EVALUATION SCHEDULE

<u>FACTOR</u>	<u>WEIGHT</u>	<u>RATING</u>	<u>SCORE</u>
A. HARDWARE			
1. COMPANY RELATED			
Overall EDP/ADP Experience			
State-of-the-Art Upkeep			
Overall Management Quality			
Service Reputation			
Overall EDP/ADP Market			
Involvement			
Objectives			
Activity Level in Minicomputer/			
Microcomputer Product Line			
Financial Analysis			
Proximity/Accessibility for Service			
SUBTOTAL			
2. SYSTEM RELATED			
a. Reliability and Maintainability:			
Central Processing Unit			
Main Memory (Core/RAM)			
Disk Drive			
Floppy Disk Drive			
Diskette Drive			
Magnetic Tape			
Printer			
Punch Card Reader			
Punch Paper/Mylar Tape Drive			
b. Cost Factors:			
Lease/Purchase Price			
Maintenance Cost			
c. Ancillary Features:			
Compatibility			
Growth/Upward Compatibility			
Main Memory Volatility			
Main Memory Expansion Limits			
Channel Capabilities and			
Expansion Limits			
Ease of Application			
Word Length			
Word Size			
Price of Additional Main Memory			
SUBTOTAL			
TOTAL			

EXHIBIT 2 (CONT'D)

WEIGHTED EVALUATION SCHEDULE

<u>FACTOR</u>	<u>WEIGHT</u>	<u>RATING</u>	<u>SCORE</u>
1. COMPANY RELATED			
Overall EDP/ADP Experience			
State-of-the-Art Upkeep			
Overall EDP/ADP Market			
Involvement			
Objectives			
Activity Level in Minicomputer/ Microcomputer Product Line			
Financial Analysis			
Proximity/Accessibility for Service			
SUBTOTAL			
2. SYSTEM RELATED			
a. Reliability and Maintainability of Operating System:			
Intertask Communication			
Shared Files Support			
Shared Programs (Reentrant)			
Multiprogramming			
Multitasking			
Batch			
Core Dump			
Power Failure/Recovery			
b. Language:			
FORTRAN Compiler/Interpreter			
PL/I Compiler/Interpreter			
APL Compiler/Interpreter			
Assembler			
Cross-Assembler			
c. System Utility:			
Conversational Editor/Text Editor			
System Command Language			
Stored Command Functions			
Task Builder			
File Transfer Programs			
SORTS			
On-line Debugging Tools			

EXHIBIT 2 (CONT'D)

WEIGHTED EVALUATION SCHEDULE

<u>FACTOR</u>	<u>WEIGHT</u>	<u>RATING</u>	<u>SCORE</u>
c. System Utility (cont'd):			
File Handling			
Communications			
Device Support			
Statistical Package			
Mathematical Programming			
Package			
Emulation Package			
Input/Output Logic or			
Circuiting			
Documentation			
Maintenance Cost			
Lease/Purchase Price			
d. Ancillary Features:			
Compatibility			
Growth/Upward Compatibility			
Ease of Application			
SUBTOTAL			
TOTAL			
GRAND TOTAL			

EXHIBIT 3

PERFORMANCE MEASUREMENT SCHEDULE

<u>FACTOR</u>	<u>WEIGHT</u>	<u>RATING</u>	<u>SCORE</u>
C. PERFORMANCE			
1. GENERAL			
Field Support			
Hardware			
Software			
SUBTOTAL			
2. CHARACTERISTICS			
a. Hardware:			
Ease of Use			
TSO Capability			
Print Quality			
RJE Capability			
Input/Output Speed			
Reliability			
Quality of Staff			
SUBTOTAL			
b. Software:			
Ease of Use			
Quality of Documentation			
Quality of Staff			
SUBTOTAL			
TOTAL			
GRAND TOTAL			

