REPORT TO ~~~~ CONGRESS

Opportunity For Greater Efficiency And Savings Through The Use Of Evaluation Techniques In The Federal Government's Computer Operations

B-115369

BY THE COMPTROLLER GENERAL OF THE UNITED STATES

B-115369

To the President of the Senate and the
C| Speaker of the House of Representatives

This is our report on opportunity for greater efficiency and savings through the use of evaluation techniques in the Federal Government's computer operations.

Our review was made 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).

Copies of this report are being sent to the Director, Office of Management and Budget, and to the heads of Federal departments and agencies.

Comptroller General
of the United States

C o n t e n t s

ABBREVIATIONS

ADP   automatic data processing

DOD   Department of Defense

GAO   General Accounting Office

NBS   National Bureau of Standards

OMB   Office of Management and Budget

OPPORTUNITY FOR GREATER EFFICIENCY
AND SAVINGS THROUGH THE USE OF
EVALUATION TECHNIQUES IN THE FEDERAL
GOVERNMENT'S COMPUTER OPERATIONS
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<u>D I G E S T</u>

WHY THE REVIEW WAS MADE

The General Accounting Office (GAO) made this review because of indications that the use of computer performance evaluation techniques could increase the productivity of computer systems--some estimate by as much as 20 to 40 percent--with only a minimal increase in cost.

Because the Federal Government has thousands of computers, the annual operating cost of which is estimated at $4 to $6 billion, the potential for savings by improving the productivity of the Government's computers is apparent. This is particularly true because there is a continued demand within the Government for additional computer capacity.

Another factor in GAO's choice of computer performance evaluation techniques as the subject of a review was the widespread congressional interest in the procurement, management, and use of computers and related equipment.

To evaluate the effect of these techniques in actual practice, GAO chose the Goddard Space Flight Center (National Aeronautics and Space Administration) because earlier work there had indicated that Goddard was making considerable use of these techniques. In view of the substantial savings in computer time and cost achieved by Goddard by correcting inefficiencies identified by using these evaluation techniques (hardware and software monitoring), GAO expanded its review to determine whether other Government agencies could use these techniques advantageously.

Background

The term "computer performance evaluation techniques" is associated with methods used to measure and/or evaluate the performance of computer systems. This report is concerned with hardware monitoring and software monitoring, two of the many techniques used.

Hardware monitoring uses electronic monitoring devices to determine how much and when the various components of a computer system are being used. With this information, the workload can be distributed as evenly as possible among the components and greater efficiency in their use can thus be obtained.

Software monitoring uses special computer programs to check other computer programs to see if these programs use computer capabilities efficiently.

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By identifying inefficient processes in the other programs, the special program enables management to adopt more efficient processing procedure and cuts down the time the computer requires to perform the operations.

FINDINGS AND CONCLUSIONS

Use of performance evaluation techniques by Goddard

Some examples of increases in productivity from Goddard's use of these techniques were:

--The number of jobs processed by one computer was increased by 50 percent without increasing the number of hours the computer was use (See p. 20.)

--The number of jobs processed by another computer was increased by 25 percent with a 10-percent increase in hours of usage and a 7-percent increase in the utilization of the central processing unit. (See p. 20.)

--Computer time worth $433,000 annually was saved through the use of these techniques and the acquisition of a more efficient compiler (a program that translates language used by the programers into machine language). The one-time cost of making the changes was estimated at $60,000. (See p. 21.)

Use of performance evaluation techniques by other agencies

Some Department of Defense computer facilities have used performance evaluation techniques with favorable results. (See pp. 22 and 23.)

Of 10 Government computer facilities visited by GAO, three were using the techniques, five had not made any use of them, and two had made onl limited, exploratory use of the techniques.

Each of these seven facilities that had made limited or no use of these techniques spends more than $1 million a year on its computer operatior Thus even a modest increase in computer efficiency could result in substantial savings. (See p. 24.)

Potential Government-wide savings

Officials of the National Bureau of Standards, Department of Commerce, agreed that the efficiency of many Government computers could be increased significantly through use of the performance evaluation techniques. They pointed out that increasing efficiency and use of existir ADP equipment should result in substantial savings to the Government by eliminating or postponing the need for additional equipment. (See p. 2

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Bureau of Standards officials stated that modern computers were far too complex and too fast for their performance to be evaluated by anyone without employing sophisticated techniques which utilize computers to provide the data necessary for intelligent management.

Bureau of Standards officials estimated that using electronic monitoring devices to evaluate the performance of the Government's 458 largest computers (each of which is valued at more than $1.5 million and costs about $1.7 million a year to operate) would permit improvements in computer utilization and would result in savings of many millions of dollars by avoiding equipment lease and purchase costs.

The Office of Management and Budget (OMB), responsible for providing leadership and coordination in Government computer management, has recognized the potential for savings through the use of computer performance evaluation techniques. On August 26, 1971, OMB amended Circular A-54, "Policies on Selection and Acquisition of Automatic Data Processing (ADP Equipment," to encourage the use of computer performance evaluation techniques by Government agencies. However, much work needs to be done befo optimum use of the techniques is achieved.

RECOMMENDATIONS OR SUGGESTIONS
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OMB agreed generally with GAO's findings, conclusions, and recommendations and planned to encourage the development of computer performance evaluation techniques.

GAO recommends that OMB's planned efforts to encourage the use of these techniques include:

--Directing heads of Federal agencies to consider using computer evall tion techniques to improve the efficiency of computer performance, especially before acquiring additional computer capacity.

--Promoting more use of the hardware and software techniques that are currently developed and in use.

--Encouraging the development of productivity and performance criteri encouraging more training in the use of the techniques, and encoura ing manufacturers to design "built in" computer performance evaluat techniques in future ADP systems.

--Obtaining periodic reports on agency efforts to evaluate the efficiency of their computer operations to determine if further action are needed and distributing such reports to other agencies to assi: them in recognizing the potential benefits available through performance evaluations.

AGENCY ACTIONS AND UNRESOLVED ISSUES

OMB indicated that immediate Government-wide use of these techniques ' not yet feasible due to a lack of well-defined procedures, techniques and principles. In addition, OMB indicated that Government-wide imple mentation of performance evaluation would be constrained by shortages both tools and trained personnel.

