GAO 108982

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

B-183134

March 16, 1979

RELEASED
...the General Accounting Office unless specifically approved by the Office of Congressional Relations.

To The Honorable Edmund S. Muskie, Chairman, and
The Honorable Henry Bellmon, Ranking Minority Member,
Committee on the Budget
United States Senate

Sen 00 90

Your January 25, 1979, letter requested information on the National Aeronautics and Space Administration's (NASA) fiscal year 1979 supplemental request of $185 million for the Space Shuttle Program. NASA estimates that denial of this request would delay the first Shuttle launch date of November 1979 by 6 or more months and would cause substantial increases in required Federal funding of the Space Shuttle during fiscal years 1980-84.

Because of severe time constraints and the complexity of the issue, we discussed with your Office what information we could provide on or about March 16, 1979. We agreed that we would submit information on the following matters:

--NASA's justification for the $185 million supplemental request.

--NASA's rationale in arriving at the $400 million to $600 million cost increase should the request be denied.

--The rationale behind the $787 million additional costs should the request be denied.

--Alternatives to granting the $185 million request.

The justification for the request and the rationale for the cost increases are discussed in the following sections of this letter and are discussed in more detail in enclosures I through III. As requested by your Office, a summary of our previous reports on the Space Transportation System is contained in enclosure IV. With respect to alternatives, the Congress might consider (1) granting the supplemental request

504149

PSAD-79-59
(952237)

rept restrict

with the hope that unforeseen problems will not again throw the Shuttle program off track with a resulting need for more funds, (2) directing NASA to reprogram the $185 million from other programs, which could result in their disruption or elimination, (3) granting some portion of the request and directing NASA to reprogram the balance needed from other NASA programs, or (4) denying the supplemental request, which means there will be added costs unless the Shuttle program content is reduced. Compounding the difficulty of making a choice is the necessity to balance the needs of the Shuttle program with the desirability of maintaining the integrity of the budget resolution process and the need to relate the decision to sound fiscal policy.

NASA's Shuttle program has experienced technical problems which will cost more to resolve than NASA planned for. Accordingly, NASA is asking the Congress for an additional $185 million in fiscal year 1979 funds to keep the program on schedule and to avoid several hundred million dollars in added costs which will be incurred if the requested money is denied. Assuming NASA does not change the program content (such as reducing the number of orbiters or the projected number of Shuttle flights), these costs will be incurred if NASA is not granted the supplemental funds.

Contributing to this situation is NASA's success oriented approach to managing the Shuttle development program. This approach means that unforeseen problems in the development stage cause severe disruptions in the production and operations schedules and significant cost penalties.

Our past reports have pointed out that increased costs arise when the "fly before you buy" concept is violated. This concept is based on the premise that development prototypes should demonstrate success before production and operations schedules are fixed and before significant funds are committed to production.

We cannot vouch for the validity of NASA's cost-penalty estimates. However, we believe that the near-term estimates should be more accurate than the long-term estimates because of the added assumptions involved in projecting further in the future. However, even if NASA is given the funds, unforeseen problems could place the Shuttle program in the same or a more serious situation than exists today. Accordingly, there is no assurance that additional reprograming or supplemental request actions will not be required in the future.

We were unable in the time available to independently estimate the cost growth which would be incurred for the development, production, and operation of the Shuttle if NASA's request is not approved. Of necessity, NASA made many assumptions in calculating the estimates. These assumptions were based on professional judgments, tempered by experience on both the Shuttle program and other development projects. As agreed with your Office, we relied on NASA's figures. However, as evidenced by the following discussions, there are uncertainties surrounding the estimates. In general, the further in the future one attempts to project, the more unreliable the estimates become.

SHUTTLE FUNDING PERSPECTIVE

NASA is requesting $185 million to supplement its approved fiscal year 1979 research and development appropriation of $3,292 million. Not affected by the request are NASA's $910 million research and program management (largely personnel costs) appropriation or its $147 million construction of facilities appropriation.

The $185 million would be applied to Shuttle activity designated as design, development, test and evaluation (DDT&E). NASA estimates that funding for this development activity will amount to about $7 billion through fiscal year 1979 and $7.7 billion upon completion. NASA estimates that production costs for the Shuttle will amount to $3.1 billion. Operating costs through 1992 have been estimated by NASA at $10.2 billion, including reimbursables.

JUSTIFICATION FOR $185 MILLION

According to NASA, the need for additional funds is because of:

--Technical problems encountered in development, manufacturing, and testing of Shuttle systems.

--The need for design changes and weight reductions.

--The requirements of prime contractors and subcontractors for increased engineering and manufacturing effort to fabricate hardware and conduct test activities.

In August 1978, NASA undertook a comprehensive program review to assess the significance of technical problems encountered. The conclusion of the detailed review indicated

that while substantial progress had been achieved, the overall program progress was slower than planned at the time the fiscal year 1979 budget was prepared.

Based on the assessment of the engine development and the status and plans for all elements of the program, it was determined that it was reasonable to continue to plan to accomplish the first orbital test during 1979. Achieving this target is dependent on successfully completing the key remaining ground tests and on encountering no major unforeseen problems. The program review also identified the need for additional funding of $185 million to provide timely support for urgent program requirements.

A more detailed discussion of the need for the $185 million and how it would be applied to Shuttle activities is discussed in enclosure 1.

COST INCREASE OF $400 MILLION TO $600 MILLION IF REQUEST IS DENIED

In its request for $185 million, NASA stated that if the supplemental appropriation is not approved, a delay will occur, and the effect of such a delay on the overall Space Shuttle Program was estimated at $400 million to $600 million.

According to NASA officials, the $400 million cost growth was predicated on the fiscal year 1979 supplemental being denied but additional funding being granted in fiscal year 1980. The failure to receive additional funding in fiscal year 1979 or 1980 would result in a $600 million cost growth to the program. These estimates, prepared in September 1978, represent cost growth to Shuttle development and production programs.

During the latter part of January 1979, NASA revised the $400 million estimate to $583 million. The $583 million is made up of $431 million in development funds and $152 million in production funds. NASA did not reexamine the $600 million figure. The $583 million cost increase in the program is based on disruption of work at prime contractors and subcontractors, an increase in the fixed-cost base because work would be transferred to later program years, and increases in costs because its development program would be extended 5 months.

