

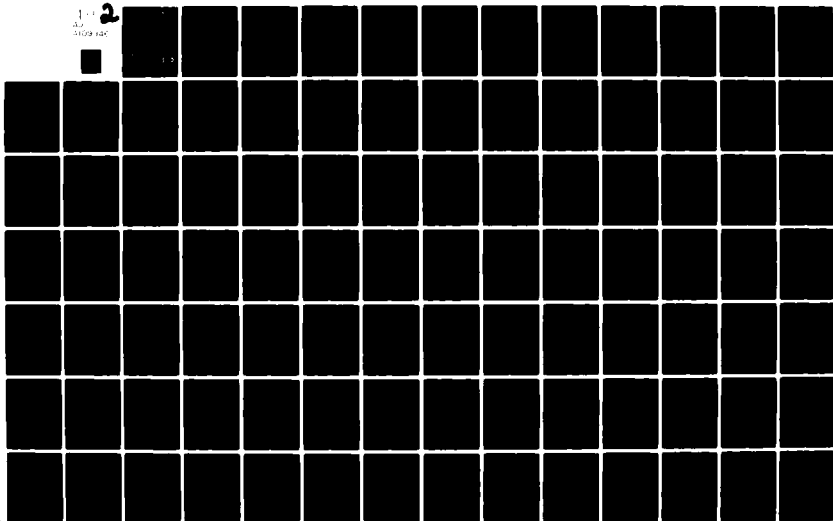
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INTERRELATIONSHIPS OF TECHNOLOGY, SYSTEM PERFORMANCE, AND PRICE--ETC(U)
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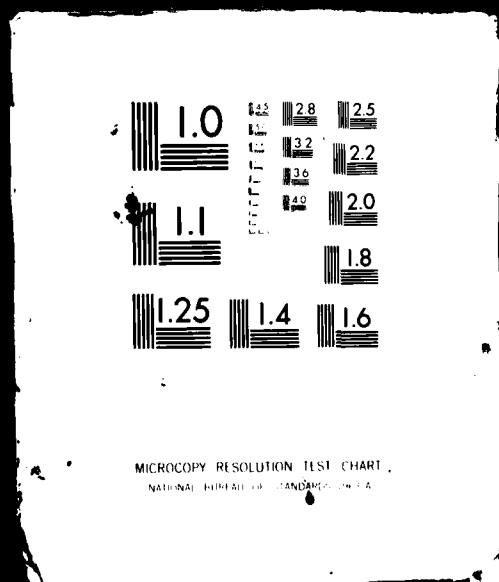
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INTERRELATIONSHIPS OF TECHNOLOGY, SYSTEM
PERFORMANCE, AND PRICES FOR MINI/MIDICOMPUTERS

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Edward H. Yates

August 1980

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1 SUMMARY

A study has been performed on the interrelationships of technology, prices, and performance of mini/midcomputers. The key functional characteristics and prices of 203 commercial and 13 military processors from 46 different manufacturers were compiled and analyzed. Multiple correlations among technology, performance characteristics, and prices were conducted by using a RAND Corporation multi-form regression analysis program called Curves. Although the variance statistics were somewhat poor, cost estimating relationships were developed from the data which can be used to estimate the "industry average" price of new mini-midcomputer configurations.

Differences between commercial and military versions are discussed. Typical military specifications are presented which show why military computers cost from 2 to 2.5 times more than their commercial counterparts.

The effect of technology on prices over the time period 1965 to 1980 is derived for both commercial and military processors. The results showed that technology did reduce prices of commercial computers approximately 15 to 26 percent annually, depending on the assumptions made about inflation and statistical manipulation. The corresponding results for military computers showed 20 to 43 percent annually.

2 INTRODUCTION AND STUDY OBJECTIVES

2.1 OBJECTIVES

Because technological advances in small computers have significantly reduced prices in data processing, it is necessary for BMDO* to update its assessment of state-of-the-art and technology projections for this type of equipment for incorporation in new BMD concepts and potential deployments. It is also necessary to assess the price differences between commercial and military equipment, because commercial equipment is often used as the baseline design for military counterparts. The objective of this study is to provide this information for use by the BMDO when examining new BMD concepts or systems.

In summary, this is a study of the interrelationships of small computer prices, technology, and performance.

2.2 TASKS

In order to accomplish the above objectives, the following tasks have been identified:

- a. Review other survey efforts of small scientific-oriented computers to avoid duplication of study effort.
- b. Collect available information on small computer capabilities and costs for both commercial and military versions.
- c. Develop generalized cost estimating relationships (CERs) based on the tabulated data, identifying the relationships among processor and memory prices, performance, and technology.
- d. Define cost factor differences between commercial and military computers.
- e. Assess the technology impact on computer prices over the past 15 years.

* Ballistic Missile Defense Organization (BMDO) is meant to include both the BMD Systems Command (BMDSCOM) and the Advanced Technology Center (ATC).

2.3 REPORT ORGANIZATION

The presentation of this report is organized to respond to the tasks identified in Section 2.2 above. Task a (survey review) and Task b (data collection) are discussed in this report's Section 4 (collection of data), while Task c (CER development), Task d (military versus commercial) and Task e (technology trends) are discussed in Section 5 (analysis of data). Section 6 of this report presents the study conclusions and recommendations.

2.4 CAVEAT

The reader should be cautioned that it would be unwise to rely solely on the information contained in this report except in a general way, i.e., this information should be regarded as a general data base on which selected price and technology trends can be identified. There is not universal agreement on some of the performance characteristics presented in this report, and it should be remembered that prices are peculiar to any specific situation and time period. Other causes of uncertainty are due to manufacturers' secrecy about their system performance and prices of their equipment, and inconsistent definitions and classifications of systems. Any serious consideration of selecting a particular computer configuration should be based on a detailed investigation of price and performance from the manufacturer.

However, on the positive side, an attempt has been made to record values as accurately as possible from more reliable sources and to engage in "cross-checking" values from alternate sources. In many cases, value judgements had to be made among conflicting estimates of physical, performance and economic characteristics.

3 DEVELOPMENT OF HYPOTHESES

3.1 CLASSIFICATION

The first issue to address is what types of computers should be included in this study. It was generally agreed that the emphasis should be on smaller computers because the larger types are better defined and well known, while the smaller ones with innovations in technology and manufacturing may offer better cost-effectiveness solutions for BMD. Unfortunately, classification schemes are plentiful but not universal. There is disagreement within the industry itself as to how to classify computers. Rigid definitions can be made on the basis of price, equipment complement, software support, applications support, flexibility, peripheral availability, work size, purpose, physical size, or combinations of these.

For purposes of this study of BMD computer technology, the classification problem was simplified so as to include a broad data base of available general purpose, digital, ground-based computers classified loosely as minicomputers and midicomputers. The main classification would be arbitrary price ranges where the central processor unit* (CPU) would, in most cases, cost less than \$100,000. Although not important to the study results, arbitrary subgroupings could be made where: (a) mini-computer CPUs would usually have prices between \$1,000 and \$50,000 and usually have word lengths less than 32-bits, and (b) midicomputer CPUs would generally cost between \$50,000 to \$100,000 and usually have at least 32-bit word lengths.

Excluded from this study would be personal computers, special purpose microprocessors, space or airborne computers, and small business computers that would be inefficient for scientific or engineering applications, as well as the large-scale computers costing over \$100,000.

* A more precise hardware definition is presented in Section 3.2.

3.2 SCOPE

Before the scope of equipment covered by this study can be described, it is necessary first to discuss the definitions of terms in the next paragraph.

Processors are devices which perform or control a sequence of operations on data, and are closely tied to the main memory. Included in this category are central processing units (CPUs), input-output processors, and a variety of processor options such as floating point arithmetic units. The memory stores information, received through an input unit or developed during the processing of data, so that it can be brought from storage for use without being destroyed. Although classification schemes are many, there appears to be agreement on categorization into two kinds. One is main memory, also called working storage or internal memory/storage, and the other is mass storage or auxiliary memory/storage. The main memory holds the data directly manipulated by the arithmetic unit of the processor. Because of the speed of processing, the data must be readily available, so they are moved from mass storage into main memory.

Peripherals are the input-output devices (and auxiliary memory units) designed to provide the processors with data. Included in this category are magnetic tape units, line printers, punched card equipment, and moving-head and head-per-track disks and drums (and their controllers). Terminals, which are input-output devices connected to the processor, are sometimes classified as peripherals and sometimes in a separate category. Similarly, auxiliary memory or storage units can be classified separately or as peripherals.

For the purposes of this study, the major cost emphasis is on the processors (sometimes inaccurately abbreviated as "CPU" in this report) and its internal main memory. The price data which was collected not only included all types of processors (i.e., CPU, I/O, and hardware floating point) but also power supply, front panel, and minimum memory in the chassis.

Mass storage, peripherals, and terminals have been excluded from the scope. Multiprocessor configurations are also excluded. Most BMD tactical applications do not require vast amounts of peripherals, but when specific requirements are identified, this equipment would be costed on an ad hoc basis.

The time period considered for this analysis of prices, technology, and performance is between 1965 and 1980, with the major emphasis on the 1970 to 1980 decade.

3.3 PERFORMANCE EVALUATION

In selecting CPU performance measures for this study, it was necessary to conduct a library search. Several of the alternatives are discussed below:

- a. Phister's Raw Speed. As noted in his recent publication*, Phister observes that "although it is hard to pick a single parameter to characterize CPU performance, the best choice is probably addition time, including memory access."
- b. Knight's Performance Measure. Although quite old, this measure devised by K. Knight at Carnegie-Mellon Institute is still being discussed. It is somewhat more sophisticated as it simultaneously attempts to take into account arithmetic speed, memory size, memory word-length, and the degree of overlap permitted between the CPU and the I/O system. It also has different instruction mixes for commercial and scientific systems.

* Page 60, Data Processing Technology and Economics, Second Edition, by Montgomery Phister, Jr., Digital Press, 1979.

- c. Other analytical techniques include those known as Grosch's Law, the Whetstone Technique, an approach by the Institute of Software Engineering, and a series of weighted MIP equations developed by Rein Turn of TRW for BMD applications.
- d. Benchmarks for performance evaluation have been synthesized by a number of organizations including Auerbach and more recently TRW* for the Army BMDSCOM.

All of the analytical techniques mentioned in a. through c. appear to exclude such basic factors as the type of operating system and the job workload size and complexity. The most satisfying evaluation process would be to take the particular application required and run it on all the alternative computer systems, i.e., to use a benchmark representing the real application. Thus, a rational decision could be made on the time and cost to handle this specific type of workload and compare the performance of the alternate systems being considered. Although this approach is theoretically possible, it is impractical for this type of study emcumbered with limited resources.

Therefore, it seemed most practical and relevant to modify and use Turn's MIP equations, and these are discussed in the definitions in subsection 4.3 and in Appendix D.

3.4 SELECTION OF IMPORTANT CER VARIABLES

The question now is to hypothesize which independent variables have a "first-order" effect on processor price with a size-normalized internal main memory. Based on previous studies and discussions with experts, the following variables are selected for primary analysis:

* Burns, I.F., et. al., Advanced Data Processing Technology, CDRL A004, TRW Report 32 304-6921-001, 16 January 1978.

- a. First Delivery, year (Technology Surrogate)
- b. Word Length, bits
- c. Main Memory Type, core or semiconductor
- d. Millions of Instructions Per Second (MIPS) which is a function of:
 - Instruction Execution Times, microseconds
 - . Add
 - . Multiply/Divide
 - Memory Cycle Time, microseconds
- e. Maximum Memory Capacity, bits, which is a function of:
 - Word Length, bits
 - Maximum Memory Capacity, words
- f. Floating Point Hardware, yes or no

So, there are six independent variables (later identified as X1 through X6) to be tested for correlation to processor price as the dependent variable (Y). The analysis is presented in Subsection 5.2.

Data was collected on additional variables which were hypothesized to only have "second-order" effects on price. These are:

- g. Number of Accumulators
- h. Direct Memory Access
- i. Number of I/O Channels
- j. Vector Interrupt
- k. Minimum Memory Capacity, words

Definitions of all of the above variables are included in Subsection 4.3.

There was an additional set of features or options which are included as standard in some of the mini/midicomputers. They are listed below but not explicitly accounted for in this study because they are hypothesized to have "third order" effects on processor cost.

- Memory Management
- Hardware Memory Protection
- Memory Interleave Capability
- Cache Memory
- Microprogrammable
- Power Fail/Auto Restart
- Real Time Clock/Timer
- Battery Backup Power
- Multiprocessor Capability

3.5 MILITARIZATION PRICE DIFFERENTIALS

It is hypothesized that military specifications make military computers cost more than commercial computers. To test this hypothesis, the relevant military specifications will be identified, and a quantitative analysis will be made of price differentials, using both the general CER equations and case examples. This analysis in Subsection 5.4 should determine if the hypothesis is supported.

3.6 IMPACT OF TECHNOLOGY

The cost of a mini/midicomputer is influenced by a large number of factors as discussed in Subsection 3.4. The traditional CER development would attempt to relate cost to one or several of the equipment's physical and/or performance characteristics. However, in the case of mini/midicomputers, it is well known that innovations in design and manufacturing technology (and the competitive market place) are resulting in the availability of mini/midicomputers with steadily lower prices and increased capabilities. This leads to the hypothesis that technology must be a key variable in determining price and performance. It is further hypothesized that the first year of delivery of a new computer configuration would be the surrogate variable for technology.

In addition to including technology as a variable in the CER, a more detailed analysis is conducted on technology trends, i.e., how technology affects prices quantitatively over the 1965 to 1980 time period. It is hypothesized that technology reduces prices over time, and this is analyzed in Subsection 5.5.

4 COLLECTION OF DATA

4.1 REVIEW PREVIOUS SURVEYS

Many inquiries were made in the research community about available surveys that may be related to this investigation. Investigations were made, with the conclusion drawn that the other surveys did not include (a) all of the desired physical and performance characteristics data, (b) a clear enough explanation of the cost assumptions, or (c) a complete set of mini/midi computers of the relevant type for the time period of interest. The surveys investigated included those made by TRW, GRC, Aerospace Corporation, SDC, The RAND Corporation, Datamation, Byte, Auerbach, DataPro, and GML.

4.2 SOURCE OF DATA

The task of conducting a quantitative survey of mini/midicomputer costs and characteristics proved to be quite challenging as well as difficult. About 75 percent of the data was readily available but, in many cases, the missing data had to be painfully obtained from the designers or manufacturers. In some cases, estimates had to be made by manufacturers' representatives or by this study investigator, using the techniques of analogy or interpolation/extrapolation of similarly known information.

Consequently, it should be realized by users of this data that: (1) much of the data was obtained from secondary sources (DataPro's EDP Buyer's Bible, Auerbach Buyer's Guide, GML Minicomputer Review, and Datamation) and not always accurate, (2) some of the data was based on informed estimates from knowledgeable individuals, and again, not always completely accurate.

It is in this context that the data was assembled and tabulated. Large work sheets were designed which allowed space for recording input values from alternate sources (sometimes quite contradicting). Then, in some cases, judgements had to be made (with the assistance of experts) on which value was the most realistic.

The data sets were stratified into two groups -- 203 commercial and 13 militarized mini/midicomputers, for a total population of 216 data sets.

4.3 DEFINITION OF DATA AND VARIABLES

The data base which was collected and used to develop the cost/technology estimating relationships is presented in Appendix A. The key functional characteristics and costs of 203 commercial and 13 military mini/midicomputers from 46 different manufacturers are presented in these tables. For each CPU and system listed, complete sets of data were compiled except where noted as "optional." The optional data sets were incomplete and excluded from the regression analyses. These data should be regarded as supplementary information which might be utilized in future cost/technology investigations.

Definitions for the data tables follow:

1. Manufacturer. This is a 3-letter code to indicate the present manufacturer. Product lines and equipment acquired from prior owners are listed under the new owner's coding, e.g., Interdata computers are listed under Perkin Elmer, and Varian computers under Sperry Univac. The systems are grouped together by manufacturer, and their code symbols are defined in Appendix C.
2. Model. The particular computer system model name and number is listed in this column. Where a choice of CPU models was possible, its model designator is also given in parenthesis following the system designator.
3. First Year Delivery. This indicates the year when the first production model was delivered to a customer. The date of announcement is usually one to six months prior to that date. It is used as an important variable in this study as a surrogate for design and production technology. The last 2 digits of

the year are used as the input, e.g., "76" would be the equation input value to represent the year 1976.

4. Word Length. This is the computer's fundamental word length, expressed in bits. It is sometimes called data format size, memory bandwidth, or input/output bus width. It is the number of binary digits (bits) that can be stored in or retrieved from main storage during a single (clock) cycle. To this basic length has been added any parity bits or ERCC (error-correcting) bits. Parity checking usually requires the addition of one more bit to each main storage location. This added bit is set to the appropriate value whenever a word is written into main storage and checked each time the word is read out, permitting detection of most read and write errors. ERCC is a rather new form of error correction. It involves appending five or six check bits to each word of memory. The check bits, often called a Hamming code, and special algorithms allow a system to detect and correct single-bit errors and also to detect most multiple-bit errors that occur. In general, the longer the total word length, the greater the efficiency and accuracy of a computer's internal architecture and operations.
5. Add Time. This is the first of three possible variables which represent instruction execution times, expressed in microseconds. These are average timings for a full basic word, single precision, fixed point arithmetic-operands. In general, the indicated add times are the times required to retrieve a one-word operand from main storage and add it to another operand already contained in an accumulator, with no indexing or indirect addressing. It should be cautioned that even these times are not always directly comparable, due to the way the manufacturer performed the test, or because of differences in word lengths, instruction repertoires, or hardware architecture. It should also be noted that instruction execution speed depends on memory cycle time as well as the CPU's internal logic.

6. Multiply Time. This is the second of three possible variables which represent instruction execution times in microseconds. Many minicomputer applications impose little or no need for multiplication (or division) operations and therefore contain no multiply/divide hardware. In these cases, multiplication (and division) must be performed by means of programmed sub-routines at a significant reduction in execution speeds. For machines with no hardware multiplication (or division), the time required for a programmed multiplication (or division) is recorded, if available.
7. Division Time. This is the last of three possible variables which represent instruction execution times in microseconds. The previous explanation in Variation 6 (above), Multiple Time, also applies here. These data are not used in the MIPS calculation.
8. MIPS. Millions of Instructions Per Second. The speed or rate at which adds, multiplies, or divides and memory cycles can be performed is the inverse of their execution times, converted to millions of instructions per second. By modifying the instruction mix formulas for BMD applications given by Dr. Rein Turn of TRW*, MIPS were calculated for each computer system. The choice of which formula to use depended upon the computer architecture (hardware multiply?; look ahead?) and upon the data available. The alternative formulas are presented in Appendix D.

* See Appendix D for derivation and modification of these formulas.

9. Floating Point. A coding system has been devised to distinguish between those computer systems which hardware floating point is built-in and included in the CPU price, and those which do not have floating point or it is a cost-plus option. The coding is:

1. = No or Optional (no floating point)
2. = Yes (floating point included in CPU price)

Hardware floating point has not been included in the standard instruction repertoires of most of the currently available minicomputers, despite the fact that floating-point arithmetic is highly desirable, if not essential, in many scientific and BMD applications. However, there is an increasing tendency to include this feature as standard on many of the recent minicomputers, and while this feature now is rather costly*, the trend of including it as standard firmware may eliminate the differential cost as an option in the future.

10. DMA. The coding system is:

1. = No DMA capability or optional at extra cost
2. = Yes (DMA capability included in CPU price).

Direct Memory Access (DMA) is a method of data transfer using a hardware device that establishes a high-speed data path to link memory with peripheral devices. When a DMA channel is used, the I/O data bypasses the computer's main hardware registers and the I/O operation proceeds independently of program control once it has been initiated by the program. There is a growing trend to include this feature as standard. Although it is an important factor, it is considered to have a "second order" price effect, and therefore classified as an optional (no primary cost effect) variable in this study.

* Roughly \$2,000 to \$10,000 incremental cost.

11. Accumulators. The number of accumulators is considered an optional variable in this study because of its hypothesized "second order" cost effect, and also because the values could not be obtained for the complete data set without a costly investigation into each processor's internal architecture. However, it is recognized that the number of accumulators can have a significant effect upon internal flexibility and processing power. An accumulator is defined as a special type of hardware register which holds one operand and permits various arithmetic and logical operations to be performed upon it. In computers with multiple accumulators, instructions involving operands in two of the accumulators can often be executed more rapidly than instructions which require the retrieval of an operand from main storage.

12. I/O Channels. The number of I/O channels or ports is considered an optional variable in this study because of its hypothesized "second order" cost effect and because of the relative ease of expanding the number of I/O channels with I/O expanders and buses. For any particular computer system, the design goal is to have a balanced system which is neither I/O-limited or CPU computation-limited. For specific types of applications, one would add I/O channels (in buffered modes) until system throughput is maximized.* Further, it is rationalized that other considerations reduce the need to consider the number of I/O channels as a key cost-determining variable, e.g.,

- DMA is a type of I/O channel which greatly facilitates I/O operations
- I/O rate is equally as important as number of I/O channels
- Maximum memory/storage capacity might be interrelated to number of channels.