GAO recognizes that there are many problems to be overcome before max1 practical use of these techniques is achieved. GAO believes, however, that with strong leadership from OMB worthwhile savings can be achieve in the near future and very sizable savings can be achieved when the availability of trained personnel and equipment makes Government-wide of these techniques feasible.

GAO is conducting further research into the use of hardware monitoring and software monitoring as well as other techniques--such as accountin systems, analytical techniques, benchmarking, instrumentation, saturat analysis, and simulation--for improving computer efficiency. A more co plete report to the Congress on this subject will be issued at a later date.

MATTERS FOR CONSIDERATION BY THE CONGRESS

GAO is sending this report to the Congress because of the widespread general congressional interest in the management and use of computers and related equipment and the specific interest of the Joint Economic Committee and the House Government Operations Committee in computer procurement, utilization, and performance evaluation. Both committees have held hearings on the subject within the past 2 years.

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CHAPTER 1

INTRODUCTION

The Federal Government is the largest single user of Automatic Data Processing (ADP) equipment in the world. The number of computer systems in the Government's inventory, as reported by the General Services Administration (GSA), has increased from 531 at June 30, 1960, to 5,961 at June 30, 1971. Of these 5,961 systems, 4,296 were owned wholly or partially and 1,665 were rented.

According to the GSA report, the Government spent about $2.4 billion in operating and maintaining 3,389 of its computer systems during fiscal year 1971. The cost of operating and maintaining the remaining 2,572 systems was not readily available. Government expenditures for the rental of ADP equipment amounted to $451 million in fiscal year 1971.

During hearings held by the Subcommittee on Economy in Government of the Joint Economic Committee during July 1970, the Government's total expenditures for ADP activities were estimated from $4 billion to $6 billion annually.

The enormity of these annual expenditures makes it important as an economy measure

  --to make the most efficient use of existing computers practicable and

  --to avoid acquiring additional computers whenever the need can be filled by more efficient use of already-installed computers in the Government.

The use of computer evaluation techniques which permit identification and correction of inefficient practices is considered to be an effective means of achieving increased efficiency.

To evaluate the effectiveness of these techniques in actual practice, we chose the Goddard Space Flight Center (National Aeronautics and Space Administration) because earlier work at that location had indicated it was making

considerable use of these techniques. We also inquired
into the computer operations of other selected agencies to
determine whether they were using these techniques to eval-
uate the efficiency of their computer operations.

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CHAPTER 2

RESPONSIBILITIES OF CENTRAL AGENCIES

OFFICE OF MANAGEMENT AND BUDGET

On October 30, 1965, the Congress enacted Public Law 89-306 (Brooks bill) which provides GSA with exclusive authority for procuring all general-purpose ADP equipment for use by Federal departments and agencies. This law, however, reserves to the individual agency the right to determine ADP requirements, develop specifications for computers, select specific types and computer configuration to fullfil its data processing needs, and determine the use to be made of the subject computer systems. The Department of Commerce, through the National Bureau of Standards (NBS), is required by the law to provide GSA and other agencies, upon request, with technical advisory services pertaining to ADP and related systems. The responsibilities which the law conferred upon GSA and NBS are discussed more fully on page 8 of this report.

Additionally the Brooks bill assigned the Office of Management and Budget (OMB), formerly the Bureau of the Budget, the responsibility of exercising fiscal and policy control over GSA and NBS in the implementation of their respective responsibilities set forth in the law.

For many years OMB issued policy guidance and numerous instructions to the heads of executive departments and agencies concerning the management and use of ADP equipment.

In January 1966 OMB established a new ADP management branch to carry out its responsibilities under the Brooks bill. This group defined the objectives and overall content of working programs to be performed by GSA and NBS and issued policy guidance letters to the two agencies on May 4, 1966, and December 15, 1966, respectively. OMB was the focal unit in interagency forums, and recently two major ADP conferences were held--one at Charlottesville, Va., and the other at Myrtle Beach, S.C. The reports issued on the result of the meetings indicate that various user and management problems were identified and discussed.

GENERAL SERVICES ADMINISTRATION

The Brooks bill made GSA responsible for the acquisition and maintenance of ADP equipment. In May 1966 GSA received policy guidance from OMB which provided broad guidelines for the implementation of GSA responsibilities under the Brooks bill. This policy guidance provides that GSA evaluate the procurement processes employed by the Federal Government for acquiring ADP equipment and services to determine the area in which revised techniques, methods, and practices would offer greater efficiency and economy in acquisition of the end product. GSA is specifically prohibited by law from interfering with, or attempting to control in any way, the use made of ADP equipment by any agency.

DEPARTMENT OF COMMERCE

The Brooks bill authorized the Department of Commerce to provide agencies and GSA with scientific and technological advisory services relating to ADP systems and to undertake research in the sciences and technologies of ADP systems. The Department has delegated its responsibilities to NBS.

CHAPTER 3

PROBLEMS IN EVALUATING COMPUTER PERFORMANCE

The speed and complexity of computer operations made
the evaluation of system efficiency difficult even when
computers were used primarily to process a single job at a
time. With the advancements which have been made in com-
puter technology over the past several years, including the
development of computers that can process several jobs con-
currently and operate at much faster speeds, evaluation of
the efficiency of a computer operation has become extremely
complex.

PROBLEMS IN EVALUATING COMPUTER SYSTEMS

The normal approach to evaluating any system that per-
forms a function is to measure the performance of the system
and to compare actual performance with a standard. Computer
systems generally are not evaluated in this manner because
most computer facilities have neither adequate means for
measuring performance nor standards with which to compare
performance. Although tools for measuring the use of com-
puter system components have been developed, the establish-
ment of performance standards for computer systems remains
a formidable task.

Wide variations in both design of computer systems and
purposes for which computers are used make it difficult to
establish performance standards for such systems. To achieve
maximum efficiency, each computer system used by a Govern-
ment agency should be designed for that agency and for the
particular type of work the agency plans to perform with
the system. The design of a computer system usually depends
on many considerations, including the (1) mission of the
agency, (2) objectives which agency management establishes
for the system, and (3) operating requirements which will
be placed on the system.

