REPORT TO THE CONGRESS

Tools And Techniques For Improving The Efficiency Of Federal Automatic Data Processing Operation

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BY THE COMPTROLLER GENERAL OF THE UNITED STATES

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COMPTROLLER GENERAL OF THE UNITED STATES
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To the President of the Senate and the
Speaker of the House of Representatives

This is our report on tools and techniques for improving the efficiency of Federal automatic data processing operations.

We made our review pursuant to the Budget and Accounting Act, 1921 (31 U.S.C. 53), and the Accounting and Auditing Act of 1950 (31 U.S.C. 67).

We are sending copies of this report to the Administrator of General Services and to the heads of Federal departments and agencies.

Acting Comptroller General
of the United States

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ABBREVIATIONS

ADP	automatic data processing
COBOL	common business oriented language
CPU	central processing unit
FEDSIM	Federal Computer Performance Evaluation and Simulation Center
GAO	General Accounting Office
GSA	General Services Administration
NBS	National Bureau of Standards
OMB	Office of Management and Budget

COMPTROLLER GENERAL'S
REPORT TO THE CONGRESS

TOOLS AND TECHNIQUES FOR IMPROVING THE EFFICIENCY OF FEDERAL AUTOMATIC DATA PROCESSING OPERATIONS B-115369

D I G E S T

WHY THE REVIEW WAS MADE

An earlier GAO report[1] described some tools and techniques that could be used for reducing computer operating costs through identifying ways to increase operational efficiency. These tools and techniques were relatively new, and the opportunity for their increased use by Government agencies was extensive.

This review of 43 computer installations in industry and Government was made to identify additional uses of these and other techniques. The Federal Government has thousands of computers with annual operating costs estimated at several billion dollars; consequently, increased efficiency can produce worthwhile savings.

FINDINGS AND CONCLUSIONS

Areas affecting efficiency and examples of benefits

Some installations have improved their efficiency by examining specific areas of their computer services. For example:

--One Federal installation eliminated 208 unnecessary reports, which represented 13 percent of the products it reviewed. (See p. 9.)

--One Government agency estimated that it saved more than $1.7 million annually by improving a few key programs. (See p. 14.)

--A large financial institution estimated that it annually saves $132,000 in one instance and $79,000 in another by keeping its operating system properly "tuned" to the needs of its operating environment. (See pp. 21 and 22.)

--One organization identified annual savings of $150,000 in hardware and reduced personnel costs through more effective determination of its hardware requirements. (See p. 33.)

Chapters 2 through 7 contain additional findings in these and other areas and some methods, tools, and techniques that helped to obtain these increases in efficiency and economy.

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[1]"Opportunity for Greater Efficiency and Savings through the Use of Evaluation Techniques in the Federal Government's Computer Operations" (B-115369, August 22, 1972).

Need for specific guidance on increasing computer efficiency

The Federal Government has taken several steps to help agencies improve their computer operations. (See pp. 34 and 35.)

--The Office of Management and Budget established a policy that agencies should determine the efficiency of existing equipment before acquiring more.

--The National Bureau of Standards formed the Federal Information Processing Standards Task Group 10 to establish guidelines for using simulation, performance monitors, benchmarks, and analytic methods.

--The Computer Performance Evaluation Users Group was transferred from Department of Defense to National Bureau of Standards sponsorship.

--The General Services Administration formed the Federal Computer Performance Evaluation and Simulation Center to provide Federal agencies with an economical source for computer simulation and performance monitoring services. (See p. 35 and app. I.)

Most of these steps are oriented specifically toward using individual tools, such as performance monitors and simulation. They do not address overall areas affecting computer efficiency or provide specific guidance in these areas.

In view of the benefits that many installations obtained, more Federal computer installations should be provided with more specific guidance on increasing computer efficiency.

Many managers and authorities interviewed stated that it would be most desirable for computer manufacturers to provide users with comprehensive guides to help them obtain increased system efficiency. Such guides could greatly assist in developing programs for improved operations.

RECOMMENDATIONS

Since the General Services Administration is responsible for centralized procurement and management policy for automatic data processing equipment, GAO recommends that the Administrator:

--Give priority to preparing and issuing detailed guidance to Federal agencies on methods to increase the efficiency of their systems.

--Consider the extent to which agency managements have evaluated and improved the efficiency of their existing systems (including their use of the Federal Computer Performance Evaluation and Simulation Center) before approving procurement of additional or more powerful systems. (See p. 36.)

AGENCY ACTIONS AND UNRESOLVED ISSUES

The General Services Administration generally agrees with the content of

this report and is taking steps to implement the recommendations (see app. II).

MATTERS FOR CONSIDERATION BY THE CONGRESS

Although the specific matters in this report concern actions to be taken by agency automatic data processing managements, the report is being furnished to the Congress because the Joint Economic Committee, the House Committee on Government Operations, and other committees have expressed concern about cost trends in the computer field.

We are sending copies of this report to the heads of Federal departments and agencies.

CHAPTER 1

INTRODUCTION

In the early and mid-1950s, computer systems (referred to as first-generation vacuum tube computers) were extremely simple, at least compared with those of today. Hardware was generally expensive and unsophisticated. Very little flexibility existed in selecting peripheral equipment. Basically, a manager's greatest opportunity for increasing the efficiency of his system was to shorten the running time of computer programs, usually by repositioning program instructions.

During the late 1950s and early 1960s, second-generation (solid state) computers emerged. Because of their faster computational capability, faster input-output devices became standard equipment. These systems were more productive because they were able to execute program instructions and perform input and output functions simultaneously. This was accomplished by a new type of computer program, called an operating system, which provided for transition from one computer program to another and for control over input-output procedures.

During the second-generation era, improving computer operations was not generally emphasized, possibly because top managements associated a degree of mystique with complex computers and delegated many of their responsibilities to computer technicians. Managers often had only an elementary understanding of automatic data processing (ADP) operations and were not in a position to have much impact on insuring efficient ADP operations.