* For a thorough discussion of I/O design, see: Phister, Montgomery, Jr., Data Processing Technology and Economics, Second Edition, Digital Press, December 1979.

13. Memory Type. The type of memory or storage generally falls into one of two basic categories, and the coding is as follows:

1. = Semiconductor (MOS or Bipolar)
2. = Core (or other)

Semiconductor memories are generally of two types -- metal oxide semiconductor (MOS) or bipolar transistor (bipolar). MOS appears to be more popular for commercial applications because of its compactness, producibility, and price. However, bipolar technology, a type of transistor-transistor logic, offers a classic tradeoff -- higher speed at the expense of more space, greater power consumed, and usually higher price. The type of MOS main memory considered in this study is Random-Access Memory (RAM), but other types are also often used in small systems and controllers, such as Read-Only Memory (ROM) and Programmable ROM (PROM). ROM is a memory containing permanently available, frequently used programs and data. It is designed and sequenced as it is manufactured and cannot be changed. With PROM, the programmer can decide on the subroutines, which are entered electronically at the beginning but are not easily changed.

Magnetic core storage has been widely used for the past ten years and has proved to be sufficiently fast, flexible, and reliable. Also, there are several advantages for using core for military applications, e.g., it is nonvolatile, i.e., if power is lost, the contents remain stable. Also included in this category is an older memory technology called "plated wire" used in a few of the early (pre-1970) small computers.

14. Memory Cycle Time. This is the minimum time interval, in microseconds, between two successive accesses to any one particular storage location. It is the time to read (and restore) a single word in memory.

Cycle times are directly related to the type (core versus MOS) and size (8K, 16K, etc.) of memory selected for the computer system. The cycle time values included in this study are those directly related to the type of memory selected, if this option was available.

15. Minimum Memory. This is the minimum capacity of the main memory/storage, in thousands of full words, of each particular computer. In most cases, this information was expressed in terms of bytes and had to be transformed to words to account for computers that do not utilize an 8-bit byte. The price for this memory is included in the unadjusted CPU price.
16. Maximum Memory. This is the maximum capacity of the main storage capacity of the main storage, expressed in thousands of full words, and is used as an indicator of minicomputer capability. The main memory is described by its word size and capacity. The word length is the amount of data that can be stored in one memory location, and the capacity is the total number of memory locations or words available. For this study, the maximum number of words is recorded, but this is later multiplied by word length to obtain the total cost impact in bits of a computer's capability, and used as variable X 5.
17. Memory Cost. This set of information provides data on memory economics, expressed in terms of cents per bit by type of memory. For some systems, processors are offered in several configurations, each having a different memory size. For these systems, cost per bit was calculated by examining the prices for various memory increments. In other cases, memory is offered as a separate increment or add-on memory, and the cost per bit was derived in this fashion. Memory cost is shown for each computer configuration and classified by type (semiconductor versus core) and time period (manufacturing technology).

18. Typical System Cost. The values shown are in thousands of "then year" dollars. This is an optional variable because of its peculiar nature, i.e., each application and customer may have unique preferences and requirements, so that any cost generalizations become difficult. The reason for including this "typical system cost" in the survey data is that it indicates the importance (and cost) of the peripherals. For BMD applications, the ratio of peripherals to CPU would be considerably smaller, and a "shopping list" approach would be used to select and price them.
19. CPU Cost. The values shown are in thousands of "then year" dollars. An attempt was made to normalize these figures to account for the same scope of costs for each system, i.e., the price to include CPU*, power supply, front panel, and minimum memory in the chassis (as identified in data set variable number 15). In general, an attempt was made to record the prices quoted during the first several years after a model was introduced. This is imprecise since there are two (but luckily countervailing) trends. First, inflation would tend to raise the prices as time progresses. But, secondly, the intense competitive market place would tend to force the manufacturers to lower their prices of the older models. The prices collected are associated with quantity buys of around 10 for identical configurations. Subsection 5.3 discusses how to make price-quantity adjustments.

* And any other processors, e.g., I/O, floating point.

20. Adjusted CPU Cost*. This is an adjustment of the CPU cost shown in data set number 19 to normalize such that each CPU would have the same minimum memory of 8K words. This figure will act as the dependent variable in the regression analysis, along with its word length acting as one of the independent variables. The adjusted CPU prices are analyzed and presented in 2 different ways -- non-inflated (then year dollars) and inflated (constant 1980 dollars). This is discussed further in Subsection 5.2.

* The terms "cost" and "price" are used interchangeably in this report. The manufacturer's price is the Government's cost.

5 ANALYSIS OF DATA

5.1 CORRELATION ANALYSIS

The next step in the scientific method process is to test the hypotheses developed in Section 3 using the data described in Section 4 and contained in Appendix A.

After an assessment of available correlation analysis techniques, it was decided to utilize a multiple regression (curve-fitting) program* called "Curves" developed by H. E. Boren, Jr., and Captain G. W. Corwin at The RAND Corporation in 1976. "Curves" was designed as a cost analysis tool, although its potential scope of application goes far beyond this. The program provides least-squares fits for eight equations representing alternative functional forms, most of which permit up to seven independent variables. These equations are listed below:

1. Linear

$$Y = A + B*X1 + C*X2 + \dots + H*X7$$

2. Quadratic

$$Y = A + B*X1 + C*X1**2$$

3. Power

$$Y = A*(X1**B) * (X2**C) * \dots * (X7**H)$$

4. Asymptotic-Power

$$Y = A + B* (X1**C)$$

5. Exponential

$$Y = \text{EXP}(A + B*X1 + C*X2 + \dots + H*X7)$$

6. Logarithmic-Linear

$$\text{ALOG}(Y) = \text{ALOG}(A) + B*\text{ALOG}(X1) + \dots + H*\text{ALOG}(X7)$$

7. Semilog-Linear - Log of dependent versus independent

$$\text{ALOG}(Y) = A + B*X1 + C*X2 + \dots + H*X7$$

8. Semilog-Linear - Dependent versus log of independent

$$Y = A + B*\text{ALOG}(X1) + C*\text{ALOG}(X2) + \dots + H*\text{ALOG}(X7)$$

* A full description and listing of the program appears in RAND Report R-1753-1-PR.

where:

Y = dependent variable

X1,X2,...,X7 = independent variables

A,B,...,H = parameters estimated by program

EXP = exponential function (e^x)

ALOG = natural logarithm function

It should be noted that only Equations 2 (Quadratic) and 4 (Asymptotic-Power) restrict the user to less than seven independent variables. Although Equation 6 (Log-linear) can be derived from Equation 3 (Power) by taking the log of both sides of 3, and likewise Equation 7 (Semilog-linear with log of dependent) can be derived from Equation 5 (Exponential), the parameters estimated by the equations will not be the same (except possibly for the case of perfect fit).

In addition to the estimates of the regression parameters, Curves calculates and prints various statistical measures of variance. The Curves report lists and defines these statistics. Included are the standard error of the estimate, standard deviation of the input variables, students' T-ratio, and Durbin-Watson statistic. Samples of the output sheets are presented in Appendix B.

Some of the statistical concerns stem from the fact that good statistical fits (e.g., high R^2 values) may not guarantee that the resulting CER will be meaningful and useful. The regression only reveals the best "mathematical fit." Therefore, in selecting the "best" CER among alternative equations, several factors have to be checked, including:

- a. Are the mathematical signs (+) correct?
- b. Are the CER coefficients meaningful?
- c. Does the CER functional form support the hypotheses?

5.2 CER DEVELOPMENT

Separate multiple regressions were run for the commercial and military computers. As referenced before, the data for the regressions are contained in Appendix A. The statistical analyses and variance parameters for each of the selected regressions are presented in Appendix B.

Of the 150 total regression analyses run, the preferred 20 CERs are presented next, followed by an explanation of the alternative cases.

COMMERCIAL PROCESSORS:

- a. 6 variables, uninflated \$, semi-log, $R^2 = .42$

$$\ln C = 5.29 - .0643 (X 1) + .01469 (X 2) + .0691 (X 3) + .774 (X 4) + .00000241 (X 5) + .717 (X 6)$$
$$C^* = 12.5$$

- b. 6 variables, constant 80\$, semi-log, $R^2 = .42$

$$\ln C = 7.61 - .0908 (X 1) + .0455 (X 2) + .0813 (X 3) + .731 (X 4) + .0000023 (X 5) + .708 (X 6)$$
$$C^* = 16.9$$

- c. 5 variables, constant 80\$, linear, $R^2 = .43$

$$C = 118 - 2 (X 1) + 1.53 (X 2) + 18.4 (X 4) + .0000336 (X 5) + 19.8 (X 6)$$
$$C^* = 25.6$$

- **d. 5 variables, constant 80\$, power, $R^2 = .46$

$$C = 1.4 \times 10^{12} (X 1)^{-6.56} (X 2)^{1.08} (X 4)^{.109} (X 5)^{.0476} (X 6)^{.974}$$
$$C^* = 26.7$$

- e. 4 variables, all with flt. pt. hdw., constant 80\$, linear, $R^2 = .36$

$$C = 138 - 1.94 (X 1) + 1.65 (X 2) + 25 (X 4) + .0000705 (X 5)$$
$$C^* = 30.6$$

- f. 4 variables, all with flt. pt. hdw., constant 80\$, power, $R^2 = .36$

$$C = 1.31 \times 10^{11} (X 1)^{-5.98} (X 2)^{.966} (X 4)^{.0845} (X 5)^{.113}$$
$$C^* = 34.4$$

See Footnote on Page 5-6.

MILITARY PROCESSORS:

- a. 6 variables, uninflated \$, log-linear, $R^2 = .84$

$$\begin{aligned}\ln C &= 36.1 - 11.1 (\ln X 1) + 4.61 (\ln X 2) + .489 (\ln X 3) \\ &+ .175 (\ln X 4) + .351 (\ln X 5) + .498 (\ln X 6) \\ C^* &= 33.5\end{aligned}$$

- b. 6 variables, constant 80\$, log-linear, $R^2 = .86$

$$\begin{aligned}\ln C &= 51.6 - 14.8 (\ln X 1) + 4.9 (\ln X 2) + .414 (\ln X 3) \\ &+ .237 (\ln X 4) + .340 (\ln X 5) + .768 (\ln X 6) \\ C^* &= 43.1\end{aligned}$$

- **c. 5 variables, constant 80\$, power, $R^2 = .87$

$$\begin{aligned}C &= 7.05 \times 10^{25} (X 1)^{-17.6} (X 2)^{6.11} (X 4)^{.0174} (X 5)^{.437} (X 6)^{1.02} \\ C^* &= 64.1\end{aligned}$$

- d. 4 variables, all with flt. pt. hdw., constant 80\$, linear, $R^2 = .60$

$$\begin{aligned}C &= 499 - 7.79 (X 1) + 7.94 (X 2) + 18.9 (X 4) + .00359 (X 5) \\ C^* &= 54.4\end{aligned}$$

- e. 4 variables, all with flt. pt. hdw., constant 80\$, power, $R^2 = .57$

$$\begin{aligned}C &= 1.41 \times 10^{18} (X 1)^{-10.5} (X 2)^{1.92} (X 4)^{.0872} (X 5)^{.310} \\ C^* &= 67.9\end{aligned}$$

- f. 4 variables, all with flt. pt. hdw., constant 80\$, log-linear, $R^2 = .69$

$$\begin{aligned}\ln C &= 46.3 - 13 (\ln X 1) + 4.33 (\ln X 2) + .405 (\ln X 4) + .324 (\ln X 5) \\ C^* &= 48.4\end{aligned}$$

See Footnote on Page 5-6.

COMMERCIAL MEMORY (SEMICONDUCTOR):

- a. 2 variables, uninflated \$, semi-log, $R^2 = .38$

$$\ln C_m = 13.5 - .179 (X_1) - .0655 (X_{2_m})$$

$$C_m^* = .85$$

- b. 2 variables, constant 80\$, linear, $R^2 = .33$

$$C_m = 25.6 - .316 (X_1) - .0636 (X_{2_m})$$

$$C_m^* = 1.48$$

- c. 2 variables, constant 80\$, semi-log, $R^2 = .46$

$$\ln C_m = 16.6 - .216 (X_1) - .0849 (X_{2_m})$$

$$C_m^* = 1.08$$

COMMERCIAL MEMORY (CORE):

- a. 2 variables, uninflated \$, exponential, $R^2 = .67$

$$C_m = \text{Exp} [28 - .359(X_1) - .996(X_{2_m})]$$

$$C_m^* = 2.16$$

- b. 2 variables, constant 80\$, linear, $R^2 = .39$

$$C_m = 186 - 2.41 (X_1) - 2.83 (X_{2_m})$$

$$C_m^* = 6.69$$

- c. 2 variables, constant 80\$, exponential, $R^2 = .68$

$$C_m = \text{Exp} [28.9 - .365(X_1) - .986(X_{2_m})]$$

$$C_m^* = 3.27$$

See Footnote on Page 5-6.

MILITARY MEMORY (CORE):

- a. 2 variables, constant 80\$, linear, $R^2 = .06$

$$C_m = 29.6 - .253 (X_1) - 4.97 (X_{2m})$$

$$C_m^* = 4.88$$

- b. 2 variables, constant 80\$, exponential, $R^2 = .09$

$$C_m = \text{Exp} [10.2 - .0879(X_1) - 1.75(X_{2m})]$$

$$C_m^* = 4.74$$

where:

C = CPU Cost including power supply, front panel, and 8K words internal main memory, \$thousands, for either uninflated or constant '80\$ case.

C_m = Memory Cost per bit, cents, for either uninflated or constant '80\$ case.

X_1 = First Delivery, year (last 2 digits), where $65 \leq X_1 \leq 80$.

X_2 = Word Length, bits

X_{2m} = Memory Cycle, microseconds

X_3 = Memory Type, where 1 = semiconductor; 2 = core

X_4 = Millions of Instructions Per Second (MIPS)

X_5 = Maximum Memory (K words x word length), thousands of bits

X_6 = Floating Point Hardware, where 1 = No or option; 2 = Yes

* C values are calculated using the "mean" X values shown in Appendix B.

** Preferred CERS to use; for add-on memory costs, use Table 1 instead of the CERS.

TABLE 1

DIFFERENTIAL MEMORY PRICES

<u>Year</u>	Typical Prices (cents per bit)		Differentials	
	<u>Core</u>	<u>Semiconductor</u>	<u>Uninflated</u>	<u>Inflated</u>
1964	4.5	2.5	2.0	3.3
1965	4.3	2.3	2.0	3.2
1966	4.0	2.2	1.8	2.8
1967	3.7	2.0	1.7	2.6
1968	3.6	2.0	1.6	2.5
1969	3.5	1.9	1.6	2.5
1970	3.2	1.8	1.4	2.2
1971	3.0	1.6	1.4	2.1
1972	2.7	1.5	1.2	1.8
1973	2.4	1.3	1.1	1.6
1974	2.1	1.2	0.9	1.4
1975	1.9	1.0	0.9	1.2
1976	1.6	0.9	0.7	0.9
1977	1.3	0.7	0.6	0.8
1978	1.1	0.5	0.6	0.7
1979	1.0	0.4	0.6	0.7
1980	1.0	0.4	0.6	0.7

The descriptors for the 20 preferred CERs will now be explained. The 6 variable case means that there were 6 independent variables (X1, X2, X3, X4, X5 and X6) correlated to the one dependent variable, C. Since many of these regression results were unsatisfying, it was then decided to search for better fits by eliminating certain variables that could be "normalized" by adjusting the data base properly. Hence, for the 5 variable cases, X3 (memory type) was dropped, and the memory was normalized such that all commercial computers had 8K words semiconductor memory, and all military computers had 8K words core memory. The adjustments were computerized by using the differential costs shown in Table 1 which were to be added or subtracted as appropriate. For the 4 variable cases, both X3 and X6 were dropped. The memory type (X3) was normalized as just described, and, in addition, the floating point option (X6) was normalized such that all computers had the hardware floating point capability. The algorithm used to add floating point is shown in Figure 1. The function, $FPH\$ = 3 + .067 (CPU\$)$, is an "eyeball" fit to the data consisting of 16 commercial and military computer cases. This same cost function can be used to subtract floating point cost from the 4 variable cases, if desired.

The second descriptor is whether the case is uninflated or inflated (i.e., in constant 1980 dollars). Normally, one would prefer the "constant dollar" case, but both cases are shown here because there is a price index problem; there appears to be no accurate price index series to properly adjust for inflation. Table 2 shows candidate price index series published by the Bureau of Labor Statistics (BLS) and Department of Defense (DOD). It is believed that the series in columns 4 and 5 are based on output factor prices*. It is hoped that column 3 (BLS Series 11.78) indexes are based on input factor (in the economic theory sense) differentials. As shown in

* In economic terms, output factors are finished goods prices, while input factors are prices of the basic resources used in production such as hourly labor cost, cost per pound of material, etc. In adjusting for price inflation, it would be preferable to use an index series based on input factors.

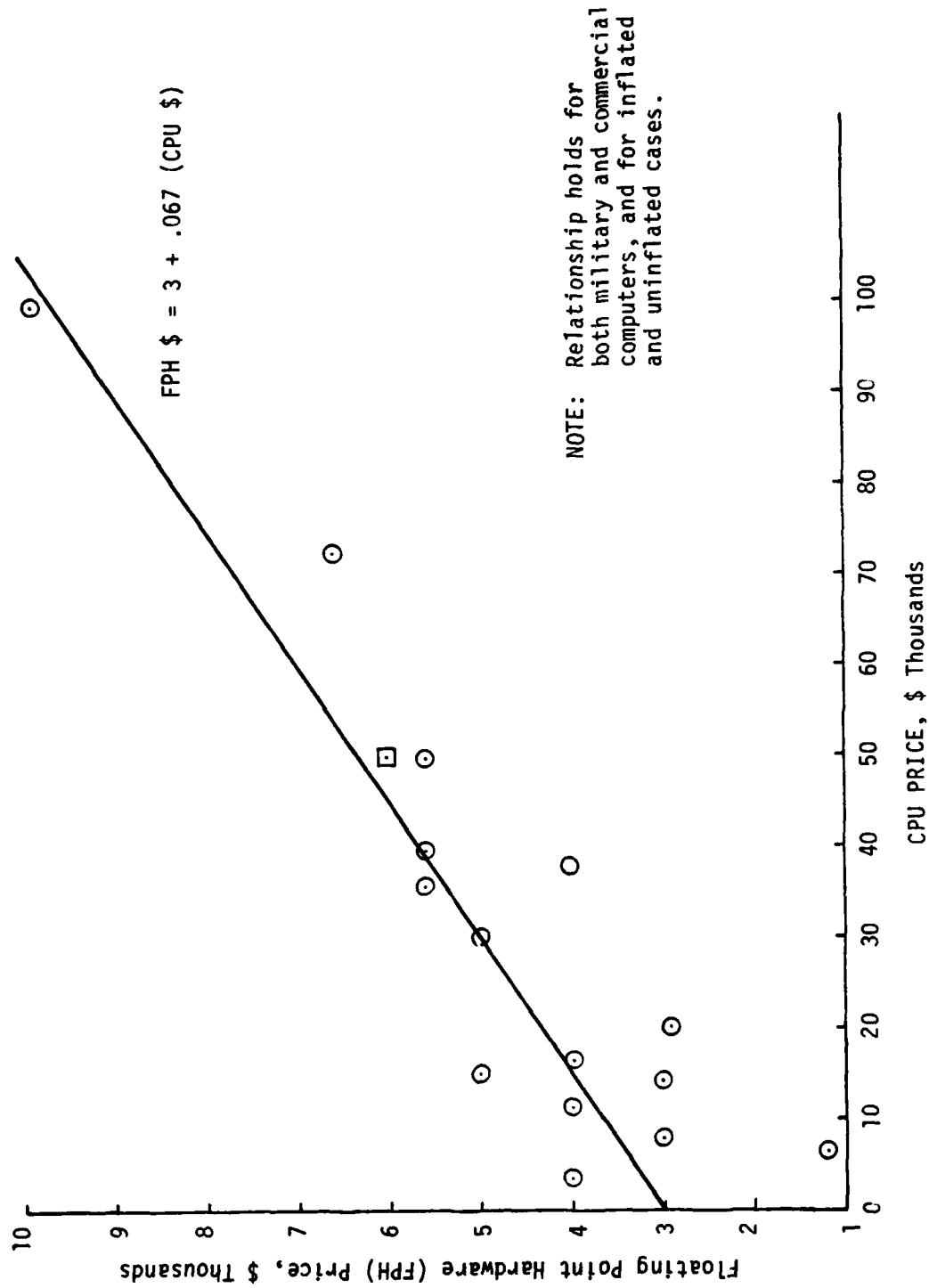


Figure 1. Floating Point Hardware Price Vs. CPU Price (Unadjusted \$ Thousands)

TABLE 2
ALTERNATIVE PRICE INDEX SERIES

(1)	(2)	(3)	(4)	(5)	(6)
	<u>BLS COMMODITY CODE</u>			<u>DOD</u>	<u>BLS</u>
	11.7	11.78	11.7842		11.78
<u>CAL. YEAR</u>	<u>ELECTRICAL MACH + EQPT</u>	<u>ELECTRONIC COM + ACCES</u>	<u>DIGITAL MOS ICs</u>	<u>COMPUTER PURCHASES(FY)</u>	<u>ADJUSTED TO 1980=0</u>
1965	95.1	97.5(est)		36.3	62.4
1966	97.2	99.7		38.0	63.8
1967	100.0	100.0		39.9	64.0
1968	101.3	99.2		41.9	63.5
1969	102.9	100.7		42.8	64.5
1970	106.4	101.0		44.7	64.7
1971	109.2	102.4		46.8	65.6
1972	110.4	103.4		48.7	66.2
1973	112.4	104.4		50.4	66.8
1974	125.0	111.4		55.2	71.3
1975	140.7	115.5	77.7	62.9	73.9
1976	146.7	115.8	63.4	67.3	74.1
1977	154.1	119.5	59.4	72.1	76.5
1978	164.9	126.9	53.7	77.1	81.2
1979	178.9	135.8	51.2	84.0	86.9
1980	205.7(est)	156.2(est)	58.9(est)	91.8(est)	100.0

Table 3, the inflated results are particularly sensitive to the inflation rate selected. The BLS Series 11.78 was considered to be the most appropriate index, so it was normalized to where 1980 = 100 (column 6 of Table 2) and used for the inflated (constant 1980 dollar) cases.

