OVERSIGHT

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY U.S. HOUSE OF REPRESENTATIVES

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SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

THURSDAY, JUNE 28, 1979

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, D.C.

The subcommittee was convened at 9 a.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua (chairman of the subcommittee), presiding.

Mr. FUQUA. The subcommittee will be in order.

Today the Subcommittee on Space Science and Applications will review the current cost, schedule, and performance status of the Space Shuttle program and will examine the need for a $220 million budget amendment which has been requested by NASA.

On March 28, of this year, H.R. 1786, the fiscal year 1980 NASA authorization bill, was passed by the House of Representatives. On May 14 of this year, the President transmitted to the Congress an amendment to the 1980 budget to increase by $220 million NASA's fiscal year 1980 authorization and specifically for the Space Shuttle program stating that these additional resources are needed to maintain the development and production pace necessary to meet civil and military requirements.

The Senate, in considering the original fiscal year 1980 NASA budget request and the budget amendment, has included the $220 million in the amendment to H.R. 1786. The Senate passed the bill, H.R. 1786, as amended on June 14, 1979, and the $220 million will be one item of major difference between the House action and the Senate action.

The subcommittee is recorded in strong support of the Space Shuttle program for many years. We are also on record for questioning the wisdom of limiting the Space Shuttle capability with a four-orbiter as opposed to a five-orbiter fleet.

The budget amendment was transmitted to Congress only a few weeks after the committee's February authorization hearings where both the NASA fiscal year 1979 supplemental request and the fiscal year 1980 authorization request were being considered. Considering the subcommittee hearings in February with headquarters officials, field hearings at the Space Shuttle development centers, and field hearings at the contractors, the timing of this subsequent budget amendment raises questions with regard to the accuracy and candor of testimony and responses to questions in the February hearings. It is

most difficult to understand how a problem of this magnitude developed between March and May.

Today the subcommittee will examine the basis for the $220 million budget amendment, how the funding problem developed, impact on production Orbiter schedules of the reallocation of more than $70 million from production to D.D.T. & E. in fiscal year 1979, what NASA and the contractors are doing to assure that the problem does not repeat itself, the impact of schedule slips on both civilian and military requirements, NASA's current cost and schedule assessment for the D.D.T. & E. program and NASA's plan for establishing a firm schedule and a resource plan for the production phase of the Shuttle program.

I would like to at this time yield to the distinguished ranking minority member of the subcommittee and one that has been involved in this program since long before its inception, the gentleman from Kansas, Mr. Winn?

Mr. WINN. Thank you, Mr. Chairman. I want to take this opportunity to again publicly state my support for the Space Shuttle program. I have been involved with this program from its inception and I am thoroughly convinced that this expenditure of tax dollars is more than justified. We are just beginning to see the vast benefits of our space program and the Shuttle offers the promise to unfold many more opportunities. Even the administration seems to be enthusiastically supporting the program for the many potential benefits that it can bring to our Nation.

I must admit though that I am not happy about the purpose for which these hearings are being held. The apparent cost overruns which have been incurred could have profound effects on the entire space program, not just the Space Shuttle. The political controversies that will occur because of these overruns will continue for some time and may do irreparable damage to the integrity of NASA as a mission-oriented agency.

The factor which distresses me most though is the fact that these overruns come as somewhat of a surprise. For 12 years I have been actively involved with NASA programs. I started visting the centers and contractors that were involved in the Shuttle program in the early 1970's. I remember visiting the wooden Shuttle Orbiter mockups long before we even thought of building any hardware. After the hardware development started, the chairman and I personally visited each of the lead centers and prime contractors each and every year to get a firsthand account of the status and the future of the program.

Time and time again we asked the same questions—"Are we on the cost plan of $5.22 billion and are we on schedule?" And time and time again we were told that we were on schedule and within the $5.22 billion.

Over a year ago we began to realize that supplemental funding would be required and a schedule slip would occur. However, this did not seem unreasonable. A 10-percent cost growth in 10 years for a high technology program should probably be commended.

Now, though, just a few weeks after the passage of that supple-

mental legislation we are looking at a substantially larger overrun and a further schedule slip.

This makes me feel like a total failure. After spending all of these years traveling from one briefing on the Shuttle status to the next, I feel like I have totally wasted my time. The visits gave me the confidence to go before my colleagues in the House of Representatives and fight for the necessary support to move this program along. I can see now that it was a false sense of confidence.

As late as last fall, when we held our Shuttle cost and schedule review hearings, I impressed upon John Yardly the importance of making sure that the fiscal year 1979 supplemental request be large enough. I think my words were, "We can only go to the well once."

Now a matter of a few weeks later we have reprogramed another $80 million in fiscal year 1979 and added another $220 million to the fiscal year 1980 budget and we are looking at a total D.D.T. & E. estimate in the neighborhood of $6 billion.

I don't know whether I was misled about the total D.D.T. & E. cost estimate or whether people just were not aware that the program was going to exceed the limit. In some ways I would hope that I was misled because it would at least show that someone was assessing whether the program was going to stay within the $5.22 billion.

I can appreciate the problems that NASA faces in attempting to support the administration budget policies and manage those competitive contracts. However, I was confident that sufficient mechanisms were available to allow the program managers to communicate any form of managerial problems that may require the assistance of this committee and of the Congress.

Mr. Chairman, we face a yeoman's task, a task I do not relish. We must reestablish our own confidence before we can face our colleagues in the House. I hope these hearings and subsequent conversations will adequately relieve my concerns and allow me to continue the avid support for NASA that I have displayed in the past.

Thank you, Mr. Chairman.

Mr. FUQUA. Thank you, Mr. Winn.

Mr. Flippo?

Mr. FLIPPO. Nothing at this time, Mr. Chairman. Thank you.

Mr. FUQUA. Our first witness this morning will be Dr. Robert A. Frosch, the Administrator of the National Aeronautics and Space Administration.

Dr. Frosch, we will be happy to hear from you.

STATEMENT OF DR. ROBERT A. FROSCH, ADMINISTRATOR NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Dr. FROSCH. Thank you, Mr. Chairman.

I am here today to discuss the Space Shuttle program, its status and problems, and our plans for fiscal year 1979 and fiscal year 1980 with particular emphasis on our request for a fiscal year 1980 authorization budget amendment in the amount of $220 million. As the subcommittee knows from our briefings and from the staff reviews at our centers and contractors, it has been necessary for us to spend more resources to accomplish the development program than we had planned, and the completion of this development will take longer than anticipated.

With your permission, I would like to submit my full statement for the record and limit my oral testimony before you to a synopsis that highlights the status of the Shuttle program today and the justification of the President's fiscal year 1980 budget amendment in the amount of $220 million.

Mr. FUQUA. Without objection, the statement in its entirety will be printed in the record and you may summarize it in any fashion you may desire.

[The prepared statement of Robert A. Frosch follows:]

STATEMENT OF ROBERT A. FROSCH, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. Chairman and members of the subcommittee: I am here today to discuss the Space Shuttle program, its status and problems, and our plans for Fiscal Year 1979 and Fiscal Year 1980 with particular emphasis on our request for an Fiscal Year 1980 Authorization Budget Amendment in the amount of $220 million. As the Subcommittee knows from our briefings and from the staff reviews at our centers and contractors, it has been necessary for us to spend more resources to accomplish the development program than we had planned, and the completion of this development will take longer than anticipated.

With your permission, I would like to submit my full statement for the record and to limit my oral testimony before you to a synopsis that highlights the status of the Shuttle program today and the justification for the President's Fiscal Year 1980 Budget Amendment in the amount of $220 million.

First, I want to stress that I have found no reason to question the basic soundness of the Shuttle concept or its technical design.

Second, I wish to make it clear for the record that the Carter Administration is fully committed to this program, with an emphasis on having an operational four-orbiter, two-site capability as early as possible to meet critical space program needs, particularly in the national security sector.

Third, I would like to outline for you our current best schedule estimates for those operational capabilities, assuming that the Fiscal Year 1979 supplemental and Fiscal Year 1980 requests of both NASA and DOD are approved by the Congress. Our focus has been upon completion of the initial development and accomplishment of the first successful manned flight.

We believe that is the proper focus of our attention, but we recognize that we need also to assure adequate emphasis on the overall program schedule, including production.

As the Subcommittee knows, over the past few weeks we have conducted an intensive assessment of the work remaining until STS-1, the first manned orbital flight. The next key milestone on the path to STS-1 is movement of the orbiter Columbia out of the Orbiter Processing Facility (OPF) at the Kennedy Space Center (KSC) to the Vehicle Assembly Building (VAB). On Monday, I reviewed the detailed integrated plan that covers all the known work necessary to complete the manufacturing work and checkout in the OPF. If we can accomplish all these tasks in the right order, and if we have allowed enough time for the inevitable work-around problems we will have, then we could finish the basic work on the Orbiter in November and move it to the VAB before Christmas. This schedule could culminate in a first launch by the end of March. If I include some conservatism—such as the possibility we would need to return to the VAB from the pad before launch, or an allowance for unknown uncertainties, I would have to add some 10 to 12 weeks to that date. In summary, I feel we have one chance in five of launching by the end of the first quarter; I believe the chance of flight by the end of the second quarter of 1980 is 50–50.

Operational flights of the first orbiter will begin in the late summer of 1981. The second orbiter, 099, will be delivered in the spring of 1982. We are scheduling delivery of the third orbiter, 103, in the summer of 1983 to support the initial operational capability at Vandenberg Air Force Base, scheduled for the winter of 1983. Orbiter 104 will be scheduled for delivery in late 1984.

Fourth, we are experiencing a DDT&E cost growth of about 15 percent, and a schedule extension of about the same degree, when measured against the Ad-

ministration's 1972 commitments. While I am not satisfied with this performance, I believe that our performance to date and projected into the future, when tested against those estimates at the beginning of the program compares favorably with other complex, high technology development programs.

Lastly, much has been said about technical problems encountered during development of the orbiter, the main engines, the external tank, and the solid rocket boosters. I would like to point out that the very essence of the development process—and of the advanced capability it engenders—is the discovery of technical problems and the successful application of new solutions. We find and solve the major difficulties in a new system on the ground; spaceflight is not the proper domain for such experimentation.

The remainder of my statement treats each area of development in some detail, and notes the cumulative effect of schedule extensions and cost estimate changes which have resulted in the need for the Budget Amendment. I would like to first review the current status of the program.

Space Shuttle development is in a period of peak activity with primary concentration on the remaining work needed before the first orbital flight. Our plans for fiscal year 1979 have been predicated on receiving the full $185 million supplemental appropriation and now include a reallocation of $70 to $90 million from production to development to meet current needs. It is crucial that the supplemental funds be available at the earliest possible date. These funds are necessary to maintain the high rate of activity required for development efforts throughout all of fiscal year 1979. To allow for approval of the supplemental funds as late as July, and to accommodate technical problems, it has been necessary to restrict funding in our production program through the third quarter of this fiscal year. This production restriction, together with the reallocation of funds from production to development and delays in structural testing will cause Orbiter 099 (Challenger) to be delayed approximately 6 months. We now expect to deliver Challenger to KSC in March of 1982.

SPACE SHUTTLE STATUS

With respect to the Space Shuttle development program, all major system elements are proceeding in test and manufacture, and major ground test programs are being conducted and completed. The design certification review of the overall Space Shuttle configuration was completed in April. In general, development testing throughout the program has been successfully completed or soon will be, and we are now deeply involved in the qualification of flight configured elements. This in-depth qualification testing involves tests in all Shuttle projects to give us the assurance that every element will perform its function in flight reliably.

The Mated Vertical Ground Vibration Test conducted at the Marshall Space Flight Center (MSFC) has been successfully completed, and these Space Shuttle elements have been shipped to the KSC for us in verification testing of the KSC facilities and prelaunch checkout processes. This is now underway and the experience obtained from handling this full scale hardware and the numerous fit checks with all the launch facilities have been very useful. The second phase of the main propulsion system tests at the National Space Technology Laboratories (NSTL) has started and will continue through 1979. These tests include three main engines of flight configuration mounted on an orbiter aft fuselage, with propellants being fed from a flight-type external tank. A 54 second firing was made on June 12, 1979. Preparation for the next firing at full duration is nearly complete, and the test should be accomplished this week.

The Orbiter 102 (*Columbia*), which will be used for the orbital flight tests, has been delivered to KSC where it is being prepared for the initial launch. Deliveries of the engines, the external tank, and the solid rocket boosters to KSC for this first flight will be completed early this summer.

In the orbiter project, the structural test article is currently in test under subcontract by the Lockheed Corporation in Palmdale, California. This test article has a flight worthy airframe and it will be converted to the second orbital vehicle, Challenger, after structural testing is completed late this year.

Work on *Columbia* at KSC is proceeding at a slower pace than planned, and there is considerably more work remaining to be accomplished before the first flight than originally planned. The late arrival of *Columbia*, incomplete orbiter

manufacturing and assembly work transferred to KSC, the high backlog of thermal protection system (TPS) tile work remaining, and additional modifications delaying testing and checkout have all contributed to delay in orbiter flight readiness. The TPS tile problem is most severe. There are still about 10,000 tiles to be installed at KSC. This includes tiles yet to be installed on the orbital maneuvering system pods after they arrive at KSC and tiles which are removed due to deficiencies. So far we have achieved an installation rate of slightly over 300 tiles per week as opposed to an originally planned rate as high as 650 per week to be ready for a September 1979 rollout from the Orbiter Processing Facility (OPF). However, learning is progressing and efforts are underway to improve this situation by reorienting the management structure, expediting tile manufacture, adding more manpower, and improving the training. To complete the tile work in the OPF this year, we will need to achieve a 450 to 500 tiles per week rate.

During the past 2 weeks, we have had several full duration engine firings of 520 seconds each at NSTL, including a successful "over stress" test at 102 percent RPL and we now have achieved approximately 50,000 test seconds of engine operation of the 80,000 seconds planned for STS–1 certification. The engine problem with the main oxidizer valve has been corrected by redesign and the main engines are now operating satisfactorily. Previous major engine development problems have been overcome and residual turbine problems are now being analyzed. A plan to eliminate hydrogen pump turbine blade cracking to extend operating life of the pump is well underway. This includes testing different blade coatings, redesigning the blades, and studying new blade materials. In addition, preliminary tests have shown that changes to the engine start sequence to reduce temperature spikes have reduced the incidence of blade cracking. The three flight engines for *Columbia* being acceptance tested at NSTL in Mississippi, are scheduled to be shipped to KSC this July and August.

However, recent problems did cause engine deliveries for *Columbia* to be delayed, and engine manufacturing workforces were maintained at higher levels longer than planned at the Rocketdyne Engine Plant in Canoga Park, California. To protect the engine development program against further test problems, three additional engines and a number of additional engine components are being added to the program, and deliveries of engines are also being accelerated. These steps were taken to insure that sufficient engines would be available to meet any further design or engine life problems that might be encountered during the engine development testing at operating levels up to 109 percent of rated power.

Three external tank test articles have been completed and are in use on the program for structural testing, launch facility verification and the main propulsion tests. Our first flight tank, the fourth to be built, has completed assembly and is undergoing final checkout prior to shipment to KSC in early July. In addition, four other flight tanks are in various stages of manufacture for future flights. Thermal protection system application problems, plus late technical changes for an orbiter bracket interference problem and relocations of a liquid oxygen engine cut-off sensor, have delayed this first flight external tank by about one month at increased project costs.

The fourth and final solid rocket motor (SRM) development firing was completed in February 1979, and the first of three qualification motor firings was successfully completed in June. Efforts now are concentrated on completion of qualification testing and delivery of booster subsystems for STS–1. Casting of the propellant has been completed in all motor segments and some solid rocket booster (SRB) subsystems are already at KSC. Due to development motor handling, manufacturing and subsystem qualification test problems, the SRB development program is using increased manpower and overtime. Tight manufacturing quality control is necessary to insure success, since these solid rocket motors cannot be test fired prior to use. Delivery of the final segment for the first complete flight boosters is now scheduled for early August.

All facilities at KSC are complete and in place for the first manned orbital flight. Although ground support equipment and the computerized launch processing system (LPS) installations have been delayed, they are in the final stages of completion and software validation is in process. Because software and computers utilized for launch operations fell behind schedule early this year, additional shifts of personnel and extensive overtime have been required. The LPS hardware deliveries have now been completed, simulation support is continuing

for development of checkout procedures, and checkout sofeware is being developed and validated. Integration of all the ground support equipment will continue, and initial flight equipment is being checked out and processed for launch.

In summary, all elements of the program are now coming together for the first launch. I would now like to address the reasons for the Budget Amendment.

BACKGROUND

Early in the Space Shuttle program NASA established a philosophy of maintaining an austere budget environment. Budgetary reserves were maintained at Headquarters and only utilized after review by the highest levels of management. This was a different philosophy than used in Apollo, in which reserves were approved and maintained at lower levels of management. This new practice was adopted to minimize program costs. Further, tight schedules were specified for accomplishment of the development program, since working toward a tight but achievable schedule would provide the minimum overall program cost, and we budgeted accordingly. We have, of course, made adjustments to this plan as necessary. In Fiscal Year 1978, we reallocated $100 million from Shuttle funds planned for follow-on orbiter production into the development program. In Fiscal Year 1979, the Administration requested, and the Congress has authorized, a supplemental appropriation.

NEED FOR $220 MILLION BUDGET AMENDMENT IN FISCAL YEAR 1980

Last summer, during the initial preparation for the fiscal year 1980 budget submission, we reassessed the program status and requirements based on a success oriented schedule, with the first Space Shuttle flight scheduled in September. We included reserves for fiscal year 1979 and fiscal year 1980, consistent with an initial flight test in late 1979 and continued development flight tests throughout fiscal year 1980. The recommended fiscal year 1979 Supplemental appropriation request and fiscal year 1980 budget were consistent with this plan. We started experiencing problems early in fiscal year 1979, and achieving this schedule is no longer possible. Significant cost increases were indicated by the Rockwell International Corporation, the orbiter prime contractor, in October; similar increases followed from the other Space Shuttle elements later in the Fall. We intended to handle these identified increases within our planned reserves, and if the schedule had been maintained, the reserves probably would have been sufficient. However, by April it had become clear that additional funds must be expended in fiscal year 1979 for the Design, Development, Test and Evaluation (DDT&E) phase and additional DDT&E resources in fiscal year 1980 are also required. Therefore, in addition to the reallocation of fiscal year 1979 funding, we requested the fiscal year 1980 Budget Amendment to accommodate program growth experienced to date and the maintenance of larger work forces. We have also increased our reserve requirements as a precaution against further problems.

It has also become apparent, based on information received from the contractor and JSC, that the funding requirements for follow-on orbiter production may be significantly in excess of those previously estimated. We are in the process of intensive review of these funding requirements. It is clear that the amount of any necessary increase over the previous estimates is subject to engineering and management judgment in a number of areas. We have not completed or flight tested the first orbiter and therefore do not have complete data on actual effort required to build an operational orbiter. In our planning, we expect to achieve considerably greater efficiency in producing the follow-on orbiters, but the extent to which the efficiency can be improved is a matter of judgment. Another important unknown is the amount of change activity that will be required on the second, third, and fourth orbiter as a result of flight test experience on the first. A third area which involves uncertainty is the amount of engineering and related activities that will be required in support of early flight activities and the duration for which it will be necessary to continue various levels of support. Before we can arrive at a reasonably reliable estimate of the cost of these orbiters, we will need to arrive at judgments with respect to these uncertainties and to apply those judgments to the available data base. This is the part of our cost review now in process in preparation for our fiscal year 1981 budget recommendation.

The $220 million Budget Amendment is required to sustain the development program at a higher rate of activity for a longer period of time than previously planned. The original fiscal year 1980 budget preparation was based on a September–December 1979 first manned orbital flight (STS–1), with completion of the flight test program in early 1981. Due to additional technical and manufacturing problems, the first manned orbital flight is now being delayed.

The orbiter portion of the fiscal year 1980 Budget Amendment provides for the completion of tasks previously planned for fiscal year 1979, the incorporation of design changes, and increased development support through the flight test program based on our fiscal year 1979 experience. Specifically, this increase provides for additional orbiter and systems integration engineering support (Rockwell International) throughout the flight test program, and increased manufacturing personnel to complete mission kits (unique flight, test and/or support hardware) that were previously planned for fiscal year 1979. These items were delayed to fiscal year 1980 principally due to the TPS problems and the need to transfer additional manpower for the solution of these problems in fiscal year 1979. The orbiter qualification and certification test programs have also experienced delays. Priority is being given to completing those tests designed to certify subsystems for the first test flight. The test activities to demonstrate required lifetime have been largely deferred to fiscal year 1980. A combination of technical problems and schedule extensions have caused substantial cost increases in subsystems such as the orbital maneuvering engine and the reaction control thrusters.

Among the orbiter subcontractor activities planned for fiscal year 1980, the orbiter KU band communications/rendezvous radar system implementation was previously delayed until flight STS–8. However, the design and development effort for the KU band was substantially underestimated and additional effort is now required in fiscal year 1980. The development of the S–Band communications system to be used for payloads has encountered a number of technical problems and is more complex than originally thought, thus requiring more effort. A partial redesign is required on the auxiliary power units to institute an active cooling system to provide the capability for rapid restart of the system in flight. The Honeywell flight control effort was substantially increased in fiscal year 1980 based on our experience in fiscal year 1979. Additionally, as a result of the experience in fiscal year 1979 and the schedule delay in STS–1, overall subcontractor support and analysis activities will be retained for a longer period of time and at a higher level than had been previously planned.

Further, there have also been cost increases in Space Shuttle support areas including the main propulsion test program, the astronaut suit and its portable life support system for extravehicular activity and also in the engineering and simulation activities at JSC. The original astronaut suit [extravehicular mobility unit (EMU)] contract estimates were optimistic and have been significantly affected by vendor cost escalation and delays. Both subsystems use concepts new to space flight application for the purpose of long term operational advantages, and several costly design changes have been required during development. The increased number of astronauts, requiring some small size suits, has made it necessary to increase the number of sizes of EMU components and therefore increased our cost and schedule estimates. A recent EMU failure during astronaut training exercises in the watertank at JSC has further delayed this effort and added additional cost.

The main engine increase is necessary due to the test failures experienced in fiscal year 1979 and the need to phase the engine development to meet early mission requirements. As a result of the main liquid oxygen valve failure in the main engine last December, it has been necessary to further delay the main propulsion system test. These tests, to verify propulsion system performance at main engine operation of 100 percent rated power level, will extend from fiscal year 1979 into fiscal year 1980 and additional tests have been added to certify the system at the 109 percent rated power level. The fiscal year 1980 Budget Amendment provides for more engineering and manufacturing manpower than was previously planned, for rebuilding of development engines, and for added engine tests to improve the engine performance to 109 percent of rated power. The 109 percent power level is need for delivery of a 65,000 pound payload to a 150 nautical mile orbit, as well as abort requirements for specific missions. Currently, the engine operation has been demonstrated to above the 100 percent level required for the early Space Shuttle missions. Engine testing to demonstrate the

109 percent power level planned for later Space Shuttle missions is now scheduled for fiscal year 1980. It is anticipated that further design improvement to components of the turbopumps and combustion devices may be required to obtain this higher performance level and to increase the engine operating life.

In addition, the delivery schedule of production engines has been accelerated to implement a more efficient production build cycle. Also, three new engines and additional components are being added to the production program with funding starting in fiscal year 1980 and fiscal year 1981, to assure that sufficient engine hardware is available in the test program.

The external tank (ET) portion of the Budget Amendment is principally attributable to unexpected effort in the manufacture and application of the thermal protection system in fiscal year 1979, and the need to further improve that system. Manufacturing manpower greater than planned will be required through fiscal year 1980 for TPS application. Also, a new development effort is required starting in fiscal year 1980 to improve both TPS performance and overall ET productibility. This action has been taken in an attempt to reduce the future cost per flight of the Space Shuttle system. This new development effort will examine new materials and products as well as better thermal protection characteristics for potential use on the external tank. This effort is designed to provide improved performance of the external tank at less weight.

The launch and landing increase included in the Budget Amendment is necessary to sustain a larger workforce for launch operations than previously planned. This requirement is based on our experience to date, which includes more development contractor personnel and overtime than previously projected. Further, to support around-the-clock launch operations and ground testing, we have converted certain supporting functions to a three-shift operation. The automated launch processing system (LPS), used for vehicle checkout, test and launch control, has recently been converted to an around-the-clock operation for software verification. The Budget Amendment will provide for the continuation of all of these operations on a three-shift basis. Further, to relieve the LPS load somewhat, we are procuring an additional core memory to be used in the central data subsystem, thus providing improved off-line usage of the system to check out and validate new applications programs.

While the assessment of the cumulative impact of these development problems is continuing, it is clear that additional budget authority in fiscal year 1980 is required to continue the Space Shuttle development and test activities at an effective pace. With the additional funding in fiscal year 1980, the resources applied to production activities will remain at the level contained in the original fiscal year 1980 budget estimates. We have also proceeded into a detailed review to establish a revised production program. This review includes the effect of reduced production funding in fiscal year 1979, the need for additional main engines in the program and the increased manufacturing and assembly time requirements that we have witnessed with Orbiter 102. While we cannot yet predict with certainty what our requirements will be for fiscal year 1981, and beyond, it is clear that the orbiter production deliveries will be delayed, as I indicated earlier.

We will continue further evaluation through the summer to establish our fiscal year 1981 budget requirements. Delivery of the production orbiters is, of course, dependent on the fiscal year 1981 and subsequent budgets. Of course, much of the analysis and understanding of what it really takes to manufacture an orbiter is known from our exeprience on *Columbia* so far. However, much remains to be done on this orbiter and many details of production still must be defined to accurately predict the phased cost for the follow-on production. In fact, each orbiter will require many custom operations during manufacture which is certainly not typical of normal produtcion programs. In addition, we are only now starting to thoroughly understand the operational requirements for sustaining engineering which must be included in our future budget requests. Knowledge in this area is being accumulated as we work on *Columbia* and will be modified as we provide the actual support required during the orbital flight test program. The Administration is committed to requesting and applying the necessary resources in future years sufficient to assure meeting the essential DOD and civil operational schedule requirements.

In summary then, the requirement for the fiscal year 1980 Budget Amendment arises from the cumulative impact of problems encountered in main engine testing, installation of thermal protection on the orbiter and external tank,

qualification testing of orbiter systems and other development activities. The $220 million is requested to augment the $610.5 million for Design, Development, Test and Evaluation included in the basic fiscal year 1980 budget request. With the amended budget, we expect to be able to conduct the first orbital flight test, to continue ground testing to verify system life and performance and to continue a series of orbital flight tests leading to an operational capability in 1981.

IMPACT OF NOT RECEIVING THE $220 MILLION FOR FISCAL YEAR 1980

If additional funds for DDT&E were not available in fiscal year 1980, we would have only about three-fourths of the funds required to support an efficient program pace. If we did not replace these funds with production money, it would be necessary to sharply reduce the overall DDT&E level of effort, delaying the first orbital flight by up to an additional 6 months and other elements of the Shuttle program up to a year more. I believe the successful first orbital flight is more important to the ultimate schedule of prospective Space Shuttle users than holding a particular production schedule. Thus, it is likely that we would find it prudent, as we have in fiscal year 1979, to reallocate funds from Space Shuttle production to make up all or a major part of the shortfall. This would allow us to continue to concentrate efforts on conducting the first manned orbital flight tests as soon as safely possible. However, this reallocation would severely impact our production schedules, and make it impossible to meet our civil and military requirements, including the start of operation at the Western Test Range. I would hope that we could minimize the further delay on each orbiter, but additional delays of the third and fourth orbiters could be as long as a year, depending in part on future year funding levels.

The direct program cost impact of delays of this kind depend on many variables, including, of course the precise elements of the program that are delayed. These direct costs would certainly exceed the $220 million requested, and could range as high as a half billion dollars.

The indirect costs—including additional expendable launch vehicles and foregone launch services revenues—also depend on the detailed program phasing decisions we would make. These additional costs would be of the same general size as the additional direct costs.

PROGRAM MANAGEMENT ACTIONS

We have taken a number of actions to strengthen management of the Space Shuttle program. Some of these actions are corrective in nature while others are designed to aid in understanding our status and to provide a better basis for future decisions.

The need for corrective actions, especially in the prime contractor's subcontract management and cost analysis areas, was recognized late last Fall, and we have proceeded to take those corrective actions. We placed initial emphasis on subcontractor escalation causes and "roll-through," that is, efforts that have been deferred to a later year either by plan or as a result of the lack of accomplishment.

Rockwell International has restructured its subcontracts management office by integrating the technical managers and the cost managers into a single organizational unit. This will facilitate the exchange of data between these functions so that cost impacts and technical problems will be recognized more rapidly. Also, Rockwell has augmented its subcontracts management personnel by about 30 percent. Rockwell has also established an improved system for tracking subcontractor budget impacts which requires certain data from the subcontract managers to be reviewed by program management on a monthly basis. Rockwell and the subcontractors plan more frequent reviews for preparing their resource requirements and have scheduled these reviews to support the NASA budget process. These improvements will substantially increase visibility into subcontractor performance.

In another important area, we have structured our award fee criteria to motivate the contractor to improve the accuracy and timeliness of cost projections. We have a unique feature in our contract with Rockwell International that enables us to adjust retroactively cost awards previously given, within certain limits. This is a valuable feature for cost projections, where obviously the quality of performance can only be determined after the period that the projec-

tions cover. We are stressing that provision in our determination of award fee to be granted to Rockwell and we believe this will have a positive impact on improving cost projections.

A final area of corrective actions that we have also taken recently are actions at the Kennedy Space Center to make the flow of the first flight article more efficient, and achieve the first orbital flight as early as possible. Leadership and lines of authority at KSC have been clarified regarding Space Shuttle work. We have placed the KSC Shuttle Manager in charge of all KSC elements working on the Shuttle. JSC has been assigned the full responsibility for completing the installation and assembly of components on Orbiter 102. KSC will supply responsive support to JSC in this role. We have directed JSC to prepare a plan and schedule of specific actions to improve the TPS situation. We are adding TPS installers and supervisors, and we are reviewing all work methods. Finally, we are examining KSC administrative areas with a view toward simplification that could then speed up work flow. In addition, Rockwell International has taken similar actions for their KSC operations.

These areas I have just covered are the actions we have already taken to correct deficiencies and to improve management processes in the Space Shuttle Program. We are also proceeding in other areas.

I have asked Dr. Lovelace to undertake an overall management assessment of the Space Transportation System. He has assembled a small special senior staff to assist him in this review of the STS management organization and processes. The senior special staff members are: Dr. Richard C. McCurdy, former NASA Associate Administrator for Organization and Management; Willis H. Shapley, former NASA Associate Deputy Administrator; Maj. Gen. James Abrahamson, F–16 Program Director, United States Air Force; A. Thomas Young, Deputy Director, NASA Ames Research Center, and John E. O'Brien, Assistant General Counsel for Procurement Matters, NASA Headquarters. Abraham Spinak, Associate Director, NASA Wallops Flight Center, is executive assistant.

To utilize their expertise most effectively, these individuals will be afforded the maximum of independence in the exercise of their responsibilities. A series of fact finding reviews are underway and inputs will be made to Dr. Lovelace for his analysis and use. Reviews were conducted in late May and early June at the Johnson Space Center, the Marshall Space Flight Center, the Kennedy Space Center, and the Rockwell International Corporation. Following additional visits and activities, an interim assessment to Dr. Lovelace is projected for mid-July, followed by his final assessment to me later in the summer.

In preparation for the fiscal year 1981 budget, I have asked the NASA Comptroller to undertake a detailed review of our cost and scheduling. A Space Shuttle resources requirements review team will analyze the fiscal year 1981 Space Shuttle budget requirements and future year projections in detail, including assessment of contractor and vendor estimates, to fully explore the basis of the cost estimates and to test the adequacy of the resources considering the potential for future changes. The resources review will supplement the normal budget review and estimating process, with completion scheduled in time to support the fiscal year 1981 budget submission to OMB this fall.

SUMMARY

In summary, Mr. Chairman, I would like to reiterate that the Space Shuttle program is technically sound and the fiscal year 1979 supplemental and fiscal year 1980 Budget Amendment will allow us to proceed with the development effort in an efficient and cost effective manner towards the first orbital flight and establishment of an East Coast KSC operational capability. These additional development funds will enable us to minimize further impact on delivery of production orbiters and to continue to focus critical attention on important areas affecting performance, for example, 109 percent engine operation and weight reductions. These activities are essential to continued progress towards attaining a polar/near polar launch capability by early 1984 at the Vandenberg Air Force Base and a timely operational orbiter fleet. In addition to the high priority national security programs, polar/near polar launches from Vandenberg are essential to support important civil science, technology and operational efforts in global earth viewing and Earth-Sun dynamics.

Again, I would like to emphasize that the Administration is committed to applying the necessary resources to the national Space Transportation System to

insure the successful and timely accomplishment of the essential performance and schedule objectives of critical DOD and civil space missions.

Dr. FROSCH. Thank you, Mr. Chairman.

I am accompanied today by the Deputy Administrator of the Agency, Dr. Lovelace, by Mr. John Yardley, who is the Associate Administrator for Space Transportation System, and by Bill Lilly who is the Comptroller of NASA.

Mr. FUQUA. Very familiar faces I might say.

Dr. FROSCH. First, I want to stress that I have found no reason to question the basic soundness of the Shuttle concept or its technical design.

Second, I wish to make it clear for the record that the Carter administration is fully committed to this program, with an emphasis on having an operational four-orbiter, two-site capability as early as possible to meet critical space program needs, particularly in the national security sector.

Third, I would like to outline for you our current best schedule estimates for those operational capabilities, assuming that the fiscal year 1979 supplemental and fiscal year 1980 requests of both NASA and DOD are approved by the Congress. Our focus has been upon completion of the initial development and accomplishment of the first successful manned flight.

We believe that is the proper focus of our attention, but we recognize that we need also to assure adequate emphasis on the overall program schedule, including production.

As the subcommittee knows, over the past few weeks we have conducted an intensive assessment of the work remaining until we launch STS–1, the first manned orbital flight. The next key milestone on the path to STS–1 is movement of the orbiter Columbia out of the orbiter processing facility (OPF) at the Kennedy Space Center (KSC) to the vehicle assembly building (VAB). On Monday, I reviewed the detailed integrated plan that covers all the known work necessary to complete the manufacturing work and checkout in the OPF.

If we can accomplish all these tasks in the right order, and if we have allowed enough time for the inevitable work-around problems we will have, then we could finish the basic work on the orbiter in November and move it to the VAB before Christmas.