According to NASA, the increase from $400 million to $583 million is attributable to two factors: (1) since the calculation in September 1978, NASA has decided to maintain the pace of the main engine development program regardless of whether or not the supplemental funds are received and

(2) NASA has anticipated receiving the funds and is spending at a rate which assumes the 1979 DDT&E budget contains the $185 million. At the same time, NASA has constrained spending in the production budget to offset increased spending in the DDT&E budget. NASA believes that to have constrained spending to the fiscal year 1979 budget level would have assured schedule slippages and cost overruns because sufficient time would not have remained after congressional action to effectively spend the additional funds. NASA expects that by the time the Congress acts on the supplemental request, only 3 months of the fiscal year will remain. As a result, if the supplemental is disapproved, NASA's fourth quarter spending plan will have to be modified. NASA believes that congressional disapproval of the supplemental will have to be accompanied by an authorization to transfer funds from production or some other budget line item to the development program to make up any shortfall.

The following table shows the net effect the denial of the supplemental request would have on the development and production programs by fiscal year for the period 1979-84.

	Fiscal year						
	1979	1980	1981	1982	1983	1984	Total
	(millions)						
Development	$ -74	$215	$290	$ -	$ -	$ -	$431
Production	-111	-24	-27	101	89	124	152
Total	$-185	$191	$263	$101	$89	$124	$583

The above estimates are in 1980 dollars and assume no inflation beyond 1980. Converting the $583 million to 1979 dollars results in a figure of $545 million. Details of NASA's computation of the $583 million are contained in enclosure II.

ADDITIONAL COSTS OF $787 MILLION IF REQUEST IS DENIED

NASA estimates that in addition to the increased development and production costs of $583 million, other costs of $787 million would be borne by the Government and users of the space transportation system, as follows:

	(millions)
NASA	$344
Other civil agencies	75
U.S. commercial	187
Foreign	157
Department of Defense	24
Total	$787

These added costs would be caused by the need to keep personnel in place during program extensions, the added cost of expendable launch vehicles to take the place of Shuttle flights, payload losses, and increased costs of the tracking network. It should be noted that the entire $787 million would not be added budget costs. Costs borne by commercial and foreign users would be paid to NASA to the extent they represent user fees. Thus, these costs would be offsets to direct appropriations required by NASA.

Details of NASA's computation of the $787 million are contained in enclosure III.

IMPACT OF ADDED COSTS ON BUDGET FUNCTIONS

The Federal budget is categorized by budget functions. The $185 million supplemental request, if granted, would breach the fiscal year 1979 $5.2 billion ceiling set for budget function 250--General Science, Space, and Technology. The $583 million of increased costs would also come under budget function 250. Of the $787 million added costs discussed above, $344 million would come under budget function 250; $24 million would come under budget function 050--Defense; and the $75 million applicable to other civil agencies would come under various other budget functions.

ALTERNATIVES TO GRANTING THE $185 MILLION SUPPLEMENT

In view of the Senate Budget Committee's concerns that the supplement would breach the budget ceiling set for function 250 (General Science, Space, and Technology) of the

Second Budget Resolution, alternatives such as reprograming might be considered as sources of funds for the Shuttle program.

In testimony given before the Subcommittee on Space Science and Applications, Committee on Science and Technology, House of Representatives, on February 15, 1979, the Associate Administrator for Space Transportation Systems of NASA stated that various alternatives were considered for coping with the increased funding requirement. The alternatives included:

--Reprograming $185 million from other NASA programs.

--Delaying DDT&E even further.

--Reallocating $185 million from production to DDT&E.

--Reducing program content.

These alternative approaches were evaluated by NASA; however, they were not considered practical due to inefficiencies, program disruptions, and increased runout costs.

The Associate Administrator stated that given the magnitude of the identified Shuttle funding problem in fiscal year 1979, reprograming from other programs to solve the Shuttle problem was not a feasible alternative.

The Associate Administrator went on to state that transferring funds from production to development would require that follow-on orbiters be delayed even further and at increased costs. This would cause further serious disruption in the manufacturing flow with increased manpower requirements. Further reductions in program content were not considered possible--the Shuttle program requirements reviews in 1974, 1975, and 1976 had already reduced program content to a minimum. For example, a December 1974 review resulted in the elimination or delay of a number of work tasks, test articles, and test programs.

We discussed the above with NASA officials and they informed us that they had considered in August 1978 what alternatives were available. They evaluated them and, for various reasons, considered them impractical. We were informed that NASA considered taking the funds from all new initiatives for the coming year, but this only amounted to

$23 million. They also considered the option of canceling the Galileo program, but decided that while there was a marginal launch window 1/ in 1983, there was a long time (7 years) until the next available window and decided to continue with the January 1982 launch date.

Even by canceling Galileo, they estimated that only $50 million of the $79 million in fiscal year 1979 Galileo funds would be recoverable. Other programs or combinations thereof were considered but were not judged practical. While reprograming between NASA budget line items would have been quicker, NASA could not make a unilateral decision of that magnitude affecting other program areas. They believed that congressional reaction would have been very pronounced had they done so.

NASA officials stated that they had never really considered delaying the development program further or reallocating the $185 million from the $458 million production budget to development. A further delay of the development program would have created a greater overlap between the development and production programs and would have resulted in higher costs. The reallocation of funds from production was not a viable alternative. With a reallocation, a supplemental for the production funds would have had to be requested. The House Conference Report No. 95-1569 directed NASA not to reprogram any fiscal year 1979 funds from Shuttle production unless a supplemental request to restore such funds had been transmitted to the Congress.

POSSIBILITY OF FUTURE PROGRAM SLIPPAGE

The Shuttle development schedule has been "success oriented," which means it could be met only if no major technical problems were encountered. NASA officials established tight time frames, because they believed that such an approach would result in completing the development program at the earliest possible date for the least cost. Such an approach is based on the theory that "work expands to fill the time available." The question arises as to the extent to which such an approach should be pursued in a research and development program which is so tightly linked to a production

---

1/A time frame during which the planetary alinement is such that the spacecraft can perform its mission, but not to the desired capability.

program and an operational schedule. As evidenced by NASA's projections, today's technical development problems can cause significant cost growth and schedule slippage in the production and operations phases of the program.

