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Organization Concerned: National Aeronautics and Space Administration.
Congressional Relevance: House Committee on Science and Technology; Senate Committee on Commerce, Science and Transportation; Congress.

The Space Telescope Project will develop a complex space observatory with the objectives of serving the scientific community and extending knowledge of the universe. National Aeronautics and Space Administration (NASA) estimates for Project costs have increased because of inflation factors and inclusion of changes in scope and administrative costs. Findings/Conclusions: NASA has not prepared a lifecycle cost estimate for the telescope. In addition to excluded development costs of $227.2 million, operation costs of $709.4 million should be included in estimates, which would bring the lifecycle cost to about $1.4 billion. Technical uncertainties still remaining deal with component development, stabilization control, contamination effects, thermal control, and testing limitations. International cooperation has not been formally achieved, but negotiations are in the final stages. NASA is planning an institute to manage observation programs during the operational phase. Recommendations: The NASA Administrator should provide to Congress a lifecycle cost estimate, and submit periodic project status reports if telescope development is approved. (HTW)

REPORT TO THE CONGRESS

BY THE COMPTROLLER GENERAL OF THE UNITED STATES

Status And Issues Pertaining To The Proposed Development Of The Space Telescope Project

National Aeronautics and Space Administration

The Space Telescope will be the largest, most complex space observatory ever developed. GAO estimates that the development and operational costs could total about $1.4 billion. However, a lifecycle cost estimate has not been prepared by NASA.

A number of technical problems must be overcome if the Space Telescope is to achieve its scientific objectives. Other issues include the scope of international participation and the establishment of an institute to manage the scientific observation programs during the Telescope's operational phase.

NASA has requested that the Congress approve the Space Telescope for development in fiscal year 1978.

PSAD-77-98

MAY 4, 1977

COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

B-183134

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

This is our second report on the National Aeronautics and Space Administration's proposed development of the Space Telescope Project. It discusses the Telescope's cost and status and issues pertaining to its development and operational phases.

This review was made as a part of our continuing effort to apprise the Congress of the status of major system acquisitions and to assist it in exercising its legislative and review functions. A copy of this report was reviewed by agency officials responsible for the management of the Project, and their comments are incorporated as appropriate.

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

We are sending copies of this report to the Director, Office of Management and Budget, and to the Administrator, National Aeronautics and Space Administration.

Comptroller General
of the United States

COMPTROLLER GENERAL'S
REPORT TO THE CONGRESS

STATUS AND ISSUES PERTAINING TO THE PROPOSED DEVELOPMENT OF THE SPACE TELESCOPE PROJECT National Aeronautics and Space Administration

D I G E S T

NASA plans to seek authority to begin Space Telescope Project development during fiscal year 1978. Development and operational costs could total about $1.4 billion. The Congress should obtain from NASA

--a lifecycle cost estimate to include all costs associated with the Project,

--periodic reports on the status of known technical uncertainties and their effect on fulfilling the Telescope's scientific objectives,

--its plan for providing adequate funds in the operational phase for data management and development of advanced scientific instruments, and

--its plan for obtaining substantial international participation in the Project.

PROJECT COST AND STATUS

The Telescope will be the largest, most complex space observatory ever developed by NASA. NASA's primary objective is to operate a large, high resolution system which will (1) be useful to the international scientific community and (2) extend and expand man's knowledge of the universe.

Through September 30, 1976, $14 million had been appropriated for the Telescope; however, the Congress did not provide any funding for fiscal year 1977.

Marshall Space Flight Center's estimated Project cost for development of the Telescope has increased $138 million, from $297 million in July 1975 to $435 million in July 1976, because the Center

--used different assumptions regarding inflation factors,

--made additions and scope changes,

--increased Project reserves,

--included headquarters' contract administration costs, and

--deleted the cost of early study effort. (See p. 8.)

NASA stated that the official estimate for the Telescope's development is between $435 million and $470 million in fiscal year 1978 dollars. According to NASA, except for an allowance for inflation, this estimate is essentially the same as the estimate provided to the Office of Management and Budget when the Telescope was being considered for a new start in fiscal year 1977. Additional development costs of $227.2 million are not included in NASA's estimate for

--early study effort,

--tracking and data acquisition capability,

--inflation after fiscal year 1978,

--civil service personnel assigned to the Project, and

--shuttle transportation to launch the Telescope.

NASA has not prepared a lifecycle cost estimate for the Telescope. Since it has an expected operational life of 10 to 15 years, NASA's development estimate of $435 million does not indicate the total cost of the Project. In addition to the excluded development cost of $227.2 million, GAO identified operations costs of $709.4 million, which should be included in a lifecycle estimate. These costs, together with NASA's development estimate of $435 million, could increase the total lifecycle cost to about $1.4 billion. NASA stated that the GAO approach to lifecycle cost estimating for the Telescope is inappropriate;

however, in GAO's view the costs it identified are in fact indicative of the Telescope's potential lifecycle costs. (See pp. 9 to 12.)

The planned launch date for the Telescope has slipped about 1-1/2 years, from June 1982 to late 1983. Marshall officials attribute the slippage to

--a 6-month delay to realine milestones for starting the development of a 2.4-meter Telescope in fiscal year 1977 and

--a 1-year delay in obtaining administration approval to initiate development. (See pp. 4 and 13.)

NASA has established broad performance requirements to meet the Telescope's scientific objectives. The overall goal is to achieve near perfect optical performance over a wide spectral range with emphasis on observing faint objects. However, a major change in the performance requirements was a reduction of the Telescope's aperture from 3.0 to 2.4 meters, which will cause some loss of effectiveness in observing faint objects. NASA estimates the loss of scientific data from relatively bright objects will be insignificant. (See pp. 13 and 14.)

While no formal commitments have been made by international participants, NASA believes that the European Space Agency will provide a faint object camera, parts of the solar power system, and contribute to the costs of the Project's operation. NASA stated that an agreement with the European Space Agency is in the final stages of negotiation. The European Space Agency's Science Planning Council has approved a contribution to the Project of about $88 million based on the current rate of exchange if development is approved. (See pp. 15 and 16.)

NASA has recently initiated an external reporting system designed to present the cost, schedule, and performance status of six of its major projects. If the Congress approves the Telescope for development, GAO believes

it should be included in this reporting system. (See p. 16.)

TECHNICAL DEVELOPMENT UNCERTAINTIES

During the Telescope's definition phase, NASA identified several technical uncertainties that could degrade performance. These uncertainties include

--development of critical components,

--fine pointing and stabilization control,

--control of contamination effects,

--development of adequate thermal control, and

--testing limitations.

NASA believes that there are no major technical problems remaining in the development path of the Telescope. (See pp. 18 to 22.)

OPERATION PHASE

NASA plans to establish a separate operation control center and a science institute to manage the Telescope after it becomes operational. The center will be responsible for the Telescope's day-to-day operations while the science institute will plan and implement the scientific observation programs. The estimated operations costs in GAO's life-cycle cost estimate include the costs of establishing an operation control center and a science institute. (See pp. 12, 23, and 24.)

OTHER ISSUES

Data management has been a problem on past space science projects. Since the Telescope is expected to operate for as long as 15 years, it will generate vast amounts of scientific data. GAO believes that NASA should carefully consider the problems associated with managing the data when planning Telescope operations. (See p. 25.)

NASA has supported the construction and operation of a number of ground-based telescopes. However, the benefits of such investments have not been fully realized because funds to provide these telescopes with advanced instruments have not been available. The Telescope probably will require updated scientific instrumentation during its expected life. NASA should plan its budgets to make sure that funds are available for this purpose. (See p. 25.)

RECOMMENDATIONS

The NASA Administrator should

--provide to the Congress, as soon as possible, a lifecycle cost estimate to include all costs associated with the Project; this would provide the Congress more complete information on which to base its authorization and appropriation decisions and

--submit periodic project status reports to the Congress if the Telescope is approved for development; these reports would permit the Congress to monitor more effectively the Project's cost, schedule, and performance progress.

AGENCY COMMENTS

NASA reviewed this report and did not agree with GAO's recommendations. NASA's comments have been added where appropriate and included in entirety as appendix I.

Also attached, as appendix II, is a letter from the Office of Management and Budget in which it concurred with the statements in the report about that office.

Contents

ABBREVIATIONS

ESA	European Space Agency
GAO	General Accounting Office
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration

CHAPTER 1

INTRODUCTION

This report contains the results of our second review 1/ of the Space Telescope Project which will be the largest, most complex space observatory ever developed by the National Aeronautics and Space Administration (NASA).

The report contains information on the Project's (1) current cost, schedule, and performance status; (2) technical development uncertainties; and (3) operation phase.

OBJECTIVES

The primary objective of the Project is to develop and operate a large optical space telescope system which will be useful to the international scientific community and significantly extend man's knowledge of the universe. Specific scientific objectives are to develop a better understanding of the (1) universe's origin and evolution; (2) stars, galaxies, and the nature and behavior of materials and fields between them; and (3) physical aspects of the universe.

DESCRIPTION

The Project includes the design, development, production, integration, launch, orbital verification, and preparation for mission operation of an unmanned astronomical observatory. The elements of the system are: an optical telescope assembly; scientific instruments; a support systems module; and all unique equipment and procedures needed to test, handle, launch, and support on-orbit operational verification.