TABLE 4  
SUGGESTED WEIGHT SYSTEM

<u>WEIGHT</u>	<u>DESCRIPTOR</u>
50	Critical
40	Major
30	Important
20	Desirable
10	Minor

TABLE 5  
SUGGESTED RATING SYSTEM

<u>RATING</u>	<u>DESCRIPTOR</u>
8-10	Superior
6-7	Very Good
5	Good
4	Satisfactory--Meets all Minimum Requirements
3	Adequate
2	Poor
1	Reject

#### 4. FINDINGS AND CONCLUSIONS

##### 4.1 Findings

Minicomputer/microcomputer systems are being used to perform the following kinds of tasks: monitoring and controlling specific processes, monitoring specified processes and displaying prescribed output, data retrieval, reduction and analysis, communication, inventory control, payroll, production control, scheduling, dispatching, S&E problem solving, management information systems, and word processing.

Savings can accrue from procuring and implementing a minicomputer/microcomputer system which satisfies the particular needs of a given user.

A clear distinction cannot be delineated among a minicomputer, microcomputer, and large-scale computer.

Minicomputer/microcomputer systems are manufactured which are compatible with present day computer systems, and permit upward compatibility and growth. (See the Glossary.)

##### 4.2 Conclusions

It may be concluded that:

a. Before a purchaser or user procures a computer system, he (she) should evaluate his (her) specific computer requirements.

b. A minicomputer/microcomputer system that satisfies an individual user's requirements can be procured without difficulty. (There is no longer any need for a purchaser or user to buy more computing power than he (she) needs.)

5. RECOMMENDATION

It is recommended that the Directorate for Plans and Analysis, Systems and Cost Analysis Division, and other potential computer users evaluate their S&E and data management requirements for a large-scale computer system (its tie-in RJE and/or TSO terminals, and their associated telecommunications) versus a customized in-house minicomputer/microcomputer system before acquiring additional computer support.

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APPENDIX A

MINICOMPUTER/MICROCOMPUTER  
MANUFACTURERS AND SOME  
OF THEIR SYSTEMS

TABLE 6  
 MINICOMPUTER/MICROCOMPUTER MANUFACTURERS  
 AND SOME OF THEIR SYSTEMS

<u>MANUFACTURER</u>	<u>CODE</u>	<u>COMPUTER</u>
Altair Corp. 6200 Hiawatha Avenue Chicago, IL 60646	ALTAIR	8800A/B
AMBAC Industries, Inc. Roosevelt Field Garden City, NY 11530	AMBAC	MICRO D
Burroughs Corp. Second Avenue at Burroughs Detroit, MI 48976	B	D-210
Business Informations Technology, Inc. 5 Strathmore Road Natick, MA 01760	BIT	BIT-483
Compiler Systems, Inc. P. O. Box 366 Ridgefield, CT 06877	CSI	CSI-16
Computer Automation, Inc. 895 W. 16th St. Newport Beach, CA 92660	CAI	PDC-208; PDC-216
Data General Corp. Route 9 Southboro, MA 01772	DG	NOVA; SUPER NOVA; 800; 1200
Data Technology, Inc. 1050 E. Meadow Circle Palo Alto, CA 94303	DT	DT-1600
Datamate Computer Systems Box 310 Big Spring, TX 79720	DCS	Datamate-16
Digital Equipment Corp. 146 Main Street Maynard, MA 01754	DEC	PDP-8/I; PDP-8/L; PDP-9/L; PDP-11/20; PDP-15/10, TSS-8
Electronic Associates, Inc. 187 Monmouth Park Hwy. West Long Branch, NJ 07764	EAI	EAI-640; MICRO-68

TABLE 6 (CONT'D)

