PERFORMANCE MONITORING: A SURVEY OF TECHNIQUES UTILIZED BY THE UNITED STATES ARMY

by

THOMAS BRYANT

B. S., Morgan State University, 1963

A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Computer Science

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1976

Approved by:

Major Professor

ACKNOWLEDGMENT

The writer wishes to express his appreciation to Drs. Paul S. Fisher, Myron Calhoun, and Virgil E. Wallentine of the Department of Computer Science, Kansas State University, for the constructive criticism and advice given in the preparation of this report. The writer also wishes to thank his wife, Sandra, for her patience and endurance during the compiling of this report.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

1 Introduction

1.1. Background

The complex applications of the current generation of digital computers have increased the importance of methods used to measure and evaluate a computing system's performance. In the past, computers were designed with a fairly simple objective, which was to be as fast as possible in performing a particular application. However the measurement of speed was often dependent on the area of application.[1]

Early computers were designed for either general purpose or special purpose use. General-purpose computers were usually classified as either scientific or commercial.

Because the principle application of scientific computers was to perform calculations, the speed of scientific computers was based on certain discrete capabilities such as add, multiply, or divide time. Frequently, the computer was used to perform a well defined application which required a repetitive set of calculations. The arithmetic speed of a system would be measured in relation to the calculation process.

The commercial data processing field evaluated computing systems based on input/output rates. Large volumes of data were fed into computing system through use of a card reader or some other type of input device; the data was processed by the system, and such things as payrolls,

[1]Mansford E. Drummond, Jr., Evaluation and Measurement Techniques for Digital Computer Systems (New Jersey: Prentice-Hall, Inc., 1973), p. 23.

inventories, accounts, and billings resulted. The computing system's performance was assessed by the rates at which reading and writing occurred. Cards per minute, lines per minute and characters per second were typical performance parameters used in commercial data processing.

As computing systems and their applications changed, the simple but useful evaluation techniques of examining the add time or input/output rates were inadequate when evaluating a computer systems performance. Innovations such as I/O buffering have been devised. This technique allows the slow process of reading or writing of data to be overlapped with some other computing activity. Other innovations developed have been large capacity direct access storage devices and programming packages capable of loading other programs from an input storage medium into main storage. These innovations have increased the complexities of computing systems.[2]

Consequently, as computing systems have become more complex, there has been an increase in the number of elements to be measured in order to evaluate a computing systems performance.

To evaluate the total system's performance, such things as secondary storage, I/O channel and peripheral unit performance must be evaluated. In addition to the hardware performance, the software performance must also be considered. This requires the use of different measurement techniques to properly evaluate a computer system's performance.

Currently there are various measurement tools and techniques available which can be utilized to evaluate both the hardware and software performance of a computer system.

---

[2] Ibid., pp. 32-60.

1.2. Purpose of the Report

The United States Army is a very large user of computer systems and has several Data Processing Installations (DPI) and computing centers located throughout the Continental United States, the Pacific, and Europe, whose function is to process various personnel, finance, and logistic records. The United States Army utilizes various performances monitoring techniques to evaluate the performance of their computer system's hardware and software.

The purpose of the report is to survey the performance monitoring techniques utilized by the United States Army.

1.3. Organization of the Report

Section 2 highlights the current state-of-the-art in performance monitoring. Specifically, this section examines the tools and techniques which are available and used in conducting performance monitoring of computing systems. In this section only the hardware, software, and hybrid monitors are discussed.

Section 3 surveys performance monitoring tools and techniques utilized by the United States Army. Included is a discussion of how these tools and techniques used by the United States Army compare with the tools and techniques available on the commercial market.

Section 4 contains the conclusion and recommendations reached as a result of the survey. This section discusses the "effectiveness" of the United States Army's computer's performance monitoring techniques. Recommendations are made for deficiencies or shortcomings noted.

2 Highlights of Performance Monitoring

Tools and techniques for computer system performance monitoring have been around for several years.[1] The purpose of this section is to highlight the current state-of-the-art in performance monitoring. As such this section will examine the tools and techniques which are available and are used in conducting performance monitoring of computer systems. The ability of these tools in providing assistance in improving the effectiveness or optimization of computing systems will be discussed. General advantages and disadvantages which the users of the performance monitoring tools should be aware of will be listed.

2.1. The Need for Performance Monitoring

The computer equipment presently in use throughout the world represents an investment of billions of dollars.[2] The operating, programming and maintenance expenses of computer hardware are very large. With these tremendous expenses involved, it would seem reasonable to expect that computer systems perform to their maximum or at least optimal capabilities. However, reports have shown that the average large computer

---

[1] Mansford E. Drummond, Jr., Evaluation and Measurement Techniques for Digital Computer Systems (New Jersey: Prentice-Hall, Inc., 1973), p. 265.

[2] James H. Sood, "Shopping the World Computer Market," Info Systems, Vol. 20, No. 3 (Mar. 1973), p. 57.

operates at less than 30 percent efficiency.[3] Furthermore, the reports indicate that many computer systems are poorly coordinated and wasteful; the central processing unit (cpu) is not active much of the time, with very little cpu/peripheral overlap.

These inefficiencies in computer systems have affected the job turn-around time and system throughput rates. This would indicate that such inefficiencies represent a very poor return on the amount of money invested in computer systems and that there exists a need to improve the computer system performance. A possible solution to poor computer system performance could be to purchase a "bigger and better" computing system, however this does not guarantee that the same inefficiencies will not exist in the "bigger and better" system.

A more viable solution would be to correct the inefficiencies that may exist in the present computer systems. The correction will require the optimization or tuning of all available computer systems resources. This would include the hardware which consist of the cpu, memory, tapes, disc, card readers, and other peripherals and the software consisting of the assembler, compiler, operating system, subroutine libraries etc. Optimization of a computer system could mean a change in the number, type, speed, and organization of system components; greater interaction between peripherals; more cpu-I/O overlap, or a redistribution of peak loads and other bottlenecks that degrade a systems performance.

Before any of these changes can be accomplished effectively, a thorough evaluation of the computer system will be required. Questions such as the following will have to be answered. What is the system

---

[3]Dudley Warner, "Monitoring: A Key to Cost Efficiency," <u>Datamation</u> (January, 1971), p. 41.

doing? When is it doing it? Why and what is the priority? To what end is the system utilizing its resources? These questions can be answered through the use of system performance measurement techniques.[4]

2.2. Performance Measurement Defined

What is a performance measurement? A performance measurement can be defined as the process of quantitatively describing the operating characteristics of a digital computer system.[5] It may also be defined as a process which allows the user to obtain quantitative measurements of a computer system's performance while normal processing is underway. These definitions represent a contrast to the intuitive measurement of system performance that might be provided by users of computer systems.