Third-generation computers which emerged in the mid-1960s were smaller in size but normally able to compute and process data much faster. They were modularly designed so that their capacities could be increased as an organization's data processing needs increased. Operating-system software became more complex, because it now controlled several computer programs which operated concurrently in the computer system (multiprograming). With this advanced hardware and operating systems also came continued growth in applications. In addition to batch processing, new applica-

tions with characteristics of (1) remote access,[1] (2) online processing,[2] and (3) real time processing[3] were developed.

Third-generation computers are more technical, so ADP operations managers faced more difficult tasks in attempting to improve the efficiency and effectiveness of ADP operations. Some problems became more complex; for example:

--Evaluating computer applications.

--Analyzing and increasing the efficiency of operating systems.

--Educating the computer operator about the complex system.

--Scheduling the computer for multiprograming.

Because it was difficult to cope with these and other problems, shifting from one generation to another became a costly undertaking. Rather than convert all their programs, many installations used third-generation computers as second-generation equipment. This process, usually referred to as emulation and designed as a crutch to aid users in coverting to new systems, allowed the installations to increase performance due to increased speeds but not to realize the full productive potential of the new equipment.

No clear delineation of computer systems exists beyond the third-generation, although computer technology has advanced significantly since the mid-1960s. The complexity of computer systems and the management problems of improving their efficiency have grown concomitantly.

Recognizing that management's problem of evaluating computer performance has also become more complex, we made this study to identify methods, tools, and techniques which Federal managers can use to increase the efficiency of their computer systems.

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[1]Communication with a computer system by one or more stations distant from the computer.

[2]Ability to directly interact with the computer.

[3]Pertaining to the performance of a computation during the actual time the related physical process transpires, in order that results of the computation can be used in guiding the physical process.

Computer installations have differing objectives and operating requirements. Not all installations will have problems in each of the areas identified in chapters 2 through 7 of this report; therefore, we are not suggesting that every installation should acquire or develop methods, tools, and techniques for detailed evaluation of efficiency in each of the areas. Each management should identify its system's greatest deterrent to improved performance which, if corrected, would yield a better return on investment or a better cost-benefit ratio. After making this determination, management may wish to use some of the methods, tools, or techniques set forth in this report.

CHAPTER 2

MAKING SURE COMPUTER PRODUCTS ARE NEEDED AND PROPERLY DESIGNED

It would be of no value to spend time and resources increasing the efficiency of a computer system which is performing useless tasks. The most important consideration in enhancing productivity is to assess the value of computer output by (1) determining whether an application is needed and should be computerized, and (2) insuring that an application is designed to use computer resources efficiently.

PRODUCT NEED

Unless sufficient formal controls exist and are being enforced, the computer system may be performing work which is not necessary or justifiable.

Some programs on computers which may not be contributing to ADP productivity are those

--allowed to run only because time is available,

--which should not have been automated because requirements could have been more economically fulfilled by other means, and

--no longer meeting needs of an organization.

Some new installations had formalized procedures for reviewing existing workloads. At the Army Ammunition Procurement and Supply Agency, the Systems Review and Audit Branch is responsible for evaluating, and recommending whether to continue, revise, or end computer-produced products or reports. At the time of our visit, the Branch was evaluating its products by means of a questionnaire asking report recipients such questions as:

--Could this report be canceled?

--Could it be replaced by some other existing report?

--Could it be replaced by combining it with another report or by modifying another report?

--Should the data content be changed?

--Could its frequency be changed?

--Could the number of copies received be changed?

--Explain the requirement for and purpose of this report.

The Branch schedules all recurring computer reports for review once a year on a staggered monthly schedule. For a 1-year period the results of the review were as follows.

Not changed	919
Canceled	208
Changed in frequency and distribution of copies	172
Required modifications in format, etc.	81
Under review at time of visit	220
Number of products reviewed	1,600

We believe more installations should regularly evaluate their computer products in a similar way.

SYSTEMS DESIGN

Many products from early computers resulted from converting punch card systems to run on faster computer systems. The criterion often employed in making these conversions was insuring that the new system received the same inputs and produced the same outputs. Little emphasis was given to redesigning programs to better fulfill user requirements or to take advantage of advanced features of the computers.

As new computer systems emerged, they usually were capable of acting like old systems, through emulation. Using the emulation technique allows some cost-performance

improvements. However, in most cases, had the systems been redesigned to take advantage of new features and to better meet changing requirements, much greater efficiency and productivity may have resulted. Many installations we visited were still emulating old systems.

Reported examples of improved efficiency through redesigning of systems include:

--A group of local banks organized a data processing center to provide economical data processing services. From the mid-1960s to the late 1960s, the center used a second-generation computer to batch process transactions, which required daily printing of all accounts. The printing consisted of 3,000 pages of output a night (600,000 line items a month) and took 8 to 10 hours of processing time daily. Late in 1969 the group developed a central information file and software to permit real-time inquiry concurrent with batch processing and added random access storage and data communications capability. The real-time inquiry designed permitted a 3- to 4-second response to inquiries as opposed to the time required to manually search through a computer printout. The new design has reduced print requirements by 80 percent, saving 6 to 8 hours of central processing unit (CPU) time daily and increasing the system's capacity by 30 to 40 percent.

--A major communications equipment manufacturer saved money and increased efficiency through design changes in processing data files. The company uses sequential batch systems, in which the usual method of processing files is to read the entire file for each program processed. It redesigned its systems to read each file only once to process several programs. This design change saved over $18,000 a year in computer time on one file alone. Total computer time saved is estimated at $76,000 annually. The company also identified additional savings attributable to reductions in setup time (time required by the computer operator to prepare computer programs to run) and in the number of magnetic tape reels required.