NASA's supplemental request states that it was determined that it was reasonable to continue to plan to accomplish the first orbital test during 1979. However, achieving this target is dependent on successfully completing the key remaining ground tests and on encountering no major unforeseen problems.

There have been past slips in the Shuttle program schedule due to technical problems and there could be future slips. In its August 1978 comprehensive review, NASA officials stated that the probability of achieving the first manned orbital flight in September 1979 was low (15 percent) and in March 1980 was high (85 percent). The first manned orbital flight is now scheduled for November 9, 1979.

According to a February 1979 National Research Council Ad Hoc Committee for Review of the Space Shuttle Main Engine Development Program report, it appears unlikely that the first manned orbital flight will occur before April or May 1980. The only way it could be somewhat earlier is if the engine testing program encounters minimal or no difficulties. According to the Committee, this is an improbability, considering the previous test history of the Shuttle main engine.

The Committee report 1/ indicated that the plans to perform flight certification tests on the engine that will take the Shuttle and its first crew into orbit are premature. The engine that will ultimately fly the Shuttle will not be the same configuration that will be tested. The report points out that at the heart of the delay is NASA's "success dependent" strategy which is based on the concept that each engine part will work properly when first installed. The report also indicates that while such a strategy offers potential savings in time and equipment, each time a part fails an entire engine is jeopardized and time and money are lost.

1/"Second Review--Technical Status of the Space Shuttle Main Engine," dated February 1979. The first review, dated March 1978, resulted in recommendations which, in part, required NASA to request a supplemental.

As your Office requested, we did not obtain written comments from NASA. However, we discussed the above matters with responsible officials and considered their comments where appropriate. Your Office also requested that we not release this report for 30 days or until you have made it public.

Comptroller General
of the United States

ENCLOSURE I

JUSTIFICATION FOR $185 MILLION

SUPPLEMENTAL REQUEST

The National Aeronautics and Space Administration (NASA) is requesting $185 million of additional fiscal year 1979 money to avoid further delays in the Space Shuttle Program and increased cost growth in future years. Granting the request would increase NASA's fiscal year 1979 Shuttle funds from $1,443.3 million to $1,628.3 million.

In August 1978, NASA undertook a comprehensive program review to assess the significance of technical problems encountered in several areas. The conclusion of the detailed review indicated that while substantial progress had been achieved, the overall program progress was slower than planned at the time the fiscal year 1979 budget was prepared.

Based on the assessment of the engine status and the status and plans for all elements of the program, it was determined that it was reasonable to continue to plan to accomplish the first orbital test during 1979. Achieving this target is dependent on successfully completing the key remaining ground tests and on encountering no major unforeseen problems. The program review also identified the need for additional 1979 funding of $185 million to provide timely support for urgent program requirements. If obtained, the additional funding will be applied to continue development efforts on schedule and to restore the funding needed for production activities.

A comparison of NASA's original fiscal year 1979 Shuttle budget estimates and its current estimate is as follows:

ENCLOSURE I

	1979 Budget	
	Original estimate	Current estimate (note a)
	(millions)	
DDT&E (note b):		
Orbiter	$536.5	$ 654.9
Main engine	176.7	161.4
External tank	80.5	107.6
Solid rocket booster	63.5	100.2
Launch and landing	128.1	146.2
Subtotal	985.3	1,170.3
Production:		
Orbiter	401.0	344.1
Main engine	18.0	81.3
Launch and landing	11.0	12.4
Spares and equipment	28.0	20.2
Subtotal	458.0	458.0
Total	$1,443.3	$1,628.3

a/Includes the $185 million requested.

b/Design, development, test and evaluation.

A breakdown of the $185 million by program element for DDT&E and production follows.

	DDT&E	Production	Supplemental requested
	(millions)		
Program element:			
Orbiter	$118.4	$-56.9	$ 61.5
Main engine	-15.3	63.3	48.0
External tank	27.1	-	27.1
Solid rocket booster	36.7	-	36.7
Launch and landing	18.1	1.4	19.5
Spares and equipment	-	-7.8	-7.8
Total	$185.0	-	$185.0

It should be noted that NASA has assumed that it will receive the additional funds and has included them in its funding plans.

According to NASA, the request is a result of development problems; program changes; and the need for more work than was previously planned, particularly in the fabrication and assembly of flight and test hardware and in systems qualification and certification. The impact of these difficulties has been hardware schedule delays, increased engineering and manufacturing requirements in prime and subcontractor efforts, and significant deferrals of work into fiscal year 1979.

NASA states that fabrication activities on the second and subsequent orbiters have been proceeding on a constrained basis to keep development efforts on the new schedule directed towards the first orbital flight in late 1979.

A summary of the reasons for the funding request for each of the elements follows. The information has been provided by NASA officials and has not been verified with either the prime contractors involved or with the project managers for each of the programs.

ORBITER

According to NASA, an additional $118.4 million is needed for DDT&E work related to the orbiter. This $118.4 million requirement is partially offset by the 7-month deferral of manufacturing and assembly efforts for Orbiter 099 and the 3-month deferral of Orbiters 103 and 104. The deferral means that $56.9 million less effort will be expended on the production orbiters in fiscal year 1979.

According to NASA, the net increase in funding of $61.5 million is caused by a combination of mandatory design changes, technical problems in fiscal year 1978 that caused work to be deferred in fiscal year 1979, and the need for more work than was previously planned.

NASA's supplemental request lists the following as some of the reasons for the need for more money:

--During fiscal year 1978, test results, engineering analysis, and systems evaluation identified the need for more technical changes than were previously anticipated.

--The effort required by the prime contractor to manufacture the primary structures for Orbiter 102, install the subsystems, and assemble the vehicle was greater than previously estimated.

--A number of subcontractors also experienced technical problems and increased cost requirements in fiscal year 1978.

--Orbiter software problems and a large number of changes caused increased requirements.

--Cost increases also occurred on the extravehicular mobility units.

--A schedule stretchout of the main propulsion tests, due to main engine problems and implementation of a phased approach to the main propulsion certification, requires additional funds in fiscal year 1979.