For example, computers used for administrative work,
such as maintenance of inventory records, generally process
large volumes of data on a routine basis. This type of

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work usually requires numerous input devices[1] for introducing large amounts of data into the system and numerous output devices[1] for obtaining large quantities of finished data from the system. However, this type of work usually requires relatively few arithmetic computations to be made by the central processing unit. On the other hand, computers used for scientific work usually require many arithmetic computations to be made by the central processing unit and generally need fewer input/output devices for introducing data into the system and obtaining data from the system.

The scheduling of a computer's workload also has an effect on its performance. For example, efficient scheduling of the workload of computers operated as service centers to meet the needs of many users is more complex than efficient scheduling of the workload of computers which perform specific functions on a routine basis. Also, efficient scheduling is difficult when jobs (single execution of programs submitted for processing) are introduced directly into a computer from several locations on an unscheduled basis. For example, three of the computers that we reviewed at Goddard have devices in various locations which scientists and other personnel can use to introduce jobs directly into the computers. This makes it difficult for the personnel operating the computers to plan the computers' workloads.

Also, variances in operating characteristics and capacities of computers and components produced by the different manufacturers must be considered in establishing performance standards for computer systems.

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[1] Card, magnetic ink, and optical character readers are examples of input devices. Card punches, printers, and microfilm units are examples of output devices. Magnetic disk drum and tape units are utilized as both input and output devices.

PROBLEMS IN EVALUATING COMPUTER PROGRAMS

Improving the efficiency of a computer system can increase significantly the amount of work the system can perform. However, even an efficient system will perform a substantial amount of unnecessary work unless the users' computer programs are written in an efficient manner.

Computer programs must instruct a computer in minute detail. Consequently, a program prepared for a relatively simple task may include several hundred separate instructions. Programs prepared for complex tasks may contain more than a hundred thousand instructions. The length and complexity of computer programs make their preparation difficult and time consuming. Extensive effort often is required to develop a program which will perform the required task and provide reliable results.

Currently personnel preparing programs for computers use compilers to convert English instructions into detailed coded machine instructions which the computer can follow.

The process of preparing computer programs for use with a compiler does not require personnel to have an intimate knowledge of the internal activities of a computer system. This fact--combined with the length and complexity of programs--often results in the preparation and use of computer programs that do not perform their tasks in the most efficient manner. For example, computer programs frequently contain unnecessary instructions or may not use the most efficient combination of program instructions or may not use the most efficient mathematical procedures.

Traditional methods of evaluating the efficiency of computer programs consist of an analysis of each program instruction. This analysis requires experienced personnel and is both difficult and time consuming. Most computer facilities do not have enough qualified personnel to perform this type of evaluation on more than a small portion of their computer programs. Consequently computer programs often are evaluated only to determine the validity of their results, with little or no consideration of their efficiency.

It is important to note that controls built into a computer program to insure the accuracy of the results often introduce some degree of inefficiency or overhead in the program. Thus the time required to run a program could vary considerably depending on the emphasis that the system designer places on these controls. This type of program inefficiency usually is necessary because it provides for more reliability in the system.

DEVELOPMENTS IN COMPUTER PERFORMANCE

EVALUATION TECHNIQUES

Within the past few years several techniques have been developed to evaluate the efficiency of both hardware and software computer systems. The techniques discussed in this report use performance measurement tools (hardware and software monitors) to measure the use made of the components of a computer system and to identify inefficiencies.

Additional techniques currently in use to evaluate computer systems are accounting systems, analytical methods, benchmarking, instrumentation, saturation analysis, simulation, etc.

The use of evaluation techniques does not automatically correct inefficiencies in computer performance. To correct conditions that cause the inefficiencies, action must be taken to improve the design or configuration of the computer system or to review instructions contained in computer programs. Changes in a system may or may not require acquisition of additional ADP equipment. Generally the cost of such equipment should be much more than offset by increased computer productivity.

Details of the computer performance evaluation techniques covered in our review are discussed below.

TECHNIQUES FOR EVALUATING COMPUTER SYSTEMS

Even though performance standards for evaluating computer systems are not available, the efficiency of computer systems can and is being evaluated.

These evaluations generally start with the use of a performance measurement tool to measure use of such system components as the central processing unit, data channels, tape drives, disks, and drums. The resulting measurements can then be compared with the time the components are

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available for use. In addition, the measurements can be used as a basis for comparison with future measurements. Although this concept is simple, in actual practice the process of analysis and evaluation of the measurements is highly complex because the total system is evaluated on the basis of the use made of individual components.

When computer systems could process only one job at a time, use could be measured with a watch or a clock. Any time that at least one component of an older computer system was working on a job, the computer was considered to be fully utilized. For example, a system would be considered to be fully utilized when only the output device that recorded finished data was being used, even though input components that received data into the system and the central processing unit were idle. Time spent each day by this type of computer system in processing jobs could be compared to a 24-hour period to obtain a percentage of utilization. Development of high-speed computer systems having the ability to process several jobs concurrently made measurement of computer use by clock or watch unfeasible.

Full utilization of a computer system that can process several jobs concurrently means, in theory, that every component of the system would have to be in use all the time. In actual practice this is almost impossible because computer workloads impose varying needs on system components and cannot be scheduled so that every component is continuously used. However, utilization of a computer system can be evaluated by determining the percentage of available time each system component is used.

To get maximum use from a computer system, the workload should be distributed as evenly as possible between those components of the system that perform the same type of work. This significantly reduces the time one component is forced to wait for the availability of another component. Delays of this type severely reduce productivity of a computer system.

For example, two jobs scheduled to run concurrently may require different programs which are stored on the same storage device. In this situation, one job would be forced to wait until the other job finished using the storage device. If the personnel of a computer facility are aware of

conflicts of this type, the delays can be minimized by
storing standard programs on different storage devices,
thus enabling several jobs to be processed at the same time.

The ability to evaluate efficiency of computer systems
has increased significantly. Within the past few years
techniques for evaluating computer efficiency have been de-
veloped by computer manufacturers and by manufacturers of
computer performance measurement products. These techniques
start with the simultaneous measurement of use of the vari-
ous components of a computer system by using a performance
measurement tool. Although no performance standards exist,
trained personnel can analyze these measurements and iden-
tify these components which are being overloaded or under-
loaded and thus are creating bottlenecks or are otherwise
reducing efficiency of the system. Computer personnel can
then redistribute the workload among the various system com-
ponents to increase efficiency and productivity of the sys-
tem.

