U. S. GENERAL ACCOUNTING OFFICE

STAFF STUDY

# SPACE TRANSPORTATION SYSTEM

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FEBRUARY 1975

# C O N T E N T S

## ABBREVIATIONS

| | |
|---|---|
| DDT&E | Design, Development, Test & Evaluation |
| DOD | Department of Defense |
| ESRO | European Space Research Organization |
| GAO | General Accounting Office |
| MSFC | George C. Marshall Space Flight Center |
| NASA | National Aeronautics and Space Administration |
| OMB | Office of Management and Budget |
| SAMSO | Space and Missile Systems Organization |
| SRB | Solid Rocket Booster |
| STS | Space Transportation System |
| USAF | United States Air Force |

## SUMMARY

This is the second staff study of the Space Transportation System (STS) under development by the National Aeronautics and Space Administration (NASA) The study updates the program's status through September 1974 This study also covers Spacelab status information

The space shuttle and the space tug are the two major components of the STS Additionally, the Spacelab, being developed under a cooperative program with European countries, is a reusable shuttle payload designed to support a large number of scientific experiments. The space shuttle will consist of a manned reusable orbiter, which looks like a delta-winged airplane, an expendable, liquid propellant tank, and two reusable solid rocket boosters.

The space tug is an upper stage that places payloads in higher orbits than those achievable by the orbiter alone During the 1980-83 period, an interim tug known as the interim upper stage will be used but will have limited capabilities.

## RESPONSIBILITIES

While the overall program direction is the responsibility of the Program Director in Washington, day-to-day management of the shuttle and tug program has been delegated to the Johnson Space Center and Marshall Space Flight Center, respectively. Separate space shuttle project managers have been designated for the orbiter, solid rocket booster, space shuttle main engines, external tank and launch and landing systems. These managers report to the Space Shuttle Program Manager at the Johnson Space Center on program management matters. The United States Air Force is responsible for assuring that Department of Defense (DOD) interests in the STS are considered and for making provisions for the DOD STS program.

ESTIMATED COST OF THE SPACE
TRANSPORTATION SYSTEM

NASA has not developed a cost estimate for the total cost of the development and operation of the STS but has established baseline cost estimates for four STS elements. These estimates in 1971 dollars are (1) $5.15 billion for space shuttle design, development, test and evaluation (DDT&E) (2) $300 million for NASA's space shuttle facilities, (3) $ 1 billion for production of 3 orbiters and refurbishment of two development orbiters, and (4) an average cost per flight of $10 45 million in 1971 dollars

When the present shuttle configuration was approved in March 1972, NASA presented to the Congress the results of an analysis of the development and operations of the STS from 1972 through 1990 based on a mission model of 581[1/] flights The purpose of the analysis was to compare the economics of the projected space effort for NASA, DOD, and others, using the STS and alternate programs of existing and/or new expendable launch systems

The analysis included a $16 1 billion cost estimate, including DOD costs and STS operating costs from 1979 through 1990 Certain costs such as Government institutional costs paid through NASA's Research and Program Management (R&PM) Appropriation and Research and Development (R&D) technology costs were excluded from the economic analysis because they were considered applicable to all competing transportation systems.

1/ NASA has updated its mission model throughout the program. Therefore, matters presented in the staff study involve 439, 581, or 782 flight mission models

NASA advised the Congress that the total in-house costs which could be related or pro-rated to design, development, test, and evaluation of the space shuttle were estimated at about $2.049 billion (1975 dollars) through fiscal year 1981 NASA has characterized the mission model used for the economic analysis as a representative set of candidate space missions rather than an approved program plan Also, the $16.1 billion estimate was in 1971 dollars, therefore it did not consider inflation over the life of the program

NASA officials stated that they have confidence in the estimates for defined program elements identified as baselines, whereas, other estimates are considered preliminary or planning estimates which are likely to change when the final configurations have been established.

STATUS OF SPACE SHUTTLE DEVELOPMENT

NASA's commitment dates to Congress for completion of space shuttle development have been extended 13 to 15 months and cost estimates have been increased by $50 million in 1971 dollars because of budget constraints placed on fiscal years 1973, 1974 and 1975. NASA's position is that $5.2 billion in 1971 dollars will be sufficient to meet its revised commitment dates of June 1979 for the First Manned Orbital Flight and June 1980 for the Initial Operational Capability unless major problems are encountered Including provision for inflation, the $5 2 billion DDT&E cost estimate equates to about $7 billion in expenditure year dollars according to NASA

In our opinion, the risk of encountering cost overruns on the space shuttle development program has been increased. At the time of our review, realistic internal NASA projections of expected run-out costs for individual projects and related reserves were not available because NASA management limits cost estimates to predetermined annual ceilings during their budgeting process. This is partially because of an agreement between NASA and OMB for funding limitations through fiscal year 1977. At the same time, prime contractors were projecting cost increases, some known technical problems were not resolved, and NASA personnel believed inflation was eroding the buying power of the budget. In August 1974, the Space Shuttle Program Manager expressed his concern by stating that, "Overall, we feel that the funding available for Shuttle Projects for fiscal years 1975 through 1977 is very marginal since there are no funds available for growth or change allowances."

Adjustments had been made to delete, defer or reprogram work to align the development program within the predetermined cost ceilings. However, some adjustments increased the risks to overall program cost, schedule, and performance targets. Other adjustments moved funding problems into the future or out of the DDT&E budget into other budgets where potential cost growth will not be readily identifiable. This situation suggested that, if cost overruns are encountered, they will either not be recognized and/or not be identified until the latter stages of the program.

NASA top management was concerned about this situation and in December 1974, after we had completed our field work, NASA concluded an in-depth requirements review designed to realign the program with the mid-year

budget limitations. In the process, a number of work tasks, test articles, and test programs were eliminated, delayed, and/or consolidated to the extent NASA believes feasible. As a result, NASA now believes that it is back on track with adequate reserves for contingencies through the balance of the DDT&E program.

We are still concerned that the budget and schedule goals may be overly optimistic. For example, the adjustments made to realign costs may have further increased the risk of encountering cost growth later in the program. Approximately 40 percent of the adjustments involved the reduction in scope of test articles and programs. In the coming year we plan to review and evaluate the adequacy of the newly revised program costs and schedule goals.

COST PER FLIGHT

NASA's use of $10.45 million in news releases and congressional testimony as cost per flight is misleading and may create confusion outside the agency. Internally, NASA uses cost per flight to evaluate decisions concerning system trade-offs between initial investment and recurring operating costs. It is the average recurring costs for a stated traffic model for operating the space shuttle only. The confusion occurs because the $10.45 million is not the total cost of space shuttle or STS operations. It may not be the cost which will be charged to space shuttle users.

A user charge policy for the space shuttle has not been formulated although NASA currently has this under study. The $10.45 million does not include all costs which would be recovered under NASA's present user charge policy for non-Government users. For example, NASA policy would require a percentage surcharge of NASA overhead and administrative expenses, depreciation expenses on facilities and ground support equipment, and tracking and data acquisitions services. In addition, it does not include provision for inflation or the recurring cost of the tug for the payloads which require its use.

The current user charge policy may not be appropriate for the space shuttle. The STS is being developed to lower space transportation cost for all users. Approximately 50 percent of the projected payloads will be non-NASA payloads of which approximately 12 percent are non-government users. Therefore, NASA will frequently be acting as a transportation agency for space flight. Under these conditions, NASA studies should consider whether a full-cost recovery policy may be appropriate. Information upon which such a decision could be made should be furnished to Congress as soon as possible.

ENVIRONMENTAL EFFECTS

NASA's Environmental Statement for the Space Shuttle, published in July 1972, concluded that the potential environmental effect would be acceptable. This report and other NASA documents identified atmospheric, sonic boom, medical and ecological effects Further, all potential medical and ecological effects have not been quantified and analyzed. Funding constraints have been imposed by NASA on environmental studies, as with other elements of the shuttle program.

NASA officials believe that the proper priority is being given to the environmental issues and there are no indications at this time of unacceptable effects. NASA officials also believe they have adequately fulfilled their legal requirements for public disclosure. These effects, in their opinion, have been adequately examined in various environmental statements which were sent to Federal and State Government agencies for comment and their availability to all persons was announced in the Federal Register However, NASA has not conducted open hearings with the public at affected area sites.

STATUS OF CONSTRUCTION OF FACILITIES

Congress has appropriated $202.5 million for shuttle facilities through fiscal year 1975. As of July 1974, NASA estimated the total cost of its facilities would be about $412 to $429 million in expenditure year dollars. NASA plans to revise this estimate to about $472 million because of higher inflation than anticipated and a recent decision to defer construction of some launch and landing facilities.

We were unable to evaluate NASA's progress in meeting the facility commitment because the type of documentation needed was not available at the time of our review. Subsequent to our review, NASA furnished cost estimates for the facilities.

DOD INVOLVEMENT

STS budget projections for DOD involvement presented to the joint NASA/DOD Space Transportation System Committee, placed the DOD involvement at about $1.5 billion in March 1974. A subsequent DOD estimate placed the amount at $1.9 billion. These estimates included procurement of two orbiters and construction of facilities at the western test range. Some important areas of DOD involvement, however, were not included in the above projection, because they had not been clearly defined and the cost could not be fully estimated.

DOD NEED FOR STS

The DOD is committed to use the space shuttle as its primary launch vehicle after 1980 and believes it will provide economic and other benefits. However, their development program has not progressed to the stage where expected benefits can be substantiated. The Air Force has adopted an approach which can accommodate changes in the NASA STS program and still take advantage of potential benefits from the program. The approach is to minimize the risk to military space programs and yet recognize the need

to transition its existing expendable launch systems to the STS program The Air Force is following this approach because STS is still relatively early in the development cycle The redesign of military satellites is currently limited to configurations which can also be launched with the available expendable vehicles until sufficient STS flight experience is available to warrant complete reliance on the STS system In this regard, all of the currently planned satellites could be launched with present expendable boosters

The potential for reducing space program costs through recovery, reuse, and in-space maintenance of satellites is one of the primary justifications for the STS The Air Force officials advised us that there are no plans to recover or do in-space maintenance on any satellites planned through 1991 However, studies conducted have shown varying benefits to be gained from such operations depending upon the class of satellites studied. Some studies show potential cost benefits of from 20 to 30 percent Other have indicated that modifications required to existing satellites might offset savings Air Force officials also advised us that more study will be required to determine which specific satellite programs can benefit from recovery, reuse, or in-space maintenance

Current Program Status

USAF officials advised us that there is as yet no agreement between DOD and NASA as whether DOD will buy two of the five orbiters The orbiter procurement decision has been deferred by DOD, therefore, the Air Force has been directed not to include funds for this purpose in their budget.