--An orbiter weight savings program has been implemented for the production of Orbiters 099, 103, and 104.

Within the orbiter project, the need for the increase in funding is as follows:

	(millions)
Prime contractor	$ 98.2
Marshall Space Flight Center	15.3
Johnson Space Center	6.0
Reduction in contract administration changes	-1.1
Total	$118.4

The $98.2 million for the prime contractor is required due to three factors: (1) an increase of engineering and manufacturing man-hours ($19.8 million), (2) a cost growth in the subcontractor effort, due to the deferral of work from prior years and unanticipated technical problems ($34.2 million), and (3) technical changes, redesign effort, and systems engineering work ($44.2 million).

Some specifics with regard to the man-hour increases are that there have been approximately 1,055 secondary structures added to the primary structure and the fabrication and assembly man-hours required on the entire structure were underestimated.

The subcontractor increases are due to several factors:

--The production of an acceptable thermal protection system or surface insulation tiles was lower than estimated, and a 2-month strike delayed deliveries.

--Producibility problems occurred with the reaction control system and orbital maneuvering systems.

--Changes were required to include the latest loads data.

The auxiliary power unit had technical problems which resulted in more tests and resolution effort. Also, revisions were necessary to upgrade a number of operational capabilities.

The technical changes and redesign work has been caused by an increase in requirements for bottles for the main engine helium purge system. The backup flight control system was changed to add abort capabilities. The engine base heat shield and other system integration tasks were modified or added.

The increases at the Marshall Space Flight Center are basically due to the extension of the main propulsion test and the mated vertical-ground vibration tests. These have caused an increase of $9.0 million and $3.2 million, respectively.

The Johnson Space Center support costs have increased $14.1 million, mainly because of problems in software development ($5.1 million), simulator growth ($2.1 million), and a cost growth in the extravehicular mobility unit ($6.9 million). Deferrals and reductions in work offset $8.1 million of this increase to arrive at the net $6.0 million increase.

MAIN ENGINE

The main engine development estimate for fiscal year 1979 has decreased by $15.3 million. This decrease in the development is due to the transfer of three main engines to production to be consistent with the conversion of the orbiter structural test article to flight status in the production phase. Also, there was a reduction in propellant needs for the East Coast test site. These reductions were partially offset by NASA's activation of a third engine test stand at Santa Susana late in fiscal year 1978. The test

ENCLOSURE I

stand was added to enhance development progress by establishing an increased capability to conduct engine system testing. The test stand capability was in response to the recommendations of the National Research Council's Ad Hoc Committee for review of the Space Shuttle main engine development program. The need for development funding was further impacted by the deferral of work necessitated by analysis and resolution of engine test problems.

The following schedule shows a breakdown of funding actions which impact the main engine development program.

	(millions)
Transfer of engines to production	$-26.0
Reduce propellants	-11.5
Activation of test stand	15.0
Test problems	7.2
Net reduction	$-15.3

The increased need for production funds is due to the following factors:

	(millions)
Transfer of engines from development	$26.0
Acceleration of engine delivery	8.0
Design changes, spares, and tooling	29.3
Total	$63.3

The transfer of the engines into production resulted in an increase in the production budget. It should be pointed out that the additional production funding needed for the main engine is being obtained by NASA from a shifting of funds within the production budget. There has been no reprograming of funds from development to production.

The accelerated delivery of engines was recommended by the ad hoc committee to provide additional hardware in the event it is needed for testing.

The $29.3 million needed is a result of numerous factors, including, for example, the need for critical parts, deferral of work into fiscal year 1979, and fabrication growth.

ENCLOSURE I

EXTERNAL TANK

The need for $27.1 million in additional fiscal year 1979 funding for the external tank is due largely to technical design changes, increased contractor manpower, a weight reduction program, additional ground test support and work deferred into fiscal year 1979.

The following table depicts the costs associated with each.

	(millions)
Technical design	$ 9.2
Work deferred into FY 1979	7.4
Increased manpower	2.0
Ground test support	4.5
Weight reduction	4.0
Total	$27.1

With regard to the increase in technical design, a revision of the aerodynamic loads, a change in the predicted ascent propulsion lines and cable trays, and a large increase in the amount of thermal protection coverage were required. Spray-on foam insulation and ice protection systems were also added.

As a result of these design changes, work that was scheduled in fiscal year 1978 in efforts relating to manufacture and assembly had to be deferred until fiscal year 1979. The changes also resulted in increased requirements at the Michoud Assembly Facility.

Additional maintenance and test support is required, due to the stretchout of the main propulsion, ground vibration, and structural test programs.

NASA presently has a program to reduce the weight of the external tank by 4,000 pounds. The weight reduction program is aimed at reducing the external tank an additional 2,000 pounds to be able to meet the performance requirements of missions, such as the Galileo launch scheduled for January 1982.

SOLID ROCKET BOOSTER

According to NASA, increased funding is needed for most of the subsystems on the booster. In the structures area a

ENCLOSURE I

number of changes occurred, including modification to the aft skirt skin forming tools and changes to the heat shield attachments. Cost increases were also caused by welding and assembly problems of the forward and aft skirts. Redesign changes to components being procured by the booster assembly contractor and the deferral of ground support equipment from fiscal year 1978 resulted in the need for additional funding. Also, checkout software support to the launch processing system was greater than previously planned.

The prime contractor for the solid rocket motor experienced increased cost requirements. Other subsystems, such as integrated electronics, thrust vector control, and the recovery system all experienced changes due to test results and engineering updates.

The following is a breakdown of the additional requirements by cause:

Cause		(millions)
Solid rocket motor changes		$ 2.9
Solid rocket motor growth/overrun		14.7
Deferral of qualification motor from FY 1978		4.6
Deferred procurements from FY 1978 to aline with revised schedule		7.2
Subsystem changes caused by testing		10.9
Subsystem changes caused by underestimates and technical problems		6.9
Subtotal		$47.2
Less:		
Defer manufacture of 4 motor nozzles into FY 1980	$9.0	
Deferral of booster assembly contractor	1.5	10.5
Total funding required		$36.7

The solid rocket motor changes are the result of development motor firing tests run by the contractor.