The Space Telescope will be launched from the Kennedy Space Center on a manned Space Shuttle and put in a circular orbit about 270 nautical miles above the Earth. An operation control center will send operational commands to the spacecraft, monitor the status of its systems, determine failures, and identify degraded systems.

The Space Shuttle is to rendezvous with the Telescope when necessary for limited maintenance and servicing and/or

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1/Staff Study "Space Telescope Project" (PSAD-76-66, January 1976)

return it to Earth for major maintenance or refurbishment to extend its life and upgrade its scientific capability. The illustration on page 3 shows the various stages of a Space Telescope mission.

JUSTIFICATION

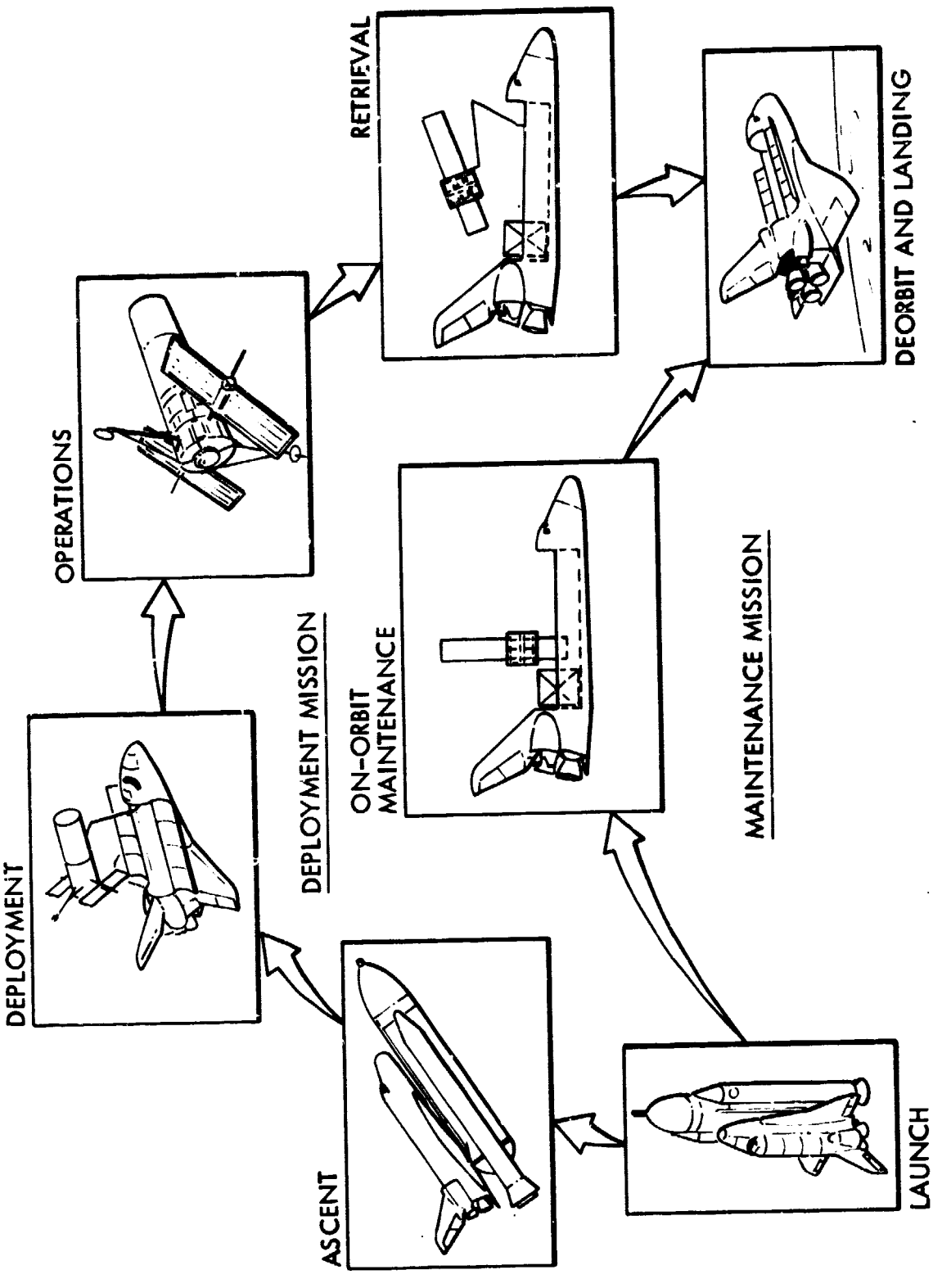
As early as 1923, a scientist recognized that an astronomical telescope in orbit above the atmosphere would have tremendous advantages over ground-based instruments which are affected by fluctuation, distortion, and absorption effects of the Earth's atmosphere. The atmosphere blocks out most of the shortwave radiation emitted by the sun and stars and limits observations made by ground-based telescopes to a small fraction of the electromagnetic spectrum. Space telescopes, however, have important advantages over ground-based telescopes, including the ability to intercept radiation that cannot penetrate the atmosphere.

Astronomers believe that the Space Telescope will assist in resolving major questions in astronomy which cannot be answered with data obtained from ground-based telescopes. Scientists expect to be able to systematically study weather conditions on other planets which should lead to a better understanding of the Earth's weather and the origin of climate changes and to study the physical process of explosions in the universe in search of new sources of energy for use on Earth. By using the Telescope, scientists may be able to discover phenomena contributing to man's basic needs, see the edge of the observable universe, and even answer the age-old question: Are we alone in the universe?

Since the Space Telescope concept was first proposed, it has been studied and endorsed by a number of scientific groups. The scientific community considers the Telescope vitally important to space research and the next logical step in the field of astronomy. A recent study by the Space Science Board, National Academy of Sciences, stated that the Telescope is the highest priority program in astronomy and concluded that "it is clear that the time is ripe for this important project; nothing is to be gained by delay."

HISTORY

In late 1971 NASA authorized Space Telescope feasibility studies, which were completed in December 1972. Based on the potential benefits of such a project, NASA started in April 1973 to better define the design requirements for a 3.0-meter aperture Telescope. Then, in August 1973, NASA awarded contracts to two competing contractors for parallel definition of the optical Telescope assembly and scientific



STAGES OF A SPACE TELESCOPE MISSION

instruments. In December 1974 NASA awarded contracts to three competing contractors to complete definition of the support systems module.

During fiscal year 1975, the Congress directed NASA to investigate means to reduce costs and to obtain international participation in the Project. To determine the most cost-effective approach, NASA directed its definition contractors to evaluate telescopes with 1.8-, 2.4-, and 3.0-meter apertures. In May 1975 the NASA Administrator selected the 2.4-meter system for final definition because (1) its projected weight was well within Space Shuttle payload requirements, (2) required technology was considered to be within current capabilities, (3) estimated costs were substantially less than for the 3.0-meter system, and (4) the 2.4-meter system was considered to be capable of achieving the established scientific objectives. Also, NASA representatives pursued whether the United Kingdom and the European Space Agency (ESA) would participate in the Project. Although both showed interest in the Project, they made no formal commitments to participate. (See pp. 15 to 16.)

NASA included the Space Telescope in its fiscal year 1977 budget as a candidate new start project for development, but the Office of Management and Budget deleted the request because of funding limitations. Through September 30, 1976, $14 million had been appropriated for definition and advanced technology development of the Telescope; however, the Congress did not provide any fiscal year 1977 funds for the Telescope.

MANAGEMENT

NASA's Office of Space Science is responsible for overall management of the Project, such as establishing policy and technical requirements, approving plans, determining goals and objectives, and allocating funds. Marshall Space Flight Center (MSFC), NASA's lead center for the Project, is responsible for Project implementation and meeting cost, schedule, and performance goals.

The Goddard Space Flight Center is responsible for developing scientific instruments and performing mission and data operations. The Johnson Space Center is responsible for Space Shuttle and Telescope interface, and the Kennedy Space Center, for launch operations. NASA's Office of Tracking and Data Acquisition will be responsible for providing tracking and data acquisition support.

To provide scientific operations services to a wide spectrum of the scientific community, including Government scientists, NASA is considering the establishment of a Space Telescope science institute as the science operations element of the Project. The institute would include a staff of scientists and might be operated by a consortium of universities under contract to NASA. (See p. 24.)

SCOPE OF REVIEW

Information contained in this report was obtained by reviewing Project plans, reports, correspondence, and other documents prepared by NASA, its contractors, and other organizations. We also discussed various aspects of the Project with NASA, the Space Science Board, and Space Program Advisory Council Officials. The latter is comprised of a number of well-known industry and Government experts who advise NASA on space matters.

CHAPTER 2

PROJECT STATUS

The Space Telescope Project has completed the definition phase of the acquisition cycle. Work in this phase included detailed studies, comparative analyses, and preliminary design for the purpose of selecting a single project approach from several approaches or concepts for accomplishing the proposed mission.

ESTIMATED COST

Cost estimates for development of the Space Telescope have varied from MSFC's initial estimate in July 1974 of $463.8 million (real year dollars) 1/ for a 3.0-meter Telescope to its latest estimate ranging from $406 million to $435 million (fiscal year 1975 dollars inflated to fiscal year 1978 dollars) for a 2.4-meter Telescope.

Space Telescope Development Cost Estimates

	Amount (millions)
July 1974 (3.0-meter)	a/$463.8
Mar. 1975 (2.4-meter)	a/373.0
July 1975 (2.4-meter)	b/297.0
Mar. and July 1976 (2.4-meter)	c/406-435

a/Real year dollars.

b/Fiscal year 1977 dollars.

c/Fiscal year 1978 dollars.