DOD's decision concerning the timing of and purchase of the orbiters could have a major impact on the cost and schedule of the STS program. It could either cause a major program delay or force NASA to either fund the orbiters or delete them.

UPPER STAGES

About 50 percent of the payloads planned through 1991 require orbits beyond the shuttle's low-earth orbit capability To meet this need, a two-phase upper stage development program is planned The first phase is development of a limited capability interim upper stage by the Air Force The second phase consists of development by NASA of a full capability space tug In addition, some payloads will be boosted into higher energy orbits with expendable "kick stages," small propulsive units affixed directly to the payload

Estimated Costs

About $1 1 billion[1/] was included in NASA's program estimate for upper stages. The latest estimate for upper stage development, including the interim and full capability tugs, is approximately $525 to $550 million [2/] NASA's estimates for the full capability tug show that another $199.2 million[2/] for the procurement of tugs, ground support equipment, etc , $166 million[2/] for operations, and $1 to $1 2 million[2/] for each kick stage will be required. Additional costs will be involved in providing ground facilities for the upper stages and for ground support equipment, procurement and operation costs of the Air Force's interim upper stage program

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1/ 1971 dollars

2/ 1974 dollars

Justification of Interim Upper Stage

The interim upper stage is needed because NASA funding constraints precluded parallel development of the space shuttle and full capability tug. This is a more costly approach because the interim upper stage will be used for only about 3-1/2 years, from June 1980 through 1983. Data was not available showing the total estimated savings and program benefits that could be achieved by introducing the full capability tug earlier than December 1983. The $125 to $150 million estimated for development plus the planned investment in interim upper stage vehicles and kick stages might be saved.

Agency Position

NASA recognized the cost benefits of going with a full capability tug and discussed this in Congressional hearings for fiscal year 1975. NASA officials also stated that the development of a tug for operation concurrent with the shuttle operational date would require early funding considerably over that expected to be available to NASA or DOD. The officials also indicated that, transition impact to DOD payloads and the lack of a hard requirement for retrieval of payloads in the early years of shuttle operations "rather naturally" led to the current phased program concept.

Air Force officials advised us that the development of the interim tug is necessary because (1) time is not available to conduct a full tug development and acquisition program prior to shuttle operational date of 1980 without high risk and inefficient cost commitments, (2) technology is not currently available to support the full objectives, and (3) such

a major development program at this time would probably divert NASA management and technical expertise from the STS and increase program risk. For the interim upper stage, the Air Force is planning a modification of an existing expendable upper stage vehicle which will meet DOD needs during the period prior to full tug availability

RESTRICTIONS ON REVIEW

Attempts to resolve access to records issues encountered during our first review have not been completely successful. Restrictions on access to records have again limited the depth and effectiveness of our review. The restrictions have consisted primarily of numerous delays ranging from a few days to over three months, and NASA's hesitance to release certain planning information in sufficient time for analysis and inclusion in this report. NASA has issued instructions for its various activities to follow in their relations with GAO but we continued to encounter access problems. NASA has assured us that this matter has been remedied

AGENCY COMMENTS

A draft of this staff study was reviewed by NASA and Air Force officials associated with the management of this program. Their comments have been incorporated as appropriate. NASA's comments of February 27, 1975, are included in Appendix II.

MATTERS FOR CONSIDERATION

The following matters warrant special attention·

1. The Congress may wish to require NASA and DOD to provide cost estimates for all STS elements and related costs, including the spacelab, together with an analysis of the current status of each element regardless of the source of financing. We believe this recommendation could appropriately be accomplished through a report

similar to Systems Acquisition Reports used to show the progress of major DOD systems acquisitions.

2. The Congress may wish NASA to incorporate in their management system information on the risks and potential higher costs that may result from annual funding constraints.

3. GAO did not have an opportunity to make an in-depth review of NASA's recently completed requirements review and cannot express an opinion as to its adequacy. However, NASA's recent actions generally support our earlier concern on the status of the program. Congress may wish to examine the changes in detail during forthcoming budget hearings.

4. NASA's present user charge policy may not be appropriate for the STS. We believe consideration should be given to recovering all cost associated with the development and operation of the STS. A comprehensive analysis of various user charge policies should be furnished to the Congress as soon as possible. This would enable the Congress to (1) determine whether non-Government users must be subsidized in order for the program to be economical and the extent to which they are willing to provide such subsidy and (2) whether it would be advisable for other Government agencies to reimburse NASA for their full share of the costs.

5. The potential environmental effects of the space shuttle have not been fully quantified and NASA has not conducted open hearings with the public at affected area sites Since NASA has imposed funding constraints on environmental studies, the Congress

may wish to determine whether NASA's progress in identifying and solving environmental problems is satisfactory.

6. Discontinuing the interim upper stage and proceeding with early development of the space tug seems to offer major program cost savings. A cost benefits analysis and feasibility study of this alternative would allow the Congress to make an informed decision as to whether to provide earlier funding for the space tug.
7. Since the decision has not been made on whether NASA or DOD will buy two of the five orbiters, Congress may wish to determine the status of the pending decision and the impact on the STS program.

QUESTIONS

1. Does the shuttle reporting system have the capability to identify cost changes to the major elements of the DDT&E $5.15 billion estimate by categories -- quantity, engineering, support, schedule, economic and estimating? Can such a breakout be provided?

2. Since much of the shuttle development work is being performed in-house, how does NASA's Performance Management System control and report the cost, schedule, and performance of these tasks?

3. Provide a current list by task of space shuttle related development work NASA is performining in-house. What is the dollar amount not being charged to the Space Shuttle Design, Development, Test and Engineering?

4. What alternatives are available should DOD not fund two orbiters either within the originally planned time frames or not at all? To what extent would these alternatives increase the STS costs and what effect would this have on the program's cost benefits? Also, how will the additional two orbiter's required for NASA's projected 725 flights be funded?

5. The Air Force does not currently plan to recover or perform in-space maintenance of their satellites through 1991. Is this true for other potential space shuttle users? How does this effect the projected benefits of the shuttle?

6. Is the NASA full capability tug being coordinated to interface with all the DOD high priority payloads and will it be capable of carrying them?

7. We understand that the main engine redefinition provides for deleting certain hardware items from the contract and for transferring certain work from period A of the contract to period B. Provide a list of the items deleted and transferred with applicable dollar amounts. Are these actions being taken in an attempt to reduce DDT&E costs?

8. Provide a brief explanation of the SRB range safety system. With the baseline system being installed only on the SRB's, what assurance does NASA have that the propellants contained in the external tank will be adequately dispersed? Will the present baseline system satsify Air Force range safety requirements? If not, does NASA plan to request a waiver from the Air Force?

9. If the SRB's destruct at relatively low altitudes, will a serious crew and ground hazard be created as a result of intense fire levels from propellants in the external tank? What actions are being taken to avoid this situation?

10. We understand that NASA has deleted the requirement for a thrust termination system on the SRB's. Was this done in an attempt to reduce DDT&E costs? Will the deletion of the system pose a crew and ground hazard? Without such a system, what happens if only one SRB ignites?

11. Will there be a duplication of tug launch and refurbishment facilities at the Eastern and Western Test Ranges? Provide a listing of tug facilities at these two sites, including a brief description and estimated cost for each facility. Explain why it is necessary for NASA and the Air Force to have separate mission control facilities for the space tug.

12. Will tug refurbishment be accomplished by a single crew or will a crew be trained for each launch and recovery site? How much could be saved if only a single crew did the refurbishment work?

13. How much duplication will exist between DOD and NASA computer software programs for space tug missions? What actions are being taken to reduce duplication to the extent possible?

14. Has NASA established a policy concerning a cost per flight for the space lab? Please explain in detail the costs that will be included in the cost per flight.

15. In June 1974, NASA reduced its March 1974 space lab program cost estimate of $624 million to $355 million. What accounts for such a large reduction?

16. Please discuss studies made or underway by other than NASA groups on the environmental issues concerning the STS. What is the status of your environmental studies and discuss the problems identified to date and how they are being solve?