The growth/overrun is mainly because one of the development motors had to be disassembled, recast, and reassembled due to excessive propellant technical problems. Also, development motor casting segments were damaged and had to be replaced.

The manufacturing of a motor in fiscal year 1978 to be used in qualification testing program was deferred and put into fiscal year 1979, because of redesign and scheduling problems.

Because of the revised schedule, some subsystem procurement buys from fiscal year 1978 were slipped to fiscal year 1979. These include booster assembly and checkout, integrated electronics, and structural work. There were some savings in fiscal year 1978 which were used to offset the additional requirements.

Because of development test results, subsystem changes had to be made including a redesign of the aft strut shoes, structural changes, adding redundant integrated electronics power supplies, redesign of the thrust vector control, and other subsystems.

Also, there was a drogue parachute failure and redesign and an overrun and controller test failures in the auxiliary power unit.

The offset of $10.5 million alines the booster assembly and manufacture of the motor nozzles to meet the revised schedules.

LAUNCH AND LANDING

The increase of $18.1 million in the fiscal year 1979 funding estimate for development is due to the deferral of fiscal year 1978 effort and increased requirements in fiscal year 1979. Due to the delay in shipment of the first flight elements to Cape Kennedy, efforts such as ground support equipment procurement, installation, and checkout; propellant purchases; and launch processing system equipment buys were deferred into fiscal year 1979.

In addition, more ground support equipment and manpower were required than anticipated. Also, the effort required to

activate the various station sets such as the orbiter processing facility, the hypergolic system maintenance facility, and the disassembly area for the solid rocket booster was greater than planned. There has been a funding increase in the launch processing system. This increase is due to additional memory capacity of the central data system and the addition of a third shift for operations.

The additional $1.4 million in production is needed for the procurement of additional ground and launch support equipment.

SPARES AND EQUIPMENT

The reduction of $7.8 million needed in the production budget for spares and equipment is because the crew equipment and orbiter flight spares have been deferred into fiscal year 1980. This is consistent with the schedule adjustment of the first orbital flight and the associated delay of 9 months in the initial operating capability.

ENCLOSURE II

COST AND SCHEDULE PENALTIES

IF REQUEST IS DENIED

In its request for $185 million for the Shuttle, NASA states that if the supplemental appropriation is not approved, a delay will occur, and the effect of such a delay on the overall Space Shuttle Program costs is estimated at $400 million to $600 million.

According to NASA officials, the $400 million cost growth was predicated on the fiscal year 1979 supplemental being denied but additional funding being granted in fiscal year 1980. The failure to receive additional funding in fiscal year 1979 or 1980 would result in a $600 million cost growth to the program. These estimates, prepared in September 1978, are expressed in 1980 dollars. Both figures represent cost growth to Shuttle development and production programs.

REVISED ESTIMATE

During the latter part of January 1979, NASA revised the $400 million estimate to $583 million. NASA did not reexamine the $600 million figure. According to NASA, the increase of $183 million is attributable to two factors: (1) since the calculation in September 1978, NASA has decided to maintain the pace of the main engine development program regardless of whether or not the supplemental funds are received and (2) NASA has anticipated receiving the funds and is spending at a rate which assumes the 1979 DDT&E budget contains the $185 million. At the same time, NASA has constrained spending in the production budget to offset increased spending in the DDT&E budget. NASA believes that to have constrained spending to the fiscal year 1979 budget level would have assured schedule slippages and cost overruns because sufficient time would not have remained after congressional action to effectively spend the additional funds. NASA expects that by the time the Congress acts on the supplemental request, only 3 months of the fiscal year will remain. As a result, if the supplemental is disapproved, NASA's fourth quarter spending plan will have to be modified. NASA believes that congressional disapproval of the supplemental will have to be accompanied by an authorization to transfer funds from production or some other budget line item to the development program to make up any shortfall.

ENCLOSURE II

The following table shows the net effect the denial of the supplemental would have on the development and production programs by fiscal year for the period 1979-84.

	Fiscal year						
	1979	1980	1981	1982	1983	1984	Total
	(millions)						
Development	$ -74	$215	$290	$ -	$ -	$ -	$431
Production	-111	-24	-27	101	89	124	152
Total	$-185	$191	$263	$101	$ 89	$124	$583

The above estimates are in 1980 dollars and assume no inflation beyond 1980. Converting the $583 million to 1979 dollars results in a figure of $545 million.

METHODOLOGY USED TO COMPUTE COST GROWTH

The estimated $583 million in cost growth should the supplemental be denied is comprised of a $431 million increase in the development program and a $152 million increase in production costs.

The estimated increase in the cost growth would be based on four factors, namely:

--Disruption of work at the prime contractors.

--Disruption of work at the subcontractor level.

--An increase in the fixed-cost base resulting from the transfer of work to later program years.

--Increase in fixed and variable cost due to extension of the development program by 5 months.

The costs associated with each of the above categories are depicted as follows:

ENCLOSURE II

	Development	Production
	(millions)	
Prime contractor	$ 74	$ 82
Subcontractor	37	30
Increased fixed base	120	40
Extension of program	200	-
Total increases	$431	$152

Development increases

In computing the increases for the development program, the deferral of the work would be impacted in 3 fiscal years--1979, 1980, and 1981. NASA estimates that as of June 30, 1979, $892 million of the baseline DDT&E budget of $1,170 million will have been spent and the cost to be covered will be $278 million. Of the $278 million, $111 million is a variable cost that could be deferred for the remaining 3 months in fiscal year 1979 to fiscal year 1980. NASA assumes that the work deferred will be at the prime contractor level and that there will be a cost disruption penalty of $37 million, or one-third of the variable cost. Also, in fiscal year 1980, NASA assumes that it will take the prime contractor 1 month to get the work force up to par and that the additional startup costs will be another $37 million. Thus, the total cost increase at the prime contractor level would be $74 million.

The $37 million increase in subcontractor effort is composed of a $22 million cost increase in fiscal year 1980 and a $15 million increase in fiscal year 1981. The basis for the increases is the same as that for the prime contractor, except that the penalty on the deferred work will amount to 20 percent. The 20 percent is applied against the slip of $111 million from fiscal year 1979 to fiscal year 1980 to compute the $22 million. Because of slips in the program, there will be $75 million of work pushed from fiscal year 1980 into fiscal year 1981, which accounts for the remaining $15 million (20 percent of $75 million).