This schedule could culminate in a first launch by the end of March. If I include some conservatism—such as the possibility we would need to return to the VAB from the pad before launch, or an allowance for unknown uncertainties, I would have to add some 10 to 12 weeks to that date. In summary, I feel we have 1 chance in 5 of launching by the end of the first quarter of calendar year 1980; I believe the chance of flight by the end of the second quarter of 1980 is 50–50.

Operational flights of the first orbiter will begin in the late summer of 1981. The second orbiter, 099, will be delivered in the spring of 1982. We are scheduling delivery of the third orbiter, 103, in the summer of 1983 to support the initial operational capability at Vandenberg Air Force Base, scheduled for late 1983. Orbiter 104 will be scheduled for delivery in late 1984.

Fourth, we are experiencing a D.D.T. & E. cost growth of about 15 percent, and a schedule extension of about the same degree, when measured against the administration's 1972 commitments. While I am

not satisfied with this performance, I believe that our performance to date and projected into the future, when tested against those estimates at the beginning of the program, compares favorably with other complex, high-technology development programs.

Lastly, much has been said about technical problems encountered during development of the orbiter, the main engines, the external tank, and the solid rocket boosters. I would like to point out that the very essence of the development process—and of the advanced capability it engenders—is the discovery of technical problems and the successful application of new solutions. We find and solve the major difficulties in a new system on the ground; spaceflight is not the proper domain for such experimentation.

The remainder of my statement treats each area of development in some detail, and notes the cumulative effect of schedule extensions and cost estimate changes which have resulted in the need for the budget amendment. I would like to first review the current status of the program.

In the interest of time I will skip to page 9 of my prepared text.

Mr. Chairman, I hope the subcommittee will agree with the Senate decision to authorize the amended request for the Shuttle. I understand that the full house voted yesterday to appropriate the funds requested in the amended budget, except the $15 million for thrust augmentation.

I would like to discuss the impact of not receiving the additional $220 million. If additional funds for D.D.T. & E. were not available in fiscal year 1980, we would have only about three-fourths of the funds required to support an efficient program pace. If we did not replace these funds with production money, it would be necessary to sharply reduce the overall D.D.T. & E. level of effort, delaying the first orbital flight by up to an additional 6 months and other elements of the Shuttle program up to a year more.

I believe the successful first orbital flight is more important to the ultimate schedule of prospective Space Shuttle users than holding a particular production schedule. Thus, it is likely that we would find it prudent, as we have in fiscal year 1979, to reallocate funds from the Space Shuttle production to make up all or a major part of the shortfall. This would allow us to continue to concentrate efforts on conducting the first manned orbital flight tests as soon as safely possible.

However, this reallocation would severely impact our production schedules, and make it impossible to meet our civil and military requirements, including the start of operation at the Western Test Range. I would hope that we could minimize the further delay on each orbiter, but additional delays of the third and fourth orbiters could be as long as a year, depending in part on future year funding levels.

The direct program cost impact of delays of this kind depend on many variables, including, of course, the precise elements of the program that are delayed. These direct costs would certainly exceed the $220 million requested and could range as high as $\$1\frac{1}{2}$ billion.

The indirect costs—including additional expendable launch vehicles and forgone launch service revenues—also depend on the detailed pro-

gram phasing decisions we would make. These additional costs would be of the same general size as the additional direct costs.

Now I will turn to the summary on page 12. In summary, Mr. Chairman, I would like to reiterate that the Space Shuttle program is technically sound, and the fiscal year 1979 supplemental and fiscal year 1980 budget amendment will allow us to proceed with the development effort in an efficient and cost-effective manner toward the first orbital flight and establishment of an east coast KSC operational capability.

These additional development funds will enable us to minimize further impact on delivery of production orbiters and to continue to focus critical attention on important areas affecting performance; for example, 109 percent engine operation and weight reductions.

These activities are essential to continued progress toward attaining a polar/near polar launch capability by early 1984 at Vandenberg Air Force Base and a timely operational orbiter fleet. In addition to the high priority national security programs, polar/near polar launches from Vandenberg are essential to support important civil science, technology, and operational efforts in global Earth viewing and Earth-Sun dynamics.

Again, I would like to emphasize that the administration is committed to applying the necessary resources to the national space transportation system to insure the successful and timely accomplishment of the essential performance and schedule objectives of critical DOD and civil space missions.

This completes my prepared statement, Mr. Chairman. We will be pleased to answer your questions.

Mr. FUQUA. Thank you, Dr. Frosch.

Based on the recent projections, the addition of the $185 million fiscal year 1979 supplemental and the budget amendment of $220 million to the Space Shuttle and anticipated possible other additions down the line for the Space Shuttle, what is the current cost estimate of the Space Shuttle development program in 1971 dollars which we have used as a base figure, including the revisions?

Dr. FROSCH. The current estimate including the revisions in 1971 dollars would come out to something between $5.9 and $6 billion.

Mr. FUQUA. What percent increase?

Dr. FROSCH. That's about a 15-percent increase over the original figure.

Mr. FUQUA. What part of this is overrun and what part is due to changes or modifications?

Dr. FROSCH. Well, I'm not sure I would know how to divide those two, unless Bill Lilly has a clearer idea. I think we would have to look at that and see whether there is some way we could separate those definitionally and provide something for the record.

Mr. FUQUA. Would that be possible?

Mr. LILLY. I would prefer to provide something for the record, Mr. Chairman.

[The information follows:]

The original estimate of $5.15 billion in 1971 dollars has grown to $5.9 to $6 billion—a total cost growth of about 15 percent. Seventy million dollars of this increase was caused by schedule stretchouts resulting from OMB budget limita-

tions. The balance of the increase has resulted from technical problems encountered during development and test. The distinction between cost growth resulting from contract changes and that from contract performance is a negotiable item between the contractors and the government and has not yet been determined.

Mr. FUQUA. What amount of funding will be required for the Space Shuttle D.D.T. & E. program for 1981 and beyond?

Dr. FROSCH. We are just in the early process of working out 1981 and 1982 and 1983. It would be difficult for me to give a very precise figure. Can you give an estimate, Bill? [Pause.]

It will be more than was shown in the 1981 column of the 1980 budget, that seems clear.

Mr. LILLY. Mr. Chairman, it will be in the neighborhood of about $500 or $550 million after fiscal year 1980.

Mr. FUQUA. $500 to $550?

Mr. LILLY. Yes.

Mr. FUQUA. What is the impact on the schedule and funding of the production program by reallocating the $70 million from production to D.D.T. & E. in fiscal year 1979?

Dr. FROSCH. I think that that impact is included in the delivery dates that I gave in my statement. So the total impact including that reallocation is shown in those dates.

Mr. FUQUA. You have underway a three-part analysis in NASA of the program, the overall management assessment headed by Dr. Lovelace, cost and scheduling by Mr. Lilly and technical status review headed by yourself, Dr. Frosch. When will these be complete and when can we possibly have the results made available to the committee?

Dr. FROSCH. I would ask my colleagues to speak for themselves.

Dr. LOVELACE. Mr. Chairman, in regard to the management review that is underway now, it is anticipated that the final results of that review would be available the first of September. There will be intermediate milestones to brief and discuss the results with Dr. Frosch. I believe that we would be in a position to discuss results and present them to the committee in September; or, possibly, at the time of the preauthorization hearings, we could cover them in detail.

Mr. LILLY. The timing on the cost and schedule analysis, Mr. Chairman, is essentially the same time period.

Dr. FROSCH. As for my examination of the technical status, I have looked at most of what I want to examine at least in the first round. There are one or two things still remaining. I would say that I have satisfied myself so far that I have not been able to find any difficulties of a basic or inherent nature or anything that is not an ordinary late development kind of problem.

But there are some aspects that I want to hear about further from John Yardley and some of the project people, and I would expect that I can meet or better the schedule of my colleagues.

Mr. FUQUA. Dr. Frosch, when do you think that NASA will have firm schedule and cost estimates for completion of the D.D.T. & E. phase?

Dr. FROSCH. Bill?

Mr. LILLY. I believe it will be as firm as I can make it by the time period I just gave you, Mr. Chairman, about the first of September.

Mr. FUQUA. Does that include also the production program?

Mr. LILLY. Yes, sir, it will.

Mr. FUQUA. Both will be about the same time?

Mr. LILLY. Yes, sir.

Mr. FUQUA. Dr. Frosch, do you believe that the contractors are kept currently informed as to the amount of funding that is being allocated to their part of the program? I assume that there is a certain amount of reserve that is not discussed with the contractors. But do you at the beginning of each fiscal year when the money is signed and sealed—what procedure do you use and are the contractors currently informed as to how much money they are going to have for that year?

Dr. FROSCH. I believe they are so informed, but I would like John Yardley and Bill Lilly to comment.

Mr. YARDLEY. Yes. The general process is started even before the beginning of the fiscal year and we have a program plan developed for each contractor. Those moneys are what is intended to cover the basic program as it is known at that time.

Now if changes come along, we try to cover those with reserves to the best of our ability. I don't know of any of our major prime contractors who ever got less money in the year then he was told at the beginning of the year that he would get.

Mr. LILLY. I would just say the same thing John did, Mr. Fuqua, that the contractors are fully expected to carry out the work defined on the contract for the price that is in the contract. Those items that are to be evaluated and changes that might occur, these obviously are discussed and they are aware of them, and we forecast as well as we can with the contractors.

Mr. FUQUA. How about the subcontractors that the contractor may have?

Mr. LILLY. Of course, the subcontractors are the responsibility of the prime contractor, and it is my belief that they are fully knowledgeable also. I think that would be an appropriate question for the prime contractor, Mr. Chairman.

Mr. FUQUA. What happens if a contractor should underspend at the early part of his fiscal year or maybe overspend, does NASA go in and take the money away, thinking that they have overfunded for that year? Or if he is overspending do you automatically make up the slack?

Mr. LILLY. Mr. Chairman, I think we ought to have John Yardley answer this in terms of his own techniques of management and in terms of control of the contractor. But in terms of underspending, I would be quite surprised in most cases, but, no, we would not take any money away.

Mr. FUQUA. I was just trying to give both sides of the picture.

Mr. YARDLEY. We're never had any underspending in the 5 years I've been here. We have, on occasion when people get into trouble, reallocated among centers. For instance, at the end of 1978, we noted that KSC was not actually spending as fast as they had planned. Now they spend with a large group of small contractors but they did not take any money away from those contractors. They just slowed them down. That's the only case I can recall.

As far as overspending, we look at the plans and see if the plans look reasonable through the year and we have discussions with the

contractor if we think he is frontloading the effort and will run out toward the end of the year. Generally, if we feel strongly about it, we will put lids on how we can spend that money during the fiscal year. We are currently doing that in fiscal year 1979.

Mr. FUQUA. Have you had cases where contractors have overallocated in the early part of the year and had to make a severe reduction at the end of the year?

Mr. YARDLEY. Yes. I think the Rockwell orbiter contractor in 1978 was that sort. Now I cannot say that NASA is not partially culpable because we saw this frontload plan and we talked to them and I personally talked to them and said don't you think you would be better off to hold this down so you can be sure of getting out of the fiscal year? And they convinced me and the project people that they had enough things that were going to be finished in the year that they could do it. As it turned out, some planned things didn't get finished and they could not take the people off. Then about June, they had to take serious action such as cutting subcontractors way back and then starting them back up in October and that sort of thing.

Mr. FUQUA. Is that part of the problem we have because of laying off and building back up?

Mr. YARDLEY. Yes. I think we all underestimated the roll-through impact and the stopping and starting. We saved some money in fiscal year 1978, but it came back to bite us in fiscal year 1979. And the bill for doing that work out of sequence was quite a bit larger than if we had that money at the end of fiscal year 1978.

Mr. FUQUA. One of the arguments for the $185 million supplemental was if you didn't get it, you were going to have to lay off people. And as soon as the fiscal year 1980 budget came into effect, you could start hiring back.

When did you first learn about the problem that there might be some accelerated cost increases?

Dr. FROSCH. I have to give the answer on two levels. In a formal sense, that is, being informed that there was clearly a problem that we had to do something about, it was some time in March when it was made clear to me.

In the informal sense, I had somewhat been aware through our normal conversations in the course of the fall and very early in the winter that there were possibilities of funding difficulties but also made aware that it was by no means clear that these were going to be real when we examined what the request meant and what really needed to be done about them.

I can add in general that it is not uncommon for me to hear, not only as Administrator of NASA but in previous jobs to hear at regular intervals that there is a fiscal problem in a program. It is also not uncommon for it to turn out that the problem is by no means what it was originally said to be. It is common to have problems, to seek additional funds for the problems, and then to have later examination make clear that one can deal with the problems without those funds. So I am not usually in the habit of doing other than listening carefully to the informal early reports.

Mr. FUQUA. It appears that the first shoe fell in the fall and the second one fell in March.

Dr. FROSCH. I would not call it a shoe falling in the fall at all. I would say that there was some talk that there might conceivably be a problem and the real analytic results came out in March that showed that the worry was real.

Mr. FUQUA. Well, Dr. Froch, there is evidence that NASA management was aware of the likelihood of additional funding requirements in December of last year, and I quote from the first page of the report by what is sometimes known in NASA circles as the Day report, report of the budget and forecasting review team: "This study was initiated because of a significant increase in cost projections by Rockwell, the orbiter contractor. After the NASA budget for 1979 and fiscal year had been established, the provision of level one allowance for program adjustments normally served to cushion cost surprises."

And then, "The instance at hand may exceed that capability when combined with other demands on allowance and program adjustments in fiscal year 1979."

That apparently was made as a result of cost projections when it was known that there were cost projection increases coming along.

Dr. FROSCH. Mr. Chairman, there are always cost projections and many of them are projections for increases. The question is, at what point does one decide those are correct and that in aggregate they are something that cannot be handled by the reserves. That report contains in the wording that you read an indication of what the decision difficulty is. We maintain reserves precisely so that we can deal with unexpected projections. The question is, are we going to run out of reserves, not are there going to be difficulties.

John, would you like to comment on that?

Mr. YARDLEY. Yes; the specific reason that we started Roy Day into this study was we did have a large revelation from Rockwell in October. When all the dust settled on that, we allocated $77 million to the development problem that they identified, out of our APA. And we still had $117 million left. Then we tried to determine it what was left would be enough. And that was the status at that time. So Dr. Froch is absolutely right, we established reserves and we expected them to be eroded. This was a little sooner and a little bigger erosion than we expected.

However, at that time, I will hasten to add, Rockwell said, after looking at the rest of the year, that they would probably need another $50 million for the rest of fiscal year 1979. Now, that was pretty reassuring because I could cover that and they are the biggest uncertainty in the program—the Rockwell orbiter. But as it turned out, that has not been nearly enough.

Mr. FUQUA. But when did you find that there was other growth in the program?

Mr. YARDLEY. Well, about March we still had substantial APA left. It was less than half of what we started with, and we only had half the fiscal year to go and the funding curve was coming down.

But at that point we got in the spring preview. We received this on March 9 and that identified some additional requirements that had not been identified previously. It showed us that it would use up all of that APA plus about $20 million. We said that just is not satisfactory. We have to solve those problems and have at least another $50 million to carry us the rest of the year.

And that's what we put together in the analysis that was presented to your staff in May, to the Senate in May and to others. That was a transfer from production of $70 to $90 million and a $10 million transfer from the teleoperator program.

Mr. FUQUA. How often do you have a Shuttle management meeting here in Washington? Is it held on a regular basis or on an "as needed" basis?

Mr. YARDLEY. There are a number of meetings. I have a monthly meeting of all the program offices at all centers. In addition, the centers conduct monthly reviews of all the contractors. After those reviews are done, Mike Malkin conducts reviews with the Shuttle people on each of the major projects. So monthly you might say we run through the whole thing.

Mr. FUQUA. Didn't you discuss this problem in your October meeting as to the growth?

Mr. YARDLEY. We probably did. I don't know for sure whether we did. But what we discussed is just what I told you—that our reserves had been hit, and about 35 percent of them were wiped out with that October revelation.

Mr. FUQUA. Still in October you did not know the magnitude of the problem or if in fact it was a real problem?

Mr. YARDLEY. That's correct. We knew the magnitude of $77 million of it.

Mr. FUQUA. Yes; but you didn't know that there was any growth in any of the other parts of the program in October?

Mr. YARDLEY. No. Now in November and December the Marshall people came in and told us that they were going to need some more money and the Kennedy people came in and said the same thing. We looked at those carefully and they had some validity, I think the Marshall number was something like $23 million, if my memory serves me correctly. But that still gave us a pretty good APA, and the requirements were pretty fuzzy so that we were somewhat suspicious of the inputs at that time.

Mr. FUQUA. There was a raid on the cookie jar?

Mr. YARDLEY. Right.

Mr. FUQUA. When did the real problem begin to show up that there was an indication that there was in fact a cost increase? You had a meeting in October. Indications were that reserves were being depleted. In November and December you had continued indications that there was something maybe amiss in the program cost. Did you ever consider Dr. Frosch—at that time you had been going to OMB to defend your fiscal year 1980 budget, is that correct?

Dr. FROSCH. No. At that point the budget—sometime in November I guess—I don't remember the exact date—the budget had been closed and finished so that we were not then in active discussions.

Mr. FUQUA. My point is did you ever consider reopening your budget request with OMB after it became repeatedly known that there were cost increases, other centers were coming in. You had the $77 million and then the other two centers came in with requests did you ever consider that maybe you had better go back to OMB and relate to them that there may be an unanticipated problem there?

Dr. FROSCH. No. At that point I would say I did not and I don't think we did, institutionally, have any valid basis to go back and do

that. We would have been going back saying something like the centers are worried and they're beginning to think they need more money and I think we had better put some more money in the budget. The question would have been how much and for what and the answer would have had to be, "Well, we're not really sure how much and we're not sure whether we'll need it, but we're working on it, so let's put some more money in." I don't think that would have been a reasonable thing for any of us to do. We just did not have a validated base of information. We had some requests.

Mr. FUQUA. I can agree maybe you didn't want to go in until you had identified the specific cost.

Dr. FROSCH. Or knew that in fact there really was that kind of a requirement.

Mr. FUQUA. What were you doing at that time to find out if in fact there was a problem?

Dr. FROSCH. I think it was in John Yardley's hands. He had the Roy Day review and some other things going on.

Mr. YARDLEY. Between January and March the NASA system goes through the whole budget and regurgitates it to us in March. That was going on in that time period. In January, we still had about 35 percent of our reserve left even after all these requests.

It turned out after they went through the review which took about 6 weeks to really digest all the data, that we determined what we needed in additional fiscal year 1979 funds. And part of that, you recall, is still uncommitted.

Mr. FUQUA. Mr. Winn?

Mr. WINN. Thank you, Mr. Chairman.

In listening to these answers to the questions, it seems to me that you guys were drowning but you didn't really know for sure so you didn't yell for help. That's just sort of a simple version of it. It seems to me—that when you had an informal knowledge, Dr. Frosch, that there might be some difficulties heading your way that you did not come to the committee, either on an informal or a formal basis and discuss this with us. Second, I agree with the chairman, it seems interesting that either on an informal or formal basis with OMB that you didn't discuss the fact that you had some flags waving. It probably would not have helped the situation, the way it was developing, but I think the committee and the subcommittee would not have been as surprised as we were when you came back to us.

Would you care to comment on that?

Dr. FROSCH. Yes. Our assessment through that period was that if the problems that we were beginning to hear something about turned out to be correct, our assessment was that they were of a level that we still had APA sufficient to cover them as part of the runout of the year. And that was in fact what the APA was for. I don't think anybody felt in a position to go around raising flags on the basis of the level of the information and worry that we had. Now this, as the event turned out, was an error in judgment. In fact, the APA, as we finally discovered the facts, was not adequate, and we would all have been much better off had we realized that earlier and gone to see what could be done about it. I am not saying that it is clear to me that that was the case. But hindsight is a wonderful thing and

as I now look back, if we had all done something else, then the conclusion would have been different. It is always a question of difficult judgment as to when you cross the line between crying wolf because you think something might happen and informing people because you're pretty sure something might happen.

We felt that we did not have the kind of information that enabled us and say that, we had a problem. We felt that we would probably be calling it a problem when probably it could be handled and should be handled within the funding we already had.

And that's what we chose to do. However, it turned out that there was a problem that was not fully evaluated and that surfaced very thoroughly somewhat later.

Mr. WINN. You could not verify that you were drowning but your lungs were filling.

Dr. FROSCH. I would have to say that we were not feeling that kind of extremis. If I am to continue your metaphor, I would say that it was clear to us that the water might be pretty rough, but it looked as though we could swim that distance.

Mr. WINN. To change the subject a little bit, because I disagree with you and it's hard for us to comprehend that. After the statements today and the informal meeting yesterday I am no more convinced that you are answering the questions now than when we met about 3 months ago. But maybe something is going to show up.

In the September 1 review panel that the chairman discussed, is this committee going to get a chance to meet with all of the members of the panel or are we going to have the coach talking about his own team?

Dr. FROSCH. I presume you are talking about the staff management review.

Mr. WINN. I'm talking about Alan's review.

Dr. FROSCH. We had not constituted it as a panel but rather as an expansion of the staff for this purpose. But I see no reason why the committee could not talk to or call upon those people who have been involved.

Mr. WINN. The chairman and I have known most of them and we have great faith in their ability, but again a lot of them are NASA graduates, and we want to be able to ascertain whatever comes out of it is going to be their version and ask them some questions rather than your version.

Dr. FROSCH. I think that would be perfectly fine. I would suggest that you choose the timing of that at a time when they feel they have pretty well completed their review and come to their conclusions.

Mr. WINN. I understand that and I know they are busy men.

Dr. LOVELACE. Mr. Winn, may I interject one point. There will only be one version and you certainly will have the opportunity to satisfy yourself on that point by talking directly with the people involved.

Mr. WINN. Dr. Frosch, in your written statement you mentioned that the budgetary reserves were maintained at headquarters which has been the policy for quite some time. After the last 2, 3, or 4 months do you anticipate changing this policy in any way?

Dr. FROSCH. That's the kind of question that I will want to address after the groups that have been looking at management and fiscal

aspects report to me. I have not tried to do any independent examination of that myself. I am depending upon their recommendation.

Mr. WINN. Do you think there is any possibility that headquarters or the centers or the contractors have become reserve happy?

Dr. FROSCH. In what sense?

Mr. WINN. They just get a little complacent or a little apathetic because they know those reserves have been there for years and they can always fall back on them. The contractor feels, well, we are so far into this contract and we are so far along on the schedule. The centers feel they are on schedule or could make schedule but they are running short of money. But there's a big fat reserve sitting up there in Washington and we will eat into that for a while.

Dr. FROSCH. I think that's a very legitimate worry. I think it would have been a more legitimate worry a couple of years ago before we went through some of the fiscal vicissitudes of the past year or two, including a supplemental and an amendment.

It would be difficult for me to believe that the people in the various levels of the project and contractor can now believe or could have believed in the course of the past year, after we had to go for a supplemental, that there were large reserves to be eaten into. They knew there were reserves and we thought they were adequate to cover the problems that were reasonable to arise, but I don't think anybody could believe that they were so large that one could relax and expect the reserve to bail them out of any trouble that came along.

Mr. WINN. Whether they are large reserves or just reserves, don't you think it is possible from headquarters clear on down to the contractor or subcontractor that they feel all they have to do is make the request and get their heads together and sooner or later they will get that money?

Dr. FROSCH. I think it is unlikely that they have felt that way, because it has not been so easy for them to get money for everything for which they asked. As John pointed out, when requests came in they were pretty carefully scrubbed and only part of what was asked for was likely to be allowed, based upon an assessment of headquarters with the center and with the contractor as to what was really necessary in those tasks.

Mr. WINN. The philosophy of maintaining the reserves at headquarters, as I understand it, was to minimize cost. Do you feel that in light of the current program overruns and potential growth in the production cost that this philosophy is effective and, if so, how do you know that it is effective? How do you measure your performance?

Dr. FROSCH. I was about to answer the first half. I think it has been effective. I do not know how to find out because I don't know how to run the experiment both ways.

Mr. WINN. You are saying compared to what?

Dr. FROSCH. Compared to what and compared to the same program run a different way; we're not doing that experiment. I can only say that having watched programs that did not have a reserve system at all but depended upon living precisely within the budget or coming back for more money when required, my impression of the history of the two kinds of programs is that the ones without reserves have habitually gotten into as much or more difficulty. I think it still

comes out that our problem is not so much—and I say this in spite of the large amounts of money involved—our problem is not so much a question of whether we are overrunning. If there is a problem that I have to inquire about, it is a question of whether the management system allows us to be tightly managed but inevitably produces surprises for ourselves and others. I think that's the question we have to examine. But I think I really have to wait for what the teams have to say before I can be sure that that guess of mine is correct.

What I'm saying is I think we are likely to discover that we have an information and prediction problem as part of the consequence of the way we are running the program rather than a problem in managing the technical program or managing the actual expenditure.

Mr. WINN. We are faced with nearly another 2 years of D.D.T. & E. I am trying to figure out if there is any hope of being able to better anticipate the future problems and project a realistic total program cost. Maybe John or Bill would like to address that, or whoever wants to answer.

Dr. FROSCH. Let me only comment that that is clearly one of the major tasks that we have got to come to grips with in the next month or two based on the information that is being collected. Is our problem this question of prediction and estimation and if it is—and I'm guessing now that that is one of the problems, maybe the problem—what are we going to do about it? How are we going to improve our performance in prediction?

Mr. WINN. In the last 2 or 3 months I have been waiting for someone to tell me what the problem is. I keep waiting for our own investigative team, that has been going around the country, to tell us what the problem is. Everything is very vague. I'm not trying to point a finger, but I'm trying to get something to build a base on from now on, because we just can't keep going back to Congress or the taxpayer. Do you want to comment on that?

Dr. FROSCH. Only to say that's what we are all trying to do. We have an extremely complex program and we want to be sure we have the facts straight and the analysis straight before we try to fix it.

Mr. WINN. I'm not patient, but I'm going to have to be patient until around September 1, I guess.

One last question, Mr. Chairman.

I would like to ask Dr. Frosch about the delivery dates and that again may require Mr. Yardley to answer. The delivery date of orbiter 103 is being delayed now until the summer of 1983. Is this delivery consistent with the DOD requirements?

Dr. FROSCH. We have been discussing this with DOD and we believe we are agreed that it is consistent with the DOD requirements.

Mr. WINN. If it is not consistent with DOD requirements, then it's my understanding that DOD is going to have to make some substitutions or do some more purchasing and that would be expensive. Am I right?

Dr. FROSCH. If it is not consistent either we will have to find some way in the program by adjusting all the assets on the schedule to make it consistent or DOD will have to, it is my understanding, essentially buy insurance by purchasing expendable launch vehicles as back up for certain of the events that would otherwise be launched on the Shuttle. That will be expensive.

Mr. WINN. When you get through with these deliberations and discussions I wonder if either on a formal or informal basis, again at the discretion of the chairman, if you would keep us informed.

Dr. FROSCH. We certainly will. I can only say that perhaps you do know, but I suspect you do not know how eager I would be to be able today to tell you what our conclusions and what our actions would be. That would, obviously, be the best thing from our point of view and your point of view and everyone's point of view. The only reason I cannot do that is because we are not really prepared to say. We are not through with the analyses.

Mr. WINN. I understand that and I appreciate that. I just don't think I can stand any more surprises this year.

Thank you, Mr. Chairman.

Mr. FUQUA. Thank you, Mr. Winn.

Mr. Flippo?

Mr. FLIPPO. Thank you, Mr. Chairman.

I want to pursue a statement made by Mr. Yardley in regard to other centers coming in for additional funding, if I might. I believe you expressed some skepticism as to the legitimacy of those requests that come in later. Would you care to comment on that further?

Mr. YARDLEY. Basically. When they first came in they had a valid case for about a third of what they came in for. Now as time went on and they kept coming back they made a good case for more of it. But other things had come up since that time. For example, we burned an engine in December. That was not known when they were trying to ge the money in November.

So all I'm saying is they wanted to make sure they had enough APA, but they could not identify what they needed it for that early. They were afraid it would all be gone by the time they identified what it would be needed for.

Mr. FLIPPO. When they came in, did they not make some original projections? Is it total cost or the timing of the cost?

Mr. YARDLEY. We are talking about total fiscal year 1979.

Mr. FLIPPO. What type of actions or reactions do you consider when you have some reason to question an estimate made by a center?

Mr. YARDLEY. They come up and present their case and we may say that there is an item that looks to us like it's an allowance for a future change. So we're going to take that out, and that sort of thing.

For instance, one of the centers you may be interested in is the Marshall Space Flight Center. They may put an extra $10 million in for propellants. If they eventually don't need the propellants they may then use it for other things.

Mr. FLIPPO. I think those are very good things for you to pay very close attention to. I think that may be part of the problem with some other things in game playing and this type of activity, whether it be Marshall or Kennedy or Johnson or anywhere else.

But would you have some past actions on the part of Marshall or Kennedy or Johnson or any others in which they gave you cost projections and I would like you to submit some of them for the record, if you would.

Mr. YARDLEY. Certainly, we can give you a complete history.

Mr. FLIPPO. I would like that. I think that is something that should not be permitted to continue. I think we do have some problems, Dr. Frosch.

[The information follows:]

The following are examples of actions taken by OSTS in the process of analyzing POP 78–2 (July 1978) center submittals to Headquarters. These actions were taken where it was determined that the requirements were not fully justified or were too vague to base budget decisions upon.

ORBITER

Removed unidentified change allowance. Reduced provisioning consistent with later FMOF. Deferred docking module and OMS payload bay kit 1 year.

ORBITER SUPPORT

Reduced IBM change projection and Shuttle Mission Simulator configuration update.
Removed wind tunnel testing, SAIL reserve, and Extravehicular Mobility Unit anticipated and undefinitized growths.
Rephased food gallery development.

SSME

Adjusted Rocketdyne burner, G&A and fee. Reduced propellants.

ET

Reduced Slidell computer support consistent with prior years. Reduced MMC unnegotiated changes. Deferred weight reduction one year.

SRB

Reduced unnegotiated changes.

LAUNCH AND LANDING

Rephased anticipated changes. Reduced IBM and non-Rockwell development contractor manpower. Reduced GSE change allowance and spares.

Dr. FROSCH. Mr. Flippo, I wonder if I might comment? I have been, in the course of a possibly misspent career, project manager and program manager and a manager of project managers and program managers, so I have been through the whole set of psychological experiences that one goes through. We all tend to refer to this as game playing and, in a sense, there is a certain amount of gaming, but the point really is that the elephant looks different when you have a different job and a different angle to look at the elephant. And the project manager who has a particular job to do has always got to make sure that he is going to have enough resources to do his job and he wants to keep his reserves. He wants to make sure that if he gets into trouble he can cover himself without always running back to headquarters. That's a normal and natural thing to do and none of that should be taken as an ad hominem remark about any of the people.

On the other hand, headquarters wants to have its control and it knows that the guy who is doing the job wants to get it in his hands, so we all get into a discussion knowing what everybody knows and then work it out.

Mr. FLIPPO. What I am interested in is this $220 million budget amendment that we are talking about. I understood Mr. Yardley to say he had some skepticism about the cost estimates asked for by the centers. I would like to know what impact that has and whether or not the $220 million is needed.

Mr. YARDLEY. Let me correct a misimpression, Mr. Flippo. The money and APA in question I was referring to was fiscal year 1979

money. For the first time in a dozen years NASA had asked for a $185 million supplemental. About the time OMB said, "OK, we'll go ahead and ask for it," these other things started to come in. But they were not the fiscal year 1980 things. Up to the fiscal year 1980 review in March, the only thing we had accumulated against fiscal year 1980 was about a $48 million shortfall that Rockwell had identified in the fall. So we had plenty of reserves for fiscal year 1980 at that time. When everybody in the program worked through the system and looked at schedule slippages and other things, that's when we got surprised in mid-March because they came up with $150 million worth of extra things that we had not anticipated.

Mr. FLIPPO. It was the timing of their request. And apparently when it became evident that there was a shortfall in funds then everyone said well perhaps this is the time to talk about what we anticipate for the future?

Mr. YARDLEY. No; this is the normal midyear budget collection review which would include three things. It would include their current work plan for fiscal 1979 which still had 6 or 7 months to go, a reappraisal of what they thought they needed in 1980 which had not yet gone through Congress, and then what they predict for fiscal year 1981. Now out of that we got a $600 million extra development bill for those 3 years at that point.

Mr. FLIPPO. Just to summarize that particular question, do you have any doubts as to the authenticity or the necessity of the requests that were made from those centers that we discussed in regard to the $220 budget amendment?

Mr. YARDLEY. None at all. We scrubbed those very well. I think they are very defensible. And, of course, once we accept those, then the reserve for fiscal year 1980 goes negative and that's why the budget amendment is required. And, of course, we have included in that $220 a substantial reserve for fiscal year 1980 because we are going to have some more things we are going to learn.

Mr. FLIPPO. Mr. Chairman, I did have one or two other questions if you would permit, and I will hurry on because I realize the time is slipping by.

It would appear that after learning of significant additional funding requirements in the fall of 1978 that NASA did perhaps not give much consideration to requesting additional funding from OMB and in addition when learning of additional funding requirements in March of 1979 NASA's first reaction was to reallocate funds from production, apparently, while fully understanding the excessive cost penalties associated with such a plan.

Thirdly, back in fiscal year 1978 NASA made a decision to reallocate funds to D.D.T. & E. from production rather than requesting a supplemental. Now I do not consider that supplemental requests or budget amendments should be submitted to Congress at the drop of a hat, but I wonder if NASA gives proper consideration to these alternatives? Is it possible that NASA has been too timid in asking for the resources that they need?

Dr. FROSCH. There is no question that there is, what shall I say, a cultural tradition at NASA that I found very clearly when I came in that says we live inside our resources as we get them budgeted and

authorized and appropriated and we do our best not to keep running back and asking for more money.

When we started to talk about a 1979 supplemental, one of the first points that was made to me was that if we did this I would, as Administrator, be breaking considerable precedent and people had to search back through history to see when was the last time NASA had to go for a supplemental. And I'm not sure I remember the time, but it was at least a decade before if not a decade and a half. So it is a point of institutional pride that we can manage within our resources, and I don't think that's a bad thing. I think it is a good thing that our first reaction when we are faced with a problem is how can we manage within what Congress has authorized and appropriated for us to do to get out of this difficulty without damaging the program? I think we then have to assess whether we really are damaging the program by not asking for additional funds. I feel just slightly betwixt and between since I have now gone to the well twice and Mr. Winn has quite correctly called me on that as being something we should not have done.