Performance measurement tools are of two types: (1)
electronic monitoring devices (hardware monitors) and (2)
special computer programs (software monitors). Both types
of measurement tools may record the use of each electronic
component and some of the activity of the system control
programs. Either type of measurement tool normally provides
sufficient data for a meaningful analysis of a computer sys-
tem. However, a more thorough evaluation of system perform-
ance can be obtained by using both types of measurement
tools.

Electronic monitoring devices are independent instru-
ments which can be temporarily attached to a computer.
These devices record usage measurements without interfering
with the normal operation of the computer system.

Special computer programs are a series of instructions
or statements, in forms acceptable to a computer, prepared
in order to obtain measurement data. Also, special com-
puter programs become part of the system of control programs
which directs a computer in the performance of its work.
One advantage which the special programs have over the
electronic monitoring devices is that special programs use
the computer to perform and record component use

information and do not require the acquisition of additional equipment. Although these programs interfere with normal operation of a computer system to a limited extent (because that portion of the system which they use is not available for other work), a firm which markets one of the programs claims that it reduces the capacity of a system by less than 5 percent. Tests by the Army Materiel Command tend to substantiate this claim.

TECHNIQUES FOR EVALUATING COMPUTER PROGRAMS

New techniques have been developed for evaluating and increasing efficiency of computer programs. These techniques consist of identifying and improving the areas of a computer program that utilize the most computer processing time.

Program evaluation techniques start with the use of a performance measurement tool to measure the time each program instruction causes a computer component to work. Special computer programs are generally used to measure the time utilized by each program instruction. Some of the electronic monitoring devices used to measure use of computer system components (for system evaluation purposes) also can be used to measure use of system components in relation to program instructions (for program evaluation purposes). However, the electronic instruments generally cannot be used to measure the requirements of individual programs when a computer system is processing several programs concurrently.

Generally only a small number of program instructions utilize most of a program's processing time. Because the measurement tools identify those program instructions that require large amounts of computer usage time, trained personnel can evaluate efficiency of a computer program relatively easily by analyzing only those instructions which use significant amounts of time. Program instructions often can be deleted or revised to reduce the amount of computer work required. Also the tools can be used to test the revised programs to determine whether they perform more efficiently.

Because computer time for large systems often costs more than $75,000 a month, substantial savings can be

achieved by increasing the efficiency of computer programs.
Evaluation of computer programs which are most frequently
used offers the greatest potential for significant savings.
For example, computer time worth $6,500 could be saved each
year by a 25-percent reduction in the computer time required
to process either a program which uses computer time cost-
ing $250 and is run twice a week or a program which uses
computer time costing $100 and is run five times a week.
Increasing the efficiency of 100 such programs in this man-
ner could result, hypothetically, in an annual saving of
computer time worth $650,000.

An official of a firm which produces one of the special
computer programs for measuring computer program processing
time informed us that use of this special program typically
resulted in a 20- to 40-percent reduction in computer time
after identified program inefficiencies were corrected. He
noted that his firm had documented case studies showing
that use of the special program by a large computer instal-
lation could result in savings in computer time worth hun-
dreds of thousands of dollars a year.

GSA statistics for 382 of the Government's largest com-
puters show that these computers average 498 hours of use
each month. Increasing the efficiency of individual programs
sufficiently to achieve a 20- to 40-percent reduction in the
time required to process the workload of these computer sys-
tems would represent an annual savings of 1,200 to 2,400
hours of computer time for each of the 382 computer systems.
The computer time made available through this increased ef-
ficiency could be used to process additional work and pos-
sibly to eliminate the need for additional equipment.

CHAPTER 5

FAVORABLE RESULTS OBTAINED BY

THE GODDARD SPACE FLIGHT CENTER

FROM RECENTLY DEVELOPED EVALUATION TECHNIQUES

As one of the principal users of computers in the Government, the National Aeronautics and Space Administration has developed formal procedures for computer management. These procedures require utilization of computer resources to the fullest extent consistent with program and project requirements. Responsibility for management of the Administration's computer resources has been assigned to directors of the Administration's various installations. Included in this responsibility is a requirement for installation directors to review and evaluate utilization of computer resources.

Goddard plays an important role in the Administration's space program. It uses computers extensively to perform its mission of investigating and exploring space. As of June 30, 1970, Goddard had 225 computers, 219 of which were purchased at a cost of $102 million. Leased equipment, consisting of six computers and auxiliary equipment for the purchased computers, was valued at more than $14 million as of June 30, 1970.

Of Goddard's 225 computers, 201 were designed as special-purpose computers to be used only for specific tasks. The remaining 24 computers were designed as general-purpose computers to perform a variety of data processing tasks. The cost to operate and maintain these 24 computers in fiscal year 1970 was about $36.9 million.

We reviewed the utilization of five of the 24 general-purpose computers. These computers perform general services for Goddard's scientific and technical personnel, and three of these computers perform a few specific tasks. The general work performed by the five computers consists primarily of scientific computations in support of the space program. The computers normally are operated 7 days a week,

24 hours a day. Each week these computers process about 14,000 separate jobs. These jobs range in time from less than 1 second to several hours; most jobs require less than 2 minutes of computer time.

Goddard has utilized several methods of reviewing and evaluating utilization of its computer resources with favorable results.

TECHNIQUES USED TO EVALUATE COMPUTER SYSTEMS

In 1969 Goddard had a computer manufacturer conduct performance studies of several of Goddard's largest general-purpose computers to determine how efficiently the computers were being used and whether their productivity could be increased. The manufacturer used an electronic monitoring device to measure use of the various components of each computer system. The studies identified components which were being overloaded to the extent that they caused delays in processing work and components which could process additional work without being overloaded.

Goddard personnel used the information obtained from the studies to more evenly distribute the workload among the components. This redistribution enabled Goddard to significantly increase the productivity of its computers. For example, the movement of one set of frequently used data to a storage device with fast access resulted in an increase of about 15 percent in the productivity of one of the computer systems without acquiring any additional equipment.

Since 1969 Goddard has acquired one electronic monitoring device and two special computer programs for measuring use of computer system components. Goddard personnel used the data obtained from these measurement tools to continuously analyze the performance of its computer operations. The primary goal of these analyses is to discover ways of increasing the efficiency of computer operations.