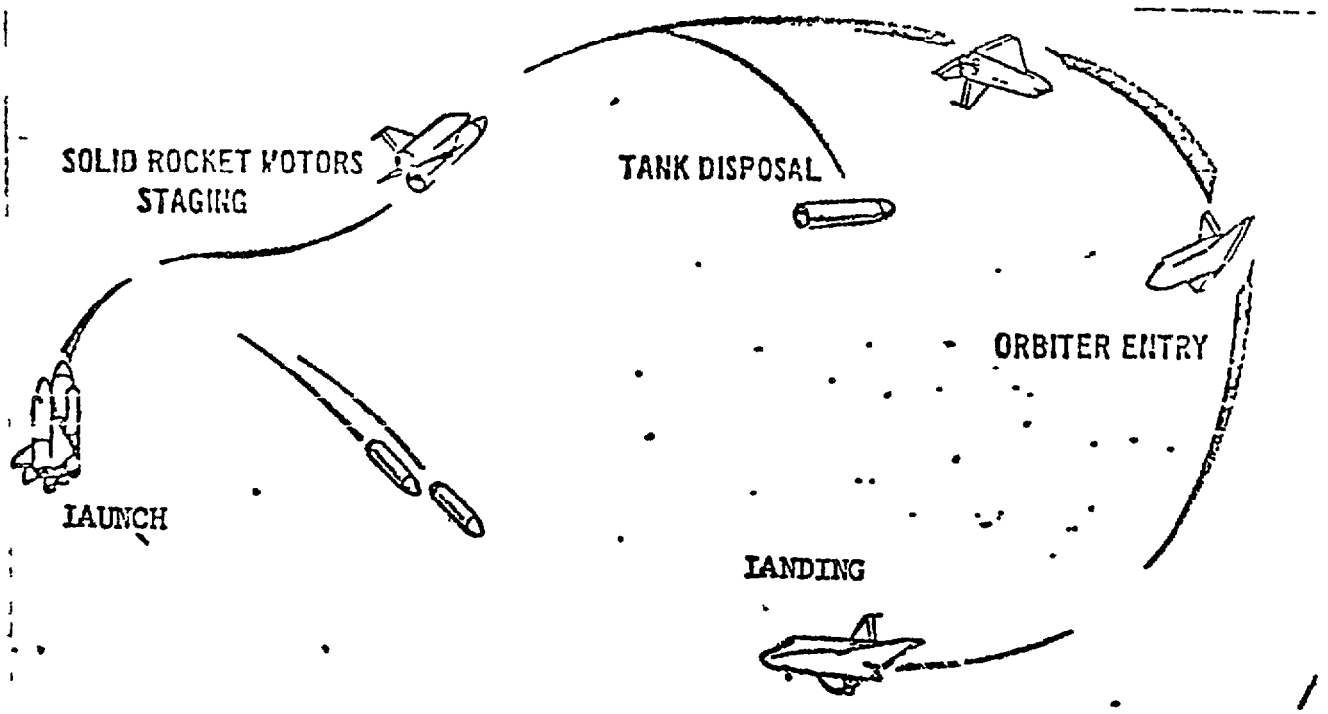
# CHAPTER 1

# INTRODUCTION

This is the second staff study of the Space Transportation System (STS) under development by the National Aeronautics and Space Administration (NASA). This study updates the program's status through September 1974. This study also covers Spacelab status information.

## DESCRIPTION

The primary objective of the STS is to provide a new space transportation capability that will substantially reduce the cost of space operations and support a wide range of scientific, defense, and commercial uses. The STS will include the space shuttle and the space tug. The space shuttle will consist of a manned reusable orbiter, which looks like a delta-winged airplane, an expendable, liquid propellant tank; and two reusable solid rocket boosters It will be boosted into space through the simultaneous burn of the space shuttle main engine and the rocket boosters. At an altitude of about 25 miles the boosters will detach and descend into the ocean by parachute for recovery and reuse. The main engine burn will continue until the orbiter and external tank are near orbit velocity, at which time the tank will be disposed of in a predetermined remote ocean site A pictorial profile of a shuttle mission follows



The Space Shuttle will be designed to place 65,000 pounds in a 150 nautical mile due-east orbit and 32,000 pounds into a specified 100 nautical mile near-polar orbit. The space tug is a propulsive or upper stage that extends the shuttle's capabilities to greater altitudes than those achievable by the orbiter alone and is expected to be operational by December 1983. During the 1980-83 period, an interim tug known as the interim upper stage will be used but will have limited capabilities.

The Spacelab is being developed, under a cooperative program with European countries, as a specific shuttle payload to support science and application activities.

RESPONSIBILITIES

NASA has the primary responsibility for overall program management and integration of the space shuttle and space tug and will fund their development, including almost all facilities except those required at the western test range, Vandenberg Air Force Base. While the overall program direction is the responsibility of the Program Director in Washington, the authority to manage the shuttle and tug program on a day-to-day basis has been delegated to the Johnson Space Center and Marshall Space Flight Center, respectively, as the lead centers. Space shuttle project managers have been designated for the orbiter, rocket boosters, main engine, external tank and launch and landing systems. These managers are responsible for the design and development of their projects, and report directly to the Space Shuttle Manager at the Johnson Space Center on program management.

The United States Air Force has been designated by the Department of Defense (DOD) as the organization responsible for assuring that DOD's interests are considered and for making provisions for the DOD STS program.

The Space and Missile Systems Organization (SAMSO) has been designated by the Air Force as the implementing agency for matters pertaining to the STS. The Air Force originally planned to purchase two production orbiters and will fund Vandenberg Air Force Base facilities and interim upper stage development.

A contractor(s) has not been selected for either the tug or the interim upper stage The responsibility for development, production, and operational support for the space shuttle is divided among four prime contractor and numerous subcontractors Rockwell International's Space Division is charged with the development and planned production of five orbiter vehicles It is also charged with overall integration responsibility of the shuttle's major components, main engine, etc

The remaining contractors are (1) Rockwell International's Rocketdyne Division - main engine, (2) Martin Marietta Corporation, Denver Division - external tank, and (3) Thiokol Chemical Corporation - Solid rocket motor portion of the booster The Marshall Space Flight Center will perform booster design and integration during the initial phase of the program Detail concerning the contracts are shown in Appendix I.

RESTRICTIONS ON REVIEW

Attempts with NASA to resolve access to records issues encountered during our first review have not been completely successful Restrictions on access to records have again limited the depth and effectiveness of this review. The restrictions have consisted primarily of numerous delays ranging from two days to over three months, and NASA's hesitance to release certain budget and planning information when requested. NASA Headquarters has issued

instructions for its activities to follow in their relations with GAO but we continued to encounter access problems NASA has assured us that this matter has been remedied

ESTIMATED STS PROGRAM COSTS

When the program was approved in March 1972, NASA presented to the Congress the results of an analysis of the development and operations of the STS from 1972 through 1990 based on a mission model of 581 flights. The purpose of the analysis was to compare the economics of the projected space effort for NASA, DOD, and others using the STS and alternate programs of existing and/or new expendable launch systems. The following table presents the cost estimate from this analysis.

TABLE 1

ESTIMATED SPACE TRANSPORTATION SYSTEM COSTS THROUGH 1990 (1971 Dollars in Billions)

| Elements | | Cost Estimate |
|---|---|---|
| Non-recurring Costs: | | |
| Space Shuttle Developmental Costs--Design, Development, Test and Evaluation (DDT&E) | | $5.150[a] |
| Orbiter Inventory (Refurbishment of the two development orbiters and production of three orbiters) | | 1.000[a] |
| Facilities (including two launch sites) | | |
| NASA | $ .300[a] | |
| DOD | .500 | .800 |
| Modifications and Requirements for expendable stage (Interim Upper Stage) | | .290 |
| Reusable Space Tugs | | |
| DDT&E | $ .638 | |
| Investment | .171 | .809 |
| | | $8.049 |
| Recurring Costs During Operations | | 8.050[b] |
| TOTAL | | $16.099 |

[a] Baseline estimate.

[b] A baseline estimate has been established for the average cost per flight of the space shuttle based on a 439 flight mission model rather than the 581 flight mission model used in this analysis.

The above estimates excluded certain costs because they were considered applicable to all competing transportation systems in the analysis. For example, the $16.1 billion estimate, does not include inflation over the life of the program, spacelab, Government salaries and travel, and certain related costs to be funded through NASA's Research and Development appropriation.

During fiscal year 1975 testimoney before the Senate Committee on Appropriations, NASA estimated about $2 billion in 1975 dollars would be required for these last two categories. A complete cost estimates for development and operation of the STS has not been provided to the Congress.

NASA made in-depth reviews of cost estimates for three STS elements and considers them to be baseline cost estimates which can be used for tracking their progress through the acquisition cycle. These estimates are (1) $5.150 billion for the Space Shuttle DDT&E, (2) $300 million for NASA's space shuttle facilities, and (3) $1 billion for refurbishment of two development orbiters and production of three orbiters. Apart from the March 1972 analysis, NASA established a baseline estimate of $10.45 million in 1971 dollars as the average cost per flight for the recurring cost of operating the shuttle.

NASA's internal cost estimates used to manage the program consider an inflation factor through the life of the program. For this reason, we have selected NASA's first management estimate, which was prepared in November 1972 and includes inflation, as the baseline for discussing program status. Cost estimates used in this study are based on real year dollars unless otherwise stated. The use of different year dollars in this report, while confusing, was unavoidable because NASA does not always have compatible estimates.

Major elements of the STS program are addressed in the following chapters of this study.

## CHAPTER 2

## COST, SCHEDULE AND PERFORMANCE SPACE SHUTTLE DDT&E

NASA has officially announced a DDT&E cost increase due to funding limitations of about $50 million in 1971 dollars. Their current internal estimate in real year dollars shows a cost increase of at least $229 million. The real year dollar estimate is higher because it shows the effect of inflation on the changes in annual spending levels caused by schedule slips.

Completion dates for the DDT&E phase have been extended 13 to 15 months beyond the baseline milestones because of funding constraints placed on fiscal years 1973, 1974 and 1975 budgets. The first extension, announced during fiscal year 1974 budget hearings, was 9 months. This delay, NASA officials testified, would not increase the $5.15 billion DDT&E estimate. However, further reductions or delays, they testified, would start causing major cost increases. A subsequent reduction in the fiscal year 1975 budget caused a second extension of 4 to 6 months, and the announced increase of the DDT&E estimate to $5.2 billion in 1971 dollars. NASA's corresponding internal estimate in real year dollars increased to about $7.009 billion. NASA's official position is that, unless major problems are encountered during the DDT&E phase, $5.2 billion (in 1971 dollars) will be sufficient to meet their schedule dates of June 1979 for the First Manned Orbital Flight and June 1980 for the Initial Operational Capability. The estimated DDT&E costs, in both 1971 dollars and real year dollars, are set out in table 2 along with recorded obligations through September 30, 1974.