2.3. Tools and Techniques

There are generally two preferred techniques to system performance measurement. Both involve the process of monitoring the computer system to obtain data describing the actual performance of an existing system. The techniques involve the use of hardware and software monitors. These terms refer more to the means used to perform the measurement than to the type of information being collected. However, each monitor has its own areas of operation. These will be explained in the discussion of each monitor.

2.3.1. Hardware Monitor

As previously stated the hardware of a computer system consists of the central processing unit (cpu), memory, tapes, discs, cardreaders, and

---

[4] Ibid., p. 40.

[5] Systems Development Corporation, "A Guide to Computer System Measurement," (unpublished, undated), p. 2.

other peripherals. A hardware monitor, sometimes called a "black box," is a device that is connected directly to the computer's circuitry and is used to measure the performance of computer hardware.[6]

Listed below are some of the categories of information that can be measured by a hardware monitor. Many other functions can be monitored and measured at the option of the user.

1. Active time of central processing unit (cpu).
2. Problem vs. supervisor time.
3. Activity by region (e.g. core mapping, data set organization, file structure).
4. Task-switching frequency.
5. Instructions executed.
6. Program and routine timing.
7. I/O organization and selection by
    a. channel.
    b. controller.
    c. device.
    d. component (e.g. disc arm).
8. Overlap of cpu-I/O.
9. Multipath balance (e.g. paths to each device).[7]

2.3.1.1. Classes of Hardware Monitors

Hardware monitors can be divided into two classes of monitors. The summary type has the characteristic that it accumulates the time or occurrence of a particular type event for the total amount of time or

---

[6] Drummond, Evaluation and Measurement Techniques for Digital Computer Systems, p. 207.

[7] Warner, "Monitoring:," p. 42.

total number of occurrences over a specified period. The summary type monitor provides the "how much" or "how often" information as to occurrences of an event. The dynamic monitor is the second type and provides the "when" of event occurrences. The inherent speed and capacity of the device and the speed of the output media are the primary differences between the two classes of hardware monitors.[8]

2.3.1.2. Organization and Function

The hardware monitor can accomplish the measurements previously listed because it is physically connected to the host computer. Figure 2.1 shows a hardware monitor and is an example of the main components of

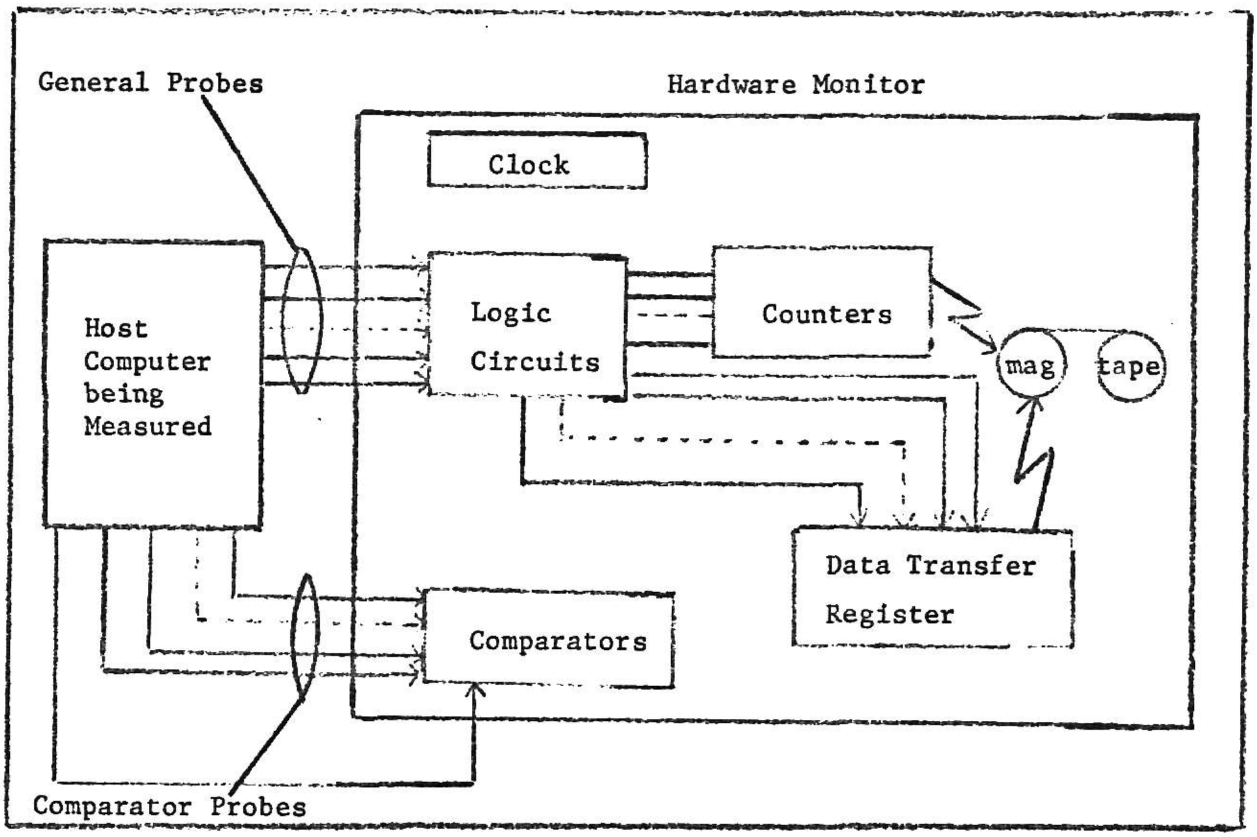

Figure 2.1: Elements of a Hardware Monitor

[8]Drummond, Evaluation and Measurement Techniques of Digital Computer Systems, p. 240.

the hardware monitor.[9] It should be noted that this figure is only one example of the many hardware monitors available on the market today.

The principle elements of a hardware monitor are:

1. General probes are a set of electronic signal signal sensors connected to the host computer system by physically connecting to the wire-wrap pins on the back panels of the computer system. These sensors detect electronic signal fluctuations representing such functions as "cpu wait," "channel busy," supervisor mode, and so forth. The sensor is used to detect the presence or absence of the signal which it is monitoring. This sensing process does not degrade the host system and the sensors are claimed to be "electronically transparent" to the host system.[10]

2. Logic circuits accept signals from the general probes and allow logical combinations of the signals (AND, OR, INVERTS, etc.). Events of interest (e.g. cpu active, channel active etc.) may be defined by combining signals from various pins in the required manner.