We expect additional costs, estimated at $937 million, to be incurred over the life of the Project. A table depicting the elements comprising the almost $1.4 billion cost expected for acquiring and operating the Telescope is shown on page 10.

1/Real year dollars means that projected inflation through Project completion is included in the estimate.

In July 1974 MSFC estimated that the 3.0-meter Space Telescope would cost $463.8 million in real year dollars. After reducing the Telescope's aperture from 3.0 meters to 2.4 meters, MSFC estimated in March 1975 that the Project would cost $373 million in real year dollars which represents a $91 million net decrease in estimated cost. The net decrease resulted primarily from

--reducing the aperture size,

--refining the cost estimate,

--revising inflation rates, and

--slipping the projected launch date from June to December 1982.

The March 1975 estimate included costs for design, development, production, launch, and 1 year of operations.

In July 1975 MSFC revised its estimate for the 2.4-meter Space Telescope to $297 million in fiscal year 1977 dollars. This represented a $76 million net decrease in estimated cost over the March 1975 estimate. The net decrease resulted primarily from

--stating the estimate in fiscal year 1977 dollars rather than real year dollars,

--reducing the contingency and operational costs,

--reducing the estimate for costs to be borne by international participants, and

--refining the estimate.

Details of changes between the March and July estimates were discussed in our previous report on the Telescope.

MSFC updated the Project cost estimate in March and July 1976 to a cost range of $406 million to $435 million in fiscal year 1978 dollars. A cost range was recommended as a means of reflecting the degree of uncertainty in inflation between fiscal years 1975 and 1978.

MSFC's July 1976 estimate was prepared using 1975 dollars as a starting point and inflating them through fiscal year 1978. Inflation factors used to arrive at the $406 million estimate were based on information from definition phase contractors for fiscal years 1975 to 1977, and on a

June 1975 Air Force Space and Missile System Organization inflation model for fiscal years 1977 to 1978. The $435 million estimate was based on inflation factors contained in an updated Space and Missile System Organization model dated April 1976. The $435 million estimate includes

--$284.4 million for design, development, and integration of hardware;

--$9.2 million for institutional management support; 1/

--$29.3 million to prepare for operations and launch as well as 1 month of flight operations;

--$106.1 million for Headquarters' and Center Project reserves; and

--$6 million for Headquarters' contract administration cost.

The July 1976 estimate represents a $138 million net increase over MSFC's July 1975 estimate of $297 million. The net increase resulted primarily from (1) a $74.6 million increase in projected inflation resulting from changing factors used for projecting inflation and stating the estimate in fiscal year 1978 rather than fiscal year 1977 dollars, (2) a $38.8 million increase because of Project additions and scope changes, (3) a $30.2 million increase in Project reserves, (4) a $6 million increase to cover Headquarters' contract administration cost, and (5) a $11.6 million decrease because NASA excluded costs of early study efforts that had been included in the July 1975 estimate.

MSFC officials told us that the $435 million estimate includes the total hardware development cost but added that the Project cost could be reduced if international agencies pay part of it.

MSFC's July 1976 estimate does not include all costs required for the development and operation of the Space Telescope. NASA regulations require that all direct and ancillary costs be identified and included in project cost estimates even though they may not be under the direct control of the project manager. Examples of such costs omitted

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1/Institutional management support consists of tasks performed by in-house and support contractor personnel that benefit the Project.

from the estimate are (1) tracking and data acquisition support, (2) operations cost beyond the first month, (3) cost of civil service personnel assigned to the Project, and (4) cost of shuttle transportation to launch, maintain, and retrieve the Telescope. (See p. 10.)

In commenting on our report, NASA stated that the official estimate for the Space Telescope's development is between $435 million and $470 million in fiscal year 1978 dollars. It told us that this estimate is essentially the same as the estimate provided to the Office of Management and Budget when the Telescope was being considered for a new start in fiscal year 1977. According to NASA, the primary difference between the two estimates is an allowance for inflation between fiscal years 1977 and 1978.

In April 1976 the Office of Management and Budget issued a policy on major systems acquisitions by all executive branch agencies (Circular A-109 dated April 5, 1976). The circular states that acquisition strategy for a project should provide a method for projecting lifecycle costs during all phases of the acquisition process to (1) provide a means of assessing cost, schedule, and performance experience against predictions and (2) provide information to agency officials for consideration at key decision points. The circular defines a lifecycle cost as:

> "the sum total of all direct, indirect, recurring, nonrecurring, and other related costs incurred, or estimated to be incurred, in the design, development, production, operation, maintenance, and support of a major system over its anticipated useful life span."

The Office of Management and Budget commented that our reference to its circular is correct. It added that NASA attempted to be responsive to the spirit of the circular and that it has the capability of providing additional cost information to the Congress, if desired. It added that their office will continue to review and assess the progress and cost of this major scientific undertaking.

In the absence of a NASA lifecycle cost estimate, we summarized the cost elements that we identified and believe should be included in such an estimate. While these cost elements, which total about $1.4 billion, are not necessarily the total Space Telescope costs that would accrue during development and operation, they provide an indication of potential lifecycle costs.

Identified Space Telescope Cost Elements

Element		Amount
		(millions)
Cost included by NASA:		
Design, development, and integration of the Space Telescope system (fiscal year 1978 dollars)		$ 435.0
Costs not included by NASA:		
Early study effort (real year dollars)	$ 14.0	
Tracking and data acquisition (fiscal year 1978 dollars) (note a)	64.6	
Inflation for development phase (after fiscal year 1978)	96.4	
Operations cost (fiscal year 1978 dollars) (note b)	469.7	
Civil service personnel:		
Development phase (real year dollars)	81.3	
Operations phase	(c)	
Shuttle transportation (fiscal year 1978 dollars)	210.6	936.6
Total		$1,371.6

a/Includes $12.1 million to establish a tracking and data acquisition capability.

b/Computation based on a 15-year life.

c/Estimate not available.

Estimates of costs not included by NASA, except for those for shuttle transportation, were furnished by MSFC. We estimate that shuttle transportation for the Space Telescope could cost as much as $210.6 million in fiscal year 1978 dollars. Although MSFC has not determined the cost for a shuttle flight or how many flights will be required, MSFC believes that nine flights may be required if the Telescope operates for the expected 15 years.

An MSFC official told us that it is difficult to accurately predict the required number of shuttle flights because the frequency of on-orbit maintenance and ground refurbishment is not known. However, current plans provide for on-orbit maintenance every 2-1/2 years and ground refurbishment

every 5 years. Ground refurbishment requires two flights--retrieval and relaunch.

We estimated shuttle transportation costs using NASA's tentative estimate of charges to a Government user (16.1 million to $18.0 million for each flight in 1975 dollars) escalated to 1978 dollars or $23.4 million a flight. The escalation rate applied was the same rate used by MSFC to escalate hardware development cost. The costs for a Space Telescope launch probably will be even greater because it will be delivered to a 270-nautical-mile-high orbit at a 28.8-degree inclination rather than a 160-nautical-mile-high orbit at a 28.5-degree inclination, on which the previously cited rate is based. The shuttle will require additional fuel to attain the higher orbit; NASA has not estimated the cost of the additional fuel.

NASA COMMENTS AND OUR EVALUATION

In commenting on our report, NASA stated that our approach to lifecycle cost-estimating for the Space Telescope is inappropriate. NASA commented:

> "The GAO estimate that the development and operational costs of the Space Telescope Project could total $1.4 billion is based on incomplete program definition and erroneous costing and could result in providing misinformation to the Congress about the budget implications of the new project start presented in the FY 1978 budget. The GAO estimate confuses official NASA estimates with preliminary field center estimates and GAO estimates that are clearly in error. Presenting this eclectic array of cost data as a life-cycle cost estimate for the Space Telescope Project is misleading because the development of the Space Telescope does not require a commitment to the program scope postulated by the life-cycle values cited in the GAO report."

We realize that all plans for the Space Telescope's operations phase have not been finalized; therefore, cost estimates for that phase of the Project are not as firm as the development cost estimate. However, NASA is asking the Congress to approve a project whose potential operations cost over its estimated 15-year life could be twice its development cost. We believe that a lifecycle cost estimate for the Telescope is essential if the Congress is to have an adequate basis for deciding whether to approve the Telescope for development.

NASA also stated that its preliminary assessments indicate that approximately $10 million to $15 million will be required annually for mission and science operations. The agency said:

> "* * *This estimate excludes costs for those elements which are variable and subject to future decisions, such as the role of a science institute, the type and scheduling of instrument refurbishment, and the degree of on-orbit maintenance, or retrieval and refurbishment."

Our estimate of lifecycle costs is based on information furnished by MSFC and provides an indication of total investment that could accrue during development and operation. For example, the estimated operations costs of $469.7 million shown in our computation of lifecycle costs included costs for (1) daily operations, (2) the science institute, (3) development of advanced instrumentation, (4) on-orbit maintenance, and (5) retrieval and refurbishment. While we recognize that field center estimates do not represent NASA's official position, we believe that they are more complete than headquarters' estimates because they are made by personnel charged with the Project's day-to-day management and, therefore, should be more representative of the expected cost of a program. Furthermore, we believe that development of the Space Telescope requires a commitment to the development and operations program if it is to achieve its maximum benefit.