The next descriptor stipulates the mathematical form of the equation (linear, power, exponential, etc.), and the last descriptor shows the value for R^2 , Coefficient of Determination, on the statistical fit.

Care must be taken to interpret the proper independent variables when examining the computerized regression output sheets in Appendix B. For example, in the 5 variable cases, X5 is floating point option -- while in the 6 variable cases, X6 represents this variable. These variables have been standardized, however, in the equations stipulated in this Subsection.

Among the 20 equations presented in this Subsection, the two preferred CERs (for commercial processors and military processors) are marked with double asterisks. Also, these two preferred cases have complete computer printouts with all the related statistical information in Appendix B.

It should also be noted that complete definitions for the independent variables (X1 through X6) are presented in Subsection 4.3.

5.3 PRICE-QUANTITY ADJUSTMENTS

The CERs yield cost estimates for the same quantities implied in the data base. An attempt was made to collect price data that applied to single-buy procurements of around ten. According to the military manufacturers, the military equipments are seldom ordered in lots of much over ten of the exact same configuration. Whatever the quantity, the Government would probably receive their 9-10 percent GSA discount. For large purchases of like commercial equipment, substantial discounts (or quantity savings) are available, perhaps as high as 40 percent. In any event, the unit costs can be adjusted quite easily to reflect various types of procurements.

TABLE 3
VARYING INFLATION RATES

<u>PRICE INDEX SERIES</u>		<u>1965→1979</u>	<u>1965→1980</u>
DOD	COMPUTER PURCHASES	231%	253%
BLS	ELECTRONICS COMPONENTS & ACCESSORIES, SERIES 11.78	138%	160%
BLS	ELECTRICAL MACHINERY & EQUIPMENT, SERIES 11.7	188%	216%

5.4 MILITARIZATION REQUIREMENTS AND PRICES

Military computers are usually designed to meet a long list of environmental extremes which would seriously impact operation of a commercial mini/midicomputer. Although the military equipment is usually software and media-compatible with their Mil-Spec commercial counterparts, their design, packaging, production processes, and testing procedures are quite different. Additionally, the military versions are designed and packaged in such a way to be easily supportable in the field.

Most of the militarized computer systems are designed to meet all three of the key military specifications:

MIL-E-5400	Airborne
MIL-E-16400	Shipboard
MIL-E-4158	Land

A typical set of Mil-Specs might be as listed below:

Standard Configuration - Case Temperature

Standard:	0°C to +65°C
Wide:	-25°C to +75°C
Extreme:	-55°C to +95°C

Vibration

10g, 5-2000 Hz, with vibration isolators (MIL-E-5400, Curve 1Va); 2g, 5-2000 Hz, hard-mounted (MIL-E-5400, Curve 11a).

Shock

15g, 11ms operating; 30g, 11ms crash safety (MIL-E-5400).
High Impact shipboard equipment, (400 lb Hammer blow)
per MIL-S-901, Grade A, Range 1 (Hardmount) (MIL-E-16400)

Humidity

95% relative

EMI Characteristics

MIL-STD-461 (400 Hz supply only)

Altitude

50,000 ft pressure altitude

Bench Handling, Explosive Atmosphere, Sand and Dust, Salt Spray and Salt Fog, and Fungus

per MIL-STD-810B

Power

+28 $\pm$ 8 Vdc $\leq$ 90 watts standard. Optional 400 Hz
115 Vac (per MIL-STD-704A, Category B)

Chassis Size

1/2 ATR (or 1 Full ATR)

Weight

___ lb with ___ K memory less I/O interfaces

In addition to the above, special electromagnetic pulse (EMP) and transient radiation effects (TRE) requirements may have to be met. Typical nuclear environment specifications might include the following elements and levels:

Radiation

Gamma dose rate: 10^8 Rad/Sec

Neutron fluence: 10^{12} n/cm²

Total ionizing dose: 3000 Rad(Si)

EMP

Damped sine wave (500 V, 10 kHz to 100 MHz, Q = 25)

The differences in cost between commercial and military computers can be derived by using several different approaches:

- (a) to use the separate CERs for commercial and military computers and to input the (differing) "mean" industry average values into the equations for various time periods;
- (b) to, again, use the separate CERs for commercial and military computers but to input the same performance values into the equations for the mean year 1976; and
- (c) to examine specific case examples and calculate an average factor differential.

All three of these approaches were used and the results are shown in Table 4. Using the alternative approaches, the resulting average factors were 2.2, 1.4, and 2.9. The simple average (mean) of these three is 2.2. It must be remembered that there are shortcomings in using any of these approaches. A conclusion might be drawn that a factor differential of 2 to 2.5 does not seem unreasonable.

5.5 TECHNOLOGY ANALYSIS

Since the equations developed in Subsection 5.2 relate technology with prices and performance, it becomes possible to insert the performance values (industry means) into the estimating equations and calculate the resulting processor price separately for each year. This shows the effect that technology has on prices.

The problem is: what set of assumptions and which set of equations best represent the situation? Since there is a basic uncertainty about the inflation index, and several equation forms to consider, it was decided to calculate technology time versus price under varying conditions and regard the concomitant results as boundaries (i.e., calculate a range of possible values).

TABLE 4
COMMERCIAL VS. MILITARY COMPUTER PRICES

- a. GENERALIZED EQUATIONS USING LINEAR, 6 VARIABLE, UNINFLATED EQUATIONS WITH SEPARATE "INDUSTRY AVERAGE" INPUTS:

	<u>1965</u>	<u>1980</u>
COMMERCIAL	\$32K	\$14K
MILITARY	\$82K	\$27K
DIFFERENTIAL PRICE FACTOR	2.6	1.9
AVERAGE MEDIAN FACTOR		2.2

- b. GENERALIZED EQUATIONS USING LINEAR, 6 VARIABLE, UNINFLATED EQUATIONS WITH COMMON "INDUSTRY AVERAGE" INPUTS:

	<u>1976</u>
COMMERCIAL	\$32K
MILITARY	\$44K
DIFFERENTIAL PRICE FACTOR	1.4

TABLE 4 (Con't)

c. CASE EXAMPLES USING CPU NORMALIZED PRICES (WITH 8KW MEMORY),
INFLATED-CONSTANT 1980\$:

	<u>COMMERCIAL</u>	<u>MILITARY</u>	<u>FACTOR</u>
DEC 11-34A	\$11.7K		
UT NORDEN 11-34M		\$53.2K	
PRICE DIFFERENTIAL			4.5
HONEYWELL 6/36	\$8.9K		
HONEYWELL 6/36		\$34.8K	
PRICE DIFFERENTIAL			3.9
DATA GENERAL ECLIPSE S-230	\$16.2K		
ROLM MSE-20		\$39.5K	
PRICE DIFFERENTIAL			2.4
DEC 11-70	\$85.2K		
UT NORDEN M2-11/70A		\$116.3K	
PRICE DIFFERENTIAL			1.4
DATA GENERAL NOVA 3/12	\$5.7K		
ROLM 1603A (UYK-12)		\$14.0K	
PRICE DIFFERENTIAL			2.4
AVERAGE MEAN FACTOR, $\frac{14.6}{5} =$			2.9

Examples of results which can be calculated from the equations are shown in Figures 2, 3, and 4. Note that each figure shows results for both the uninflated and inflated (constant 1980\$) cases. In Figure 2, the 4 variable case (top line) has floating point and semiconductor (MOS) memory for the commercial processors. It can be seen how the power functional form equation "crosses" the linear function at the mean year, 1976. As shown, the reduction in price from technology averages about 15 to 26 percent per year for these size computers.

Figure 3 shows similar results for the military processors but with the reduction in price from 20 to 43 percent annually. However, it should be kept in mind that there were no data for this curve prior to 1972.

Figure 4 is an example for commercial memory of the MOS type. Since the memory CERs were not statistically sound, it is recommended that the typical memory price values shown in Table 1 be used for technology analysis in lieu of the CER results.

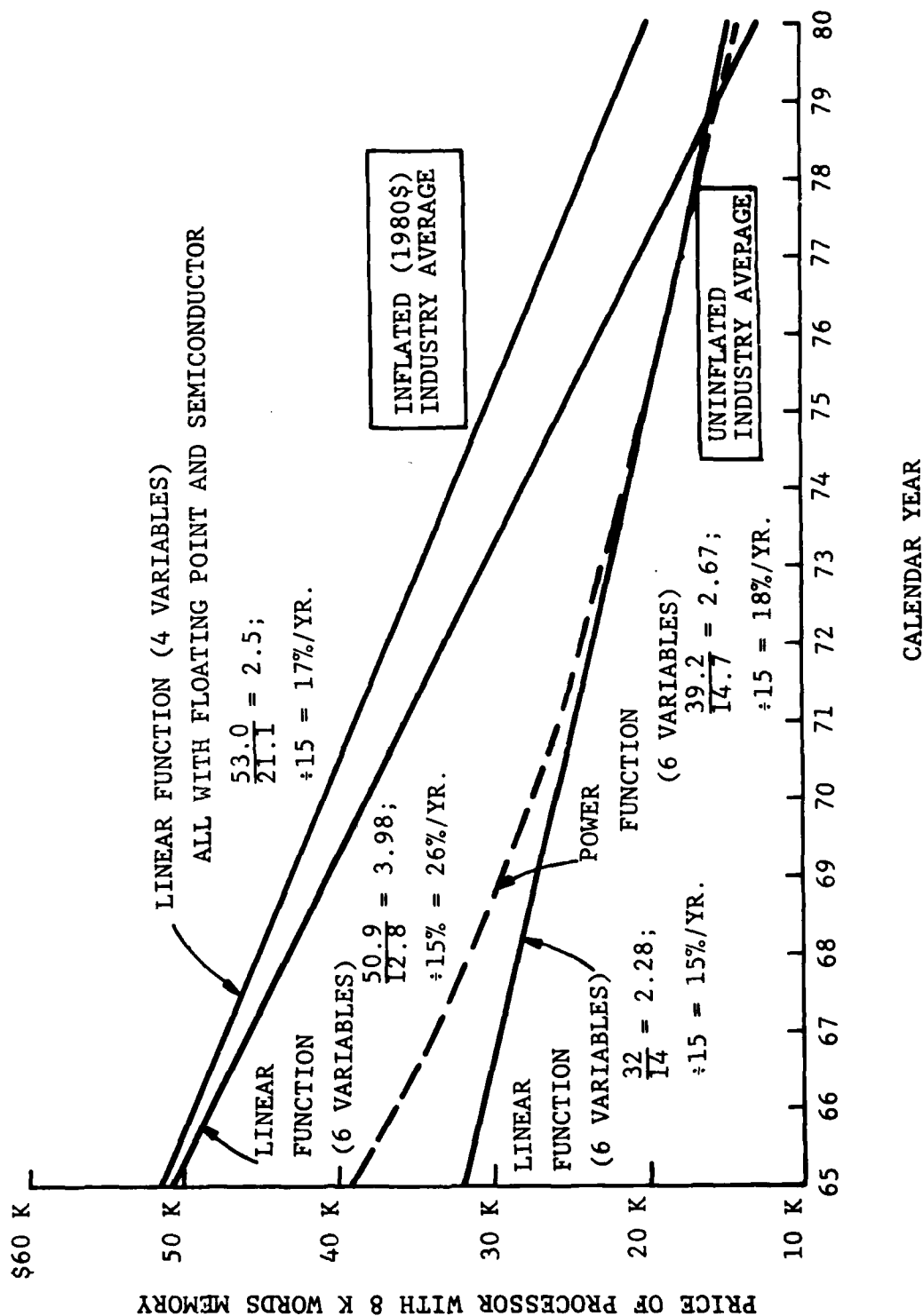


Figure 2. Technology Effect on Commercial CPU Price

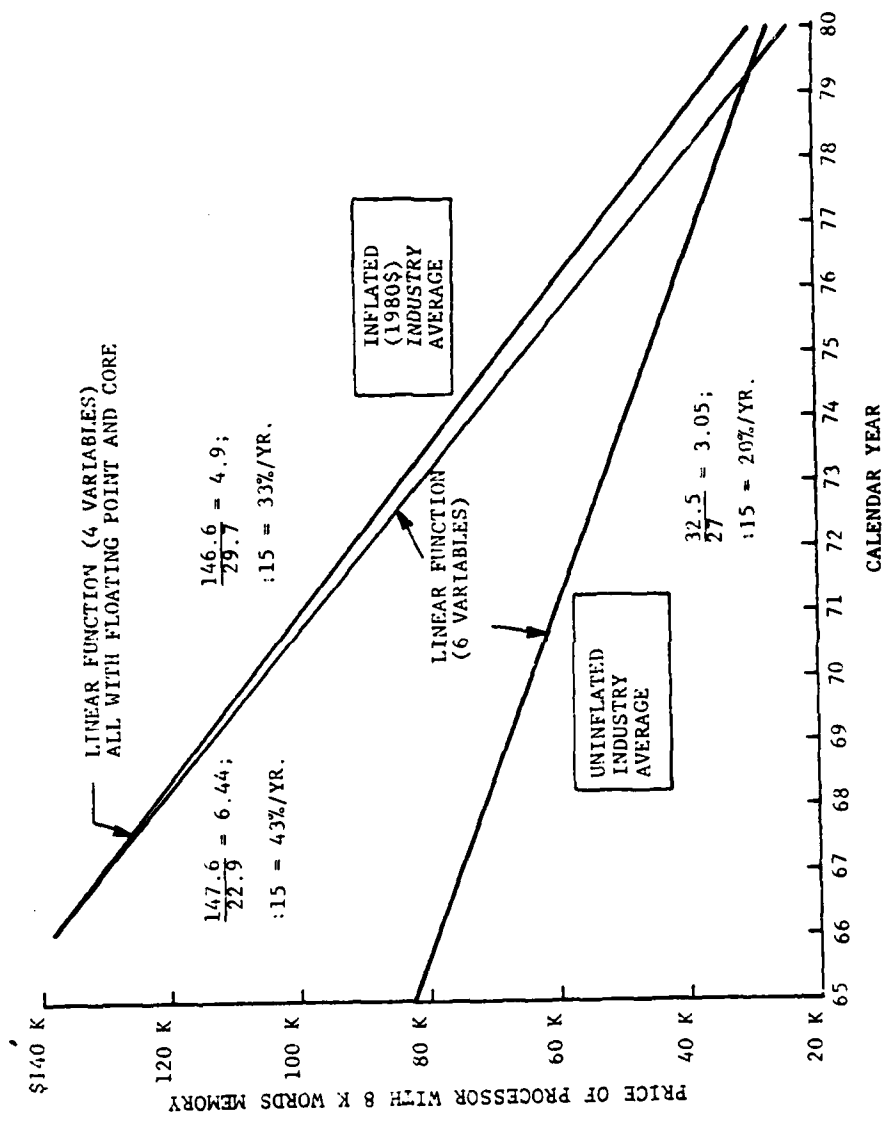


Figure 3. Technology Effect on Military CPU Price

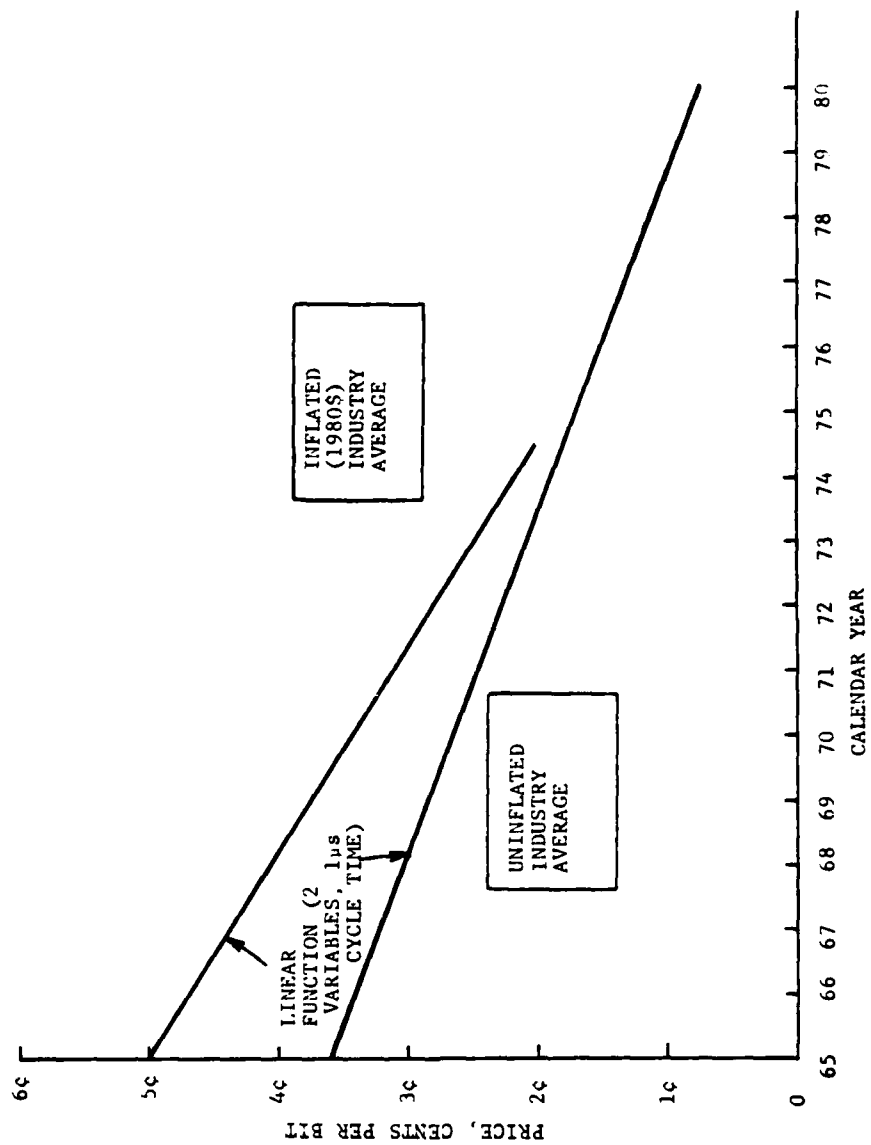


Figure 4. Technology Effect on Commercial Semiconductor Memory Price

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 DATA BASE UPDATING

The key functional characteristics, technology year, and costs have been collected for 203 commercial and 13 military mini/midicomputers from 46 different manufacturers for the time period 1965 to 1980 and this data are included as Appendix A. This data should prove useful to the Army BMDO, and it is recommended that the data base be continuously improved and updated as newer configurations and models are introduced.

6.2 CER DEVELOPMENT

Cost Estimating Relationships have been developed for both commercial and military mini/midicomputers, and they are presented in Section 5.2. These can be used when a general purpose computer is needed in a technology or advanced concept study where precise computer specifications and performance criteria have not been completely defined.

The statistics of variance were adequately high for the military equipment ($R^2 = .57$ to $.87$) but quite low for the commercial mini/midicomputers ($R^2 = .38$ to $.46$). Although this was quite disappointing, it was not surprising considering the large number of different manufacturers that have become involved over the past decade in this complex market place. There is a very wide range of cost-performance ratios for equipment in the commercial market, ranging from low to high. This accounts for some of the disparity in the data. In either case, the estimating equations reflect the averages in the industry.