TABLE 1

DDI&E ESTIMATES AND RECORDED OBLIGATIONS
(Dollars in Millions)

| Category | Estimate[1] as of March 1972 | Estimate[2] as of Nov. 1972 | Estimate as of Sept. 1974 | Nov 1972-Sept 1974 Increase (Decrease) | Recorded Obligations as of Sept. 30 1974 | Percent of Current Estimate Obligated |
|---|---|---|---|---|---|---|
| Vehicle and Engine Definition and Technology | | $ 121.7 | $ 122.0 | $ 0.3 | $ 121.6 | 99.7 |
| Main Engine | $ 412 0 | 641.3 | 769.4 | 128.1 | 214.8 | 27.9 |
| Solid Rocket Booster | 331.9 | 494.7 | 321.3 | (173.4) | 9.4 | 2.9 |
| External Tank | 301 2 | 594.5 | 249.5 | (345.0) | 35.4 | 14.2 |
| Orbiter | 2,884 9 | 3,468.2 | 3,689.1 | 220.9 | 707.6 | 19.2 |
| Launch and Landing | 69 0 | 464.5 | 507.2 | 42.7 | 5.3 | 1.0 |
| System Management (Includes Reserves) | 1,151.0 | 950.0 | 1,267.2 | 317.2 | 1.8 | 0.1 |
| Contract Administration | | 44.9 | 83.6 | 38.7 | 14.0 | 16.7 |
| Real Year Dollars | | $6,779.8 | $7,009.3 | $229.5 | | |
| Total 1971 Dollars | $5,150 00 | $5,150.0 | $5,200.0 | $ 50.0 | | |
| Obligations incurred | | | | | $1,109.9 | 15.8 |

1 The March 1972 estimate was based on 1971 dollars and did not include inflation The vehicle and engine definition and technology category and contract administration is included in the six major elements

2 This is NASA's first estimate in real year dollars No cost estimate was made in real year dollars in March 1972 (the date of NASA's commitment to Congress) Between March and November 1972 the program was extended nine months and adjustments were made to realign work tasks among the projects We estimate that NASA's real year dollar estimate in March 1972 would have been about $6.556 billion. Thus, the total cost increase between March 1972 and September 1974 would be about $450 million.

According to NASA, major performance requirements for the space shuttle have not changed. Numerous adjustments, however, have been made to individual projects, and more adjustments are being considered. Since most major tests and evaluations have not occured, the status of performance requirements is still predicated on engineering analysis. Based on these analysis, NASA now expects major performance goals to be attained.

OBSERVATIONS OF PROGRAM STATUS

At the time of our review, realistic internal NASA projections of expected run-out costs for individual projects and related reserves were not available because NASA management limits cost estimates to predetermined annual ceilings during their budgeting process. This is partially because of an agreement between NASA and OMB for funding limitations through fiscal year 1977. Thus, NASA estimates were, in many instances, predicated on what seem to be highly optimistic costs to complete.

Adjustments had been made to delete, defer or reprogram work to align the development program within the predetermined cost ceilings. However, some adjustments increased the risks to overall program costs, schedule, and performance targets. Other adjustments moved funding problems into the future or out of the DDT&E budget into other budgets where potential cost growth will not be readily identifiable. This situation suggested that, if cost overruns are encountered, they will either not be recognized and/or not be identified until the latter stages of the program.

NASA top management was concerned about this situation and in December 1974, after we had completed our field work, NASA concluded an in-depth requirements review designed to realign the program with the mid-year budget limitations. In the process, a number of work tasks, test article, and test programs were eliminated, delayed, and/or consolidated to the extent NASA

believed feasible. As a result, NASA now believes that it is back on track with adequate reserves for contingencies through the balance of the DDT&E program.

We are still concerned that the budget and schedule goals may be overly-optimistic. For example, the adjustments made to realign costs may have further increased the risk of encountering cost growth later in the program. Approximately 40 percent of the adjustments involved the reduction in scope of test articles and programs. In the coming year we plan to review and evaluate the adequacy of the newly revised program costs and schedule goals. Our observations on the program status at the completion of our field work follows.

Cost Estimates Limited to Predetermined Ceilings

The practice of limiting cost estimates and its effects are illustrated by NASA's most recent program cost projections. NASA's internal estimates of cost increases attributable to schedule delays were $100 to $125 million in 1971 dollars and as much as $360 million in real year dollars, rather than the $50 million announced to Congress. It was a NASA management's judgment that the $50 million was the most realistic figure. To keep estimates within the announced increase, the Space Shuttle Program Manager was directed not to exceed $5.2 billion when submitting subsequent planning estimates. The maximum amounts which could be estimated for any given fiscal year were also specified by NASA headquarters. As a result, project estimates may be understated and reserves overstated. Space shuttle project managers have consistently indicated a need for resources greater than the ceilings.

In August 1974, the Shuttle Program Manager summarized the program's funding status by stating that: "Overall, we feel the funding available for Shuttle Projects for FY 75-77 is very marginal since there are no funds available for growth or change allowances." We believe this is particularly

significant because changes stemming from technical uncertainties have historically been a prime cause of cost growth in major acquisition programs.

Program Adjustments

Program adjustments have been made to (1) defer work scheduled for early years of the program, (2) reprogram work from contractors to in-house, and (3) delete design and work requirements planned for DDT&E. We believe some of the adjustments have increased the risk of cost growth. During budget hearings for two consecutive fiscal years - 1974 and 1975 - NASA officials informed Congress they had gone about as far as possible in making program adjustments to reduce costs. Yet, such adjustments have continued.

Deferrals

The delays of work planned for early years of the program are "stop-gap" measures to relieve current funding problems by moving them to the future. Spending in later years to accomplish delayed work is increased by inflation and further erodes reserves allocated to those years. Additionally, NASA's delay of test programs reduces the time available to solve any problems identified.

Reprogramming

Reprogramming work to in-house reduces development cost, in part, because NASA's costs (salaries, supplies, travel, etc.) are not always charged to the space shuttle. In our opinion, this does not represent a cost reduction. By transferring these costs, shuttle cost growth is absorbed in other budgets. NASA recognizes that this does not represent

a true cost reduction since such costs are not charged to the development program. However, they feel such actions are cost effective since they take advantage of in-house skills and allow better definition of work prior to letting contracts to industry.

In-house development costs should be estimated and accounted for as part of the shuttle program. NASA defines shuttle development as including all resources required for design, fabrication, ground test, and flight test of the vehicle. Further details on the impact of in-house costs are contained in our June 1974 Staff Study.

Deletions

Since initiation of the space shuttle development program, such items as test programs, test articles, abort solid rocket motors, and landing drag chutes for the orbiter have been deleted. NASA is taking a calculated risk that no major technical problems will be encountered by the elimination of test articles and programs.

Inflation

NASA has not recognized an inflation rate higher than 5 percent in its budgets and cost projections. When inflation exceeds 5 percent, this practice amounts to a budget reduction. The shuttle program office estimates that $230 to $286 million in real year dollar buying power may be lost from fiscal year 1975 through 1977. Additional schedule extensions and related cost increases can be expected if inflation continues to reduce budget buying power.

The above constraints resulted in narrow cost and schedule margins being maintained in the space shuttle development program. We believe that little flexibility remains to overcome the difficulties that normally arise during the course of a development program. Since the space shuttle is in the early years of its development, a number of problems could occur

that affect both the schedule and cost. A detailed discussion on the major shuttle systems is presented below.

ORBITER

NASA's current estimated cost for the orbiter project is about $3.7 billion, a $220.9 million increase over the November 1972 estimate. This estimate includes no reserves through fiscal year 1978. The lack of reserves is a major concern to the project manager because inability to fund changes could delay the First Manned Orbital Flight and Initial Operational Capability.

NASA's cost estimate may also be affected by current prime contract negotiations. This will be the first opportunity to definitize increment II of this contract. The negotiations, which are scheduled to be completed by April 1975, are complicated by projected inflationary trends. NASA's estimate does not include inflation rates as great as projected by either the orbiter project manager or the contractor. The project manager believes inflation could increase contract costs by an additional $49.3 million for fiscal years 1975 and 1976 alone. A study by the prime contractor showed costs to complete orbiter DDT&E would increase about $300 million if the overall rate of inflation increased 2 percent. NASA and contractor officials have not yet agreed upon a reasonable inflation allowance which may be experienced during future years.

Project Adjustments

Efforts have been and are continuing to be made by NASA to stay within funding constraints and minimize the cost of the orbiter project. We were unable to determine the full extent of actions taken to reduce and delay development costs because NASA's original cost estimate, which was based on parametric estimating techniques, did not specify either planned work tasks or the division of work between NASA and the prime contractors. However, funding constraints during fiscal year 1973, we were told by NASA personnel, caused about $212 million of scheduled activities to be deferred, deleted, or reprogrammed. For fiscal year 1975, cost reduction changes valued at about $47 million were identified of which $21.7 million have already been implemented.

Cost reductions and deferrals have included (1) the delay and/or deletion of engineering activities, test articles and programs, Government furnished equipment, training and flight hardware, and major subcontractor's authority to proceed, and (2) reprogramming to in-house the design and engineering of such hardware as the orbiter galley, the close circuit television, and others. Adjustments of this nature do not always decrease total program costs. The orbiter project office believes the deletions and delays have increased cost and schedule risks. For example

--DDT&E costs estimates were increased by $39 million because funding limitations for fiscal year 1975 caused the contractor to delay $47 million of work to subsequent years. The increase is attributable primarily to maintaining certain support-type activities for an additional 2 months to complete the DDT&E effort.

--Significant portions of test programs which have been delayed, deleted or reduced may result in some design problems not being identified early enough to minimize the cost and schedule impacts.

--Hardware deleted from the DDT&L program may subsequently be required to meet program objectives, thus increasing development costs later in the program. Examples of hardware deletions include the drag parachute, one payload manipulator arm and the crash recorder.

Technical Uncertainties

Known major technical problems which must be overcome on the orbiter project are

Weight

Maintaining the orbiter's "dry weight" within 150,000 pounds (weight without payloads, fuel, etc ) is considered by NASA and the prime contractor as the most critical technical problem encountered so far. The contractor originally planned to have a 10 percent weight growth margin at the time of the preliminary design review, held in February 1974, because historical data indicated a 10.6 percent weight-growth from that point through the life of the program. NASA officials stated that the planned growth margin at preliminary design review was subsequently reduced to 6 percent. This goal was not met. By September 1974, the projected orbiter weight was 2,177 pounds over the 150,000 pound baseline. Subsequent adjustments during September 1974 provided a positive margin at 845 pounds. Potential weight changes now being assessed could provide a growth margin of about 1.8 percent.

Weight is critical to both cost and schedule because of the time and money required to find and implement satisfactory solutions. In addition, the shuttle's performance characteristics could be affected if weight problems cannot be resolved. Excess weight, for example, could reduce the payload carrying capability of the space shuttle and increase the orbiter's landing speed.