NASA further commented that our estimate of lifecycle costs is flawed because we included the full cost of nine shuttle flights in the cost charged to the Space Telescope. It stated:

> "* * *This approach is clearly unrealistic since each Shuttle flight for launch or return of the Space Telescope would utilize the cargo bay in one direction only, and on-orbit maintenance flights would require only small payload volume in either direction."

We believe that launch, on-orbit maintenance and retrieval of the Space Telescope may be difficult to achieve without a dedicated shuttle flight because of the multitude of potential orbits and the shuttle's limited maneuverability. Rendezvous missions will require the shuttle and the satellite to be in precisely the same orbit. For these reasons, we feel that dedicated shuttle flights may be required.

SCHEDULE

The scheduled launch date for the Space Telescope slipped about 1-1/2 years from June 1982 to late 1983. In July 1974 MSFC's planning schedule showed a launch date of June 1982 for the 3.0-meter Telescope. MSFC initially projected a December 1982 launch date for the 2.4-meter Telescope which represents a 6-month delay from the earlier projected launch date. MSFC officials attributed the slippage to a delay in starting the development phase until fiscal year 1977. Under MSFC's latest schedule, the development phase will begin during fiscal year 1978, and the launch will be in late 1983, an additional year's slippage.

MSFC's preliminary schedules, prepared to support the late 1983 projected launch date, include (1) selection of scientific instruments (October 1977 to November 1978), (2) issuance of announcement of opportunity 1/ (February 1977), (3) selection of science teams and participants at large (October 1977), and (4) award of development contracts (October 1977). NASA released requests for proposal for hardware development on January 28, 1977.

PERFORMANCE

MSFC has established broad performance requirements which must be satisfied for the Space Telescope to meet its scientific objectives. The major change in the broad performance requirements was the reduction of the Telescope's aperture from 3.0-meters to 2.4-meters. This change reduces the Telescope's effectiveness, but NASA estimates the loss of scientific data from relatively bright objects will be insignificant. For very faint objects, NASA estimates "* * *only about half as many observations can be obtained but the amount of science obtained will not be reduced by as large a factor." The Space Science Board concluded that the 2.4-meter Telescope could obtain most of the scientific data needed by increasing the viewing time. Some changes in performance requirements are:

1/An announcement by NASA soliciting proposals or investigative ideas from the scientific community interested in participating in a project.

	Initial	Present
Telescope aperture (in meters)	3.0	2.4
Number of scientific instruments	7	5
Approximate weight (in pounds)	21,000	23,000
Electrical power (in watts)	2,500	2,100
Approximate visual magnitude (note a)	28	27

a/An astronomy term used for describing the brightness or faintness of celestial objects. The relative brightness of celestial objects is measured by an inverse logarithmic scale of magnitudes with the numbers increasing with the faintness of the object. A 3.0-meter telescope would have been able to detect a star of the 28th magnitude which is approximately 2.5 times fainter than a star of the 27th magnitude.

The overall performance goal established for the Space Telescope is to achieve near perfect optical performance over a wide spectral range with emphasis on faint object observations. As presently defined, the Telescope will be capable of operating for a period of 10 to 15 years. It will be about 43.6 feet long, 14 feet in diameter, and weigh about 23,000 pounds. Electric power for the spacecraft will be provided by solar arrays and batteries.

One of several critical performance goals being studied concerns the pointing and stability requirement of .007 arcseconds. This angle is comparable to steadily viewing a dime 325 miles away. NASA officials told us that this is not an absolute requirement but a goal that can be relaxed, if necessary, provided some other parameter or specification is changed to compensate for the performance degradation. The Orbiting Astronomical Observatory has already achieved .007 pointing accuracy, but for a shorter period of time than will be required for the Space Telescope.

Another major requirement to be incorporated into the system design concerns the ability to replace scientific instruments when warranted by technological advances, changes in observational interests of the astronomical community, or performance degradations. This is a key design requirement because the Space Telescope is to serve as a long-term astronomical space observatory.

Some of the planning requirements for the Space Telescope have changed since our previous review. For example, our January 1976 report stated that the Telescope would be about 41 feet long, 15 feet in diameter, and weigh about 15,200 pounds. MSFC officials said that changes occurred because the Project's completed definition studies provided a better understanding of Project requirements.

INTERNATIONAL PARTICIPATION

NASA has responded to congressional direction to seek international participation in the Project by working closely with ESA. Although no formal commitments have been made, NASA anticipates that international participants will provide a faint object camera (as a scientific instrument), the camera's associated photon counting detector, part of the solar power system, and participate in the Project's operations phase. NASA also expects the United Kingdom to participate through ESA.

NASA told us that under the current draft memorandum of understanding, ESA will be allocated observing time on the basis of the value of the contribution compared to the total cost of the Project. The contributor would have first rights to science data obtained through its observations for 1 year. After that time the data will be deposited in the U.S. National Space Science Data Center and the Data Library of the European Space Operation Center and will be available to the international scientific community.

In May 1976 the NASA Associate Administrator for Space Science established a team to assess European capability to produce a faint object camera and a compatible detector to meet the Space Telescope's specifications and schedule. The team concluded that the Europeans have the technology, facilities, and technical expertise required to produce the instrument. However, the design being pursued did not appear to be capable of carrying out the prime scientific objectives of the faint object camera. The team's assessment showed that the European design had been compromised because too much had been included in a single instrument. The team recommended that the European instrument not be considered for the Telescope unless it is simplified to accomplish the instrument's primary scientific mission only.

ESA subsequently offered several alternatives to its preliminary faint object camera design. The Project's scientist told us that NASA and ESA have agreed on a design which would meet the requirements established for the faint object camera.

In commenting on our report, NASA stated that while no formal agreement covering ESA's participation has been signed, the agreement is in the final stages of negotiation. It also stated that the ESA Science Planning Council approved, on October 5, 1976, an ESA contribution to the Project equivalent to 80 million accounting units (about $88 million based on the rate of exchange as of February 23, 1977), contingent upon approval of the Project's development.

The Office of Management and Budget commented that it specifically requested NASA to seek maximum cost-sharing in the Project and to keep the Office informed of the progress in encouraging international participation.

PROJECT STATUS REPORTING

At the request of the Chairman of the Subcommittee on HUD-Independent Agencies, Committee on Appropriations, U.S. Senate, NASA recently initiated an external biannual reporting system designed to present the cost, schedule, and performance status of six of its major projects. The reporting system is still in the formative stages but should evolve into a meaningful tool to assist the Congress in meeting its legislative and oversight responsibilities. If the Space Telescope is approved for development, we believe it should be included in this project status reporting system.

CONCLUSIONS

We believe NASA should prepare a lifecycle cost estimate for the Project and provide it to the Congress as soon as possible. Realistic cost estimates are indispensable to both the Congress and NASA management throughout the entire planning, approval, and development process because the estimates provide a basis for deciding which projects should be developed, continued, modified, or stopped. Although costs not included in the Project estimate are included in various line items of NASA's budget and consequently reported to the Congress, NASA should prepare a single total Project estimate to show the overall impact of the Project on NASA's budget. This would provide better information for use by the Congress in making decisions on specific projects during authorization and appropriations hearings.

NASA has an opportunity to reduce its cost of the Space Telescope by obtaining international participation in the Project. NASA should continue pursuing this opportunity and make sure that any international contribution of equipment will meet Project specifications.

If the Space Telescope is approved for development, it should be included in NASA's project status reporting system. Periodic status reports on the Telescope would provide the Congress with current information on the Project's cost, schedule, and performance status and would permit the Congress to monitor more effectively the Project's progress.

RECOMMENDATIONS

The NASA Administrator should

--provide to the Congress, as soon as possible, a life-cycle cost estimate to include all costs associated with the Project and

--submit project status reports to the Congress if the Project is approved for development.

MATTER FOR THE ATTENTION OF THE CONGRESS

The Congress should obtain NASA's plan for obtaining substantial international participation in the Project.

CHAPTER 3

TECHNICAL DEVELOPMENT UNCERTAINTIES

During a project's definition phase, NASA assesses all technical issues, and plans are made to resolve any identified risks during the design and development phase. NASA has identified several technical uncertainties that could degrade the Space Telescope's performance unless satisfactorily resolved. Some of the areas identified during the definition work are (1) development of critical components, (2) fine pointing and stabilization control, (3) control of contamination effects, (4) development of adequate thermal control, and (5) testing limitations. The nature of these uncertainties, their possible impact on the Telescope's performance, and NASA's actions to resolve them are discussed below.

DEVELOPMENT OF CRITICAL COMPONENTS

Several critical components and subsystems have been defined for the Space Telescope. One of the most critical optical components is the primary mirror which collects light from observed objects and forms their images. The mirror must be polished to very stringent tolerances, and it must be sufficiently stiff to maintain its shape during the manufacturing process and in its operational environment. Any deformation of the mirror's surface during polishing would result in image errors. One definition contractor said the correction of primary image errors after the mirror is fabricated would be a difficult and costly process.

During the definition phase, Space Telescope contractors proved the feasibility of fabricating and polishing mirrors comparable to the size of the mirror defined for the Telescope. One of the contractors manufactured and polished a 1.8-meter ultralow-expansion mirror to tolerances which exceeded those required for the Telescope.