6.3 MILITARIZATION EFFECTS

From the set of military specifications included in Subsection 5.4, it can be seen why military computer versions cost more than their commercial counterparts. Several different approaches have been taken to quantify the price differential which ranged from 1.4 to 2.9. It was felt that a factor differential of 2 to 2.5 would not be unreasonable for early planning purposes, until specific designs and pricing have been accomplished.

6.4 TECHNOLOGY TRENDS

A number of different assumptions and approaches were taken. The results showed that technology reduced the price of commercial computers about 15 to 26 percent annually. The corresponding results for military computers showed 20 to 43 percent annually.

APPENDIX A

DATA BASE FOR
COMMERCIAL AND MILITARY
MINI/MIDICOMPUTERS

COMPUTER MFG. AND MODEL	FIRST YEAR	WORD LENGTH (BITS)	MICROSECS PER INSTRUCTION			MIPS	FLOAT	DMA	NO. OF ACCUMS	NO. OF I/O CHNLS
			ADD	MULT.	DIVIDE					
AID SYSTEM 2000	75	16	1.2			.177	NO	YES	16	
AJL 1500	77	4	4.0			.061	NO	YES	128	
BUR B1705	76	24	.5	2.5		.522	NO	NO		10
BUR B1720-1	76	24	.33	1.6		.483	NO	NO		10
CAD SYSTEM 20	78	8	6			.037	NO	YES	1	
CAD SYSTEM 40/4	78	8	3.2			.059	NO	YES	1	
CDI CONCEPT 2	70	16	6.8			.041	NO	YES	15	
CDI CONCEPT 1	77	16	7.5			.034	NO	YES	16	
CDP X1/35	74	16	4.2	12.9		.120	NO	YES	8	
CDP C0135	73	16	2			.114	NO	YES	8	
CCC 200	69	8	1.6			.167	NO	YES	16	
CCC 300	71	8	2.0			.130	YES	NO	16	4
CCC 1000	77	16	2.6			.112	YES	YES	16	
CML CIP/2200	71	8	12.5	69.5		.026	NO		32	
C4C CIP/2200B	74	8	10			.025	NO			
CAI LSI-2/10	73	18	4.1	14.8		.082	NO	YES	1	4
CAI LSI-3/05	75	16	6.2			.039	NO	YES	1	4
CAI LSI-4/90(MINI 4)	77	16	1.5	11.9	12.3	.175	NO	NO	2	8
CAI SYFA(15010)	76	16	2.4	12.8	15.1	.126	NO			
COI OFUS 3	70	8	2	19.4		.108	NO			
CHI 2130	74	16	1.6			.178	NO	YES	8	32
CHI 3230	76	16	2.7			.106	NO	YES	8	32
CHI 4210	77	16	4.7			.079	NO	YES	16	4
CHI 4250	76	16	5.5			.103	NO	YES	16	16
CDC CYBER 18-17A	73	17	1.6	17.4	17.4	.121	YES	YES	2	
CDC CYBER 18-20	76	21	1.76	6.6	10.5	.202	NO	YES	6	
CDC CYBER 18-10M	75	17	1.76	6.6	10.5	.212	NO	YES	6	
CDC SYSTEM 17	73	17	1.8			.164	NO	YES		

COMPUTER MFG. AND MODEL	MEMORY CHARACTERISTICS					SYSTEM COST (\$K)	CPU COST (\$K)	ADJUSTED CPU COST (\$K)	
	TYPE	CYCLE (USECS)	SIZE (K WORDS)	MIN.	MAX.			THEN YEAR \$	1980 \$
AIU SYSTEM 2000	SEMI	.6	4	32	.62		2.8	3.20	4.33
AJ1 1500	CORE	.8	32	64	1.25		18.2	15.80	20.65
BUR 81705	SEMI	1	8	24	.23	126	26	26.00	35.09
BUR 81720-1	SEMI	.68	16	68	.23	150	67	66.56	69.82
CAD SYSTEM 20	SEMI	2.5	6	10	.5		5	5.08	6.26
CAD SYSTEM 40/4	SEMI	1.3	20	48	.5		7	6.52	8.03
CDI CONCEPT 2	CORE	1.2	16	64	.94	30	22	20.80	32.14
CJI CONCEPT 3	CORE	1	16	64	.94		26.9	25.70	33.39
CDR-X1/33	CORE	.76	8	64	.78		9	9.00	12.62
CDP CUI35	CORE	.68	8	128	.78		9	9.00	13.47
CCC 200	SEMI	1	32	512	2		16.5	12.66	19.63
CCC 300	SEMI	.6	8	32	1.25	32	17	17.00	25.91
CCC 1000	SEMI	1.2	64	256	.5		20	15.52	20.29
CWC CIP/2200	SEMI	1.1	8	64	3.4		6.7	6.70	10.21
CWC CIP/2200J	SEMI	1.1	4	64	3.4		2.8	3.89	5.45
CAL LSI-2/10	CORE	.98	4	512	1.54	33	2.7	3.81	5.70
CAL LSI-3/05	SEMI	1.2	4	512	.86		.7	1.25	1.69
CAL LSI-4/50 (WAL 4)	SEMI	.55	4	256	.36	12	1	1.24	1.63
CAL SYFA (15010)	CORE	1.2	32	524	.97	102	29	25.28	34.11
CJI OPUS 3	CORE	1	4	16	.94		3.5	3.60	5.87
CHI 2130	SEMI	.8	8	2048	.58		32	32.00	44.68
CHA 3230	SEMI	1.6	8	64	.58		15	15.00	20.24
CHI 4210	SEMI	.47	16	26	.6	17	13	12.23	15.99
CHI 4250	SEMI	.47	48	1024	.63	25	25	20.97	25.82
CDC CYBER 18-17A	SEMI	.9	4	64	3.29	65	11.2	13.71	20.52
CDC CYBER 18-20	SEMI	.75	16	128	1.95	137	15.3	12.02	16.23
CDC CYBER 18-10M	SEMI	.75	8	32	1.95	60	13.7	13.70	18.54
CDC SYSTEM 17	SEMI	.8	8	64	3.69		17.3	17.30	25.90

COMPUTER MFG. AND MODEL	FIRST DELIV YEAR	WUNC LENGTH (BITS)	MICROSECS PER INSTRUCTION			MIPS	FLOAT	DMA	NO. OF ACCUMS	NO. OF I/O CHNLS
			ADD	MULT.	DIVIDE					
CDC 3100(3114)	65	24	3.25			.086	NO			4
ESP CSP-30 (SIGNAL PR00)	69	16	.2			1.430	YES		22	
UGC NUVA 600	71	17	.6			.219	NO	YES	4	
UGC NUVA 620	71	17	.6			.219	NO	YES	4	
UGC NUVA 630	74	17	.8			.202	NO	YES	4	
UGC NUVA 640	74	17	.6			.219	NO	YES	4	
UGC NUVA 1200	70	17	1.2			.146	NO	YES	4	
UGC NUVA 1210	72	17	1.2			.146	NO	YES	4	
UGC NUVA 1220	72	17	1.2			.146	NO	YES	4	
UGC MICRONUVA 656C	77	16	2.4	41.28	59.04	.063	NO	YES	4	
UGC MICRONUVA 656L	77	16	2.4	41.28	59.04	.063	NO	YES	4	
UGC MICRONUVA 8520A	79	16	2.4	41.28	59.04	.063	NO	YES	4	
UGC MICRONUVA 8670U	79	16	.84	4.92	5.52	.326	NO	YES	4	
UGC NUVA 2/4	73	17	.8			.219	NO	YES	4	
UGC NUVA 2/10	73	17	.8			.219	NO	YES	4	
UGC NUVA 3/4(8478)	76	17	.7	5.8	6.5	.135	NO	YES	4	
UGC NUVA 3/12(8486)	76	17	.7	5.8	6.5	.135	NO	YES	4	
UGC NUVA 3/0(8584)	76	17	.7	5.8	6.5	.275	NO	YES	4	
UGC NUVA 4/1(85506)	79	17	.2	4.4	5.4	.182	NO	YES	4	128
UGC NUVA 4/5(85546)	79	17	.2	4.4	5.4	.182	NO	YES	4	128
UGC NUVA 4/X(8398K)	79	17	.2	4.4	5.4	.182	NO	YES	4	128
UGC ECLIPSE S/100	75	21	.2			1.110	NO		4	
UGC ECLIPSE S/200	75	21	.2			1.110	NO		4	
UGC ECLIPSE L/300	75	21	.2			1.110	NO		4	
UGC ECLIPSE S/130(86106)	77	21	.6	7.2	8.2	.251	NO	YES	4	
UGC ECLIPSE S/230(85970)	76	21	.6	7.2	8.2	.239	NO	YES	4	
UGC ECLIPSE L/330(8599H)	76	21	.6	7.2	8.2	.239	YES	YES	4	
UGC ECLIPSE M/600(8630H)	76	21	.6	7.2	8.2	.275	YES	YES	4	

COMPUTER MFG. AND MODEL	PRIMARY CHARACTERISTICS				SYSTEM COST (\$K)	CPU COST (\$K)	ADJUSTED CPU COST (\$K)	
	TYPE	CYCLE (SECS)	SIZE (K AGRS)	PRG PAK			THEN YEAR	1980 \$
DEC 3100(3114)	CORE	1.75	4	32	9.66	726	54.27	86.96
CSP CSP-30 (SIGNAL PROC)	CORE	.1	4	128	37.2	160	58.81	91.18
DEC NOVA 800	CORE	.8	8	32	1.35	68	7.40	11.28
DEC NOVA 920	CORE	.8	8	64	1.55	70	7.50	11.43
DEC NOVA 830	CORE	1	16	128	.69	12.65	11.73	16.44
DEC NOVA 840	CORE	.8	16	128	.68	55	15.81	21.89
DEC NOVA 1200	CORE	1.2	4	32	4.61	44	7.01	10.84
DEC NOVA 1210	CORE	1.2	4	32	1.41	43	4.36	7.49
DEC NOVA 1220	CORE	1.2	4	48	1.41	44	5.86	8.85
DEC MICRONOVA 8560	SEMI	.96	2	32	.74	2.6	3.31	4.33
DEC MICRONOVA 8561	SEMI	.96	2	32	.74	2	2.71	3.34
DEC MICRONOVA 8520A	SEMI	.96	4	64	.74	1.7	2.17	2.50
DEC MICRONOVA 86700	SEMI	.5	16	32	.74	3.7	2.75	3.17
DEC NOVA 2/4	CORE	.8	4	32	1.56	42	4.56	6.83
DEC NOVA 2/10	CORE	.8	8	64	1.56	43	4.40	6.59
DEC NOVA 3/4(8476)	SEMI	.7	4	32	.93	35	3.23	4.36
DEC NOVA 3/12(8486)	SEMI	.7	4	128	.93	44	4.23	5.71
DEC NOVA 3/16(8544)	CORE	.7	32	128	.93	60	10.61	14.31
DEC NOVA 4/C(83306)	SEMI	.4	16	32	.27	2.8	2.43	2.80
DEC NOVA 4/S(83326)	SEMI	.4	16	32	.23	5.8	5.49	6.31
DEC NOVA 4/X(83344)	SEMI	.4	64	128	.26	10.4	7.92	9.12
DEC ECLIPSE S/100	CORE	.2	8	64	2.89	70	11.20	15.16
DEC ECLIPSE S/200	CORE	.2	16	128	2.89	78	14.44	19.55
DEC ECLIPSE C/100	CORE	.2	32	128	2.89	125	25.13	31.31
DEC ECLIPSE S/150(86100)	CORE	.7	8	128	1.76	60	5.20	12.03
DEC ECLIPSE S/250(85270)	CORE	.8	16	256	1.76	135	12.04	16.25
DEC ECLIPSE C/150(85590)	CORE	.8	32	256	1.76	110	21.13	28.51
DEC ECLIPSE P/600(86300)	SEMI	.5	32	1024	1.17	275	56.10	69.09

COMPUTER AFG. AND MCCLL	FIRST CELL YEAR	WORD LENGTH (BITS)	INSTRUCTIONS PER INSTRUCTION				MIPS	FLOAT	DMA	NO. OF ACCUMS	NO. OF I/O CHNLS
			ADD	MULT.	DIVIDE						
DSC C/150 ECLIPSE	79	21	.6	4	5.85	.495	YES	YES	4		
DSC S/250 ECLIPSE	79	21	.54	8.5	7.4	.566	YES	YES	8		
DSC C/350 ECLIPSE	79	21	.6	4	5.85	.495	YES	NO	8		
DSC M/2000 ECLIPSE	80	39	.22			1.190	YES	YES	8	57	
DPC 1500	77	8	1.8			.126	NO	NO	2		
DPC 1800	70	8	3.8			.065	NO	YES	2		
DPC 2200	72	8	3.2			.066	NO	YES	14		
DCC D-116H	72	16	1.0	4.0	3.2	.250	NO	YES	4	52	
DEC PDP-8/A	74	12	4.5	7.4		.122	NO	YES	1	64	
DEC PDP-11/03	76	18	3.5			.090	NO	YES	6		
DEC PDP-11/04	75	18	3.17	5.9	11.3	.140	NO	YES	6		
DEC PDP-11/35	74	18	1.07	9.16	11.58	.183	NO	YES	6	4096	
DEC PDP-11/44	80	18	.87			.363	NO	YES	8		
DEC PDP-11/45	72	18	.97	3.89	8.35	.263	NO	YES	12		
DEC PDP-11/60	77	18	2.2			.134	YES	YES	8		
DEC PDP-11/70	73	18	.4	3.4	7.9	.307	NO	YES	8		
DEC PDP-11/34A	76	18	2.03	8.9	12.6	.180	NO	YES	8		
DEC VAX-11/780	78	32	.4			.735	YES	YES	16		
DGI SYSTEMS	76	8	2.5			.070	NO	YES	16		
DSC 4036	70	18	2.9			.066	YES	YES	14		
DSC 5010	72	18	1.44			.217	NO	YES	2		
DSC MLTA 4	70	18	1.37			.226	NO	YES			
DSY MODEL 130	78	8	.5			.571	NO	YES	10		
FAI F8400	79	64	6.0			.043	YES	YES	256		
GAI 16/40	70	16	1.4	12.6	23.1	.132	NO	NO	3		
GAI 16/110	76	17	2.4	19.5	19.5	.117	NO	YES	6		
GAI 16/220	76	18	2.1	19.5	19.5	.115	NO	YES	6		
GAI 16/330	76	18	1.9	18.45	18.45	.120	NO	YES	6		

COMPUTER MFG. AND MODEL	MEMORY CHARACTERISTICS					SYSTEM COST (\$K)	CPU COST (\$K)	ADJUSTED CPU COST (\$K)	
	TYPE	CYCLE (USECS)	SIZE (K WORDS)	MIN	MAX			THEN YEAR \$	1980 \$
UGC C/150 ECLIPSE	CORE	.2	64	512	1.17	75	34	20.24	23.29
UGC S/250 ECLIPSE	CORE	.2	32	1024	1.17	140	30	24.10	27.74
UGC J/350 ECLIPSE	CORE	.2	32	1024	1.17	153	49	43.10	49.60
UGC M/2000 ECLIPSE	SEMI	.1+5	128	512	.34	165	106.4	90.49	90.49
OPC 1500	SEMI	.65	32	32	.75	17	5.95	4.51	5.90
UPC 1600	SEMI	.63	64	64	.6	19	5.5	2.81	3.46
UPC 2200	SEMI	1.6	4	16	2.0	40	8.6	9.24	13.96
DEC D-116H	SEMI	1.2	8	64	1.5	20	7.0	7.00	10.57
DEC PDP-8/A	CORE	1.4	1	16	2.97	10	1.84	4.53	6.08
DEC PDP-11/45	CORE	1.15	4	32	.77	15	2.0	2.55	3.45
DEC PDP-11/70	CORE	.98	8	32	.86	20	4.0	4.00	5.41
DEC PDP-11/55	CORE	.98	16	128	.43	30	19.8	19.18	26.90
DEC PDP-11/44	SEMI	.29	256	1024	.29	23.9	23.9	10.95	10.95
DEC PDP-11/45	CORE	.96	32	128	.43	42	39.6	37.74	57.01
DEC PDP-11/60	CORE	.92	32	256	.65	100	35.7	32.69	43.00
DEC PDP-11/70	CORE	.98	64	1024	.43	120	67.3	62.57	85.20
DEC PDP-11/34A	SEMI	.98	16	128	.625	51.9	9.1	6.20	11.07
DEC VAX-11/780	SEMI	.5	32	512	.625	180	99.7	94.90	116.87
DGI SYSTEMS	SEMI	2.5	10	64	.27		2.0	1.96	2.64
USC 4030	CORE	4.0	8	128	5.12		33.85	33.85	52.32
USC 5010	SEMI	.5	4	32	1.56		18.0	19.12	28.89
USC META 4	SEMI	.5	8	64	1.56	55	21.25	21.25	32.84
USV MODEL 150	SEMI	.5	64	128	1.76	57	34.7	26.82	36.19
FAL F6400	SEMI	.5	32	3750	.4		68.7	62.56	71.99
GAI 16/40	CORE	1.4	4	32	5.12	36	5.55	7.55	11.66
GAI 16/110	SEMI	.5	2	64	1.27		2.1	3.40	4.58
GAI 16/220	SEMI	.7	2	32	1.41	10	2.29	3.01	5.15
GAI 16/330	CORE	.72	4	32	1.27	30	4.45	5.36	7.24

COMPUTER MFG. AND MODEL	FIRST DELIV YEAR	WORD LENGTH (BITS)	MICROSECS PER INSTRUCTION			MIPS	FLOAT	CMA	NO. OF ACCUMS	NO. OF I/O CHNLS
			ADD	MULT.	DIVIDE					
GAI 16/550	77	18	.40			.454	NO	YES	6	
GAI 16/460	76	18	.70			.285	NO	YES	6	
GAI 16-60/65	71	16	.90	5.20		.235	NO			64
GAI 16-80/85	71	16	.8	4.4		.287	NO			64
GRI 99/50	76	18	1.70	68.0		.040	NO	YES	8	4096
GRI 99/30	72	16	1.70	60.0		.040	NO			4096
MCP SLASH 4-1	73	26	1.5			.230	NO	NO	5	
MCP SLASH 6	76	29	1.2			.320	NO	NO	5	
MCP SLASH 7	75	26	1.1			.377	NO	NO	5	
MCP HB00	80	48	.135			1.090	YES	YES	5	128
MCP H100(110-SLASH 41	77	26	1.5			.190	NO	YES	5	32
MCP H200(210-SLASH 7)	77	26	1.12			.241	YES	YES	5	
MPC HP2100A/S	71	16	1.96	10.8		.152	NO			14
MPC HP21MA	74	16	1.94	13		.152	YES			14
MPC HP1000W(2100)	74	17	1.9	12.5	16	.157	NO	NO	2	56
MPC HP300	79	22	1.90			.160	YES	YES		16
MPC HP3000-111	78	22	.55	5.25	6.12	.298	YES	YES	20	9
MPC HP3000-33	79	22	.45			.351	YES	NO	13	7
MPC HP3000-30	80	22	.45			.351	YES	NO		2
MOM 115(110)	70	30	.60			.000	NO	NO	6	3
MOM 2020(2021-1)	72	30	47.5			.008	NO	NO	15	3
MOM 6/33	76	18	1.9	12.7	17	.155	NO	YES	7	160
MOM 6/43	77	18	1			.263	NO	YES	7	160
MOM 6/57	78	18	.79			.305	NO	YES	7	160
MOM 6/23	75	18	1.9	12.7	17	.140	NO	YES	7	12
MOM 6/4A	76	18	1			.263	YES	YES		
MOM 6/47	76	18	.4			.435	NO	YES		160
MOM 6/53	78	18	1.4			.200	NO	YES		160