Thermal Protection System

The thermal protection system protects the orbiter's structure from overheating during ascent and entry. The thermal protection system should maintain the structures temperature below 350° Fahrenheit and be capable of at least 100 reuses with only minimum repairs and replacements. The thermal protection system is the orbiter element requiring the greatest amount of new development It consists, in part, of about 35,000 tiles of different sizes and thicknesses that are bonded to the orbiter airframe Progress has been made in assessment of the system's potential problems but further development is required in the following areas

--Reusability - The reusability requirement is an important factor in keeping cost-per-flight within the $10.45 million estimate in 1971 dollars. A criteria has not yet been established as to the amount of tile damage that can be sustained without replacement. Tests have demonstrated its survival capability for temperatures above those anticipated on normal flights. One exception is that certain spots on the wing tips are subjected to temperatures that could require thermal protection system replacement more frequently than planned.

--Installation - A method has to be developed for easy installation, identification, and replacement of damaged tiles. This is complicated because tiles have low resistance to damage during ground handling.

Avionics

The avionics system, which is composed of six intricate electronic subsystems, is considered the brains of the overall system. In designing avionics, emphasis was placed on use of off-the-shelf hardware.

Avionics is now in the early stages of subsystem development and problems encountered to date relate primarily to equipment that require new development. The greatest technical challenge and thus the highest risk area is integration and verification of all components for compatability and adequate redundancy. Integration testing is scheduled to start in June 1975, and verification testing in April 1976.

SPACE SHUTTLE MAIN ENGINES

NASA's estimated cost for the main engine project is $769.4 million, which represents a $128.1 million increase over the November 1972 cost estimate Also, the date of Final Flight Certification has slipped 20 months. Potential for further cost growth and schedule slippage exists because of NASA underestimates of prime contract costs, existing and potential funding limitations, inflation, and technical problems.

NASA is revising its cost projection for the DDT&E effort and indications are that it will increase more than $32 million $8 million due to a recent schedule change which was not reflected in their estimate and $24 million due to cost growths which resulted in prime contract tasks being deferred to a later time. Furthermore, this deferral of work will undoubtedly result in additional cost increases due to inflation.

A number of technical risks are outstanding which could impact cost or schedule, if redesigns are necessary. Furthermore, the majority of the engine's major subsystems have yet to be tested to verify their technical performance, which could also impact on cost and schedule if problems should develop.

Schedule slippages

The development program has slipped 20 months from the completion date established in May 1972. According to NASA officials, the causes for the delays relate primarily to (1) funding limitations, (2) procurement difficulties, (3) technical problems, and (4) contractor overruns. Additional slippages may be encountered in the main engine program as discussed below

The first integrated subsystem test is a major milestone in the main engine program which is pacing the development progress. The prime contractor scheduled the first integrated subsystems testing to begin in December 1974. This testing has since been deferred 5 months because of facility technical problems, procurement, and fabrication difficulties. Contractor and NASA officials stated that additional slippages could be encountered since no slack time exists on the critical path leading to this test.

In addition, the turbopump tests which are required to be performed prior to the initial integrated subsystem testing also present a potential schedule problem. As of September 1974, there was about 1 month remaining in the contractor's schedule between the high pressure turbopump and initial integrated subsystem tests, whereas there were about 5 months as recently as June 1974. One of the primary causes for schedule difficulty is associated with the welding techniques and processes required to achieve the engine's weight objectives.

Technical uncertainties

The primary performance characteristics being tracked formally on the engine are weight, thrust, and specific impulse. According to the latest estimates, the engine is achieving contract specifications. Estimated performance values are based primarily on engineering analysis. Actual performance data will not be available until the integrated subsystem tests, scheduled to start in May 1975. Known technical uncertainties on other performance characteristics are discussed below.

Engine life - Each engine must be capable of achieving 55 missions or a total of 7.5 hours operating time. The contractor's current assessment of the turbine nozzle shows that it will not satisfy reusability requirements necessary to assure compliance with the 55 mission specifications. If actual tests show the nozzle's life to be unsatisfactory it may be necessary to (1) use a different material in the nozzle, (2) redesign the nozzle, or (3) perform more expensive maintenance on the nozzle during the 55 missions.

Engine controller - The controller monitors and controls engine functions such as failure detection, thrust and propellant mixture ratio, and engine starts and shutdowns. The controller has been one of the primary concerns in the program because of developmental difficulties. NASA and contractor officials believe these difficulties have been overcome but the development program is being closely monitored and an alternate controller will be procured, if necessary.

EXTERNAL TANK

The current NASA estimate of $249.5 million is $345 million below the project's November 1972 estimate. The NASA estimate was recently increased to provide the funds needed for the contractor to meet scheduled milestones during fiscal years 1975, 1976 and 1977. The NASA estimate was not increased for potential Government directed changes and project reserves beyond fiscal year 1977. The project office estimates the additional funding required at $35 million.

Funds freed by the lower estimates on this project have been redistributed to other shuttle projects and are no longer available to offset major cost growth in the shuttle program.

Contract Negotiations

By April 1974, the external tank estimate was reduced to a low of about $199 million, including $140 million for the prime contract. Estimated costs were reduced because the winning contractor's bid was substantially less than NASA's estimate. Subsequent efforts to negotiate a contract which would support the April 1974 estimate have not been successful. In June 1974, the contractor submitted a cost estimate of $189 million, excluding fee, which is about $86 million more than his original proposal of $103 million. Primary reasons for increases were:

a. A change in accounting practices for allocation of Independent Research and Development and Bidding and Proposal costs to comply with Cost Accounting Standard No. 403;

b. A significant increase in labor and material inflation rates to reflect the projections of the Bureau of Labor Statistics Consumer Price Index and the Industrial Commodity Index, respectively, and

c. The addition of work requirements not contained in the contractor's original proposal.

The contractor's projected cost increases were unacceptable to NASA and, after attempting unsuccessfully to negotiate lower costs, the NASA Administrator advised the contractor to reduce his cost. In a letter of July 1974 to the company president, the Administrator said in part, that:

"* * * The funding level for the Space Shuttle budget is essentially fixed and will not accommodate a cost growth of this magnitude. * * * The external tank project cost must be controlled if the viability of the overall Shuttle Program is to be maintained. * * * I cannot stress too strongly the gravity of the situation and the need for expeditious resolution, so that I can determine the future course of the external tank procurement."

On August 28, 1974, the contractor submitted a revised estimate of $149 million, excluding fee. The contractor's estimate was reduced primarily by his agreeing to absorb the Independent Research and Development Bidding and Proposal above a contractual ceiling, and by significantly reducing projected inflation. About $30 million of the $40 million decrease was attributable to lower inflation rates. Contract negotiations for the tank were expected to be completed in December 1974. However, additional requirements already identified by NASA may increase the contractor estimate beyond the $149 million.

We questioned the contractor about the inflation adjustments and were advised that no studies were made to support the reductions. Instead, the new rates were mutually agreed to between the contractor and NASA. Neither the contractor nor NASA believe inflation on the tank will be as high as indicated by national indices used to prepare the contractor's earlier projection. However, a NASA study shows that inflation may be greater than the contractor's revised projections.

The contractor plans to offset inflation by (1) purchasing material in large quantities and seeking greater competition, and (2) implementing a merit promotion plan for employees in lieu of automatic cost of living increases. The success of the latter approach, the contractor said, depends on whether the company is competitive with other firms and thus retains its employees

Project Adjustments

In order to stay within funding constraints, efforts have been and are continuing to be made to reduce the external tank program's total cost and delay funding requirements to future fiscal years. Some examples are.

-- NASA has assumed the responsibility for tank thermal protection system testing, and the development of tooling and application techniques for the thermal protection system.

-- Preliminary NASA estimates indicate that an average of 286 civil service and 56 contract support service personnel will be employed on tank tasks during fiscal years 1974 thorugh 1978. Costs of these personnel are not charged to the shuttle DDT&E.

--Consideration is being given to eliminating about $10 million in requirements from the DDT&E program. For example, the tooling required to produce tanks at the rate of 60 per year may be deferred until the production/operational phase of the program. This action would reduce DDT&E funding requirements by an estimated $6 million but would also reduce the annual production capacity to 24. A production rate of 60 per year is required to meet flight schedules during the operational phase of the program, and will be accommodated by NASA by the additional of tooling at a rate consistent with program schedule.

--The external tank project development has been stretched out about 12 months. This may increase the total cost but it will relieve some of the short range funding constraints.

Technical Uncertainties

Some of the known technical problems associated with the external tank are discussed below.

Tank Entry - The impact zone of the tank must be predictable to prevent it from being a hazard to people or property. To improve predictability and prevent the tank from missing the impact zone by more than a 1,000 nautical miles, a requirement was imposed for the tank to tumble during descent. However, a subsequent review showed that excessive tumbling could cause the tank to exhibit a "frisbee" phenomena and miss the impact zone. Also, premature tumbling could result in a collision of the tank and orbiter. Studies are underway to develop a means for controlling tumbling.

External Tank Ferrying - Consideration is being given to ferrying the tank to launch sites by aircraft rather than barge. Air ferrying presents potential technical difficulties because the thermal protection system could be damaged during flight and changes in atmospheric pressure could damage the tank. A protective shroud for the thermal protection system and a means of equalizing tank pressure could be required to prevent such problems. Such measures could reduce the cost savings presently being predicted by adoption of the air ferry mode.

SOLID ROCKET BOOSTERS

NASA's current estimate of $321.3 million for the development of the booster is $173 4 million less than their November 1972 estimate The schedules have been extended by 18 months We believe the current cost estimate may not reflect all requirements necessary for completion of the project through DDT&E The project manager estimated in August 1974 that an additional $67.6 million would be needed for booster development. This estimate excluded about $6 5 million needed for a range safety system and hardware for the shuttle avionics integration laboratory

The reduction in booster cost estimates were partially achieved by placing potentially unrealistic limits on the project manager's projections The project manager has decreased the scope of work to be performed by contractors in order to minimize costs and stay within levied constraints. For example, NASA assumed a large portion of design and integration work on five of the six booster subsystems. This reduction, valued at about $58 million in 1971 dollars is attributable to in-house effort (Government salaries, travel, etc.) that will not be charged to NASA's DDT&E. In our opinion, this does not represent a cost reduction. By transferring these costs, shuttle cost growth is absorbed in other budgets. NASA recognizes that this does not represent a true cost reduction since such costs are not charged to the development program. However, they feel such actions are cost effective since they take advantage of in-house skills and allow better definition of work prior to letting contracts to industry.