<u>MANUFACTURER</u>	<u>CODE</u>	<u>COMPUTER</u>
Exxon Enterprises Inc. Zilog 540 New Haven Avenue Milford, CT 06460	ZILOG	Z-80
Fairchild Camera & Instrument Corp. 464 Ellis Street Mountain View, CA 94042	F	F-8
General Automation, Inc. 706 W. Katella Orange, CA 92668	GAI	SPC-12; SPC-16; System 18/30
General Instrument Corp. 1775 Broadway New York, NY 10019	GI	CP-1600
GRI Computer Corp. 76 Howe Street Newton, MA 02166	GRI	909
Hewlett-Packard Co. 1501 Page Mill Street Palo Alto, CA 94304	HP	HP-9830; HP-2114A/B; HP-2115A/B; HP-2116A/B
Honeywell, Inc. Computer Control Division Old Connecticut Path Framingham, MA 01701	HON	H-316; DDP-516
Hughes Aircraft Co. Certinela and Teale Culver City, CA 90230	H	HCH-201
IMS Associates, Inc. 14860 Wicks Boulevard San Leandro, CA 94577	IMSAI	8080
Information Technology, Inc. 164 Wolfe Road Sunnyvale, CA 94086	ITI	4900
INTEL Corp. 3065 Bowers Avenue Santa Clara, CA 95051	INTEL	MCS-40; MCS-80

TABLE 6 (CONT'D)

<u>MANUFACTURER</u>	<u>CODE</u>	<u>COMPUTER</u>
Interdata, Inc. 2 Crescent Place Oceanport, NJ 07757	INT	Model 3; Model 4
International Business Machines General Systems Division 875 Johnson Ferry Road, N.E. Atlanta, GA 30342	IBM	5100; System 32; Series 1
IRA Systems, Inc. 332 Second Avenue Waltham, MA 02154	IRA	SPIRAS-65
Lockheed Electronics, Inc. Data Products Division 6201 E. Randolph Street Los Angeles, CA 90022	LEI	MAC 16
Micro Systems, Inc. 644 East Young Street Santa Ana, CA 92705	MSI	800; 810
MOS Technology Inc. Valley Forge Corporate Center 950 Rittenhouse Road Morristown, PA 19401	MOS	MCS-6500
Motorola, Inc. Box 5409 Phoenix, AZ 85010	MOT	MC-6800; MDP-100
Philco-Ford, Inc., 3939 Fabian Way Palo Alto, CA 94303	PFI	1216-F
Radio Corporation of America Solid State Division New Holland Avenue Lancaster, PA 17604	RCA	CDP 1802
Raytheon Computer 2700 South Fairview Street Santa Ana, CA 92704	RAY	703; 706

TABLE 6 (CONT'D)

<u>MANUFACTURER</u>	<u>CODE</u>	<u>COMPUTER</u>
Redcor Corp. 7800 Deering Avenue P. O. Box 1031 Canoga Park, CA 91304	RC	RC-70
Rockwell International 3310 Miraloma Avenue P. O. Box 3669 Anaheim, CA 92803	RI	PPS-4; PPS-8
Scientific Control Corporation Box 96 Carrollton, TX 75006	SCC	4700
System Engineering Laboratories, Inc. Box 9148 Fort Lauderdale, FL 33310	SEL	810A/B
Tempo Computer, Inc. 340 West Collins Ave. Orange, CA 92667	TEM	TEMPO-1
Sperry Rand Corp. UNIVAC Division, Computer Systems P. O. Box 500 Blue Bell, PA 19422	UNIVAC	Add-1000
Varian Data Machines, Inc. 2722 Michelson Drive Irvine, CA 92664	VDM	520/i; 620/i
Wang Laboratories, Inc. 1 Industrial Ave. Lowell, MA 08151	WANG	WANG 2226; WANG 3300
Westinghouse Electric Corp. Computer and Instrumentation Div. 1200 West Colonial Drive Orlando, FL 32804	WES	Prodac-2000
Xerox Data Systems 701 South Aviation Boulevard El Segundo, CA 90245	XDS	CE-16; CF-16; SIGMA-3