Although Goddard has not maintained complete records of improvements that have resulted from using these evaluation techniques, we noted the following improvements in the productivity of two of the computer systems that we reviewed. Goddard personnel attributed these improvements to

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the correction of inefficiencies in the system configuration, scheduling procedures, and workload priorities. These inefficiencies were identified through computer performance evaluation.

1. The number of jobs processed on one computer was increased from about 12,000 in August 1969 to about 18,000 in March 1971, with a slight decrease in the number of hours of computer use.

2. The number of jobs processed on another computer was increased from 20,000 in March 1969 to about 25,000 in March 1971, with about a 10-percent increase in the number of hours of computer use and a 7-percent increase in the utilization of the central processing unit.

Similar improvements were achieved on the three other Goddard systems that we reviewed.

TECHNIQUES USED TO EVALUATE COMPUTER PROGRAMS

In 1969 Goddard acquired a special computer program designed to measure the work that computer programs performed. Goddard later hired a contractor to develop techniques that Goddard could use to increase the efficiency of its computer programs and to improve the performance of selected programs. Goddard furnished the contractor with the special computer program, Goddard's most efficient compiler, and the necessary computer time. The contractor's use of the special program and the compiler resulted in improvements that significantly reduced the computer time required to process the 10 frequently used programs which Goddard officials had selected for review.

The contractor's report provided estimates of the savings in computer time resulting from the improvements to each of the 10 programs. However, the report did not separate the savings achieved by using the special program from those savings achieved by using the more efficient compiler. The contractor recommended that both the compiler and the special program be used to identify areas needing improvements and to increase the efficiency of all Goddard's production programs.

Goddard officials estimated that the revisions made to the 10 programs would result in an annual savings of computer time worth about $433,000. Although the Goddard officials indicated that a substantial portion of these estimated savings would be attributable to the use of the special program, they could not furnish an accurate estimate of the part of the savings that should be attributed to the use of the compiler. The cost of identifying the inefficiencies and revising these programs was estimated by Goddard to be about $60,000.

Goddard officials informed us that Goddard initiated the evaluation of other computer programs and anticipated significant savings in computer time on numerous additional programs that were frequently used. In addition, Goddard encouraged its personnel to revise their programs to make them run more efficiently. Goddard made the special computer program, the compiler, and personnel experienced in improving the efficiency of computer programs available to assist computer-using personnel in improving the efficiency of their programs.

CHAPTER 6

USE OF COMPUTER PERFORMANCE EVALUATION

TECHNIQUES BY OTHER GOVERNMENT AGENCIES

There is no central source within the Government con-
taining data on the Government's use of computer performance
evaluation techniques. Consequently we could not obtain com-
plete information on the extent to which such techniques are
either available or used by Government agencies.

FAVORABLE RESULTS OBTAINED BY USING AGENCIES

We found that some Department of Defense (DOD) computer
facilities used computer performance evaluation techniques
with favorable results.

In November 1970 the Office of the Assistant Secretary
of Defense (Comptroller) issued a memorandum to the military
departments and Defense agencies on the development, use, and
procurement of computer performance measurement tools. Noting
that use of these tools could aid substantially in improving
computer efficiency, the memorandum required use of the tools
to assist in evaluations of existing systems as a prerequi-
site for the approval of certain ADP equipment acquisition
requests.

This regulation applies to sole-source acquisitions that
exceed $100,000 a year for lease costs or $400,000 a year for
purchase costs.

A January 1971 DOD directive (4105.55) encourages the
use of performance measurement tools in evaluating the effi-
ciency of prototypes of computer systems that are to be used
by more than one Defense installation.

An agency of the Army Materiel Command used computer
performance evaluation techniques in a 3-month test to eval-
uate a computer system and numerous computer programs. A
performance measurement tool (a special computer program) was
used to measure the use of the components of the computer
system, both in total and by specific computer programs.
Substantial increases in the system and program efficiency

were reported by the testing agency. For example, one group
of frequently used programs took 62 minutes of computer time
before they were evaluated by using the measurement tool.
According to the test report, running time for these programs
was reduced to 18 minutes after inefficiencies identified by
the tool had been corrected. This represented a 71-percent
decrease in computer time. By using the tool to measure use
of the components of the computer system, several significant
inefficiencies were identified in the system's operation.

The Army also tested one of the electronic monitoring
devices. Although we could not obtain quantitative data on
improvements resulting from the test, gross inefficiencies
were identified in the computer system used for the test.
As a result of this test, the Army is currently procuring
three more of these instruments. One of the instruments will
be used by the Army Computer Systems Support and Evaluation
Command (the Army's central ADP equipment evaluation agency)
to assist in determining the validity of requests for addi-
tional equipment.

According to DOD records, the Defense Intelligence
Agency uses performance evaluation techniques to examine ex-
isting and planned computer systems to obtain maximum balance
and utilization of ADP equipment.

Of the five DOD computer facilities that we visited, only
two had made extensive use of computer performance evaluation
techniques. One of these facilities--the Army Management
Systems Support Agency--provided us with data showing that
during 1970 the use of these techniques had enabled improve-
ments in scheduling and other areas, which resulted in in-
creasing the average number of computer jobs processed each
month from 5,700 to about 7,150 and in achieving a signifi-
cant reduction in the number of hours the computer was used.

The other DOD facility which has used performance eval-
uation techniques extensively is the Applied Physics Labora-
tory, a research facility operated by Johns Hopkins University
under contract with the Navy. We were informed by the staff
of this facility that it had designed its own electronic
monitoring devices to provide measurements of computer use
similar to those provided by the tools available commercially.

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At one of the remaining three DOD facilities that we visited--the Marine Corps' Data Systems Division--the facility's personnel informed us they had recently acquired one of the measurement tools (an electronic monitoring device) but that no results of its use were available at the time of our visit.

We also visited four non-Defense computer facilities in addition to Goddard and found that only one had made even limited use of performance evaluation techniques. This facility--the Data Management Center of the Department of Health, Education, and Welfare--leased an electronic instrument for a 2-week period; however, the data obtained during the 2-week examination had not been analyzed at the time of our visit. The same facility also had obtained a free demonstration of a special program designed to monitor other computer programs. Although the facility's personnel were favorably impressed with the program, they had not made any decision regarding its requisition at the time of our visit.