Our study showed that some companies do have and enforce effective controls. However, no detailed Government-wide procedures or guidelines have been established to aid Federal agencies in developing and enforcing controls to insure that applications performed by their computer systems are necessary and properly designed.

CHAPTER 3

WAYS TO INCREASE EFFICIENCY OF APPLICATION PROGRAMS

An application program is a set of computer instructions or steps that tell the computer exactly how to handle a complete problem, such as payroll or inventory. In early computer generations, improving application programs offered the greatest opportunity for increasing the efficiency of the overall system. Many areas affect the overall productivity of today's computer systems, but increasing the efficiency of application programs and programing procedures continues to offer dollar-saving opportunities.

Our August 22, 1972, report to the Congress[1] noted that the Goddard Space Flight Center had saved $433,000 in computer time by using a software monitor to increase the efficiency of 10 application programs.

The following additional methods, tools, and techniques are often used concurrently.

WAYS TO IDENTIFY PROGRAMS HAVING PERFORMANCE PROBLEMS

Normally it is impractical to evaluate every application program in an installation; some programs require so few computer resources and are run so infrequently that performance evaluation could not be justified. Computer accounting systems and operator feedback are two useful methods for highlighting programs to be optimized.[2]

Computer accounting systems

The computer accounting system is that portion of the computer's operating system which records the resources used in running application programs. For example, it shows the amount of storage, CPU time, and input-output resources each program uses.

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[1]"Opportunity for Greater Efficiency and Savings Through the Use of Evaluation Techniques in the Federal Government's Computer Operations" (B-115369).

[2]Optimize--rearrange instructions in storage to minimize time and transfers required to run a program.

This information is frequently used in billing customers for their use of the computer. Managers can use it to identify programs consuming relatively large percentages of computer resources and, therefore, programs offering the greatest potential for savings through optimization.

A report of the National Bureau of Standards' (NBS) Federal Information Processing Standards Task Group No. 10 showed that Federal agencies use accounting information as the principal tool for measuring computer performance and evaluating computer systems. The Defense Intelligence Agency, for example, used accounting information to identify programs offering the greatest potential for improvement. Each program exceeding predetermined limits of storage, CPU time, input-output requests, printed output, or elapsed time was identified for evaluation.

Operator feedback

A computer operator is responsible for operating the computer and observing its operations to determine whether particular application programs adversely affect system efficiency. The operator can convey this information to the programing supervisor.

A large transportation company and an insurance company have successfully implemented procedures for operators to report efficiency problems. In one instance, operators were required to prepare memorandums when program problems arose, such as when processing was halted before the job was completed or application programs appeared to be using system resources inefficiently. The memorandums were sent to the programer's supervisor and to an administrative division, thus keeping management alerted. These operator observations were used to identify programs needing improvement.

WAYS TO IDENTIFY SPECIFIC PROBLEMS

After programs needing improvement have been identified, other tools and techniques are needed to identify such specific problems as unnecessary use of the central processor and of internal storage and inefficient input and output of data. The three most common tools and

techniques for identifying these performance problems are software monitors, hardware monitors, and simulation. They can identify only the problem areas; the application programer must isolate specific problems and determine needed adjustments.

Software monitors

Software monitors are special computer programs which monitor and record the activities--such as CPU use--of application programs and/or operating system software.

Our August 22, 1972, report showed that Goddard Space Flight Center used a software monitor and an efficient compiler in revising 10 programs and saved $433,000 in computer time annually. Two installations at this agency have continued to use software monitors and estimate that the agency has saved an additional $1.7 million in computer time annually, primarily from reducing the programs' use of the central processor.

From the analysis of data provided by software monitors and from subsequent changes made to solve input-output problems, the Defense Construction Supply Center reduced the size of 1 data file from 14 reels of magnetic tape to 3 reels and reduced file-processing time from 2-1/2 hours to 44 minutes. The Center also increased the information stored on 16 reels of magnetic tape by 24 percent and decreased processing time from 7 to 2 hours. It also reduced core requirements of 1 program by 50,000 storage positions.

Hardware monitors

Hardware monitors are devices that electronically connect to computer components to monitor their activities (i.e., use of hardware resources).

Ordinarily, hardware monitors are not used to improve the efficiency of application programs. However, some larger, more advanced hardware monitors are capable of monitoring an application program's use of a computer's resources. This information can be used to identify program

areas needing improvement, e.g., areas consuming excessive amounts of CPU time.

The Defense Intelligence Agency, using data generated by the monitor, changed an application program to obtain a 5- to 10-percent decrease in running time.

Simulation

Simulation has also been used to identify areas of computer programs needing improvement. For example, a Federal Computer Performance Evaluation and Simulation Center (FEDSIM) official informed us that the Air Force Data Systems Design Center used simulation to construct models of 14 computer programs being used at 121 military installations. The programs averaged 4 hours of computer time per installation each month. By using models, alternative processing techniques were simulated, disclosing that the programs' efficiency could be increased by changing input and processing procedures. Modifying the programs reduced processing time more than 40 percent.

The cost of analyzing and modifying these programs was more than offset by the savings in computer time in the first month. These programs will continue to be used, so the return on investment will be extremely favorable.

WAYS TO DIRECTLY INCREASE PERFORMANCE

Program optimizers

Programs are currently written in compiler languages, such as common business oriented language (COBOL). A compiler takes an application program written in a language somewhat like English and prepares a machine language program the computer can execute. NBS, in Federal Information Processing Standards Publication 21, directed that new business-oriented application programs and those being extensively revised in the Federal Government be programed in Federal Standard COBOL compiler language. Major deviations from this policy are to be reported to NBS.

COBOL is commonly used, and optimizers are available which are designed to make COBOL application programs more

efficient. Program optimizers are special computer programs, designed to minimize inefficiencies in application programs, and usually reduce the amount of program storage and processing time. Several Government and private installations used program optimizers and reported they reduced program internal storage[1] requirements up to 42 percent and processing time up to 25 percent.