Another critical technical area concerns the detectors required for the scientific instruments. A detector functions much like a camera and takes the place of film in the space environment. Considerable concern has been expressed by the scientific community over the development of adequate detectors, and some reports have shown that detectors and their related technology comprise the most critical area involved in the development of scientific instruments. In addition, one definition contractor said it was apparent that existing detectors could not satisfy the Space Telescope's operational requirements and desired scientific data output.

MSFC officials responsible for detector development believe that detectors are a major area of technical concern because of their low reliability. They believe, however, that technology is available for the development of detectors with the desired capabilities. As a result, NASA has funded several contracts totaling about $3 million for advanced technological studies of various types of detectors. MSFC officials told us that if adequate detectors cannot be developed in the required timeframe, they could use available detectors having lesser capabilities. They said, however, that use of these detectors would not provide the desired performance of the Space Telescope.

In commenting on our report, NASA stated:

> "Breadboards of several types of detectors which will satisfy Space Telescope requirements are being developed and tested on ground-based telescopes as part of this effort. This testing is planned to be completed prior to selection of the instruments by NASA. A number of the concepts are now reaching a sufficient stage of development to give reasonable confidence that they will be available."

FINE POINTING AND STABILIZATION CONTROL

Pointing and stability requirements for the Space Telescope are more stringent than for any previous satellite developed and are considered to be one of the most critical technological areas in the Project. NASA and its contractors have determined that uncertainties and design difficulties associated with gravity release, vibrations during launch, and thermal conditions may result in primary and secondary mirror misalinement between launch and on-orbit operations. Such changes could cause image blur and have a significantly adverse impact on fine pointing. The result would be a degradation of scientific data.

The pointing and stability requirements received special emphasis during the definition effort. NASA informed us that:

> "* * *full-scale structural dynamic models and bread-boards were built and tested. This activity verified engineering definition of the pointing control system which is capable of meeting the Space Telescope requirements. * * *"

The Space Telescope presents a unique challenge to the structural designer, however, because of the extreme

thermal and dynamic stability required in a large, lightweight space structure. Some of the earliest studies of the Telescope system recognized that the temperature extremes of space orbit posed difficult thermal stability problems for the main Telescope metering structure and the focal plane instrument support structure.

Because of the critical requirement for dimensional stability of the Space Telescope's metering structure, one of the definition contractors investigated graphite-epoxy to determine its long-term dimensional stability, outgassing properties, 1/ and manufacturability. Graphite-epoxy has a greater stiffness and a lower coefficient of expansion than conventional materials. Tests of a 3-meter truss and a 1-1/2 meter shell proved that graphite-epoxy was a feasible structural material for the Telescope's optical structures and, according to NASA, will satisfy the stringent stability requirements.

CONTROL OF CONTAMINATION EFFECTS

NASA and its definition contractors have determined that the Space Telescope will be very susceptible to contamination because of its physical size, expected long life, and sensitivity requirements. Evaluations of this problem during the definition phase have shown that contaminants such as dust, soil, lint, gases, and vapors could degrade optical and thermal system performance and thereby reduce the quality of scientific data obtained.

Because of the potential degradation that could result from contamination, NASA requested the definition contractors to prepare plans to control the problem of contamination. These plans would require that all materials used in the Space Telescope be manufactured so as to minimize the generation of particulate and gaseous contaminants. All support system module mechanisms, potential producers of particulate contaminants, must be designed to prevent contaminant dispersion into other areas of the Telescope. In addition, NASA plans to inspect for contamination prior to integration of the Telescope's components. The inspection will use techniques established by the optical telescope assembly/scientific instruments contractor and will determine whether the optical telescope assembly/scientific instruments are within an acceptable cleanliness level. MSFC officials believe that the proposed measures being

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1/The ability of a material to evaporate minute portions of its substance in the form of gas molecules.

taken will satisfactorily resolve the potential contamination problem. However, they said the effectiveness of the contamination control system and processing plans would not be fully known until the Telescope becomes operational. According to NASA, those procedures and practices have been effective on past astronomy missions.

DEVELOPMENT OF ADEQUATE THERMAL CONTROLS

In addition to the temperature extremes found in a space environment, the Space Telescope's scientific instruments will generate heat. These temperature variations, unless controlled, could result in a reduction in the quality of scientific data obtained.

The definition contractors evaluated means of dealing with the heat generated by the scientific instruments. One contractor estimated that 700 to 800 watts of heat must be rejected from the scientific instrument assembly to prevent instrument degradation. Although MSFC and its definition contractors believe that the thermal control sub-system defined for the Space Telescope will reject the required amount of heat, there is some concern about the amount of heat the scientific instruments will actually generate. NASA said, "Extensive thermal model analyses conducted during the past year, however, have uncovered no critical problems in this area."

TESTING LIMITATIONS

In past spacecraft programs, a significant portion of program cost has been spent on assuring that the initial flight unit would work as planned because there was no way to recover the unit for repairs or modifications. Assurances, therefore, had to be obtained by extensive ground testing involving such costly items as facilities, large numbers of people, extensive development of test procedures, and considerable test analyses and evaluations. In addition, prior spacecraft programs generally have provided for testing a system at each successive step of its assembly to insure the attainment of full performance.

NASA and its contractors have determined, however, that a conventional test program for the Space Telescope would be extremely difficult and costly and may not yield the desired data because of (1) the Telescope's unique, high precision requirements and (2) the effects of the earth's environment such as vibration, atmosphere, and gravity. Furthermore, it may be impossible to test the Telescope to its full image quality, and very expensive test facilities would be required to even approach this goal.

NASA presently plans, therefore, to test and calibrate the Space Telescope at the highest practical assembly level. The total system, therefore, will not be ground tested to make sure that it will perform as expected. Mathematical models and simulations will be used in lieu of much of the normal developmental testing. MSFC officials consider the performance risk associated with reduced testing to be acceptable.

The Space Telescope would be thoroughly checked out after launch under space environment conditions which can never be perfectly simulated on the ground. From an analysis of both engineering and scientific data, a determination will be made as to whether the Telescope requires modifications. If so, these modifications would be accomplished by a space shuttle visit.

MATTER FOR THE ATTENTION OF THE CONGRESS

The Congress, in reviewing the Space Telescope's progress, should obtain from NASA periodic reports on the status of known technical uncertainties and their effect on fulfilling the Telescope's scientific objectives.

CHAPTER 4

OPERATIONAL PHASE

The Space Telescope is being developed and produced to provide a long-term national and international space-based scientific astronomical facility. NASA presently plans to operate the Telescope for 10 to 15 years. After a brief period of on-orbit checkout of the scientific instruments and supporting systems, the Telescope will be fully committed to the task of gathering scientific data.

NASA has conducted several studies to determine the required ground-based activities associated with using the Space Telescope's data-gathering capabilities to satisfy the needs of the astronomy community. On the basis of these studies, NASA plans to manage and utilize the Telescope by establishing an operation control center and a separate science institute. The duties and responsibilities of each are discussed below.

OPERATION CONTROL CENTER

A center will be established to support the Space Telescope's total mission activities from launch to retrieval for refurbishment. It will be responsible for monitoring and controlling the Telescope's orbital operations to insure its readiness throughout its mission. The center also will implement science pointing and command requirements. Its functions will include mission planning, scheduling and conducting sub-system tests, monitoring status and engineering data, spacecraft command and control, routine and emergency analysis of the Telescope's operations, specification and updating of all spacecraft operational constraints, and initiation and control of spacecraft emergency procedures.

The operation control center is to be located at and supported by Goddard. Except for certain computer hardware and software, NASA plans to use existing facilities for the operation control center.

NASA's Office of Tracking and Data Acquisition (see p. 4) will provide mission and data operations support to the Project. The Space Telescope will utilize the Tracking and Data Relay Satellite System as its primary communication link with the ground.

Science institute personnel are to be located at the operation control center to assist in evaluating the engineering status of the scientific instruments. Institute support will include science planning inputs to the mission

planning effort, consultation required to interpret science viewing requirements, support of scientific instrument command gereration, and support of the Space Telescope's performance evaluations.

SCIENCE INSTITUTE

NASA plans to establish a science institute to exercise responsibility for the Space Telescope's scientific operations. This responsibility primarily concerns planning and implementing scientific observation programs for principal and guest investigators, who will be the primary users of the Telescope. Scientific operations will include long-range planning, scheduling, and development and maintenance of the Telescope's software; principal and guest investigator support; daily planning, real time science operations, and quick look data evaluations; and science data management.

In commenting on the subject of a science institute, NASA stated:

> "In order to provide the long-term guidance and support for the scientific effort, to provide a mechanism for engaging the participation of astronomers throughout the world, and to provide a means for the dissemination and utilization of the data derived from the Space Telescope, NASA is considering the establishment of a science institute as the science operations element. Such an institute would include a staff of scientists and might be operated by a consortium of universities under contract to NASA. A final decision has not been made on whether or not an institute (versus an in-house NASA science operation) will be established or on what the specific character, extent of responsibilities, or location of an institute would be, if established."

In May 1976 NASA contracted with the Space Science Board to study the alternative methods of managing the Space Telescope's science operations. The study was completed in December 1976. NASA stated:

> "* * *NASA is now considering the results of this study along with the results of earlier in-house studies and the inputs of various advisory groups in developing specific plans for the establishment of the science operations element for the Project."