But I don't want to be in the other position of not going to the well when I have to. But I certainly don't want to go running all the time.

Mr. FLIPPO. Has NASA given some consideration to delaying the development of JOP or now known as Galileo, and the space telescope, and some of these other programs?

Dr. FROSCH. We did look at that. In fact, we looked quite formally—I guess it must have been in March or April—at the whole range of programs to see whether there was some way of avoiding doing this, and the conclusion was there was no way in which we could rearrange those program moneys. In a sense, we never got to the question of what damage we would do to the program because we could not find a way to rearrange moneys that would make any sense in terms of obviating the need for an amendment.

Mr. FLIPPO. Doctor, if I might just comment on the point you made earlier about your information system and that sort of thing being the problem, I think I would agree with that concept, not so much the magnitude of this cost overrun and because you have a long history of doing things relatively within cost projections—and I commend you for that—but my concern is that perhaps you are not aggressive enough in regard to OMB in fighting for the kind of funds that we need to maintain our technical capabilities in the program. You did rightly refer to operating within the funds authorized by Congress. This committee has consistently asked and has not been able to understand why the shoestring approach that continues to erode our capability in space when other nations are striving mightily to increase theirs. So I think the problem, in addition to the problem that you describe, is all of our ability to convince OMB of the necessity of going forward with a balanced program. We may very well wind up with a vehicle to get to space and nothing to carry in it, if we continue to rob other programs.

I thank the gentleman for his remarks.

Mr. FUQUA. Thank you, Mr. Flippo.

Mr. Nelson?

Mr. NELSON. Thank you, Mr. Chairman. I have a number of questions, Mr. Chairman, and I will be as brief as I can.

Mr. FUQUA. We have all day and all night.

Mr. NELSON. I'm going to bore in and try to articulate my questions such that they will be understandable so a meaningful response can be forthcoming.

Dr. Frosch, was there a morale and a productivity problem in California with the Rockwell people when they were installing the tiles, such problem being occasioned by the fact that they knew their employment was going to cease once their job was done; that is, the pink slips were coming once they installed the tiles.

Dr. FROSCH. Well, we certainly speculated on whether there was such a problem. I have no direct data on that and it has not really been suggested by any data that I know of that that really was the case. I would certainly not think it unusual if there was such a problem.

John?

Mr. YARDLEY. We suspected it and we talked to Rockwell, and I think you ought to ask Rockwell this question later. My overall impression after talking about it and worrying about it is that there was some, but it was not a significant factor, maybe a 5- or 10-percent type of productivity loss because of that factor.

Mr. NELSON. So, as the overall management responsibility, you assumed that that was not the main reason. You are ascribing a 5- to 10-percent factor to the overall tile problem that occurred in California?

Mr. YARDLEY. A morale productivity problem.

Mr. NELSON. Because the people were going to be terminated.

Mr. YARDLEY. Yes.

Mr. NELSON. To what would you ascribe the remaining 85 or 90 percent of the problem?

Mr. YARDLEY. The problem was the tiles took a lot more work to put on than was anticipated or planned. Another piece of the problem was that the tile manufacturing itself at Lockheed was not going on schedule. The primary reason was not that they weren't building them on the right schedule but that there was a substantial rate of rejection. This put Rockwell in the position of having to put blocks of tiles on many times with tiles missing. They just couldn't wait and they had to rebuild those tiles. So the combination of these factors was primarily the reason.

Mr. NELSON. Dr. Frosch, there have been press reports that NASA is considering a suborbital flight test of the Shuttle. Would you comment on the status of this concept, and what would be the objectives of such a flight test, if it is true?

Dr. FROSCH. That is not now our plan. Our plan is that the first flight be an orbital flight. There have been some suggestions over the years that we not do an orbital flight first. The argument given is usually—and I have to say that this has not come to me for any further decision, although it may—the argument usually given is that by going suborbital, the first flight would not put the complete reentry thermal and aerodynamic strain on the thermal protection system tiles and that there might thereby be some advantage to having a first flight with a lower stress on that part of the system.

It is clear that the counterargument is that while the stress on the tiles may be lower, the stress on the entire rest of the system would be considerably greater in order to do as a planned maneuver what we

really think of as an abort maneuver, plus the requirement that the first landing would then be on the KSC landing strip rather than on a dry lakebed. So that is the countervailing argument.

There is also the question of whether in fact by going into orbit we might not have a better opportunity to inspect and possibly even make changes to the tile system on a first flight, although I think the possibility would have to be looked at very carefully. So these are the kinds of arguments involved.

I have not heard nor has anyone brought to me yet—I don't know whether they will—a suggestion that we change our plans given that set of arguments. I note that John is going to have a further look, because I know people are going to raise it with him, and I will await his views on whether he even wants to bring a change possibility.

Mr. NELSON. With the Shuttle program you developed the lead center concept. How well do you think it is working compared to your old way of doing business?

Dr. FROSCH. That's one of the things I expect to get comments on when I hear about the management examination that Al Lovelace has been talking about. I do not yet feel in a position to answer that question, Mr. Nelson.

Mr. NELSON. By the way, I want to echo Chairman Fuqua's request where he asked for and you said you would provide a breakdown of the $5.15 billion commitment by major program element, the orbiter, main engine, et cetera.

Dr. FROSCH. We can do that.

Mr. FUQUA. Let me clarify. I was really asking for how much of that with the increases added was the overrun versus program changes that may have occurred. But you could make that same breakout.

Dr. FROSCH. We could do it in terms of such a breakout.

[The information follows:]

The original estimate of $5.15 billion (1971 $) commitment was at the total program level and not in terms of system elements. The breakdown to element level has been adjusted to the 1972 Work Breakdown Structure (WBS) after completion of definition.

D.D.T. & E.

		Preliminary [1] (current estimate 1971 dollars)		
	Original estimate 1971 dollars	Through fiscal year 1980	Balance to complete	Total
Orbiter	$3.513	$3.851		
SSME	.580	.839		
SRB	.390	.330		
ET	.331	.353		
Launch and landing	.336	.364		
Total	5.150	5.737	$0.280	$6.017

	Preliminary [1] (current estimate real year dollars)		
	Through fiscal year 1980	Balance to complete	Total
Orbiter	$5.235		
SSME	1.170		
SRB	.473		
ET	.494		
Launch and landing	.555		
Total	7.927	$0.513	$8.440

[1] These estimates are subject to change as a result of the current Shuttle reviews.

Mr. NELSON. Are you considering now because of the delays that possibly instead of six test flights you will have some lesser number, perhaps four.

Dr. FROSCH. We have always considered, quite aside from the delays, that the number of required test flights might be fewer or more than the number planned in the schedule. In fact, the history of that kind of test flight in the space program has been that generally we have required fewer flights than originally planned. It was possible to get more efficient data collection in essence than was planned. Right now we are leaving it loose in the sense of saying we are going to do the first one, two, three, or four and examine what our feeling of confidence is for saying we have to do another test or we can begin operational flying. It must be remembered that in this system there is almost no difference between a test flight and an operational flight. The actual maneuvering of the vehicle, the launch and reentry, are essentially the same, although in a test flight, there being no specific cargo requirements, one can tailor the flight profile to test and not to any external requirement. But the real point of the transition comes when the cargo ceases being flight instrumentation mostly and starts being cargo for its own sake mostly.

Mr. NELSON. Under your present schedule, you are expecting about a 6-month slip, are you not, in the first operational flight from what was originally planned?

Dr. FROSCH. We have had enough original dates so I think I had just better state the dates. What I stated in my statement was that we figure there is about a 20-percent chance of the first development flight by the end of the first quarter and 50–50 by the end of the second quarter.

Mr. NELSON. But I'm not asking about the first flight. I'm talking about——

Dr. FROSCH. The first operational flight, that I think is about a 7-month slip from what we had previously.

Mr. YARDLEY. Yes. We had planned for the end of February 1981 for the first one, and we are now talking about September. Now that's a little fatter, particularly when you consider the possibility of four instead of six flights. We think it is imprudent to schedule sooner on the higher risk basis because of the customers involved.

Mr. NELSON. You are saying that considering four instead of six test flights, you are still considering the operational flights to go in September rather than February?

Mr. YARDLEY. That's correct. But that gives us enough cushion to make the fifth flight without interrupting that.

Mr. NELSON. Yes; I understand and that's good.

Now, do you anticipate any problems with the users, the commercial users, of the operational test flights? Are they prepared to be able to absorb the 7-month delay?

Dr. FROSCH. It will certainly mean that some of the early users who had already arranged for the possibility of a backup expendable launch vehicle will shift to and use that backup expendable launch vehicle. And I think it is true that the bulk of the early users, commercial users, had in fact planned against that contingency.

Mr. NELSON. OK. Now, how about the tracking and data relay satellite program? That was supposed to go in one of the first operational

flights, as I understood it. Now, what's the impact of the 7-month delay on getting that satellite up there; what's the effect on that?

Mr. YARDLEY. It is still our first operational flight but it has slipped 7 months.

Mr. NELSON. Is there a problem with that?

Mr. YARDLEY. Well, sure, the problem is it's going to cost us more money because we will have to maintain the existing network 7 months longer. Now, from the standpoint of operational performance, we don't really need the TDRSS until the Shuttle is flying anyhow. But there are contractual commitments and things of that nature that will cost more.

Mr. NELSON. Dr. Frosch, you said in your statement and in your testimony—and I can't remember the specific date but will you please refresh my memory—your first delivery to Vandenberg for the DOD mission out there has slipped from what to what now?

Dr. FROSCH. Well, the delivery of orbiter 103 I think we stated as the summer of 1983.

Mr. NELSON. What was it originally considered to be?

Mr. YARDLEY. In the schedule that went with the fiscal year 1980 budget, it was December of 1982.

Mr. NELSON. So about a 6-month slip.

[Pause.]

I am hesitating here only to make sure that I choose my words very carefully. I want to ask you—perhaps I'd better do that in private—with regard to some of the DOD missions of a classified nature. But anyway I'm going to ask you about that in private with regard to—someone here has already asked this morning are you going to be able to fulfill the DOD mission and the answer was "Yes." I want to get into that in more detail.

Since you are slipping from December 1982 to summer of 1983 and particularly how does all of that tie in with SALT and the SALT verification? I will follow that up later on.

Dr. FROSCH. Mr. Nelson, I would suggest that that be a conversation that includes representatives of the DOD as well as representatives of NASA.

Mr. NELSON. Yes. I have had some extensive conversations already on that and I want to explore that with you.

When our staff visited KSC in May there appeared to be some questions with regard to the division of responsibility between Johnson and Kennedy for completion of the orbiter manufacturing and accomplishment of the vehicle checkout. What management changes have been initiated to resolve this discrepancy?

Dr. FROSCH. There were such problems. I would like to have John Yardley describe the management changes that have been made.

Mr. YARDLEY. There was some confusion between Kennedy and Johnson on responsibility for the work done at Kennedy on the Orbiter that had not been completed. Traditionally we always ship vehicles there with work to do and Kennedy completes that work. So traditionally it would have been Kennedy's job.

Now in this particular case we became aware that the magnitude of this job was considerably greater than it had been our practice to do with the Kennedy people, both the contractor and the NASA people.

It had been a long time since they had a new vehicle where they had to do this kind of work. Their organization was not really tailored to do a big production job. So we gave Johnson the responsibility for all the work in the Orbiter Processing Facility (OPF) for this one spacecraft. We are putting a senior Johnson man down there for that. The Kennedy people are going to support him in getting that work done. Rockwell moved their top manufacturing vice president down there to take charge of all that manufacturing. He has two senior people working for him.

Rockwell also moved the vice president-program manager down there to oversee both the launch preparations and the work while it is in OPF. Kennedy has the responsibility for testing in the OPF and, of course, everything outside the OPF. We do have to mesh the test schedule with the manufacturing schedule. They have been working the last 4 weeks detailing all of this. They have worked out a good plan and it has been reviewed and I think it is all coming together.

Mr. FLIPPO. Would the gentleman yield at this point?

Mr. NELSON. Yes.

Mr. FLIPPO. That brings a question to my mind about the overall part of our probem here. When you were getting the cost increases in last fall, the projected cost increases, was it the work to be completed that you were unsure of or was it how to cost out those tasks to be performed that you were unsure of?

Dr. FROSCH. John, do you want to comment?

Mr. YARDLEY. I think it was some of both. In the case of the thermal protection system, for example, we thought back there in the fall of 1978 we were going to be finished with it in February. Now here it is June and we've still got about 9,000 tiles to go. We knew how many tiles had to go on. We didn't know how many people it would take or how soon it would be done. So that was the problem there.

It did not really become apparent to us until about the March time frame that this would be a big additional cost item too. We have a lot of people working on those tiles now and it is taking fiscal year 1979 money.

In the manufacturing work I don't think we thought we had as much work when we delivered the vehicle as it really turned out. There is controversy on that. All the known work has now been detailed and scheduled and man loaded and costed. So I think we are in good shape there.

What we are still uncertain of is what additional work is going to come up in the next several months that extends that time period.

Mr. FLIPPO. So you feel that you have the tasks to be performed now well in hand but you don't know what will come up later. Could you elaborate on what actions you are taking to better understand how to cost these workload functions? If I understand, sort of what you have said in essence this morning is you have had all these figures in that indicated you might have a problem and you weren't sure as to the validity of those and you wanted to be very sure before you said, hey, I've got a problem here. So that is really a management judgment, is it not, as to when do I decide that I have a problem. You mentioned systems earlier, is our reporting system adequate and providing the right kind of data.

I don't know that a change in the system is going to aid us in management judgment as to when do we have a problem or when do we say, hey, we may have a problem.

Dr. FROSCH. Let me try to describe that from my point of view. I think what we were getting early in the fall was a statement that said that, the XYZ subsystem is going to need more work than we thought and that it is going to cost $15 million. That is an interesting piece of information and it may well be right and you may agree that that's the right number and the right dollars and so on, but the first thing that has to be done is to find out what the work is on the XYZ system that has to be done. How do you know it's that much work and where does the costing come out? How much manpower? How much material and so on? That takes time and until you really work your way down through it you may not be convinced that you really want to do that now. You may want to say, well, do we really have to do that at all or can we wait 6 months and decide whether it has to be done or should it really be done next year, et cetera? You have all that to worry about.

With regard to the other part of your question as to will improved information systems really help, I think to the extent to which it turns out that we have not had a continual enough flow of that kind of detailed information, that would help. The biggest loose factor in all of this in my mind is not so much the question of what it costs per man-hour or what it costs to buy a piece of equipment, although there has been some problem there, or necessarily even in defining the known tasks to be done. There are two questions. One is the question of what are the unknowns and what are the things that are not going to pass qualification. We tend to refer to those as the unknown unknowns, but they will happen.

The other question is what does one predict for the efficiency of doing the tasks? One of the things that has become clear just as a matter of fact is that in the planning over previous years the accomplishment of an event in the year of actual prediction has been something like 70 to 75 percent of what was planned. So, in fact the actual production was smaller than the expected production. Now that is not necessarily translatable into workers who weren't working. That may be translatable into the possibility that the engineers who planned it didn't understand that it was harder than they thought, which I think is part of the TPS question. Even given that background of information, what do we now do in our planning? Do we continue to take the engineer's hard estimates or do we say, well, the history of the past 3 years is such that we are going to take the hard estimates and we're going to inflate them and so on.

What we have actually done in our current planning is the latter, that is to say we have taken the hard estimates of known work and said that's all very well but we in fact know that last year and the year before they were the same grade estimates, but in fact on the average they were off by some percent.

So we are simply going to put in a deflator factor if you like and say it is going to take x percent more work to do the work you say takes 100 percent. And so we are just adding that in. I think that is a fairly conservative thing to do. Of course, there is a counterargument and

the counterargument is that you must be learning something. Every time you do this you should be doing it better, so taking last year's thing is much too conservative and you ought to be putting a learning factor on. It is that set of judgments that we are trying to exercise, and I know of no set of rules by which you can turn the crank and draw those conclusions on a program which you have not done before.

Mr. FLIPPO. Thank you very much for your response, and I thank the gentleman for his patience in yielding.

Mr. NELSON. Certainly.

Dr. Frosch, instead of the way that you designed the reprograming of the funds you certainly considered the reprograming from other programs such as the space telescope and Galileo and Landsat and so forth. What was your thinking there that you did not do that kind of reprograming?

Dr. FROSCH. We went about it in what I can describe as—although it wasn't quite planned that way—what amounted to asking two questions in sequence. One, where was there money? Without regard to what it did to a program, where was there money that could be reprogramed in some reasonable way that would produce enough money to solve the shuttle program. And then having listed those possibilities we were then prepared to ask the next question. It's all very well that the money is there but what does that do to the NASA program and the national program and so on? We never got to the second question because we rapidly concluded that there were only one or two possible places where there might be enough money. And when we looked at them in terms of delaying that program, terminating the program, how much money actually gets picked up, and what are the other consequences, that didn't look as if it would net enough reprogramable funds in the time period of concern to really obviate the need of asking for more money.

That being the case we didn't bother to ask ourselves whether it was a good idea. We just said that in any case we have to go and ask for a budget amendment, and if we're going to ask for a budget amendment, we had better ask for what we think is the right amount for the subject at hand. Then if we get into a discussion that we really ought to take some of it out of the rest of the NASA program, then we can go into the discussion of how much we can cover that way.

Mr. NELSON. I commend you for the way you came to that conclusion and also for the politics of it. It makes it easier for us. Even though it is not all that pleasant sometimes to go back and ask for more money, it makes it easier for us to do it in the present posture.

Mr. Chairman, I have two more questions.

Earlier this year under our able chairman's leadership we put $27 million additional into the authorization bill for the fifth Orbiter. Now given the fact of these delays and reprogramings that you have testified about today, when do you anticipate that that $27 million would start to plug into the process?

Dr. FROSCH. If we were to make a decision to build a fifth Orbiter, the flow of facilities and construction is such that it could not in any case be built and then delivered—until about a year after 104 was delivered. And if we work our way back from that day, what we really discover is that we would initiate production seriously on a fifth Orbiter in fiscal 1982 with some long lead activities in fiscal 1981.

So the fifth Orbiter issue now with these delays could not really arise as a budgetary issue before fiscal year 1981.

Mr. NELSON. So in essence what you are saying is that even though Chairman Fuqua's bill had the $27 million that the appropriations bill does not have the $27 million in it and there is no water lost and we will address that issue then 1 year from now when we are doing the fiscal 1981 budget.

Dr. FROSCH. That is correct.

Mr. NELSON. All right. One further question. Is there any significance between the June 1980, 50–50 probable launch date and any kind of discussions that might have occurred between the United States and the Soviet Union vis-a-vis the Soviet's concern that the Shuttle Orbiter might be used as an antisatellite weapon.

Dr. FROSCH. None whatever. I have not discussed that question. It has not affected our thinking about how to conduct the program at all. My policy and my understanding of the administration's policy and my discussions with the White House staff make it clear that we are proceeding with the Shuttle as we were going to proceed anyway.

Mr. NELSON. Mr. Chairman, I thank you. Thank you, Dr. Frosch.

Mr. FUQUA. Thank you, Mr. Nelson.

Dr. Frosch, what is your time schedule now to get the Orbiter out of the Orbiter processing facility at the Kennedy Center?

Dr. FROSCH. We are talking in terms of running our internal production and operations schedule there aimed at a date like the end of November, but noting that what we really think will happen is some date between that and about a month later.

Mr. FUQUA. By the end of this calendar year then.

Dr. FROSCH. Well, before Christmas.

Mr. FUQUA. Give or take 5 days. [Laughter.]

Dr. FROSCH. I say it that way because it is an important 5 days. It is 5 days in which we all prefer to do other things than work on Shuttle Orbiters.

Mr. FUQUA. I've been around here long enough to learn that sometimes you have to ask the right questions in order to get the appropriate answers. I don't know whether the next question is going to be appropriate or not. I thought we had asked it before. But the $220 million that you are requesting in the fiscal year 1980 budget, is that going to be enough to get you through the fiscal year 1980 budget which ends on September 30, 1980?

Dr. FROSCH. I want to answer the question as carefully as you asked it, Mr. Chairman. I have to say that I believe the answer is yes, but I am nervous. It is very simply the following situation: It is very clear that the funding including that amount is sufficient to get us to a first flight in the middle or late spring without any question and leaving some reserve within the D.D.T. & E. budget some APA, some reserve.

It is also clear that delays in first flight mean that certain expenditures in operations and orbital flight test OFT and procurement for operations are also deferred so that as we delay these things we will pick up some funding. I believe our fiscal year 1980 request with the budget amendment is adequate for the schedule, but I cannot be positive that that is the case. The event will have to tell us. The difficulty is if you ask if I need more money I could not give you an amount nor a reason.

Mr. FUQUA. But the $220 million you are requesting is also based on a success oriented testing program.

Dr. FROSCH. It is based on the assumption that we will not have major technical difficulties that we do not now know about and that the results of the qualification tests that are now going on on various components and subsystems will be what I would call kind of average results, that is, there will be some things that fail but nothing which is a major problem, that most things will satisfactorily pass and that there will be no big glitches or failures in the qualification program. I think that is a reasonable kind of assumption but it could be wrong. Do you want to add anything to that, John?

Mr. YARDLEY. Well, I would only say that we made this $220 million estimate a month or so ago. Since that time we now know more about the Cape operation and what it will take to get that thing through the OPF and there are more dollars to do that that will come out of the reserve than we planned. How many more dollars we will find, you know, we hope our reserve will cover it. I'm like Dr. Frosch, I'm more nervous with the $220 million, now that I know we're talking about the end of June as a nominal date instead of the end of March, but we are going to be working that problem for the next month or so very hard and we should get closer to either being comfortable or more nervous in that time period.

Mr. FUQUA. Are you comfortable or nervous then?

Mr. YARDLEY. I'm nervous.

Dr. FROSCH. Let me add one comment and that is that obviously we are alert to potential management and information problems now to a degree and in a way that we were not so alert 6 months ago. On the other hand, we have not identified and therefore not made any formal changes to any of our information or management systems. So there remains, I have to say, some possibility that we could surprise ourselves again, but I don't think so, because I think we are in an informal way, much more probing and alert than we were, even if we have not made a formal system change.

Mr. FLIPPO. Just to see if I understand it a little better, are you saying that the $220 million will get you through June and the first orbital flight?

Dr. FROSCH. I think we are certain it will get us through the first orbital flight, something like March, April, and maybe into May, and that at that point we would have some reserve left and we would have some possibility of picking up money from delayed OFT and delayed buys of things for operational purposes, so that it looks all right as far as we can possibly tell now. And it's not a matter of whether we can go away tomorrow and get some more information. It is as far as we can possibly tell now. I have answered that way and I hope that way of answering makes clear that we are nervous for obvious reasons.

Mr. FUQUA. Thank you very much, Dr. Frosch, Dr. Lovelace, Mr. Lilly, and Mr. Yardley. We appreciate your being here. We are always happy to have you. We hope that next time you come back that you feel more comfortable with the $220 million.

Dr. FROSCH. Thank you, Mr. Chairman.

Mr. FUQUA. Our next witness is Dr. William Perry, the Under Secretary of Defense for Research and Engineering.

Dr. Perry, we are pleased to have you before this subcommittee today, and will you introduce your associates for the record? You may proceed in any fashion you choose.

STATEMENT OF DR. WILLIAM J. PERRY, UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING

Dr. PERRY. Thank you, Mr. Chairman. I have on my right Major General Yost who is the Air Force Director of Space Systems and Command, Control, and Communications, and on my left is Mr. Barfield who works in my office. I have a statement for the record which, with your permission, I would like to submit.

Mr. FUQUA. We will make it part of the record and you may summarize it.

[The prepared statement of Dr. Perry follows:]

Statement by
Dr. William J. Perry
Under Secretary of Defense for Research and Engineering
before the House Subcommittee on
Space Science and Applications
June 28, 1979

Mr. Chairman, I am pleased to appear before your Subcommittee to discuss the Department of Defense requirements for the Space Shuttle and impacts caused by delay in the availability of the Space Shuttle.

Maj. General W. R. Yost, the Air Force Director of Space Systems and Command, Control, and Communications is with me today to assist in responding in detail to questions you may have.

The Department of Defense is making increasingly greater use of space in areas such as navigation, communications, ballistic missile early warning, surveillance and weather forecasting. In the 1980s our space programs will be depending to an increasing extent on the Space Shuttle.

The Department of Defense is opting to transition spacecraft from launch on expendable boosters to launch on the Space Shuttle. We are doing this because we receive benefits of reduced launch costs, increased reliability, increased weight and volume for our payloads, and perhaps most important of all, increased flexibility. With the Shuttle we are going to be able to recover our spacecraft from low orbit to perform repair and technological updating. We plan to use the Shuttle as a manned laboratory in space for experiments; eventually we may perform on-orbit servicing of spacecraft and assemble large structures in space.

We plan to begin the transition of our operational spacecraft to Shuttle launch in FY 1982 and this transition will be complete by FY 1985. By the mid-1980s we will be nearly totally dependent on the Shuttle for our space missions.

I should also mention the Shuttle's dependence on the Defense Department. We have two major programs underway that are crucial to the success of the Shuttle program. The Air Force is developing the Inertial Upper Stage to deliver spacecraft from the Shuttle to high orbits. The Air Force is also

constructing Shuttle launch and landing facilities at Vandenberg Air Force Base so that polar launches can be conducted to support DOD and non-DOD space programs.

In May 1979 the President submitted a $220 million amendment to the NASA FY 1980 Space Shuttle funding request. I believe that these funds are essential to allow the national Space Shuttle program to proceed in a reasonable manner.

NASA has very recently provided us revised Shuttle program dates based on their best judgment at this time. They assume early availability of the NASA FY 1979 Supplemental funding request and approval of the $220 million additional funds in FY 1980 which the President has requested.

We understand that the First Manned Orbital Flight may not occur until the end of the second quarter of 1980. The initial operational capability for the Shuttle at Kennedy Space Center will be achieved in late summer 1981, and Orbiter 099, which is the second operational orbiter, will be delivered in the spring of 1982. This schedule will support our initial launches at KSC since our first experimental payload is not scheduled on the Shuttle until late 1981 and our first operational payload is not scheduled until early 1982.

Orbiter 103 delivery is now projected for the summer of 1983, which is six to nine months later than previously planned. Orbiter 104 delivery is very late in 1984, about a year later than previously planned. These delivery dates are very dependent on FY 1981 and FY 1982 funding decisions which have not been made. The important point here is that even with these dates, DOD can meet the December 1983 Vandenberg IOC. We would, however, require a flight proven orbiter from KSC eight months prior to IOC for Vandenberg facility checkout.

We are very concerned over the delays projected for Orbiters 103 and 104 and will work very closely with NASA as the Shuttle schedules are finalized and decisions are made on FY 1981 and outyear funding. Our concern is based on the adequacy of the orbiter fleet to meet national Shuttle traffic demands which are projected to build up rapidly once the Shuttle is operational. By 1983, for example, DOD will have transitioned several programs important to our national security to Shuttle launch. In view of the need for a flight proven orbiter to check out Vandenberg, there could be periods when only one orbiter will be operational at KSC. We also note that with the projected NASA orbiter delivery schedules, the nation would be supporting operations at KSC and VAFB with three orbiters for about a year. And only one of these orbiters would provide

full performance capability. While we are working closely with NASA to establish firm Shuttle schedules, we also will be examining our payload transition and backup booster planning to determine if any adjustments are needed.

At the same time that orbiter production planning is being examined, consideration must be given to assuring that necessary logistic support - adequate spares - are provided so that all four orbiters can be maintained in service once they are delivered. Further, we must be sure that the option remains open for NASA to acquire an additional orbiter should increases in projected traffic, loss of an orbiter, or turn around times longer than now projected require such a decision.

Delays in orbiter deliveries beyond those presently projected would force consideration of an extended commitment to expendable launch vehicle operations with attendant adverse operational and economic impact.

Our program for Shuttle use remains carefully keyed to NASA Shuttle development progress and orbiter production schedules. The program has not changed since the President's budget request was submitted to the Congress early this year. Effective coordination on the Shuttle program is maintained through the Aeronautics and Astronautics Coordinating Board which is co-chaired by Dr. Lovelace, Deputy Administrator,

NASA, and myself. Through this Board Dr. Lovelace and I are able to address major issues of interest to both agencies and to provide broad policy guidance within our respective agencies. The Space Transportation System (STS) Committee provides a means for detailed top management coordination on the Shuttle. The STS Committee is co-chaired by the Air Force Assistant Secretary for Research, Development and Logistics and the NASA Associate Administrator for Space Transportation Systems. Also, we have strong day to day field level coordination and joint activity on the Shuttle; and, in addition, Air Force officers have been detailed to NASA to assist NASA in specific areas of Shuttle development. Very recently the Air Force has located a general officer at NASA Headquarters to further strengthen our joint planning and program implementation activities.

As a result of this careful coordination over an extended period, our requirements have been made known to NASA and carefully considered in the Shuttle design. The Space Shuttle orbiter is sized for DOD missions and can meet all of our launch requirements for the foreseeable future. The Shuttle will be an integral part of our future military space operations.

Through FY 1978 we have spent $257.5 million in support of our development and acquisition activities leading to DOD Shuttle utilization. In FY 1979 we are spending $390.7 million, and in FY 1980 we are requesting $444.8 million in all appropriations. The $444.8 million in FY 1980 will be applied as follows: IUS development - $67.3 million; Vandenberg Shuttle facilities - $273.1 million; and, all other DOD preparations for Shuttle use, including KSC launches - $104.4 million. The $444.8 million is made up of $175.5 million RDT&E, $191.1 million Procurement, and $78.2 million Military Construction funding.

Over the past year we have made some changes in our program. Briefly, we have rescheduled our Vandenberg Shuttle launch and landing facility to provide an initial operating capability (IOC) in late 1983 instead of mid-1983. We are providing for Shuttle thrust augmentation in the initial design and construction of the launch pad. The latest DOD launch model shows an increase in Shuttle launches from 109 to 113 through 1991, and we are placing greater emphasis on using the Shuttle as a manned laboratory in space. Let me give you an overview of our FY 1980 Shuttle related activities.

We are providing a Shuttle launch and landing capability at VAFB so that we can continue to support high inclination DOD launches. Launches into sun synchronous, polar, or near polar orbits cannot be conducted from KSC without unacceptable performance loss and overflight of populated land areas during launch. Since last year we have reoriented our VAFB activities

to phase our capability to conduct Shuttle operations starting with an initial capability of six launches per year in 1983 and building toward a final capability to conduct up to 20 evenly spaced launches per year by mid-1985. Our previous plan called for 20 launches per year capability in 1983. This phased approach provides a better opportunity to incorporate, at VAFB, any changes which may be necessary based on early flight experience at KSC and assures that the VAFB Shuttle facility will be properly sized to meet national needs.

Last January we adjusted the DOD Space Shuttle program to support an initial operational capability at Vandenberg Air Force Base (VAFB) in December 1983 rather than June 1983. A number of considerations were involved. First, we considered the earliest firm date that Shuttle launches from Vandenberg would be required. A review of military payload schedules conducted by DOD concluded there are no firmly planned military payload launches at VAFB that cannot be accommodated by the revised schedule. There were several civil payloads considered in this time frame, but they were not firm. Another factor in determining Vandenberg availability was a desire to minimize FY 1980 funding consistent with firm requirements for Shuttle use.

Finally, NASA advised the DoD that thrust augmentation is necessary to achieve the Shuttle's operational design specifications. The full 32,000 lb Performance Reference Mission 4 payload delivery capability projected for Shuttle launches from VAFB is desired by both DoD and NASA.

To achieve this capability, NASA has selected a modification to the Shuttle configuration which consists of a single strap-on solid motor attached to each of the main solid rocket boosters. This configuration is the simplest, least risk, lowest cost option of several that were considered by NASA in consultation with DoD. However, this configuration impacts the design of the VAFB launch pad and the launch mount which supports the Shuttle on the pad (funded FY 1979 projects).

To accommodate this configuration, changes must be made now in the initial design of the launch pad and the launch mount. Additional model tests must be conducted to provide acoustic and overpressure data supporting this revised design. Pad retrofit at a later date to accommodate thrust augmentation after the facilities are constructed would be a major undertaking requiring extended disruption of Shuttle operations and is not considered practical.

The time required for design, construction and activation of the launch pad and mount, which were funded in FY 1979, is critical in achieving an initial capability at Vandenberg AFB. Thus, the pad design changes for thrust augmentation significantly increased the technical and schedule risk associated with achieving a June 1983 date. Other changes to VAFB plans which may be necessary for storing and processing the strap-on solid motors are not as critical from a schedule standpoint. We will defer making these investments until firm payload schedules dictate.

The full 32,000 lb payload delivery capability (Performance Reference Mission 4) remains a valid Shuttle requirement for the mid-1980s. Thrust augmentation is not required for military payloads scheduled for Shuttle VAFB launch through FY 1984; however, NASA full capability Spacelab flights out of VAFB will have to be delayed until thrust augmentation is available. It is expected that planned payloads will grow in capability, and therefore in weight, as new concepts evolve over time and Shuttle thrust augmentation will be needed to fully utilize the Shuttle's capabilities.

FY 1979 funding for VAFB is being used for facilities, equipment and software design, procurement of launch processing and other common support equipment, and launch pad modifications. Site preparations at VAFB began in January 1979, and actual construction is scheduled to begin in

August 1979. FY 1980 funding will provide for continued facilities, equipment, and software design; ground support systems integration and initial systems activation effort; plus the continuation of procurement of common and unique equipment. Our MILCON request for VAFB includes the orbiter processing and hypergol maintenance and checkout facilities, utilities, launch pad thrust augmentation provisions, and relocation of existing Titan solid motor facilities to make room for Shuttle solid motor processing and storage.

The IUS is being developed for use on Shuttle launches to deliver DoD spacecraft to higher orbital altitudes and inclinations than the Shuttle alone provides and will also be used by NASA for synchronous orbit and planetary missions. DoD will also use the IUS on the Titan III to improve mission success and reduce costs during the early Shuttle transition period. The IUS when used on the Shuttle can deliver payloads weighing up to 5,000 lbs to geosynchronous orbit. When used on Titan IIID, up to 4,000 lbs can be delivered to this orbit. Our FY 1979 funding supports the IUS full scale development which began in April 1978, procurement of IUS ground support equipment, logistics support, and necessary modifications to the Solid Motor Assembly Building at Kennedy Space Center (KSC). The IUS design now has been baselined as a result of the Critical Design Review which is now complete.