The present trend is toward including optimizing as a compiler function. This technique has already been used on some compilers and may be extended on future compilers.

Special utility programs

Most modern business applications require substantial computer resources for sorting and merging data. Special sorting programs have been developed to use resources more efficiently.

A U.S. Marine Corps test found one such sorting program to be much more efficient than the one supplied by the equipment vendor. Specifically, it

--was two to three times faster;

--interfered less with other programs being executed concurrently, thereby allowing the computer system to operate at greater efficiency; and

--required less central processing time.

AIDS FOR PRODUCING EFFICIENT PROGRAMS

Perhaps the most effective method for increasing efficiency is to help programers produce more efficient programs. A few installations gave special attention to this area, using the techniques discussed below.

Higher level languages allow programers to communicate with the computer without programing in (speaking) the

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[1]Storage directly controlled by the processing unit of the computer system.

machine's language. Because many programers are not aware that inefficient programs can be caused by an imprudent selection of programing alternatives from higher level languages, training for programing efficiency is important. Such specialized training has been given in several ADP installations, and, although the overall effect on computer productivity cannot be measured, this training does help programers to become aware of efficient programing techniques.

Technical circulars

Some installations have issued circulars for sharing with other programers in the organization the computer performance information discovered by one programer. These circulars represent a good management practice and may significantly increase programing efficiency.

Special assistance groups

Several ADP installations have established special groups to assist programers in producing efficient programs. The functions of these groups varied from reviewing documentation to reviewing actual programs for efficiency. One group was established solely to assist programers in creating the job-control statements--used in identifying the job or describing its requirements to the operating system--required to run their programs. Several improvements in efficiency have been credited to the advice given by these groups.

A group at the Goddard Space Flight Center, whose only tool was its knowledge of efficient programing techniques, was able to save about $300,000 annually, encompassing CPU, input-output, programer, and operator time, and magnetic tape, paper, and cards. An average of 300,000 locations in internal storage have been made available for multiprograming and 15,000,000 locations in external storage have been made available to other programs.

Another group, which used a software monitor, saved the Center over $750,000 of computer time in 1 year by increasing the efficiency of key application programs.

Programing standards

Many types of standards must be considered in applications development, such as systems analysis, programing, operation, and documentation standards.

Programing standards for enhancing efficiency are established primarily to eliminate unnecessary use of computer resources and to insure against bottlenecks occurring from overusing critical resources of the system.

Standards are needed for both the test and development stages and for the production stage of application programs. Standards for test and development programing at one installation included

--size of test files,
--amount of printed output,
--program processing time,
--resident storage,
--operator console messages,
--number of tape drives, and
--use of space on random devices.

In the production stage of any application program, some of these categories may not apply, but resident storage requirements, operator interaction, and use of sequential versus random devices are areas having real potential for improved efficiency.

Enforcing standards is as important as the standards themselves. We found that enforcement ranged from reviews by the programer's supervisor to special review and enforcement groups.

We believe agency managements should insure that their computer installations have established and enforced programing standards which will further the goal of maximizing computer efficiency.

CHAPTER 4

WAYS TO INCREASE EFFICIENCY OF OPERATING SYSTEM SOFTWARE

Operating system software is the group of programs that monitor and control the operation of the computer system while the application programs are running. These monitoring and control functions include:

--Scheduling and supervising program execution.

--Allocating and releasing storage, input and output devices, and other resources of the computer system.

--Controlling all input and output operations.

--Handling errors.

--Coordinating exchange of information between the computer operator and the computer system.

--Maintaining accountability of resources used by the various programs.

Most of today's large, general-purpose multiprograming computer operating systems support all the varied applications a computer may perform, and most operating systems are designed to be flexible so that users can adapt them to their specific environments. Such adaptations can lead to more efficient computer use.

TUNING OPERATING SYSTEM SOFTWARE

The process of adjusting operating system software to get maximum efficiency is usually termed "tuning." Many of the installations we visited had made some improvements by tuning operating system software. Officials at some installations believed that greater increases in efficiency were limited because computer vendors had not provided sufficient organized, related, and coordinated information to guide users in properly tuning their computer systems.

Several areas which must be considered in tuning operating systems hardware are discussed below.

Locating operating system software in internal storage

Operating system software encompasses many functions. In most systems, it is impossible to locate more than a small portion of this software in internal storage. A large portion of the operating system is usually stored on random access devices and put into internal storage as needed. Some flexible systems permit the users to decide whether, due to frequent use, some of these portions should be located permanently in internal storage.

Properly selecting the parts to be stored internally can improve overall performance of the operating system. Specifically designed software monitors usually identify which parts to make resident, but advanced hardware monitors and detailed simulation models can also do this.

Below are examples of improvements in this area.

--A large financial institution estimated that adjusting the resident portion of the operating system as a result of using a software monitor saved computer time worth approximately $44,000 a year.

--The Atomic Energy Commission's Argonne National Laboratory reduced the use of one input-output channel[1] 18 percent by making key portions of its operating system resident in internal storage.

Locating operating system software in external storage

Not all operating system software can permanently reside in internal storage; it is simply too large to fit and still leave room to process application programs. A discussion of factors to be considered in locating software in external or auxiliary storage[2] follows.

[1]Paths along with signals (information) are exchanged between a computer's internal storage and its peripheral devices without extensively involving the central processor.

[2]Storage not directly controlled by the processing unit of the computer system.

Type of device

Operating system software is one key to the performance of the computer system, so the portion not resident in internal storage is usually located on the fastest auxiliary device attached to the computer system, generally a direct access device, such as a drum or disk.

Location of devices

Most operating systems allow externally stored portions to be located on more than one device, which increases efficiency by balancing the operating system's input-output activity. The devices can also be placed on different input-output channels to further balance activity.

