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REPORT TO THE COMMITTEE ON SCIENCE AND ASTRONAUTICS HOUSE OF REPRESENTATIVES

Followup Review Of Automatic Data Processing Activities Jet Propulsion Laboratory

B-162407(b)

National Aeronautics and Space Administration

BY THE COMPTROLLER GENERAL OF THE UNITED STATES

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COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON DC 20548

B-162407(6)

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Dear Mr. Chairman

1 This is our report on the followup review of data processing ac-
2 tivities at the Jet Propulsion Laboratory in Pasadena, California, a
3 National Aeronautics and Space Administration center. Our review
4 was made pursuant to the request of your Committee and of the Subcom-
5 mittee on NASA Oversight.

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We discussed our findings with the National Aeronautics and Space Administration and the Jet Propulsion Laboratory representatives in Pasadena. However, responsible officials of these organizations have not been given the opportunity to examine or comment on the report

We plan no further distribution of this report unless copies are specifically requested and then only after your agreement has been obtained or you have publicly announced its contents. In accordance with a suggestion of the Committee staff, however, we are sending copies of this report to the Administrator, National Aeronautics and Space Administration

Sincerely yours,

Comptroller General
of the United States

The Honorable George P. Miller, Chairman
Committee on Science and Astronautics
House of Representatives

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ABBREVIATIONS

CIT	California Institute of Technology
GAO	General Accounting Office'
JPL	Jet Propulsion Laboratory
NASA	National Aeronautics and Space Administration
OCIS	Office of Computing and Information Systems

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COMPTROLLER GENERAL'S
REPORT TO THE
COMMITTEE ON SCIENCE AND ASTRONAUTICS
HOUSE OF REPRESENTATIVES

FOLLOWUP REVIEW OF AUTOMATIC
DATA PROCESSING ACTIVITIES
JET PROPULSION LABORATORY
National Aeronautics and Space
Administration B-162407(6)

D I G E S T

WHY THE REVIEW WAS MADE

At the request of the House Committee on Science and Astronautics, the General Accounting Office (GAO) has performed a followup review of the Jet Propulsion Laboratory (JPL) attempt to consolidate its administrative and scientific computing operations. In addition, GAO has reviewed JPL's plans to acquire additional computer resources. Previous reports on JPL's automatic data processing activities were issued to the Committee on July 7, 1969, and June 9, 1971.

FINDINGS AND CONCLUSIONS

In its June 9, 1971, report GAO estimated that a consolidation of administrative and flight operations data processing activities would save \$65,000 in fiscal year 1971 and \$325,000 each year thereafter. JPL did consolidate the computer operations and saved about \$45,000 for a 4-month period during fiscal year 1971. (See p 7)

However, thereafter, an unanticipated increase in workload (which was mostly attributed to the Mariner Mars 1971 project) and problems in the development of the computer operating systems caused JPL to abandon its consolidation plans and operations and to acquire increased computer capacity. As a result of the unanticipated increase in work-

load, the capacity on the flight operations computers, which previously was available for administrative operations, was used for the increased workload and the identified opportunity for savings through consolidation disappeared.

Also, as a result of JPL's difficulties in forecasting and satisfying computing requirements, the National Aeronautics and Space Administration requested JPL to undertake a comprehensive study to determine the most efficient way to meet future computer needs. In February 1972 JPL issued their long-range plan which estimated their computer needs for the 5-year period 1972-76. Included in the plan was the proposed acquisition of additional computer systems costing about \$8.2 million. (See pp 8 and 9)

GAO noted some improvement in JPL's long-range computer planning but concluded that the method used for estimating computing needs still needed improvement. GAO found that

- Predictions of future needs for computer services were often not supported by information on past needs for the same or similar services.
- Such records of past usage as did exist had not been kept on a basis consistent with that used by JPL to predict future needs.