COMPUTER MFG. AND MODEL	MEMORY CHARACTERISTICS					SYSTEM COST (\$K)	CPU COST (\$K)	ADJUSTED CPU COST (\$K)	
	TYPE	CYCLE (USCLS)	SIZE (K WORDS)	MIN	MAX			THEN YEAR \$	1980 \$
GAI 16/550	SEMI	.5	64	1024	1.86	100	43.	24.25	31.70
GAI 16/460	SEMI	.76	16	1024	1.86	40	6.8	4.12	5.08
GAI 16-60/85	CORE	.56	4	128	3.3	12	6.8	8.71	11.28
GAI 16-80/85	CORE	.8	4	128	3.6	15	8.6	10.90	16.62
GRI 99/50	SEMI	1.76	8	32	1.52	40	6.41	6.41	8.65
GRI 99/30	CORE	1.76	8	32	1.52		5.5	5.50	8.31
HCP SLASH 4-1	CORE	.75	8	256	3.64	24	24	24.00	35.93
HCP SLASH 6	SEMI	.45	16	256	1.43		20.5	17.18	23.19
HCP SLASH 7	CORE	.675	32	256	3.51		55	30.60	41.41
HCP H600	SEMI	.29	64	512	.19	384	165.9	160.79	160.79
HCP H100(110-SLASH 4)	CORE	.75	32	256	3.18	85	45	25.16	32.88
HCP H200(210-SLASH 7)	CORE	.875	64	256	3.91	179	161	104.07	136.04
HPC HP2100A/S	CORE	.98	4	32	3.12	45	7.2	9.20	14.02
HPC HP21PX	SEMI	.65	4	64	.55		5.95	6.30	8.84
HPC HP1000(210B)	SEMI	.65	8	1024	.55	51	7.4	7.40	10.38
HPC HP300	SEMI	.5	64	256	.24	75	35	32.04	36.87
HPC HP3000-111	SEMI	.7	128	1024	.28	115	75.9	68.51	84.37
HPL HP3000-33	SEMI	.86	128	512	.39	70	37.2	26.90	30.96
HPC HP3000-30	SEMI	.86	128	1024	.39	50	28.5	18.20	18.20
HON 115(116)	CORE	2.75	3	6	2.7	166	50	54.05	83.54
HON 2020(2021-1)	CORE	2.5	5	13	2.7	116	30	32.43	48.99
HON 6/33	SEMI	.65	8	64	.68	47	5.86	5.86	7.91
HON 6/43	SEMI	.65	16	1024	.68	97	9.79	8.01	11.52
HON 6/57	SEMI	.65	16	1024	.68	217	45.74	44.76	55.12
HON 6/23	SEMI	1	16	64	.57	22	3.55	4.73	5.82
HON 6/4X	SEMI	.65	8	1024	.5	29	6.4	6.40	8.64
HON 6/47	SEMI	.65	16	1024	.5	209	21.74	21.02	25.89
HON 6/53	SEMI	.65	16	1024	.5	147	21	20.28	24.98

COMPUTER MFG. AND MODEL	FIRST CELL YEAR	WORD LENGTH (BITS)	MICROSECS PER INSTRUCTION				MIPS	FLOAT	DMA	NO. OF ACCUMS	NO. OF I/O CHNLS
			ADD	MULT.	DIVIDE						
HON 6/06	76	18	2	8.8	10	.187	NO	YES			
HON 6/34	76	18	1.9	12.7	17	.133	NO	YES	7		
HON 6/36	76	18	1.9	12.7	17	.133	NO	YES	7		
IBM SYSTEM/34(5340)	78	16	68.5			.075	NO	YES			64
IBM SYSTEM/32(5320)	75	8	150.8			.004	NO	YES	16		
IBM 5100	75	16	1000			.001	YES	YES		1	
IBM 360 MOD 20(2020,31)	64	16	473			.001	NO	YES	8		
IBM 360 MOD 20(2020,31)	68	16	731			.001	NO			8	
IBM 360 MOD 20(2020,65)	68	16	160			.004	NO		8		
IBM 360 MOD 20(2020,68)	71	16	289			.002	NO		8		
IBM 1600-2	64	16	4.5	15.25		.082	NO		8		
IBM 1130	65	18	0	15.7	76	.068	NO	NO	1		
IBM 6150	79	32	3.2			.091	NO		19		
IBM 6140	80	32	1.6			.178	NO		19		
IBM SYSTEM/7(5010,AR)	71	18	800			.001	NO		1		
IBM SYS/3-3(5406)	75	8	24.32			.027	NO	YES	8		
IBM SYS/3-12(5412)	76	8	24.32			.027	NO	YES			
IBM SYS/3-6(5406)	71	8	24.32			.055	NO	YES	1		
IBM SYS/3-10(5410)	70	8	24.32			.027	NO	YES	8		
IBM SYS/3-4(5404)	76	8	24.32			.037	NO	YES			
IBM SERIES1 MOD2(4952)	79	16	9.4			.075	NO	NO	8		
IBM SERIES1 MOD3(4953A)	76	16	8.4	13.2	15.6	.087	NO	NO	8		
IBM SERIES1 MOD5(4955A)	76	16	2.64	10.79	17.16	.156	NO	YES	8		
LEC MAC/LEC 40	69	17	2	10		.156	NO	YES	1	256	
LEC SLE 1110	72	16	2.79	15.4		.098	NO	YES	7		
LEC SYSTEM 3	73	16	2.80			.120	NO	YES	7		
MDC 3200	74	16	5.2			.576	YES				
MDC 1600	74	16	66.5	92.7		.059	NO	NO	2	32	

COMPUTER MFG. AND MODEL				MEMORY CHARACTERISTICS				SYSTEM		ADJUSTED CPU COST (\$K)	
	TYPE	CYCLE (USECS)	SIZE (K WCHLS)	MIN	MAX	COST (\$/BIT)		COST (\$K)	CPU COST (\$K)	THEN YEAR \$	1980 \$
HON 6/06	SEMI	.65	8	32		.5		46	7.1	7.10	9.58
HON 6/34	CORE	1.2	8	32		1.6		22	4.4	4.40	5.94
HON 6/36	CORE	1.2	8	64		1.6		110	6.6	6.60	8.91
IBM SYSTEM/34(5340)	SEMI	.6	16	64		.94		60	26.3	25.10	30.91
IBM SYSTEM/32(5320)	SEMI	.6	16	32		.92		32	23.5	22.91	31.00
IBM 5100	SEMI	.553	8	32		.92			6.3	6.30	8.53
IBM 360 MOD 20(2020,51)	CORE	.56	2	16		13.9		80	11.7	25.04	41.06
IBM 360 MOD 20(2020,63)	CORE	.56	2	16		10.7		42	8.2	18.47	29.09
IBM 360 MOD 20(2020,65)	CORE	.2	4	32		16		120	19	29.24	46.05
IBM 360 MOD 20(2020,66)	CORE	.36	4	16		17.8		104	11.2	22.59	34.44
IBM 1800-2	CORE	2.25	4	64		9.3		43	38.7	44.65	69.99
IBM 1130	CORE	2.2	4	32		6.46			8.63	13.57	21.75
IBM 8130	SEMI	1.5	64	128		.6		92	22.	11.25	12.94
IBM 8140	SEMI	.8	64	128		.6		182	31.	20.25	20.25
IBM SYSTEM/7(5010,AB)	CORE	.4	2	64		4.8		17	12.19	17.37	26.48
IBM SYS/3-8(5400)	SEMI	1.52	16	64		.92		66	27.1	26.51	35.87
IBM SYS/3-12(5412)	SEMI	1.52	32	64		.92		110	50.6	48.83	65.90
IBM SYS/3-8(5400)	CORE	1.52	8	256		5.16		50	22.4	22.40	34.15
IBM SYS/3-10(5410)	CORE	1.52	8	48		5.16		64	17.6	17.60	27.20
IBM SYS/3-4(5404)	SEMI	1.52	64	64		1.33		34	19.2	13.24	17.87
IBM SERIES1 MOD2(4952)	SEMI	.2	16	64		.175		30	4.6	4.38	5.04
IBM SERIES1 MOD3(4953A)	SEMI	.8	8	32		1.18		30	4.6	4.60	6.21
IBM SERIES1 MOD5(4955A)	SEMI	.66	8	64		1.18		40	6.5	6.50	8.77
LEC MAC/LEC 1A	CORE	1	8	64		3.27		14	7.6	7.60	11.78
LEC SOL 1110	CORE	1.8	16	496		1.52		10	6	4.05	6.12
LEC SYSTEM 3	SEMI	.6	16	132		.7		30	12.2	11.30	16.92
MDC 3200	SEMI	.4	4	64		.34			9.5	10.10	14.17
MDC 1600	CORE	1	4	32		2.19			5.6	7.00	10.58

COMPUTER #FG. AND MODEL	FIRST DELIV YEAR	WORD LENGTH (BITS)	MICROSECS PER INSTRUCTION				MIPS	FLOAT	UMA	NO. OF ACCUMS	NO. OF I/O CHNLS
			ACL	MULT.	DIVIDE						
MDC MICRO-ONE	74	8	73.2	1020			.036	NO	NO	2	32
MOD MODCOMP 11(10)	72	17	.08	6.1	8.8		.251	NO	YES	15	64
MOD MODCOMP 1V(33-8)	74	17	.64	4.5	8.6		.400	NO	YES	240	64
MOD MODCOMP 1	71	16	.5	10.3			.190	NO	YES		64
MOD CLASSIC 7030	73	16	.5	1.3			1.180	NO	YES	15	256
MOD CLASSIC 7060	80	16	.2				1.330	YES	YES	240	256
MOD CLASSIC 7070	70	16	.2	1.2			1.330	YES	YES	15	256
ND1 812	71	12		10.7			.116	NO		2	
PEC 50	72	16	3.25	15.4			.099	NO		16	255
PEC 70	72	16	3.25	10.2			.136	YES		16	255
PEC 74	73	16	1.5	34			.075	NO		16	255
PEC 7/16	74	17	1.5	34			.075	NO			255
PEC 7/16HS	74	17	.75	5.5			.240	YES		32	255
PEC 1610	73	16	1				.262	NO	YES		
PEC 1620	73	16	.825				.296	NO	YES		
PEC 1630	73	16	.75				.313	NO	YES		
PEC 6/16	75	17	.9	6.6	12		.262	NO	YES	16	
PEC 8/16E	77	17	.75	9.25	12.5		.208	NO	YES	16	
PEC 7/32C	74	34	1	21.75	21.75		.115	NO	YES	32	
PEC 8/32C	75	34	.4	2.7	5.5		.366	NO	YES	256	
PEC 5/16	76	16	1.2	24.9	31.5		.105	NO	YES	16	
PEC 3220	79	34	.3	8.5	11.15		.218	NO	YES		
PEC 3240	80	34	.85	3.94	5.76		.364	NO	YES		
P3S P330	77	8	1.2				.134	NO	YES	16	
P3S P350	70	64	1.5				.117	NO	YES	1	
P3S SYST-1	77	16	3.3				.072	NO	YES	8	
P3S SYST-04	77	16	3.17				.078	NO	YES	8	
PCI 550	79	32	.58	4.2	4.76		.274	YES	YES		71

COMPUTER MFG. AND MODEL		MEMORY CHARACTERISTICS					SYSTEM		ADJUSTED CPU COST (\$K)	
		TYPE	CYCLE (USECS)	SIZE(K WORDS)	LCST (#/BIT)		COST (\$K)	CPU	THEN YEAR \$	1980 \$
MDC MICRO-ONE		SEMI	1.1	8	32	.94		3.5	3.50	4.91
MDC MDCOMP 11(10)		CORE	.8	16	64	1.56		11.5	9.58	14.17
MDC MDCOMP 11(15-8)		CORE	.5	64	1024	1.5	175	42.5	28.22	39.58
MDC MDCOMP 1		CORE	.8	8	16	2.2		7.4	7.40	11.28
MDC CLASSIC 7630		SEMI	.125	64	256	.90		23.8	15.02	17.28
MDC CLASSIC 7660		SEMI	.125	64	624	.98	75	37	28.22	28.22
MDC CLASSIC 7670		SEMI	.125	256	2048	.98		61	22.11	34.16
MDI 812		CORE	2	8	16	5.2		10	10.00	15.24
PEC 50		CORE	1	4	32	1.4	46	7.4	8.30	12.53
PEC 70		CORE	1	4	32	1.4	46	7.4	6.30	12.93
PEC 74		CORE	1	4	32	1.3	43	4.6	5.43	8.13
PEC 7/16		CORE	1	4	32	1.6		4.2	5.29	7.42
PEC 7/16HS		CORE	1	4	32	1.2		9	9.82	13.77
PEC 1610		SEMI	.66	8	32	.55		5.4	5.40	6.21
PEC 1620		SEMI	.66	16	128	.55		9	6.30	9.35
PEC 1630		SEMI	.66	16	128	.55		11	10.30	11.85
PEC 6/16		CORE	.6	4	32	.78	6	4	4.53	6.13
PEC 8/16L		CORE	.75	16	131	.98	30	9.33	8.00	10.45
PEC 7/32C		CORE	.75	16	256	1.28	50	14.4	10.92	15.31
PEC 8/32C		CORE	.75	32	256	.92	180	51.9	44.39	60.07
PEC 5/16		SEMI	.6	4	32	.94		2.1	2.70	3.65
PEC 3220		SEMI	.7	64	1024	.46		53.5	24.74	26.47
PEC 3240		SEMI	.5	64	4096	.50	185	85	74.34	74.34
P35 P330		CORE	1.5	24	32	2.34		18.99	15.99	20.91
P35 P350		CORE	1.5	64	128	17.97		13.5	36.50	56.42
P35 SYST-1		SEMI	.5	16	32	.41		3.54	3.02	3.94
P35 SYST-04		SEMI	.5	16	32	.34		7.09	6.40	8.36
PCI 550		SEMI	1	64	512	.01	70	63.5	52.57	60.49

COMPUTER PFG. AND MODEL	FIRST DELIV YEAR	WORD LENGTH (BITS)	MICROSECS PER INSTRUCTION				MIPS	FLOAT	CMA	NO. OF ACCUMS	NO. OF I/O CHNLS
			ADD	FULT.	DIVIDE						
PCI 450	79	32	.50	4.2	4.76	.274	YES	YES	YES		36
PCI 350	78	16	.50			.385	YES	YES	YES		
PCI 100	73	16	2.44			.091	NO	YES	YES	1	
PCI 200	72	18	1.90			.114	NO	YES	YES	1	
PCI 300	74	18	1.50			.138	NO	YES	YES	1	
PCI 400	76	22	.50			.342	YES	YES	YES	1	
PCI 650	79	32	.50	4.2	4.70	.274	YES	YES	YES		71
PCI 750	79	32	.24	1.38	4.56	.561	YES	YES	YES		71
RDS RDS-500	73	18	1.4			.204	NO	YES	YES	8	
RDS RDS-5000	77	18	1.4			.204	NO	YES	YES	8	
SUD 9200	66	32	40.0			.023	NO			8	
SUD 920011	66	32	40.0			.023	NO			8	
SUD 930011	66	32	20.4			.040	NO			8	
SUD 90/30	74	32	5.4	39.6	65.4	.152	NO			16	
SUD V620/L-100	72	16	1.9	9.5		.164	NO			32	
SUD V77-400/410	77	16	1.32	5.94	7.92	.248	NO	YES	YES	2	
SUD V73	72	18	1.32			.210	NO	YES	YES	3	
SUD V76	70	18	1.32			.210	NO	YES	YES	8	
SUD V77-600/610	77	16	.74	4.79	5.28	.305	NO	YES	YES	2	
SUD 90/25	77	32	5.4	42	67.8	.057	NO	YES	YES	16	
SUD V77-800	79	48	.45			.430	NO	YES	YES	2	
SUD V77-200/210	77	16	2.31	5.11	7.67	.224	NO	YES	YES	2	
SEL 32/55	75	36	1.2	5.5	9.2	.271	YES	YES	YES	8	16
SEL 32/75	78	36	1.2	5.5	9.2	.271	YES	YES	YES	8	64
SEL 32/77-60	78	36	.0			.303	NO				
SEL 32/35	78	36	1.0	6.2	9.5	.203	YES	YES	YES	8	
TAN T16/1102(M)	70	17	.5	3.4	3.1	.422	NO	YES	YES	8	
TAN T16/1102(C)	76	17	.0	3.4	3.1	.314	NO	YES	YES	8	

COMPUTER MFG. AND MODEL	MEMORY CHARACTERISTICS					SYSTEM COST (\$K)	CPU COST (\$K)	ADJUSTED CPU COST (\$K)	
	TYPE	CYCLE (USCS)	SIZE (K BYTES)	MIN	MAX			THEN YEAR \$	1980 \$
PCI 450	SEMI	1	64	256	.61	70	40	29.07	33.45
PCI 350	SEMI	.6	16	128	.61	125	35	34.22	42.14
PCI 100	SEMI	1	8	64	2.06		5.5	5.50	6.23
PCI 200	SEMI	.75	8	64	3.05		6.8	6.80	10.27
PCI 300	SEMI	.75	8	64	1.66	75	17.6	17.60	24.68
PCI 400	SEMI	.75	64	4000	1.66		65.1	44.65	60.25
PCI 650	SEMI	1	64	1024	.61	200	68.5	77.57	89.26
PCI 750	SEMI	.6	128	2048	.61	240	123.5	100.08	115.16
RDS RDS-500	SEMI	.7	16	64	1.46		12.05	9.95	14.89
RDS RLS-5000	SEMI	.7	16	448	1.46	140	18.3	16.20	21.17
SUD 9200	CORE	1.2	2	4	32.9	46	12	75.17	117.82
SUD 9200II	CORE	1.2	2	8	32.9	165	15	78.17	122.52
SUD 9300II	CORE	.6	4	8	35.7	325	30	75.70	118.65
SUD 90/30	SEMI	.6	8	131	4.72	189	66	66.00	92.57
SUD V626/L-100	CORE	.95	8	52	2.73		7.7	7.70	11.63
SUD V77-400/410	SEMI	.66	16	1024	1.13	75	5.1	3.65	4.78
SUD V73	SEMI	.66	8	256	2.73		15.53	15.53	23.46
SUD V76	SEMI	.66	16	1024	1.13		8.4	6.77	9.14
SUD V77-600/610	SEMI	.66	16	1024	1.13	115	6.5	5.05	6.61
SUD 90/25	SEMI	.65	16	32	5.57	136	50	35.74	46.72
SUD V77-800	SEMI	.6	42	342	.44	150	41	33.82	38.92
SUD V77-200/210	SEMI	.66	8	32	1.13	25	3.5	3.50	4.58
SEL 32/55	CORE	.6	16	256	2.05	105	49	45.10	58.32
SEL 32/75	CORE	.6	32	2000	.83	153	72.3	65.13	80.21
SEL 32/77-60	CORE	.9	128	4056	.83	110	46	10.14	12.49
SEL 32/35	CORE	.9	8	128	1.27	74	25	25.00	33.74
TAN T16/1102(M)	SEMI	.5	48	256	.94	64	22	15.61	21.06
TAN T16/1102(C)	CORE	.6	32	128	1.56	99	20.4	14.04	18.94

COMPUTER MFG. AND MODEL	FIRST CELL YEAR	WORD LENGTH (BITS)	MICROSECS PER INSTRUCTION			MIPS	FLOAT	DMA	NO. OF ACCURS	NO. OF I/O CHNLS
			ADD	MULT.	DIVIDE					
TEK 4051	75	8	2			.135	NO	NO	2	
ILL 960B	74	22	3.6	8.6	10.9	.152	NO	YES	16	
ILL 960B	74	22	1.75	2.65	8.25	.284	NO	YES	2	256
ILL 990/4	76	17	4.7			.076	NO	NO		
ILL 990/10	76	17	3.6			.097	NO	YES		
MLI 2200VP	77	8	15			.030	YES	NO	32	9
MEC 2500	72	16	1.7	24.4		.098	NO	YES	1	2

COMPUTER MFG. AND MODEL	MEMORY CHARACTERISTICS					SYSTEM COST (\$K)	CPU COST (\$K)	ADJUSTED CPU COST (\$K)	
	TYPE	CYCLE (USECS)	SIZE (K WORDS)		COST (\$/BIT)			THEN YEAR \$	1980 \$
			MIN	MAX					
TEK 4051	SEMI	1.2	8	32	2.19	6	6.00	8.12	
III 960B	SEMI	.75	8	64	1.09	12	4.50	6.31	
III 960C	SEMI	.75	8	64	1.09	47	5.15	7.22	
III 990/4	SEMI	.67	1	32	.9	14	3.35	4.52	
III 990/10	SEMI	.65	8	1024	.7	13	3.45	4.66	
WLL 2200VP	SEMI	.6	16	64	2.34	25	6.50	8.50	
WEC 2500	CORE	.85	8	1024	1.56	60	13.70	20.69	

COMPUTER MFG. AND MODEL	FIRST YEAR	WORD LENGTH (BITS)	MICROSECS PER INSTRUCTION			AIPS	FLJAT	OMA	NO. OF ACCUMS	NO. OF I/O CHNLS
			ADD	MULT.	DIVIDE					
AUT D216	72	16	2.5	13.8	23.8	.112	NO	YES	16	16
MON-6/364MILITIANIZED	74	18	1.9	12.7	17	.133	NO	YLS	7	
MPS PA-1150/BRP	76	16	2.03			.116	NO	YES	8	
ROL MSE-30	80	16	.65	4.7		.259	YES	YES	8	64
MON-1602A/UYK-19	77	16	1	5.3	9.2	.233	NO	YES	4	56
ROL 1603A/UYK-12	76	16	5.9			.120	NO		4	56
ROL 1606/UYK-19	78	16	1			.333	NO		4	56
MON-1650/UYK-19	76	16	1.05			.327	NO		4	12
ROL 1664/UYK-19	76	16	1			.333	YES		12	56
ROL 1666/UYK-19	77	16	1			.333	NO		4	56
MON-1602B/UYK-19	76	16	1.05			.216	NO			56
UTN 11/34 M	76	16	1.9	9	13	.172	YES	YES		
UTN M2-11/70 A	78	16	.5	5.2	7.7	.337	YES			