POTENTIAL BENEFITS TO OTHER AGENCIES

As noted above, only three of the 10 Government computer facilities that we visited had made extensive use of computer performance evaluation techniques.

Of the remaining seven facilities, two had made exploratory use of the evaluation techniques and five had not used computer evaluation techniques. Because these facilities generally did not use the evaluation techniques, the efficiency of their computer performance is not known.

Each of the seven facilities spends more than $1 million annually to operate its computer systems. Therefore even a modest increase in computer efficiency could result in substantial savings.

CHAPTER 7

POTENTIAL GOVERNMENT-WIDE SAVINGS

To enable the Government to obtain greater benefits from its multibillion-dollar expenditures for computers, we believe the management of Government computer facilities should consider using performance measurement tools for identifying inefficiencies which reduce computer productivity.

Representatives of firms which market the measurement tools told us that the tools were available for virtually all modern computer equipment, regardless of the type of work performed by the computers. We noted that both the Federal Supply Schedules published by GSA and the manufacturers' instruction pamphlets on the tools confirmed the applicability of the tools to a wide variety of equipment and types of work. We noted also that some Government computer facilities used the tools on computer systems performing a wide variety of tasks.

Officials of NBS told us that performance evaluation techniques, based on the use of the measurement tools, provided the best available means for evaluating the efficiency of computer systems and programs. They said that the efficiency of many Government computers could be increased significantly through the use of these techniques.

We were unable to obtain or make a reliable estimate of the potential Government-wide savings that could be achieved by improving the efficiency of computer programs. Our review indicated, however, that improving the efficiency of computer programs should result in substantial savings in computer time at most Government computer facilities. On a Government-wide basis, these savings could amount to computer time worth many millions of dollars each year.

NBS officials commented particularly on the opportunities for increased efficiency provided by recently developed electronic monitoring instruments that can be used to measure use of the components of any computer system, regardless of the design of the system or the type of work it performs. These measurements could be evaluated to identify means by which the utilization of the components and the efficiency

of each computer system as a whole could be increased. They
said that the initial use of these devices should result in
increasing the efficiency of computer systems by about
25 percent.

NBS officials pointed out that increasing the efficiency
and utilization of existing ADP equipment should result in
substantial savings to the Government by eliminating or post-
poning the need for additional equipment. They estimated
that using the electronic monitoring devices to evaluate the
performance of the Government's 458 largest computers (each
of which is valued at more than $1.5 million and costs about
$1.7 million a year to operate) would permit improvements in
computer utilization resulting in savings of many millions
of dollars by avoiding equipment lease and purchase costs.

NBS officials stressed that the significant potential
for improvement in computer efficiency is not a reflection
on management of the Government's computer operations but is,
instead, a direct result of constantly increasing complexity
and capabilities of computers. They explained that modern
computers are far too complex and too fast for their per-
formance to be evaluated by anyone without employing sophis-
ticated techniques which utilize the computers to provide the
data necessary for intelligent management.

Government agencies can obtain both types of performance
measurement tools (electronic monitoring devices and special
computer programs) under existing GSA contracts. Informa-
tion on these tools and existing contracts is published by
GSA in the Federal Supply Schedule for ADP equipment. The
tools can be either purchased or leased or a contractor can
provide both measurements and trained personnel to evaluate
a computer system and to make recommendations for improve-
ments.

Electronic monitoring devices generally range in cost
from $5,000 to $90,000. Several models are available for
about $35,000. The special computer programs are generally
available for less than $15,000. Government agencies can
obtain one of these programs--which was prepared for the
Government for one class of computers--for about $300
through the Computer Software Management and Information
Center. Additional costs will be incurred in training

personnel, obtaining and evaluating performance measurements, and making necessary modifications to computer systems and programs. However, the total cost of evaluating computer performance should be small in comparison to the potential savings.

CHAPTER 8

RECOGNITION OF THE NEED TO

EVALUATE COMPUTER PERFORMANCE

In 1963 the Bureau of the Budget issued Circular A-61, which included a document entitled "Guidelines for Appraising Agency Practices in the Management of Automatic Data Processing (ADP) Equipment in Federal Agencies." This document, prepared by the Bureau for internal use, was distributed to Government agencies to (1) serve as a guide for agency self-appraisals and (2) indicate to the agencies the factors the Bureau might consider during its budget review processes. The document stressed the need for the agencies to continuously review their utilization of ADP equipment to improve such utilization at every practicable opportunity. The Bureau provided no guidance, however, on methods or techniques to be used in making these reviews.

In its February 1965 report to the President, the Bureau again recognized the need for evaluating the performance of ADP facilities but noted that development of criteria to assist in measuring such performance would require the assembling of information which was not available at that time. The report stated:

> "The general absence of information on the performance of installations is a handicap in establishing Government-wide criteria to evaluate performance. If such criteria were available at each computer installation, they could be used by local management to evaluate the performance of its installation and to determine where improvements are needed."

In transmitting the report to the Congress, the President noted that he had requested the Director of the Bureau of the Budget to work with interested committees of the Congress and with the executive agencies to insure the most economical and effective use of this highly important area of management. The President stated further that the Government-wide responsibilities of the Bureau and other

central agencies would be set forth in a Bureau circular at
an early date.

In March 1965 the Bureau issued Circular A-71 on "Re-
sponsibilities for the Administration and Management of
Automatic Data Processing Activities." This circular out-
lined the Bureau's responsibilities to (1) provide overall
leadership and coordination of executive branch activities
pertaining to the management of ADP equipment and (2) de-
velop programs and issue instructions for achieving in-
creased cost effectiveness through improved practices and
techniques for the selection, acquisition, and utilization
of ADP equipment.

The circular stated that the Bureau, in carrying out
these responsibilities, would (1) provide policies and cri-
teria, procedures, regulations, information, technical ad-
vice, and assistance to executive agencies in the manage-
ment of their ADP equipment and (2) evaluate the effective-
ness of the agencies in managing such equipment.

Since the issuance of Circular A-71, neither the Bureau
of the Budget nor its successor--OMB--has provided Govern-
ment agencies with effective criteria, guidance, or assist-
ance for evaluating the performance of their computer systems
or programs, nor has OMB established procedures to evaluate
the effectiveness of agency efforts to improve computer ef-
ficiency.