NASA bases its estimate of $120 million for the increase in fixed base on the assumption that it would be necessary to hold the development schedule slips to 5 months and that it would have to support a higher level of work in fiscal year 1980 than it had anticipated. In fiscal year 1979, NASA supported a fixed base which averages $50 million a month and

planned to support a $30 million average in fiscal year 1980. This reduction is because the development program is nearing completion and the production program would be increasing. As a result of the deferral, NASA contends that it would have to raise the fixed-based level in fiscal year 1980 to $40 million to prevent further slippage and that this would result in an additional $120 million.

NASA estimates that if the supplemental is denied, the development program would be extended 5 months into fiscal year 1981 and that the average monthly cost growth would be $40 million, resulting in a $200 million increase.

The following table depicts the cost increase or decrease for the 3-year period, based on the above.

	FY 79	FY 80	FY 81
	(millions)		
Spent thru June 30, 1979	$892	$ -	$ -
Available cost	278	-	-
Variable cost slip in 1979	-111	111	-
Disruption penalty--prime contractors	37	37	-
5 month slip in 1980	-	-75	-
5 month slip in 1981	-	-	75
Disruption penalty-subcontractors	-	22	15
Fixed-base support	-	120	-
Program extension in 1981	-	-	200
Total	$-74	$215	$290
Net Total		$431	

Production increases

NASA estimates that the denial of the supplemental would have an impact on the production program in fiscal years 1979 to 1984 and that the net increases would amount to $152 million. NASA notes that the program disruptions would likely cause a slip of from 6 to 12 months on the production vehicles.

ENCLOSURE III

ADDITIONAL COSTS IF REQUEST IS DENIED

NASA estimates that in addition to Shuttle development and production costs, other costs will be incurred if the supplemental is denied. These costs would be borne by the Government and all users of the Space Transportation System (STS). This cost growth is estimated at about $787 million and is based on the assumption that the fiscal year 1979 supplemental will be denied but funding will be granted in fiscal year 1980. The cost growth is expressed in fiscal year 1980 dollars. In general, the estimates represent cost increases during the expected 12 year operating life of the system. The estimated $787 million cost increases projected by NASA would be absorbed by users, as follows:

User	(millions)
NASA	$344
Other civil agencies	75
U.S. commercial	187
Foreign	157
Department of Defense	24
Total	$787

It should be noted that the entire $787 million would not be added budget costs. Costs borne by commercial and foreign users would be paid to NASA to the extent they represent user fees. Thus, these costs would be offsets to direct appropriations required by NASA.

The costs and the areas in which they will occur are as follows:

	(millions)
STS operations	$105
Transportation	406
Payload losses	216
Tracking network	60
Total	$787

The following is a discussion of the rationale used by NASA in computing the cost increases.

STS OPERATIONS

This $105 million is an increase attributable to a 6-month extension of the operations capability development

ENCLOSURE III

program of STS and the development test and mission operations support. The development contractor must demonstrate the design feasibility of Spacelab, the multipurpose payload support equipment, and other facilities and hardware and must also train operating personnel. Since these development personnel are already in place and cannot be released until after the orbital flight tests, their services would have to be extended for any delay of STS operations--an assumed 6 months in this instance.

NASA computed the $105 million by estimating the cost of personnel expected to be employed at the beginning of operations, adjusting for nonessential operations personnel during delay, and projecting the cost of a 6-month extension. A detailed analysis of the various contracts involved was not made.

TRANSPORTATION

The $406 million increase in transportation costs is the net difference between the increased cost of using expendable launch vehicles (an expendable vehicle is a rocket which is lost after launch) and a reduction in STS operating costs. NASA estimates the costs as follows:

	(millions)
Additional expendable launch vehicles	$626
Less reduced STS costs	-220
Increased transportation costs	$406

According to NASA, delay of the operational program would force its customers, whether Government or non-Government, to decide whether to delay the launch of their payload until the STS is operational or to launch the payload on an expendable vehicle to avoid a delay.

NASA estimated that 28 expendable vehicles would be needed for those customers who would elect to launch their payloads. Of the 28 expendable vehicles to be used, 9 are for the U.S. Government, 8 for commercial users, and 11 for foreign governments. NASA plans to use a number of different vehicles, and computed the additional $626 million based on the vehicle to be used.

ENCLOSURE III

NASA reduced the estimated cost of the expendable vehicles by $220 million for the Space Shuttle launches that would not be made during the time frame. NASA deleted 15 Shuttle flights, because the Shuttle is able to carry a larger payload than the vehicles and, accordingly, a number of payloads could be carried on one flight whereas the expendable vehicles are usually limited to one payload. Associating a cost with the 15 fewer flights was accomplished with cost curves depicting total operating cost for various levels of activity.

PAYLOADS LOSSES

The cost increases of $216 million associated with payload losses are one of two types. The first are those at the Kennedy Space Center and amount to $73 million. The second, amounting to $143 million, are at Vandenberg Air Force Base.

The $73 million at Kennedy is attributable to the increased development costs that customers would have to incur should they elect to defer their payload until the Shuttle is operational rather than using expendable vehicles. NASA computed the increased costs by determining the number of days each payload was expected to be delayed, then computed the additional development costs per day that would be incurred by the delay. The computation was based by assuming that 75 percent of the costs for each satellite are fixed. The cost per day was based on a 3-year payload cycle of costs as determined in a 1977 Office of Management and Budget study for payload programs. The additional costs were the result of multiplying the number of days delayed by the cost per day at 75 percent.

The $143 million increase in payload losses consists of potential savings lost, because some of the earlier payloads cannot be recovered and reused. The computation is based on the fraction of overall payload benefits attributed to specific programs. This was taken from an update of the 1977 Office of Management and Budget study.