COMPUTER MFG. AND MODEL	MEMORY CHARACTERISTICS					SYSTEM COST (\$K)	CPU COST (\$K)	ADJUSTED CPU COST (\$K)	
	TYPE	CYCLE (US/CS)	SIZE IN PAR	WORDS MAX	COST (\$/BIT)			THEN YEAR \$	1980 \$
AUT D216	CORE	1.5	2	64	2.7	100	50	52.59	79.44
HON 6/36 (MILITARIZED)	CORE	1.2	0	64	6.9	476	28.3	25.30	34.85
PPS PA-1150/SKP	SEM1	.55	16	128	.58		19.5	16.76	25.31
MOL MSE-30	CORE	1	128	1024	2.7	200	135	83.16	83.16
MOL 1602A/UYK-19	CORE	1	16	64	2.73		25.25	21.76	28.44
MOL 1603A/UYK-12	CORE	1.2	16	32	2.34		13.4	10.40	14.04
MOL 1606/UYK-19	CORE	1	16	1024	2.73		43.9	40.41	49.76
MOL 1650/UYK-19	CORE	1	16	32	2.73		26.25	22.76	30.71
MOL 1664/UYK-15	CORE	1	16	64	2.73		35.45	35.96	46.52
MOL 1666/UYK-19	CORE	1	16	1024	2.73		48.9	45.41	59.35
MOL 1602B/UYK-19	CORE	1	16	64	2.73		26.3	22.81	28.09
UTM 11/34 A	CORE	.9	32	128	7.32		67.5	39.39	53.16
UTM M2-11/70 A	CORE	.9	64	1024	7.32		160	94.41	116.27

APPENDIX B

COST ESTIMATING RELATIONSHIPS

AND

REGRESSION ANALYSES

COMMERCIAL COSTS - 6 INDEPENDENT VARIABLES - UNINFLATED - SEMI-LOG (LN Y)

SEMILOG REGRESSION -- LN Y = A + B + C + X1 + C + X2 + D + X3 + E + X4 + F + X5 + G + X6

SUMMARY TABLE

NOTE -- STATISTICS ARE BASED ON LOGARITHMS

PARAMETER	VALUE	STANDARD ERROR	T-RATIO	SIGNIF LEVEL	BETA COEFF
A (CONSTANT)	5.29490	1.53795	3.44282	.00070	-.22115
B	-.54292E-01	.01957	-3.28510	.00121	.40337
C	.40936E-01	.04750	6.29743	.00000	.03480
D	.05000E-01	.12703	.54344	.58744	.19565
E	.77395	.21524	3.62356	.00111	.05205
F	.24146E-05	.00000	.50700	.61348	.26422
G	.71605	.15171	4.72387	.00000	

CORRELATION MATRIX

VARIABLE	LN	ADD. CPU	DELIV YR	WRG LNMH	LN TECH	WIPS	MAX MEMO	FLOAT PT
LN Y								
ADD. CPU	1.00000							
DELIV YR	-.04478	1.00000						
WRG LNMH	.51847	.51847	1.2930					
LN TECH	-.50829	.15543	-.50829	1.00000				
WIPS	.02126	.02126	.02126	.02126	1.00000			
MAX MEMO	.24214	.24214	.24214	.24214	.24214	1.00000		
FLOAT PT	.24120	.24120	.24120	.24120	.24120	.24120	1.00000	

CORRELATION OF DEPENDENT VARIABLE (LN Y) WITH INDEPENDENT VARIABLES (LN X)
 COEFFICIENT OF DETERMINATION (R-SQ) .42311
 STANDARD ERROR OF ESTIMATE .70053
 SUM OF SQUARES OF RESIDUALS (LN) 113.23325
 F VALUE 29.73885
 DEGREES OF FREEDOM FOR ERROR 196
 TOTAL DEGREES OF FREEDOM 202

VARIANCE-COVARIANCE MATRIX

	A	B	C	D	E	F	G
A	.22053E+01	-.10849E-01	-.76249E-03	-.16620E-01	-.10505E-01	-.41539E-07	-.22210E-01
B	-.10849E-01	.50239E-03	-.84195E-05	.12521E-02	-.79803E-03	-.78446E-05	-.31462E-03
C	-.76249E-03	-.84195E-05	.57173E-04	-.15235E-03	-.21324E-03	-.92135E-05	-.15725E-03
D	-.16620E-01	.12521E-02	-.15235E-03	.10151E-01	-.14311E-02	.16505E-07	.12667E-02
E	-.10505E-01	-.79803E-03	-.21324E-03	-.14311E-02	.55526E-01	.30730E-07	-.79803E-07
F	-.41539E-07	-.78446E-05	-.92135E-05	.16505E-07	.30730E-07	.70631E-11	-.20159E-07
G	-.22210E-01	-.31462E-03	-.15725E-03	.12667E-02	-.79803E-07	-.20159E-07	.22210E-01

COMMERCIAL COSTS - INFLATED CPL AND MEMORY - SEMI-LOG (LN Y) FIT

SEMILOG REGRESSION -- LN Y = A + B * X1 + C * X2 + D * X3 + E * X4 + F * X5 + G * X6

SUMMARY TABLE

NOTE -- STATISTICS ARE BASED ON LOGARITHMS

PARAMETER	VALUE	STANDARD ERROR	SIGNIF LEVEL	LETA COEFF
A - (CONSTANT)	7.20091	1.52399	.00000	-.31449
B - DELIV TM	-.50750E-01	.01939	.00000	.00000
C - WRL LNM	.45330E-01	.00749	.00000	.35580
D - MEM TECH	.81031E-01	.12336	.00000	.39128
E - MFS	.73194	.23331	.00200	.12464
F - MAX PERC	.22110E-00	.00000	.00000	.05561
G - FLOAT PT	.70737	.15033	.00000	.25284

CORRELATION MATRIX

VARIABLE	LN Y	DELIV TM	WRL LNM	MEM TECH	MAX PERC	FLOAT PT
LN Y	1.00000	-.14610	.49134	.18359	.20147	.38645
DELIV TM	-.14610	1.00000	.15543	-.50829	.24214	.24120
WRL LNM	.49134	.15543	1.00000	.06166	.21145	.26580
MEM TECH	.18359	-.50829	.06166	1.00000	-.05532	-.06059
MAX PERC	.20147	.24214	.21145	.05532	1.00000	.32465
FLOAT PT	.38645	.24120	.26580	-.06059	.32465	1.00000

COEFFICIENT OF DETERMINATION (R²), R SQ .42519
 STANDARD ERROR OF ESTIMATE .75304
 SUM OF SQUARES OF RESIDUALS (LN) 111.43557
 F VALUE 24.16336
 DEGREES OF FREEDOM FOR ERROR 192
 TOTAL DEGREES OF FREEDOM 202

VARIANCE-COVARIANCE MATRIX

	A	B	C	D	E	F	G
A	.23225E+01	-.10254E-01	-.74940E-03	-.16215E-01	-.10315E-01	-.41181E-07	-.21014E-01
B	-.10254E-01	.57607E-03	-.21590E-05	.12495E-02	-.77030E-03	-.50895E-03	-.30895E-03
C	-.74940E-03	-.21590E-05	.50190E-04	-.19795E-03	-.20946E-03	-.50210E-03	-.13477E-03
D	.16215E-01	.12495E-02	-.14975E-01	.15855E-01	-.14053E-02	.16206E-07	.11449E-03
E	-.10315E-01	-.77030E-03	-.20946E-03	-.14053E-02	.35452E-01	.30180E-07	-.93194E-02
F	-.41181E-07	-.50895E-03	-.50210E-03	.16206E-07	.30180E-07	.69577E-11	-.49253E-07
G	-.21014E-01	-.30895E-03	-.13477E-03	.11449E-03	-.93194E-02	-.49253E-07	.22592E-01

COMPUTER REGRESSION ANALYSIS COMPUTER PROGRAM
(JULY 1976)

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COMPUTERIAL COSTS - MEMORY TYPE ELIMINATED - LINEAR FIT

LINEAR REGRESSION -- $Y = A + B + X1 + C + X2 + D + X3 + L + X4 + F + X5$

SUMMARY TABLE

PARAMETER	VALUE	SIGNIFICANCE	LEVEL	COEFF
A (CONSTANT)	116.36848	35.58811	0.0105	
B DELIV YR	-1.95908	4.15149	0.0005	-.23957
C AML LTH	1.52734	2.1260	0.0000	.45765
F MIPS	18.42898	0.76292	0.0045	.00194
L MAX MEMO	53.0251L-04	0.0000	0.5747	.02862
F FLOAT PT	17.00215	4.52010	0.0001	.27594

CORRELATION MATRIX

VARIABLE	MEAN	STANDARD DEVIATION	AUG. CPU	DELIV YR	AML LTH	MIPS	MAX MEMO	FLOAT PT
Y	25.90246	28.28239	1.00000	-.05506	.54259	.29552	.24554	.40123
X1	74.05222	3.45158	-.05506	1.00000	.15543	.24214	.28007	.24120
X2	19.14208	8.47227	.54295	.15543	1.00000	.21145	.50268	.26980
X3	.22915	.24709	.29552	.24214	.21145	1.00000	.15180	.05445
X4	6453.1470	24071.45011	.28007	.28007	.50268	.15180	1.00000	.26160
X5	1.13715	.55105	.40123	.24120	.26980	.55465	.26007	1.00000

B-3

COEFFICIENT OF DETERMINATION (R-SQ) = .42706
STANDARD ERROR OF ESTIMATE = 21.64998
SUM OF SQUARES OF RESIDUALS = 92330.10201
F VALUE = 29.40446
DEGREES OF FREEDOM FOR ERROR = 197
TOTAL DEGREES OF FREEDOM = 202

MEAN OF ABSOLUTE RELATIVE DEVIATIONS = 1.14762
COEFF VARIATION (STD ERR EST / MEAN Y-VALUE) = .75585
SUM OF SQUARES TOTAL = 11391.0077
CORRELATION STATISTIC = 1.95599
DEGREES OF FREEDOM FOR REGRESSION = 5
NUMBER OF DATA POINTS = 203

VARIANCE-COVARIANCE MATRIX

	A	B	C	L	F
A	.12680L+04	-.13100L+02	-.61000L+00	-.55192L+01	-.34012L-04
B	-.13100L+02	.23127L+00	.58519L-02	-.55720L+00	-.73594L-05
C	.61000L+00	.23127L+00	.45150L-01	-.16359L+00	-.73820L-05
L	-.55192L+01	-.58519L-02	-.45150L+01	.44929L+02	.26114L-04
F	-.34012L-04	-.73594L-05	-.73820L-05	.26114L-04	.57327L-02
F	-.10016L+02	-.26274L+00	-.11030L+00	-.76074L+01	-.40778L-04

COMMERCIAL COSTS - MECHAN TYPE ELIMINATED - POWER FIT

POWER REGRESSION SUMMARY TABLE

SUMMARY TABLE

PARAMETER	VALUE	INITIAL GUESS	STANDARD ERROR	T-RATIO	SIGMA LEVEL
A (CONSTANT)	.13750E+13	.50557E+13	*****	.20658	.83655
B DELIV YR	-6.55010	-6.57955	1.16434	-5.62956	.00000
C WRO LNM	1.08506	.67722	.11110	9.75191	.00000
D MIPIS	.10944	-.56730E-01	.04532	2.41494	.01665
E MAX MEMO	.47613E-01	.18672	.03957	1.20338	.23027
F FLOAT FI	.97451	1.13300	.17312	5.62698	.00000

CORRELATION MATRIX

VARIABLE	MEAN	STANDARD DEVIATION	ADJ. CPL	DELIV YR	WRO LNM	MIPIS	MAX MEMO	FLOAT FI
Y	25.90246	26.60559	1.00000	-.05586	.54299	.29512	.26854	.40123
X1	74.05222	3.35158	-.05586	1.00000	.15503	.24214	.21787	.24126
X2	19.14280	6.47327	.54299	.15503	1.00000	.21145	.50284	.21980
X3	.22415	.24709	.29512	.24214	.21145	1.00000	.13166	.32465
X4	8453.14776	24671.43011	.26854	.26807	.50284	.13166	1.00000	.26607
X5	-1.10719	.39703	.40123	.24120	.26940	.26405	.26607	1.00000

COEFFICIENT OF DETERMINATION (R-SQ) .45509 MEAN OF ABSOLUTE RELATIVE DEVIATIONS 1.12E-08

STANDARD ERROR OF ESTIMATE 21.11295 COEFF VARIATION (STD ERR EST / MEAN Y OBS) .01503

SUM OF SQUARES OF RESIDUALS 87813.94283 SUM OF SQUARES TOTAL 161391.0077

F-VALUE 32.01235 COMBINATION-SPECIFIC 1.52684

DEGREES OF FREEDOM FOR ERROR 197 DEGREES OF FREEDOM DUE TO REGRESSION 5

TOTAL DEGREES OF FREEDOM 202 NUMBER OF DATA POINTS 203

VARIANCE-COVARIANCE MATRIX

	A	B	C	D	E	F
A	.47150E+26	-.70040E+13	-.54500E+10	.68255E+11	.14271E+12	.11520E+12
B	-.70040E+13	.15571E+01	-.54149E-02	.11149E-01	-.25600E-01	-.17694E-01
C	-.54500E+10	-.54149E-02	.12244E-01	.12591E-02	-.13638E-02	.40160E-03
D	.60855E+11	.11149E-01	.12591E-02	.20537E-02	-.17056E-03	-.15493E-02
E	.14271E+12	-.25600E-01	.13638E-02	.17056E-03	.15655E-02	-.24717E-02
F	.11520E+12	-.17694E-01	.40160E-03	-.15493E-02	-.24717E-02	.29572E-01

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TABLE OF RESIDUALS (CONTINUED)

COMPUTER	CUSUMMED	DELIV YR	WRO LGTH	MIPS	MAX MEMO	FLQAT PT	COMPUTED	RESIDUAL	RELATIVE
ALG. CPU						ALG. CPU	ALG. CPU	ALG. CPU	DEVIATION
1 PLC 571	3.600	78.000	16.000	.109	512.000	1.000	13.722	-16.122	-2.412
1 PLC 322	26.400	72.000	34.000	.218	54816.000	1.000	31.902	-3.502	-.123
2 PLC 324	74.300	60.000	34.000	.364	139264.000	1.000	39.191	41.109	.153
2 PLS 433	26.400	77.000	8.000	.134	216.000	1.000	3.986	14.494	.710
2 PLS 435	43.500	70.000	64.000	.117	768.000	1.000	109.016	-65.716	-1.407
2 PPS 578	3.500	77.000	16.000	.072	512.000	1.000	12.045	-8.185	-.264
2 PLS 578	0.500	77.000	16.000	.070	512.000	1.000	12.192	-3.892	-.469
2 PLS 550	60.400	79.000	52.000	.274	16384.000	2.000	58.066	2.334	.039
3 PLS 450	33.400	79.000	32.000	.274	2192.000	2.000	50.181	-22.781	-.742
3 PLS 350	42.100	78.000	16.000	.365	2048.000	2.000	28.004	14.056	.335
3 PLS 100	0.200	79.000	16.000	.051	1024.000	1.000	10.183	-5.983	-.187
3 PLS 200	10.200	72.000	16.000	.114	1152.000	1.000	23.308	-13.108	-1.285
3 PLS 200	25.600	74.000	16.000	.138	1152.000	1.000	19.086	4.714	.192
3 PLS 400	69.200	76.000	32.000	.342	8000.000	2.000	55.957	4.043	.129
4 PLS 450	65.200	79.000	32.000	.274	32768.000	2.000	60.015	29.185	.327
4 PLS 750	113.100	77.000	32.000	.561	65536.000	2.000	67.089	46.011	.417
4 PLS 750	19.600	75.000	16.000	.204	1152.000	1.000	27.093	-7.893	-.333
4 PLS 750	21.100	77.000	16.000	.204	1024.000	1.000	17.546	3.554	.162
4 SLS 920	119.600	68.000	32.000	.023	128.000	1.000	57.151	52.449	.474
4 SLS 520	113.300	60.000	32.000	.023	256.000	1.000	60.102	55.198	.473
5 SLS 930	114.400	60.000	32.000	.046	256.000	1.000	64.088	46.502	.416
5 SLS 307	92.500	74.000	32.000	.152	4152.000	1.000	39.065	52.625	.569
5 SLS 462	7.300	72.000	16.000	.164	512.000	1.000	20.140	-11.240	-1.203
5 SLS 477	4.700	77.000	16.000	.248	16384.000	1.000	18.019	-11.819	-2.472
5 SLS 473	23.400	72.000	16.000	.216	4608.000	1.000	26.702	-3.302	-.141
5 SLS 476	7.100	76.000	16.000	.216	16422.000	1.000	20.009	-16.409	-1.492
6 SLS 477	0.600	77.000	16.000	.305	16384.000	1.000	16.093	-10.093	-1.223
6 SLS 907	42.700	77.000	32.000	.057	1024.000	1.000	25.001	20.499	.446
6 SLS 477	32.900	79.000	48.000	.460	16416.000	1.000	44.175	-9.275	-.434
6 SLS 477	4.500	77.000	16.000	.224	512.000	1.000	13.684	-5.184	-.244
6 SLS 327	54.800	75.000	36.000	.271	9216.000	2.000	56.140	-6.340	-.449
6 SLS 327	76.000	70.000	36.000	.271	7200.000	2.000	76.263	1.137	.015
7 SLS 327	10.300	78.000	31.000	.303	147456.000	1.000	40.972	-30.672	-2.972
7 SLS 327	51.000	76.000	32.000	.203	4608.000	2.000	77.469	-46.469	-1.469
7 TAD 116	21.000	76.000	17.000	.422	4352.000	1.000	18.054	2.106	.100
7 TAD 116	17.600	76.000	17.000	.314	2176.000	1.000	17.698	-.098	-.009
7 TAD 405	0.100	75.000	2.000	.135	256.000	1.000	7.024	1.676	.133
7 TAD 960	6.300	74.000	22.000	.152	1408.000	1.000	25.219	-18.919	-.303
8 TAD 980	1.200	74.000	22.000	.284	1408.000	1.000	27.004	-15.804	-.279
8 TAD 990	4.500	76.000	17.000	.076	544.000	1.000	14.185	-5.685	-.212

COMMERCIAL COSTS - MEMORY TYPE ELIMINATED - POWER FAT

TABLE OF RESIDUALS (CONTINUED)

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CURVES REGRESSION ANALYSIS COMPUTER PROGRAM (JULY 1976)

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COMMERCIAL COSTS = NO MEMORY TYPE OR FLOATING POINT - LINEAR FIT

LINEAR REGRESSION -- $Y = A + B * X1 + C * X2 + D * X3 + E * X4$

SUMMARY TABLE

PARAMETER	VALUE	STANDARD ERROR	T-RATIO	SIGNIF LEVEL	BETA COEFF
A (CONSTANT)	137.84114	37.46726	3.67898	.00030	
B DELIV YN	-1.93955	.50292	-3.85659	.00016	.23291
C NO LNM	1.64953	.22221	7.42328	.00000	.49467
D MIPS	24.96586	6.80392	3.66933	.00031	.21841
E MAX MEMU	.705440-04	.00008	.89191	.37353	.06012

CORRELATION MATRIX

VARIABLE	MEAN	STANDARD DEVIATION	ADJ. CPU	DELIV YN	WRD LNM	MIPS	MAX MEMU
Y	30.43300	28.24355	1.00000	-.08694	.53509	.27458	.27515
X1	74.85222	3.39158	-.08694	1.00000	.15543	.24214	.26887
X2	19.14288	8.47327	.53509	.15543	1.00000	.21145	.50288
X3	.22415	.24709	.27458	.24214	.21145	1.00000	.13180
X4	8493.14778	24071.43011	.27515	.26887	.50288	.13180	1.00000

B-12

COEFFICIENT OF DETERMINATION (UNADJ), R SQ .36156
 MEAN OF ABSOLUTE RELATIVE DEVIATIONS .78081
 STANDARD ERROR OF ESTIMATE 22.79409
 SUM OF SQUARES OF RESIDUALS 102874.96345
 SUM OF SQUARES TOTAL 28.03277
 DURBIN-WATSON STATISTIC 1.98
 DEGREES OF FREEDOM FOR ERROR 202
 TOTAL DEGREES OF FREEDOM 203

VARIANCE-COVARIANCE MATRIX

	A	B	C	D	E
A	.140380+04	-.167380+02	-.685800+00	-.944340+01	-.377010-04
B	-.167380+02	.252930+00	.143890-02	-.737600+00	-.883840-05
C	-.685800+00	.143890-02	.493770-01	-.254310+00	-.845100-05
D	-.944340+01	-.737600+00	-.254310+00	.462430+02	.103270-04
E	-.377010-04	-.883840-05	-.845100-05	.103270-04	.625590-08