3. A group of counters are used to count the occurrences of various events or to measure the time between events by counting the number of intervening clock pulses. An example would be to count the occurrence of disc seeks, and also time the duration of these seeks. Selected information is then placed into buffered storage, or accumulating storage or both for later output. This operation may vary depending on the type of hardware monitor.

4. Comparator probes are similar to the general probes, but are used to

---

[9] Jerre D. Noe, "Acquiring and Using a Hardware Monitor," Datamation (April 1974), p. 89.

[10] Ibid.

sense a number of bits that appear in parallel (e.g. as in an address register).

5. Comparators provide a means for comparing the parallel bits with some value that has been preset by the user and may be used to determine either equality of incoming signals or the relationship of the signals to boundary conditions.

6. The data transfer register provides the means for passing data directly from the host computer to a magnetic tape recorder or to some display depending on the type monitor.

Hardware monitors may vary in function, cost, etc., but certain aspects (e.g. use of sensing probes, etc.) are common to all hardware monitors. Information is displayed and recorded in a number of ways. In an operational environment, some monitors have real time displays available on a small video screen, while for a more permanent record, a magnetic tape recorder is used.[11]

At the high price end of hardware monitors, a dedicated processor such as the Dynaprobe 8000 with a PDP 11-45, represents some of the latest technology. Earlier hardware monitors were specially constructed devices designed to perform the monitoring function. The use of another computer, specifically a minicomputer, represents a response to the rising cost of these specially designed hardware monitors. As the cost of specially designed hardware monitors rises, it approaches that of a minicomputer.[12] The minicomputer can be used to handle the monitoring task as well as a variety of other functions.

---

[11]Richard Slatter, "Sparing the Time to Analyse," Data Processing (July-August, 1974), p. 222.

[12]See Data Pro 70 The EDP Buyers Bible for price comparisons.

2.3.2. Software Monitor

The second technique of monitoring involves the use of a software monitor. The feasibility of a software monitor is derived from the method used by most operating systems to detect conditions that affect resource utilization (e.g. privileged operation mode and the interrupt structure).

A software monitor is a specially written program(s) which when used resides in memory and by an intercept or a sampling concept extracts data on various facts about the computer system environment. By inserting additional code at key points in the system control program or problem programs, intercept points are established which invoke the software monitor routine. Figure 2.2 shows the concept of intercept points to invoke the software monitoring routines. The sampling concept involves the invoking of the software monitor program at a regular interval, or time or when a combination of events occur that meets some criterion.[13]

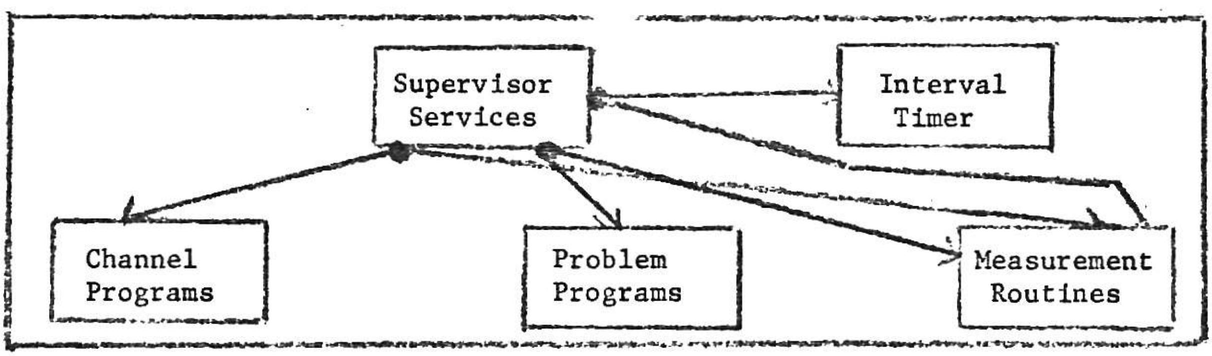

Figure 2.2: Concept of Intercept Points

When the software monitor is executed, it examines and extracts data pertinent to the activity about the system. Periodically this

[13] Drummond, Evaluation and Measurement Techniques of Digital Computer Systems, pp. 219-20.

accumulated information is recorded on suitable media such as tape or disk. A program analyzer, normally supplied with commercially available software monitor, is used for reduction and analysis of data gathered.

The output reports produced by the analyzer display information in the form of lists and charts. Information, identified as system or application related, of the following types is usually included in such reports:

1. Total elapsed system time.
2. CPU active time.
3. CPU wait time.
4. Operating system CPU time.
5. Problem program CPU time.
6. Channel(s) busy time.
7. Channel(s) overlap time.
8. Controller(s) busy time.
9. Device(s) busy time.
10. Total number of interrupts.
11. Total number of seeks on direct access storage devices.
12. Core memory partition usage.
13. Device activity (number of events).

There are two basic types of software monitors available. One type is the system monitor which gets its name because it is a facility used to measure the overall computer system activity and is device resource oriented. A second type is the program monitor which is used to measure program related activity in order to identify inefficiencies or bottlenecks in a particular program. Figure 2.3 illustrates one structure of a software monitor. This structure minimizes core usage by separating the