OTHER MATTERS

A Space Science Board official told us that data management is one of the largest problems in space science projects. Therefore, the December 1976 study performed by the Space Science Board addressed the subject of data storage, organization, and dissemination. It recommended the establishment of a science institute to provide a means for the dissemination and utilization of the data derived from the Space Telescope.

The subject of data management was also addressed in a recent study by the Space Program Advisory Council's Physical Sciences Committee. The study concluded that a more farsighted approach to the management of data analysis is needed. The committee urged that adequate provisions for data analysis be made in connection with planning for a mission.

Since the Space Telescope is to operate for 10 to 15 years, it no doubt will generate vast amounts of scientific data. NASA should give special consideration to the problems associated with managing this data as it formulates plans for the operational phase of the Project.

The Physical Sciences Committee's study also pointed out that NASA has supported the construction and operation of ground-based telescopes used extensively for planetary observations. However, the study notes that NASA did not provide funds to purchase advanced instruments for these telescopes, thus diminishing their research capability. The lack of funds for specialized instrumentation means that the investments already made are not being effectively used. The study pointed out that rapidly escalating costs are preventing the development and application of the modern specialized instrumentation needed for planetary observations.

If the Space Telescope is to serve as a useful research tool, it will likely require updated scientific instrumentation from time to time. Since the Telescope is to be a long-life project, NASA should plan to provide the funding necessary to assure maximum benefits from the Project.

NASA COMMENTS AND OUR EVALUATION

In commenting on our report, NASA stated:

"The report comments on the need to carefully plan and manage data from the Space Telescope Project and instrumentation to be used with the Space Telescope. It is clear that the amount of data

possible with the Space Shuttle will require careful planning and innovative management. The report prepared by the Space Science Board at NASA'S request is expected to be of major assistance in data planning for the Project. The Physical Sciences Committee report referred to by GAO was based on experience with past free-flying spacecraft with finite mission life designs. Funding for data analysis for missions exceeding their expected lifetimes has often been a problem, although funding data analysis from extended missions is most cost-effective. The Physical Sciences Committee report did not address the issue of handling data from such major facilities as the Space Telescope. NASA intends to review all pertinent experience and obtain assistance from all relevant sources in preparing to handle space Telescope data. Similarly, NASA is developing plans for the continued updating of detectors and other instrumentation for use with an operational Space Telescope. Supporting Research and Technology funds are being spent in several areas of developing instrumentation which will benefit the Space Telescope and other projects.

The results of NASA's planning for data analysis and future instrumentation for the Space Telescope Project will be discussed with the Congress and will be presented in future NASA budgets."

We agree with NASA's position on planning for data analysis and future instrumentation for the Space Telescope. If properly considered and implemented, these matters should contribute heavily to the success of the Project.

MATTER FOR THE ATTENTION OF THE CONGRESS

The Congress should obtain NASA's plans for providing adequate funds in the operational phase for data management and development of advanced scientific instruments.

APPENDIX I

National Aeronautics and
Space Administration

Washington, D C
20546

18 FEB 1977

Reply to Attn of W

Mr. R. W. Gutmann
Director
Procurement and Systems
Acquisition Division
U.S. General Accounting Office
Washington, DC 20548

Dear Mr. Gutmann:

Thank you for the opportunity to comment on GAO's draft report entitled, "Status And Issues Pertaining To The Proposed Development Of The Space Telescope," Code 952141, which was prepared at the request of the Chairman, Subcommittee on HUD-Independent Agencies, Senate Committee on Appropriations.

The enclosed comments are keyed to the respective parts of the draft report to which they pertain.

Sincerely,

John M. Coulter
Acting Assistant Administrator for
DoD and Interagency Affairs

Enclosure

GAO note: Page numbers in enclosure refer to a preliminary draft of this report.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

COMMENTS ON

DRAFT OF REPORT TO THE CONGRESS OF THE UNITED STATES

STATUS AND ISSUES PERTAINING
TO THE PROPOSED DEVELOPMENT
OF THE SPACE TELESCOPE
(CODE 952141)

NASA has completed its review of the GAO report and has concluded that, although the report is generally supportive of the Space Telescope Project, several aspects require major revision to insure accurate representation of the current status of the Space Telescope Project. It is unfortunate that NASA was unable to meet with the GAO, as planned, to work with them on clarification of the issues raised by the report. In the absence of such a meeting, these comments serve to document NASA's position with respect to those items which are improperly represented. Our major objections are as follows:

1) It is NASA's position that the GAO approach to life-cycle cost-estimating for the Space Telescope is inappropriate.

The GAO initiates its report with a statement on the front cover that the Space Telescope could cost as much as $1.4 billion on a life-cycle basis covering 23 years. This statement, based upon GAO's interpretation of life-cycle elements and assumptions with regard to those elements, is clearly inaccurate. The cost elements selected do not logically or clearly follow from the decision to develop the Space Telescope. Further, the GAO appears to rationalize its position on life-cycle costing by citing the requirements of OMB Circular A-109. In fact, the Space Telescope Project has been submitted for initiation in the President's FY 1978 budget, and it is our understanding that the NASA resources analyses in support of the Space Telescope Project are consistent with the provisions of A-109, as applied by the OMB in the budget review process.

The GAO estimate that the development and operational costs of the Space Telescope Project could total $1.4 billion is based on incomplete program definition and erroneous costing and could result in providing misinformation to the Congress about the budget implications of the new project start presented in the FY 1978 budget. The GAO estimate confuses official NASA estimates with preliminary field center estimates and GAO estimates that are clearly in error. Presenting this eclectic array of cost data as a life-cycle cost estimate for the Space Telescope Project is misleading because the development of the Space Telescope does not require a commitment to the program scope postulated by the life-cycle values cited in the GAO report.

NASA has provided firm Agency planning estimates for the development of the Space Telescope of $435 - $470 million, in dollars of the FY 1978 budget. In addition, NASA has estimated the base cost of recurring mission and science operations at a level of $10 - $15 million dollars per year. This funding will provide for the six-year development and, together with a single shuttle launch, would support three to five years of orbital operations through 1986-1988. Following that period, there are additional potential costs that could be incurred for new instruments, on-orbit maintenance, retrieval, and refurbishment. The NASA approach would be to provide estimates for these costs when the technical characteristics and performance requirements of the new hardware and operating mode have attained adequate definition to provide realistic option estimates.

The NASA position is that official Agency project estimates should be based on a consistent costing base which reflects the economic impact of the project on the NASA budget. In addition, the NASA position is that meaningful, long-term costing requires a realistic definition of technical configuration and operating plans. The GAO estimate for the life-cycle cost of the Space Telescope represents a very preliminary effort in this direction and is based on only one set of assumptions on the possible modes of operation for the Space Telescope. In addition, the estimate is flawed because the GAO has included the full cost of nine Shuttle flights in the cost charged to the

Space Telescope. This approach is clearly unrealistic since each Shuttle flight for launch or return of the Space Telescope would utilize the cargo bay in one direction only, and the on-orbit maintenance flights would require only small payload volume in either direction.

2) It is NASA's position that, if this report is intended to inform the Congress of the current status of the Space Telescope Project, the sections addressing International Participation and Technical Development Uncertainties must be updated.

With regard to international participation in the Space Telescope, the GAO report stresses in several places that "no formal commitments have been made." While this statement is technically true, negotiations in this area have reached a much more advanced stage than implied in the GAO document. On October 5, 1976, the ESA Science Planning Council approved ESA contributions to the Space Telescope Program equivalent to 80 million accounting units. The NASA/ESA Memorandum of Understanding (MOU) covering this participation is currently in an advanced state of negotiation.

On the subject of technical development uncertainties, the GAO report correctly points out that during the definition phase, several technical uncertainties were identified that could degrade performance unless satisfactorily resolved. What the report fails to make clear is that the lengthy definition period allowed meaningful technology efforts to be carried out which have virtually eliminated these areas from significant concern. Our detailed comments, which follow, provide the current status of technical development.

3) It is NASA's position that the GAO discussion of a Space Telescope science institute is misleading and is inappropriate.

The GAO report implies that a decision has been made by NASA to implement a Space Telescope science institute and describes the institute by paraphrasing an early report put together by an internal NASA science institute study team. This report is just one of a number of inputs obtained by

NASA in this area. NASA has not yet determined the implementation mode for Space Telescope science operations. In-house studies are being initiated which will lead to a final decision on the nature of the science operational element, its location, mode of operation, etc.

4) It is NASA's position that GAO comments on NASA's performance with respect to provision of advanced instrumentation for existing telescopes are ill-advised.

On page v and again on page 34, the GAO report comments to the effect that NASA did not provide funds for purchase of advanced instruments for certain ground-based telescopes. The GAC should be aware that the primary sources of funding for the operation of the telescopes, which are the subject of the cited PSC report, are the universities managing the particular observatories. NASA and NSF contribute funds only in conjunction with research activities in support of specific investigations. In advocating that NASA provide additional funding for these instruments, the GAO has involved itself in an advocacy role in the budget decision process. An initiated reader would have perceived that the issue is not the provision of funding, but the funding levels, i.e., the report marshals arguments to justify higher levels of federal support to this important research. The point is that, under constrained budget conditions, the activity is obtaining less funding than the managers of these telescopes feel is merited. This is not a unique position among those who conduct federally-sponsored research.