PLUEN REGRESSION == Y = A * X1**B + X2**C + X3**D + X4**E

SUMMARY TABLE

PARAMETER	VALUE	INITIAL GUESS	STANDARD ERROR	T-RATIO	SIGNIF LEVEL
A (CONSTANT)	.131480+12	.930558+18	*****	.20353	.83893
B DELIV YR	-5.97508	-5.36356	1.17366	-5.09099	.00000
C WRD LNTN	.96585	.62362	.10754	8.98094	.00000
D MIPS	.848690+01	-.394070+01	.04706	1.79084	.07421
E MAX MEMO	.11318	.18527	.03643	3.10669	.00217

CORRELATION MATRIX

VARIABLE	MEAN	STANDARD DEVIATION	ADJ. CPU	DELIV YR	WRD LNTN	MIPS	MAX MEMO
Y	30.43300	28.24355	1.00000	-.08694	.53509	.27458	.27515
X1	74.85222	3.39158	-.08694	1.00000	.15543	.24214	.26887
X2	19.14286	8.47327	.53509	.15543	1.00000	.21145	.50288
X3	.22415	.20709	.27458	.24214	.21145	1.00000	.13160
X4	8493.14778	24071.43011	.27515	.26887	.50288	.13160	1.00000

COEFFICIENT OF DETERMINATION (UNADJ), R SQ .35889 MEAN OF ABSOLUTE RELATIVE DEVIATIONS .76057
 STANDARD ERROR OF ESTIMATE 22.84165 COEFF VARIATION (STD ERR EST / MEAN Y OBS) .75056
 SUM OF SQUARES OF RESIDUALS 103304.68639 SUM OF SQUARES TOTAL 161134.96887
 F VALUE 27.71025 DUMINATION STATISTIC 1.53397
 DEGREES OF FREEDOM FOR ERROR 198 DEGREES OF FREEDOM DUE TO REGRESSION 4
 TOTAL DEGREES OF FREEDOM 202 NUMBER OF DATA POINTS 203

VARIANCE-COVARIANCE MATRIX

	A	B	C	D	E
A	.417320+24	-.756140+12	-.647290+10	.897500+10	.142150+11
B	-.756140+12	.137750+01	.555810-02	-.150490-01	-.268550-01
C	-.647290+10	.555810-02	.115680-01	.917610-03	-.127270-02
D	.897500+10	-.150490-01	.917610-03	.221490-02	-.300570-03
E	.142150+11	-.268550-01	-.127270-02	-.300570-03	.132710+02

LOG-LINEAR REGRESSION -- $LN Y = LN A + C * LN X1 + D * LN X2 + E * LN X3 + F * LN X4 + G * LN X5 + H * LN X6$

SUMMARY TABLE

NOTE -- STATISTICS ARE BASED ON LOGARITHMS

PARAMETER	VALUE	STANDARD ERROR	T-RATIO	SIGNIF LEVEL	DELTA COEFF
LN A (CONSTANT)	247261.23	12.24743	2.07690	.03659	
LN X1	54.06243	5.06425	-2.91766	.02671	-.63045
LN X2	-14.77275	5.43060	1.42766	.20350	.27590
LN X3	4.05161	5.2260	.75366	.47956	.13207
LN X4	2.2724	5.0653	.45176	.65488	.18363
LN X5	5.3366	5.0454	1.05763	.30658	.01116
LN X6	7.6705	5.0052	1.53413	.04313	.44072

CORRELATION MATRIX

VARIABLE	LN A	LN X1	LN X2	LN X3	LN X4	LN X5	LN X6	LN Y
LN A	1.00000							
LN X1	.67000	1.00000						
LN X2	-.11637	.19681	1.00000					
LN X3	.27553	.06353	.06353	1.00000				
LN X4	.47457	.31610	.31610	.40762	1.00000			
LN X5	.60717	.52472	.52472	.50279	.50279	1.00000		
LN X6	.59175	.26713	.26713	.19245	.19245	.34069	1.00000	
LN Y	.57559	.07000	.11057	.27553	.47457	.50279	.59175	1.00000

COEFFICIENT OF DETERMINATION (R-SQ)	.82600
STANDARD ERROR OF ESTIMATE	.51059
SUM OF SQUARES OF RESIDUALS (LN)	5.96500
F-VALUE	12
DEGREES OF FREEDOM FOR ERROR	12
TOTAL DEGREES OF FREEDOM	13

VARIANCE-COVARIANCE MATRIX

LN A	LN X1	LN X2	LN X3	LN X4	LN X5	LN X6	LN Y
LN A	1.00000						
LN X1	.34000	1.00000					
LN X2	-.05200	.19681	1.00000				
LN X3	.06353	.06353	.06353	1.00000			
LN X4	.40762	.31610	.31610	.40762	1.00000		
LN X5	.50279	.50279	.50279	.50279	.50279	1.00000	
LN X6	.34069	.19245	.19245	.34069	.34069	.34069	1.00000
LN Y	.07000	.11057	.27553	.47457	.50279	.59175	1.00000

MILITARY COSTS - MEMORY TYPE ELIMINATED - POWER FIT

POWER REGRESSION -- Y = A + A1X + A2X^2 + A3X^3 + A4X^4 + A5X^5

SUMMARY TABLE

PARAMETER	VALUE	INITIAL GUESS	STANDARD ERROR	T-RATIO	SIG. IF LEVEL
A (CONSTANT)	.70347E+26	.102E+26	*****	.05774	.95557
A1	-17.55904	-15.74196	4.85268	-3.62668	.00043
A2	6.13001	6.12636	4.25557	1.44250	.15237
A3	.17447E-01	.41432	.27091	.06440	.55045
A4	.45705	.32297	.10010	4.36361	.00329
A5	1.01348	.82432	.24751	4.11500	.00447

CORRELATION MATRIX

VARIABLE	MEAN	STANDARD DEVIATION	ADJ. CPL	DELIV YR	WHD LNTH	MIPS	MAX MEMO	FLOAT PT
1	49.75385	29.06277	1.00000	.05542	-.15490	.37448	.65008	.60931
2	76.78924	1.07767	.05542	1.00000	.19695	.40996	.54693	.27005
3	16.15385	.55470	-.15490	.19695	1.00000	-.31951	-.15208	-.15245
4	.23282	.09374	.37448	.40996	-.31951	1.00000	.53511	.51561
5	5850.78924	7331.50329	.65008	.54693	-.15208	.53511	1.00000	.25541
6	1.30765	.40038	.60931	.27005	-.15245	.51561	.25541	1.00000

COEFFICIENT OF DETERMINATION (R-SQ) = .87077
 STANDARD ERROR OF ESTIMATE = 13.85261
 SUM OF SQUARES OF RESIDUALS = 1304.75609
 F VALUE = 9.43375
 DEGREES OF FREEDOM FOR ERROR = 7
 TOTAL DEGREES OF FREEDOM = 12

MEAN OF ABSOLUTE RELATIVE DEVIATIONS = .23362
 COEFF. OF VARIATION (STD ERR EST / MEAN Y OBS) = .27440
 SUM OF SQUARES TOTAL = 10096.71251
 CORRELATION STATISTIC = 2.65553
 DEGREES OF FREEDOM FOR REGRESSION = 5
 TOTAL DEGREES OF FREEDOM = 13

VARIANCE-COVARIANCE MATRIX

	A	B	C	D	E	F
A	1.4925E+55	-.4081E+26	-.1490E+27	.4003E+26	.5036E+26	.5544E+26
B	-.4081E+26	.2354E+02	-.1123E+02	-.4014E+00	-.2862E+00	-.5770E+00
C	-.1490E+27	-.1123E+02	.1754E+02	.2840E+00	.1535E+00	.3604E+00
D	.4003E+26	-.4014E+00	.2840E+00	.7359E-01	-.9524E-02	-.4295E-02
E	.5036E+26	-.2862E+00	.1535E+00	-.9524E-02	.1002E-01	.7516E-02
F	.5544E+26	-.5770E+00	.3604E+00	-.4295E-02	.7516E-02	.6126E-01

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MILITARY CCSIS - MEMORY TYPE ELIMINATED - POWER FIT

TABLE OF RESIDUALS

COMPUTER	RESERVED ADJ. CPU	CELL YR	WMD LMT	MIPS	AMPLIFIED MAX MEMU	FLOAT PT	COMPUTED ADJ. CPU	RESIDUAL ADJ. CPU	RELATIVE DEVIATION
A RCL 021	72.400	72.000	16.000	.112	1024.000	1.000	65.640	13.760	.173
B RCL 073	39.600	76.000	16.000	.133	1152.000	1.000	34.600	.000	.000
C PLS P-2	21.600	76.000	16.000	.116	2048.000	1.000	34.336	-12.736	-.590
D RCL 052	63.100	76.000	16.000	.259	16384.000	2.000	71.018	-12.082	.145
E RCL 160	28.400	77.000	16.000	.233	1024.000	1.000	20.397	6.003	.282
F RCL 160	14.500	76.000	16.000	.120	512.000	1.000	16.745	-4.745	-.339
G RCL 160	43.700	76.000	16.000	.333	16384.000	1.000	54.540	-5.240	-.105
H RCL 163	30.700	76.000	16.000	.327	512.000	1.000	19.076	11.624	.379
I RCL 166	48.500	76.000	16.000	.333	1024.000	2.000	52.369	-3.869	-.080
J RCL 166	53.500	77.000	16.000	.333	16384.000	1.000	68.546	-9.646	-.163
K RCL 166	28.300	73.000	16.000	.216	1024.000	1.000	16.232	11.768	.420
L UTR 117	53.100	76.000	16.000	.172	2048.000	2.000	70.086	-16.986	-.320
M UTR 12-	116.200	76.000	16.000	.337	16384.000	2.000	111.397	4.803	.041

MINIMUM RELATIVE DEVIATION = -.58963. MEAN ABSOLUTE RELATIVE DEVIATION = .23362. MAXIMUM RELATIVE DEVIATION = .42029

TRANSFORMATION FACTORS -- Y: 0.00000 X1: 0.00000 X2: 0.00000 X3: 0.00000 X4: 12.00000 X5: 0.00000

CURVES REGRESSION ANALYSIS COMPUTER PROGRAM
(JULY 1976)

DATE: 06/24/80 TIME: 13.26.23. PAGE: 1

MILITARY COSTS - NO MEMORY ON FLOATING POINT - LINEAR FIT

LINEAR REGRESSION -- $Y = A + B * X1 + C * X2 + D * X3 + E * X4$

SUMMARY TABLE

PARAMETER	VALUE	STANDARD ERROR	F-RATIO	SIGNIF LEVEL	DETA COEFF
A (CONSTANT)	459.1000	311.7100	1.00134	.14797	-.52524
B DELIV IN	-7.79425	4.35550	-1.77320	.11413	.15009
C AND LITH	7.54124	15.04050	.00096	.51944	.06354
D AIRS	10.87004	80.63920	.21371	.83612	.94331
E VAA DELU	.350110-02	.00110	3.03252	.01625	

CORRELATION MATRIX

VARIABLE	PLAN	STANDARD DEVIATION	ADJ. R ²	DELIV IN	AND LITH	AIRS	VAA DELU
Y	54.4130	27.86547	1.00000	.04780	-.14602	.35907	.66347
X1	70.7020	1.57727	.04700	1.00000	.19695	.40996	.54693
X2	10.1300	.25470	-.14632	.19695	1.00000	-.51531	-.19208
X3	.22200	.07374	.35907	.40996	-.51531	1.00000	.59511
X4	500.7020	7301.5030	.66347	.54693	-.19208	.59511	1.00000

COEFFICIENT OF DETERMINATION (R²) = .80001
STANDARD ERROR OF ESTIMATE = 21.57450
SUM OF SQUARES OF RESIDUALS = 3725.69944
F VALUE = 3.00300
DEGREES OF FREEDOM FOR ERROR = 12
TOTAL DEGREES OF FREEDOM = 14
MEAN OF ABSOLUTE RELATIVE DEVIATIONS = .28317
COEFF VARIATION (STD ERR EST / MEAN Y OBS) = .59240
SUM OF SQUARES TOTAL = 9316.47652
CORRELATION STATISTICS = 1.41723
PEOPLE OF FAMILIES DUE TO REGRESSION = 4
NUMBER OF DATA POINTS = 15

VARIANCE-COVARIANCE MATRIX

	A	B	C	D	E
A	.972000+05	-.044000+03	-.202000+04	-.102000+04	-.421360-02
B	-.044000+03	.172000+02	-.239070+02	-.950051+02	-.232700-02
C	-.202000+04	-.239070+02	.170000+03	.382180+03	.291000-02
D	-.102000+04	-.950051+02	.382180+03	.700380+04	-.404310-01
E	-.421360-02	-.232700-02	.291000-02	-.404310-01	.139770-03

MILITARY COSTS - NO REPORT OR FLOATING POINT - POWER FIT

POWER REGRESSION -- Y = A + A1X + A2X^2 + A3X^3 + A4X^4 + A5X^5

SUMMARY TABLE

PARAMETER	VALUE	INITIAL GUESS	STANDARD ERROR	T-RATIO	SIGNIF LEVEL
A (CONSTANT)	.14119E+19	.13500E+20	*****	.04127	.98809
A1	-1.0547E+04	-1.0593E+04	8.10530	-1.2876	.12876
A2	1.9250E+02	4.3258E+02	5.45090	.35022	.73522
A3	.07405E-01	.45144	.40533	.21584	.83451
A4	.5070E	.32377	.12430	2.48599	.03176

CORRELATION MATRIX

VARIABLE	MEAN	STANDARD DEVIATION	ADJ. CORR	DELIV YR	WRU LNTH	MIPS	MAX MEMO
Y	54.41330	27.00347	1.00000	.04780	-.14622	.55907	.66347
A1	76.70223	1.07707	.04780	1.00000	.19095	.40990	.54693
A2	10.15583	.55473	-.14622	.13695	1.00000	-.51931	-.19208
A3	.23284	.05374	.35797	.40996	-.51931	1.00000	.59511
A4	5830.7622	7331.3333	.06347	.54693	-.19208	.59511	1.00000

B-20

COEFFICIENT OF DETERMINATION (R^2) = .57101
 STANDARD ERROR OF ESTIMATE = 22.55140
 SUM OF SQUARES OF RESIDUALS = 5990.70033
 F VALUE = 2.66204
 DEGREES OF FREEDOM FOR ERROR = 12
 TOTAL DEGREES OF FREEDOM = 13

VARIANCE-COVARIANCE MATRIX

	A	A1	A2	A3	A4
A	-.11704E+00	-.17440E+21	-.26301E+20	.47403E+19	.97033E+10
A1	-.17440E+21	.50282E+02	-.15023E+02	-.11390E+01	-.28338E+00
A2	-.26301E+20	-.15023E+02	.50140E+02	.72200E+00	.13677E+00
A3	.47403E+19	-.11390E+01	.72200E+00	.16300E+00	-.21155E-01
A4	.97033E+10	-.28338E+00	.13677E+00	-.21155E-01	.15515E-01

MEAN OF ABSOLUTE RELATIVE DEVIATIONS
 COEFF VARIATION (STD ERR EST / PARAM Y OBS)
 SUM OF SQUARES TOTAL
 CORRELATION-WATSON STATISTIC
 DEGREES OF FREEDOM DUE TO REGRESSION
 NUMBER OF DATA POINTS

.25732
 .41070
 9316.47652
 1.77729
 4
 13

MILITARY COSTS - NO MEMORY ON FLOATING POINT - LOG-LINKER FIT

LOG-LINKER REGRESSION -- $LN Y = LN A + B * LN X1 + C * LN X2 + D * LN X3 + E * LN X4$

SUMMARY TABLE

NOTE -- STATISTICS ARE BASED ON LOGARITHMS

PARAMETER	VALUE	STANDARD ERROR	T-RATIO	SIGNIF LEVEL	BETA COEFF
A (CONSTANT)	1.00000	1.00000	2.16094	.06192	
B (LN X1)	1.00000	1.00000	2.16094	.06192	
C (LN X2)	1.00000	1.00000	2.16094	.06192	
D (LN X3)	1.00000	1.00000	2.16094	.06192	
E (LN X4)	1.00000	1.00000	2.16094	.06192	
LN Y	5.07325	.50716			
LN X1	4.24002	.02475			
LN X2	2.78162	.03267			
LN X3	2.54506	.04003			
LN X4	7.73504	1.00000			

B-21

CORRELATION MATRIX

VARIABLE	LN Y	LN X1	LN X2	LN X3	LN X4	LN Y	LN X1	LN X2	LN X3	LN X4
LN Y	1.00000					1.00000				
LN X1	.05350	1.00000				.05350	1.00000			
LN X2	.19651	.00000	1.00000			.19651	.00000	1.00000		
LN X3	.41106	.47457	.51610	1.00000		.41106	.47457	.51610	1.00000	
LN X4	.52472	.52472	.52472	.52472	1.00000	.52472	.52472	.52472	.52472	1.00000

COEFFICIENT OF DETERMINATION (UNADJ.) R SQ	.6599
STANDARD ERROR OF ESTIMATE	.24505
SUM OF SQUARES OF RESIDUALS (LN)	.5000
DEGREES OF FREEDOM FOR ERROR	4.9999
TOTAL DEGREES OF FREEDOM	12

UNADJUSTED-COVARIANCE MATRIX

LN A	LN B	LN C	LN D	LN E
4.00270E+03	1.70040E+02	1.25000E+02	1.00000E+01	1.00000E+01
1.70040E+02	1.00000E+01	1.00000E+01	1.00000E+01	1.00000E+01
1.25000E+02	1.00000E+01	1.00000E+01	1.00000E+01	1.00000E+01
1.00000E+01	1.00000E+01	1.00000E+01	1.00000E+01	1.00000E+01
1.00000E+01	1.00000E+01	1.00000E+01	1.00000E+01	1.00000E+01

MEAN OF ABSOLUTE RELATIVE DEVIATIONS (LN)
 COEFF VARIATION (STD ERR EST / MEAN Y UBS)
 SUM OF SQUARES TOTAL (LN)
 FORDIN-WATSON STATISTIC
 DEGREES OF FREEDOM FOR REGRESSION
 NUMBER OF DATA POINTS

.05591
 .08915
 2.00000
 1.03787
 4
 13

SEMILOG REGRESSION -- LN Y = A + B * X1 + C * X2

SUMMARY TABLE

NOTE -- STATISTICS ARE BASED ON LOGARITHMS

PARAMETER	VALUE	STANDARD ERROR	T-RATIO	SIGNIF LEVEL	BETA COLFF
A (CONSTANT)	13.49338	1.64518	8.20177	.00000	
B DELIV YR	-.17018	.02135	-8.34472	.00000	-.62314
C CYCLE	-.655340-01	.12658	-.51774	.60566	-.03866

CORRELATION MATRIX

VARIABLE	MEAN	STANDARD DEVIATION	LN CNTS/BIT	DELIV YR	CYCLE
LN Y	13.49338	.70199	1.00000	-.61859	.03476
X1 DELIV YR	76.52174	2.45503	-.61859	1.00000	-.11783
X2 CYCLE	.76520	.41414	.03476	-.11783	1.00000

COEFFICIENT OF DETERMINATION (UNADJ), R SQ .38412 MEAN OF ABSOLUTE RELATIVE DEVIATIONS (LN 1.98724
STANDARD ERROR OF ESTIMATE .55581 COEFF VARIATION (STD ERR EST / MEAN Y OBS) -.353493
SUM OF SQUARES OF RESIDUALS (LN 34.59098 SUM OF SQUARES TOTAL (LN 56.17826
F VALUE 34.92705 CORBIN-WATSON STATISTIC 1.27553
DEGREES OF FREEDOM FOR ERROR 112 DEGREES OF FREEDOM DUE TO REGRESSION 2
TOTAL DEGREES OF FREEDOM 114 NUMBER OF DATA POINTS 115

VARIANCE-COVARIANCE MATRIX

	A	B	C
A	.270660+01	-.343140-01	-.124210-01
B	-.343140-01	.455530-03	.318460-03
C	-.124210-01	.318460-03	.160220-01

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COMMERICAL REPORT VS. YEAR AND CYCLE TIME - SEMILOGNOLITION - LINEAR FIT

LINEAR REGRESSION: -- $Y = A + B \cdot X1 + C \cdot X2$

SUMMARY TABLE

PARAMETER	VALUE	STANDARD ERROR	T-RATIO	SIGNIF LEVEL	BETA COEFF
A (CONSTANT)	25.82012	5.27482	7.82520	.00000	
B (CYCLE)	-0.31503	.04245	-7.42765	.00000	
C (CYCLE)	-0.63500E-01	.25751	-.24690	.80543	
					-.57752
					-.01920