TRACKING NETWORK

NASA's new Tracking and Data Relay Satellite System is being developed by and will be leased from Western Union Telegraph Company. The system, which will consist of a series of satellites plus a single ground station, is intended to be more efficient than and will replace NASA's network of ground stations now in operation. The $60 million increase

ENCLOSURE III

for this factor represents the cost of operating the present network for 6 additional months. Tracking and Data Relay Satellite System satellites cannot be placed in orbit until Shuttle operations commence.

ENCLOSURE IV

SUMMARY OF OUR PRIOR STS REPORTS

The Space Shuttle is one of the systems undergoing development by NASA as part of its STS. Over the years, we have issued a number of reports, including staff studies which have dealt with STS, including the Space Shuttle. A summary of each report follows.

THE SPACE TRANSPORTATION SYSTEM, DATED JUNE 1974

This staff study was the first issued. It provided data on the cost, schedule, and technical performance of STS. It also provided matters for the consideration of the Congress.

Estimated cost of STS

The study pointed out that NASA has not developed an estimate for the total cost of the development and operation of STS, but has established baseline cost estimates for four STS elements.

The estimates were:

1. $5.150 billion for research, development, test and evaluation of the Space Shuttle.

2. $300 million for NASA's Space Shuttle facilities.

3. $1 billion for refurbishment of the two development orbiters and production of three additional orbiters.

4. $10.45 million as the average cost per flight for the Shuttle, based on a 439 flight mission model.

It was NASA's position that baseline cost estimates should be identified with definitive program content and/or specific system configuration. We believed that baseline estimates should be prepared early in program definition and that, if necessary, a range of costs may be provided to bracket the various system configurations under consideration.

Schedule

The staff study showed that NASA had established schedule baselines for certain critical milestones for STS and that changes had occurred from the baseline date of March 1972 to the fiscal year 1975 request. The changes in the schedule had caused the milestones to slip about 12 months. Since the original production schedule was established to produce the most efficient flow consistent with anticipated annual funding, NASA stated that the production stretchout may increase STS costs because of inflation and a less efficient production schedule.

Performance

The staff study stated that NASA had established performance requirements to serve as guidelines for the design and development of the Space Shuttle Program. At the time of the study, numerous changes had been made to the performance requirements at all levels; but, according to NASA personnel, the changes had not significantly altered overall program objectives and cost projections.

The staff study discussed the status of three characteristics:

--Payload-to-orbit--the weight the Shuttle System is expected to be able to place in orbit.

--Orbiter weight--the weight of the orbiter designed to a "dry weight" limitation (weight without payloads, fuel, and so forth.)

--Thermal protection system--the thermal protection system protects the primary airframe structure of the orbiter vehicle from the effects of aerodynamic heating during ascent and entry.

Matters for consideration of the Congress

The staff study pointed out several areas which warrant special attention:

1. The absence of baseline cost estimates for some elements of STS limits visibility and

reduces management's capability to monitor and control the total STS effort. The study suggested that the Congress may wish to require NASA to provide cost estimates for all elements of STS.

2. Two high-risk areas identified by NASA were the Space Shuttle's thermal protection system and the orbiter weight.

3. The study suggested that the Congress may wish to have NASA explain the impact the change in planned tug capabilities and the extension of operational dates for the Vandenberg Air Force launch sites will have on the program. The Vandenberg site operational date was 2 years later than assumed.

SPACE TRANSPORTATION SYSTEM, DATED FEBRUARY 1975

This was the second staff study issued and it updated the program's status through September 1974.

The study stated that, in our opinion, the risk of encountering cost overruns on the Space Shuttle development program had increased. At the time of our review, realistic internal NASA projections of expected runout costs for individual projects and related reserves were not available, because NASA management limits cost estimates to predetermined annual ceilings during their budgeting process. At the 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.

The staff study stated that adjustments had been made to delete, defer, or reprogram work to aline 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.

ENCLOSURE IV

In December 1974, NASA concluded an in-depth requirements review designed to realine 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 believed feasible. NASA believed that it was back on track with adequate reserves for contingencies through the balance of the DDT&E program.

Matters for consideration of the Congress

The staff study set forth several matters for the consideration of the Congress. These were:

1. The Congress may wish to require NASA and the Department of Defense to provide cost estimates for all STS elements and related costs together with an analysis of the current status of each element, regardless of the source of financing.

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

3. The Congress may wish to examine in detail the changes in NASA's actions during forthcoming budget hearings.

4. NASA's present user charge policy may not be appropriate for STS.

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.

STATUS AND ISSUES RELATING TO THE SPACE TRANSPORTATION SYSTEM

This staff study dated April 21, 1976, was primarily concerned with the Space Shuttle's status and progress related to cost, schedule, and performance and the rationale and assumptions inherent in the 1973 mission model. The 1973 model was used to compare the revised STS program's cost effectiveness with expendable launch systems.

ENCLOSURE IV

Program costs

The staff study stated that the development program will experience cost growth of more than $1 billion. It is important to recognize that some cost growth is not controllable by NASA, as is the case with the $524 million resulting from increases in inflation. The remaining $621 million also contains inflation which could be categorized as controllable, because that inflation would not have been incurred if NASA had not decided to delay certain actions to the later years of the program. A primary objective of NASA's decision to delay work was to reduce funding requirements for the early period to stay within overall agency funding limitation imposed by the Office of Management and Budget.

NASA did not agree with the $1 billion cost growth projection, primarily because it has never taken an official position on the amount of inflation which will be experienced.

Changes in other system elements

The status of other program elements, including production, cost per flight (operations), construction of facilities, upper stages, and the Spacelab had changed since the February 1975 report. Generally, budget limitations have caused reductions and delayed starts in the other program elements. These, in turn, have increased costs because of inefficiencies in the revised development plan and the additional inflation which may be experienced because of the delays.

Changes in the Shuttle's DDT&E

The staff study stated that Office of Management and Budget funding constraints have resulted in a change in NASA's development plan for the Space Shuttle's DDT&E program. In addition to the cost impact discussed above, the following observations were made:

--The development completion date had been extended.

--Development schedules had been compressed. As a result, less time will be available to solve major technical problems that may occur.

--Development testing had been reduced to the extent that there was less testing planned than on past programs.

--Significant contingency reserves have already been allocated. In total, program reserves have been declined by over 55 percent since NASA initiated the development program, while only 30 percent of the projected funding had been obligated as of October 31, 1975. This could result in additional funds being needed before the program is completed.