APPENDIX B

ABBREVIATIONS, ACRONYMS AND SYMBOLS

## ABBREVIATIONS, ACRONYMS AND SYMBOLS

ASCII	American Standard Code for Information Interchange
BCD	Binary Coded Decimal
BPI	Bits Per Inch
CPS	Characters Per Second; Cards Per Second
CPU	Central Processor Unit
CRT	Cathode Ray Tube
DASD	Direct Access Storage Devices
DMA	Direct Memory Access
DMC	Direct Multiplexor Channel
EBCDIC	Extended Binary Coded Decimal Information/Interchange Code
EPROM	Erasable Programmable Read Only Memory
EROM	Erasable Read Only Memory
ICP	International Computer Programs, Inc.
I/O	Input/Output
IPS	Inches Per Second
ISAM	Indexed Sequential Access System
ISP	Instruction Set Processor
K	1, 024 words, 4-, 8-, 12-, 16-, 24-, 32-bit words
LPM	Lines Per Minute
LSI	Large-Scale Integration
$\mu$	Micro, Millionth
MNOS	Metallic Nitride Oxide Semiconductor
MOS	Metallic Oxide Semiconductor
MPU	Microprocessor Unit

ABBREVIATIONS, ACRONYMS AND SYMBOLS (Cont'd)

MSI	Medium-Scale Integration
NDRO	Nondestructive Read Out
OEM	Original Equipment Manufacturer
OS	Operating System
PROM	Programmable Read Only Memory
RA	Relative Address
ROM	Read Only Memory
UART	Universal Asynchronous Receiver-Transmitter
WCS	Work Core Storage

APPENDIX C

GLOSSARY

## GLOSSARY

- Assembler** A computer program which translates symbolic assembly language input into machine language output; a computer program that converts the natural language (English, Swahili, etc.) equivalent of machine instructions into actual machine code on a one-for-one basis.
- Baud** A data transmission rate of one bit per second.
- Binary Coded Decimal (BCD)** A method of representing decimal digits in the form of four bit words.
- Bit** One binary digit.
- Byte** A cell in computer memory which can store eight binary bits of information; a unit of data which consists of eight binary digits.
- Compiler** A computer program which translates symbolic statements of a high level computer language input into machine language output; a language processor that evaluates algebraic source statements and produces object code (machine language) to solve the user's problem.
- Computer System** The sum total of the central processor unit (CPU): main memory, input/output from the CPU, mass storage, and software; a computer complete with the peripheral equipment and extensive software capabilities, operating system, compilers, interpreters, and application support, ready for application to problem solving.
- Cross-Assembler** Utilizing an assembler of another computer (preferably a large-scale computer) to produce operational machine code for a host computer.
- Distributed Computer Processing** Apportioning the computing power among various operating level user organizations through placement of select computer hardware and software systems in different geographic locations for direct user application; the marriage of telecommunication and minicomputer systems which emanate from different geographical locations but are linked to specific host computer systems; a network of hardware and software systems where operating level users (who originate and use data from various geographical locations) are permitted and encouraged to preprocess, access, and postprocess a substantial portion of the data on the network, while still leaving central control of the network to the host organization.

- Erasable Read Only Memory (EROM) A special type of ROM which (a) can be programmed electrically, and (b) retain data even with the power disconnected, except it can be erased by exposure to short wave-length ultraviolet light.
- Interpreter A computer program which translates symbolic statements of a high level computer language input into an immediate action; a computer program that converts the user's input (a source program) into a form which produces the desired output.
- Interrupt Anything that causes a running program to be suspended, resulting in the activation of another program. (The user's program call causes an interrupt which invokes the operating system's executive module.)
- Language Processor A computer program that accepts natural language input, analyzes it, and produces output as either the desired immediate action or in the machine language form.
- Main Memory Core, solid state electronic, or bubble storage.
- Mass Storage A medium for storing larger amounts of data than can fit into the main memory of a given processor at one time.
- Microcomputer A microprocessor affixed with main memory, input/output logic or circuitry, and some programming facility which makes it capable of problem solving.
- Microcomputer System An assemblage consisting of a microcomputer, peripheral equipment, and software, which are integrated to achieve the capability of problem solving.
- Microprocessor A central processing unit (CPU) contained in a single semiconductor chip.
- Microprocessor Unit (MPU) A CPU implemented with an integrated circuit microprocessor.
- Minicomputer A small-scale computer (perhaps a large microcomputer), consisting of CPU, main memory, input/output circuitry, power supplies, and some programming facility.
- Minicomputer System An assemblage consisting of a minicomputer, peripheral equipment, and software, which are integrated to achieve the capability of problem solving.