In FY 1980 development of the basic two-stage IUS configuration will be nearing completion. We will continue IUS/-Orbiter integration efforts, and procure IUS airborne and ground support equipment as well as pre-production vehicles to support the initial flights. The first DOD IUS flight is scheduled for late 1980 on a Titan IIID vehicle, and for FY 1982 on the Shuttle. The first NASA IUS flight is scheduled to occur on the Shuttle in 1981. We are now coordinating with NASA the incorporation into the DOD IUS program of NASA-unique requirements. NASA twin and twin plus spinner IUS configuration development, funded by NASA for planetary missions, will continue toward a first flight in 1982. As the various elements have matured, IUS, orbiter and spacecraft interactions have led to the requirement for IUS design changes to insure adequate performance for the Galileo mission. Solutions appear to be at hand, but additional funding may be required for these performance improvements.

Other Shuttle activities include preparations for DOD launches at KSC, payload integration, mission operations capabilities development, and DOD modifications at Johnson Space Center (JSC). Our FY 1979 funding covers continued development of airborne support and interface verification equipment for DOD payloads, design of security systems, procurement of security and ground communications equipment, systems engineering, software development, and continued implementation of the Johnson Space Center controlled mode to support classified DOD missions. In

FY 1980, payload integration efforts to support early DOD Shuttle flights will continue. Facility modifications will be made at JSC, and equipment will be procured to provide security to conduct Shuttle operations. Software validation and verification will continue, and results from the manned orbital flight tests of the Shuttle will be evaluated to assure compatibility of DOD payloads.

DOD planning for early Shuttle launches is based on using NASA's JSC for simulation, training, and Shuttle flight control for all DOD missions. Since the JSC facilities, as presently designed, cannot concurrently handle classified and unclassified payload data, we have worked closely with NASA to define modifications needed. A validated modification approach will assure adequate protection of DOD classified data and have a minimum impact on concurrent civil space operations. This approach, called the controlled mode, is now being implemented. Detailed design modifications of the JSC facilities and procurement of essential additional equipment will continue in FY 1980. We will acquire the controlled mode capability at JSC in time to support our first calssified payload launch on the Shuttle. Our investment for this purpose will be held to a minimum consistent with our essential security needs and projected classified launches on the Shuttle through the mid-1980s. For the longer term we feel that a dedicated backup DOD Shuttle flight control facility will be required. Such a

backup control facility would avoid total dependence on the single mission control facility at JSC and improve our capabilities for certain missions in the late 1980s. We will include this requirement in any new facility which we may consider to improve our satellite control capabilities and enhance the survivability of our space systems. In the interim we will be totally dependent on JSC. We have 19 classified launches scheduled through 1985, the earliest date when any new facility capability could be brought on line.

The latest Department of Defense Space Mission Model for the FY 1979 - 1991 period projects 113 Shuttle launches, 64 from KSC and 49 from VAFB. This is an increase in DOD Shuttle traffic over the 109 launches we projected last year. Initial DOD use of the Shuttle is planned for an experimental payload in late 1981. The first DOD operational payload, DSCS II, is scheduled for launch in 1982, and by the mid-1980s all DOD payloads will have transitioned from launch on current expendable boosters to Shuttle launch.

As we progress in our plan to use the Shuttle we also plan to phase out current launch vehicles. Phase down of the Titan III production line will begin in FY 1980 and the end of new expendable launch vehicle production is planned for

FY 1983. However, we will retain a minimum number of these vehicles and associated launch pads as a backup capability through FY 1985. This is necessary to assure that our highest priority spacecraft can be launched if the Shuttle encounters difficulties during transition. We will examine both our payload transition and backup booster planning to see if any adjustments are necessary as a result of the Shuttle program schedule changes which are currently under consideration.

Within the past year we have begun to explore more fully the manned laboratory capabilities of the Shuttle for conducting Defense experiments. The Space Test Program (STP) has been tasked to serve in a pathfinder role for DOD in aggressively exploring ways to use the Shuttle to conduct DOD experiments in space more effectively. A plan has been developed and is now being implemented. STP will develop suitable equipment to support experiments in the Shuttle payload bay and to allow the payload specialist to interact in real time with the experiments.

We hope this approach will speed up the infusion of technology into space systems, allow more ideas to be tested in a given time, and minimize our investment in bad ideas. We will rely on man as an experimenter to react in real time

to unexpected events and allow the experiment design to be less complex. A number of candidate experiments have been defined at this point, and we are proceeding toward our first sortie mode Shuttle flight. We believe the experience gained here will contribute greatly to defining the ultimate role of military man in space.

In summary, the $220 million requested by the President is essential to allow the national Shuttle program to proceed in a reasonable manner and to support national security programs committed to use the Shuttle. The orbiter delivery schedules now under discussion will permit the Department of Defense to activate Vandenberg on schedule by December 1985. The full 32,000 lb. payload delivery capability for polar launches remains a valid NASA/DoD requirement for the mid-1980s, and we are now providing for thrust augmentation in our Vandenberg Shuttle launch pad design. We are moving aggressively to transition our spacecraft to the Shuttle and to take full advantage of the Shuttle's capabilities to achieve more effective space operations. I solicit your full support for both NASA and DoD FY 1980 Shuttle funding requests.

Dr. PERRY. Mr. Chairman, as this committee is aware and certainly as is reflected in some of the questions you were asking some of the NASA witnesses, the Defense Department is becoming increasingly dependent, first of all, on space systems in general, and as time goes on, specifically on the Shuttle.

Our dependence on space for navigation, communications, early warning, surveillance and weather forecasting will become even greater in the decade of the 1980's. We will begin in 1982 to transition our space systems to the Shuttle vehicle and later we will be conducting all of our space operations with the Shuttle. The reason for this is that we believe that the Shuttle will be cheaper and more reliable than current launch vehicles. It will provide us greater weight and volume for our new payloads and perhaps, most importantly, it will give us the flexibility to recover payloads, to service vehicles in orbit, and to have a man in space which we think will be extremely important in the decades ahead of us.

I would like to start off this testimony by reaffirming the support of the Department of Defense for the Shuttle program. Our transition plan involves phasing down our Titan III expendable launch vehicle production beginning in fiscal 1980. So we are very close already to that decision point. We plan to shut down the Titan III production line in fiscal 1983 and to close up the launch complexes in fiscal 1985. By 1985, we will be almost totally dependent on the Shuttle for our space missions.

In the first 10 years of our use of this Shuttle we anticipate conducting 113 launches for an average of about 11 per year. Actually that figure is a little misleading because we will be gradually increasing the quantity and we will be approaching an average more like 15 per year by the end of that period.

While I have stressed the dependence of the Department of Defense on the Shuttle program I should also mention the other side of that coin; namely, the Shuttle program's dependence on the Department of Defense. We are developing the IUS, the inertial upper stage for all users of the Shuttle—not only Department of Defense. We are also developing a launch facility at Vandenberg Air Force Base. The inertial upper stage will allow the Shuttle program to deliver payloads to very high orbits.

For example, we will be able to carry 5,000 pounds to geosynchronous orbit with the IUS vehicle. The design of that stage is moving along fine. The first launch of it is scheduled for next year. That will be on a Titan vehicle. The first launch on the Shuttle will be 1981 for a NASA payload and 1982 for a DOD payload.

Site preparation has started at Vandenberg. The actual construction will start this fall. The reason for the Vandenberg facility primarily is to accommodate polar or near polar launches without unacceptable performance losses and without flying over populated land areas.

The present plan calls for the Vandenberg facility to achieve its initial operational capability in December 1983. At that time we will have the capability of conducting six launches per year. We will gradually increase the capability at Vandenberg so that by mid-1985 we will be able to operate at the rate of up to 20 launches per year.

You have raised questions with NASA today about the impact of the revised schedule. We have worked very closely with NASA and the

schedule which they have presented to you will support DOD requirements. Our first experimental payload will be launched in late 1981 on the Shuttle and the first operational payload in early 1982. Both of those will be at Kennedy Space Center. And both of those are compatible with present plans that NASA has for the Shuttle. Most crucial to us are the launches at Vandenberg.

The present NASA plan calls for the delivery of vehicle 103 in the late summer of 1983. We have an IOC planned in December of 1983 and we have the first DOD launch planned for 1984. That gives us adequate time for the checkout of the Vandenberg facility and preparations for the first launch in the 1984 time frame.

Vehicle 104 is scheduled to be delivered 1 year later. Both of those schedules, of course, depend on not only the technical issues and programmatic issues which you have been discussing with NASA today, but they also depend on 1981 and 1982 funding.

To answer the question which several of the members asked relative to the DOD programs, we can met the launch date of all planned DOD programs if the schedule dates for the Shuttle Orbiter deliveries are maintained.

I must say though that we have used up nearly all the margin of the program by these slips and we are looking now at launches that are going to occur 5 years from now—we have precious little margin left. My concern in the program is simply a matter of prudent planning and is oriented around two issues. First of all there is very little margin left in the schedule between the delivery of the orbiters and the planned launch dates, and second, there will be no backup in terms of orbiter vehicles available. We will be operating for the first year with a single orbiter vehicle at Vandenberg. So my concern is equally as great for the delivery of 104 as it is for the delivery of 103.

Now we manifest that concern by providing backup expendable launch vehicles. Our present program calls for four complete Titan III vehicles and two sets of long-lead Titan hardware to be maintained as a backup. I am reexamining with the Air Force whether those four Titan vehicles provide adequate protection against all of the uncertain factors which could occur in the next 5 years.

If, in our judgment, it is not an adequate hedge, we will be requesting additional funds in the Defense Department budget for more expendable launch vehicles. The margin for error which we have to be concerned about is, first, the possibility of greater delays in the Orbiters, notwithstanding the best judgments made today. Second, there is always the possibility of an accident—either to an Orbiter or a pad. And finally there is a possibility that our requirements will change sometime in the next 5 years with the number and urgency of launches we are talking about.

For all of those reasons we will be reexamining our plan for backup expendable launch vehicles and should have within a few months a judgment on that point which will be manifested, if there are any changes required, in our budget request for 1981.

Any action we take—in order to avoid exorbitant cost for expendable launch vehicles—has to be taken before we begin to shut down the production line. So it is a near-term decision for us.

Let me summarize very briefly the Defense Department's part of the Shuttle program. By the mid-1980's we are scheduled to spend ap-

proximately $2 billion on the Shuttle program in the Defense Department budget. To date we have spent only a small fraction of that, through fiscal 1978 something in excess of $250 million. Our fiscal year 1979 budget is $390 million and our request in fiscal year 1980 is $445 million. The bulk of that money is going for Vandenberg facilities. The second largest funding requirement is for the inertial upper stage vehicle. I think there is one other point that is perhaps worth mentioning here. We are making a modification to the Johnson Space Center to accommodate the control of our classified payload launches. The Johnson Space Center presently is an open facility. So we also have funding in our budget to accommodate that change.

In summary, I would note that the Defense Department is dependent on the Shuttle program and will be nearly totally dependent on the Shuttle program by the mid-1980s. The request that NASA has made for the budget amendment in 1980, we believe, is essential in order to give us the opportunity to meet the schedule for vital national security programs.

I am also concerned, even with the amendment, that sufficient margin in the schedules exist. So we are reexamining the requirements for backup expendable launch vehicles. We are completely and totally committed and dedicated to the Shuttle. We believe that it is an imaginative program which we aggressively support. We believe it will give us much greater capability, and ultimately lower cost, in our space operations than any other alternative. So we are soliciting the support of this committee for the budget amendment request that NASA has made.

I think that is perhaps all I will make in the way of preliminary statements. I will be happy to try to answer the questions you may have.

Mr. FUQUA. Dr. Perry, we have a rollcall vote. I think it would be appropriate at this time to take a short break to answer the rollcall and we'll be right back.

[Recess.]

Mr. FUQUA. The subcommittee will resume.

Dr. Perry, you mentioned that the time margin because of the anticipated timeframe for launch of the Shuttle that the margins had been somewhat used up between that and your expendable vehicles, and you did say that you had an adequate supply of Titans, I believe, to take care of the transition phase of expendable vehicles from the time of 1981 of the first Shuttle launch.

Dr. PERRY. We have an adequate supply of Titans for all of the planned expendable launches through 1984, and in addition to that we are procuring four extra Titans for reserve and two sets of long-lead parts beyond the four extra Titans.

Mr. FUQUA. That will not interfere then with your production line that may have to be closed out at some point?

Dr. PERRY. The present plan is to begin the phasedown of the production line in fiscal 1980, but the production line would still be operating as late as 1982 even with that plan.

Mr. FUQUA. Then the slippage of the Shuttle schedule—has that caused you to have to switch any of your Shuttle launches to expendable launches?

Dr. PERRY. No. The NASA schedule still accommodates all of the dates that we were planning for DOD flights.

Mr. FUQUA. In the military construction budget which just passed the House recently the funds were deleted for the construction activities to support the Shuttle at Vandenberg. Is that going to delay any of your Vandenberg launches?

Dr. PERRY. Yes; our best judgment now, Mr. Chairman, is that that would occasion essentially a 12-month delay in the activation at Vandenberg, which is to say that it would slip from December 1983 to December 1984. We have three DOD flights planned at Vandenberg for this period, two in fiscal year 1984 and one in early fiscal year 1985. Those then would not be able to use the Shuttle. We would have to make those launches with expendable launch vehicles. So, if that were sustained in the final authorization and appropriation bills, we would have to then come back with requests for additional expendable launch vehicles to accommodate that slip in the launch schedule. There would be other problems as well. The most immediate problem would be probably an increase in program cost of about $200 million to accommodate the requirement for providing for the expendable launch vehicles.

Mr. FUQUA. Mr. Brown?

Mr. BROWN. Thank you, Mr. Chairman.

Dr. Perry, I am not as much up to speed on this project as I would like to be. Some of my questions may therefore appear to be a little stupid.

Can you tell me a little bit more about this intertial upper stage system, how it works and if it is too complicated, would you supply it for the record.

Dr. PERRY. The concept is quite straightforward. The Shuttle simply delivers its payload to a low altitude orbit. If the mission can be performed from that orbit, then the intertial upper stage is not needed. If the mission requires a higher altitude, we need another stage to carry the payload up to that altitude. The intertial upper stage is simply a rocket-powered stage which will carry the payload from the low-altitude Shuttle orbit up to a higher altitude orbit required by the payload in order to perform its mission.

Mr. BROWN. All right, so when you talk about 4,000 or 5,000 pounds, that includes both the rocket and the load it is carrying.

Dr. PERRY. The 5,000 is just the payload. That's the payload that the IUS will carry to a geosynchronous orbit. So, if we want, for example, to put a communications satellite at that orbit and it weighs 5,000 pounds, then the IUS will carry it to that orbit.

Mr. BROWN. I would assume that some reasonable proportion of your missions will require boosting into higher orbits?

Dr. PERRY. Yes, that is correct.

Mr. BROWN. Can you give me a rough guess as to what proportion?

Dr. PERRY. Yes; in round figures about 50 percent of them.

Mr. BROWN. You are talking about somewhere on the order of, what did you say—110 or 120 DOD missions on the Shuttle up through 1991?

Dr. PERRY. That's correct. We get up to about 15 a year per year by the end of 1980's.

Mr. BROWN. Dr. Perry, it is obvious that several members of the committee have an interest in these DOD missions, many of which

are classified. I have raised with you occasionally this question of military-civilian interface in projects like this which sometimes makes for difficulty on the part of our committees in determining appropriate actions or policies.

Could I presume to ask if it would be possible to get a classified briefing on the military missions involved in this project at some appropriate time?

Dr. PERRY. Certainly, that could be provided at your convenience.

Mr. BROWN. Several other members of the committee are interested and haven't had it—some may already have had it—it might be easier to arrange it for several of us. I would like to investigate that anyway.

I suspect that some of those issues do involve communication and sensing from outer space which I am quite interested in as a civilian activity and I would like more information.

You made a couple of statements which were somewhat provocative to me in your written testimony. For example, you look forward to the eventuality of on-orbit servicing and large structural assemblies using the shuttle. Is that in both the near-Earth orbit and possibly synchronous orbit that you are making reference to?

Dr. PERRY. When I am describing the assembly of large structures in orbit, I am describing the assembly taking place in near-Earth, low-altitude orbit, but once assembled the structure may be propelled to a higher altitude, for example, to geosynchronous altitudes.

Mr. BROWN. Using the IUS?

Dr. PERRY. Probably not.

Mr. BROWN. Would the same kind of a rocket propulsion system be usable for moving a space structure from lower orbit to upper orbit?

Dr. PERRY. Not as the IUS is presently designed. The IUS would certainly have to be modified in order to propel these larger space structures.

Mr. BROWN. I saw an interesting science fiction program last night here in the building in which this problem was solved with something called a mass driver. It was essentially a linear electric motor which was used to create a reaction by propelling a mass out of the linear motor and I presume driving whatever the motor was inbedded in forward as the mass goes backwards. Have you been working on anything like that?

Dr. PERRY. We have not been in the Defense Department, no.

Mr. BROWN. You never know.

In that connection, you have indicated several times that the Space Shuttle has been designed for DOD mission and can meet—I think you make the statement "can meet all your launch requirements for the foreseeable future." Is that consistent with your statement about eventually wanting an on-orbit servicing capability and a large structural assembly capability eventually, or is the eventuality further out?

Dr. PERRY. It is consistent from the very beginning of the DOD's use of the Shuttle. I was trying to discriminate between missions that are already planned and missions that are not yet planned. We don't yet have any planned missions for the assembly of large structures in space, but I anticipate that we will and probably within the time frame we are talking about.

Mr. BROWN. And the on-orbit servicing which I think is really an important mission.

Dr. PERRY. The on-orbit servicing will be an important feature of the Shuttle within the same time frame.

Mr. BROWN. But you have not made specific plans for particular launches to accomplish these kinds of missions?

Dr. PERRY. We have not made specific plans yet, for example, for the assembly of large structures in space, but we are studying that now, and I anticipate that we will be making such plans and we will be doing that early in the usage of the Shuttle.

Mr. BROWN. Are you coordinating that with any studies that NASA might be making?

Dr. PERRY. Yes. We have a very close coordination with NASA not just at the senior management level but at working levels, all levels in the organization.

Mr. BROWN. You may have testified on the results of your studies or your tentative plans, and I'm unaware of it, but I do know that this subcommittee has been looking at near Earth industrial developments and other kinds of activities which would require space structures of some sort, and it seems to me that the proper coordination is essential in this kind of a forward planning operation.

Dr. PERRY. Yes. For example, if this large structure were to turn out to be a very large antenna, the applications would be to civil as well as to military programs, and probably we would want to sponsor a single development program to do that rather than having two separate ones.

Mr. BROWN. Correct. By a very large antenna, are you thinking of something like a radio telescope?

Dr. PERRY. Yes; a radio telescope or a communications antenna, but it might involve structures which could be many hundreds or thousands of feet in aperture. It is quite conceivable to assemble those kinds of structures with the Shuttle program and quite inconceivable to assemble them on the ground and launch them.

Mr. BROWN. We may have already had some discussions of this and I don't want to probe into it too much, but basically I think we have a concern about this cost overrun and schedule slippage in the Shuttle. And yet in looking at it overall it seems to me that an overrun of the order of magnitude of 15 percent and slippage of 6 months or so is not particularly unusual in large systems of this sort. Have you commented on this already?

Dr. PERRY. I have not commented on that. I would be happy to, if you would like.

Mr. BROWN. Would you in the light of defense systems of comparable magnitude.

Dr. PERRY. In the Defense Department we submit to the Congress a quarterly report called the SAR, the Systems Acquisition Report, which summarizes the cost and programmatic status of all of the major programs. We have presently 58 programs that are included in that SAR. If you look at the cost history of those 58 programs from the time of their development estimate, that is, when we submitted an estimate based on the development proposal, and then compare that with the cost estimate of the program today, aggregating all 58 of those programs and subtracting out the effects of inflation and subtracting out

the effects of increased quantities, we end up with an average of about a 15-percent cost increase over the life of those programs.

These are all large programs, several billion dollars, and programs which have a high degree of technical complexity, so they may be fairly compared with the Shuttle program. They are all programs which take place over maybe a 10-year time period. So without suggesting that a 15-percent overrun is a good thing, if we are simply looking for a standard of comparison, I would say DOD major programs are a fair standard of comparison for the Shuttle, and by that standard the Shuttle falls in about the center of what our history has been.

Mr. BROWN. And, of course, the importance of maintaining the kind of surveillance which allows you to make early detections of any possible errors that may have caused these overruns and correct them, I assume.

Dr. PERRY. That is true, but I would like to speak somewhat in defense of NASA's committee perception, the committee's perception of late calling of this overrun. My experience in the management of DOD programs suggests they can go along for years without any real evidence of problems, and the evidence begins to surface in a very brief period of time when you reach what is called the moment of truth in a program, when you start assembling the equipment, and then all of your hopes and dreams and aspirations have to be faced with the reality of trying to make the hardware work. And when that happens, the expectations or fears of problems that you may have been thinking about for a year or two before that become quite concrete. I imagine that is what has happened in the NASA program here. It is not atypical of the way major cost and schedule problems develop on a large and complex program of this sort. They do tend to develop. All of a sudden, even though you've had some indications of them for months ahead, the really hard indications develop very suddenly within a few months when you start trying to put the equipment together.

Mr. BROWN. Again, I confess to my lack of detailed knowledge of this, but in reading Dr. Frosch's testimony and listening to his comments, I got the impression that what we see here is the accumulation of a rather substantial number of relatively minor miscalculations, I guess you might say, misjudgments or unanticipated difficulties and not any one major thing.

For example, as I recall, he mentioned a problem with the hydrogen turbine blades, a problem with the tiles, heat shielding, the radar docking, a problem with even the number and size of the extravehicular mobility equipment which doesn't seem like a big thing to me, but it may run into quite a few dollars. Am I misconceiving this that we were caught up with an accumulation of a number of items at this moment of truth, as you use the term, instead of any one major thing?

Dr. PERRY. I would make two comments about that. The first is that I think that is a correct assessment, and I am differentiating between a project where you are beginning to perceive a fundamental difficulty, a fundamental overreaching. I do not think that is happening in this program. I think it is an accumulation of relatively small

items. The second comment I would make is that I don't think we've seen the end of that accumulation of small problems. I do not think they have all surfaced yet, and I think NASA will be hearing about more of them and this committee will be hearing about more of them. I do not think the moment of truth has been fully reached, and it will not be for several more months yet.

That is not a comment based on a specific knowledge of this program. I am not intimately involved in the management of this program. It is as an interested observer who has followed many programs and watched their problems and it just seems to me that not all of the problems have surfaced yet.

Mr. BROWN. That's my impression. I was just seeking to see if you would confirm it. It also seems to me that there might be a possibility, say, if the Shuttle were a production-run vehicle as like a major aircraft procurement that some of that might be made up by virtue of having worked out the bugs on the first model and being able to get over your learning curve and achieve efficiencies of production on subsequent units. Is there any possibility in this program that we could recoup some of these miscalculations or losses or whatever you want to call them.

Dr. PERRY. That is, of course, a possibility. I have to comment that I spent 20 years of my career in industry managing a company and trying to conduct large programs like this, and I had a sign which I kept near my desk which helped me quite a bit and the sign said: "Hope is the greatest enemy of the businessman." [Laughter.]

And I wouldn't want to count too much on the hope of this being realized.

Mr. BROWN. Of course, the Shuttle isn't a very long production run.

Dr. PERRY. That's correct.

Mr. BROWN. I appreciate your response, Dr. Perry, and I will be following up on this other matter of the DOD mission aspect.

Dr. PERRY. We will be happy to follow up with you on that.

Mr. FUQUA. Mr. Winn?

Mr. WINN. Thank you, Mr. Chairman.

Dr. Perry, does DOD have any input in the various Space Shuttle review panels that are supposed to report around September 1?

Dr. PERRY. Let me answer that two different ways, Mr. Winn. I am the Cochairman with Mr. Lovelace of the Coordinating Board between NASA and Department of Defense, and at that level I will be discussing this problem with him. In addition to that, we actually have a participating member of the review panel, General Abramson who was the F–16 program manager. So in both of those respects we do.

Mr. WINN. I appreciate that. I was given the list when they were selected over the telephone and a very short briefing, and I did not recall you being the Coadministrator.

Dr. PERRY. That's the Aeronautics and Astronautics Coordinating Board, the AACB. It is not specific to this project.

Mr. WINN. I'm talking about the special review board that was referred to here a little while ago.

Dr. PERRY. The special review board, General Abramson is on the board, but I would expect that the AACB will be reviewing the results of this panel and in that respect as Cochairman I will be reviewing it with Dr. Lovelace.

Mr. WINN. You would and could have some input.

Dr. PERRY. As I indicated, we have a heavy stake in this program and are terribly interested in how it turns out.

Mr. WINN. This may have been asked because I was delayed in getting back, but I would like to ask it for my own verification as to whether DOD has increased its procurement of the Titan launch vehicles to act as a backup. I referred to that in one of my earlier questions.

Dr. PERRY. I will summarize that very briefly. I did mention it before. We have four extra Titans planned for backup and we will be, in the course of our 1981 budget review, considering whether we ought to increase that number to give us a greater margin of safety. We will have a judgment on that in the next few months.

Mr. WINN. How much money are you talking about, if you have to get the backup Titans?

Dr. PERRY. We don't know yet. We have a study underway to determine that right now. Titans in the past have cost us about $50 million apiece.

Mr. WINN. You can't get them for that now?

Dr. PERRY. No; I don't believe you could.

Mr. WINN. How much do you allow for inflation, design changes? Just from an information standpoint how much do you figure you have to allow for that?

Dr. PERRY. That is one of the things we have asked the study to tell us. Inflation alone though can be easily 7 or 8 percent per year, and we would be talking about Titans that would be built in 1982 and 1983. So there would be a significant increment just for inflation alone.

Mr. WINN. When do you think you will have that information?

Dr. PERRY. Within a few months.

Mr. WINN. Will you make that available to the committee on an informal basis?

Dr. PERRY. If you would like, certainly. The reason we are preparing it is to determine what our 1981 budget request ought to be and whether we ought to include funds in the budget for this.

Mr. WINN. No; I understand that, but I think the fact is that members of this committee are extremely interested in the whole kit and caboodle and the more information we have as we go along rather than just get the surprises and jolts—we'd like to know what we're going to be faced with. It doesn't have to be a hearing.

Dr. PERRY. If the Milcon funding for Vandenberg is not approved in 1980 then it is certain we will have to come back for more expendable launch vehicles, irrespective of our judgment about how much reserve is needed, just to accommodate for the vehicles we will have to launch from Vandenberg in 1984 that would have been launched on the Shuttle.

Mr. WINN. Will four vehicles do the job or is that a part of the study?

Dr. PERRY. That is the issue right now and that's the number that I'm nervous about and that's the specific issue we will be examining as to whether four is a sufficient margin.

Mr. WINN. No wonder you can't give me a price if you don't know the number. Thank you very much.

Thank you, Mr. Chairman.

Mr. FUQUA. Mr. Flippo.

Mr. FLIPPO. I think Mr. Winn covered my questions.

Dr. PERRY. Excuse me, Mr. Winn. Let me just qualify one point. The four that I have referred to we already have funded, that is, they are already planned and programed. The question is whether there is to be more than four and what the cost of those additional ones would be.

Mr. FLIPPO. My question was really in regard to the fifth Orbiter and whether you were willing to support NASA with regard to that fifth Orbiter.

Dr. PERRY. Yes.

Mr. FLIPPO. Thank you.

Mr. FUQUA. Thank you very much, Dr. Perry. We appreciate you and your associates being here with us this morning.

Dr. PERRY. Thank you, Mr. Chairman.

Mr. FUQUA. Our next witness will be Mr. George Jeffs, the president of the Aerospace Group of Rockwell International. I might say to Mr. Jeffs and those who are scheduled to follow that it will be our intention to probably go until about 12:15 and take a break for lunch and come back at about 1:30 and try to finish up as soon as possible. I realize that some people have some schedule commitments that they are trying to meet and I hope that they can be accommodated. We may conclude with you, George, or we may not. It depends on how long your statement is and how many questions we have. I don't know whether we will conclude prior to that time, but we will try to go about 12:15 and take a break.

We are very happy to have you and your associates and we appreciate your being here with us. We will be happy to hear any comments that you might desire to make.

STATEMENT OF GEORGE W. JEFFS, PRESIDENT, NORTH AMERICAN AEROSPACE OPERATIONS AND CORPORATE VICE PRESIDENT, ROCKWELL INTERNATIONAL CORP.

Mr. JEFFS. Thank you very much, Mr. Chairman.

Mr. Chairman and members of the subcommittee, I welcome this opportunity to appear on behalf of Rockwell International's Space Shuttle Orbiter, integration, and main engine programs. My statement will address constrained budgeting management; fiscal year 1978 and 1979 program visibility; the Orbiter flight hardware shipment to KSC; the Orbiter 102 status at KSC, the main engine status, Shuttle system integration, the Orbiter increment 3 program and a summary.

The Rockwell International executives accompanying me today are George B. Merrick, president of the Space Systems Group, Edward P. Smith, vice president and general manager of the Shuttle Orbiter Division, Norman J. Ryker, president of the Rocketdyne Division, and Robert C. Lashbrook, vice president and controller of the Space Systems Group.

CONSTRAINED BUDGET MANAGEMENT

A constrained group management philosophy has been effectively applied throughout the Space Shuttle program. For the purpose of this specific discussion I have selected the Shuttle Orbiter as the ex-

ample; however, this process has been applied to other elements of the program within our responsibility.

It provides for good communication at the beginning and throughout the program. It limits the program to only absolutely essential costs. It is a good practice, but it has its complications. I, therefore, want to explain what constrained budgeting means as it has been applied to our STS programs and call your attention to where we are today.

Constrained budget management provides a fixed amount for the program at the beginning of a fiscal year and often, it is less than that commensurate with the statement of work and schedule to be accomplished. And that is really by design. The program elements are constrained to specific dollar levels and the reserves are held at higher NASA levels. There are, therefore, no provisions in Rockwell's budgets for contingencies, or changes in the work content that may occur during the year, although we hold back in our internal budget through the course of the year to provide some flexibility. Whenever significant management changes are identified either internally or by NASA, some other program tasks have to be deleted or deferred to later time periods to make up for them.

The constrained budget management process—that is, fixed yearly expenditures—forces restructuring and rescheduling of many sub-tier level tasks to accommodate any significant change. Since a major portion of the program is subcontracted, these revisions normally occur to both Rockwell and our subconstractors' baselines. Inherent, therefore, in this complex process is a time lag in establishing the best way to do the job and the manitude of costs deferred to susequent years.

This requirement, of course, does not arise on other programs where new dollars are provided for each new item as it arises. Through the years we estimate that such additions to the program during a given year have approached 25 percent of the baseline content. As a result there will always be less than 100 percent of the originally planned work accomplished each year, since we are continually adding to the baseline.

To manage in this change environment, real-time decisionmaking interfaces between the NASA and contractor element program offices have been developed. A master change record system—a very effective master change record system—is used on the Orbiter element to implement these decisions. Concurrently, the master change record is used as a key element for cost management purposes.

In the early phases of a program, the constrained budgeting process results in minimum total expenditures. However, as the D.D.T. & E. program moves closer to completion, management reprograming flexibility is greatly reduced, since detailed task schedules are no longer movable. This is where we are today and have been since 1978. There is no way to accommodate changes to the program without appropriate additional dollars. A management reserve is now essential for real-time contingencies at the element contract level.

FISCAL YEARS 1978 AND 1979 PROGRAM VISIBILITY

During the completion phase of the Orbiter at Palmdale in fiscal year 1978 substantial unplanned effort was added to the program. Un-

planned effort consists of new program requirements, additional effort required to accomplish existing tasks, and added effort in response to test program results.

In June of 1978, NASA reiterated that funds for the new work were not available and directed that Rockwell stay within the fiscal year 1978 funding limits. We advised NASA that we were concerned about the potential magnitude of the effect of this deferred work on fiscal year 1979 funding, and that it was going to take time to assess the cost and schedule impact. During the next 3 months we were restructuring the program, identifying costs, and reviewing internal and subcontractor cost inputs and schedule impacts.

This delay in visibility was further complicated by additional funding requirements that just happened to occur at that time period for thermal protection system tile fabrication, OMS pod assembly and test, and other changes which were being incorporated during the same period.

Rockwell's award fee for cost performance was substantially reduced for this delay in visibility. The reason given was marginal performance against the standard for providing such visibility. In actuality, there is no standard for measuring performance in providing such visibility while operating in such a constrained budget management system. We were disappointed with this award fee and we have so informed NASA.

The management system which provided us the ability to redefine the fiscal year 1979 program content I believe is fundamentally sound and gives us the information needed to do so.

In the future we will be more formal in communicating the interim progress of these activities and the first order estimates of the cost and schedule impact. We are providing such interim visibility in the "533" reporting system. We've just begun to do that. This will apply to both longer term program modifications as well as specific changes.

ORBITER FLIGHT HARDWARE SHIPMENT TO KSC

Orbiter 102—Columbia—was delivered to KSC in March. The shipment of the Columbia to KSC was preceded by a detailed delineation of work deferred to KSC. This review was conducted over a period of time and with detailed reviews on specific dates by Rockwell and NASA personnel at Palmdale in which KSC people did participate, ours and NASA's. The tasks remaining to be completed on the vehicle were not a surprise, although the magnitude of the effort for their accomplishment was underestimated and further complicated by temporary tile removal and cleanup.

The decision was made to ship the vehicle to KSC following checkout but before all the flight tiles could be completed due to late delivery problems. This required parallel checkout of the vehicle and tile installation at KSC but, since they could be accomplished without interference, we avoided serial schedule delay, which would have occurred had we waited 3 to 4 months for delivery of all flight tiles.

Temporary tiles were installed to protect already installed flight tiles during ferry flight. To minimize the subsequent cleanup job at the Cape and potential damage to adjacent flight tiles, sticky-back tape

and "armour" tape were used for their installation and verified on T–38 flights.

Additional armour tape was applied in certain areas for fairing and it was this armour tape that initiated the damage experienced in the preferry flight test on the 747 at Edwards Air Force Base. Subsequently, the temporary tiles were removed and the sticky-back tape replaced with RTV—room temperature vulcanizing compound—for their installation. Cleanup work of the RTV installation greatly increased the magnitude of the tile task at KSC.

It has been suggested that configuration management was not rigorously applied to the temporary tile installation but that is not so. The tiles were designed, tested, installed to drawings, and applied by process specification. Configuration management was not our problem, actually it was the extra "tender loving care" we attempted to provide in the form of the "belt and suspenders" armour tape and the sticky-back tape on the tiles.

Qualification of the Orbiter's subsystems and components is another area of the program where concurrency is being utilized to improve program schedule position and minimize program costs. Concurrency of manufacturing, vehicle testing, and qualification testing is a common practice on research and development programs.