Technical Uncertainties

Some of the booster's technical uncertainties which have not been resolved are:

Salt Water Corrosion - A protective coating has been identified to prevent serious corrosion from salt water but its application will increase production costs. The corrosive effects of salt water are still under study.

Water Impact Damage - The extent of damage to the booster during entry depends upon its velocity, angle of impact, and structural design. Maximum design requirements would also increase program system weight but minimum requirements would also increase program costs from higher booster attrition rates. A new computer program has been developed for use in trade-off studies.

Vibration Effects - Noise generated by the boosters and main engines will cause severe vibrations to the structures and electronic components of the space shuttle. This could, in turn, impose severe design requirements on the booster in order to assure the space shuttle's structural adequacy and overall reliability. The booster's accoustical environment and its effect on structures and electronic components is under evaluation.

## CHAPTER 3

## COST PER FLIGHT

NASA's use of the $10 45[1] million in news releases and congressional testimony as cost per flight is misleading and may create confusion outside the agency. Internally, NASA uses cost per flight estimates to evaluate decisions and system trade-offs between initial investment and recurring cost. It is the average recurring costs for a stated traffic model for operating the space shuttle only. The $10.45[1] million is not, contrary to occasional NASA officials use of the term, the cost which will be charged to space shuttle users.

NASA uses the $10.45[1] million cost per flight to measure their success in accomplishing one of the space shuttle's objectives of reducing the cost of space operations. While it is undoubtedly a useful managment tool, it is unclear when used publicly and can be interpreted as the total STS costs amortized over the projected number of missions.

Most persons, for example, would include depreciation on their automobile, as well as gas, oil, and maintenance if asked what its operating costs were. Likewise, they understand that the purchase of their automobile includes an amount for the manufacturer's design, development, and production costs, and inflation through the year in which it was purchased.

The $10.45[1] million cost per flight is not stated in current year dollars and excludes design, development, production and investment in facility costs. Also, excluded are the recurring and developments costs for the space tug.

If a cost per flight figure is considered essential for public disclosures, it should include all cost elements An alternative would be for NASA to

[1]1971 dollars.

refrain from referring to the $10 45 million in 1971 dollars when attempting to show economic advantage of the space shuttle NASA officials pointed out that other Government agencies generally use recurring cost only in similar situations.

USER CHARGES

Users of the STS, including other Government agencies, public and private organizations of the United States and foreign countries, will be required to reimburse NASA for certain costs associated with its use A user charge policy for the space shuttle has not yet been developed although NASA currently has this under study

**The space shuttle is being developed to lower the cost of space transportation for all users. Approximately 50 percent of the payloads in the projected mission model will be non-NASA payloads of which approximately 12 percent will be non-government users. NASA has therefore, placed itself in a position of sometimes becoming a transportation agency for space flight. Under these conditions, NASA studies should consider whether a full cost recovery policy may be appropriate. Information upon which such a decision could be made should be furnished to Congress as soon as possible.**

A full-cost recovery policy for non-government users would be consistent with Title V of the Independent Offices Appropriation Act of 1952 (31 U S C. 484 (a)) as implemented by Bureau of the Budget Circular A-25, dated September 23, 1959 These directives essentially stated that an agency providing work or services to non-government users be self-sustaining by imposing a charge to recover the full cost to the Federal Government of rendering that service **The National Aeronautics and Space Act of 1958, as amended, is the authority for the establishment of user charge policies for NASA.**

## CHAPTER 4

## ENVIRONMENTAL EFFECTS

In our opinion, identification and evaluation of all environment problems, particularly medical/ecological adversities and shuttle operational constraints should receive the highest priority Informed decisions on the usefulness and acceptability of the program cannot be made by the Congress and other public officials without this information However, funding constraints have been imposed on NASA on environmental studies as with other elements of the shuttle program.

NASA published an "Environmental Statement for the Space Shuttle Program" in July 1972. This report concluded that the shuttle's potential effects would be environmentally acceptable, localized, short in duration, and controllable However, this same report, together with other NASA documents, identified atmospheric and sonic boom effects Potential medical and ecological effects have been identified but not all analyzed.

### ATMOSPHERIC EFFECTS

According to NASA studies, emissions from the rocket booster propellants will affect the upper atmosphere, potentially resulting in an increase in the incident of skin cancer, and the dispersion of hydrogen chloride in and around launch sites Orbiter reentry through the atmosphere will start a chemical reaction that could cause short duration interference with telecommunications and radio signals Some of these effects could impose launch constraints on the space shuttle including the cancellation and deferral of launches

Potential effects and mission constraints have not been quantified and research is continuing NASA is also studying alternative propellants for shuttle boosters to eliminate any potential stratospheric effects

SONIC BOOMS

NASA documents show the orbiter will produce sonic booms during landing operations of sufficient intensity to cause minor damage (window and plaster cracking) to houses not in good repair and discomfort over populated areas in and around the two selected landing sites--the Vandenberg AFB,CA and the Kennedy Space Center, Fla Greater disturbances could also occur under certain abort and other conditions where shuttle operational constraints cannot practically or predictable be imposed

Sonic booms will also occur during launch and reentry of the rocket boosters The former will be capable of causing structural damage to houses For this reason, they will be limited to ocean areas where they will do no harm Shuttle launch rates will be as high as once every 6 days

NASA has essentially completed their study of sonic boom effects, however, the necessary mission constraints have not been fully developed The next report on sonic boom effects is not expected until mid-1975 Their July 1972 report concluded that the effects will be environmentally acceptable Notwithstanding, all cognizant parties, including communities which will be subjected to sonic booms have not been consulted.

MEDICAL/ECOLOGICAL

All medical and ecological effects have not been identified by NASA or any other institution NASA is receiving assistance in this from the outside scientific community Criteria to evaluate these effects have not been completely formulated Current assessments of potential medical/ecological effects, therefore, are tentative, and can be expected to be refined as new information becomes available

NASA initiated a small program to provide a baseline ecological model of the area in and around the Kennedy Space Center and assess the effects of Shuttle chemical emissions. In August 1973 this program was reviewed by an advisory committee to the Office of Manned Space Flight Life Sciences, who criticized both the program and the personnel carrying out the work. As a result, the American Institute of Biological Sciences was requested to assess the Shuttle effects on living organisms, such as local effects on plants and crops, and the incidence of skin lesions likely to result from different percentage changes in ultra-violet radiation. This assessment was recently received by NASA. No unacceptable local ecological effects are foreseen according to NASA

Agency Comments

NASA officials believe that top priority is being given to the space shuttle's environmental effects. The effects, in their opinion, have been adequately examined in various environmental statements which were sent to Federal and state Government agencies for comment and their availability to all persons was announced in the Federal Register. Comments received from these agencies did not indicate the program will be unacceptable.

NASA personnel also believe that the major unresolved effect of the space shuttle is the postulated effect of ozone in the stratosphere. However, they point out that the concensus of a group of experts from both inside and outside the Federal Government is that while the potential effects on ozone is of concern, preliminary calculation show that it should not alarm anyone

NASA personnel emphasized that studies are continuing in all areas of the space shuttle's environmental effects. If such studies indicate a significant change, NASA will provide amendments to or additional environmental statements.

The GAO comments in this staff study should not be interpreted to mean that NASA has not fulfilled their legal requirements to report on the environmental effects of the space shuttle nor that the effects will be unacceptable. Notwithstanding:

--All medical and ecological effects have not been quantified by NASA or by any other institution or agency. Criteria to evaluate and monitor these effects have not been completely formulated.

--The effects of ozone depletion by the space shuttle, while potentially not significant in itself, could be significant in combination with other ozone depletion sources. NASA states that if further research shows space shuttle exhausts to be unacceptable, alternate propellents will be substituted. However, this could have significant technical and cost implications on the shuttle development program by increasing performance risk and cost.

--Funding limitations have resulted in the delay and deletion of portions of the environmental effects studies.

--The potential environmental effects of the space shuttle have not been discussed with all cognizant parties, principally the communities that will be affected to determine their acceptability

## CHAPTER 5

## CONSTRUCTION OF FACILITIES - COST SCHEDULE AND PERFORMANCE

Through fiscal year 1975 Congress appropriated $202 6 million for shuttle facilities In addition, NASA used $23 million of shuttle research and development funds for construction at Government owned/ contractor operated facilities The $23 million is applicable to NASA's $5 2 billion[1] DDT&E commitment, not to the $300 million[1] commitment for facilities

As of July 1974 NASA estimated the total facilities cost at $292 to $302 million in 1971 dollars and $412 to $429 million in construction year dollars (see the following table)

[1] 1971 dollars

TABLE

Facilities Cost Estimate
FY 1971 - 1980
(Millions of Dollars)

| Facility Category | Estimate March 1972 | Current Estimate July 1974 (Range) | | Variance from Baseline (Range) | |
|---|---|---|---|---|---|
| Technology | $ 8 6 | $ 9.9 | $ 9.9 | $ 1.3 | $1 3 |
| Engine | 22.5 | 18.5 | 18.5 | (4.0) | (4.0) |
| Manufacturing and final assembly | 16.5 | 32.8 | 32.8 | 16.3 | 16.3 |
| Solid rocket booster production and test | 67.9 | 62.6 | 65.6 | (5.3) | (2.3 |
| Ground test | 53.1 | 50.5 | 52.5 | (2.6) | (0.6) |
| Launch and landing | 212.0 | 211.3 | 223.3 | (0.7) | 11.3 |
| Total projects | $ 380.6 | $ 385.6 | $402.6 | $ 5.0 | $ 22.0 |
| Facility planning and design | $ 29.4 | $ 26.4 | $26.4 | $(3 0) | ( 3.0) |
| Total (real year dollars) | $ 410.0 | $ 412.0 | $429.0 | $ 2.0 | $19.0 |
| Total (1971 dollars) | $ 300.0 | $292.1 | $302.1 | $(7.9) | $ 2.1 |

In February 1975 NASA advised us that the estimate had been revised to about $472 million in construction year dollars, an increase of about $62 million over the March 1972 estimate NASA also stated the estimate was within $300 million on the basis of 1971 dollars and attributed the increase primarily to higher than anticipated inflation NASA did not give us details of the revised estimate in sufficient time to enable us to evaluate the changes.