A large financial institution used a software monitor to balance the operating system software input-output activity between two channels and estimated that the resultant increase in efficiency saved approximately $132,000 in computer time annually.

Location on device

Most random access devices use movable mechanisms to store and retrieve data. The process of physically moving the mechanism from one location to another in order to store or retrieve data is usually termed "seeking" and the time required to so reposition is termed "seek time."

Each time an external portion of the operating system software is required for running a program, it must be brought into internal storage from its location on external storage. To do this the computer system usually must first-position the access mechanism to read a directory to determine the exact location of the required portion, then the access mechanism must reposition to read the portion itself. The seek time required to move from the directory to the portion can be significant if the portion is located a great distance from the directory. Therefore, to maintain a high level of efficiency, frequently used modules should usually be positioned close to the directory. A software monitor can identify these modules.

One financial institution estimates that it saves approximately $79,000 annually in computer time by optimally locating such portions to reduce nonproductive seek time.

MODIFYING STANDARD OPERATING SYSTEM SOFTWARE

Some installations found it desirable to modify vendor-supplied operating system software to obtain higher levels of efficiency. Reported improvements from such modifications ranged from 25-percent reductions in operating system overhead to 30-percent increases in throughput capacities.

We generally do not recommend that Federal ADP installations modify vendor-supplied operating systems to obtain increases in efficiency. Operating system software is usually very complex, and modifying it is extremely costly and requires qualified experts and considerable computer resources. When the software is modified, flexibility to take advantage of new features that may later be incorporated in standard vendor-supplied software is sometimes precluded. Most vendors make new versions of their operating systems available at least once a year. To take advantage of these new features as they become available, the installation may have to repeatedly modify each new vendor-supplied operating system, thereby incurring repeated costs.

We believe that (1) agencies should consider modifying operating systems only if there are clear indications that returns on investment will be substantially greater than the continuing investment required and (2) many performance objectives can be reached through properly selecting operating systems, or options within them, and through tuning the systems. Generally, modifying operating systems is not desirable.

CHAPTER 5

WAYS TO IMPROVE OPERATION OF COMPUTER SYSTEMS

First- and second-generation computers were not too complex to operate. Basic functions were insuring that the computer had programs to execute and satisfying requests of application programs while they were running; e.g., "mount a tape" or "insert more cards for punching." With the advent of multiprograming, the role and importance of computer operators increased significantly. Operators now provide computers with several programs to execute concurrently and must satisfy the demands of these several programs--mount tapes, change forms in the printers, etc.--in a timely fashion.

Information from private industry demonstrated that operators were vital to computer efficiency. A study of two similar computer systems was made to compare the operators of a "typical" user with those of a computer vendor, assuming that the vendor's operators would be more knowledgeable of the computer systems. The study showed that, primarily due to its operators, the vendor had over 90 percent fewer interruptions[1] in the normal work cycle than the user.

Operations personnel can be keys to the productivity of computer systems. Milliseconds and seconds that can be gained from tuning operating-system software and application programs can be easily negated by the time lost through inefficient manual procedures. Two important management concerns then, are (1) how to determine whether operations are achieving maximum efficiency and (2) what methods and aids to use to improve the efficiency of operations personnel.

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[1]Temporary cessations in the productive use of a computer system.

WAY TO EVALUATE OPERATIONS

Computer accounting systems

The most-used method was to process accounting data that the computer itself produced and to develop several indicators used by installation managers in determining whether operations personnel were getting efficient system use.

These indicators included:

--Extent or ratio of multiprograming (average number of application program running concurrently).

--Machine down time (time computer is unavailable due to malfunctions of hardware or operating system software).

--Trends in the elapsed time of a job.

--Set-up time (time it takes to prepare an application program to run).

--Idle time (time computer is available but not being used).

We believe these indicators, in conjunction with one another and with other indicators, can be useful in determining the relative efficiency of operations personnel. Officials at one installation advised us that they directly related efficiency indicators to the evaluation of operators when considering operators for salary raises and promotions.

Rerun analysis

Several installations placed importance on analyzing the reruns caused by operators. A large insurance company calculated the cost of each operator-caused rerun and, if it exceeded a predetermined limit, gave special management attention to the operator (or team of operators) causing the error.

Observation

The simplest method we found was direct observation of the system during production periods. The Defense Intelligence Agency, using this method, identified the following factors which affected the efficiency of the data processing function.

--Programers and unauthorized personnel in the machine room caused congestion and confusion.

--Insufficient space in computer room.

--Operators taken away from job to answer telephones.

--Operators leaving the computing area to admit programers and visitors to the computer room.

--Operators performing duties not related to operating the equipment.

--Changing operating systems.

At the Army Finance Center, four closed-circuit television screens were installed in the operation manager's office so he could continually observe the operators' progress and activities.

METHODS TO IMPROVE EFFICIENCY OF OPERATIONS

Training

Most installations we visited required extensive operator training. One installation specifically attributed an 83-percent reduction in operator-caused reruns to intensive operator training. The Army Finance Center (a user of more than one manufacturer's equipment) increased productivity by cross-training personnel, so they could be shifted from one system to another to better handle peak workloads.

Technical bulletins

To keep its trained operators up-to-date, a few installations had established a procedure for periodically disseminating current technical information to them.

Special coordinators

Officials in a few installations indicated that the quality and quantity of work noticeably improved when special coordinators were assigned to directly supervise computer operators, tape handlers, and print operators. At one installation the coordinator was responsible for (1) effective continuity of operations, (2) settling problems, (3) corrective actions, and (4) changing schedules to improve timely support of customers. Reruns due to operator error were reduced, and recoveries due to hardware problems were minimized.

Documentation for running programs

The program documentation package usually has a document, called an operations manual or run book, that tells operators how to run the job. It includes information on setup, sequence of steps, input and output formats, messages generated by the program, replies to these messages, restart procedures, disposition of input and output after run, etc.