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--Performance evaluation techniques that could have improved computer efficiency and could have decreased overall needs for computer services received only minimal usage

Because estimates of workload requirements and computer capacity were not fully supported by existing utilization records, there is no assurance that all, if any of the additional computing capacity is actually required. Accordingly, GAO

believes that JPL should delay any further computer acquisition plans until the estimating methods are significantly improved

Also, GAO believes that NASA should require JPL to make greater use of performance evaluation techniques to identify and correct possible inefficiencies in present operations before acquiring additional computers

CHAPTER 1

INTRODUCTION

The General Accounting Office (GAO) has reviewed the computer operations of the Jet Propulsion Laboratory (JPL) in Pasadena, California. This review was made pursuant to a request from the House Committee on Science and Astronautics that GAO review JPL plans to acquire additional computers and to a request from the Subcommittee on NASA Oversight that GAO maintain surveillance over JPL's consolidation of computer systems.

JPL is a Government-owned research and development center located in Pasadena. The Laboratory is operated by the California Institute of Technology (CIT) under a cost-type contract awarded by the National Aeronautics and Space Administration (NASA). JPL has three basic functions--to perform research and advance development, to explore the solar system with unmanned spacecraft, and to operate a deep-space communications and tracking network.

To achieve potential economic and functional benefits, JPL has taken various steps to combine its administrative and scientific data processing activities. We have been following the progress of these efforts at the request of the House Committee on Science and Astronautics and have periodically reported to this Committee.

In a report dated July 7, 1969, we recommended that NASA become more actively involved in coordinating JPL's data processing equipment acquisitions, specifically as they related to combining its administrative and scientific computing operations. In a followup report, dated June 9, 1971, we reported on JPL's actions to place its administrative data processing workload on its flight operations computers and to release its administrative computers. This is the third report in this series.

BACKGROUND

After manned lunar flights were established as a national space goal in 1961, NASA assigned projects to JPL for unmanned exploration of the moon and several planets. JPL's

most recent major space project--Mariner Mars 1971--provided an orbiting spacecraft to take pictures and to investigate atmosphere and surface features of Mars. Other current projects include the first fly-by mission of the planet Mercury in 1973 and the 1975 Viking project involving an un-manned landing on Mars.

JPL, unlike NASA as a whole, has been sustained at a fairly constant funding level during the last few years, with a \$22 million increase in fiscal year 1972. A history of JPL expenditures and administrative and scientific computing costs, beginning with fiscal year 1970, follows.

	Fiscal year		
	<u>1970</u>	<u>1971</u>	<u>1972^a</u>
Total expenditures	\$ <u>189,063,000</u>	\$ <u>176,324,000</u>	\$ <u>198,299,000</u>
General-purpose computing cost			
Operating costs	\$ 7,948,000	\$ 9,172,000	\$ 8,461,000
Contractual services	4,335,000	6,437,000	6,385,000
Capital costs	<u>1,170,000</u>	<u>6,863,000</u>	<u>4,455,000</u>
Total costs	\$ <u>13,453,000</u>	\$ <u>22,472,000</u>	\$ <u>19,301,000</u>

^aProjected expenditures and costs.

The administrative and scientific computing costs related primarily to the following three major data processing organizations at JPL.

--The Scientific Computing Facility (scientific computing) performs general-purpose scientific, engineering, and navigation computing.

--The Administrative Computing Service (administrative computing) processes all financial and management information.

--The Space Flight Operations Facility (flight operations computing) supports the flight projects' processing of tracking, telemetry, command, monitor, and

operations control data for mission and network control.

SCOPE OF REVIEW

Our review included determining the status of JPL's combination of its scientific and administrative data processing activities, the cost savings resulting from this combination, and the plans and the justification for acquiring additional computer resources. We examined pertinent regulations, records, and reports and held discussions with responsible NASA and JPL representatives. Although we discussed the results of our review with NASA and JPL officials in Pasadena, we did not obtain their official comments on the report.