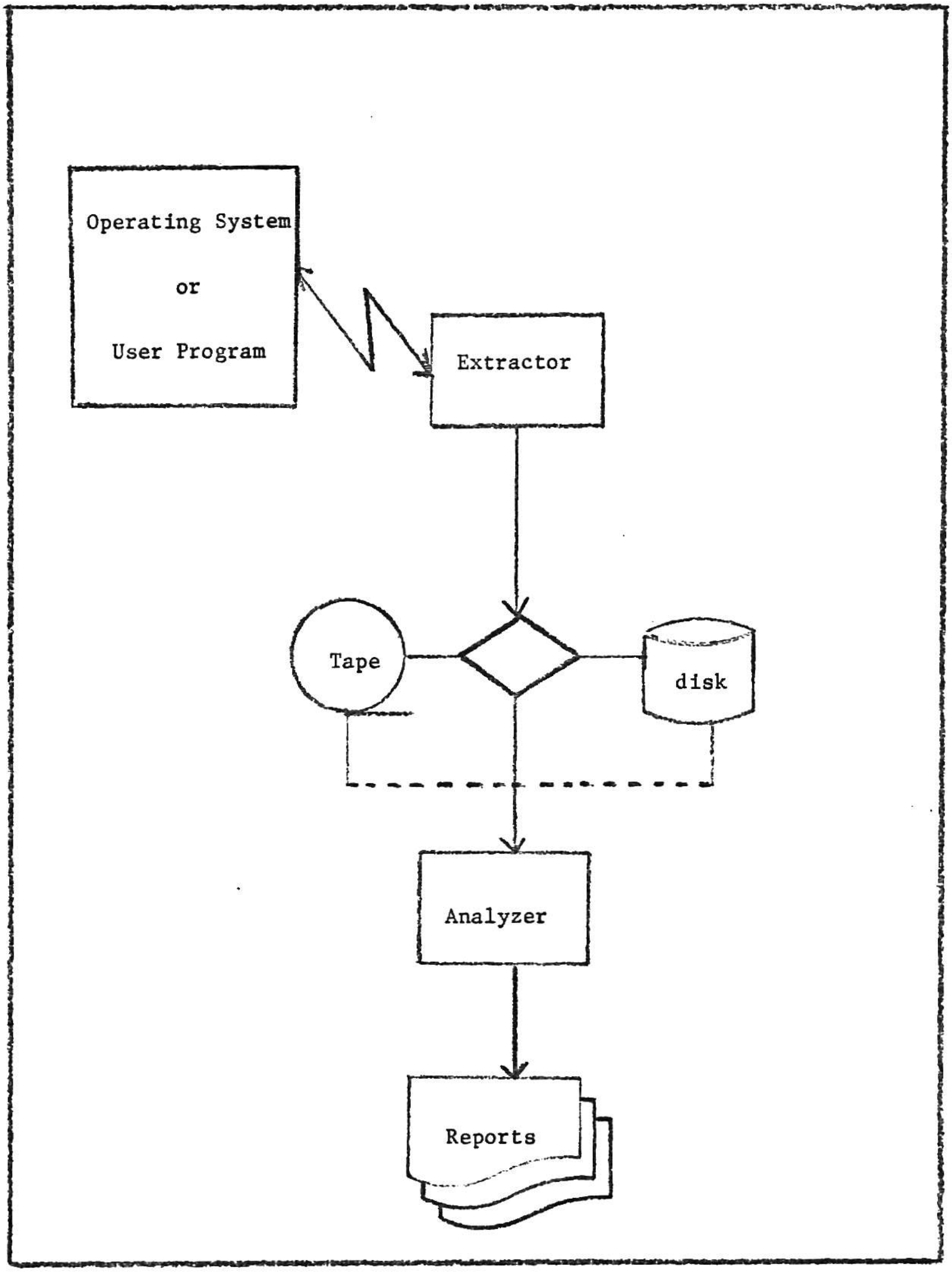

Figure 2.3: Type of Software Monitor

data extractor mechanism from data analysis function. While some software measurement tools combine the extractor and data reduction mechanisms, experience with them tends to strengthen the case for separation. Through various methods, the extractor enters a problem program or the operating system to collect data about the program or system. This data is periodically written on tape or disk. When the analyzer is invoked, the data is processed and various reports are produced.

2.3.3. General Advantages and Disadvantages

Hardware and software monitors each have their relative merits. Each type of monitor has its advantages and disadvantages. Figure 2.4 is a comparison of the hardware monitor versus the software monitor.

	Hardware	Software
1. Cost	High	Low-medium
2. Overhead	None	10-40%
3. Hardware/System dependent	No	Yes
4. Precision	Monitor dependent	Host dependent
5. Qualitative Measurement	Limited	Yes
6. User Training Required	Extensive	Limited
7. Flexibility	Good	Poor
8. Ease of Use	Poor	Good
9. Portability	Fair	Good
10. Device Monitoring	Yes	Maybe
11. Interrupt Recognition	Yes	Yes
12. Lifetime	Good	Fair

Figure 2.4: Comparison of Hardware vs Software Monitors

A software monitor has the following advantages: (1) very easy to use, (2) portable, (3) can monitor entire system and point out bottlenecks, (4) relatively inexpensive ($8-12K), (5) can also monitor individual programs, (6) has a unique advantage in that it can determine queue lengths.

A software monitor has the following disadvantages: (1) distortion of results (Heisenberg uncertainty principle),[14] (2) high overhead while executing, (3) operating system dependent, (4) cannot monitor multiple cpu's, (5) sampling technique prevents gathering all occurrences.

A hardware monitor has the following advantages: (1) no cpu or device overhead on monitored system, (2) no distortion of data, (3) can sample or collect all events, (4) extremely accurate, (5) has special advantages of being able to monitor multiple cpu's and can accurately monitor the activity of the operating system.

The disadvantages of a hardware monitor are: (1) very expensive ($70K), (2) talented user required, (3) high set-up time, (4) can collect data, but provides little intuition.[15]

2.3.4. Hybrid Monitor

The choice between a hardware and software monitor must be weighed in terms of system resource utilization and consequent degradation caused by the type of instrumentation used and the relative degree of difficulty dictated by the technique to be employed. Therefore, the very purpose of

---

[14] While using a software monitor to measure the performance of a computer system, the monitoring may have an effect on the performance of the computer.

[15] The hardware monitor has a major defect, in that it cannot conveniently provide detailed information about where in the system and problem programs and the data sets the various activities are concentrated.

monitoring which was to gain insight into the behavior of the system, to help trace and determine cause/effect relationships suggests a combination of both techniques. Since a computer system should be viewed from an integrated (hardware/software) point of view, a concept was developed using a similar approach in the monitoring field. This approach resulted in the development of the hybrid monitor. The hybrid monitor retains a hardware data acquisition front end while having a software that can interact with the operating system. The HEMI (Hybrid Events Monitoring Instrument) represents an attempt at synthesizing the former hardware and software monitoring techniques. It is an experimental instrumentation system being developed for use with the CYBER 70 and 170 series computers. This effort represents some of the newer technology in the field of monitoring.

2.4. Utility of Performance Monitoring Tools

Although hardware and software monitors have been around for several years and improvements in the technology of the monitors have been accomplished, the widespread use of monitors did not occur until the early 70's.[16] Perhaps the reason for this slowly developing acceptance and use lies in the fact that these monitors are fairly sophisticated scientific tools and in the past there weren't that many skilled people with the knowledge of how these monitors should be used. Perhaps, the use of monitors did not become important until computers and their applications became so complex.

Experience of some users of monitors has shown that the best results have been obtained in those cases where the user had defined a specific

---

[16] Kenneth W. Kolence, "A Software View of Measurement Tools," Datamation (January, 1971), p. 32.

problem area in his shop and used a hardware or software monitor to identify the causes of the problem. The worst results occurred when the user simply monitored his system with no specific goal in mind.