At one installation, this documentation had been automated and performance significantly improved. An inexpensive 35mm slide projector was used to display the information required to process each step, and operators controlled the display by simply pressing a button. Providing instructions by this means was reported to have increased throughput 10 percent and decreased operator-caused reruns 3 percent.

Competition between operators

Officials at one installation having both second- and third-generation equipment believed they had achieved a high level of efficiency by making the operating of equipment competitive. An operator of second-generation equipment who

could prove himself more qualified and competent than the operator of third-generation equipment would be moved to the newer equipment.

CHAPTER 6

WAYS TO IMPROVE SCHEDULING OF COMPUTER SYSTEMS

In earlier systems, good scheduling meant meeting deadlines by properly sequencing jobs. The entire system could work on only one application program at a time, so there was no need to be concerned whether the individual resources of the computer (input-output, CPU, etc.) were being used near capacity. With the advent of multi-programing, several programs contend for the computer's resources concurrently. Each program can temporarily influence the progress of others by gaining exclusive use of an individual resource. Today's computer systems have three basic types of resources.

1. Internal storage.

2. CPU time.

3. Input-output facilities.

Program requirements for these resources vary; some require a great deal of central processing time, others require many input-output facilities.

If several programs which use one type of resource are run concurrently, each program would be slowed. Meanwhile, other resources may hardly be used at all. To avoid this inefficiency, ADP management should schedule the work according to program resource requirements as well as processing deadlines.

The installations we visited had two types of resource scheduling, external and internal.

EXTERNAL SCHEDULING

Manual scheduling systems are most commonly used, probably as a carryover from second-generation practices. Many installations leave the scheduling to the operator or shift supervisor. Some installations found this method

inadequate and established groups, independent of actual machine operation, to schedule the computer systems according to resource requirements. Techniques used by such groups ranged from visual analysis of computer accounting data to the critical-path method of quantitative analysis. Some groups used visual aids, such as chalkboards, billboards, and flowcharts, in developing multiprograming schedules to improve efficiency.

A few installations used automated scheduling methods, usually based on both resource requirements and deadlines. One gave partial credit to this method for eliminating third-shift operations, saving both hardware rentals and salaries.

INTERNAL SCHEDULING

Internal scheduling methods allow the machine to schedule the jobs. Programers or schedulers classify programs according to priority and resources required. They indicate which programs use large amounts of central processing time and which use large amounts of input-output resources. The operating system then attempts to keep a mix of both classes running to obtain balanced use, which avoids lost time due to conflicts.

The Department of Agriculture found that it was meeting estimated turnaround time on only 65 to 75 percent of its jobs, yet the computers' resources were not being fully used. Many jobs were manually scheduled, so a change was made to allow the operating system to do most of the scheduling internally. The system now runs a balanced mix of compatible programs, and this has resulted in a significant improvement. Even though workload has increased 33 percent, 90 percent of the programs are now processed promptly. The daily backlog of jobs has been reduced, and weekend processing has been virtually eliminated.

CHAPTER 7

WAYS TO IMPROVE PRODUCTIVITY OF COMPUTER HARDWARE

One factor to be considered in enhancing computer system productivity is the hardware itself. Many areas affect computer efficiency, and, if each area is managed properly, significant increases in efficiency can be achieved. However, there is a point where further changes of the types discussed in the previous chapters are not feasible, and changes and/or additions to hardware must be considered if more production is needed.

Many early computer step-ups to larger gear were justified on the basis of economic analyses and/or the simple fact that the existing equipment was in use 24 hours a day, 7 days a week. When considering present-day computers, this rationale is inappropriate. In systems which have multiprograming capability, the number of hours the computer is in use is not the only indication of whether the system can or cannot accomplish additional work.

Many computer systems manufactured today are modularly expandable, which means that their three basic resources can usually be increased by adding components, such as additional internal storage, peripheral devices, and processing units.

Our previous report discussed two of the tools commonly used to identify bottlenecks--hardware and software monitors. We also identified significant savings attributed to their use.

In this study, we found increased use of these tools and others. The most widely used additional tool was computer accounting data, in which the computer itself records the use made of its resources. By analyzing this data, installations identified the limiting resources and made valid determinations of their hardware requirements.

If an ADP manager identifies the use levels of components of his system, he may take several actions, such as eliminating unused or little-used components. If he

finds that his hardware is operating near capacity, several options are usually available other than acquiring an additional computer system. Most of these alternatives center around the computing system being modularly designed and the installation identifying its bottlenecks. The alternatives discussed in this report are:

--Exchanging little-used components for those able to eliminate bottlenecks.

--Upgrading highly used components to those having increased performance or capacity.

--Adding modular components.

--Acquiring a large computer system to replace several small computers.

We found numerous examples of savings resulting from some of these alternatives.

EXCHANGING LITTLE-USED COMPONENTS

The Defense Intelligence Agency, through use of a hardware monitor, determined that by exchanging the expensive high speed drum, associated control unit, and existing disk storage unit for less expensive and faster access disk devices, it could:

--Increase direct access storage capacity 39 percent.

--Reduce the cost of external storage units 33 percent.

--Increase performance 20 percent.

UPGRADING HIGHLY USED COMPONENTS

Several installations, by exchanging existing equipment for plug-compatible units,[1] increased performance and

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[1]For a discussion of plug-compatible units, see our June 24, 1969, report "Study of the Acquisition of Peripheral Equipment for use with Automated Data Processing System" (B-115369).

eliminated bottlenecks. The following examples are typical.

Headquarters, Air Force Logistics Command, replaced its extended internal storage with that of another manufacturer and reduced (1) rental costs by about $12,000 a year (2) memory access time by over 75 percent, and (3) CPU use by 50 percent. As a result, it avoided charges of about $168,000 a year for an additional CPU that had been initially proposed.