CHAPTER 2

COMPUTER ORGANIZATION AND SYSTEM CHANGES

JPL has made several organizational and computer system changes influencing the consolidation of administrative and scientific computing. Our previous report stated that JPL had determined the feasibility of placing its administrative workload on the flight operation computers and that it took action to effect this transfer. However, a larger than anticipated increase in workload along with computer operating system development problems caused JPL to discontinue this combination and to return to processing the workloads separately--with administrative computing being processed under contract at CIT. On the basis of further evaluations of the current and the projected computing workload, JPL is requesting NASA approval to acquire new equipment costing about \$8.2 million. The following sections of this chapter describe the organizational and computer system changes which have taken place since our last report and the status of JPL's plans to acquire additional computers.

COMPUTER ORGANIZATIONAL STATUS

JPL first attempted to centralize its computer activities in November 1969. This reorganization placed all three major computing organizations under the Assistant Laboratory Director for Technical Divisions. In June 1971 JPL took the responsibility for computing away from this major data processing user and established the Office of Computing and Information Systems (OCIS), an independent office reporting directly to JPL's Deputy Director. OCIS was given the responsibility for managing all major computing systems that support flight operations, scientific, and administrative computing.

OCIS was created to centralize the control, management, and direction of JPL's general-purpose computing and to increase emphasis on long-range computer planning. The responsibilities of OCIS include the initiation of research and development activities in computing science for JPL needs, the evaluation and approval of data processing acquisition plans, the establishment of a communications link between computer personnel at JPL, and the performance of other management functions regarding computer operations.

COMPUTER SYSTEMS STATUS

After installing two flight operations IBM 360/75 computers, JPL decided in September 1970 to transfer administrative computing from a leased IBM 360/40 computer to the flight operations computers to make use of excess capacity and to realize cost benefits. This transfer was completed in December 1970, and the IBM 360/40 was returned to the vendor. The decision for this combination was based on workload forecasts prepared in the spring of 1970 showing that administrative computing could be handled for several years on the flight operations computers. We reported to the Committee that the possible savings from this transfer would be about \$65,000 during fiscal year 1971 and \$325,000 annually thereafter.

For approximately 4 months JPL performed administrative computing on the flight operation computers, using block time, i.e., time during which the total computer system is dedicated to one user or to one type of work. Program testing was partially performed in a multiple-user environment on the flight operation computers, and time was purchased from CIT for overflow testing. In April 1971 JPL determined that flight operations computing requirements would be appreciably greater than originally forecasted and that sufficient capacity would not be available to support administrative computing. In addition, JPL was experiencing problems in improving the capabilities of its flight operations computer operating systems, resulting in the need for more computer time than initially planned. Consequently, in May 1971 administrative computing was removed from the flight operations computers and commercial computer time was purchased to handle this workload. Computer time was initially purchased from an aerospace contractor until an IBM 370/155 computer became available at CIT. By June 23, 1971, all administrative computing was transferred to the CIT computer.

Although the estimated fiscal year 1971 savings from combining the administrative and flight operations computing was not completely realized, JPL did achieve a savings of about \$45,000 through the temporary consolidation. Because the consolidation was not in effect during fiscal year 1972, the \$325,000 savings was not realized. The cost of using the CIT computer in fiscal year 1972 is estimated at \$430,000.

In addition to contributing to the removal of administrative computing from the flight operation computers, the unanticipated increase in the Mariner Mars 1971 workload resulted in the acquisition of an additional leased IBM 360/75. In July 1971 NASA approved JPL's acquisition plan for the computer, and it was installed by September 1971. The acquisition was considered an interim measure to solve specific Mariner Mars 1971 problems and was not intended to influence any long-range plans. The estimated cost of leasing and operating the computer for the proposed 15-month period ending December 1, 1972, is \$988,000.

In June 1972 JPL was still processing its administrative computing at CIT. The principal computers being used by JPL's other major general-purpose computing activities were.