CORRELATION MATRIX

VARIABLE	YEAR	STANDARD DEVIATION	CNTS/BIT	DELIV YR	CYCLE
Y	1.47656	1.34652	1.00000	-.57537	.04549
X1	78.35552	2.46445	-.57537	1.00000	-.11200
X2	.77681	.40669	.04549	-.11200	1.00000

COEFFICIENT OF DETERMINATION (R²), R SQ .33141
STANDARD ERROR OF ESTIMATE 1.11110
SUM OF SQUARES OF RESIDUALS 130.27840
F VALUE 27.75026
DEGREES OF FREEDOM FOR ERROR 112
TOTAL DEGREES OF FREEDOM 114

MEAN OF ABSOLUTE RELATIVE DEVIATIONS .60794
COEFF VARIATION (STD ERR EST / MEAN Y OBS) .75280
SUM OF SQUARES TOTAL 206.01738
DURBIN-WATSON STATISTIC 1.54295
DEGREES OF FREEDOM DUE TO REGRESSION 2
NUMBER OF DATA POINTS 115

VARIABLE-COVARIANCE MATRIX

	A	B	C
A	.10724E+02	-.13615E+00	-.50264E-01
B	-.13615E+00	.10052E-02	.12256E-02
C	-.50264E-01	.12256E-02	.86310E-01

COMPARISON OF REGRESSION VS. YEAR AND CYCLE TIME - SEMI-LOG (LN Y)

SEMI-LOG REGRESSION -- LN Y = A + B * X1 + C * X2

SUMMARY TABLE

NOTE -- STATISTICS ARE BASED ON LOGARITHMS

PARAMETER	VALUE	STANDARD ERROR	T-RATIO	SIGNIF LEVEL	BETA COEFF
A (CONSTANT)	10.64975	1.71467	9.71017	.00000	
B (COEFF)	-.21621	.02225	-9.71757	.00000	-.60928
C (COEFF)	-.00000	.13483	-.62991	.53004	-.04410

CORRELATION MATRIX

VARIABLE	MEAN	STANDARD DEVIATION	LN	CNTS/UNIT	DELIV YR	CYCLE
LN Y	0.7441	.76323	1.00000			.03210
X1	70.55052	2.46445	-.67534		1.00000	-.11200
X2	.77001	.40629	.03210		-.11200	1.00000

COEFFICIENT OF DETERMINATION (R²) = .45801
 STANDARD ERROR OF ESTIMATE = .50170
 SUM OF SQUARES OF RESIDUALS = 37.50853
 F VALUE = 47.32199
 DEGREES OF FREEDOM FOR ERROR = 112
 TOTAL DEGREES OF FREEDOM = 114

MEAN OF ABSOLUTE RELATIVE DEVIATIONS (LN) = 1.20388
 COEFF VARIATION (STD ERR EST / MEAN Y OBS) = 7.81006
 SUM OF SQUARES TOTAL (LN) = 69.94222
 CORRELATION COEFFICIENT = 1.23201
 DEGREES OF FREEDOM DUE TO REGRESSION = 2
 NUMBER OF DATA POINTS = 115

VARIANCE-COVARIANCE MATRIX

	A	B	C
A	.254011+01	-.073261-01	-.135940-01
B	-.073261-01	.432051-03	.336000-03
C	-.135940-01	.336000-03	.101790-01

EXPONENTIAL REGRESSION -- Y = EXP(A + B * X1 + C * X2)

SUMMARY TABLE

PARAMETER	VALUE	INITIAL GUESS	STANDARD ERROR	T-RATIO	SIGNIF LEVEL
A (CONSTANT)	28.04221	15.60409	2.0527	13.77811	.00000
B DELIV YR	-.35876	-.20329	.02977	-12.05092	.00000
C CYCLE	-.99644	.105890-01	.11511	-8.65670	.00000

CORRELATION MATRIX

VARIABLE	MEAN	STANDARD DEVIATION	CNTS/BIT	DELIV YR	CYCLE
Y	4.55185	7.45593	1.00000	-.59325	.18309
X1	72.90000	3.41197	-.55325	1.00000	-.53212
X2	1.12367	.74522	.18309	-.53212	1.00000

COEFFICIENT OF DETERMINATION (UNADJ), R SQ .67306
 STANDARD ERROR OF ESTIMATE 4.31182
 SUM OF SQUARES OF RESIDUALS 1617.40409
 F VALUE 89.55846
 Y INTERCEPT 1508613806256.96875
 DEGREES OF FREEDOM FOR ERROR 87
 TOTAL DEGREES OF FREEDOM 89

MEAN OF ABSOLUTE RELATIVE DEVIATIONS .90620
 COLFF VARIATION (STD ERR EST / MEAN Y OBS) .99079
 SUM OF SQUARES TOTAL 4947.58478
 DURBIN-WATSON STATISTIC 1.34697

DEGREES OF FREEDOM DUE TO REGRESSION 2
 NUMBER OF DATA POINTS 90

VARIANCE-COVARIANCE MATRIX

	A	B	C
A	.41424C+01	-.60453D-01	-.90422D-01
B	-.60453C-01	.86627D-03	.11690C-02
C	-.90422C-01	.11690C-02	.13249D-01

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COMMERCIAL MOUNT VS. YEAR AND CYCLE TIME - CURVE - LINEAR FIT

LINEAR REGRESSION: $Y = A + B \cdot X1 + C \cdot X2$

SUMMARY TABLE

PARAMETER	VALUE	STANDARD ERROR	T-RATIO	SIGNIF LEVEL	BETA COEFF
A (CONSTANT)	189.79782	20.01399	7.14222	.00000	
B DELIV YR	-2.41367	.34321	-7.03255	.00000	-.70187
C CYCLE	-2.83210	1.57191	-1.80175	.07513	-.17582

CORRELATION MATRIX

VARIABLE	MEAN	STANDARD DEVIATION	CORR/UNIT	DELIV YR	CYCLE
Y	0.69170	11.63750	1.00000		
X1	72.80836	3.44224	-.60656	1.00000	
X2	1.12004	.75155	.19217	-.53000	1.00000

COEFFICIENT OF DETERMINATION (UNADJ) R SQ .39117
 STANDARD ERROR OF ESTIMATE .34957
 SUM OF SQUARES OF RESIDUALS 7422.27904
 F VALUE 27.30636
 DEGREES OF FREEDOM FOR ERROR 85
 TOTAL DEGREES OF FREEDOM 87

MEAN OF ABSOLUTE RELATIVE DEVIATIONS 2.14501
 COEFF VARIATION (STD ERR EST / PLAN Y OBS) 1.39244
 SUM OF SQUARES TOTAL 12191.11004
 CORRELATION STATISTIC 1.26124
 DEGREES OF FREEDOM DUE TO REGRESSION 2
 NUMBER OF DATA POINTS 89

VARIABLE-COVARIANCE MATRIX

	A	B	C
A	.67870L+03	-.61740L+01	-.199650+01
B	-.61740L+01	.11780L+00	.285540+00
C	-.199650L+01	.285540L+00	.247050L+01

COMMERCIAL MEMORY VS. YEAR AND CYCLE TIME - CORE - EXPONENTIAL FIT

EXPONENTIAL REGRESSION -- $Y = EXP(A + B * X1 + C * X2)$

SUMMARY TABLE

PARAMETER	VALUE	INITIAL GUESS	STANDARD ERROR	T-RATIO	SIGNIF LEVEL
A (CONSTANT)	20.09001	17.52125	2.10678	13.71600	.00000
X1 (ELIV YR)	-0.36501	-0.22478	.03005	-11.83190	.00000
C (CYCLE)	-0.98604	.166140-01	.11515	-8.56310	.00000

CORRELATION MATRIX

VARIABLE	MEAN	STANDARD DEVIATION	CHISQ/DF	DEGIV YR	CYCLE
Y	0.03110	11.03753	1.00000	-0.6056	.19217
X1	72.08630	3.44224	-0.6056	1.00000	-0.53000
X2	1.12004	.75109	.19217	-0.53000	1.00000

COEFFICIENT OF DETERMINATION (UNADJ). R SQ .60108
 STANDARD ERROR OF ESTIMATE 0.76324
 SUM OF SQUARES OF RESIDUALS 3086.02005
 F VALUE 90.76125
 Y INTERCEPT 3545100520720.57107
 DEGREES OF FREEDOM FOR ERROR 85
 TOTAL DEGREES OF FREEDOM 87
 MEAN OF ABSOLUTE RELATIVE DEVIATIONS .92292
 COEFF VARIATION (STD ERR EST / MEAN Y OBS) 1.01069
 SUM OF SQUARES TOTAL 12191.11004
 CORBIN-WATSON STATISTIC 1.37591
 DEGREES OF FREEDOM DUE TO REGRESSION 2
 NUMBER OF DATA POINTS 88

VARIANCE-COVARIANCE MATRIX

	A	B	C
A	.443820-01	-.0648340-01	-.955570-01
B	-.0648340-01	.501710-03	.124500-02
C	-.955570-01	.124500-02	.132530-01

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MILITARY MEMORY VS. YEAR AND CYCLE TYPE - CUME - LINEAR FIT

LINEAR REGRESSION -- $Y = A + B \cdot X1 + C \cdot X2$

SUMMARY TABLE

PARAMETER	VALUE	STANDARD ERROR	T-RATIO	SIGNIF. LEVEL	BETA COEFF
A (CONSTANT)	29.55674	49.45330	.59548	.56428	
B DELIV YR	-2.5327	.57041	-4.3787	.67180	-.18948
C CYCLE	-4.96852	6.71484	-.73590	.47822	-.32018

CORRELATION MATRIX

VARIABLE	MEAN	STANDARD DEVIATION	CORR/B1	DELIV YR	CYCLE
Y	4.87917	2.60149	1.00000	.02313	-.19435
X1 DELIV YR	78.65533	1.94225	.02313	1.00000	-.66404
X2 CYCLE	1.00503	.18765	-.15435	-.66404	1.00000

COEFFICIENT OF DETERMINATION (UNADJ.) R SQ .05784
 STANDARD ERROR OF ESTIMATE 2.79163
 SUM OF SQUARES OF RESIDUALS 70.13684
 F VALUE .27629
 DEGREES OF FREEDOM FOR ERROR 11
 TOTAL DEGREES OF FREEDOM 12
 MEAN OF ABSOLUTE RELATIVE DEVIATIONS .42476
 COEFF VARIATION (STD ERR EST / MEAN Y OBS) .57215
 SUM OF SQUARES TOTAL 74.44309
 FOMBIN-WATSON STATISTIC 1.26529
 DEGREES OF FREEDOM DUE TO REGRESSION 2
 NUMBER OF DATA POINTS 12

VARIANCE-COVARIANCE MATRIX

	A	B	C
A	244561+04	-.14371E+02	-.26678E+02
B	-.14371E+02	.53456E+00	.25791E+01
C	-.26678E+02	.25791E+01	.45099E+04

EXPONENTIAL REGRESSION -- $Y = \exp(A + B \cdot X1 + C \cdot X2)$

SUMMARY TABLE

PARAMETER	VALUE	INITIAL GUESS	STANDARD ERROR	T-RATIO	SIGNIF LEVEL
A (CONSTANT)	10.10071	6.74431	10.55532	.96262	.30089
B (COEFF YR)	-0.01210-01	-0.50770-01	.10000	-.65470	.50472
C (CYCLE)	-0.74005	-0.83010	1.47503	-1.18502	.26656

CORRELATION MATRIX

VARIABLE	MEAN	STANDARD DEVIATION	CORR/SEIT	DELIV YR	CYCLE
Y	4.87917	2.60149	1.00000	.02313	-.19435
X1	70.85530	1.94025	.02313	1.00000	-.65404
X2	4.05530	.10705	-.19435	-.65404	1.00000

COEFFICIENT OF DETERMINATION (UNADJ). R SQ .09436
 STANDARD ERROR OF ESTIMATE 2.73700
 SUM OF SQUARES OF RESIDUALS 67.42034
 F VALUE .46037
 Y INTERCEPT 25000.70044
 DEGREES OF FREEDOM FOR ERROR 11
 TOTAL DEGREES OF FREEDOM 12

MEAN OF ABSOLUTE RELATIVE DEVIATIONS .41574
 COEFF VARIATION (STD ERR EST / MEAN Y OBS) .50050
 SUM OF SQUARES TOTAL 74.44509
 CORBIN-WATSON STATISTIC 1.23337

VARIABLE-COVARIANCE MATRIX

	A	B	C
A	.111410+03	-.132550+01	-.942850+01
B	-.132550+01	.160110-01	.540340-01
C	-.942850+01	.540340-01	.217010+01

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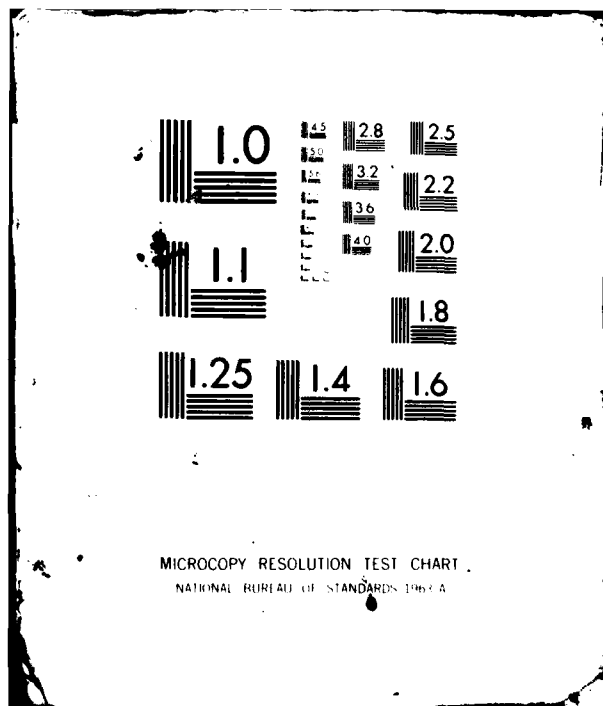
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APPENDIX C
MANUFACTURERS' CODES

Commercial

1. AID Advanced Information Design, Inc.
2. AJI Anderson-Jacobson, Inc.
3. BUR Burroughs Corporation
4. CAD Cado Systems Corporation
5. CDI Cascade Data, Inc.
6. CDP California Data Processors
7. CCC Century Computer Corporation
8. CMC Cincinnati Milacron, Inc.
9. CAI Computer Automation, Inc.
10. CHI Computer Hardware, Inc.
11. CDC Control Data Corporation
12. CSP CSP, Inc.
13. DGC Data General Computer
14. DPC Datapoint Corporation
15. DCC Digital Computer Controls
16. DEC Digital Equipment Corporation
17. DGI Digital Group, Inc.
18. DSC Digital Scientific Corporation
19. DSY Digital Systems Corporation
20. FAI Functional Automation, Inc.
21. GAI General Automation, Inc.
22. GRI GRI Computer Corporation
23. HCP Harris Corporation
24. HPC Hewlett-Packard Company
25. HON Honeywell Information Systems, Inc.
26. IBM International Business Machines Corporation
27. LEC Lockheed Electronics Company
28. MDC Microdata Corporation
29. MOD Modular Computer Systems, Inc.

Commercial (Cont'd)

- 30. NDC Nanodata Corporation
- 31. NDI Nuclear Data, Inc.
- 32. PEC Perkin Elmer Computer Systems Division
- 33. PBS Philips Business Systems, Inc.
- 34. PPS Plessey Peripheral Systems, Inc.
- 35. PCI Prime Computer, Inc.
- 36. RDS Raytheon Data Systems Company
- 37. SUD Sperry Univac Division, Sperry Rand Corporation
- 38. SEL Systems Engineering Laboratories, Inc.
- 39. TAN Tandem Computers, Inc.
- 40. TEK Tektronix, Inc.
- 41. TII Texas Instruments, Inc.
- 42. WLI Wang Laboratories, Inc.
- 43. WEC Westinghouse Electric Corporation

Military

- 1. AUT Autonetics Division, Rockwell Corporation
- 2. HON Honeywell Information Systems, Inc.
- 3. PPS Plessey Peripheral Systems, Inc.
- 4. ROL RoIm Corporation
- 5. UTN United Technologies, Norden Division

APPENDIX D DERIVATION OF MIPS FORMULAS

The basic formulas shown in equations (a) and (d) below are from Dr. Rein Turn's publications*:

- (a) For CPUs with hardware or software multiply, and multiplication time datum available:

$$\text{MIPS} = \frac{1}{0.7(t_a) + 0.3(t_m) + 2.0(t_{mc})}$$

- (b) For CPUs with software multiply, but multiplication time datum not available (assumes $t_m = 10(t_a)$):

$$\text{MIPS} = \frac{1}{3.7(t_a) + 2.0(t_{mc})}$$

- (c) For CPUs with hardware multiply, but multiplication time datum not available (assumes $t_m = 6(t_a)$):

$$\text{MIPS} = \frac{1}{2.5(t_a) + 2.0(t_{mc})}$$

- (d) For CPUs with hardware or software multiply, multiplication time datum available, and has "look ahead" pipeline feature:

$$\text{MIPS} = \frac{1}{0.7(t_a) + 0.3(t_m) + 2.0(k)(t_{mc})}$$

where:

t_a = instruction execution add time, microseconds

t_m = instruction execution multiply time, microseconds

t_{mc} = memory cycle time, microseconds

k = look ahead factor (1.0 = no look ahead)

* (1) Kennedy, J.R., et al, Advanced Data Processing Technology, CDRL A004, TRW Report 32 304-6921-008, 15 July 1978.

(2) Turn, Rein, Computers in the 1980's, Columbia University Press, 1974.

For some computer models, the multiplication execution times were not available, so equations (b) and (c) had to be developed. Equations (b) and (c) were derived from the general equation (a) by inserting separate average multiplication factors for software and hardware cases where the actual multiplication times were not known. The average factors were 6 times add time for hardware multiply CPUs, and 10 times for software multiply (i.e., performed by programmed subroutines). These factors were empirically - derived from the data shown in Tables D.1 and D.2.

It has been pointed out by some experts that the 30 percent multiply instructions assumed in all the equations may be conservative (i.e., too high of a percentage). Consequently, the calculated MIPS values may also be conservative (i.e., estimated MIPS may be low).

TABLE D.1

PROCESSORS WITH HARDWARE MULTIPLY/DIVIDE AS STANDARD

	FIXED POINT		
	<u>ADD</u>	<u>MULTIPLY</u>	<u>FACTOR RELATIONSHIP</u>
DEC PDP 11/55	0.97	3.89	4.0
DEC VAX 11/780	0.4	3.4	8.5
CAI LSI-2	4.1	14.8	3.6
CAI LSI-4/90	1.5	11.9	7.9
CAI SYFA	2.4	12.8	5.3
CDC 18-17A	1.8	17.4	9.7
CDC 18-20	1.76	6.6	12.0
DGC C/330	0.6	7.2	12.0
HPC HP2100	1.96	10.8	5.5
↓ HP21Mx	1.94	13.0	6.7
↓ HP1000M	1.9	12.5	6.6
↓ HP3000-III	0.55	5.25	9.5
HON 6/06	2.0	8.8	4.4
HON 6/34	1.9	12.7	6.7
PEC 6/16	0.9	6.6	7.3
↓ 8/16	0.75	9.25	12.3
↓ 8/32C	0.4	2.7	6.8
↓ 3240	0.85	3.84	4.5
MDC 3200	0.41	5.2	12.7
↓ 7870	0.2	1.2	6.0
↓ 7830	0.2	1.3	6.5
↓ Modcomp IV	0.64	3.5	5.5
PCI 550	0.56	4.2	7.5
PCI 750	0.24	1.38	5.8
SEL 32/35	1.8	6.2	3.4
SEL 32/75	1.2	5.5	4.6
TII 960B	3.6	8.6	2.4
TII 980B	1.75	2.65	1.5
SUD V77-400	1.32	5.94	4.5
SUD V77-600	0.74	4.79	6.5
SUD V77-200	2.31	5.11	2.2

Average of 32 factor relationships, $\frac{198.2}{32} = 6.19$ (use 6 rounded)

TABLE D.2

PROCESSORS WITH SOFTWARE MULTIPLY/DIVIDE

			FIXED POINT		
			<u>ADD</u>	<u>MULTIPLY</u>	<u>FACTOR RELATIONSHIP</u>
DEC	PDP	11/04	3.2	9.9	3.09
		11/34A	2.03	8.9	4.38
		11/45	.30	3.3	11.0
		11/35	1.07	9.16	8.56
DGC	Nova	4/C	0.4	4.4	10.0
DGC	Nova	4/X	0.2	4.4	20.0
PEC	50		3.25	19.4	5.97
PEC	74		1.5	34.0	22.7
IBM	Series/1,	Model 5	2.64	10.78	4.8

Average of 9 factor relationships, $\frac{89.78}{9} = 9.98$

Use 10 rounded

NOTE: These processors perform multiplies and divides by programmed subroutines.

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