Users of monitors indicate that before monitoring is attempted, one should define a specific objective to be accomplished. This objective could be one of the following: (1) increase throughput (get more work done by the system), (2) reduce turnaround time (get a job, program, or transaction through the system in less time), (3) improve cost performance (get the work done at minimum cost).

With this objective established, the environment in which the monitors are to be used must be identified which involves the determining of the following: (1) representative work cycle (daily, weekly, and monthly), (2) operations scheduling constraints (pre-emptive priorities), (3) equipment schedules (is the equipment configuration going to change in the near future?).

After the objective and the environment have been identified, a general system profile should be obtained by using a hardware or software monitor. The profile should provide a good picture of overall systems performance, from which areas of potential improvement can be identified. If changes in system hardware or software organization are indicated from the profile, these changes should be accomplished and measurements repeated to see if changes had any effect.

An example of a performance measurement that resulted in improved job turnaround, was the measurement conducted at an Allied Chemical Data Center. The center had an IBM 360/50 and a 360/40 with a work load consisting of local batch processing, remote job entry and online systems. Measurements were taking using both hardware and software monitors.

These measurements revealed a cpu utilization on the 360/50 of 37-percent and selector channel utilization low and unbalanced. Consequent system changes and reorganization that were accomplished after the initial monitoring, resulted in a 57-percent cpu utilization and an increase in channel and cpu overlap on the 360/50. All the center's workload was transferred to the 360/50 and 360/40 was released. This report and others have indicated the utility of hardware and software monitors.[17]

---

[17] Philip G. Bookman, Barry A. Brotman, and Kurt L. Schmitt, "Use Measurement Engineering for Better System Performance," Computer Decisions (April, 1972), pp. 27-32.

3 Survey of Performance Monitoring in the United States Army

The United States Army spends more than $378 million annually for computing systems. It manages approximately 950 computers of all types and sizes. As a user of computer systems the United States Army has an interest in insuring that these computer systems perform effectively. One manifestation of this interest is the performance monitoring efforts taken by various Army agencies. This section surveys the performance monitoring tools and techniques utilized by the United States Army. This survey includes a discussion of the need for performance monitoring within the Army and examines the performance monitoring that is conducted by various Army agencies.

3.1. The Need for Performance Monitoring Within the Army

The costly commitment to computing systems by the Army developed during the 1960 decade. An annual growth rate of 15 percent occurred as a result of the "information explosion," and the use of sophisticated weaponry, personnel, and logistics techniques. Although the Army made significant gains in the battle to stem spiraling computing systems costs, the resource commitment remains significant. As a constant goal, the Army has sought to support its various information needs efficiently and at the lowest possible cost.

Various circumstances have retarded progress in attainment of this goal. One of the circumstances has been the fact that over the years, new applications and increasing workloads have imposed greater requirements for sophisticated computing equipment and highly skilled personnel. This resulted in an ever greater system complexity. This complexity has, in turn, challenged management efforts to obtain accurate measurement of hardware performance. Traditional job accounting systems furnished by computer manufacturers for performance measurement have become less and less satisfactory. The simple measurement of job run time and collection of "billing type information" fail to provide information of the kind and in the amount necessary to manage efficiently today's average computer system and workload. A second circumstance related closely to the first is the increasing reliance on sophisticated software and, in particular, the significant rise in software development and maintenance costs in recent years. This attaches increased importance to software costs in relation to other system costs.

Fortunately, various products and techniques to measure hardware performance and to curb and reduce software development costs have appeared over the last few years.

The Army recognized the potential of these new computer performance measurement products and techniques as early as December 1970 when information relative to their use was first disseminated Army-wide. Limited use began in 1972. The acquisition and use of these devices have thus far been accomplished on a decentralized basis. Various Army publications contain verbal policy encouraging individual data processing installations to use the new techniques. None of these publications prescribe a specified performance measurement program. It would seem that a centralized approach for the development and implementation of policy and procedures for performance measurement would more fully tap its available potential and yield a much wider range of benefits.[1]

3.2. Performance Monitoring in the Army

Experience in performance monitor usage has been growing since the first market survey was made by the U.S. Army Computer Systems and Evaluation Agency (CSSEA) in February 1970. In December 1970, the Army published Technical Bulletin, 18-20, Improving Computer System Efficiency. This bulletin contains general information on monitor usage, a list of vendors, their advantages and disadvantages, and represents an initial effort to encourage use.

In May 1972, CSSEA acquired a Dynaprobe 7700 hardware monitor. With the acquisition of this monitor, CSSEA has also had responsibility for maintaining a current and thorough knowledge of performance monitors, providing advice and assistance on monitor usage to all Army activities, and conducting performance measurements with monitors as requested.

In February 1973, a change to Army Regulation 18-1 required Army activities to obtain approval prior to acquisition of monitors. Except for this provision, no other policies, procedures, or standards for monitor usage are mentioned in this or related regulations. The approach to performance measurement largely has been a decentralized program. Noteworthy results with monitors, however, have been achieved at CSSEA, Computer System Command (CSC) and the Automated Logistices Management System Agency (ALMSA).

---

[1] U.S., Department of the Army, Army Audit Agency, "Armywide Audit of Selected Aspects of the Utilization and Management of Automatic Data Processing Equipment" (5 Oct. 1973), p. 116.

3.2.1. Computer System and Evaluation Agency

On May 2, 1973, CSSEA completed a report of the monitored usage of a UNIVAC 1108 system at White Sands Missile Range. The performance analysis objectives were to:

1. Determine use of equipment installed.
2. Verify improvement in job turnaround resulting from an installed equipment augmentation.
3. Determine extent of utilization of magnetic tape drives.

CSSEA used their hardware monitor, the Dynaprobe 7700. It was used to measure I/O activity on the magnetic tape drives and augmented drum storage units during peak workload processing periods. A number of noted deficiencies hampered the measurement process. Systems activity logging procedures and data reduction programs were found to be deficient. Data reduction programs, for example, did not adequately present useable data, were in a "test state" and were not documented prior to or during the measurement effort. Descriptions of data reduction report contents proved to be inaccurate and incomplete. These deficiencies prevented direct analysis of magnetic tape file and core storage utilization. In spite of this, these conslusions were derived:

1. Drum storage units usage was unacceptably low and imbalanced. Lack of separate data paths to these devices appeared to be the prime contributing factor causing low utilization.

2. Measurement of core storage utilization was not done.

3. Job turnaround time improved by a factor of approximately 18.7 percent and throughput by approximately 20.6 percent. This is considered to be a small return for the equipment augmentation previously undertaken.