INDIVIDUAL FACILITY BASELINES

NASA has provided cost estimates to Congress on individual facility projects estimated to cost about 51 percent of the $300 million commitment

To independently analyze the NASA's progress in meeting the total facility commitment, we requested NASA to provide a listing of all of the planned space shuttle facilities We also requested documentation showing facility descriptions and how project amounts were originally determined in developing the initial $300 million estimate

NASA furnished a listing of the facilities and the basic assumptions used to develop the $300 million commitment However, various changes were made in the facilities and we could not evaluate NASA's progress in facility acquisition in relation to its original plan

Concerning the information provided, NASA stated that

> "***It must be emphasized that none of the individual facility items or associated costs was approved as such by NASA, except as they are reviewed individually and included in the agency's budget request. Our commitment remains $300 million (1971) for the total facility program. We recognized then, as we do today, that certain facility items will change, others would drop from considerations, and still others become valid needs as shuttle program requirements become more definitized and mature. Certain changes have occurred already and others will. We kept the Congressional Committees advised of the major changes.
>
> For the above reasons, these documents must be viewed judiciously. As we previously stated to you, any attempt to rationalize or justify individual facility item changes or cost variations from the "baseline" to the validated budget would be non-productive and time consuming. However, we are prepared to explain any deviations in scope and cost that may occur in the facility projects that have been authorized to date."

At the time of our review, we were unable to obtain from NASA a description and cost estimate for those individual facilities planned but not presented to the Congress which would complete the $300 million commitment because NASA regarded this as restricted budgetary date. In effect, we could not evaluate the progress in meeting the $300 million commitment. However, as mentioned above, subsequent to our detailed review, in February 1975, NASA provided us a current listing of individual facilities through fiscal year 1976 as well as estimates on those planned which will complete the $300 million facility commitment.

## CHAPTER 6

## DOD INVOLVEMENT

The DOD is committed to use the space shuttle as its primary launch vehicle after 1980. The scope and schedule for DOD's participation in the shuttle program has not been fully defined and is dependent upon NASA's development schedule and the availability of funds. USAF officials advised us that there is yet no agreement between DOD and NASA as to whether DOD will buy two of the five orbiters. DOD's orbiter procurement decision has been deferred, therefore, the Air Force has been directed not to include funds for this purchase in their budget submissions.

### DOD NEED FOR STS

The DOD is committed to use the space shuttle as its primary launch vehicle after 1980 and believes it will provide economic and other benefits. However, the development program has not progressed to the state where these benefits can be substantiated To meet this commitment, the Air Force has adopted a phased development approach which provides for changes in the NASA STS program and allows DOD to take advantage of potential benefits from the program. The approach is designed to minimize the risk to military space programs and recognize the need to transition existing expendable launch systems to the STS program. The Air Force is following this approach because the STS is still relatively early in the development cycle, the design of military satellites is responsive to changes in requirements or technical improvements, and the redesign of military satellites is currently limited to configurations which can also be launched with the

available expendable vehicles until sufficient STS flight experience is available to warrant complete reliance on the STS system. In this regard, all of the currently planned satellites could be launched with the present expendable boosters.

DOD's phased approach also prevents the expected cost or other benefits of the STS to DOD from being quantified until late in the program. For example, the potential for reducing space program costs through recovery, reuse, and in-space maintenance of satellites is one of the primary justifications for the STS. Because of the reasons mentioned above, Air Force officials advised us that there are no specific plans to recover or do in-space maintenance on any satellites planned through 1991. However, studies conducted have shown varying potential benefits to be gained from such operations depending upon class of satellites studied.
Some studies show potential cost benefits of from 20 to 30 percent. Others have indicated that modification required to existing satellites might offset savings. Air Force officials advised us that more study will be required to determine which specific satellite programs can benefit from recovery, reuse, or in-space maintenance. A SAMSO study planned for completion by October 1975 should provide preliminary information for such economic evaluation of DOD's participation in the STS program.

SCOPE OF DOD INVOLVEMENT

The total cost of DOD participation in the STS program is not yet available, but is being developed as the program and the DOD method of operations are defined. However, the following STS budget projections for DOD involvement were presented to the joint NASA/USAF Space Transportation System Committee in March 1974.

| Program element | Estimated cost (millions in FY 1974 dollars) |
|---|---|
| Procurement of two orbiters | $ 559 |
| Facilities at Vandenberg Air Force Base | 640($710 million in 1975 dollars) |
| Operations - manpower costs to operate Vandenberg Air Force Base facilities | 123 |
| Upper stage modifications (see Ch. 7) | 100 |
| Payload transition - expendable booster to shuttle | 98 |
| | $1,520 |

A subsequent DOD study showed that about $1.9 billion in 1975 dollars would be needed for their involvement. Some areas of DOD involvement in the STS were not included in the above projections because they have not been clearly defined and the cost could not be fully estimated. Some of the more significant incomplete or excluded areas are

--Modification and operating costs for a DOD Mission Control capability.

--Computer software for support of DOD's operations.

--Operational costs for orbiters, rocket boosters, external tanks, and upper stages.

--Acquisition and integration costs for upper stages.

Definition and cost estimates for some of these areas are being developed.

## CURRENT PROGRAM STATUS

During the course of our review, the major concern was over the availability of enough funds to properly support the DOD development work. Because of this concern several options were being considered should the funds be less than needed. However, Air Force officials advised us on February 1975 that the funds included in the fiscal year 1976 budget and those planned for future years will support the DOD development effort.

### Orbiters

USAF officials advised us that there is yet no agreement between DOD and NASA as to whether DOD will fund two of the five orbiters.

The orbiter procurement decision has been deferred, therefore, the Air Force has been directed not to include funds for this purpose in their budget. DOD's decision concerning the timing of and purchase of the orbiters could have a major impact on the STS program. It could either cause a major program delay or force NASA to either fund the orbiters or delete them. Prior NASA investigation showed that an 18-month delay in procurement of DOD's orbiter would cost about $350 million, an amount NASA indicated was unacceptable.

Vandenberg Air Force Base Facilities

On the basis of a study completed October 31, 1974, SAMSO revised the March 1974 estimate from $710 million to $626 million. The reduction was effected by changing a transportation concept, scaling down the size of some facilities, making use of some existing facilities, and deleting a marine facility that was to be used for receiving external tank and rocket boosters. Deletion was made possible by accepting NASA's contention that air ferry of tanks was feasible and by shifting booster recovery operations to a Navy facility located about 80 miles from Vandenberg. If a marine facility is later necessary because tank air ferry is not feasible, a minimum of $25 million will have to be added.

The cost of facilities could increase if additional fuel storage is desired--current plans do not address the need for fuel storage We were advised by a SAMSO official that a recommendation to provide additional storage capacity is likely. He did not estimate the cost increase associated with such a change.

Initial operations for Vandenberg facilities are scheduled for late 1982. However, this date is uncertain since the Air Force STS program is keyed to NASA's development schedule.

Operations

Based on the October 31, 1974 study, SAMSO increased its estimate of operations cost from $123 million to $315 million for 10-year period. This estimate includes the direct manpower costs to operate the Vandenberg facilities, the manpower and material costs associated with facility and support equipment maintenance and spares, and the estimated cost of propellants. It does not include recurring operational costs for the flight hardware (orbiters, tanks, boosters, and interim upper stage )

# CHAPTER 7

# UPPER STAGES

A propulsive upper stage is an essential part of the STS because about 50 percent of the projected payloads being considered for launch through 1991 require orbits that are beyond the shuttle's low-earth orbit capability. An upper stage is needed to attain these higher orbits and to accomplish planetary missions.

An upper stage capability is to be developed in a two-phased approach. The Air Force plans to develop an interim upper stage to be available in June 1980, and NASA plans to develop a full capability space tug to be available in December 1983.

The capabilities to be provided by the interim system will be considerably less than those planned for the space tug. For example, the interim system is to perform only spacecraft delivery missions whereas the space tug is to perform delivery, retrieval, roundtrip, and on-orbit service missions. The interim system may require extensive use of an auxiliary kick stage to provide additional propulsive capability for some NASA payloads

## PROGRAM HISTORY

During 1970 and 1971, NASA and the Air Force made a number of studies to define various upper stage concepts, operating modes, and projected missions. These studies established the desirability and benefits of developing a reusable space tug to be available with the space shuttle in 1979 in order to provide maximum operational, performance, and cost benefits. Because of budget constraints, however, NASA changed the availability date of the tug from 1979 to 1983 and advised the Congress that

existing upper stages would be modified to meet program requirements during the interim period.

NASA and the Air Force continued study efforts during 1972 and 1973 to better define the upper stage requirements, and in late 1973 NASA and DOD agreed that the Air Force would develop the interim upper stage and NASA would develop the space tug.

## PROGRAM STATUS

Both the interim system and space tug programs are in an early stage of definition. Most of the current work consists of various studies to assist in defining an interim system vehicle configuration and to support continuing planning for development of the space tug.

### Interim Upper Stage

Development of the interim system is planned to be accomplished in three phases: conceptual, validation, and full-scale development. In October 1974 the Air Force awarded study contracts to evaluate the use of five existing upper stages as candidates for an expendable vehicle. The contractors are to also evaluate a reusable and a short length version and provide some life-cycle cost elements for their proposed system.

#### Cost

The Air Force has established a ceiling cost of $100 million in 1974 dollars to develop the interim system. This estimate includes research and development, test and evaluation, first production prototype, and system engineering and contract technical services from an aerospace contractor. Estimate of procurement, facilities, and operations costs have not been prepared becuase these program elements have not been defined. The decision concerning reusuability will have a direct impact on the development and operational cost of the vehicle.

NASA estimates that about $25 to $50 million[1] will be required for its peculiar development requirements, including ground handling equipment, payload adapters, computer software programs, and kick stages. NASA's development cost for peculiar system requirements depends on the upper stage selected for modification and the extent of commonality between Air Force and NASA system requirements.

Schedule

The Air Force expects to complete the conceptual phase contracts in June 1975, but it is maintaining a flexible position on the remaining two program phases in an attempt to key interim upper stage development with NASA's progress on the space shuttle. The Air Force plans to delay initiation of full-scale development until successful completion of the orbiter's approach and landing tests because it does not want to make a large financial commitment until more confidence is gained in the shuttle operational date.