<u>Organization</u>	<u>Quantity</u>	<u>Computer</u>
Scientific Computing Facility	2	UNIVAC 1108
	1	IBM 360/75 ^a
Space Flight Operations Facility	2	IBM 360/75

^aOn temporary lease for Mariner Mars 1971 workload until December 1, 1972

LONG RANGE COMPUTING PLAN

Due to the difficulties JPL experienced in meeting its computing requirements, particularly in the Mariner Mars 1971 project, NASA requested, on July 20, 1971, that JPL undertake a comprehensive study to determine the most cost-effective way to fulfill its computing requirements in the foreseeable future. NASA told JPL that it was imperative that this study be given highest priority in order to preclude further interim solutions to data processing requirements.

In response to the NASA request, JPL issued a long-range computing plan on February 2, 1972, covering the 1972-76 period. Although JPL had been preparing the NASA-required annual plans and the individual acquisition plans supporting its equipment procurements, this was JPL's first attempt to put together a long-range plan considering all

its major computing activities. Plan objectives included (1) meeting realistic requirements in a cost-effective manner and maintaining costs within reasonable limits, (2) improving user support and user access to computer systems, and (3) increasing computer systems reliability and backup capability.

The general approach used by JPL in developing the plan was first to determine user (JPL departments using computer services) requirements and then to categorize them as either flight operations or administrative and scientific computing--categories that logically grouped all users. Flight operations requirements included tracking, command, mission control and analysis, and some simulation and telemetry processing associated with supporting the flight projects. Administrative and scientific requirements included such users as engineering, scientific, administrative, navigation, and other nonflight operations computing. Requirements were then reviewed and endorsed by various user committees and by JPL management.

On the basis of the user requirements and the defined computer capacities, the long-range plan recommended the acquisition of an additional IBM 360/75 computer for flight operations and an IBM 370/165 computer for administrative and scientific computing at an additional cost of approximately \$8.2 million. JPL believes that the acquisition of these computers by late 1972 will enable it to realistically meet its computing requirements through 1976. The acquisition would also permit the return of administrative computing to the laboratory without any reprogramming to be performed on the IBM 360/75 computers.

The principal computers at JPL, after the proposed acquisitions, would consist of

<u>Organization</u>	<u>Quantity</u>	<u>Computer</u>
Scientific and administration computing	2	UNIVAC 1108
	1	IBM 370/165 ^a
Flight operations computing	3	IBM 360/75

^aJPL considers the IBM 370/165 to be the equivalent in capacity to two IBM 360/75 or UNIVAC 1108 computers.

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Although NASA had not approved the computer acquisition as of June 1972, it agreed with JPL's concept and proposed general configuration for meeting projected requirements. At the conclusion of our review in June 1972, JPL was preparing detailed acquisition plans for the computers identified in the plan.

CHAPTER 3

NEED TO IMPROVE COMPUTER PLANNING

During fiscal year 1972 JPL took steps to improve its long-range computer planning. However, much work needs to be done to improve the methods used by JPL in estimating computer requirements and to develop the capability to improve the efficiency of installed computers before acquiring additional resources.

We found that

- Predictions of future needs for computer services were often not supported by information on past needs for the same or similar services.
- Such records of past usage as did exist had not been kept on a basis consistent with that used by JPL to predict future needs.
- Performance evaluation techniques that could have improved computer efficiency and could have decreased overall needs for computer services received only minimal usage.

LONG-RANGE COMPUTING PLAN

The long-range computing plan, which JPL used to support its computer needs, indicated that an increase in the number of computers was needed in order for JPL to meet its data processing requirements through 1976. JPL determined that this increase was necessary by comparing the estimated workload requirements and the estimated computer capacity. To make a valid comparison of computer requirements to computer capacity, JPL stated the requirements and the computer capacity in a common unit of measure.