4. Magnetic tape drives usage was moderate and available tape drives appeared to be sufficient for the existing workload. Capacity for additional workload was available.[2]

On 1 August 1973, CSSEA completed a measurement study at Aberdeen Proving Ground which had an installed IBM 360/65 system. The performance analysis objectives were to identify areas of inefficiency, verify them, determine causes, and formulate methods for improvement. The performance analysis approach required time to develop an understanding of the total system operation and, as in the first example, use of the Dynaprobe 7700 hardware monitor. The analysis revealed rudimentary workload scheduling procedures in need of improvement. CPU utilization was satisfactory but the great majority of workload was I/O bound (85 percent). Core storage waste by problem programs was significant (18.6 percent). Core storage was often unused when a sufficient amount was available to execute additional programs. Failure to utilize a sufficient number of system initiators was the primary cause. Unsatisfactory selector channel usage existed. In addition to low usage, the system lacked appreciable channel overlap. This condition appeared to be due to a failure to utilize channel separation for tape files and temporary data sets and to the I/O data paths provided with existing hardware configuration. As a result of this analysis, CSSEA made recommendations to improve channel separation and to change the hardware configuration. Recommendations were made for the implementation of procedures for analysis of direct access storage

---

[2] U.S. Army Computer Systems Support and Evaluation Command, "Report on Performance Measurement" (unpublished, 2 May 1973).

utilization for temporary data systems and the acquisition of an additional IBM Operating System Job Initiator.[3]

CSSEA currently uses the following off-the shelf hardware and software monitors: Dynaprobe 7700 hardware monitor; Dynaprobe 8700 hardware monitor; CUE, PPE and LEAP software monitors.[4]

These on-site measurements by CSSEA are not intended to cast criticism at the installations concerned, but are used solely to illustrate what can be accomplished. Treatment of this type of information in day to day operations is, in fact, one of management's biggest problems in conducting an effective measurement program. Reaction by management to this information will, of course, either sustain or weaken the program.

3.2.2. Computer Systems Command

Since activation on 31 March 1969 the Computer Systems Command (CSC) has designed, developed, programmed, installed, maintained, and improved Army Multicommand ADP information systems. These systems must meet the needs of as many as 42 identical Army-wide processing installations. Maximization of throughput, without reconfiguration, has led to program performance measurement for reduction of program run time, and to configuration measurement for identifying hardware and software bottlenecks. The command has a research charter to push the performance measurements state-of-the-art and works on the development of automated evaluation of performance monitor data. Grants have been provided to various institutions to research and develop resource utilization monitors. One

---

[3] Ibid. (unpublished, 1 August, 1973).

[4] CSSEA, interview with selected personnel of the Performance Analysis Division (October, 1975).

such grant was the project worked on by the Department of Computer Science at Kansas State University. This project was designed to provide CSC with a low cost monitoring tool which could be utilized to measure 360/370 computing systems. In the meantime, intensive operational use of off-the-shelf hardware and software monitors is being made. The inventory of these at CSC now is: X-Ray 160 hardware monitor; Testdata Model 1185D hardware; CUE, PPE and LEAP software monitors. CSC uses these monitors throughout the system life cycle for the development, operation, and maintenance. As soon as object programs are available, program performance monitoring begins along with efforts to reduce program run time. Performance measurements and analysis, made during installation and after the system reaches operational status, insure that no bottlenecks work into the system. A study of one multi-command system showed that monitor usage reduced average processing time by 21.7 percent for nine programs. This eliminated three hours from a daily processing cycle. When multiplied by the number of computer systems involved (42), one can immediately see the substantial savings achieved for the Army.[5]

3.2.3. Automated Logistics Management System

Computer system performance at ALMSA provides assistance in problem identification, operational control, simulation, equipment selection and system tuning.

The inventory of performance monitors currently being used at ALMSA includes the following:

---

[5] U.S. Army Computer Systems Command, interview with selected personnel (October, 1975).

1. Software monitors:

a. Problem Program Evaluator (PPE). A product of Boole and Babbage, the evaluator measures the efficiency of the application program being executed. Program activity is recorded and reduced as a separate step of the measurement action. Reports show time spent in various sections of the application program.

b. Configuration Utilization Evaluation (CUE). This is also a product of Boole and Babbage, and the program operates much like PPE. The specific difference is that CUE samples component (system) activity.

2. Hardware Monitors: The monitor currently used by ALMSA is a Dynaprobe 8000 produced by COMRESS Inc. This monitor is used to complement the PPE and CUE software monitors.

Hardware and software monitors have been used by ALMSA to improve overall computing system performance and to improve the performance of various 360 computing systems with the Army Materiel Command. The monitors have also been used by ALMSA to show subordinate units what can be done with performance monitoring devices. This has resulted in the six commodity commands of the Army Materiel Command acquiring software monitors to be used in monitoring the performance of the computing systems they operate.

The ALMSA's performance measurement team conducted a performance measurement study of the White Sand Missile Range's (WSMR) Model 360/50 system. The objective was to measure and evaluate the utilization and performance of the WSMR 360/50 system. This system processes work for eight different users including WSMR and seven remote terminals. Remote terminals include several different types of front end systems connected to KBlines. The WSMR system runs 24 hours a day, 7 days a week, with heaviest workload occurring during weekday processing. The system runs OS/MVT with six HASP initiators. Each initiator is dedicated to a particular user for the purpose of processing his workload. Three of the six initiators are normally dedicated to the heaviest users; WSMR, Dugway, and Yuma, while the remaining initiators are shared by the other five terminal users. Figure 3.1 shows the percentage of total system workload for each user. These percentages were obtained from a three month accounting data package.

User	Percentage
1. WSMR	50
2. Dugway	23
3. Yuma	15
4. Tropic	4
5. Ft. Sill	3
6. Ft. Huachuca	2
7. Ft. Bliss	2
8. Artic	1

Figure 3.1: User Percentage WSMR

The WSMR general system profile, a summary of hardware monitor statistics compiled from two weeks of collecting data is shown in Figure 3.2.

After developing general system profile for the WSMR system, the hardware monitor was reconfigured to measure the utilization of tape and disk as well as the two channel switches and disk.