On August 26, 1971, OMB suggested that Government
agencies consider using computer performance evaluation
techniques to improve the performance of existing ADP equip-
ment before making a decision to replace or upgrade such
equipment. This suggestion was included in an amendment to
OMB Circular A-54, which prescribes Government-wide policies
on selection and acquisition of ADP equipment. The pertinent
part of the amendment is as follows:

"*** techniques are available to assist in evalu-
ating the performance of existing operations and
identifying possible areas of improvement. By
making such improvements, it may be possible to
streamline the current process to a degree equal-
ing or exceeding that achieved through complete
replacement of the equipment."

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In September 1971 NBS established a task group to study
computer performance measurements and evaluation. This task
group was instructed to obtain advice and assistance from
Federal agencies in developing procedures for improving the
operation of computer installations and to assist the
agencies in selecting computer components and systems. The
task group's work program provides for identifying techni-
cally valid performance measurement criteria, techniques,
and procedures. Upon completion of its study, the task
group is to make recommendations regarding computer perform-
ance evaluation techniques and procedures for possible
Government-wide use.

CHAPTER 9

CONCLUSIONS, RECOMMENDATIONS, AND COMMENTS OF

OFFICE OF MANAGEMENT AND BUDGET

CONCLUSIONS

In view of the Federal Government's large expenditures for ADP activities, it is essential that the Government's computer systems perform at a high level of efficiency. Assurance of efficient computer operations can be provided only through use of effective techniques for evaluating computer performance.

As previously noted (see p. 29), OMB has encouraged the use of computer performance evaluation techniques by Government agencies. This encouragement, which directs attention to the potential benefits of performance evaluation techniques, should help to prevent the acquisition of unneeded ADP equipment. More positive action should be taken, however, by OMB to insure that Government-wide use is made of these techniques and that unneeded ADP equipment will not be acquired.

Also, an effort should be made by OMB to promote the use of computer evaluation techniques by Federal agencies in evaluating the efficiency of their computer systems and programs. We noted instances in which agencies were not determining the efficiency of their computer operations. In view of the benefits achieved by agencies which, on their own initiative, are using computer performance evaluation techniques, the use of such techniques on a Government-wide basis could result in making many millions of dollars worth of computer time available for other uses each year.

We believe that a realistic approach to the evaluation of computer operations would be for each computer facility to use its own personnel to evaluate selected programs in accordance with agencywide and central agency guidelines. This approach should enable each facility to take prompt action to improve the efficiency of its computer programs and should save substantial amounts of computer time without disrupting normal operations.

Finally, in view of the financial savings obtainable through more efficient utilization of computers, each Government computer facility should employ all possible means of expanding the productivity of existing ADP equipment--including the use of computer performance evaluation techniques--before making any decision to acquire additional equipment.

NBS officials agreed that Government-wide procedures should be established to require the use of the new techniques to measure and evaluate performance of computer systems and programs. NBS recently has initiated action which may eventually lead to the development of Federal standards for computer performance evaluation techniques.

In the meantime, however, available computer performance evaluation techniques are sufficiently developed to warrant more extensive use by Government computer users. Prompt implementation of these techniques would provide significant savings to Government computer users. In addition, information gained from the experience of these users could be used to assist in the future development of Government-wide standards for computer performance measurement techniques and procedures.

RECOMMENDATIONS

OMB agreed generally with our findings, conclusions, and recommendations and it plans to encourage the development of computer performance evaluation techniques.

We recommend that OMB's planned efforts to encourage the use of these techniques include:

--Directing heads of Federal agencies to consider using computer evaluation techniques to improve the efficiency of computer performance, especially before acquiring additional computer capacity.

--Promoting more use of the hardware and software techniques that are currently developed and in use.

--Encouraging the development of productivity and performance criteria, encouraging more training in the

use of the techniques, and encouraging manufacturers
to design "built in" computer performance evaluation
techniques in future ADP systems.

--Obtaining periodic reports on agency efforts to
evaluate the efficiency of their computer operations
to determine if further actions are needed and distrib-
uting such reports to other agencies to assist them
in recognizing the potential benefits available
through performance evaluations.

OFFICE OF MANAGEMENT AND BUDGET COMMENTS

Early in our review, in May 1971, the possibility of at-
taining savings in computer costs through the use of these
techniques was discussed with OMB. On August 26, 1971, OMB
amended Circular A-54 (Policies on Selection and Acquisition
of Automatic Data Processing (ADP) Equipment) to encourage
the use of computer performance evaluation techniques by
Government agencies.

In January 1972 a draft of this report was submitted to
OMB for its review and comments. OMB's comments were eval-
uated and appropriately considered in the body of our report.

OMB indicated that immediate Government-wide use of
these techniques is not yet feasible due to a lack of well-
defined procedures, techniques, and principles. OMB also
indicated that Government-wide implementation of performance
evaluation would be constrained by shortages of both tools
and trained personnel.

GAO recognizes that there are many problems to be over-
come before maximum practical use of these techniques is
achieved. GAO believes, however, that, with strong leader-
ship from OMB, worthwhile savings can be achieved in the
near future, and very sizable savings can be achieved when
the availability of trained personnel and equipment makes
Government-wide use of these techniques feasible.

GAO is conducting further research into the use of
hardware monitoring and software monitoring as well as other
techniques--such as accounting systems, analytical techniques,
benchmarking, instrumentation, saturation analysis, and

simulation--for improving computer efficiency. A more
complete report to the Congress on this subject will be is-
sued at a later date.

SCOPE OF REVIEW

Our review examined the use of computer performance evaluation techniques in computer operations. To evaluate the effect of these techniques in actual practice, we chose Goddard because earlier work at that location had indicated it was making considerable use of these techniques. We reviewed the operating procedures established by Goddard for the computers and the programing practices and procedures used. We also reviewed pertinent legislation and procedures established by Goddard, the National Aeronautics and Space Administration, and OMB for evaluating and increasing the efficiency of computer systems and programs.

In addition, we conducted numerous interviews concerning the feasibility of using computer performance evaluation techniques to measure and increase the efficiency of other Government computer operations. These interviews were with management officials of nine additional Government computer facilities (listed in app. I), the Office of the Assistant Secretary of Defense (Comptroller), OMB, NBS, firms that market computer performance measurement tools, and a leading computer manufacturer.