Technical

Detailed performance requirements for the interim system have not been defined because the program is still in a conceptual stage. After completion of this phase, the Air Force should be in a position to choose the stage which meets the DOD baseline critical design and performance requirements

Space Tug Program

Program planning for the tug is presently in the preliminary analysis phase. In June 1974, NASA awarded six study contracts to better define critical performance areas and to assist in continuing planning for space tug development.

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[1]1974 dollars.

Cost

NASA's preliminary estimate of tug development costs totals $399.4 million[1] excluding modification cost for previously developed interim system kick stages for use with the space tug. An estimate of these costs is to be developed in 1975.

Based on a projection of 163 space tug flights, NASA estimates that about $209 million will be required for procurement of tugs, kick stages, ground support equipment, and other related items and support.

NASA's most current estimate of operations cost totals $166 million[1] which includes all related costs for launching, recovering, and preparing tugs for relaunch. The cost-per-flight is estimated at about $1 million without a kick stage and $2.2 million with a kick stage.

NASA has not prepared an estimate of space tug facilities cost. This estimate will not be made until after the interim upper stage facilities have been defined.

Schedule

The supporting studies of critical performance areas are scheduled for completion in 1976, and NASA's preliminary planning schedule provides for starting phase B tug definition studies in November 1976. Development of the engine and vehicle are scheduled to start in late 1978

Technical

NASA has established preliminary specifications for space tug system requirements, configuration, ground operations, and flight operations. The tug is to have the capability of meeting all user requirements. It is to

[1]1974 dollars.

deliver 6,000 to 8,000 pounds to geosynchronous orbit[1] and retrieve 3,000 to 4,000 pounds from this orbit.

Within these performance parameters, the space tug is to be capable of accomplishing on a single mission either of the following (1) delivering up to three space craft into geosynchronous orbit and retrieving one, or (2) deploying one planetary spacecraft.

JUSTIFICATION OF INTERIM UPPER STAGE

We believe that it is questionable to spend $125 to $150 million to develop the interim system and kick stages rather than developing the space tug to be operational at about the same time as the shuttle. These costs may be much more if the vehicle is to be reusuable and, even if expendable, a considerable investment will be required for vehicles and associated kick stages to meet planned mission requirements.

Before the interim stage decision in late 1973, NASA's evaluations showed that the space tug should be available at about the same time as the space shuttle in order to achieve maximum-program operational, performance, and cost benefits. One aspect of these evaluations included, for example, an assessment of the cost effectiveness of deferring the space tug beyond 1983 and using a reusable transtage for an interim upper stage. The assessment showed that program cost savings or benefits were reduced an average of $250 million for each year the tug was deferred.

Although data was not available to show the amount of cost savings on program benefits that could be achieved by introducing the space tug earlier than December 1983, the $125 to $150 million development cost plus a rather substantial investment in interim stage vehicles and kick stages

[1]Orbits where payloads or satellites match the earth's revolution and thus are always over the same point on earth.

could be avoided. Operational and performance benefits would, of course, significantly exceed those that could be offered by the interim system.

NASA recognized the cost benefits of going with a full capability tug and discussed this in congressional hearings for fiscal year 1975. The NASA officials also stated that the development of a tug for operation concurrent with the shuttle operational date would require "front end" resources considerably over those expected to be available to NASA or the DOD. The officials also indicated that in addition, minimization of the modification of DOD payloads and the lack of a hard requirement for retrieval of payloads in the early years of shuttle operations "rather naturally" led us to current phased program concept.

Air Force officials advised us that the development of the interim tug is necessary because (1) time is not available to conduct a full tug development and acquisition program prior to shuttle operational date of 1980 without high risk and inefficient cost commitments, (2) technology is not currently available to support the full objectives, and (3) such a major development program at this time would probably divert NASA management and technical expertise from the STS and increase program risk For the interim tug, the Air Force is planning a modification of an existing expendable upper stage vehicle which will meet DOD needs during the period prior to full tug availability.

# CHAPTER 8

# SPACELAB

The spacelab program is a cooperative venture between the NASA and the European Space Research Organization (ESRO). The major program objectives are to (1) provide a versatile laboratory and observatory facilities at the lowest practical cost, (2) reduce time and cost required for space experimentation, and (3) make direct space research possible for qualified scientists and engineers.

## SPACELAB DESCRIPTION

The spacelab is comprised of reusable modules and pallets for accommodating sortie missions lasting from 7 to 30 days. It will be transported to and from orbit in the orbiter cargo bay and will remain attached to the orbiter throughout its mission.

The program presently provides for launching 336 sortie payloads over a 12-year period of 1980 through 1991. These 336 sortie payloads will require 276 dedicated space shuttle flights. At the present time, the Department of Defense does not have any payloads planned but is considering space test program flights for the spacelab

## PROGRAM DESCRIPTION

The overall spacelab program includes the definition, design, and development of modules, pallets, and associated equipment. In addition, the program requires planning for both ground and flight operations, including program elements such as experiment integration, maintenance, mission control, and crew training.

To implement the above program, the NASA Administrator and the ESRO Director General signed a Memorandum of Understanding dated August 14, 1973, which divided responsibility for the program elements between NASA and the Europeans.

ESRO is responsible for the design, development, and manufacture of one spacelab flight unit (consisting of one set of module and pallet sections), one spacelab engineering model, two sets of ground support equipment, initial spare parts, and engineering documentation. ESRO is also responsible for testing and qualifying the above equipment according to NASA specifications and requirements. This equipment is to be provided by ESRO at no cost to the United States.

ESRO agreed to turn over to NASA without charge all drawings, hardware, and documentation relating to the spacelab if it abandons the development, is unable to deliver the flight unit before the first operational shuttle flight, or is unable to meet specifications and development schedules.

NASA is responsible for providing general and technical assistance, developing certain peripheral equipment, and for managing all operational activities after ESRO delivers the spacelab flight unit. NASA is to purchase from ESRO any additional items that are needed to meet spacelab program requirements, provided they are in accordance with agreed specifications and schedules and are reasonably priced.

PROGRAM STATUS

ESRO has completed both the feasibility and definition phases of the program and in June 1974 awarded a contract for the design and development of the spacelab and associated equipment. NASA is continuing its efforts

to better define those portions of the program for which it has responsibility.

Cost

ESRO's development of spacelab, including the deliverable items discussed above, is expected to cost about $370 million In June 1974 Marshall Space Flight Center (MSFC), lead center for the spacelab program estimated NASA's involvement in the program would cost about $355 million.

MSFC's preliminary estimate of $355 million is for the 336 sortie payloads comprised of about $157 million for development, $186 million for procurement, and $12 million for facilities. About $180 million of the $186 million is for hardware to be procured from the Europeans. This hardware is in addition to the quantities to be provided NASA at no cost.

Schedule

A spacelab preliminary design review is scheduled for the second quarter of 1976, and a critical design review is to be held in the first quarter of 1978. The first flight unit of spacelab, necessary ground support equipment software, and certain items of common payload support equipment are to be delivered to NASA in the second quarter of 1979. The first spacelab flight is schedule for the second half of 1980.

Technical

Technical system requirements for design and development of spacelab were baselined in early 1974. The spacelab has a design objective of successfully accomplishing 95 percent of its 7-day missions. The module is to provide the crew with efficient and safe working conditions with easy access to living quarters in the orbiter. The module is to have a shirt-sleeve environment.

The spacelab is to be capable of use for a minimum of 10 years and of low cost refurbishment and maintenance for at least 50 missions of 7 days duration. The design landing weight for the spacelab, including its payload and other associated items, is not to exceed 32,000 pounds.

APPENDIX I

SPACE SHUTTLE CONTRACT DATA AS OF OCTOBER 1974
(Dollars in Millions)

| CONTRACTOR | ITEM | TYPE OF CONTRACT | TARGET COST | BASE FEE | TARGET PRICE | POTENTIAL AWARD FEE |
|---|---|---|---|---|---|---|
| Rockwell International Corporation | | | | | | |
| Space Division | Orbiter Shuttle Integration-Increment I | Cost Plus Award Fee | 918.1 | 41.8 | 959.9 | 35.7 |
| Rocketdyne Div. | Main Engine | Cost Plus Award Fee | | | | |
| | Phase A | | 223.1 | 9.2 | 232.3 | 9.8 |
| | Phase B | | 226.9 | 9.5 | 236.4 | 12.3 |
| | Total | | 450.0 | 18.7 | 468.7 | 22.1 |
| Martin-Marietta Corporation | External Tank | -a- | -a- | -a- | -a- | -a- |
| Thiokol Chemical Corporation | Solid Rocket Motor | -a- | -a- | -a- | -a- | -a- |

a - The value of the Martin Marietta and Thiokol contracts are not expected to be established until December 1974 due to difficulties encountered in negotiating a definitive contract.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
[illegible] D.C. 20546

February 27, 1975

OFFICE OF THE ADMINISTRATOR



Honorable Elmer B Staats
Comptroller General of the United States
Washington, D. C. 20548

Dear Mr. Staats

We have concluded the NASA review of the second staff study by the GAO on the Space Transportation System, and I appreciate the opportunity to comment on the preliminary draft. There are still many points in the report which will require further clarification and better understanding, we will address these as we continue to work with the GAO Staff.

But there is one point I must clarify now. The staff study could be seriously misleading on the development status of the space shuttle and NASA's cost commitment to the Congress to develop the space shuttle for $5.2 billion (in 1971 $) NASA is managing the program to the commitment of $5.2B, on schedule for mid-1979 launch. We have effectively accomplished this by internal schedule adjustments, and, in some cases, deletions of effort, without impacting the performance or safety of the system. This process does involve the imposition of annual cost ceilings, a sound management process which we will continue in the future

I have recently reviewed the development status and cost projections for the program and have concluded there are

adequate funds available, including downstream reserves, to carry out the space shuttle development.

I am personally satisfied we are meeting NASA's commitments on the space shuttle and I have no reason to anticipate cost overruns above the $5.2B 1971$ commitment.

Sincerely,

James C. Fletcher
Administrator