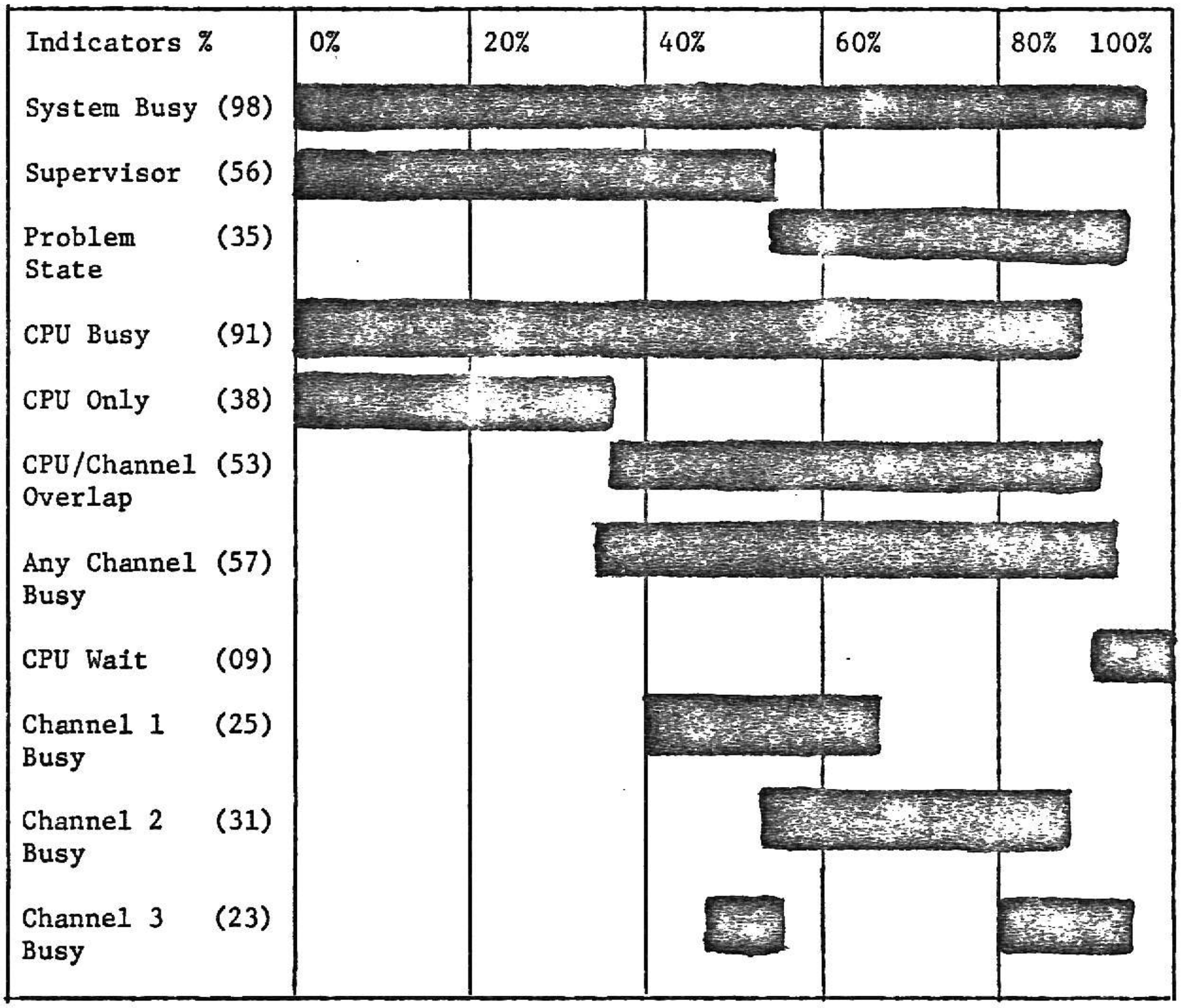

Figure 3.2: White Sands Missile Range General Systems Profile

1. 69% of all uses of tape and disk were to disk.

2. The combined usage of the tape drive is 10 percent with less than 1 percent overlap between the primary and alternate channels.

3. The hardware monitors showed that the accesses to each disk are evenly divided between the two channel switches. Monitoring also showed efficient utilization of the two channel switches in that a 10 percent overlap was indicated. This meant that both channel switches were simultaneously busy about 10 percent of the time.

After capturing several general system profiles using a hardware monitor, efforts were directed toward performance optimization. A Boole and Babbage CUE software monitor was used. The following changes were made to the system, resulting in a 20 percent decrease in system resident pack activity and an 8 percent increase in system throughput.

1. System overhead time was significantly reduced by making all HASP core resident. This eliminated the time required to load these highly accessed routines. An additional 20 K of core was required to accomplish this change.

2. CUE revealed several non-resident SVC's were highly active while some resident SVC's had rather low usage. Two low usage SVC's were deleted and eight more SVC's were added. An additional 6 K of core was required while SVC loads were reduced by 30 percent.

3. Contention on the system resident pack and head movement time was reduced by moving SYS1.JOBQUE from a highly accessed system resident pack to a low usage library pack. Head movement time was also reduced by expanding primary space allocation from SYS2.LINKLIB to include the secondary allocations which were located on the opposite end of the disk pack.

These optimization efforts resulted in an eight percent increase in system throughput. Both the hardware and software were tuned to process with greater efficiency. In order to provide the White Sands Missile Range with the capability of maintaining optimum system performance, ALSMA recommended the WSMR procure Boole and Babbage CUE.[6]

---

[6]U.S., The Automated Logistics Management Systems Agency, "Performance Measurement Study: Final Analysis of White Sands Missile Range's (WSMR) 360/50 System" (unpublished, n.d.).

3.2.4. Analysis of Tools Used

The performance monitoring tools currently used by Army agencies are the same as those available commercially. These Army agencies currently use the off-the-shelf Comress and Testdata hardware monitors, and the Boole and Babbage software monitors. These tools have been useful in providing assistance in optimizing/tuning the performance of many Army's computing systems. CSSEA, CSC, and ALSMA have indicated that their use will continue.

4 Conclusion and Recommendations

Although performance monitoring tools have some disadvantages, the advantages of these tools overrides the disadvantages and supports their continued use. These tools can be extremely useful in optimizing a computer system's performance.

In light of recent budget constraints, complexity of installed computer systems, and pressures of modern day management, the need for computer performance measurement within the Army will increase. Available hardware and software monitoring techniques provide excellent relief for accurately estimating system performance to achieve greater efficiency. The installation's budget, resources, and nature of processing dictate selection of the proper technique. Either or both may practicably be used.

Experiences of Army agencies using monitors have positively demonstrated the capability and potential of these techniques. The United States Army profits from their use and actively pursues development of policy and procedures necessary for more effectiveness. The use of both types of monitors is beginning to spread throughout the Army.

Cost restraints permitting, the Army should provide a software monitor to each data processing installation. In so doing, the installation would have the capability to continuously monitor its own computer system. Should a verification of the software monitors results be required, then a hardware monitor could be brought in from CSSEA, CSC, or ALSMA.

In the meantime, the continued education of potential Army users at all levels is paramount. As a minimum, the importance of performance measurement, the nature of available tools, and the possible benefits should be made a matter of continued emphasis.