Orbiter 102 at KSC: I will now cover the extensive management actions that have been implemented by Rockwell at KSC since the Columbia arrived and its status. Our efforts have been timely, aggressive, and thoughtful with respect to work plans, daily and weekly schedules, and the application of resources to ready Orbiter 102 for flight.

Ed Smith, vice president and general manager of the Space Systems Group's Shuttle Orbiter Division, is leading the Rockwell team at KSC to complete the orbiter mechanical and thermal protection systems installations and checkout while the vehicle is in the Orbiter Processing Facility (OPF). This organization brings to bear key management and technical resources of the corporation to insure the earliest possible rollout of the vehicle from the Orbiter Processing Facility.

A detailed integrated flow and build schedule has been established, in conjunction with NASA, considering availability of hardware, checkout sequences, manufacturing timing, and staffing plans. The systems installations are proceeding according to plan, and the rate of tile installation is increasing toward planned levels. We have approximately 700 tile people working on that problem at KSC. Of those, about 376 are installers. Of those installers, approximately 200 are skilled people comprised of California people and people that had gone through training courses before the vehicle arrived at KSC. The critical thing here is to have the experienced leadership so that some of the younger folks in the tile installation area can be properly guided. We do have those capabilities in place.

Verification of the software is proceeding, and we are benefiting from the background of checkout of the first orbiter, the Enterprise.

Rockwell's extra effort in facilitating all aspects of Orbiter 102's hardware and software operations at KSC will be sustained. The same thrust will continue through the element stacking, the move to the pad, checkout and changes at the pad, flight readiness firings and

launch. We are dedicated to completing the D.D.T. & E. as quickly as possible without compromising safety.

Space Shuttle main engine: The development of the SSME is now progressing well. The engine has accumulated over 400 tests—48,000 seconds—toward the goal of 65,000 single engine testing seconds prior to first manned orbital flight. And 75,000 seconds will be accumulated by the end of 1979.

The formal preliminary flight certification test has commenced, and approximately 80 percent of the required 13 tests totaling 5,000 seconds run time has been accomplished. The certification tests will be completed in July 1979. Actually, the 13-test series has now been completed. As a matter of fact, yesterday we completed the final test on the engine to a duration of 823 seconds, which increased the cumulative test time to over 5,200 seconds for the PFC engine, a very successful test series. We have two or three things we are still looking at on the engine but we think we can make fixes for those satisfactorily. And as part of that effort, on June 25, a critical thrust level test for 520 seconds duration at 102 percent was successfully run. The development problems experienced in the past 2 years have been satisfactorily resolved for purposes of supporting first flight.

Plans and funding requirements are being analyzed that provide for the start of engine development for the full-power level capability in September 1979, and provide for final certification at full-power level by the end of 1980. The certification of the engine at the full-power level by the end of 1980 will support the present mission plans being developed by NASA.

Flight engine delivery has progressed through the successful completion of hot fire testing of two of the three engines with the third one scheduled for early July. The three engines will be delivered to KSC in July 1979 to support the orderly flow from the OPF.

Three SSME engines are installed in the main propulsion test article, and six tests have been completed. The main propulsion system demonstrated successful performance at the 100-percent thrust rated power level.

System integration: The major task of developing the requirements for the integrated Space Shuttle elements and the allocation of these requirements to the elements was completed early in the program. At this point in time, our major task is to review and assess the impact of changes in these requirements on the overall system performance and on the system interfaces. Control of the interface design documents is being formally accomplished at Rockwell through interface control documents and configuration control drawings, as appropriate. Direct support is being continuously provided to the level II program manager in the evaluation of proposed changes.

In support of the verification program, Rockwell system integration has been responsible for the management and accomplishment of two major ground tests. The ground vibration test, consisting of a quarter-scale replicated model of the integrated vehicle and a full-scale ground vibration test using flight-type hardware, has been successfully completed and has provided an outstanding data bank for the Shuttle dynamic analyses. Further quarter-scale tests are now in progress to

verify the dynamic characteristics of realistic payload-orbiter combinations.

The main propulsion test program at NSTL successfully completed the first four exploratory tests last year to confirm test article and facility compatibility. The verification test series was initiated this spring wherein two test firings have been accomplished to date with no significant system anomalies in the main propulsion system itself. It is anticipated that the third firing in this series (static firing-6) will be accomplished about July 1. We think we have resolved the problems that were previously experienced.

Support to the launch facility at KSC has been provided on a continuing basis. The demonstration of vehicle processing using the Orbiter 101 Enterprise has indicated the effectiveness of prior planning and interface definition.

At this point in the program, the development of the Vandenberg Air Force Base facility design is underway. Analytical support and facility design review support is being provided in a manner which insures a good transfer of the experience gained at KSC to the design of the Vandenberg Air Force Base facility.

Our evaluation now shows that the elements are meeting the allocated design and performance requirements to adequately and safely perform the intended missions.

Increment 3 production program: We have completed our negotiations with NASA for the increment 3 contract. Our negotiated program called for Rockwell orbiter expenditures of $356 million in fiscal year 1979, $559 million in fiscal year 1980, and the delivery of Orbiter 103 in December of 1982. However, increment 3 fiscal year 1979 funding limitation in the first year of the contract has been constrained to $256 million. This, of course, would cause a schedule extension unless accompanied by increased funding, particularly in the 1980–81 time period. With such funding additions, we believe a summer of 1983 delivery of Orbiter 103 is doable but very demanding.

It is demanding from the aspect of requiring doubling and then tripling of our efforts relative to 1979, in 1980 and 1981, respectively, and during the early phase of the program, having to incorporate as yet undefined changes arising during the D.D.T. & E. program flight tests.

Although Rockwell does not have visibility into the makeup of NASA's estimates of multi-million-dollar increase requirements as discussed recently with the Congress, we do believe it necessary to carry adequate firm reserves for contingencies if the production program is to meet the plan.

Mr. Chairman, I would like to summarize my remarks:

Constrained funding has been effective in our view in minimizing program costs. It is most productive in the early phases. It results in a continually changing program structure, which will always have some time delay associated with final cost-visibility impacts of significant changes.

The application of cost-award fee contracts in combination with constrained budgets is not inconsistent, but must accommodate adequate time required for in-depth reviews before the contractor should

be required to formally report associated cost growth. It is my observation that the constrained funding and award, fee management system has been ably practiced on Orbiter and main engine contracts by NASA, Rockwell, and our subcontractors, resulting in a balanced program versus time. This experience is providing a new management system for future program applications.

The present financial contract reporting and visibility system is fundamentally sound. Its formal and informal elements must be retained. Changes which would limit program management flexibility and degrade the ability to best balance the program in real time must be avoided. Some additions in the formal system of enhancing projections with preliminary data can be made to provide added visibility. Those data must be recognized as first order visibility as the effects of major changes are being determined.

The reduction in Rockwell's award fee for the 6-month period ending in December 1978, was attributed to marginal performance against a standard. In fact, we are parties in pioneering the application of this management process and in developing such a standard. We believe nothing should have been done differently, except for providing interim formal reporting visibility of the in-depth review activities in late summer of 1978, as they were taking place.

The configuration management system is excellent. There is no evidence of inadequacies nor of its violation as it relates to Orbiter 102.

The program has a record of over 7 years of accomplishments prior to the delivery of Orbiter 102 to KSC. Rockwell has been aggressive in support of Orbiter 102 at KSC and will continue to be through the flight program. Wherever possible, we are pushing ahead at KSC whether it be software, the launch pad, or other areas, to do all Rockwell can do to provide a safe flight at the earliest possible date.

At this early phase of the Orbiter production contract, funding is already reduced under the baseline plan. There are exercise underway to deliver the production Orbiters earlier than we are currently planning. We believe, given the commensurate funding, that earlier deliveries can be accomplished, although they represent a real challenge to NASA, Rockwell, other prime contractors, and the subcontractors.

There is little flexibility in the production program and adequate provisions must be made in NASA's reserves for changes such as those from Orbiter 102 D.D.T. & E. flights.

Mr. Chairman, although funding requirement visibility with respect to the budgetary cycle timing, particularly the revised estimate of last fall and the Orbiter added work presently extending schedules at KSC, are of great concern to us all, these are only contributors to the added program funding requirements recently presented to the Congress by NASA.

Although Rockwell is not privy to the detailed makeup of these projections, we believe them to be attributable to the recognition of the need for adequate reserves to conduct the program, including changes, through the completion of firmly established D.D.T. & E. and production work and schedules ahead. Since no flexibility except through added dollars exists, we would endorse this requirement in principle.

I am ready for your questions and also have members of my team here to respond to questions from you.

Mr. FUQUA. Thank you very much for your statement, George. We have about reached the hour that we were contemplating taking a break. Why don't we do that and come back at 1:30. I am sure there will be some questions.

Mr. JEFFS. We will be here.

Mr. FUQUA. Thank you very much. The subcommittee will stand in recess until 1:30.

[Whereupon, at 12:15 p.m., the subcommittee was adjourned to reconvene at 1:30 p.m. this same day.]

AFTERNOON SESSION

Mr. WINN. George, if you're ready I'll go ahead and ask my questions if you don't mind.

Mr. JEFFS. Yes, sir. Thank you.

Mr. WINN. I too want to welcome you here. It's nice seeing you on our playing field instead of yours all of the time.

Each year when you submit a funding request to NASA to accomplish contracted objectives you probably go through some form of negotiations to reach an equitable figure for the year.

What I'm wondering, has there ever been a year when you were not provided the agreed upon amount of money?

Mr. JEFFS. The difficulty with answering that question is that, just as you say, the program managers go through a detailed review of the work to be done through the year and they end up with a handshake with respect to how much is going to be required to accomplish the tasks. Then, as new tasks come in as the year progresses, they are done at the expense of some of those previously agreed upon tasks.

Mr. WINN. Are you talking about changes?

Mr. JEFFS. Yes. Changes that are either brought about by the complexity of the work being more than had been anticipated and/or new things required to be done to the vehicle. If they don't have immediate additional funds they "go for it," so to speak. In other words, they try to see if they can't absorb those additional work tasks within the total dollars that had been originally planned, until they get to the point where there's just no way to absorb any more. Then they've got to get more money.

But the answer to your question directly is I don't think there has been a case where we have gotten less money than the program managers agreed that they were going to work to at the beginning of the year.

Mr. WINN. What percentage would be changes originated by NASA and which ones would come from your shop as you progress? That would vary quite a bit.

Mr. JEFFS. I would like to give you a better answer. We're going to go back and reflect on that some more and provide it for the record. I think for the first quarter of this fiscal year it's about 50–50.[1]

Mr. WINN. Have you ever entered a fiscal year without knowing what funds were going to be available for the next year at the negotiation stage?

[1] For the first 8 months of fiscal year 1979, NASA-directed changes have accounted for 40 percent of the authorized work growth.

Mr. JEFFS. Yes, such as with increment 3 right now. For example, for the first three quarters, we're spending at a given rate that's consistent with the total expenditure for the end of the year. If, in fact, there was difficulty with the $185 million supplement, then we would have to move a lot of people off the program come July, or the fourth quarter of the year. So we're expending at a rate, on increment 3, that can either go up or go down, depending on what happens at the end of this June.

Mr. WINN. If you were to enter into another program which utilized the same management philosophy that you discussed, centralizing the contingencies at headquarters, what changes would you anticipate in your corporation?

Mr. JEFFS. As I mentioned, I happen to favor some of the things that the constrained budget management technique does for you at the beginning of a program. It forces you to think very carefully about all the tasks, the timing of the tasks, and the way we're going about trying to accomplish the tasks.

For example, one of the fallouts of constrained budget management earlier in the program, or in the earlier phases, was the utilization of the static test article as a flight article. I think that in the Apollo days we probably would have moved right ahead and tested that vehicle to destruction. But I think that the very tight funding constraints forced us to really scratch our heads and see if we couldn't learn from it what we had to without destroying it and therefore making it available for operations. I think that saved the program something on the order of $50 million to $100 million. This approach, along with deferrals and more ingenious ways of getting additional data beyond those specified for a given test is an example that falls out of constrained management.

Now, I think that's possible in the earlier phases of a program, but once you're gone through that phase and the drawings are hard and the vehicle is built, then there's no flexibility for such creative mobility of tasks or for modifying the way in which you approach them.

Mr. WINN. So when you enter into a negotiated contract and you end up with a shake of the hand, as you describe it, you're sort of playing a "have faith in me" or "trust me" type of philosophy because of your experience in working with NASA.

You've talked about figures. You talk about round figures, based on what they submit to you at the time, or what you submit to them at the time. Am I right?

Mr. JEFFS. That's right. I think that NASA normally follows up with a piece of paper on it though.

Mr. WINN. How soon?

Mr. JEFFS. I think that it's not too late. On specific cases I'd have to refer that to Mr. Smith.

Mr. SMITH. Within weeks.

Mr. WINN. It would never go as long as a 60- to 90-day period?

Mr. SMITH. I believe there have been instances, but they are rare.

Mr. WINN. But isn't it true that, inflation alone, in a 60-day or 90-day period would cost you additional money?

Mr. SMITH. If you didn't plan——

Mr. WINN. From what you agreed upon with a handshake, before you got it in writing, is what I'm saying.

Mr. SMITH. In a pure sense, yes.

Mr. WINN. And in that 60- to 90-day period—I'm just speculating—let's just say that there could be additional design changes or additional changes that would develop. That wouldn't be unusual, would it?

Mr. SMITH. No?

Mr. WINN. And those would be costly.

Mr. SMITH. Yes.

Mr. WINN. Easily could be. Not necessarily, but they could be because the inflation is there. It's sailing right along every month.

Mr. JEFFS. Yes, sir. But when there is agreement on a task, then it is started, even though it still has not been completely determined how such action is going to impact other tasks, to provide room for the additional work.

Mr. WINN. You lost me there. Say that again in laymen's terms.

Mr. JEFFS. If it is decided 2 months into the year, after a handshake on the total dollars, that something must be fixed or done differently, then the program managers will review the problem, decide what has to be done about it, when it has to be done, and how much it's going to cost. The work is then started, and, at the same time, the program managers are in the process of determining how they must reconstruct the remainder of the program to make room for the effort, providing additional funds cannot be provided above the total that was agreed to at the beginning of the year.

Mr. WINN. Where do they get the cost estimates?

Mr. JEFFS. They make the cost estimates.

Mr. WINN. They make them?

Mr. JEFFS. Yes, sir.

Mr. WINN. But somewhere along the line if you're the prime contractor you would have to agree basically with their cost estimates or say "We can't do it for that kind of money."

Mr. JEFFS. I'm sorry, sir. I misled you.

We make the cost estimates. By "they" I meant the program managers, NASA and Rockwell, review the cost estimates and understand what it's going to take to do that. Ofttimes it's with the subcontractor, for example.

Mr. WINN. When you enter into an agreement with a subcontractor, you as the prime contractor, do you use the same type of verbal agreement right at first, early on, before you get it into writing?

Mr. JEFFS. I think it depends on the problem. It depends on the urgency of solving the problem. If it has to be done right now, sometimes they give them the go-ahead, just like a letter contract. Then they work out the details in parallel, early parallel, with the subcontractor on the content, the timing, and the cost.

Mr. WINN. I'm just trying to figure out if there's a better system than the one that NASA's using at the present time.

Mr. JEFFS. Let me cite the example of the OMS pod. Presume there are some differences in the basic load inputs into the pod. The pods are three-quarters built. We've got to fix the pods. Our people and the NASA people review the new requirement and make sure it's real. They review the approaches to fixing it, the time it's going to take, and how they can fit it into the total program. They also get a first

order cost estimate, and then they start the work. But they're still in the position of not having given the subcontractor anything but a piece of paper to proceed and noting that we are going to negotiate with him specifically on what it's going to cost and what we're going to add to the contract for the work.

Mr. WINN. On page 3 of your testimony George, the bottom paragraph:

> This delay in visibility was further complicated by additional funding requirements for thermal protection system tile fabrication, OMS pod assembly and test, and other changes which were being incorporated during the same period.

Obviously, that was a combination of a lot of changes that were being made.

Is that what is referred to somewhere in the trade as "Rockwell's $100 million surprise to NASA"?

Mr. JEFFS. That was a contributor.

Mr. WINN. Your wording here says: "This delay in visibility was further complicated * * *"

Further, to me, means that there was something going on prior to that, before these things became apparent.

Mr. JEFFS. There were a lot of things going on in the beginning of the fiscal year 1978 and in the mid-part of the year that were driving the dollars over the total handshake agreed upon dollars for that year.

In June of that year we made a special effort to defer tasks that we could without damaging the program in subsequent years. We were in the process of doing that, and at the same time compounding the problem was the fact that we were having difficulties with the tiles at Lockheed. So we had to give additional money to Lockheed because of those tile problems. At the same time we had OMS pod problems. All of this compounded the problem of holding the dollars, without any new dollars being added to the program, to the total that was agreed to with NASA at the beginning of the year.

Mr. WINN. At that stage, at that point in time, is NASA fully cognizant of the problems that you have, the changes that you're working on your own, not the ones they make, but the ones you're making, or discovering?

Mr. JEFFS. I would say that NASA was aware of the changes we were making. The visibility that they might have in a dollar sense on individual changes, that's not quite the same as knowing the total amount.

Mr. WINN. They don't have access to your bookkeeping?

Mr. JEFFS. No. In many cases, we hadn't finalized exactly what it was going to cost us anyhow. We knew that we had to do certain things, so we go and do them and then restructure the program, because there's no point in having a vehicle all checked out and ready to go without tiles on it. So obviously we put money in the tiles and then we figure out how to take money out of other areas to make up for that new addition.

Mr. WINN. You're moving ahead prior to your actual written funding.

Mr. JEFFS. That's right. Actually, we had a total funding for the year, so NASA hadn't changed that, unless, in fact, they could find somewhere in the budget, such as John Yardley talked about, room

for some dollars they could put on that particular kind of a problem toward the end of the year, like the Lockheed tile problem.

Mr. WINN. By the Lockheed problem do you mean the tile?

Mr. JEFFS. The tiles.

Mr. WINN. When we were out to your shop, however, in one of the briefings I and the chairman well remember that we were reassured that that tile problem had all been worked out with Lockheed. We were aware of it, and we slanted some questions in that direction, and we were assured by your people that yes, that had all been worked out, that problem is solved. And we haven't solved that problem yet.

Mr. JEFFS. Of course, I was assured that it was worked out to and, as a matter of fact, as you know, Jim Plummer, Chris Kraft, and George Jeffs became the "ex officio" project engineers on tiles for the last 6 months in 1978. Lockheed projected continually that they thought they had a way to get the tiles done for the year, and I think that they did, if it hadn't been for, obviously, some of the problems they had gotten into. I think some of the basic problems resulted in our working together to put teams of people up there to help them mutually disposition MR problems with the tiles that were holding up the flow process. We also got into the position of not accepting a lot of arrays, for example, which were short of tiles. What I mean is: There would be a whole array complete except for a couple of missing tiles and they were holding up delivery of those tiles. So we broke the log jam and started to get those tiles more rapidly dispositioned into our shop. But it did cause a delay beyond what we had projected and what you and the chairman had heard when you were at Lockheed.

Mr. WINN. Thank you very much. Thank you, Mr. Chairman.

Mr. FUQUA. Mr. Flippo.

Mr. FLIPPO. Thank you, Mr. Chairman.

I wonder, Mr. Jeffs. You state that more substantial unplanned effort was added to the Orbiter program in fiscal year 1978.

Would you estimate the amount of unplanned effort which has been added to the Orbiter program in fiscal year 1979?

Mr. JEFFS. I would defer that to George Merrick.

Mr. MERRICK. We started the fiscal year with a base understanding of authorized work for D.D.T. & E. at $379 million, and we're up now to about $462 million—authorization of $455 million plus reserve for future charges of $7 million. In the main, you could say that the difference is the unplanned effort that has come on the program subsequent to the time that we had established what we thought the planned work was going to be.

Now, we had some estimates in October of what that unplanned effort was going to be in 1979.

Mr. FLIPPO. Would you tell me a little bit about the nature of that? Is that something that NASA ordered, or authorized, or what?

Mr. MERRICK. I think George, in his testimony, tried to describe that in context. Some of it is directed changes, which are really changes in requirements. Some are increased efforts above those which had been originally anticipated such as reactions to test problems and recycling pieces of hardware.

Mr. FLIPPO. Can you give me some estimate of those directed changes that were required in total, to the total changes that were required?

Mr. MERRICK. Like in 1979?

Mr. FLIPPO. Yes.

Mr. MERRICK. Do you mean an estimate in dollars?

Mr. FLIPPO. Yes, percentages—25 percent, 50 percent.

Mr. MERRICK. Of the changes from the $379 million to the $462 million, it's like $35 million worth of directed changes. So that's about 50 percent.

Mr. JEFFS. Regarding the $462 million, that also includes money for working the tiles at KSC. That wasn't planned originally.

Mr. FLIPPO. I guess my point is: Are you surprised that NASA was surprised with the increase in cost estimates? Do you think NASA should have been surprised with the increase in cost estimates, having directed a substantial amount of the changes?

Mr. JEFFS. I guess that's my question.

Mr. FLIPPO. Anyone can answer. That's fine.

Mr. JEFFS. I don't think it was that big a surprise myself. There were discussions that I think you heard earlier regarding how budgets are handled. When someone asks for an additional $50 million or says it might be needed for the year, then I think it's very human to put that aside and say, "That's not very firm. I will consider the need when required."

The 533 reports show that in May of 1978 our estimates were about $366 million, of which a significant amount, about $37 million, was for reserve and potential changes. We feel that's the kind of a baseline that we started from, the $366 million, and evolved to the $429 million requirement in October. So it was a $50 million change, not a $100 million change, in our view, and at the same time, I think that everybody knew there was going to be some increase in cost although NASA didn't know any more than we did about the detailed cost breakdown or the effect on 1979 since we were determining it.

So therefore, No. 1, the fact that there was an increase was not a surprise in anyone's mind, and certainly not ours; and NASA is close enough to what we do that they shouldn't have been surprised in that area. They might have been surprised by the magnitude.

Mr. FLIPPO. I'm not really that familiar with the 533. Would you tell me some of the weaknesses of the 533 and the benefits?

Mr. JEFFS. Since we just got through looking at how we could improve the 533, as we had stated in the testimony, I'd like to call upon Mr. Lashbrook behind me to talk about it and answer that question.

Bob?

Mr. LASHBROOK. The report itself doesn't really have any weaknesses with respect to format. If there is a weakness, it's obvious due to the humans that put the data into the report. The requirements of the report are clear, and we think that we comply with those requirements, and so report.

Mr. JEFFS. As I said, on the report, we are going to add interim reporting on activities such as the type that was referred to with respect to the poor visibility lead times.

Mr. FLIPPO. Could you tell us about the major differences between the management of the Orbiter and the management of the main engine?

Mr. JEFFS. Let me respond first, and Norm might like to add to that.

I don't think there's any fundamental difference with respect to

the overall process. It's a constrained funding management process. The informal program manager groups do exist and are most effective in getting the tasks directed and done in a timely fashion. They are also most instrumental in working out the costs and trading off tasks and costs to minimize the effect on the overall program for the year, with a good view of the total program effects.

So I think that's very positive. The whole concept is to keep all the horses running with their noses about at the same point on the track. It's kind of like the same situation as that with handicapping horses, if you will. You add weight to them so they all run the race in the same time, and that's the idea of balancing the total program.

Now, it just so happened that the Orbiter was out ahead of the pack a little bit to begin with, and so money came from the Orbiter to make up for the horses that were in trouble. One of the horses that was in trouble early, because of the technical problems associated with it, was the engine. We needed to put more money on the engines and NASA agreed. Albeit, there might not have been enough hardware early enough, as we all discussed, but nonetheless when the problems arose the money went onto the engines.

So it's been more a matter of the problems pulling the money in, like on the engine, than it has been balancing the programs; if they have a problem, put money on it and fix it. So they've been more in that mode than they have in restructuring the elements like the Orbiter.

Mr. FLIPPO. Are you in a position to make firm cost-and-schedule estimates for the production Orbiters, and, if not, when do you expect to be able to?

Mr. JEFFS. As you know, and as I've said in the testimony, we have just negotiated a contract with NASA for increment 3, the so-called production Orbiters. Of course, they're not really production Orbiters, in that it is not a production program, as you normally experience or think about it, since each one is a little different.

We did set firm schedules and we did set with those firm schedules firm costing schedules—that is, dollar requirements tied to those schedules.

We are working with NASA right now to try to determine the distribution of the tasks and the dollars associated with meeting the midsummer delivery date of Orbiter 103 in 1983, which is the swing vehicle in that schedule plan. As you know, we were forced into a new schedule structure because of the decrease of the first-year dollars. So now it really is up to NASA to establish the final plan they need. We have developed various options for them as a function of the dollars that they may have available.

Mr. FLIPPO. Would you care to comment on whether or not the budget amendment of $220 million will get us there?

Mr. JEFFS. As far as the $220 million goes, I don't know what all is in its makeup. It's not all for the Orbiter. There are other things, as I mentioned earlier in my testimony.

We feel very bullish about getting the vehicle certainly out of the Orbiter processing facility by the end of the year. As a matter of fact, we think we can do better than that. We're trying real hard to do so. From there on the flow is influenced by many other things that aren't all Rockwell.

Mr. FLIPPO. This is probably a wild question. But could you tell this committee something, can you help us in trying to find the way we can be most helpful to NASA and to the operation to advance the Shuttle? What's the No. 1 thing holding us back here? Are we trying to do things on shoestrings, inadequate funding, inadequate scheduling? What can we do to advance this program?

Mr. JEFFS. First off, I would like to commend the committee for their continuing support of the space program and of the Space Shuttle program. I think that you, Mr. Stevenson, Mr. Schmitt, and others who have supported the program so ably have made it as facile as it has been so far to get where we are. I think we are a long way down the road on this system to making it operational.

I think one of the biggest problems that we have had is associated with, I'll call it, the funding "yo-yoing" on the program, because the dollars are not as important as that of a continuous plan. As we go up and down, and when we try to move subcontractors, who represent 50 percent of the effort, up and down, it becomes a horrendous task. The Orbiter or the Shuttle is only a small part of the subcontractor's total business, whereas it's a very important part of ours, the biggest part. For some of the subcontractors, it's just something in their back shop. So it's difficult for them to move as easily as it is for us.

I would think that continuity of support by the committee, continuity of funding and understanding the plan, a real-time understanding by the committee, by the NASA management, by Rockwell management, and everybody else is necessary. All must know where we are, what the problems are, and they are, and, hopefully, with enough leadtime to do something about them so that they don't become surprises.

Mr. FLIPPO. I thank the gentleman for his replies, and I thank the chairman for the time.

Mr. FUQUA. Thank you, Mr. Flippo.

George, in July and September 1978, there was some cost growth in the program that I think John Yardley said was $77 million, a $77 million increase in the last quarter of the 1978 fiscal year.

Then there was a meeting at NASA Headquarters in October of 1978 to discuss these changes in consideration of the fiscal year 1979 supplement of $185 million.

When did you first communicate to NASA the possibility of cost growths, or cost growth, that might be affected by the request that's before us now, the $220 million? Were they considered at the same time, or did they get an indication from you, or did you talk to them about it, or did your company at some time discuss the need for funds in addition to the supplemental request that they came in with?

Mr. JEFFS. In addition to the $185 million?

Mr. FUQUA. Yes.

Mr. JEFFS. I'll have to refer that to George.

Mr. MERRICK. They certainly were different considerations, the $185 million in the summer, and then the $220 million later on. I would have to say that the $220 million was a reflection of the kinds of reserves, contingency funding requirements that were being developed from our growth as it existed in 1978 and 1979, and I would expect from the other elements of the program also. We didn't have

a specific discussion with NASA other than our normal types of reviews, which we are now doing more often than we were doing a year ago.

I couldn't point to a specific time when we really had a discussion about the $220 million amendment.

Mr. FUQUA. Was it in the fall of 1978?

Mr. JEFFS. Let me try to add to that.

The $429 million was the number that was discussed in October, and we have discussed that. We also heard Mr. Yardley talk about the ability of the reserve to handle that amount, or the marginal ability to handle it, and so on.

We didn't get involved in any additional funds beyond the $429 million until we got into the difficulties with the tiles on shipment of Orbiter 102.

Mr. FUQUA. When did that occur?

Mr. JEFFS. That came on shipment of Orbiter 102, sir. The shipment was in March. That's when we got into the problems of having to do all the work up at Edwards, taking the tiles off and putting the tiles back on again at Edwards, and then taking the vehicle to the cape.

Mr. FUQUA. That didn't cost $220 million?

Mr. JEFFS. Oh, no, no. The only difference is the increase from $429 to $462 million. That's our portion of the requirement.

Sometimes there are other requirements that cause the dollar increase request. If you look at the Orbiter budget line item, for example, not all that's Rockwell Orbiter program. There's IBM in there; there's other things such as JSC support, support contractors, and space suits.

So we didn't make a request for additional dollars above and beyond what is required now to recover at the cape because of those tile problems, and we all had visibility into that.

Mr. MERRICK. That will have some impact in 1980 on the $220 million.

Mr. FUQUA. But it's a, I'd say, R registered program.

Mr. MERRICK. That is correct.

Mr. FUQUA. But my point is some time last fall was there any indication that came through information from your subcontractors or from your own involvement that it appeared that the budget request for fiscal year 1980 was, in fact, going to exceed the amount that they had been talking about, that there was a cost increase on the horizon?

Mr. JEFFS. I think the problem with that is that we don't know how much, or we only had first order of information as to how much of the $185 million supplement was to go to Orbiter. So if more money was required for Orbiter, we did not really know whether that could be accommodated within the NASA APA or whether it couldn't. But for the 1980 budget, I don't——

Mr. FUQUA. You may have to go and ask for some of the reserves or get additional funding, more than possibly had been projected.

Mr. JEFFS. We knew that JSC would have to go and do that.

Mr. FUQUA. When did you find that out approximately?

Mr. JEFFS. Ed, I think you're going to have to help me, because the only things I can think of are the problems associated with delivery.

What happened was a change in planned delivery. When the $420 million request was submitted to NASA, we had just rescheduled

delivery of the vehicle from December 1978 to March 1979 due to difficulties with the tiles.

Mr. FUQUA. The point is NASA had testified before this subcommittee in February that the amount requested by the administration was adequate, the $185 million was adequate.

We were at Johnson, or we had Chris Kraft testify before us at White Sands. There was not indication there that there was a severe problem. We were at the Rockwell facility in California. There was no indication that there was a real big problem. And then suddenly in May, the first part of May, we find out that there is a big problem, and I'm wondering where the conductor was while the orchestra was asleep between February, really the first of March, and the first of May.

Mr. JEFFS. We didn't change any requirements in that period. In fact, we were planning to live with the——

Mr. FUQUA. I'm not saying you changed requirements.

Mr. JEFFS. No, sir. But as far as dollars are concerned, we were planning to live with the $429.9 million for the year. The only thing that caused any additional money requirement on our part, was an increase from the $429 million to the $462 million, because of the problems associated with the vehicle at the cape.

Mr. FUQUA. And that's the only increase over and above?

Mr. JEFFS. That's it.

Mr. FUQUA. Dr. Frosch was here this morning, and you were here and you heard what he said, that he didn't feel very comfortable with the $220 million additional. John Yardley said he felt nervous, I think, if I'm not misquoting his reaction to that, and since a large part of that will be spent through Rockwell on the Orbiter, of the $220 million, how comfortable do you feel with the $220 million? Is that going to be enough to do the job?

Mr. JEFFS. If the delta in the $220 million covers this requirement on the Orbiter funding increase to the $462 million level, then I feel very comfortable that we're going to be able to get that vehicle out of the OPF before the end of the year with those funds.

Mr. FUQUA. The end of the fiscal year?

Mr. JEFFS. The calendar year, out of OPF.

Mr. FUQUA. OK, in the fall.

Mr. JEFFS. What the dollar requirements are after that depends on what kind of a schedule is finally set to launch the vehicle, and we are only participants in setting that schedule. NASA is the one that determines the schedule. Now, if they end up with a schedule for FMOF in June, I think if that's what the $220 million is basically for, then I'm sure that will eat into what the basic plan is, just as Dr. Frosch said.

There are other things in development that are still going on that bother me, and that is the 109-percent thrust level on the engine. We must proceed with that demonstrating the 109 percent level, and some of those dollars may well be addressed to continuing support of the engine for that purpose.

But I don't think the big problem in that regard is the Orbiter, except for schedule movement relative to any dollar requirements above that $462 million.

Mr. FUQUA. Norm, with the recent tests on the SSME, do you anticipate any additional problems with that?

Mr. RYKER. Sir, do you mean the completion of our PFC last night when we ran for 823 seconds?

Mr. FUQUA. Yes.

Mr. RYKER. It looks pretty good. We've completed that PFC sequence. We don't see any additional problems. We still have the problem with the fuel line coming down to the manifold at the end of the nozzle. That we understand, and we have not yet developed a fix. We do know that, both from analysis and from tests, that we can fire a limited number of times without encountering a problem.

I don't foresee any significant problem in meeting FMOF. So I think the engine is all right now.

Mr. JEFFS. There is one other thing that I would like to clarify. And that is that there is an addition of about $20 million that no doubt is associated in part with that $220 million, and that has to do with the fact that we are not rolling the vehicle out of the OPF until December. So there will be some dollars required to complete that activity on the vehicle in the first part of 1980.

Mr. FUQUA. Thank you very much, George. We appreciate your testimony and that of the other members of your group.

Mr. JEFFS. Thank you.

Mr. RYKER. Thank you.

Mr. FUQUA. Thank you very much.

Our next witness will be Mr. James M. Stone, the vice president of Thiokol Corp.

Mr. Stone, we're very pleased to have you here with us, and we'll be happy to hear your comments.

Mr. STONE. Thank you very much.

Mr. FUQUA. You might want to identify your associates for the record.

Mr. STONE. Fine. I will.

STATEMENT OF JAMES M. STONE, GROUP VICE PRESIDENT, GOVERNMENT SYSTEMS, THIOKOL CORP., ACCOMPANIED BY ANTONIO L. SAVOCA, VICE PRESIDENT AND GENERAL MANAGER, WASATCH DIVISION, THIOKOL CORP.; AND EDWARD G. DORSEY, DIRECTOR, SOLID ROCKET MOTOR PROJECT, THIOKOL CORP.

Mr. STONE. I am Jim Stone, vice president of Government systems of Thiokol Corp., and I have with me today Mr. Tony Savoca, vice president and general manager of our Wasatch Division, who is responsible for the solid rocket motor. I also have Mr. Ed Dorsey, who is the program manager for the solid rocket motor.