A university exchanged existing disk storage units with plug-compatible units and (1) increased storage space by 50 percent, (2) decreased data access time by 50 percent, and (3) saved $42,000 annually.

ADDING MODULAR COMPONENTS

The U.S. Marine Corps found that one of its large-scale multiprograming computer systems was not meeting the established limit of 24-hour turnaround time for batch-processing jobs and that its workload was steadly increasing. Apparent alternatives were to

--obtain an additional computer,
--obtain a larger and faster CPU,
--change the 24-hour limit, or
--increase processing efficiency.

A study showed that the amount of internal storage was the limiting component. Additional internal storage was added to the system and the 24-hour turnaround limit was easily met for all jobs--even though the average number of jobs processed each day subsequently increased by more than 70 percent.

ACQUIRING A LARGER COMPUTER SYSTEM

Large computing systems usually have a more favorable cost-performance ratio than small systems. Therefore, when a small computing system needs to be expanded, it may be prudent to add components to an existing large computer and have it absorb the workload of the small one.

For example, the Defense Intelligence Agency found that its large computer system with added components absorbed the workload of its medium-sized computer system. As a result, the agency estimated it would save $150,000 annually in hardware costs alone.

Acquiring a large computer system to replace several saturated small computer systems may also be appropriate. A large insurance company needed to increase its capacity beyond its four small computers, so it released them and acquired two large computers. These large systems have the capacity to perform 5 times more work, yet rental costs were about $144,000 a year less than for the 4 small systems. The workweek was reduced from 7 to 5 days, and, because less hardware was involved in the new system, 9 computer operators were released.

CHAPTER 8

AREAS FOR IMPROVEMENT, RECOMMENDATIONS, AND AGENCY ACTIONS

NEED FOR MORE SPECIFIC GUIDANCE ON INCREASING COMPUTER EFFICIENCY

Federal agencies need further guidance on how to maximize efficiency of their ADP resources. Revised Office of Management and Budget (OMB) Circular A-54 established a policy that agencies should insure the efficiency of existing equipment before acquiring more and suggested that attention be given to workload revalidation, program modifications, improved scheduling, and other areas impacting on processing efficiency. However, guidance on how to achieve this objective has not been issued by OMB or by the General Services Administration (GSA).

The Federal Government has taken the following steps to help agencies improve their computer operations.

--In August 1971 NBS formed the Federal Information Processing Standards Task Group 10 (FIPS TG10). The Group was to identify and recommend guidelines for (1) hardware and software component evaluation criteria, (2) measurement techniques, and (3) procedures that could be applied throughout the Federal Government to aid in installations operational improvements and computer system and component selections. Specific areas of investigation included the use of simulation, performance monitors, benchmarks, and analytic methods. In March 1973 the Group recommended a 2-year project to develop appropriate guidance for the use of these techniques. Thus, little can be expected from this source for some time.

--The Computer Performance Evaluation Users Group was formed in the Department of Defense and transferred to NBS sponsorship early in 1971. This Group

provides a means of exchanging information between Federal agencies on performance evaluation techniques but has no responsibility for developing Government-wide guidance.

--GSA established FEDSIM to serve Federal agencies throughout the country. FEDSIM's purpose is to provide economical services on a cost-reimbursable basis, not to establish specific Government-wide guidance. (See app. I.)

These steps all contribute to improving computer resource use and should continue to receive Government support. However, most of them are specifically oriented toward use of simulation, performance monitors, benchmarks, and analytical techniques.

Chapters 2 through 7 indicate the potential for improving computer operations, as exemplified by the results obtained through various techniques used at a number of Government and private installations. In view of the potential benefits for other computer installations, we believe GSA should provide more specific guidance on these matters for Federal computer installations.

As a minimum, this guidance should consist of approval and periodic revalidation processes for computer applications, methods for determining areas of greatest deterrence to improved performance (application software, operating system software, operators, scheduling, and hardware), and a basic approach to improving efficiency in each area. We believe this report provides a basic framework for additional study and for establishing detailed guidance.

We believe OMB, GSA, and NBS should provide strong leadership so that more Federal agencies can capitalize on these opportunities. We would expect that the accumulated experience in increasing efficiency to individual agencies should contribute substantially to ongoing research projects and should assist in formulating detailed guidance.

Many managers and authorities we interviewed stated that it would be most desirable for computer users to be provided with manufacturer-prepared comprehensive guides

containing information to aid them in obtaining increased efficiency from the systems. Such guides could greatly assist in developing programs for improved operations. We believe GSA could serve a very useful purpose in proposing, in future procurement-contract negotiations with manufacturers, that such information be collected, published, and made available to Federal computer users. Several experts agreed that such action could be extremely valuable.

RECOMMENDATIONS

Since GSA is responsible for centralized procurement and management policy for ADP equipment, we recommend that the Administrator:

--Give priority to preparing and issuing detailed guidance to Federal agencies on methods to increase the efficiency of their systems. One approach could be to make the availability of a comprehensive guide to aid users in increasing efficiency a highly desirable item in future procurement contract negotiations with manufacturers.

--Consider, consistent with the provisions of the Brooks bill (Public Law 89-306), the extent to which agency managements have evaluated and improved the efficiency of their existing systems (including their use of FEDSIM) before approving procurement of additional or more powerful systems.

AGENCY ACTIONS

The Deputy Administrator, GSA, advised us that GSA generally agreed with the content of our report and the recommendations. His letter of February 27, 1974 (app. II), covered points of specific agreement and outlined steps being taken.

GSA concurs that it is necessary to give priority to preparing and issuing detailed guidance to agencies on methods to increase the efficiency and effectiveness of their ADP systems and that manufacturer-supplied information in this regard would be highly desirable. GSA suggested, and we concur, that users would play a major role in

determining specific requirements in this area. Therefore, copies of this report are being sent to the heads of Federal departments and agencies.