NASA's minimum recommended changes/corrections to the report, consistent with the positions outlined above, are as follows:

LIFE CYCLE COSTS

Page i, Digest, 2nd sentence

REPLACE WITH THE FOLLOWING: Development, test, integration, launch, and initial checkout costs are estimated to be $435 - $470 million. NASA has not prepared firm estimates for operational costs, but preliminary assessments indicate

that approximately $10 - $15 million will be required annually for mission and science operations. This estimate excludes costs for those elements which are subject to future decision, such as the role of a science institute, the type and scheduling of telescope refurbishment, the degree of on-orbit maintenance, and scheduling of retrieval and refurbishment.

Page i, Digest, 3rd sentence

DELETE STATEMENT ABOUT "life cycle cost estimate."

Page ii, 1st full paragraph

BEGIN THE PARAGRAPH WITH THE FOLLOWING SENTENCE: NASA's estimate for the development of the Space Telescope is essentially the same as that provided to the OMB last year, for consideration of the Space Telescope as a FY 1977 New Start.

Page ii, 2nd full paragraph

DELETE

Page 8, 2nd paragraph

BEGIN "ESTIMATED COST" SECTION WITH THE FOLLOWING: NASA's estimate of $435 - $470 million for the development of the Space Telescope is essentially the same as the estimate provided to the OMB last year, when the Space Telescope was being considered for a FY 1977 New Start. The primary difference between the two estimates is allowance for inflation between FY 1977 and FY 1978. Preliminary planning estimates leading to the above-mentioned estimates submitted by NASA have varied from MSFC's initial estimate.

Page 8, table of estimates

THE HEADING SHOULD BE "MSFC Telescope Development Cost Estimates."

Pages 8-9

DELETE SENTENCES AT THE BOTTOM OF THE PAGE (COMPLETED ON PAGE 9) BEGINNING WITH "GAO expects ..." THROUGH "... is shown on page 13." (CONSISTENT WITH COMMENTS ON PAGES 11-14, WHICH FOLLOW)

Pages 11-14

This section of the report should be substantially rewritten, because the GAO approach reflected here is inappropriate and could misinform the Congress. The NASA position on life-cycle costs for the Space Telescope has been discussed in earlier comments. Specific corrections to items in this section are as follows:

Page 11, 3rd paragraph, 3rd sentence

REPLACE WITH THE FOLLOWING: In the case of the Space Telescope, these related costs are $12 million for tracking and data acquisition and $21.5 million for the fourth quarter 1983 Shuttle launch.

Page 12, 1st full paragraph

DELETE

Page 12, last paragraph

REPLACE WITH THE FOLLOWING: NASA has not prepared a life-cycle cost estimate, but preliminary assessments indicate that approximately $10 - $15 million will be required annually for mission and science operations. This estimate excludes costs for those elements which are variable and subject to future decisions, such as the role of a science institute, the type and scheduling of instrument refurbishment, and the degree of on-orbit maintenance, or retrieval and refurbishment.

Pages 13-14

DELETE TABLE OF "IDENTIFIED SPACE TELESCOPE COST ELEMENTS" AND FOLLOWING PARAGRAPHS (THROUGH "...cost of the additional fuel" ON PAGE 14).

Page 20, 1st paragraph

DELETE

Page 21

DELETE FIRST RECOMMENDATION

INTERNATIONAL PARTICIPATION

Page iii, 2nd full paragraph

REPLACE WITH THE FOLLOWING: Interest by the European Space Agency (ESA) in the Space Telescope Project has led to a proposal from that Agency to participate in the Project. While a formal NASA/ESA Memorandum of Understanding (MOU) covering the ESA participation has not been signed, such a document is in the final stages of negotiation. Accordingly, the ESA Science Planning Council, on October 5, 1976, unanimously approved the commitment of ESA contributions to the Space Telescope Project equivalent to 80 million accounting units contingent upon U.S. approval of the Project. Under this arrangement, ESA will: 1) provide a Faint Object Camera (a scientific instrument), including the associated detector; 2) provide the solar array for the Telescope's electrical power subsystem; 3) provide a number of personnel for the science operations staff; and, 4) assist in the on-orbit maintenance and major refurbishment of the Telescope.

Page 6, 1st paragraph (partial), last sentence

INSERT AFTER "commitments": "... at that time ..."

Page 17, last paragraph

AFTER FIRST SENTENCE, REPLACE REST OF PARAGRAPH WITH THE FOLLOWING: Interest by ESA led to a proposal to participate in the Project through possible provision of scientific instruments and subsystems for the Space Telescope and assistance in the operation of the Space Telescope and related facilities and in the on-orbit maintenance, major refurbishments, and re-flights.

Page 18, 1st full paragraph

REPLACE FIRST PORTION OF FIRST SENTENCE WITH THE FOLLOWING: "Under the terms of the current draft MOU, ESA will be allocated observing time..."

MOVE THE ENTIRE PARAGRAPH TO END OF SECTION ON "INTERNATIONAL PARTICIPATION."

Page 19, 2nd full paragraph

REPLACE WITH THE FOLLOWING: While a formal NASA/ESA MOU covering the ESA participation has not been signed, such a document is in the final stages of negotiation, Accordingly, the ESA Science Planning Council, on October 5, 1976, unamimously approved the commitment of ESA contributions to the Space Telescope Project equivalent to 80 million accounting units, contingent upon U.S. approval of the Project. Under this arrangement, ESA will: 1) provide a Faint Object Camera (a scientific instrument), including the associated detector; 2) provide the solar array for the Telescope's electrical power subsystem; 3) provide a number of personnel for the science operations staff; and, 4) assist in the on-orbit maintenance and major refurbishments of the Telescope.

TECHNICAL DEVELOPMENT UNCERTAINTIES

Page i, Digest, 3rd sentence

DELETE STATEMENT ABOUT "periodic reports on the status of known technical uncertainties..."

Page iv, 1st paragraph

IN THE FOURTH LINE, REPLACE "include" WITH "included."

REPLACE THE LAST SENTENCE WITH THE FOLLOWING: As a result of technology efforts in these areas, which have been completed during the definition phase of the Project, NASA believes that there are no major technical problems remaining in the development path of the Space Telescope.

Page 23, 1st full paragraph, last sentence

REPLACE "... very stringent tolerances." WITH "... $\lambda/65$ wave front error which exceeds the Space Telescope requirement of $\lambda/50$."

Page 23, last paragraph, 1st sentence

SHOULD READ "Some Marshall officials agree with the concern that the currently available detectors are not capable of fully utilizing the inherent capability of the Space Telescope.

Page 24, 1st line

BEFORE "MSFC officials told us..." INSERT THE FOLLOWING: Breadboards of several types of detectors which will satisfy Space Telescope requirements are being developed and tested on ground-based telescopes as part of this effort. This testing is planned to be completed prior to selection of the instruments by NASA. A number of the concepts are now reaching a sufficient stage of development to give reasonable confidence that they will be available.

Page 24, 2nd full paragraph

ADD THE FOLLOWING TO THE END OF PARAGRAPH: In addition, full-scale structural dynamic models and breadboards were built and tested. This activity verified engineering definition of the pointing control system which is capable of meeting the Space Telescope requirements. For example, two versions of the fine guidance breadboard demonstrated a sensitivity of .002 arc seconds which exceeds the requirement of .003 arc seconds. Also, an integrated pointing control breadboard demonstrated the .005 arc-second requirement for that portion of the system.

Page 25, 1st full paragraph, last sentence

REPLACE "... assist in meeting the ..." WITH "... satisfy the ..."

APPENDIX I

Page 25, 1st full paragraph

ADD THE FOLLOWING TO THE END OF PARAGRAPH: The three-meter metering structure demonstrated a secondary mirror movement of ± 1.2μm under simulated thermal environment, which is better than the ± 2μm requirement for the Telescope.

Page 26, 1st full paragraph

ADD THE FOLLOWING TO THE END OF PARAGRAPH: These procedures and practices have been effective on past NASA astronomy missions.

Page 27, 1st full paragraph, last sentence

REPLACE WITH THE FOLLOWING: Extensive thermal model analyses conducted during the past year, however, have uncovered nc critical problems in this areas.

Page 28, 1st paragraph, 1st sentence

REPLACE THE FIRST PORTION WITH THE FOLLOWING: NASA and its contractors have determined, however, that a test of the total integrated Space Telescope would be extremely difficult and costly and may not yield the desired data because ..."

Page 29

DELETE ENTIRE STATEMENT

SCIENCE INSTITUTE

Page iv, 2nd paragraph

REPLACE FIRST SENTENCE WITH THE FOLLOWING: NASA plans to establish, separately, an operations control center and a science operations element to manage the Telescope after it becomes operational.

IN SECOND SENTENCE, REPLACE "science institute" WITH "science operations element."

Page iv, 2nd paragraph, 3rd sentence

REPLACE "operations" WITH "science operations as they would impact the characteristics of the science operations element."

Page 2, 1st paragraph, last sentence

REPLACE "operations" WITH "operational verification."

Page 7, 2nd full paragraph

IN FIRST SENTENCE, REPLACE "... NASA plans to establish a Space Telescope Science Institute." WITH "... NASA is considering establishment of a Space Telescope science institute as the science operations element of the Project."

REPLACE SECOND SENTENCE WITH THE FOLLOWING: Such an institute would include a staff of scientists and might be operated by a consortium of universities under contract to NASA.

Page 30, 2nd paragraph, 2nd sentence

REPLACE "institute" WITH "operations element."