We welcome this opportunity to appear before the subcommittee to review the status of this project. The solid rocket motor weighs almost three times more than any other in existence. My statement today addresses the technical, schedule and cost status of our SRM project.

We are keenly aware of the importance of our part of the program to the overall success of the Space Shuttle mission, and let me assure you that the solid rocket motor is in a very good technical posi-

tion and we will successfully support the first orbital flight and those which follow. We have had five out of five successful full-duration, full-thrust static firings out of the seven which are planned. The total propulsive energy delivered by the motor exceeds that required by the contract specification, which contributed to increased payload capability. In addition, we have tailored the thrust-time characteristics of the motor to meet vehicle structural requirements, while maintaining this plus contribution to the payload capability.

Now I would like to expand upon the project's technical and schedule status as a background for the subsequent discussion of the cost status.

We are near the end of a peak period of development activity. Only two qualification motors remain to be fired. One of these has already been loaded with propellant and is entering the final steps of the manufacturing process. It will be static-fired in September. The last qualification motor has now entered the initial steps of our manufacturing process, and it will complete final assembly and be static-fired in December of this year.

In addition to the successful test program there were other significant accomplishments. A structural test article has been delivered to Marshall Space Flight Center. It was delivered in early fiscal year 1978, and testing has confirmed the ability of the motor structure to withstand design loads. Four other motors were delivered in early fiscal year 1979. Two were fully loaded with inert propellant to simulate a lift-off configuration and two were manufactured to simulate a burn-out configuration. These motors were used in the mated vertical ground vibration test program at MSFC. After test completion the two inert loaded motors were shipped to Kennedy Space Center for assembly there. We think it's important to note that these shipping, handling, and assembly operations at Thiokol, MSFC and KSC have verified the design concepts, the equipment for transportation and handling, and the vehicle interfaces for the solid rocket motor. The work has provided confidence that shipping and assembly of the flight motors will proceed well.

I would like to report briefly on the status of the first flight motors. The eight segments required for the two motors have all been loaded with propellant. Both nozzles have been manufactured and installed on the aft segments, which are the first two to be shipped. We are now installing the system tunnel base plates, the thermal protection system, and the flight instrumentation. We expect to begin motor shipments in July and complete them in August. This will support the first orbital flight at the Kennedy Space Center, whenever it is.

These accomplishments, as you know, have not been entirely free of technical problems, which in turn have impacted the development schedule and cost. Now I'll single out some particular examples which have had a significant effect.

The static firing of the third development motor, which was planned for June 1978, was not accomplished until October 1978, a 5-month delay. The delay was caused by a decision to remove the motor from the static-firing test stand, return the loaded segments to the manufacturing area and rework a propellant inhibitor. Although the previous development motor, No. 2, had been fired successfully, a continuing

detailed examination of the internal insulation found an unexpected erosion pattern which prompted a design change to the inhibitor.

The motor was reworked, reassembled, and successfully tested. The design change has been incorporated in all subsequent motors. The test schedule for the fourth development motor was delayed from late 1978 until February 1979 by development problems which resulted in the replacement of two motor segments. One segment was replaced because of an excessive number of propellant voids. This finding led to improvements in the casting tooling and the process techniques which have subsequently produced excellent propellant grains. The other segment was damaged in December 1978 during a breakover operation from a vertical to a horizontal position. As you can imagine, the handling of 300,000-pound segments is not a simple task and it requires the use of massive tools and equipment. This incident that we had resulted in redesign of our breakover tooling and changes in our operating procedures. In addition, a very detailed review of all our handling equipment and procedures for critical moves was initiated in December and was completed this month.

The purpose of the entire development motor test series, of course, is to find and correct any design or manufacturing problems with potential adverse effect on flight performance. A significant part of this effort has been what I shall call the "fine-tuning" of the internal insulation and the nozzle design. Each motor firing produces erosion data which allows a comparison of the actual to the design safety factors at any location throughout the motor. The fine-tuning consists of adjusting the thickness and configuration of the material to achieve the required safety factor. This work has produced a sound motor design, but the man-hours required and the material cost have exceeded our earlier estimates.

The final significant problem which I shall review is a bonding problem with the nozzle flexible bearing. The bearing consists of alternate layers of steel shims and rubber pads which are bonded together. Earlier work produced a number of bearings which passed all acceptance tests and were successfully used in static firings. However, in recent months newly manufactured bearings have experienced bond failures during acceptance testing. The cause is now being investigated by a special task force. However, we do have acceptable bearings for STS–1 and are confident that we will be able to solve the problem without impacting future flight schedules.

To summarize this portion of my statement, the SRM project has experienced technical and schedule problems of the type which do occur in development programs. The majority of these have been solved, and the few which remain will be resolved, and the solid rocket motor overall is in a good technical posture. Now I would like to talk a minute about the cost status.

The development phase began in June 1974, and is presently estimated to be completed in early 1981. Our current estimate for the cost at completion of this nearly 7 years is $282 million. To date the cost growth is $38.95 million and when projected to completion to account for all these problems we have encountered will be $59.8 million in total cost growth. None of us want to experience cost growth in a development program, but unforeseen technical prob-

lems and schedule changes do occur, and these are the principal factors which lead us to cost growth. The cost elements of our estimated increase are 67-percent labor, 22-percent materials and subcontractors, and 11-percent tooling and other direct charges.

Now looking specifically at fiscal year 1979 and fiscal year 1980, we were estimating $68.2 million cost in fiscal year 1979 and $44.4 million in fiscal year 1980. However, funding limitations make it necessary to limit our fiscal year 1979 work to approximately $61 million. As that is accomplished, the fiscal year 1980 cost will increase as the effort moves into that year.

In summary, Mr. Chairman, I want to reemphasize my opening remark that the solid rocket motor project is on a very sound technical footing and that this project will successfully support the first orbital flight. We have made substantial progress and we are nearing the conclusion of our peak period of development activity. Technical problems have been encountered, but we are confident of solving the few remaining. My cost status report covered a development span of nearly 7 years and included our recent estimates for fiscal year 1979 and fiscal year 1980.

Finally, I would like to say that the entire Thiokol Corp., is dedicated to a wholehearted support of the Space Shuttle program, and we appreciate the opportunity to appear before you.

Mr. FUQUA. Thank you very much, Mr. Stone.

[Biographical sketch on Mr. Stone follows:]

BIOGRAPHICAL DATA SHEET

JAMES M. STONE

GROUP VICE PRESIDENT
GOVERNMENT SYSTEMS

THIOKOL CORPORATION

James M. Stone directs the activities of Thiokol's Government Systems Group, comprising Propulsion, Ordnance, and Education Operations.

The Propulsion divisions lead the nation in the production of solid propulsion systems for use in strategic and tactical military applications as well as for space exploration and research. They are located at Elkton, Maryland; Huntsville, Alabama; and Brigham City, Utah.

Ordnance divisions are located at Minden, Louisiana and Marshall, Texas.

Education divisions include the Clearfield Job Corps Center at Clearfield, Utah; the Charleston Job Corps Center, Charleston, West Virginia; the Atlanta Regional Manpower Center, Atlanta, Georgia; and the Turner Job Corps Center, Albany, Georgia. They provide vocational and technical training programs, career education, educational systems design and personal development to persons ranging in age from preschool children to adults.

Stone came to Thiokol in 1960 from the Solar Aircraft Company, where he was General Manager of the Des Moines Division. He was named General Manager of the Wasatch Division in 1967, a Vice President of the Corporation in 1969, and became Group Vice President in July 1974.

A native of Virginia, Stone studied law and business administration at the Dallas, Texas School of Law and Business and at Southern Methodist University. During World War II, he served with the U.S. Navy. Stone and his wife, Margaret, reside in Brigham City and are the parents of two married sons, James Jr. of Utah and Don of Texas.

In June 1972, Utah State University awarded Stone an honorary degree (Doctor of Science). In January 1977, Stone was the recipient of a Presidential Appointment to membership on the National Armed Forces Museum Advisory Board of the Smithsonian Institution. He is Chairman of the Board of the American Defense Preparedness Association (ADPA); a member of the Board of Governors, Aerospace Industries Association; a board member of the First Security Corporation; and serves on the Advisory Board of First Security Bank, Northern Utah Division. He has served as a board member of the Utah Safety Council, the Box Elder County Industrial Commission, and the Box Elder Chapter of the American Red Cross.

Mr. FUQUA. Mr. Stone, you indicated that the funds for fiscal year 1979 are going to be reduced to approximately $61 million from $68.2 million.

How much where you estimating for 1979—I'm speaking of fiscal year—at the beginning of the fiscal year?

Mr. STONE. The $68.2 million.

Mr. FUQUA. That's what you requested?

Mr. STONE. That's what we requested to do the work that was planned. We run our cost every month. We take the work that we know is ahead of us, based on the requirements given to us that we know, and those given to us by NASA, and we estimate that program to its completion every month and send that to NASA.

Mr. FUQUA. Do you know what your fiscal year 1980 funding is going to be?

Mr. DORSEY. Not yet.

Mr. STONE. No. We don't know yet. We don't know what that will be. We know what we need in fiscal year 1980.

Mr. FUQUA. How much will you need? Or how much are you requesting? Let me put it that way.

Mr. STONE. Based on our $68.2 million request, we would have required $44.4 million in 1980. But now if we don't get that $6.8 million, that money will move into 1980, and it incidentally may be a little larger because of that being deferred a year, and inflation, as you know, when you move it a year it costs you more.

Mr. FUQUA. So it could be about $52 million or $53 million?

Mr. STONE. In that neighborhood, I would say.

Mr. DORSEY. Yes, sir. That's right.

Mr. FUQUA. You indicated that you found an unexpected erosion pattern which promoted a design change to the inhibitor.

What does that mean?

Mr. STONE. I'll ask Mr. Dorsey to answer that, if you would, Ed.

Mr. DORSEY. Yes.

Each time before we static fire a motor, depending on the burning time and the design of that motor, we actually make a prediction of the amount of rubber insulation that will be eroded in the motor, by location in the motor, and then when we go back and make the measurements we compare the actual thickness which remains and the location of that thickness with the prefiring prediction.

The motor, of course, is 125 feet long and there are hundreds of square feet of surface area, and we go through first and make a sample inspection, if you will, at a number of locations, and look for any gross differences.

When we did that on that development motor, we didn't see any gross differences from the prediction. Routinely we always go back then and expand a number of measurements to a fine grid so that we look in much more detail. When we did that we found that in one of the segments of the motor the pattern of erosion showed more rubber insulation removed than had been predicted, and that prompted us to look for a reason as to why the actual erosion and the predicted differed from one another, and in looking at that a scenario which could have caused that would be for the propellant to be ignited at the inhibitor location earlier than predicted, which would indicate that the in-

hibitor was thinner than would be desired to resist the erosion at that area.

In looking at that we realized that in the next motor to be tested, which was development motor 3, we were making another step toward the flight configuration, which meant that we had removed some insulation weight, which then gave us concern about the safety factor if that early ignition were repeated, and for that reason the motor was disassembled, the inhibitor was reworked to increase the thickness of the inhibitor and give added protection against early ignition. As a matter of interest, the firing of that motor and the disassembling and inspection showed that the rework was completely successful; the erosion was as predicted.

Mr. FUQUA. Mr. Stone, how would you characterize the cost growth of the solid rocket booster? Is it normal, or abnormal, or how would you characterize it for a program of this type?

Mr. STONE. I would say it's reasonably normal for a program of this size, based on the problems, you see. As I said, this was by far the largest solid rocket motor that had ever been built, in weight. We were advancing the state of the art as far as size was concerned, and handling was a big problem. You've got to remember this is a loaded 300,000-pound segment that we're handling all through the plant. It's not like handling 300,000 pounds of steel. So you have to be pretty careful with it, and we had some learning to do in that process.

Generally, I would say it would be fairly average, wouldn't you?

Mr. DORSEY. Yes. It's within the range of experience which you will see on other solid rocket motor development programs; yes.

Mr. FUQUA. Mr. Flippo.

Mr. FLIPPO. Thank you, Mr. Chairman.

Mr. Stone, I appreciate your testimony. It's refreshing to hear someone saying can do and will do.

I wonder, in regards to your follow-on procurement—your present contract, your contract for the development phase of the Shuttle program, ends in early 1981, I believe—do you have any concerns about being able to meet the requirements for the follow-on procurement?

Mr. STONE. None whatsoever.

Mr. FLIPPO. What would have happened if you had not detected those voids that you referred to earlier, if you had not discovered those? What does that mean? Later you mentioned propellant voids. What does this mean, and what would have been the consequences if those had not been discovered?

Mr. STONE. First, I would like to say that they would have been discovered because we X-ray those motors and we would have discovered them.

I don't believe, as far as the test firing of that motor, that we would have hardly noticed them. I'll have to ask the program manager if he agrees with me on that. But for the safety factors that we wanted to have in the motor, it was felt by both NASA and ourselves that we should disassemble that motor and repair those, find out what was causing it, and, as I say, do the work. As far as the test is concerned, I would not have expected you to even notice it. Is that right, Ed?

Mr. DORSEY. Yes; I would like to add that the X-ray capability that we have, which uses, I believe, a 15-million electron volt?

Mr. SAVOCA. That's right; 15 million.

Mr. DORSEY. A 15-million electron volt linear accelerator is so good that you can find an object no bigger than the end of my pencil in that 300,000 pounds of propellant. You can find an object or a void in there that's just tiny in nature. So that there's no question in my mind that any voids would be found, so I don't have any concern about one going through this undetected.

The second aspect of it as far as, you might say, the pressure capability in the motor is concerned, the thing you concern yourself with for propellant voids, are really three things: One would be an increased pressure in the motor due to an increased burning surface. That's one thing. The second thing you have to concern yourself with is the early exposure of the insulation which means you could get more erosion than expected. That would be No. 2. Then the third thing which you have to look at is the shape of the pressure time curve which you're trying to generate to meet the vehicle specifications.

Now, in going over those three potential problems, the pressure capability wouldn't be the problem at all. The Shuttle motor's design will achieve a safety factor of 1.4 on burst, and, in fact, we've demonstrated a higher capability than that. So we would not have had a problem with that.

On the early exposure of the insulation, I would not predict that we would have a failure on the motor, but I would predict that we would not meet the design safety factor, and I want to add a statement to that when I cover No. 3.

The third thing has to do with the shape of the pressure time trace. I do not believe we would have duplicated the specification requirement in the shape of the pressure time trace because of a change in the burning surface.

Then let me talk about those last two together, and that is the early exposure, and so on, the safety factors, and the pressure time trace.

There are only seven motor firings in the entire solid rocket motor project before you fly it, seven, and so every single one of those tests is very important to you, and I think then it's very important to demonstrate the design factor safety and it's very important to reproduce the pressure time trace because that's a body of data that you've got to use to commit to flight.

So for those reasons, not really because of a big hazard, but because of the value of the test, I think it was important to replace that segment, to be sure that the test results verified the motor design, and that's really why it was done.

Mr. SAVOCA. I would like to add one thing to that.

The motor that was made with the voids, the excessive voids, in our opinion, was made that way for a reason, and we had to discover that reason, and then we had to prove out that that reason was fixed, and as it turned out it was a change in the casting tooling, basically because of the size of the motor and the way the propellant mixes in this particular motor as it's being cast that caused the voids, and it was important, as Ed said, to determine that we could make good motors early, and in order to do that we had to find the cause, which was the tooling, and demonstrate that. We could have fired that motor, and it would have been a good test.

Mr. FLIPPO. Mr. Stone, you've been in this business for sometime. Is this the first time that you've been exposed to the constrained budget management techniques of NASA?

Mr. STONE. As far as NASA is concerned, yes, it is our first experience.

You know, you get a lot of different kinds of techniques of managing dollars, and they get many names as you move along, and sometimes they pick up a word like "constrained budgeting." It's not much different than saying, "Hey, hold back those dollars and don't spend them, and if you need more come back and tell me what's wrong and I'll give you some more dollars if you can prove to me why you need it," and so forth.

We've lived under that with Air Force programs, Navy programs It's just a name, I think. But it is our first experience with that technique with NASA.

Mr. FLIPPO. My question is in the positive sense. I wonder if you could tell me what you think that we have learned from this type of management technique. I guess really what I'm interested in is how can we improve the way we do business.

Let me just state that we used to have a term called "zero budgeting," until I think in some cases people really thought that meant how many more zeroes do you want to add to last year's budget, which is not really the kind of thing that I think it was intended to be.

I would like your evaluation of this particular management technique.

Mr. STONE. I believe that we've got to be realistic when we decide what it's going to take to do the job. We're always in the habit of saying, "Well, I don't think the customer or I don't think the Congress is going to buy that figure because it's too high. So let's try to go in with a little lower, something that will sell," and we're always being too optimistic in what we think we can accomplish, particularly in a development type program. Remember, if you knew what it was going to cost you could make a fixed price contract, and the reason you contract the way you do is because you're advancing, you're exploring new areas and you don't know, and sometimes we tend to make our estimates based on nothing happening. If everything I plan goes exactly as I plan it this is what it's going to cost, and we don't put any contingencies in there. Then, as George Jeffs said, when we get down to facing the facts things do happen and they cost more money.

Mr. FLIPPO. I thank you very much for your assessment and for your testimony.

Thank you, Mr. Chairman.

Mr. FUQUA. Mr. Kramer.

Mr. KRAMER. No questions. Thank you.

Mr. FUQUA. Mr. Stone, when do you believe that you will have the definitive results on the flexed nozzle process problem?

Mr. SAVOCA. We'll be curing another bearing, we'll complete making another bearing in about another 2 weeks.

Mr. FUQUA. Will that be the final?

Mr. SAVOCA. That will be the final bearing made. But since we ran into the problem—and you must remember we made a number of bearings that are good and they've been fired in the program, and

some of them have been reused—we ran into the problem that we have, and we've had a team of people working on it to identify the cause, and we believe that we have identified the cause. We'll be making another bearing, and will have made another bearing within another 2 weeks, and we'll test it and we'll know then.

Mr. STONE. I might add that this is not an unusual kind of problem. When you're bonding the shims together, rubber and metal, if the rubber is not perfect coming from the vendor you do run into these. We've run into them on other problems. But we have hundreds of these bearings flying on missiles in other programs today, and we've run into these same kind of problems on those programs but have eventually been able to solve it all right.

Mr. FUQUA. Do you think that the flight test program for the Shuttle can be supported with a new flexed nozzle?

Mr. STONE. With a new one?

Mr. FUQUA. With a new one, yes.

Mr. STONE. Do you mean the current design, but a newly made one?

Mr. FUQUA. Yes.

Mr. STONE. Yes, I certainly do. Yes, absolutely.

Mr. FUQUA. Thank you very much, Mr. Stone.

Mr. STONE. Thank you.

Mr. FUQUA. We appreciate your coming here, and we hope that we haven't detained you too long.

Mr. STONE. No, sir. I'm going to Utah right now.

Mr. FUQUA. Our next witness will be Mr. Kenneth Timmons, the vice president and general manager of Michoud Operations, Martin Marietta.

Mr. Timmons, I'm glad to see you again. I want to welcome you. I think this is the first time you've had an opportunity to appear before the committee.

Mr. TIMMONS. On this program, that's right.

Mr. FUQUA. We're very happy to have you.

Mr. TIMMONS. Thank you.

Mr. Chairman, members of the subcommittee and staff, my testimony has been submitted, and I'll summarize it if you agree.

Mr. FUQUA. Yes, sir. Without objection, we will make the submitted statement in its entirety part of the record and you may summarize.

[The statement of Mr. Kenneth P. Timmons follows:]

HOLD FOR RELEASE UNTIL
PRESENTED BY WITNESS

STATEMENT OF MR. KENNETH P. TIMMONS
VICE-PRESIDENT-EXTERNAL TANK PROJECT

MARTIN MARIETTA AEROSPACE - DENVER DIVISION
MICHOUD OPERATIONS
FOR THE

SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS OF
THE COMMITTEE ON SCIENCE AND TECHNOLOGY

U. S. HOUSE OF REPRESENTATIVES

MR. CHAIRMAN AND MEMBERS OF THE SUBCOMMITTEE

The External Tank is that component of the Space Shuttle designed to supply liquid propellants to the Orbiter's main engines during the boost phase of the operation. The tank also serves as the structural backbone for the Shuttle vehicle, accepting the variety of loads imposed on it by the Orbiter and the Solid Rocket Boosters during launch and powered flight.

The External Tank assembly is approximately 155 feet in length, 28 feet in diameter and consists of a Liquid Oxygen (LO_2) tank, an Intertank and a Liquid Hydrogen (LH_2) tank. The LO_2 section is approximately 55 feet long and, when loaded, contains 1,337,609 pounds (140,800 gallons) of liquid oxygen. The LH_2 tank is approximately 100 feet long and contains 226,000 pounds (382,460 gallons) of liquid hydrogen. The Intertank (22.5 feet long) is the splicing structure between the LO_2 and the LH_2 tanks that provides a protective compartment for some of the instrumentation components.

The liquid oxygen temperature is nominally -297°F. and the liquid hydrogen temperature is -423°F. Special thermal protection is required to prevent boil-off and frost formation. Portions of the outer surface of the tank are thermally protected with Super Light Ablator (SLA). Spray-on foam is applied over the entire tank to minimize ice or frost formation during pre-launch operations. This protects the Orbiter insulation from free falling ice during flight.

TEST ARTICLES

One complete External Tank, identified as the Main Propulsion Test Article (MPTA), was delivered in September 1977. It has successfully undergone four static firings at the National Space Technology Laboratories (NSTL) in Bay St. Louis, Mississippi, proving the integrity of the structure and propellant system. Assessment of the measurements obtained indicated no anomalies. There will be nine more static firings in this series of tests.

The Structural Test Article liquid oxygen tank (STA LO_2) was delivered to Marshall Space Flight Center (MSFC), Huntsville, Alabama, in November 1977. All of the planned modal tests which were performed on the STA LO_2 to determine characteristic vibration frequencies, modal shapes and structural damping and influence coefficient testing are complete. This article is being readied for some additional special testing.

The Structural Test Article liquid hydrogen tank (STA LH_2) was delivered to MSFC in March 1978 in a dual delivery, arriving with another complete External Tank identified as the Ground Vibration Test Article (GVTA). Both of these test articles have successfully completed their test programs. The GVTA, Orbiter 101 and Solid Rocket Boosters were mated during June and July 1978 for Boost, Launch and Burnout configuration testing. This series of tests proved the structural integrity of the Space Transportation System. The GVTA was then transported by barge to Kennedy Space Center where it is being used for facility verification to identify problems which could have been encountered during pre-launch operations of the first flight article.

In addition to these major tests, there has been an extensive component qualification program which is scheduled for completion in August 1979. There were a total of 75 electrical components and 54 propulsion components requiring qualification. Only seven items are still in test.

PROCUREMENT

The planned expenditure for material and subcontract through DDT&E phase is $100M. This includes tooling, production and engineering, materials and subcontract. Expenditures through May 1979 are $89M with purchase order commitments of $95M.

The geographic distribution of major procurements is basically the same for both DDT&E and Increment II and is spread

throughout the Unted States. We have made a very determined effort, since the inception of the ET Program, to provide maximum opportunity for small and minority business firms to participate in our procurements. For example, a full-time specialist, who is familiar with the capabilities of the minority business community, screens each requirement for possible bidding by minority suppliers. The results have been most gratifying. Minority opportunities to bid now total $8.5M, and there have been over 1,500 awards valued at $2.5M.

Our small business program has also established an excellent record of 78.6% of applicable purchase orders, and 44.3% of the procurement dollars going to small business. For the last two years, the dollars exceeded 50%.

The aerospace industry is experiencing a high level of activity due to various private and government programs. We have been able to protect our sources for fabricated parts by the use of options included in the Increment I subcontracts. These options continue to support fully the current Mission Model of the Shuttle Program. Extensive effort has been necessary to protect our sources of raw material for the 27 ship sets covered by Increment IIA. One major material, hard aluminum alloy used on the External Tank, has been on allocation since mid-1978. Of the 8,000,000 pounds required for the 27 ship sets, 6,500,000 pounds are covered by firm orders and we are assured that the balance will be made available out of allotments for 1981.

THERMAL PROTECTION

A Thermal Protection System (TPS) is an essential part of the External Tank. It maintains acceptable structural temperatures, minimizes boil-off of the cryogenic propellants, and prevents ice/frost formation from ambient air. TPS materials applied directly to the tank surface are either of ablative or low density foam type. The ablator insulation is applied to selected areas of the tank. Foam insulation is sprayed over the entire surface. Application of either material is an extremely complex process requiring considerable "customized" handling by factory personnel.

The ablator material (SLA) is applied on 1,100 separate panels. It is very sensitive to bond line condition - the tank surface must be carefully cleaned and primed before an adhesive is applied. Actual attachment of the ablator panel is accomplished by using a vacuum bag system that applies pressure for 16 hours, restricting application to 2-4 panels at one time.

The foam type insulator (SOFI) must be applied under very carefully controlled ambient air and tank surface conditions. The entire tank surface must be controlled to a temperature of between 125°F. and 155°F. During application,

a complete propellant tank (LO_2 or LH_2) is mounted vertically on a turntable and rotated as a spray gun is automatically programmed to apply foam at a precise rate up the tank.

In addition to this large scale application of insulation, we also apply protective material (primarily ablative type) to over 2,000 individual components including externally routed propellant lines, support brackets, and Orbiter interface hardware. Each of these components is unique in shape and many require buildup of alternating layers of ablator and foam materials for which the environmental conditions described earlier must be maintained.

In addition to the major area of External Tank cost growth caused by program changes, we have experienced cost growth in the development of these thermal protection systems and their complex processing. We are achieving dramatic learning-curve results from the development work on ET-1 as evidenced by our experience on ET-2.

ATTRITION

Attrition of our work force had been at an unacceptable high rate during the past three to four years. Concentrated management attention and set goals among our various departments have achieved good results for 1979.

Extrapolating the figures for the first 24 weeks of 1979, we are converging on an overall 17% attrition goal for our Michoud

work force. While this figure is still relatively high by national standards, it is a definite improvement at Michoud. It's the result of a program which includes increased compensation benefits, planned working area improvements, and other "hygiene" considerations. Special emphasis is placed on individual recognition of employee contributions to program success and full participation of all employees in program improvements. This is epitomized in our "Quality Circle" work where the work groups are furnished statistical data on their own performance, and they convene to analyze their own performance and suggest ways to improve. This has been extremely successful as a motivational tool and has had the by-product of product improvement.

We have other formal award and performance recognition programs, but a more subtle, very successful and mutually rewarding experience has been the routine and periodic visits to all work areas by all top management people.

SCHEDULE/FUNDING HISTORY

Early in the program, emphasis was placed on getting the design complete and building the test articles. The emphasis then shifted to the delivery and testing of the major ground articles with the flight article delivery schedules remaining relatively unchanged. This resulted finally in a realistic shift in the flight article delivery schedule, and as the overall shuttle program matured, the flight delivery schedules were aligned to be compatible with program requirements.

ET-1, the first flight tank, has slipped eight months since mid-1976, while ET-6, the last of the DDT&E tanks, has moved out 13 months in the same period. This mid-point change and the program extension has been a contributor to cost growth.

FUNDING

Since mid-1976, we have accurately predicted our program operating plan cost two years in advance. The close working relationships and open interchange between NASA-MSFC ET Project Office and Martin Marietta Michoud Operations has given a timely match of funding requirements and funding availability. This has enabled us to align the work effort to be compatible with both funding and hardware delivery requirements. We are on a budget plan which maintains the present level of employment in our Michoud operation while adhering to the funding constraint coordinated with the ET Project Office. We are also currently coordinating our POP 79-2 requirements estimates with MSFC to continue our deliveries consistent with the Mission Model and to determine that our fiscal plans are consistent with fiscal funding.

ET-1 AND KSC EFFORT

When the ET-1 arrives at KSC, checkout and pre-launch activities will start. Some hardware will be shipped with the tank. This hardware, as well as that furnished by the government to KSC, is planned for installation at KSC on all delivered tanks. The planned work consists of range safety system ordnance installation and other items which cannot be installed until ET/SRB mating.

There will be three items of deferred work to KSC. These are items that must be accomplished with the tank in the vertical attitude to allow access to the areas of work.

There will be six modifications incorporated into the tank at KSC. Four of these changes are new requirements, one is a design improvement, and one as the result of static testing. Incorporation of these changes at KSC was necessitated by the unavailability of parts at Michoud prior to delivery of the tank. Total hours required to incorporate these modifications are approximately 392 manhours.

Our only concern at KSC is the constraints of ice and debris prevention requirements for the ET-1. These requirements were generated to eliminate ice and other debris which could contact the Orbiter tile and cause damage. This requires the design, fabrication and installation of varying configurations of low density (styrofoam) components. These components will be installed over those protuberances on the tank, such as feed-line flanges and fairings which are under the Orbiter where ice or debris is likely to be generated. These insulation components are to be attached in such a way that they will separate from the tank at lift-off or prior to the build-up of high relative air speeds. Our schedule for accomplishing this activity will support the milestones at KSC for first flight.

PRODUCTION READINESS/PRODUCIBILITY PROGRAM

In order to increase our ability to support Mission Model build rates at minimum cost, we have initiated a Production Readiness/Producibility Program. A review of all elements of the build cycle assures that tooling, facilities and processes are capable of accomplishing maximum efficiency. Such a detailed review of all aspects of tank fabrication develops cost effective methods improvements. This activity has resulted in the identification, to date, of 311 candidates which are currently in the screening process. This work will continue through Increment II to fulfill our commitments represented by our POP 79-1.

WEIGHT REDUCTION

In order to obtain an overall performance improvement of the Space Shuttle System, we are in the early design release and procurement planning phases of an External Tank 6,000 Pound Weight Reduction Program. Our weight reduction work is definitely counter to our producibility efforts, and an increase in Cost-Per-Flight will result. The reduction requirement appears to be a cost effective contribution to the need for improved performance.

COST-PER-FLIGHT

The development of the Cost-Per-Flight (CPF) Design-to-Cost targets/status is based upon the overall requirements of NASA in identifying, monitoring and statusing of the CPF

targets. The current Cost-Per-Flight target is mechanically computed based on an average of 439 operational vehicles using discrete estimates for recurring cost on a cumulative average cost at unit 100 in 1971 dollars. This cost is currently computed to be $2.462M.

CONCLUSION

Design, procurement, tool fabrication and facility construction are in process to support a build rate of 24 tanks per year. These tools will be functional by the end of 1982. The additional tools and facilities to accommodate rates above 24 per year as dictated by the 79-1 Mission Model have been identified and are in the definition and design stages of procurement.

The External Tank Project has already begun the transition from DDT&E phase to Operations phase. We are currently responding to the request-for-proposal for 27 flight tanks. We expect to receive contractual authority to proceed on this operation phase and begin fabrication of the first operational tank during 1979. We received long lead authority for these tanks in early 1978.

In conjunction with the initiation of the operation phase (all post-DDT&E tanks), and at the timely and perceptive direction of the MSFC Program Office, we have revised our make/buy plan for future tank production. Our aim is to retain the intent of Michoud as an assembly facility, reduce tank costs,

inhibit the workforce buildup at Michoud, and proceed into the operations phase with a mature, stable, well-trained, and experienced workforce.

We are confident that the External Tank will meet performance and delivery requirements during Operational Flight Tests, and we are ready to produce tanks to support fully the future operational phases of the program.

Our first flight article, ET-1, will be delivered tomorrow.

STATEMENT OF KENNETH P. TIMMONS, VICE PRESIDENT, EXTERNAL TANK PROJECT, MICHOUD OPERATIONS, MARTIN MARIETTA AEROSPACE, ACCOMPANIED BY WILLIAM P. EWIG, RESOURCES MANAGER, EXTERNAL TANK PROJECT, MICHOUD OPERATIONS, MARTIN MARIETTA AEROSPACE

Mr. TIMMONS. My colleague with me today is Bill Ewig, who is the resources manager of the program at Michoud, business manager, and he's also going to be explaining some of my visual aids.

The element of the Shuttle that we have is the external tank, and it's under contract with the Marshall Space Flight Center. Jim Odom at the Marshall Space Flight Center is the program manager.

I will go through the thermal protection work which is the new development work that we're doing versus the well-characterized, well-known work that all aerospace knows how to do and we know how to do, and that's the mechanical assembly. I'll tell you what we're doing to keep the cost-per-flight down, and I'll show that we're supporting fully the Space Shuttle program.

[Viewgraphs shown.]

Mr. TIMMONS. The reason for the advertising picture there is that that best exemplifies, I think, what we call the acreage TPS, or the thermal protection system, that's applied over the entire vehicle.

What you're loking at is about an inch thick, sprayed on foam insulation.

Let's go to the next one, please.

[Next viewgraph shown.]

Mr. TIMMONS. The elements of the external tank are clearly displayed by this breakaway drawing. The forward tank, the liquid oxygen tank, is about four times the weight of the hydrogen carried aboard. The hydrogen is about three times the volume of the oxidizer tank. They are connected together with the intertank structure in between. This is the type of work that I say that is well characterized by the industry and well known by us, and we had the added advantage of having put together the test articles which comprise essentially three of these three external tanks. These test articles were put together on the same tooling, the hard tooling that was bought earlier in the program, which proved that tooling and gave us additional points on the learning curve for the all-up flight articles.

There are six flight articles in our D.D.T. & E. contract, as you can see by that visual aid. The test articles have all been delivered and the required testing on them has been completed, with the exception of the propulsion tests at the NSTL facility.

We have gone through the four static firings with no significant anomalies for the external tank during those static firings.

The test article, the MPTA test article, was fully insulated with a spray-on foam insulation, but that was the BX–250, or the more dense foam insulation, which was not found suitable for flight use. We subsequently switched to a lighter weight foam insulation, which has been sprayed on the first article.

In addition to the main flight articles for the major test program, a quick summary of the qualification status:

We have five items (two of them are two apiece), a total of seven units, still in test, to be completed in August. The testing is completed

on 122 of the qualification items within the program for the external tank.

Flight article status: ET–1 is in final acceptance today at Michoud. There is a board meeting there attended by Jim Odom, by Rick Davis, who runs the external tank program at Michoud, and Tom Wirth is also there. They would have been valuable allies here today, but they are needed for the board meeting. The tank is being accepted. The word at noon today is that it will not be delayed. However, we have one or two additional small items added during the final inspection and final acceptance.