The current decentralized approach to performance measurement within the Army should be closely studied. A stronger, centralized approach appears needed to capitalize on potential performance measurement benefits. Centralized development of policy, measurement procedures and standards, and reporting procedures can strengthen the program. Pertinent Army regulations for information systems should be modified to specify the program, require usage where practical, and provide for feedback reporting of usage for evaluation and future action.

Emphasis should be placed on dissemination of performance measurement information to potential and actual users in the field. Devices and methods being used, benefits derived, problems, cost information and the like, if documented and forwarded to data processing installations, would provide valuable support to an announced program.

Bibliography

Bell, T. E., Boehm, B. W., and Watson, R. A. "How to Get Started on Performance Improvement." Computer Decisions, March, 1973, pp. 30-34.

Bell, Thomas. "Performance Determination Selection of Tools If Any." AFIPS, Vol. 42, 1973.

Bookman, Philip G., Brotman, Barry A., and Schmitt, Kurt L. "Use Measurement Engineering for Better System Performance." Computer Decisions, April, 1972, pp. 28-32.

Calingaert, Peter. "System Performance Evaluation Survey and Appraisal." Communications of the ACM, Vol. 10, Number 1, January, 1967, pp. 12-18.

Castle, Richard. "Performance Measurement at USACSC." Unpublished Article from United States Army Computer Systems Command, Fort Belvoir, Virginia, no date (Xerox).

Cockrum, J. S., and Crockett, E. D. "Interpreting the Results of a Hardware System Monitor." PROC Spring Joint Computer Conference, 1971, pp. 23-38.

Darden, Stephen C., and Heller, Steven B. "Streamline Your Software Development." Computer Decisions, October, 1970, pp. 29-33.

Drummond, Mansford E., Jr. Evaluation and Measurement Techniques for Digital Computer Systems. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1973.

Ferrari, Domenica. "Workload Characterization and Selection in Computer Performance Measurement." Computer, July/August, 1972, pp. 18-24.

Gemar, Bill. "Improved Performance for Less Cost." Data Processing, July-August, 1974, pp. 225-228.

Hellerman, Herbert, and Conroy, F. Thomas. Computer System Performance. New York: McGraw-Hill, 1975.

Hughes, Kevin, Binns, John, and Cooke, Arthur. "Keeping in Tune." Data Processing, July-August, 1974, pp. 218-221.

Johnson, R. R. "Needed: A Measure for Measure." Datamation, December 15, 1970, pp. 22-30.

Karush, Arnold. "Performance Measurement." Data Management, July, 1971, pp. 36-40.

Kolence, Kenneth W. "A Software View of Measurement Tools." Datamation, January 1, 1971, pp. 32-38.

Lucas, Henry C., Jr. "Performance Evaluation and Monitoring." Computing Survey, Vol. 3, Number 3, September, 1971, pp. 79-91.

Peterson, Thomas G. "A Comparison of Software and Hardware Monitors." Performance Evaluation Review, Vol. 3, Number 2, January, 1974, p. 2.

Sebastian, Peter R. "Hemi (Hybrid Events Monitoring Instrument)." Performance Evaluation Review, Vol. 3, Number 4, December, 1974, pp. 127-137.

Sewald, Milton D., Rauch, Michael E., Rodick, Lyle, and Wertz, Langston. "A Pragmatic Approach to Systems Measurement." Computer Decisions, July, 1971, pp. 38-40.

Slatter, Richard. "Sparing the Time to Analyse." Data Processing, July-August, 1974, pp. 221-224.

Sood, James H. "Shopping the World Computer Market." Info Systems, Vol. 20, Number 3, March, 1973, pp. 55-60.

Stang, H. "Performance Evaluation of 3rd Generation Computers." Datamation, Vol. 15, November 11, 1969, pp. 181-190.

System Development Corporation. "A Guide to Computer System Measurement." No date, unpublished, pp. 1-20 (Xerox).

Testdata Systems Corporation. "General Information 1100 Series." 1973, unpublished, pp. 2-16.

Testdata Systems Corporation. "Software Systems General Information Manual." No date, unpublished, pp. 3-19.

U.S. Army Automated Logistics Management Systems Agency. "Performance Measurement Study Analysis of ECOM Model 360/65 Alpha System." June 4, 1975.

U.S. Army Automated Logistics Management Systems Agency. "Performance Measurement Study Analysis of MICOM's Model 360/65 Alpha System." February 27, 1975 (Xerox).

U.S. Army Automated Logistics Management Systems Agency. "ARMCOM Performance Measurement Study." October 29, 1974 (Xerox).

U.S. Army Automated Logistics Management Systems Agency. "Performance Measurement Study: Final Analysis of White Sands Missile Range's (WSMR) Model 360/50 System." No date (Xerox).

U.S. Army Computer Systems Support and Evaluation Command. "Report on Performance Measurement and Evaluation of the Aberdeen Proving Ground IBM 360/65 Computer System." August 1, 1973 (Xerox).

U.S. Army Computer Systems Support and Evaluation Command. "Report on Performance Measurement and Analysis of the White Sands Missile Range." May 2, 1973 (Xerox).

Wallentine, V., Anderson, G., Keller, R., and Fisher, P. Research Into and Development of a Low-Cost Hardware Monitor. Prepared for the U.S. Army Computer Systems Command, Ft. Belvoir, Virginia, July, 1975, Manhattan, Kansas.

Warner, Dudley C. "Monitoring: A Key to Cost Efficiency." Datamation, January 1, 1971, pp. 40-49.

PERFORMANCE MONITORING: A SURVEY OF TECHNIQUES UTILIZED BY THE UNITED STATES ARMY

by

THOMAS BRYANT

B. S., Morgan State University, 1963

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Computer Science

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1976

ABSTRACT

The United States Army annually invests millions of dollars in computer systems and presently utilizes equipment representing cost of billions of dollars. With this large capital investment, the United States Army has an interest in insuring that these computing systems perform optimally, yet reports have indicated that many computing systems operate at less than 30 percent efficiency. This inefficiency affects the job turnaround time, throughput rates and increases the computing cost. Fortunately, computing systems performance can be improved with the help of hardware and software monitors. This report highlights the state-of-the-art in computer performance monitoring and surveys the computer performance monitoring techniques utilized by United States Army agencies for improving the performance of their computing systems. In light of recent budget constraints and the pressures of modern day management, the need for computer performance monitoring within the Army will increase. Emphasis should be placed on dissemination of performance measurement information to potential and actual users. If cost will allow, each installation should have the capability to monitor its computer systems performance.