Page 31, 3rd full paragraph

IN FIRST SENTENCE, REPLACE "Science institute personnel..." WITH "Personnel from the separately established science operations element..."

IN SECOND SENTENCE, REPLACE "Institute support..." WITH "Support from the science operations element..."

Page 31, last paragraph, 1st sentence

REPLACE "science institute" WITH "separate science operations element" AND DELETE "full."

Page 32, 1st full paragraph

DELETE

Page 32, 2nd full paragraph

DELETE

APPENDIX I

Page 32, last paragraph

DELETE

Page 33, 1st paragraph

REPLACE WITH THE FOLLOWING: In order to provide the long-term guidance and support for the scientific effort, to provide a mechanism for engaging the participation of astronomers throughout the world, and to provide a means for the dissemination and utilization of the data derived from the Space Telescope, NASA is considering the establishment of a science institute as the science operations element. Such an institute would include a staff of scientists and might be operated by a consortium of universities under contract to NASA. A final decision has not been made on whether or not an institute (versus an in-house NASA science operation) will be established or on what the specific character, extent of responsibilities, or location of an institute would be, if established.

Page 33, 2nd paragraph

IN FIRST SENTENCE, REPLACE "operations" WITH "science operations."

REPLACE SECOND SENTENCE WITH THE FOLLOWING: The results of this study were reported to NASA in December 1976. NASA is now considering the results of this study along with the results of earlier in-house studies and the inputs of various advisory groups in developing specific plans for the establishment of the science operations element for the Project.

PROVISION OF ADVANCED INSTRUMENTATION

Page v, 2nd paragraph

DELETE

Page 34, 3rd paragraph

DELETE

APPENDIX I

ADDITIONAL CHANGES AND COMMENTS

Page ii, 1st paragraph, 1st sentence

REPLACE WITH THE FOLLOWING: Through September 30, 1976, $14 million had been appropriated for early definition and advanced technology development of the Space Telescope.

Page iii, last paragraph

COMMENT:

There has been no indication from Congressional sources of need for reports on additional projects. Unless there is a special need, which we have not discerned, we proposed that no additional projects be included in this extra compilation process.

Page iv, 3rd paragraph, 1st sentence

REPLACE WITH THE FOLLOWING: A Physical Sciences Committee report on supporting research and technology and data research indicates that data management has been a problem on past space science projects.

Page 2, 1st paragraph, last sentence

REPLACE LAST PORTION WITH "... and procedures needed to test, handle, and launch the Telescope, and to support on-orbit operations.

Page 6, 1st full paragraph, 2nd sentence

REPLACE WITH THE FOLLOWING: Through September 30, 1976, $14 million had been appropriated for early definition and advanced technology development of the Space Telescope.

Page 8, 1st paragraph, 1st sentence

REPLACE "... is in ..." WITH "... has completed ..."

Page 14, last paragraph (Schedule)

COMMENT:

The point of the GAO discussion regarding schedule is not obvious. The launch dates cited are center schedules developed with different assumptions of project start dates and project design. While these schedules were valid at one point in time with certain assumptions, comparing such schedules serves no purpose. The launch dates endorsed by NASA are those dates used in testimony or backup to the OMB and/or the Congress. In discussion of the FY 1977 budget with OMB, NASA stated the Space Telescope was planned "to be launched by the Shuttle in 1983." The Project was not included in the President's budget in FY 1977. In the material provided to the Congress in justification of the FY 1978 budget, launch of the Space Telescope is proposed for the "last quarter of 1983." This represents a slip of less than a full year even though the initiation of the Project was delayed one year.

Page 15, 1st full paragraph,

REPLACE "September 1977" WITH "October 1977" IN BOTH PLACES.

Page 16 (in the table)

UNDER "Electrical power" (Present), REPLACE "1,500" WITH "2,100."

UNDER "Approximate weight" (Present), REPLACE "19,600" WITH "23,000."

Page 16, 1st full paragraph, 3rd sentence

REPLACE "... 9.8 feet in diameter ..." WITH "... 14 feet in diameter ..."

REPLACE "... 19,600 pounds." WITH "... 23,000 pounds."

Page 33, 3rd paragraph

NASA feels that it is inappropriate to include an unqualified statement attributed to an unnamed individual. THE FIRST SENTENCE SHOULD BE DELETED, AND THE SECOND SENTENCE SHOULD BEGIN WITH "The study being ..."

Page 34, 1st paragraph, 1st sentence

DELETE "also."

Pages 33-35 (Other Matters)

COMMENT:

The report comments on the need to carefully plan and manage data from the Space Telescope Project and instrumentation to be used with the Space Telescope. It is clear that the amount of data possible with the Space Shuttle will require careful planning and innovative management. The report prepared by the Space Science Board at NASA's request is expected to be of major assistance in data planning for the Project. The Physical Sciences Committee report referred to by GAO was based on experience with past free-flying spacecraft with finite mission life designs. Funding for data analysis for missions exceeding their expected lifetimes has often been a problem, although funding data analysis from extended missions is most cost-effective. The Physical Sciences Committee report did not address the issue of handling data from such major facilities as the Space Telescope. NASA intends to review all pertinent experience and obtain assistance from all relevant sources in preparing to handle Space Telescope data. Similarly, NASA is developing plans for the continued updating of detectors and other instrumentation for use with an operational Space Telescope. Supporting Research and Technology funds are being spent in several areas of developing instrumentation which will benefit the Space Telescope and other projects.

The results of NASA's planning for data analysis and future instrumentation for the Space Telescope Project will be discussed with the Congress and will be presented in future NASA budgets.

J. B. Hinners

for Noel W. Hinners
Associate Administrator
for Space Science

Date: Feb 18, 1977

APPENDIX II

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

MAR 10 1977

Mr. Richard W. Gutmann
Director
Procurement and Systems
Acquisition Division
U. S. General Accounting Office
Washington, D. C. 20548

Dear Mr. Gutmann:

We appreciate the opportunity to review and provide comments on your staff's draft report on the NASA proposed Space Telescope project which was forwarded with your letter of January 18, 1977. In your letter you requested our comments on those portions of the report that make reference to OMB's involvement in the formulation of the NASA budget which resulted in the Space Telescope being deferred in the FY 1977 budget for future consideration; and on OMB Circular No. A-109 which provides general guidance to Federal agencies that engage in the acquisition of major hardware systems. In this letter we address these specific items; however, with regard to the many other substantive matters raised in the report (particularly the discussion of technical development uncertainties and technical aspects of operations), we defer comments to NASA.

We are interested in and have reviewed many of the matters raised by your staff related to the total costs of the Space Telescope, the technical hurdles which need to be overcome, the need to begin to define the project's operational phase, and means for keeping OMB and the Congress informed about the status of the project. You can be assured that we will continue to review and assess the progress and costs of this major scientific undertaking. OMB has specifically requested NASA to seek maximum international cost-sharing in the Space Telescope project and to keep us currently informed of the agency's progress in encouraging international participation.

With regard to deferring the Space Telescope in the 1977 budget, the draft report is correct in stating that the project was deferred because of budgetary constraints. However, the Space Telescope is included in the FY 1978 budget to the Congress. We believe that the Space Telescope has significant potential for enhancing fundamental scientific knowledge about the universe and represents an appropriate investment in the nation's basic scientific research effort.

With respect to the second point related to OMB Circular A-109, the reference in the draft report about this circular is correct. We believe that NASA has attempted to be responsive to the spirit of this circular in developing the Space Telescope proposal and that NASA has the capability to provide additional cost information to the Congress, if desired. With respect to the early phase of project planning for the Space Telescope, we would note that alternative sizes and technical designs for the telescope were developed and evaluated by NASA, and its contractors and advisory groups. Cost estimates were developed for each technical alternative evaluated. With regard to future operating costs, NASA has developed tentative projections based on assumptions about how the Space Telescope will be operated; at the present time, however, there is necessarily some uncertainty about the best operational arrangements for the Space Telescope, including the extent of international cost participation which can be obtained. We expect to work with NASA and the agency's scientific advisory groups to explore the options available for future Space Telescope operations.

Again we appreciate very much having this opportunity to comment on the GAO draft report. When completed, the report should be useful in helping to bring into focus significant issues related to the development and future operation of the Space Telescope.

Sincerely yours,

James T. McIntyre, Jr.

APPENDIX III

PRINCIPAL OFFICIALS OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION RESPONSIBLE FOR ACTIVITIES DISCUSSED IN THIS REPORT

	Tenure of office	
	From	To
ADMINISTRATOR:		
James C. Fletcher	Apr. 1971	Present
George M. Low (acting)	Sept. 1970	Apr. 1971
DEPUTY ADMINISTRATOR:		
Alan M. Lovelace	June 1976	Present
George M. Low	Dec. 1969	June 1976
ASSOCIATE ADMINISTRATOR FOR OFFICE OF SPACE SCIENCE:		
Noel W. Hinners	June 1974	Present
John E. Naugle (acting)	Mar. 1974	June 1974
John E. Naugle	Dec. 1971	Mar. 1974
DIRECTOR, GODDARD SPACE FLIGHT CENTER:		
Dr. Robert S. Cooper	July 1976	Present
Dr. John F. Clark	May 1966	June 1976
DIRECTOR, MARSHALL SPACE FLIGHT CENTER:		
William R. Lucas	June 1974	Present
R. A. Petrone	Jan. 1973	June 1974
Eberhard F.M. Rees	Mar. 1970	Jan. 1973