The second external tank is fully assembled. The thermal protection system is being applied. The third tank also is fully assembled and being prepared for the thermal protection system application. All subassembly welds are completed on external tank 4. On the last two, all the major hardware is in and being assembled. On the ET–6, the last of the D.D.T. & E. vehicles, we're starting now to weld together over a half-mile of weld which comprises the assembly of that tank.

[Next viewgraph shown.]

Mr. TIMMONS. I wanted to show by this chart that the procurement for the D.D.T. & E. phase is well-known, approaching completion, with only 5 million identified yet to spend for procurement. The full run-out D.D.T. & E. procurement costs I think are very well-known, and only a cleanup needs to be done as engineering changes may come in or as rebuys have to be made.

The one driving effort we have is to try to continue to hold as constant as we can the work force at Michoud, and that is by agreement with the Marshall Space Flight Center. In conjunction with that we are trying to reduce the component count. We've gone back over our "make or buy analysis" and have identified more items that we can buy. As you can see as is natural during the D.D.T. & E. phase we had to make some of them, as we were in the development phase and wanted the project to know how they could be built and how they should be built.

In increments 2 and 3, which are really the operational phases of the program, increment 2 is identified as 27 additional vehicles, and the remainder run-out under increment 3.

We will be, if our make-buy plan is held constant, and if we are able to find satisfactory vendors for those items that we label buy, we'll be reducing the component count down to 10 percent make and 90 percent buy. Michoud is supposed to be an assembly facility, and we're trying to get it into that mode.

[Next viewgraph shown.]

Mr. TIMMONS. The liquid hydrogen tank, by mistake is labeled in the work that I gave you as ET–1 liquid hydrogen tank. This is ET–2 liquid hydrogen tank. The distinction is that ET–2 was sprayed with a different development arrangement that we have made. It was sprayed with a Binks gun. ET–1 was sprayed with an oscillating gusmer gun.

ET–2 went to completion in one pass from the bottom of the tank to the top of the tank, and represented a significant development, significant improvement, and a real step up in producibility. That hydrogen tank is mounted vertically in the cell. The spray gun was programed from top to bottom of the tank in one continuous pass, spraying on the foam insulation to a nominal 1-inch thickness.

On the first tank, ET–1, the spray gun stopped three times on the way up. On ET–2 the Binks gun, which was jointly developed by us and by Marshall Space Flight Center, went to completion in one pass. This was not an accident. We spray earlier passes on a fully Kraft paper wrapped tank to prove the process, and then take off the insulation and the Kraft paper and then go into the actual assembly process. It did complete the pass in good time, in 55 minutes to spray the entire cylindrical portion of the tank.

[Next viewgraph shown.]

Mr. TIMMONS. In addition to what I call the acreage TPS, we have the components TPS. This is a typical example of the components TPS, and for added clarity I gave some colored pictures to the members of your committee.

The component begins as is shown in the present picture. The next thing we do is either spray on and/or apply the heavier underlying thermal protection system, which is a "super light ablator." In this case it was sprayed on and then machined. "Machined" is a euphemism for a lot of hand work. There's very little machining that's mechanized on it. It's hand filing, hand cutting, and for all the cutting we have to use nonmetal knives because we don't want to damage or cut the subtrate by cutting through. So we use fiberglass type knives, fiberglass end mills, and fiberglass machining in order properly to finish that surface, and I'm showing that to emphasize the fact that it is development work. It's an area in which we nor no one had a lot of experience in applying that much thermal protection system to that large a vehicle.

[Next viewgraph shown.]

Mr. TIMMONS. This chart shows that one of our objectives, as I said, was to keep the total people on roll at Michoud down, and by going through that make-buy reassignment we have, I think, accomplished significantly a reduction in the increase that we would have had to have for the rate that we were building had we maintained the same make-buy ratio of components that we had on the first, D.D.T. & E. articles. It shows a stable work force going out into the future up until the early 1990's.

That is a new approach, I think, in New Orleans, where they're accustomed to having Bell, and then Chrysler, and then Boeing, and then ending the program, and they were short-term compared to what we're looking at down there. We have a lot of hope that we can develop a good stable work force in the New Orleans area and make it a good aerospace environment.

[Next viewgraph shown.]

Mr. TIMMONS. In the earlier years, as we built up there, our attrition was unacceptably high, and I know that people within NASA at the outset anticipated that the New Orleans work force is not as trained as some other sections of the country in the aerospace business. So we have experienced some reasonably high attrition, and particularly in the hourly area, as that chart shows, we've had what I consider fully unacceptably high attrition.

We've taken very discreet, significant steps, in addition to trying to keep the hiring of manpower down, but to keep that level work force and make them like their job to the extent they stay on the job.

One of the things that we're doing is a process that was originated by the Japanese back in the early 1950's. The Japanese decided that "Made in Japan" should not be a bad name, should not a pejorative term, should be a good thing, and they developed the "quality circle" concept, as they called it, and within the United States, Motorola and some aerospace firms have applied this. We are applying it.

What it involves is a group of people who volunteer to participate in a quality circle, and the group is then furnished statistical data by us, by our quality area, of those things that we have found in the way of defects in their area. They then convene themselves into a round table discussion to discuss among themselves how those defects could be eliminated. We get primarily participation by the employees, and the employees feel appreciated, and, as Hertzberg says, it's the highest order of reward for an employee to feel that he is participating and being appreciated.

[Next viewgraph shown.]

Mr. TIMMONS. Looking down the columns on this one, I am attempting to show that approximately two program operating plan budget reviews in advance of the fiscal year, that is three POP cycles really reflected there, that we are able quite accurately with good coordination with the Marshall Space Flight Center to anticipate and predict the fiscal funding requirements.

In 1977, the block that's framed in indicates the year-end final actuals. Similarly in 1978. In 1979 we're on course with an agreed to approximately $85 million fiscal funding requirement for the D.D.T. & E. work, plus the weight savings work that's been incorporated into the D.D.T. & E. contract. The run-out cost as evidenced on that is $437 million at program end.

[Next viewgraph shown.]

Mr. TIMMONS. We have a formal design-to-cost and cost-per-flight model that was established earlier in the program. In fact, it was established, I believe, before the program was under contract. It's reflected in 1971 dollars. There is no quick relationship to what it's going to cost in real year dollars per flight, but it is a good means of continually tracking what is the effect on the program of changes; what is the effect on the program of our cost growth within our own company; and how good a job are we doing.

It is being converted presently to 1978 dollars so it will bear a little more reasonable relationship to what the actual cost per flight is, but it is not to be associated with the cost of x flight out in the future in real year dollars. It does reflect the outer circle there as being the cost-per-flight target, and it shows you in the upper left that the thermal protection system application is the one where we have to focus most of our attention because that's the one that's farthest out there on the cost growth versus what we anticipated it would cost.

The mechanical assembly and structures work is well in hand.

[Next viewgraph shown.]

Mr. TIMMONS. So to combat that cost growth and to look toward lower cost per units in the future we have formalized the cost reduction and producibility program with agreement with the Marshall Space Flight Center. The formal approach is to identify by all means (contributions from the employees on what they think we can do different-

ly, engineering redesign, every foreman and supervisor suggesting techniques for reducing the cost in the future) entering those into this procedure, and, as you can see, there are 311 identified cost avoidance or producibility items in the upper left. Those, then, will be screened for the obvious acceptance or rejection of things that we can tell without having a trade study that we should or should not do. If accepted, they will then go into a decision of whether or not development effort is required or can we go directly to tooling, process changes, procedures changes, or introduce it immediately into the production process and reduce the overall cost per flight of the vehicle.

[Next viewgraph shown.]

Mr. TIMMONS. The final viewgraph that I have indicates the work that we have coming up at the Kennedy Space Center.

Tom Wirth at the Kennedy Space Center reports to me, and Tom indeed reported to me in 1972 and 1973 when I was at the Kennedy Space Center with the Skylab program.

John Yardley mentioned this morning that the Kennedy Space Center anticipates a certain amount of work to be completed on a vehicle when they get it. I can't quantify that into any amount of work that they anticipate, but my experience there tells me that the average work to be completed at the Kennedy Space Center far outstrips what we're sending there in the way of unfinished work. We anticipate delivering tomorrow a very clean product to the Kennedy Space Center, based on past standards of products delivered to KSC.

In the left-hand column is the work that has been planned at all times to be done at the Kennedy Space Center.

The middle column represents program changes that have come along, and in looking at the schedule for those changes in the procurement cycle it was determined that they should be done at the Kennedy Space Center to avoid any delay in delivery out of Michoud.

The right-hand column is work we actually have deferred. We have determined that it cannot be finished at Michoud, things that came up late in the program. They best can be performed in a vertical position. We're in a horizontal position now with our final test and check-out of ET–1, so that work is being deferred.

Down at the bottom you'll see it's approximately 400 man-hours of effort in total. To that is added approximately 175 man-hours of effort that I have determined have been uncovered during the last 2 days of inspection prior to the shipment with about 40 to 70 NASA people in, reviewing the paper and actually looking at the flight article. Only about 175 man-hours of work have been identified. So we're sending a vehicle to the Kennedy Space Center with a very low amount of add-on man-hours of work associated with it. The schedule can be accommodated by Tom Wirth at the Kennedy Space Center, who has been working with us on this review. He knows what his normal check-out is and this work is added to it. His schedule fully supports the program requirements.

In summary, with a mature, stable, and a well trained work force, with our commitment to cost-per-flight reduction, and with the delivery tomorrow of the first flight article we're ready fully to support the shuttle program.

That completes my formal testimony, Mr. Chairman.

Mr. WINN. Thank you very much, Mr. Timmons. We appreciate your trading places with Mr. Stone so that we could accommodate everybody.

You stated in your last summary that there's approximately 392 man-hours of work that must be done at the Cape on the external tank.

We witnessed a rather dramatic growth in the time estimate on the Orbiter when it arrived at the Cape, and I just wondered if you anticipate a similar growth in your estimate.

Mr. TIMMONS. Our remaining program concern is just that. However, I don't consider it to be a dramatic growth. We will have to do additional ice and debris protection work at the Kennedy Space Center. That work is not of the precision nor of the complexity of the tile work that's been going on there.

We do have to apply a very low density, one pound per cubic foot, insulation to those areas which could form ice and shed that ice during the early portion of the flight. It's a procedure which will be well identified in another 30 days, and the amount of work there that we have to do we have worked off through Jim Odom at the Marshall Space Flight Center and with our man, Tom Wirth, at the Kennedy Space Center, and what we see we have to do can be done in support of the anticipated lift-off date for the Orbiter.

Mr. WINN. Have you experienced any broad fluctuations in manpower levels during the tank production?

Mr. TIMMONS. No, we have not. That's one area we work toward, to maintain a stable work force. We've had no broad fluctuations.

Mr. WINN. Do you keep or have available a peaks and valleys chart of any type that you might furnish the committee?

Mr. TIMMONS. From past performance?

Mr. WINN. Yes.

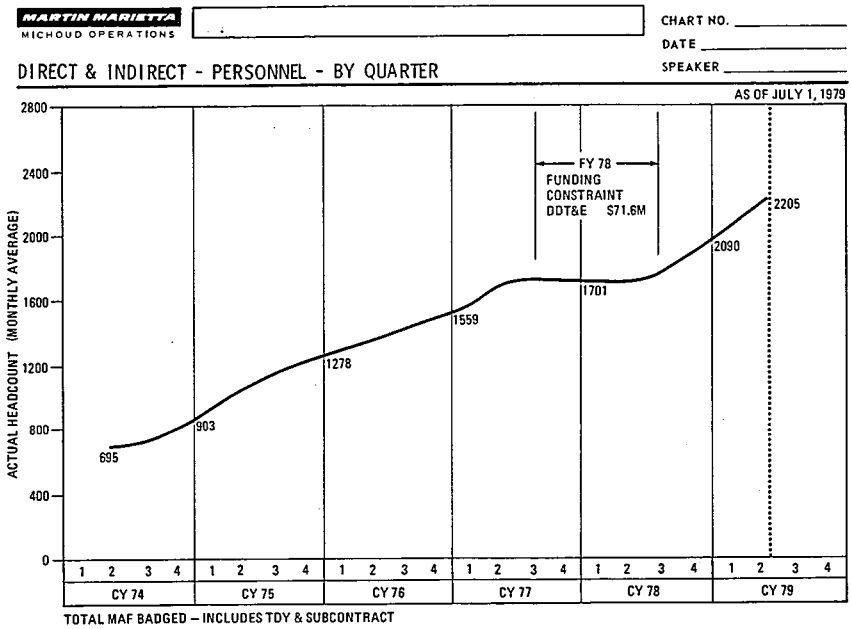
Mr. TIMMONS. We certainly do have one of those and can furnish it to you.

Mr. WINN. I don't want you to go to a lot of expense, but however you keep that. As I remember, we saw some of your earlier past performances on some charts when we were down there.

Mr. TIMMONS. Perhaps you did. We do have it. I think in about 1975 there was a reduction. We have been stable since then. We'll be happy to furnish that for the record.

Mr. WINN. I would appreciate that.

[The material to be provided is as follows:]



Mr. WINN. You mentioned the attrition problem. I wonder if you could clarify that a little more than what you did when you showed the slide, please?

Mr. TIMMONS. Yes. It's by national standards higher at the outset than the average for aerospace.

Mr. WINN. It's higher?

Mr. TIMMONS. Higher. It has been.

Mr. WINN. Why?

Mr. TIMMONS. We have difficulty identifying the exact reason. I think the work force there is being introduced into a new area of work, and there is high competition. After being trained by us as welders, or being trained in any specific area, there is a good opportunity for them to go elsewhere, such as the boat and shipbuilding industry in the area and the petrochemical industry, all are paying——

Mr. WINN. Do they pay more money?

Mr. TIMMONS. They're paying slightly more than we are.

Mr. WINN. Aren't you competitive in salaries?

Mr. TIMMONS. We're low, a little bit lower than some of the present averages in the area on salary.

Mr. WINN. Have you ever heard that there is a morale problem down there, or there was a morale problem?

Mr. TIMMONS. No. I had not heard that.

Mr. WINN. It's never gotten back to you?

Mr. TIMMONS. Not that there was a morale problem, no. We felt that a morale problem could have contributed to the attrition rate

and that's why we've taken all the steps that we have, shown in some of the visual aids that I didn't display here, in order to come up with the employee recognition programs and awards. Also, we have a requirement now that we all get out on the floor and talk to the people on the floor routinely to show that we are interested, that we are working hard to make them a part of our entire team.

Mr. WINN. I think that's very wise because, as you know, I've been down there several times, as has the Chairman, and we got the idea that at one time there was a morale problem. That may or may not have anything to do with the attrition.

Mr. TIMMONS. I invite you to return later and see if that's still your feeling, Mr. Winn.

Mr. WINN. I missed this part, and I apologize. But why do you think that you have been able to accurately predict your funding requirements 2 years in advance?

Mr. TIMMONS. I think I said POP cycles in advance. I think it's the close coordination that we have at the Marshall Space Flight Center with Jim Odom, where we are in routine constant communication with him.

Mr. WINN. Do you think that's unique, as far as communication between the centers is concerned?

Mr. TIMMONS. I can't speak for other centers and other contractors. My prior experience is that it's not unique. I worked with the Marshall Space Flight Center on the Skylab program and found it to be the same open communication at that time.

Mr. WINN. Have you spotted any problem, I mean any real, substantial problem, as far as communication is concerned with any the centers, between yourself as the prime contractor and the centers?

Mr. TIMMONS. No. We have very little communication with other centers or with headquarters, and zero on cost communications. Good technical interchange, however, at the level 2. The level 2 work is that work controlled by Bob Thompson at the Johnson Space Center. Good communications there, good, open interchange, advanced knowledge of the possibility of changes in the interface requirements, which I think is a good indication of the interchange.

Mr. WINN. What happens if you see that you are really headed for some problems somewhere on cost control, something that's getting out of hand? Whom do you report it to immediately, Marshall?

Mr. TIMMONS. Yes. Jim Odom.

Mr. WINN. And you don't communicate with headquarters simultaneously?

Mr. TIMMONS. Not at all.

Mr. WINN. Nor with Johnson?

Mr. TIMMONS. That's right. Not with Johnson either on cost difficulties.

Mr. WINN. So any information of that type, what we call could be a flag as far as these cost overruns are concerned, as far as the industry is concerned, any passing of that along to headquarters would have to come through the center in your case?

Mr. TIMMONS. That's right.

Mr. WINN. Is that unusual, or is that the way most of the prime contractors work?

Mr. TIMMONS. I'm sorry, I can't answer for most of the prime contractors.

Mr. WINN. Don't you guys ever sit down and just shoot the bull, and compare, and lie?

Mr. TIMMONS. No. I had the assumption they all work the same way. Because of the satisfactory relations we have with Marshall I assume the others are doing the same thing.

Mr. WINN. I know your main obligation is to Marshall, and I understand that, and I've always been impressed with that relationship.

We've still been sitting here a lot of hours today, and a few yesterday, and some more when we come back, and I haven't gotten a lot of the answers that I've been looking for. I haven't been here all the time, but we're still trying to figure out when these warnings of some cost overruns or that somebody was heading into trouble occurred. I know you've been sitting here all day. We're still trying to figure out why that word didn't come forth somewhere. We read it in the press is when we first get it; which always makes us pleased. I don't know. We're still looking.

Mr. Flippo.

Mr. FLIPPO. Thank you, Mr. Winn.

Mr. Timmons, I was impressed with the degree of training that you were involved in for the employees in your shop out there, and I'm sure they are highly desirable employees to other industries in New Orleans at this time too. I noticed with great interest that you mentioned the great learning curve from ET–1 to ET–2.

Could you tell me anything about the reduction in per unit cost from your original estimates to after that going to ET–2, and what do you expect for the future?

Mr. TIMMONS. I can't give you a complete estimate of that. We are following the 82-percent learning curve in the mechanical assembly area, but we're doing dramatically better than that in the thermal protection system application. I believe we currently are showing about 40-percent reduction of the effort needed that we had on ET–1 to apply the thermal protection system to ET–2. That's the product producibility work that we have going.

Incidentally, Mr. Flippo, we need to exceed the 82-percent learning curve on ET–2 to achieve the cost-per-flight target.

Mr. FLIPPO. What are your major concerns with achieving the 6,000-pound weight reduction on the ET–2?

Mr. TIMMONS. We feel pretty confident with the 6,000-pound weight reduction. My major concern is the cost-per-flight impact that it will have. As I mentioned in my testimony, it runs counter to producibility. As you all know, weight reduction late in a program is an expensive item to apply. It will bring the cost-per-flight up.

Mr. FLIPPO. Do you believe that adequate funds are included in the Martin input to NASA to cover the weight reduction program in fiscal year 1980 and fiscal year 1981?

Mr. TIMMONS. Yes, fiscal year 1980 and fiscal year 1981. We have a nonrecurring estimate in there with Marshall. I don't have an indication yet what the 1980 and 1981 funds finally will be because we're just entering into that POP cycle, which will define for us the final

mark on the 1980 and 1981 funds. They know very well the $42.6 million we estimate for nonrecurring costs in the weight reduction program.

Mr. FLIPPO. Do you have any concerns that NASA's fiscal year 1980 budget and budget amendment contain sufficient allocation of funds to support your fiscal year 1980 program?

Mr. TIMMONS. I don't have enough insight to be, say, worried. We have started that cycle with Marshall and in about another week we will have finalized our preliminary coordination with Marshall on the POP '79 2, which will identify our fiscal year 1980 requirements and their mark against our requirements, which they, of course, will take to headquarters. I believe we'll be all right, Mr. Flippo.

Mr. FLIPPO. I want to ask you, I guess, a question that if I knew a little bit more about the scientific aspects of it I probably wouldn't need to ask. But you're spraying a lot of insulation on those tanks there. Wouldn't it be wonderful if we could do a similar type of thing to the tile problem on the Orbiter? Are we talking about apples and oranges? Will this technology ever evolve to such an application?

Mr. TIMMONS. Yes. We have no reentry problem with the tank. The tank reenters, and we hope it gets consumed, rather than protecting it against getting consumed. We have applied the insulation to protect against boil-off, to protect against the formation of ice, but the insulation we apply then becomes a debris generator. That's why we're having to abandon some of the earlier what we call "close out" procedures with the 2.5 pounds per cubic foot foam and go to the 1 pound per cubic foot foam on those things which might come off after lift-off.

Mr. FLIPPO. Thank you very much for your testimony. I appreciate it.

Mr. WINN. Before I call on Mr. Kramer, I went back and was reviewing the part of your testimony that I missed, and on page 6 you stated that the major area of cost growth was caused by program changes.

I think you probably heard me ask Rockwell and some other people how that comes about, how do you characterize those, and what, if anything, can be done about those changes?

Mr. TIMMONS. The program changes have been a significant contributor to the cost growth toward that $437 million figure. In fact, directed changes account for about 41 percent of that, Mr. Winn.

Mr. WINN. 41 percent?

Mr. TIMMONS. Yes, of that total figure.

Mr. WINN. I think somebody else said about 50–50.

Mr. TIMMONS. There may be different ways of expressing it.

Mr. WINN. Yes. Right.

Mr. TIMMONS. I'm thinking of the total figure, if you break it into components, for example, from the original estimate that we had to do the job, which is about 27 of that total. Unanticipated inflation gives us about 5 percent, and accounting changes, the Contract Accounting Standards, give about a 2-percent increase in the overall runout cost of the program; schedule adjustments, about 9 percent; the directed changes, 41 percent; our growth, our overrun, about 6 percent of that final runout cost is our overrun; and the weight

reduction, the nonrecurring weight reduction effort, is about 10 percent of the final figure.

Your question, how that could be reduced, I don't know. It is a development program. When the interface requires a change on one side or the other our program is far enough advanced and well enough known and the loads are well enough known and the testing is essentially complete that we're able to adopt a change to adapt to the interface, and we've had two recent reasonably significant interface changes in that area, and I would expect that kind of a thing to occur in almost any development program.

Mr. WINN. Do you look for any major changes in the future?

Mr. TIMMONS. No, I do not. Flight results I don't think are going to be significant as they affect the tank, and that would be the next area of major changes.

Mr. WINN. Mr. Kramer.

Mr. KRAMER. Thank you.

Mr. Timmons, can you tell me at what level your attrition rate had been running prior to 1979?

Mr. TIMMONS. Yes. I can tell you specifically.

Mr. KRAMER. I think perhaps you flashed those figures on the screen, but I missed seeing them.

Mr. TIMMONS. Overall, in 1977 we had 26.7 percent attrition. In 1978 it was 24.2. This year, based on what we have seen in approximately the first 6 months and projecting that rate to the end of the year, we have that reduced to 18.7. We have set a goal overall of 17½ percent. We're approaching that goal and I do believe we're going to make it.

Mr. KRAMER. These are primarily highly skilled people, are they not?

Mr. TIMMONS. The higher attrition is in the lower wage categories, or the hourly people. Many are not what I would call highly skilled. It's in the overall hourly labor force where we get the highest attrition.

Mr. KRAMER. Is there great competition for their services, or are there difficulties among that segment of the working corps to obtain employment?

Mr. TIMMONS. No. As I mentioned earlier, there are people in the area who will pay more. We have various things that help us, I think, to reduce the attrition. We have an air-conditioned facility. In New Orleans that is a definite asset. In Colorado that's a ho-hum operation, but it's worthwhile in New Orleans.

But I don't want to leave you with the thought that we have a remaining tremendous attrition problem. I think we have taken those steps which have reduced it. We've set the goals that we are achieving, and I believe we are winding up with a stable work force. We have been building up rather significantly over the past 2 years. Generally a build-up will engender attrition. Nothing really helps the reduction of attrition like longevity, where people have a good knowledge of their job; they have a vested interest in the company. I think those who have been with us longest will stay longest. It's a self-generating thing.

Mr. KRAMER. Yes. The bottom line really on attrition, or anything else I guess, is how it impacts on the project negatively, if at all. Obviously, it's not a plus, but do you feel that that attrition rate in any way has impacted adversely on either the problems with stay-

ing within certain cost figures, or on the timing of the completion of your work, or on the quality at all?

Mr. TIMMONS. I think that particularly on the first and third there has been an impact. The attrition has been largest with those people in those areas where we actually apply the thermal protection system. We have tried to train, and have lost, and had to retrain, and that did cause some poor performance perhaps on a learning curve basis on the first article. The second article, as I said, though shows about a 40 percent reduction in the time to apply the thermal protection system, indicating that we have retained the best skilled areas of those people in the hourly areas. They are staying with us, and, as I say, I don't want to leave you with the feeling that attrition is a significant problem. It is an area in which we are focused and I think we are doing a good job of reducing it.

Mr. KRAMER. How many people do you employ there?

Mr. TIMMONS. Around 2,000, a little over 2,000. Directly on the program though we have about 1,800 people plus 300 and some odd in overhead, about 325 people in the overhead category and about 1,800 people directly.

Mr. KRAMER. And you're utilizing their services entirely on this project?

Mr. TIMMONS. Those people in that count that I just gave you, yes, that is entirely on the external tank. We have some people out of that number who are at the NSTL facility and some people at Marshall. Not in that count are the 185 people that I have at the Kennedy Space Center under a separate contract to the Kennedy Space Center.

Mr. KRAMER. So is it fair to say that this plant—and I don't know the history, so excuse me—was developed in response to this program?

Mr. TIMMONS. No. This program is at this plant because the plant was there for a variety of production, dating clear back to World War II, when it was established. It is a large area, 40 acres in a single building, plus additional buildings. It was used during the Saturn program for the S–1C and the S–1B stages there.

Mr. KRAMER. Thank you very much.

Mr. FUQUA. Thank you, Mr. Kramer.

Mr. Timmons, you mentioned in your statement about a cost growth caused by program changes.

Could you elaborate on that point?

Mr. TIMMONS. Yes. I was breaking down the overall estimated complete run-out cost for the D.D.T. & E. program and assigning various segments of that estimate of complete cost to those things which caused the increase in the program as we went along, and I had about 41 percent of the final cost being directed changes in the program.

Mr. FUQUA. By NASA or by you?

Mr. TIMMONS. No. By directed changes I mean by NASA.

Mr. FUQUA. And what were some of the specific changes in program?

Mr. TIMMONS. Starting most recently, the relocation of the engine cutoff sensors would probably be the most recent change that came through the level 2, or from the Orbiter Project Office area. We had an interface mismatch with the Orbiter and to adjust the interface we agreed to, and did, make the change which allowed the interface to work properly. That was a significant modification to an attach

fitting that we have in the external tank. We took it off, put on a modified one.

But throughout the program I think the continuing definition of requirements in the thermal, in the TPS, area have been the biggest contributor to the changes, the tightened requirements in the TPS area, Mr. Fuqua.

Mr. FUQUA. Mr. Timmons, thank you very much for being here. I'm sorry you had to wait all day.

Mr. TIMMONS. My pleasure.

Mr. FUQUA. Thank you very much for your testimony this afternoon.

Mr. TIMMONS. Thank you.

Mr. FUQUA. The subcommittee will stand adjourned.

[Whereupon, at 3:25 p.m., the subcommittee was adjourned.]

APPENDIX

Questions and Answers Submitted for the Record

SPACE SHUTTLE

QUESTION:

	9/78 Assessment	6/6 Assessment	Difference
Memo dated 6/79 from Code M/Mr. Yardley to Legislative Affairs**	$1165.6M*	$1272.9M	$107.3M

	Previous Assessment	Current Assessment	Difference
Budget Amendment Book	$1170.3M*	$1250.3M	$80.0M

NASA has announced a plan for obtaining $80M for DDT&E by reallocation of $70M from production and $10M from the Teleoperator Retrieval System. How does NASA plan to get the balance of $27.3M for Shuttle DDT&E in FY 1979?

*Includes $185M Supplemental Request
**Subject of Memo is Space Shuttle DDT&E Cost Traceability

ANSWER:

The current plan, as reflected in Dr. Frosch's statement, is to utilize $10 million from the TRS and $70 to $90 million from production. The numbers in the cited memo are estimated "accrued cost" during the year and the numbers in the Budget Amendment are "obligations" during the fiscal year. The two numbers are not directly comparable. The costs will be incurred against the cumulative obligational authority on the contract.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #1:

What is the current total cost at completion of the Space Shuttle development program in FY 1971 budget dollars?

ANSWER:

The total cost and schedule are under review. The current preliminary DDT&E estimate at completion (in 1971 dollars) is approximately $5.9-$6.0 billion.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #2:

When compared with the original estimate of $5.15 billion, what is the percentage cost growth? What part of this cost growth is overrun?

ANSWER:

The original estimate of $5.15 billion in 1971 dollars has grown to $5.9 to $6.0 billion -- a total cost growth of about 15%. Seventy million dollars of this increase was caused by schedule stretchouts resulting from OMB budget limitations. The balance of the increase has resulted from technical problems encountered during development and test. The distinction between cost growth resulting from contract changes and that from contract performance is a negotiable item between the contractors and the government and has not yet been determined.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #3:

a. What is current estimate (in real year dollars) of the funding amounts required for the Space Shuttle development program for fiscal year 1979, 1980, 1981, 1982?

b. What amount of funding will be required for the Space Shuttle design, development, test, and evaluation program for FY 1981 and beyond?

ANSWER:

The current preliminary estimates (in FY 1980 budget dollars) for Space Shuttle DDT&E are $1250 to $1270 million for FY 1979 and $831 million for FY 1980. The requirements for FY 1981 and FY 1982 are still under review, but our present preliminary estimates indicate that about $500 to $550 million will be required after FY 1980.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #4:

What is the impact (schedule and funding) on the production program of reallocating $70 million from production to DDT&E in FY 1979?

ANSWER:

Production funding in FY 1979 has been constrained through the third quarter due to the uncertainty of the FY 1979 supplemental request. This funding constraint, together with technical problems, has resulted in a delay in the buildup of activity on the follow-on orbiters, with preliminary schedule impacts estimated at approximately six to twelve months on Orbiter 099, 103 and 104. Because of this constrained buildup, it is not possible to productively use the full $458 million for production in FY 1979. A $70 to $90 million reallocation to development would have no further impact on the production schedule.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #5:

What would be the impact (schedule and funding) on the production program of reallocating $220 million from production to DDT&E in FY 1980?

ANSWER:

If the $220 million were reallocated to development in FY 1980, there would be further orbiter delivery delays and significant cost penalties. This delay would be over and above the production delay attributable to constrained FY 1979 funding caused by the uncertainty of the approval of the $185 million supplemental and the need to transfer $70 to $90 million to development. The additional delay, caused by a $220 million reallocation from production in FY 1980, would be six to twelve months for Orbiters 103 and 104, with resultant total cost increases for production of the orbiters of up to $500 million.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #6:

Will the budget amendment of $220 million in FY 1980 be used for DDT&E or for production activities?

ANSWER:

It will be used for DDT&E. The additional $220 million to the development program in FY 1980 would alleviate the need to reallocate money from production assuming our current cost projections are accurate and no additional unexpected technical problems occur. This would allow the orbiter production program to proceed at a pace to support national defense and civilian needs.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #7:

With the $70 million reallocation in FY 1979 and approval of the $220 million budget amendment in FY 1980, can NASA support the requirements of the Department of Defense at Vandenberg Air Force Base? What is the delivery schedule and estimated cost of Orbiter 099, 103, and 104 (funding requirements should be specified by Orbiter and by fiscal year)?

ANSWER:

With the $70 to $90 million reallocation to development in FY 1979, the approval of the $185 million FY 1979 supplemental and the $220 million additional funding for development in FY 1980, plus adequate future year funding availability, NASA can support the DOD requirements at Vandenberg AFB. The current preliminary orbiter delivery schedule is as follows:

Orbiter 099	March 1982
Orbiter 103	Summer 1983
Orbiter 104	Fall 1984

The costs associated with the revised schedule are being developed as part of the FY 1981 budget formulation process.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #8:

a. Has NASA considered reprogramming funds from other programs such as the Space Telescope, Galileo, and Landsat D?

b. What would be the impact on these programs of any such reprogramming?

ANSWER:

Yes, NASA did give consideration to reprogramming funds from other programs to alleviate the Shuttle funding problem. The conclusion was that reallocation of funds from sources such as the Space Telescope and Galileo would not contribute substantially to solution of the Shuttle funding needs and in fact would severely disrupt the development progress in these programs, resulting in increased costs.

Stretchout of the Galileo launch would require complete restructuring of the Galileo and International Solar Polar Mission (ISPM) projects. Shifting Galileo to 1983 and the Solar Polar Mission to 1984 would require development of a new Shuttle Upper Stage capability. A preliminary estimate is that such a decision could result in a reduction of $30-40 million in FY 1980 funding requirements, but an increase in total NASA funding requirements of about $200 million depending on the upper stage development requirements.

While the Space Telescope does not have a specific launch period which must be met, an assessment of the project budget situation has led to the conclusion that any significant reduction in FY 1980 funding would have a major impact on the program. Such a reduction would cause a serious disruption of a successful and carefully-planned program and would introduce inherent schedule and cost risks. At least a three-month effort would be required to accurately replan the program and identify actual impacts and effects. However, it is estimated, for example, that a $20 million reduction in FY 1980 would likely result in a slip of six months in the launch schedule, with an overall increase of approximately $50 million in runout costs due to schedule stretchout.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #9:

What is the impact of the delay in the first manned orbital flight on the requirements for Space Flight Operations funding?

ANSWER:

The seven month delay in the first manned orbital flight causes a corresponding delay in the first operational flight. The currently estimated IOC of late summer of 1981 would permit NASA to fly only one mission in FY 1981 and ten missions in FY 1982. This would reduce the flight rate from twenty-three to eleven in FY 1981/82. The lower flight rate would make it possible to reduce FY 1980 funding requirements for flight hardware procurement. However, the loss of reimbursements due to cancellation of reimbursable flights may offset this reduction. Additionally, it may be cost-effective to maintain production of external tanks and solid rocket motors at a certain fixed rate of production notwithstanding the decrease in FY 1981 planned flights.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #10:

In February 1979, NASA stated that $27 million would be needed in FY 1980 to maintain an option for the fifth Shuttle orbiter. With production program schedule delays, when would production have to be initiated to provide a minimum cost production schedule? When would long lead items be required to maintain the option for the fifth orbiter? Would any funds be required in FY 1980?

ANSWER:

Considering the new orbiter delivery schedule it would not be prudent to initiate Orbiter 105 production in FY 1980. Based on an Orbiter 105 production start in FY 1982, to assure an efficient manufacturing cycle, long lead activities should be started in FY 1981.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #11(a):

What is the impact of the first manned orbital flight delay and the production delivery delays on the Tracking and Data Relay Satellite Program?