- Object Code The machine code version of a computer program.
- Operating System A computer program that controls and provides services to a user's application program, as well as controls system interrupt handling and other system activity. An operating system consists of three basic modules: executive, supervisor/command processor, and input/output device.
- Original Equipment Manufacturer (OEM) A company that (a) produces or procures operating systems, systems applications and other software for target computer systems, (b) interacts directly with various computer hardware and peripheral equipment manufacturers for the marriage of computer hardware, peripheral equipment, and software of (and to procure, market, and maintain) target computer systems, and (c) markets and sells a complete package (computer hardware, peripheral equipment, software, and maintenance) to potential users.
- Overlay A memory management method which may be used by a computer programmer to instruct the CPU to move data from a peripheral device to an area of memory that currently contains part of the program. The part of the program which is being replaced (overlaid) is stored in a peripheral. This memory management concept is under user control.
- Page A computer memory concept wherein computer memory is divided into blocks of multiple bytes.
- Parser A computer program mechanism which takes a set of syntax rules (a grammar) and an input string and decomposes the input string into tokens in accordance with the specified set of syntax rules.
- Peripheral Any input/output device.
- Programmable Read Only Memory (PROM) A ROM in which programming is performed by burning out fusible links at each cell. (This is accomplished by flowing a large current through the nichrome link.)
- Random Access Memory (RAM) A set of memory cells which can have either a one or zero stored in it. (Individual cells may be accessed in any order.)
- Read Only Memory (ROM) A memory device which has a fixed content in each location.

- Real-Time Pertaining to the actual time during which a physical process transpires.
- Service Bureau A company that markets and sells complete customized computer resources to potential users.
- Simulator A computer program that is written for a specific minicomputer or large-scale computer system and used to interpret the assembly or machine language program that has been written for a target computer system in order to produce the desired action. The idea is for the minicomputer or large-scale computer to emulate the target computer.
- Source Program A nonmachine code version of a minicomputer program, e.g., Assembly, BASIC, FORTRAN, PL/I, etc.
- Statement A computer programming language equivalent of a sentence in a natural language.
- Subroutine A special purpose section of a computer program which is called upon to perform a specific function.
- System A set of objects or components which is united by some form of interaction or interdependence.
- Token A basic unit of the syntax of an expression.
- Universal Asynchronous Receiver-Transmitter The transceiver converts serial input data to parallel output data at a rate determined by the receiver data clock. The transmitter accepts parallel input data and transmits it serially. It also inserts the desired number of start bits (at the transmitted word) and stop bits (at the end of the transmitted word). (A parity bit may be inserted.) Data are then transmitted out a baud rate determined by the transmitter data clock.
- Upward Compatibility of Computer Hardware The capability and facility for the same series or later generation computer hardware system of a given manufacturer to fully exercise the software of the other. (If a computer software system works on a given manufacturer's product line, and also works on the same series, a larger, or later generation piece of computer hardware (from that manufacturer) in the same or a different product line, it is said to be upward compatible.)

Variable A symbolically named data location.

Virtual Memory A memory management method where main memory (which may be small) is made to look larger to the computer programmer. Without user control, ancillary memory, such as disk, magnetic tape, etc. is made to look like main memory to the computer programmer.

word A set of characters that occupies one storage location and is treated by the computer circuits and transported as one unit; one unit of data.