Because most modern computer systems have only one central processing unit and because all applications systems run by the computer must utilize the central processor to accomplish desired results, JPL felt that a unit of measure based on the use of the computer's central processing unit provided the best common base for comparing computer capacity and user requirements

The unit of measure, as defined in the plan, consists of the following elements

- Direct central processor time used by a program.
- Indirect central processor time used by the computer's operating system, in support of the program.
- Central processor idle time due to program mix (varies depending on how efficiently the mixture of programs utilize the central processor).

Using this unit of measure to define its data processing requirements and capacity, JPL estimated that it would require between four and five UNIVAC 1108 or IBM 360/75 equivalent computers for administrative and scientific computing over the 5 years covered by the plan. For flight operations computing, JPL projected a need for three IBM 360/75 computers. In effect, JPL was projecting a need to almost double its computing power from the four existing permanent large-scale computers to the seven or eight equivalent computers.

Basis for user requirements of questionable validity

We made a review of the data processing requirement determinations made by JPL and found that they did not provide a convincing basis for support of their projected computer needs. We found that information on computer usage is not recorded for most flight operations and that information on administrative and scientific operations, although available, was not in a form that was usable to estimate requirements. Details of our findings follow.

Flight operations requirements

No computer utilization data is recorded or maintained during most of the time that flight operations computers are in operation

JPL has a job accounting system for the flight operations computers that can record utilization data which is generally consistent with the unit of measure defined in

the plan. However, this accounting system is not used during the blocks of time that the computers are dedicated to specific project users. These blocks of time compose approximately two-thirds of the flight operations computers' available time.

Without specific data on usage during two-thirds of the time that the computers are operating, past usage data is of limited value for predicting future needs.

Administrative and scientific computing

Available records did not provide administrative and scientific users with computer utilization data which could be used to estimate long-range requirements. Therefore, users estimated their data processing requirements on the basis of their data processing budgets--assuming that their budgets were to remain fairly constant. However, users were later asked to reestimate their requirements without budget constraints. The results were that estimated monthly administrative and scientific requirements were increased an average of 23 percent for the purpose of the long-range plan.

Basis for computing computer capacity was not very specific

JPL determined the capacity of their computing systems by reducing the total monthly available hours by the time the computer could not be used to process workload requirements. Because flight operations computing was considered less efficient than administrative and scientific computing, separate computer capacity limits were established for each category. A table illustrating JPL's computation of computer capacity follows.

	Flight operations <u>IBM 360/75</u>		Administrative and scientific <u>UNIVAC 1108</u>	
Available monthly hours		730		730
Less hours unavailable, due to				
Maintenance, diagnostics etc	120		120	
System setup	87		-	
Scheduling unavailability	<u>103</u>	<u>310</u>	<u>90</u>	<u>210</u>
Computer capacity (maximum monthly hours available)		<u>420</u>		<u>520</u>

JPL estimates that its flight operations computers have less available time, because some project users require sole occupancy of the computers or require the computing systems to be placed in a standby mode during critical flight periods.

In reviewing JPL's basis for determining computer capacity, we found that a portion of the deductions from available time were not fully supported by existing utilization records. Consequently, there was no assurance that capacity was being properly stated in terms of hours available or that additional computing capacity was actually required. A discussion of some of our findings follows.

Maintenance, diagnostics, etc.

JPL estimated a 120 hour per month reduction in each computer's capacity to process users' requirements, due to overhead work which must be performed--scheduled and unscheduled maintenance, running diagnostics, hardware modifications, reruns, and utility programs.

In analyzing this 120-hour reduction, we found a few instances in which estimates were not based on any existing utilization data and could not be supported.

System setup

System setup time is basically that period of time which is wasted when the flight operations computers must set up and switch to a different version of the operating system

The system setup time deduction of 87 hours for the flight operation computers was not directly supportable from any utilization records. In analyzing flight operations indirect method for supporting the 87 hours, we found an average of 500 hours of idle time for a 1-year period erroneously included as system setup time. We believe that this error caused system setup time to be overstated by about 42 hours each month (500 hours ÷ 12 months = 41.7 hours each month)

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Scheduling unavailability .