NASA believed the program adjustments discussed above had been reasonable and had not resulted in unacceptable cost, schedule, or technical risks.

Although the effect of the interaction of the above factors on DDT&E was not precisely predictable, historical evidence suggests the probable outcome will be increased cost and reduced performance, coupled with a longer period of uncertainty as to whether the Space Shuttle can reliably carry out its mission.

Questions for the Congress

The study set forth some questions that should be asked by the Congress in future deliberations on authorizing and appropriating funds for development, production, and operational phases of the STS program.

--Should separate budget line items be established for Space Shuttle development, production, and operations to insure better program visibility? The completion date for the development program may need to be extended to encompass testing planned to verify the capabilities of the Space Shuttle. Should the cost of all development tests be included as a cost of the development program?

--Should funding authority for orbiter production and western test range facilities be delayed until the benefits of a single STS could be substantiated?

ENCLOSURE IV

THE SPACE TRANSPORTATION SYSTEM: PAST, PRESENT, AND FUTURE

This report dated May 27, 1977, described the technical problems NASA had encountered in developing STS. It recommended that the Congress assess the advantages and disadvantages of initiating procurement of the third orbiter and delaying funding of orbiters four and five.

The report pointed out that the decision to proceed with or delay production of the three orbiters is complex, with little assurance that either option selected will ultimately prove to be the best decision. NASA officials believed the best approach was to proceed with production at that time. Department of Defense officials believed the program should proceed as planned by NASA.

The report stated that according to NASA, five orbiters would provide an assured launch capability for all users and most expendable launch vehicles could be eliminated. NASA studies had also shown that a delay of 3 years in the production of orbiters three, four, and five could result in a cost increase of $1.6 billion in 1978 dollars.

There was little doubt that production should proceed if (1) no technical problems were encountered, (2) space activity increases twofold as predicted, and (3) the cost of operation is significantly reduced over expendable vehicles. Under those conditions, a delay in production would have increased costs, but not to the extent projected by NASA.

The report also stated that there are no assurances that technical problems would not be encountered, that space activity would increase twofold, or that STS would greatly reduce the cost of space operations. Information presented in the report suggested that these three prerequisites for proceeding with production might not be met.

According to the study, the most cost-effective approach is usually to delay production until there is adequate assurance that the system will accomplish its objectives. An issue for congressional decision was whether a delay in production, and thus a delay in achieving a more extensive manned program than two flights a month, would adversely affect national prestige. If so, the Congress might wish to proceed with the production of the remaining three orbiters.

ENCLOSURE IV

A third alternative might have offered some advantages over either delaying or proceeding with full-scale production. Production of the third orbiter could be initiated and the remaining two could be delayed until there are more adequate assurances regarding technical problems, space flight activity, and the cost of operations.

The study also contained the following recommendations to the Congress: until there is sufficient confidence in the Shuttle development program and more information is available on STS operations cost and plans for future space activity, the Congress should assess the advantages and disadvantages of initiating the production of a third orbiter and delaying funding of the remaining two orbiters.

A SECOND LAUNCH SITE FOR THE SHUTTLE? AN ANALYSIS OF NEED FOR THE NATION'S SPACE PROGRAM

This report, dated August 4, 1978, questioned the need for an STS consisting of two Shuttle launch and landing sites and five orbiters. It discussed the potential for accomplishing a balanced and viable space program with an STS consisting of three or four orbiters operating from the Kennedy Space Center launch and landing site at a potential saving of about $2.3 billion to $3.5 billion.

Why a second launch site?

According to the report, the proposed STS facilities at Vandenberg Air Force Base had been justified primarily on the basis that northerly launches were not permissible from Kennedy Space Center, due to the danger of flying over land. Also Department of Defense officials said that Kennedy Shuttle launches would not have the capability to handle certain Defense payloads and that northerly launches from Kennedy could cause an adverse reaction from the Soviet Union.

The flight over land constraints seem unwarranted; the most critical phase of a Shuttle launch is between the time of lift-off and separation of the solid rocket boosters. The critical phase or initial ascent of northerly launches from Kennedy will be over 345 miles of ocean between the Center and the coast of South Carolina.

The principal proponent for the second site is Defense; yet, the military payload model projects an average of only four Shuttle launches a year from Vandenberg.

The Department of Defense believed that one of its space programs, involving two defense satellites a year projected for the Vandenberg launch, could not be accommodated from Kennedy because of a 32,000-pound delivery capability requirement. However, the Kennedy delivery capability can be increased to meet this requirement by making adjustments to the mission or operating profile as appropriate.

Also, the Department of State expressed a concern about the possibility of adverse Soviet reaction to northerly launches from Kennedy. Further congressional inquiry may be needed to determine if this concern is serious enough to justify spending up to $3.5 billion to construct and operate a second site.

The investment cost per orbiter is about $600 million to $850 million. NASA and Defense have taken the position that five orbiters are needed. This view is based largely on the national payload mission model put together by NASA, which projects 560 Shuttle flights during 1980-91. Possibly the most significant aspect of the present model is Spacelab--almost one-half of the proposed payloads in the model involves this STS element. However, whether such extensive manned activity in space is needed is unknown. During the fiscal year 1978 budget process, the Office of Management and Budget recommended that, until the long-range goals and objectives of the U.S. space programs are assessed, funding of space station studies be deferred.

Considering the substantial capabilities of three orbiters, it is difficult to foresee needs beyond that fleet size. An additional orbiter obviously could provide an increased yearly launch rate of 53 to over 60 a year. The fourth orbiter would also provide a cushion for attrition. The present Administration has decided to support a four-orbiter fleet, with consideration for a fifth in future years if the projected flight rates or the accidental loss of an orbiter warrant such an action.

Recommendations to the Congress

The report contained a number of recommendations to the Congress. These were:

--Unless there are compelling national security reasons for the West Coast STS site, the Congress should not fund Vandenberg Air Force Base modifications to accommodate the Shuttle.

ENCLOSURE IV

--The Congress should fund no more than the four orbiters now under development and production. Consistent with this position, NASA's request for Orbiter 104 in the fiscal year 1979 budget should be denied.