GOVERNMENT COMPUTER FACILITIES VISITED

DOD facilities:

Management Systems Support Agency, Department of the
Army, Pentagon, Washington, D.C.

Office of Data Automation, Department of the Air Force,
Pentagon, Washington, D.C.

Data Systems Division, Headquarters, Marine Corps,
Arlington Annex, Washington, D.C.

Scientific and Management Information Division, Army
Materiel Command, Department of the Army, Washing-
ton, D.C.

Applied Physics Laboratory, Johns Hopkins University,
Department of the Navy, Howard County, Maryland

Civilian facilities:

Goddard Space Flight Center, National Aeronautics and
Space Administration, Greenbelt, Maryland

Federal Deposit Insurance Corporation, Washington, D.C.

Federal Highway Administration, Department of Tran porta-
tion, Washington, D.C.

Data Management Center, Department of Health, Education,
and Welfare, Washington, D.C.

Government Printing Office, Washington, D.C.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C 20503

JUN 15 1972

Mr. D. L. Scantlebury
Director, Division of Financial
  and Management Studies
General Accounting Office
Washington, D.C.   20548

Dear Mr. Scantlebury:

This letter is in response to the draft GAO report on
"Opportunity for Government-wide Savings Through the
Use of Computer Performance Analysis Techniques."   We
have read the draft report with interest and have had
a full discussion of our comments with members of your
staff in two meetings over the last several months.
Although we agree with the overall aims of the report
in improving the operating efficiency of Government
computers, we feel that the technique is now only in
an early development stage and immediate Government-wide
implementation would be premature.   We are, however,
continuing to encourage the development of this technique.
When it has matured, it should serve as a significant
addition to the tools for the development and management
of computers.

Although there have been fragmentary and isolated projects
for the measurement of computer activity since 1962, it
is only in the last two years that the research projects
have been given practical application.   Basic definitions
of concepts and methods of application are still evolving.
The National Bureau of Standards established a development
program in October 1971 to further its evolutionary
development.   A Computer Performance Evaluation Users
Group (CPEUG) recently transferred to NBS sponsorship was
formed approximately a year ago in DOD.   The group is made
up of Federal users who are now interchanging experiences
which should add materially to the further development of
those techniques.   Examples of Government installations
beginning to use the techniques are the Department of
Defense, NASA and Treasury.   Some of this measurement
activity was undertaken in response to OMB encouragement
in the August 1971 revision to Circular A-54 which required

agencies to consider all possible means of increasing computer effectiveness before increasing computer capacity. The National Bureau of Standards plans a conference in the last half of 1972 to bring together interested Government, academic and industry groups to continue the process of constructing definitions, cataloging techniques and methods, and recommending specific techniques for subsequent testing at selected installations.

The computer industry is also in early stages of developing these techniques. It has achieved only a limited production capability and market penetration. By NBS count there are only six firms manufacturing electronic equipment which will measure computer performance. It is estimated that this group can produce between 50 to 100 monitors per year, and has made between 100 to 200 units so far. In addition to this electronic equipment, a small number of firms have produced computer programs for evaluating computer performance. These programs have been sold to an estimated 400 firms and agencies in the last 18 months. Collectively, this constitutes a rather limited market penetration since it is estimated that there are more than 80,000 computer installations in the U. S.

NBS and industry representatives have indicated that the scarcity of experienced personnel for reading, interpreting, analyzing and applying the results of these techniques is one of their chief limiting factors. Experience to date indicates that it is necessary to expend as much as a man-month to analyze and interpret the data resulting from a single application.

Before this potentially useful tool can be successfully applied Government-wide, there must be a well-defined body of procedures, techniques and principles which will make computer performance measurement more of a science and less of an art. Answers must be provided to a number of difficult questions such as: the kinds of computer installations which will gain the greatest benefit from measurement of performance, the type of measurement best suited to various operational environments, the techniques best suited to each make of equipment, the changes which should be made to computer programs as shown by measurement results, the methods for determining cost benefit trade-offs in making changes to computer systems, the basis for deciding between continuous monitoring or sampling, the trade-offs between centralized or decentralized staff.
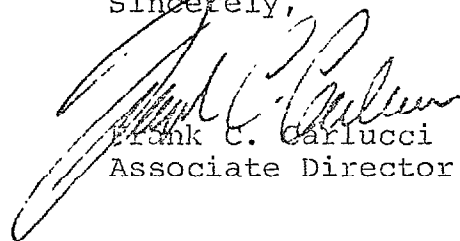
APPENDIX II

While both hardware and software approaches to computer
performance measurement hold significant promise for
improved efficiency in computer operations, they do not
address a number of important factors which must be
considered in the design of effective systems. For
example:

° Effective systems require a very harmonious inter-
action between people and computers. Unfortunately,
many systems in the past have failed to meet their
intended purpose because of inadequate consideration
of the human element in the system design. The
subject computer performance measurement techniques
focus only on the efficient use of computers. Unless
very judiciously applied, they could lead to systems
designed for the convenience of computers rather than
the people and functions to be served by the system.

° The subject computer performance measurement techniques
do not consider the full costs of a particular applica-
tion. Normally, less than one-third of the costs of
any particular system are hardware related costs. Con-
sequently, unless these techniques are very carefully
applied, they could lead to erroneous judgments on
increased operational efficiencies.

We welcome your interest and support in developing this new
technique.

Sincerely,

Frank C. Carlucci
Associate Director

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PRINCIPAL OFFICIALS OF

THE OFFICE OF MANAGEMENT AND BUDGET

RESPONSIBLE FOR THE ADMINISTRATION OF ACTIVITIES

DISCUSSED IN THIS REPORT

	Tenure of office	
	From	To
DIRECTOR, OFFICE OF MANAGEMENT AND BUDGET:		
Caspar W. Weinberger	June 1972	Present
George P. Shultz	July 1970	June 1972
DIRECTOR, BUREAU OF THE BUDGET (note a)		
Robert P. Mayo	Jan. 1969	June 1970
Charles J. Zwick	Jan. 1968	Jan. 1969
Charles L. Schultze	June 1965	Jan. 1968

[a]Under the President's Reorganization Plan 2, effective July 1, 1970, the Bureau of the Budget was incorporated into the newly established Office of Management and Budget.