GSA is revising OMB Circular A-54 as a Federal Management Circular, which will reemphasize agency evaluating and improving the efficiency of existing ADP systems before procuring additional equipment. Additionally, GSA will amend Federal Property Management Regulations section 101-32 to require certification that this has been done. Finally, GSA concurs that agency use of FEDSIM would be of value but cautions that FEDSIM's current capability is limited.

CHAPTER 9

SCOPE OF REVIEW

Our study identified the methods, tools, and techniques being used by 43 Government and industry computer installations (see figs. 1 and 2) to increase the efficiency and effectiveness of computer systems.

The savings figures in the report were provided by the agencies; we did not verify their accuracy. Our inquiries at the installations did not include an overall evaluation of any agency's computer system.

Figure I

Federal Government Facilities Contacted (24)

Military

Department of the Army:
- Ammunition Procurement and Supply Agency
- Military Traffic Management and Terminal Service
- Computer Systems Command
- Computer Systems Support and Evaluation Command
- Finance Center

Department of the Navy:
- Chief of Naval Operation
- Headquarters, Marine Corps

Department of the Air Force:
- Data Services Center
- Logistics Command
- Supply Command

Other:
- Defense Communications Agency
- Defense Supply Agency
- Defense Intelligence Agency

Civil

Department of Agriculture

Department of Commerce:
- National Bureau of Standards

National Aeronautics and Space Administration:
- Goddard Space Flight Center

Department of Health, Education, and Welfare:
- Office of the Secretary
- National Institute of Health

Veterans Administration:
- VA Hospital, Washington
- Data Processing Center, Hines, Ill.

GSA:
- Federal Computer Performance Evaluation and Simulation Center

Atomic Energy Commission:
- Argonne National Laboratories

Railroad Retirement Board

Central Intelligence Agency

Figure II

Non-Federal Facilities Visited (19) (note a)

Profit organizations	Nonprofit organizations
Insurance companies	State Governments
Utilities	Universities
Transportation	
Banks and financial institutions	
Communications	
Manufacturers of:	
Chemicals	
Steel	
Farm and construction equipment	
Electronics	
Communications equipment	
Computers	

[a]Most of these organizations asked not to be specifically identified.

FEDERAL COMPUTER PERFORMANCE EVALUATION AND SIMULATION CENTER

Our previous study noted that using computer measurement and evaluation tools and techniques required highly skilled technicians and that little training was available in these areas. Therefore, we were pleased to see GSA establish FEDSIM.

FEDSIM's purpose is to provide computer performance evaluation services to the agencies of the Federal Government. It is located in the National Capitol region and will serve Federal agencies throughout the country. The U.S. Air Force operates FEDSIM and its policies are established by a joint committee of representatives from GSA, the Air Force, the Office of the Secretary of Defense, and NBS.

FEDSIM provides a central source for computer simulation and monitoring services so individual agencies will not need to develop independent capabilities for using advanced techniques of computer performance measurement and evaluation. This allows all agencies to have access to powerful techniques, on a cost-reimbursement basis, without incurring high individual startup costs in time, money, and expertise.

FEDSIM provides services in three basic areas.

1. Computer performance evaluation consultant services and technical assistance for systems design and specifications; computer equipment configuration, program improvement, and systems tuning; and ADP equipment selection.

2. Contractual assistance for purchase, lease, or use of simulation packages and languages; hardware and software monitors; analytical techniques; and accounting data reduction packages.

3. Training in applying computer performance measurement and evaluation techniques.

At the time of our survey, FEDSIM had provided or was providing services to nearly 20 Government agencies. It told

us that the average payback on investment to date for the agencies served was more than 10 to 1.

We believe FEDSIM can contribute greatly to improved efficiency in Government computer operations.

UNITED STATES OF AMERICA
GENERAL SERVICES ADMINISTRATION
WASHINGTON, D.C. 20405

FEB 27 1974

Honorable Elmer B. Staats
Comptroller General of the United States
General Accounting Office
Washington, DC 20548

Dear Mr. Staats:

Thank you for the opportunity to comment on your draft report, "Tools and Techniques for Improving the Efficiency of Federal ADP Operations."

We generally agree with the content and recommendations; however, we have the following comments:

A. We agree that there is a necessity to give priority to preparing and issuing detailed guidance to Federal agencies on methods to increase the efficiency and effectiveness of their ADP systems. We also agree with the recommendation that it would be highly desirable for computer users to be provided with a comprehensive guide prepared by the computer manufacturer to aid in obtaining increased system efficiency. However, it should be recognized that the type of user aid may vary with each ADP installation; therefore, the major burden for determining the requirements in this area must fall upon the user.

B. We agree that agency management should evaluate and improve the efficiency of existing systems prior to obtaining additional or more powerful ADP systems, and that GSA should encourage such improvements. The following actions are currently under way in GSA:

1. Office of Federal Management Policy (OFMP). The policies on selection and acquisition of ADP equipment which are enunciated in OMB Circular A-54 are currently being revised by the OFMP as a Federal Management Circular. This circular will reemphasize that Federal agency managements must evaluate existing systems and make efforts to improve the efficiency of such systems prior to procuring additional or more powerful ones.

2. Automated Data and Telecommunications Service. An amendment to FPMR §101-32 will be issued to require agency certification of its having evaluated and improved the efficiency of existing systems when submitting requests for delegations of authority to procure ADP systems. The FPMR should encourage agencies, in those instances where they are not required to come to GSA for a specific delegation, to make such certifications to higher levels of management within their agency. This requirement will have to be consistent with the provisions of Public Law 89-306, which states that "the Administrator shall not interfere with, or attempt to control in any way, the use made of automatic data processing equipment or components thereof by any agency."

With regard to agencies' use of FEDSIM to assist in optimizing their ADP operations, we agree that it would be of value; however, due to a lack of resources, FEDSIM's current capability is limited.

If there are any questions, please let us know.

Sincerely,

Dwight [illegible]
Deputy

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