Scheduling unavailability is that time during which a computer system is idle and is not scheduled or manned to process work. JPL believes that computers should not be scheduled to process work 100 percent of available time, even though JPL's computer centers are operated 24 hours a day and 7 days a week. Most scheduling unavailability time occurs during holidays, weekends, and on third-shift operations.

We recognize that it may not be realistic to assume that a computer should operate 100 percent of the time. However, we question whether considering approximately 14 percent of total available computer time as unavailable is reasonable--particularly when the result is used to justify additional computer resources.

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PLANS TO IMPROVE COMPUTER UTILIZATION REPORTING

As indicated previously, we found that JPL's existing methods of recording computer utilization did not provide usage data consistent with the unit of measure used in preparing their long-range computer plan. As a result, JPL was forced to use various alternative means to forecast its data processing requirements. Although JPL representatives still believe that the methods used were technically competent for long-range planning purposes, they concede that better forecasting techniques are required. They also recognize that some assumptions and estimates made in preparing the plan were not adequately supported.

JPL has begun taking steps to improve its method of recording computer utilization. During our review JPL performed an analysis of the methods it used to collect IBM 360/75 and UNIVAC 1108 computer utilization statistics. JPL representatives concluded, on the basis of this analysis, that the basic data needed for reporting computer utilization, within the parameters of computer capacity defined in the long-range plan, was available. However, those representatives agreed that additional programs, reports, and procedures were necessary to develop the data in the required format. Accordingly, JPL was developing this capability when we completed our review in June 1972.

PLANS TO IMPROVE COMPUTER PERFORMANCE EVALUATION

JPL has made some limited efforts to evaluate and improve the performance of its data processing activities through the use of performance evaluation techniques--software monitoring and computer modeling. Software monitors are special computer programs which monitor various system functions during actual operating conditions, whereas computer modeling is a technique of estimating the performance of a computer under simulated operating conditions. Both techniques are used to identify inefficiencies in computer processing so that computer usage can be made more efficient and the workload can be accomplished in less computer time.

Although the use of these techniques has resulted in some improvements in system efficiency, JPL recognized the need for a broader application of computer performance measurement techniques to increase the efficiency of its data processing activities. JPL has made only a limited number of performance evaluations on its flight operations computers, due to the design limitations of its software monitor and the limited resources available for this purpose. For instance, JPL does not allow its software monitor on the flight operations computers during flight support because of the amount of computer resources required to run the monitor.

In a recent report to the Congress, "Opportunity for Greater Efficiency and Savings Through the Use of Evaluation Techniques in the Federal Government's Computer Operations" (B-115369, Aug. 22, 1972), we identified some of the uses made of performance measurement techniques and the potential benefits available to Government data processing activities from their use. We pointed out, for instance, that another NASA center, Goddard Space Flight Center, was able to achieve increases in production time from its computers, with little or no additional computer resources being used.

JPL has recognized the potential benefits available through the use of these techniques and is taking steps to improve its capability for evaluating computer system performance. In May 1972 JPL established a performance measurement and evaluation project whose primary function is analyzing and evaluating computer systems to be able to make system improvements. In addition, JPL was acquiring two computer hardware monitors for delivery in early fiscal year 1973 to provide a better means of evaluating system performance. A hardware monitor is an external hardware device connected to a computer system that monitors the status of resources without imposing any additional load on the system--a primary advantage of a hardware monitor over JPL's software monitor. In the near future, NASA will make available to JPL a new version of its software monitor which will have additional capabilities and will require less system resources.

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CHAPTER 4

CONCLUSIONS

Although there have been some improvements in JPL's long-range computer planning, the estimates of computing needs are not, in our judgement, sound enough to warrant confidence in the results. Accordingly, we believe that JPL should delay any further computer acquisition plans until the estimating methods are significantly improved.

Also, we believe that NASA should require JPL to make greater use of performance evaluation techniques to identify and correct possible inefficiencies in present operations before acquiring additional computers. .