ANSWER:

The launch of TDRS-A will probably be delayed until late summer of 1981. This schedule change will delay the initiation of loan repayments and will increase contract costs. The contract cost of the schedule delay will be on the order of several millions per month with the bulk of the costs generated by interest on the FFB loan.

A more refined estimate of the impact will require definition of launch dates beyond the first mission, interaction with contractor teams to investigate the most economic method of meeting the revised schedule, and an analysis of the effects of the delay on planned network station closures. Delays in station closures are expected to cost an additional several million dollars per month.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #11(b)·

What is the impact of the first manned orbital flight delay on Expendable Launch Vehicles?

ANSWER:

The delay in the first manned orbital flight and the consequent rescheduling of the first operational flight may cause some commercial and foreign users to consider an ELV instead of Shuttle. A recent survey of the early customers, however, indicates little interest in launching on the more expensive expendable systems.

NASA has planned for some time to support up to six Delta and one Atlas/Centaur launch vehicle as potential back-ups in case the Shuttle is not available for customer mandatory launch dates. These back-up vehicles may be requested by the user up to the First Manned Orbital Flight (FMOF) of the Shuttle.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #11(c):

What is the impact of the first manned orbital flight delay on Department of Defense requirements?

ANSWER:

Since utilization of the Shuttle by DOD does not commence until late in 1982, DOD flight requirements can be satisfied in accordance with requested launch dates. Delay of the first manned orbital flight, therefore, does not have a significant impact on DOD requirements as far as NASA can determine.

Requests for more detailed information with regard to DOD mission requirements should be addressed to the Department of Defense.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION 11(d):

What is the impact of the first manned orbital flight delay on other missions?

ANSWER:

The operational date slip caused by the delay in the first manned orbital flight has generally moved all operational missions a similar period. NASA is attempting to hold important missions with mandatory launch dates to their present schedules at the expense of lower priority, non-schedule constrained missions. This arrangement affects primarily NASA missions.

In addition, cargo manifests are being revised to take full advantage of available cargo bay space and Shuttle weight and turn-around capabilities. These changes, which are currently being assessed, will tend to minimize the impact of the FMOF delay.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #12:

Has NASA selected the Thrust Augmentation design which will bring the Space Shuttle up to the original performance specifications? Will the Thrust Augmentation development be accomplished as part of the Design, Development, Test and Evaluation Program? What is the impact of a one-year funding delay for Thrust Augmentation activities?

ANSWER:

NASA is continuing the assessment of two Thrust Augmentation concepts: strap-on solid motors (SOSM) to the SRB and Titan engines with modified Titan propellant tanks mounted under the External Tank, to bring the Space Shuttle up to original specifications. Either concept will be capable of providing the required additional performance and each will have some growth margin beyond that. Their impact on the Shuttle system is currently being compared.

The Thrust Augmentation study effort is being funded in the Operation Capability Development budget within the Space Flight Operations line item.

A one-year delay in the funding of Thrust Augmentation would impact the analysis to identify changes to other Shuttle elements which should be incorporated in follow-on orbiters and the VAFB design, plus probably delay the targeted operational capability date of mid-1984.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #13:

What is the impact of the recent test failure of the APU? Will a redesign of the APU be required? How long will it take?

ANSWER:

Our current assessment of the Shuttle schedule impact, because of the recent APU failure, can only be estimated at this time. It is our feeling that no impact to the actual Shuttle STS-1 launch schedule will exist, but that there will be some impact on program cost and qualification test schedules. As of this date, JSC has not received a firm recovery plan or the additional cost estimate for the APU modifications from the contractor.

Some minor fuel system redesign also will be necessary to maintain a maximum fuel pump and propellant control valve temperature of 200°F or less. Designs for active and passive cooling are currently underway at the APU contractor. The total time to make the design and test program changes and verify them is currently unknown, but are being pursued vigorously with the expectation that the majority of the required changes will be completed in early FY 1980.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #14:

When the staff visited the Kennedy Space Center in May 1979, there appeared to be some questions with regard to the division of responsibility between Johnson Space Center and Kennedy Space Center for completion of the Orbiter manufacturing and accomplishment of vehicle checkout activities. What management changes have been initiated to resolve this problem?

ANSWER:

The following management changes were implemented subsequent to the staff visit to Kennedy Space Center (KSC) in May 1979:

(1) The NASA KSC Space Shuttle Projects Manager was assigned responsibility for, and authority over, all Space Shuttle work performed by the various KSC Directorates.

(2) The NASA JSC Orbiter Project Office was assigned responsibility for, and authority over, all orbiter manufacturing work in the Orbiter Processing Facility (OPF). A JSC representative was placed in residence at KSC to manage this manufacturing effort. He is supported by a small staff of JSC and appropriate key KSC personnel and is further responsible for integrating the KSC test and checkout activities with the manufacturing work until the orbiter leaves the OPF.

(3) Rockwell International placed a Vice President from their Downey manufacturing headquarters in residence at KSC with authority over all the contractor's manufacturing, test, and checkout activities. His staff includes a manager for thermal protection system installation, a manager for other manufacturing work, and a manager for test and checkout.

In addition to the above management changes, specific work planning, manpower, training, supervision, logistics, and administrative support actions have been taken by both NASA and the contractor to expedite and improve the installation and checkout work.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #15:

In a briefing to the Committee staff in May 1979, NASA stated that the $220 million budget amendment would be adequate to carry the program until the first manned orbital flight in March 1980. How does NASA plan to support the Shuttle DDT&E in FY 1980 if the FMOF is delayed beyond March 1980?

ANSWER:

If the FMOF occurs beyond March-April 1980, there is concern as to the adequacy of the $220 million addition to Shuttle development. We will have a clearer understanding of what the FMOF is likely to be and the associated funding requirements by September 1979, as we finalize our FY 1981 budget to OMB.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #16:

NASA has a three-part analysis of the Space Shuttle program underway:
1) An overall management assessment by Dr. Lovelace
2) A detailed review of cost and scheduling by Mr. Lilly
3) A technical status review by Dr. Frosch.

When will these reviews be complete?
How and when will the results be made available to the Committee?

ANSWER:

NASA's ongoing three-part analysis of the Space Shuttle program is expected to be completed in September. We are planning to make the results available to the Committee at that time, at the Committee's convenience.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #17:

When will NASA have firm schedule and cost estimates for completion of DDT&E?

ANSWER:

We should have better cost and schedule estimates for the completion of DDT&E as we finalize the FY 1981 budget to OMB.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #18(a):

When will NASA have firm schedule and cost estimates for the production program?

ANSWER:

The follow-on orbiter cost and delivery schedule projections are currently being evaluated. The results of this evaluation will be available as part of the FY 1981 budget process with the OMB.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #18(b):

Contractors and subcontractors do not currently have a firm plan for production orbiter funding in FY 1979 nor in FY 1980. How can NASA expect to make realistic cost and schedule estimates for the production orbiters in FY 1981 and FY 1982 with this situation?

ANSWER:

Our contractors have had funding availability for FY 1979 from the beginning of the fiscal year. We have time-phased these funds to be concentrated in the final quarter of FY 1979 as a hedge against availability of the $185 supplemental, and against needing more DDT&E funds. The FY 1980 production funds were detailed in the submittal of the FY 1980 budget in January, and still represent our current planning. Schedules will be adjusted to compensate for the early FY 1979 funding constraint.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #18(c):

Will current estimates by the major contractors and subcontractors for FY 1981 and FY 1982 have any validity with no firm plan for FY 1979 and FY 1980?

ANSWER:

We believe that the major contractors and subcontractors now have sufficient information upon which to base valid estimates for FY 1981 and FY 1982.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #18(d):

It would appear that the changes in plan which have occurred in the production orbiter program in the past year are following the same path as the DDT&E program with resulting increases in funding requirements. Would you comment?

ANSWER:

Although there certainly are developmental program impacts on the production program (i.e., weight and schedule changes), the production program basically requires independent planning. This schedule and cost planning does not involve the same degree of uncertainty as the development process, because you are basically building things you have built before. Of course inflation, workload in the aerospace industry, necessary flight test changes, incorporation of new technology where beneficial, schedule slips for whatever reason, are factors which produce undertainty and require the planning of appropriate funding contingencies.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #19:

What funding is planned for Orbiter 103 in FY 1980?

ANSWER:

With the revised production delivery schedule, the FY 1980 requirements are still under review and firm estimates for each vehicle will not be completed until September 1979.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #20:

There have been infusions for funds into the Shuttle DDT&E program in FY 1977, FY 1978, FY 1979, and FY 1980. Please provide a table which includes the amounts, rationale for need, and a brief explanation of how money was applied across the major program elements.

ANSWER:

In FY 1977, an increase in funds of $55 million was provided from the following sources:

$25 million -- Economic Stimulus Appropriation Act, 1977
$30 million -- from the Space Flight Operations budget, including $27 million of residual Apollo-Soyuz Test Project funds

The increased funding was applied in the following areas:

Orbiter

- Additional manpower to improve Orbiter 102 schedule;
- Increase subcontract effort in critical development areas (i.e., Auxiliary Power Unit, Reaction Control System, Thermal Protection System);
- Technical change to on-board General Purpose Computer to provide increase memory capability based on OFT requirements and provisions for reasonable growth;
- Provisioning of timely integration of flight software and hardware by upgrading the Avionics Development Lab at Downey to the Orbiter 102 hardware configuration thus allowing validation in parallel of ALT and OFT hardware and software.

Main Engine

- Enhance accumulation of engine test time.

Solid Rocket Booster

- Improve Development/Qualification motor deliveries;
- Improve Subsystem areas (i.e., Auxiliary Power Unit, Integrated Electronics Assembly Structures).

External Tank

- Based on wind tunnel testing, redesign of the ET was necessary in areas such as the intertank and at the SRM attach fittings to withstand greater loads than previously anticipated.

(Question #20, cont'd.)

In FY 1978, $100 million of funds was transferred from "production" to DDT&E to provide for increased effort resulting from deferrals and delays from FY 1977 to FY 1978, plus new requirements. The funds were applied to the following areas:

Orbiter

- o Orbiter 102 aft fuselage secondary structure installation;
- o Assembly of 102 modules;
- o Extravehicular mobility unit (EMU) and logistics procurements;
- o Buildup for MPT test;
- o Subcontractor growth.

Solid Rocket Booster

- o Qualification motor testing;
- o Increased effort on Thiokol manufacturing manpower and structures.

External Tank

- o Martin growth;
- o Rephasing of support requirements.

In FY 1979, additional funds were identified from a requested supplemental of $185.0 million, $10.0 million from the Teleoperator Retrieval System (TRS) project, and a $70-90 million transfer from production. These funds are required in the following areas:

Orbiter

- o The increase in funding requirements for FY 1979 results from a combination of mandatory design changes, technical problems in FY 1978 that increased workload in FY 1979;
- o Increased requirements in Orbiter software leading to a large number of changes;
- o Cost increases in the extravehicular mobility units;
- o A schedule stretchout of the main propulsion tests (MPT) due to main engine problems and implementation of a phased approach to the main propulsion certification;
- o The need for additional funds for the mated vertical ground vibration tests (MVGVT) due to hardware delays and the identification of additional test requirements.

(Question #20, cont'd.)

Main Engine

- NASA activated a three engine test stand at Santa Susana, which was previously unplanned, and began testing in order to enhance development progress by establishing an increased capability to conduct engine system testing;
- Acceleration of follow-on engines to be available in the event additional test hardware is needed and the acquisition of additional critical parts;
- Deferral of work from FY 1978 to FY 1979;
- Resolution of engine test problems;
- Increased engine manufacturing and assembly requirements.

Solid Rocket Booster

- Changes to the structures areas including modification of the aft skirt skin forming tools and changes to the heat skirt attachments;
- Assembly problems of the forward and aft skirts;
- Redesign changes to components being procurred by the booster assembly contractor and the deferral of ground support equipment from FY 1978;
- Changes required for integrated electronics, thrust vector control and the recovery system, based on test results;
- Component redesign, inhibitor modifications and tooling redesigns, following test motor firings.

External Tank

- Technical design changes;
- Revised aerodynamic loads and a change in the preselected ascent aerothermal environments resulted in a redesign of the external propulsion lines and cable;
- Deferral of manufacture and assembly effort into FY 1979 as result of design changes.

Launch and Landing

- Deferral of effort from FY 1978 of ground support equipment (GSE) procurement, installation and checkout; propellant purchases; and launch processing system equipment; delivery of the first flight elements;
- Increase in requirements for ground support equipment spares;
- Activation of various station sets, such as the Orbiter processing facility, hypergolic system maintenance facility, and solid rocket booster disassembly area.

(Question #20, cont'd.)

In FY 1980, an additional $220 million has been requested as an amendment to the budget. This funding will be applied in the following areas:

Orbiter

- o Complete manufacturing and assembly work on OV 102;
- o Increase development support;
- o Increase personnel to complete Mission Kits;
- o Additional effort in qualification and certification program;
- o Subcontractor cost increases.

Main Engine

- o Additional engines and parts;
- o Engine testing extended;
- o Increase in manpower requirements.

External Tank

- o Thermal protection system application problems;
- o Schedule impact of mandatory changes, such as bracket interference and liquid oxygen sensor relocation;
- o New development effort initiated to improve productivity.

Launch and Landing

- o Launch processing systems installation, application software development and verification;
- o Manpower increase required for launch operations for OV 102.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #21:

Please provide a chronology of the Space Shuttle design, development, test and evaluation (DDT&E) program, including changes in first manned orbital flight, first operational flight, total DDT&E cost estimates, and rationale for change.

ANSWER:

See enclosure.

National Aeronautics and Space Administration

SPACE SHUTTLE DDT&E CHRONOLOGY

	FMOF*	IOC**	TOTAL DDT&E COST Billions of 1971 $	CHANGE	REASON FOR CHANGE
FY 1973 BUDGET	Mar. 1978	Mar. 1979	$5.150	---	March 1972 Decision to develop solid rocket booster configuration.
FY 1974 BUDGET	Sept-Dec. 1978	Dec. 1979	5.150	---	FY 1974 budget reduced $85M by OMB; 6-9 month delay in FMOF; no change in total cost.
FY 1975 BUDGET	Mar-June 1979	June 1980	5.200	+.050	OMB reduction of FY 1975 funding for DDT&E by $89 million and additional delay of early year build-up; delay FMOF 6 months; increased total cost $50 million in 1971$.
FY 1976 BUDGET	Same	Same	Same	---	
FY 1977 BUDGET	Same	Same	5.220	+.020	Reduced FY 1977 funding ($15M in DDT&E and $85M in production); no delay in FMOF; $20 million increase in total cost.
FY 1978 BUDGET	Same	Aug. 1980	Same	---	
FY 1979 BUDGET	Same	Aug. 1980	5.430	+.210	Technical and cost problems in fabrication and test activities. Cost estimate increased 4% to incorporate actual experience; no change in FMOF schedule objective.
Sept. 1978 Announcement	Sept-Dec. 1979	Feb-May 1981			
FY 1980 BUDGET (Jan. 1979 Announcement)	Nov-Dec. 1979	Feb-May 1981	5.654	+.224	Technical problems including engine & thermal protection; necessary design changes; additional engine test stand; and program deferrals result in 6 month delay in FMOF and an additional 4% increase in total cost.
FY 1980 BUDGET AMENDMENT (May 1979)	Early 1980	Same	5.9-6.0 1/	+.250-.350	Cumulative effects of technical problems, including increased fabrication and assembly efforts on the first orbital vehicle; technical changes to the external tank; and problems during testing of the main engine and SRB subsystems resulting in a delay of FMOF. Also, the addition of main engine hardware to support development testing.

*First Manned Orbital Flight.
**Initial Operational Capability.

1/ Equates to $8.3 to $8.45 billion in real year dollars.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #22:

Please provide a breakdown of the original $5.15 billion commitment by major program element including Orbiter, Main Engine, External Tank, Solid Rocket Booster, Launch and Landing, etc. Please provide a breakdown of the current Space Shuttle estimate at completion by major program element in real year dollars and in FY 1971 dollars.

ANSWER:

The original estimate of $5.15 billion (1971 $) commitment was at the total program level and not in terms of system elements. The breakdown to element level has been adjusted to the 1972 Work Breakdown Structure (WBS) after completion of definition.

DDT&E

	Original Estimate 1971 dollars	Preliminary[1] Current Estimate 1971 dollars		
		Thru FY 1980	Balance to complete	Total
Orbiter	$3.513	$3.851		
SSME	.580	.839		
SRB	.390	.330		
ET	.331	.353		
Launch & Landing	.336	.364		
TOTAL	$5.150	$5.737	$ .280	$6.017

	Preliminary[1] Current Estimate Real Yr. dollars		
	Thru FY 1980	Balance to complete	Total
Orbiter	$5.235		
SSME	1.170		
SRB	.473		
ET	.494		
Launch & Landing	.555		
TOTAL	$7.927	$ .513	$8.440

[1] These estimates are subject to change as a result of the current Shuttle reviews.

SPACE SHUTTLE COST, PERFORMANCE, AND SCHEDULE REVIEW

QUESTION #23(a):

Do you believe that the constractors are kept currently informed as to the amount of funding being allocated to their part of the program? I am assuming that you do not inform contractors of any funding reserves (or APA) you may be holding?

ANSWER:

The contractors are aware on a continuing basis of the current amounts that are planned for their authorized contract work. The contractors do not know the amount of funds held by NASA for changes that may be authorized and negotiated.

MANAGEMENT

QUESTION #1:

The OMB budget cycle is such that the NASA submission is fixed approximately 4 to 5 months before the budget submission to Congress. Build up by NASA centers to support the budget submission must be developed as much as 6 to 9 months before submission to Congress. Would the provision for a budget update to OMB after September 15 and prior to budget submission to Congress improve the accuracy of budget estimates?

ANSWER:

The period from submission of the budget request to OMB in mid-September to printing of the President's budget by the first of January is too tight to schedule time for update revisions by all agencies. The opportunity always exists for an agency head to reopen budget and program decisions with OMB and the President if the agency head has the facts to support such reconsiderations.

MANAGEMENT

QUESTION #2:

To what depth does senior, non-Shuttle NASA management review the cost and schedule estimates of the Shuttle program? How can that review be strengthened?

ANSWER:

Non-Shuttle NASA senior management officials review the cost and schedule estimates to the depth necessary to assure themselves that the requests are as accurate as can be reasonably estimated for complex Research and Development efforts that have never before been done.

NASA's estimates for Research and Development activities have been as good and in most cases better than any other organization of which we are aware. We do our best to anticipate problem areas, but we cannot always make a precise prediction of each problem or the magnitude of technical difficulties that may be encountered in pioneering Research and Development efforts.

MANAGEMENT

QUESTION #3:

Should NASA senior management review of the Shuttle program be strengthened? Would an executive advisory board for review assistance to the Administrator of NASA aid in discharging his responsibilities to review the Shuttle program?

ANSWER:

The dynamic nature of R&D programs is always a motivating force for seeking ways of improving all aspects of management, including Shuttle program reviews. The Administrator has requested and used executive advisory assistance on the Shuttle program on a number of occasions. Recent examples include the Hawkins Committee's review of the total program and the Covert Committee's review of a specific area such as the main engine. Currently, we have a Management Assessment group, headed by the Deputy Administrator, which will present its final report to the Administrator in September.

MANAGEMENT

QUESTION #4:

Has NASA considered augmenting the management analysis and control resources of the Associate Administrator, Office of Space Flight, by contracting for appropriate assistance, at headquarters level, during the remainder of the Shuttle development program and transition to operational status?

ANSWER:

Before the initiation of Shuttle development, a number of management arrangements were considered. At the present time, a detailed three-part analysis of the Space Shuttle program including management is underway and will be reviewed in detail by the Administrator in September.

MANAGEMENT

QUESTION #5:

The Johnson, Marshall and Kennedy Space Center work force is heavily devoted, but not exclusively, to the Shuttle program. Would it be prudent to place these centers under the direct management of the Associate Administrator, Office of Space Transportation System, for the remainder of the Shuttle development program and its transition to operational status?

ANSWER:

Dr. Lovelace and his group are specifically looking at the management aspects and organizational arrangements for the Shuttle program. They should complete their review in September and the Agency will be reporting to the Committee at that time.

MANAGEMENT

QUESTION #6:

Incentive contracting has been used as a management tool by NASA for many years. Has incentive contracting contributed to better management of the Shuttle program? If so, what positive results have been obtained? Can the use of incentive contracting emphasis be changed in a timely manner to reflect NASA program management emphasis?

ANSWER:

The Shuttle contracts use a type of incentive contract involving award fees. Award fee contracting has been a positive management tool used by NASA in the Shuttle program. For instance, in the Increment I DDT&E Shuttle Orbiter contract with Rockwell International, the performance award fee earned by the contractor ranged from 55% to 86% of the available award fee. In the Space Shuttle Main Engine contract with Rocketdyne for the period of April 1972 through September 1976, the percentage of award fee earned ranged from a low of 20% to a high of 85%.

We think the above examples indicate the use of award fee contracting as a management tool. As to changing the contracting emphasis, NASA has included in the Shuttle contracts language which allows NASA to place emphasis on certain areas of work provided the contractor is notified of these areas thirty days prior to the start of each evaluation period.

MANAGEMENT

QUESTION #7:

It appears from data available to the Committee, the Space Shuttle Program has been developed under a very tight fiscal constraint. This was not like Apollo!

-Are we now seeing the consequences of this constraint?

-Did the character of the program change as a result of this constraint?

-What was the Management approach employed in the various stages of the program?

ANSWER:

NASA has attempted to learn from and apply the considerable experience gained from the Apollo program. In doing so, we tried to limit the hardware produced and specify a tight schedule in order to minimize the cost. It was fully recognized that this approach involved an increased schedule risk. Perhaps when the development is complete, speculations can be made as to whether this approach enhances cost-effectiveness. Realistically, since the development was not done in two modes -- constrained and unconstrained, it is doubtful that a definitive assessment can be made. The basic fact is that in the executive, legislative and national environment of the early 1970's the question was whether or not the Shuttle development would be initiated and not a consideration of providing additional funds.

MANAGEMENT

QUESTION #8:

From a technical management viewpoint, how would you characterize the Shuttle program? What are the pacing technical problems of the program?

ANSWER:

Although we are not satisfied with the Shuttle program progress it does compare reasonably well to past aerospace programs of such a complex nature at the same stage of their development. Solving technical problems is the essential part of the development of an advanced capability such as the Space Shuttle. The two significant pacing technical problems presently existing are described below.

The Space Shuttle Main Engine

The Space Shuttle Main Engine has been one of the pacing technical problems in the program for some time. However, recent test experience indicates that the engine is gaining substantial maturity. The initial series of certification tests for STS-1 of 5,200 seconds in 16 tests has been completed. Eight of these tests were full flight duration at rated power level or greater accumulating over 4,900 seconds. This engine will begin a repeat of the test series this month. A second engine now in acceptance test will also be tested to assist in certification.

A recent failure of a main fuel valve during propulsion system testing is now being reviewed and its impact is being assessed.

Two of the STS-1 engines have completed acceptance tests, and have been delivered to KSC for installation in Orbiter-102. The third flight engine will be delivered to KSC in early August 1979.

Thermal Protection System (TPS)

Another of the primary pacing technical problems is the physical application of the relatively large number of tiles required to complete the Orbiter TPS. Included are a number of instrumented tiles, difficult installations, and some very complex closeout tiles, such as, at the interface with the nosecone. This interface is in an area where tile position is very critical.

Several areas where large pressure gradients exist, such as the trailing edges of the control surfaces, require fillers in the gaps between the tiles. Installing these fillers is time consumming.

MANAGEMENT

QUESTION #8: (Continued)

Completion of the structural analysis of the TPS has disclosed that some tiles have a negative strength margin, which may necessitate some rework.

MANAGEMENT

QUESTION #9:

Prior to the Space Shuttle Program, NASA incorporated a "lead center" concept in their management of major programs. How would you summarize this concept. How well is it working? Do you feel it was a good technique or should we go back to the old way of doing business?

ANSWER:

The "lead center" concept was selected for management of the Shuttle program in order to capitalize on the technical expertise and skilled manpower resources available at NASA field centers. This is particularly true with respect to systems engineering and systems integration. Responsibility for these important tasks has been assigned to the Shuttle program office at the Johnson Space Center. A part of the rationale was to keep the staff of the Shuttle Program Office at NASA Headquarters small. We believe that the effective use of the "lead center" method is somewhat dependent upon the size of the project as well as the number and complexity of technical interfaces between center responsibilities. The effectiveness of the concept in this case will be one of the subjects reviewed by Dr. Lovelace's Management Rev iew, and will be reported upon at a later time.

MANAGEMENT

QUESTION #10:

What impact, if any, has the lack of travel funds played in providing proper program visibility of the Shuttle Program at Headquarters?

ANSWER:

Communications for the program office management occurs on a daily basis between Headquarters and the Centers involved with Shuttle work. Individuals are continually in contact on current problems and, on a weekly and monthly basis, many engineers and managers hold essential program teleconferences. In the interest of conserving travel funds, we are relying heavily on the large NASA teleconference network and written information. This method of data collection, while not perfect, has proven adequate in most instances because of personal interfaces developed over the years between Headquarters and Center personnel.

MANAGEMENT

QUESTION #11:

How was the supplemental request figure of $185 million developed? What is the basis for the additional $220 million request for FY 1980?

ANSWER:

In both the FY 1979 supplemental and FY 1980 budget amendment cases, the additional funding estimates were developed to allow the continuation of the pace of development, test and manufacturing activities necessary to meet civil and military requirements. The specific estimates were a result of program status evaluations in the late summer of 1978 and spring of 1979, respectively. These program evaluations took into consideration schedule status and the need for additional resources to compensate for technical problems, design changes, schedule delays and the underestimate of work efforts subsequent to the estimate provided in the applicable Congressional budgets. The need for additional funding represented the best judgement at that particular time of the program requirements, allowing a minimal reserve for unanticipated changes and growth. The additional resources amounts were not intended to provide the program with the funding flexibility to accommodate major unforeseen problems and growth.

MANAGEMENT

QUESTION #12:

Is the $220 million budget amendment adequate to support DDT&E requirements in FY 1980?

ANSWER:

The adequacy of the $220 million budget amendment in FY 1980 depends on our ability to meet an STS-1 date in the March-April 1980 timeframe. Any significant slippage beyond that date will probably require some additional development funds. We will have firmer estimates of the STS-1 schedule and the FY 1980 funding requirements as we develop our FY 1981 OMB budget in September 1979.

MANAGEMENT

QUESTION #13:

What alternatives to the budget amendment were considered?

ANSWER:

The primary alternative considered was readjustment of programs and schedules within the Agency's budget plan for fiscal year 1980. This consideration included an assessment of the consequences of adjusting projects such as Galileo and Space Telescope, as well as adjusting Shuttle orbiter deliveries and schedules. We concluded that the only reasonable alternative was to adjust orbiter deliveries and to reallocate funds to development. After discussing the alternatives with members of the Executive Office of the President, a decision was made to request the additional funds necessary to meet critical defense and civil needs.

MANAGEMENT

QUESTION #14:

It would appear that after learning of significant additional funding requirements in the Fall of 1978 that NASA did not give much consideration to requesting additional funds from OMB. In addition, when learning of additional funding requirements in March, 1979, NASA's first reaction was to reallocate funds from Production while fully understanding the excessive cost penalities associated with such a plan.

Thirdly, back in fiscal year 1978 NASA made a decision to reallocate funds to DDT&E from Production rather than requesting a supplemental:

a) Now, I do not consider that supplemental requests or budget amendment should be submitted to Congress at the drop of a hat, but I wonder if NASA gives proper consideration to these alternatives?

b) On occasions it appears that NASA is too timid in asking for the resources which they need?

ANSWER:

As I indicated in my testimony, I think it is appropriate when we are faced with a problem to try to manage within the annual funds authorized and appropriated by the Congress. We then have to assess whether we are damaging the program by not asking for additional funds. In the case of the Shuttle development requirements for fiscal year 1980, we discussed the alternatives with members of the Executive Office of the President and a decision was made to request a Budget Amendment.

MANAGEMENT

QUESTION #15:

There have been press reports that NASA is considering a suborbital flight test of the Shuttle. Would you elaborate on the status of this concept? What would be the objectives of such a flight test?

ANSWER:

The concept of a suborbital flight test of the Shuttle is being studied at the Johnson Space Center. The study results are scheduled to be reviewed by NASA management in late August.

The reason for studying a suborbital flight is to determine if a flight test that would provide data on the Thermal Protection System tiles under a benign entry thermal environment is a worthwhile endeavor prior to committing to an entry from orbit.

The Shuttle program baseline continues to be that STS-1 will be an orbital flight. The suborbital flight study results will be reviewed to determine whether this baseline should be changed. There are numerous significant trade-offs involved, many of which are not related to the TPS, and it is quite possible that there would be an increase in risk to other elements of the program if we made a suborbital flight.

MANAGEMENT

QUESTION #16:

In November 1978, the Shuttle Program conducted a review of budget forecasting. How has NASA implemented the recommendations of this review?

ANSWER:

This budget formulation review team was headed by the Deputy Director of the Space Shuttle Program, and examined our budget forecasting techniques, among other areas, to identify factors which influence cost projections.

The team findings and recommendations for corrective actions were made in December 1978. The recommendations were implemented by letter from the Program Director in early 1979. In turn, the projects have directed their own offices and their contractors to implement the corrective actions which are now in place and which are being used to support our current FY 1981 budget planning. Some brief examples of the incorporation of the team's findings are:

1. In-depth monthly cost reviews are conducted which include projections of increased requirements.

2. More direct involvement by prime contractors in sizing requirements for downstream years in a timely manner to support NASA fiscal cycles.

3. Independent cost projections conducted by the Program Managers' resource analysis staff.

RECOGNITION OF THE PROBLEM

QUESTION #1:

Addressing your present cost and schedule problem on the Space Shuttle Program:

(a) When did you first learn of the problem?
(b) When did you understand the magnitude of the problem?
(c) What happened after you learned you had a large problem?
(d) How did you assess the problem?
(e) After you called in the Shuttle Management to Washington for a complete scrubbing of the problem, what happened after that?
(f) Why did it take from October 1978 to May 1979 to report this problem to the Committee?
(g) When do you expect to have a firm understanding of cost and schedule for the first flight?

ANSWER:

As we stated in our testimony before the Committee in response to these questions, there was no single problem or occurrence which clearly indicated the need for requesting additional funds. Starting in October 1978, after submission of our FY 1979 supplemental request and FY 1980 budget to OMB in September, some forecasts of potential additional requirements were received from our centers. Immediate actions were taken to assess both the validity and magnitude of the forecasted problems. In December, an additional engine test problem occurred. The status of our assessments was that we did not have information sufficient to change our basic budget requests. At that time, we felt that sufficient program reserves were contained in our budget requests to cover known problems as well as some, yet to be identified problems. Our assessments at the time were reported to Congress -- that is, some technical difficulties were continuing to occur, our planned reserves were eroding, but we thought that our budget requeste were sufficient to carry out our programs.

As Shuttle development activities continued during the first quarter of 1979, it was becoming more clear that planned progress on the development was not occurring. The technical progress assessments by our Centers in March was that schedules would have to slip and additional funds would be required. The Administrator initiated an immediate assessment of the problems, outlook, and alternatives. The results of the detailed assessments of status, schedules, and funding options were reviewed with the Administrator in April. The options were immediately discussed with OMB and the Executive Office, which resulted in a decision to initiate a budget amendment request. The Committees and

(Question #1, cont'd.)

staffs were immediately notified of the Agency's assessment and the planned actions.

We expect to complete our current reviews and report to the Committee in September 1979.

RECOGNITION OF THE PROBLEM

QUESTION #2:

NASA became aware of increases in resource requirements in September-October, 1978. Was any consideration given to reopening budget negotiations with OMB during this time and prior to the FY 1979 Supplemental and FY 1980 Budget Submittal to Congress?

ANSWER:

NASA became aware of some potential unanticipated resource requirements in the September-December 1978 timeframe, and during this period we were actively engaged in trying to ascertain the validity of these indications of problems. Our assessment of the magnitude of the problems at the time of the "closing up" of the President's FY 1980 Budget was that we could accommodate the estimated cost increases within the amounts contained in the budget. Therefore, we did not contemplate reopening the budget decisions with the President at that point.

RECOGNITION OF THE PROBLEM

QUESTION #3:

There is evidence that NASA management was aware of the likelihood of a need for additional FY 1979 resource requirements in December, 1978, and I quote from the first page of the Report of the Budget Forecasting Review Team "This study was initiated because of a significant increase in cost projection by Rockwell, the Orbiter contractor, after the NASA budget for FY-79 and FY-80 had been established. The provision of Level I Allowance for Program Adjustment normally serves to cushion cost surprises; the instance at hand may exceed that capability when combined with other demands on Allowance for Program Adjustment in FY-79." This statement which was made as a result of increases in cost projections for other elements of the Programs would appear to offer ample evidence of knowledge of a problem by NASA Management.

Would you care to comment?

ANSWER:

As I discussed in my testimony, the Report language quoted indicates the uncertainty of the total potential requirements. The question is this: At what point does one decide that the potential requirements cannot in fact be handled by existing reserves? Our assessment at that time was that there was a reasonable chance that our reserves would be adequate.

PROGRAM RESERVES FOR RESEARCH & DEVELOPMENT

Question: Dr. Perry, what size program reserves does the DOD carry for research and development programs?

Dr. Perry: The DOD Research and Development Program has no reserve fund as such. In planning individual R&D programs, program managers do consider contingencies for problems likely to occur during development. The amount of resources provided for such contingencies varies with each program, depending upon technical risk, complexity, and schedule. When situations arise where resources available to individual programs are inadequate, the program must either be delayed or funds reprogrammed from lower priority programs. Congressional approval is obtained for reprogramming actions, as necessary, when the program involved is of particular interest to one or more of the Congressional Committees.

Estimating Budget Year Funding Requirements

Question: How does DoD deal with the problem of estimating budget year funding requirements 12 to 18 months ahead of time?

Dr. Perry: The entire DoD program is projected for a period of five years in our Five Year Defense Program (FYDP). In our annual Budget Submission the following year's funding requirements for authorized items are displayed for the Congress. Admittedly these amounts are only the best estimates at the time but every attempt is made to make them as accurate as possible and projected inflation factors are included for all major systems.

Question: Does DoD on occasion re-open budget negotiations with OMB for higher ceilings after the September 15 deadline?

Dr. Perry: The OMB review of the DoD Budget is, by special arrangement, a joint review with the Office of the Secretary of Defense that usually extends into late December. The final total for the DoD Budget is generally determined at that time and there is seldom any ceiling negotiations after that.

IUS Support of Galileo Mission

Question: What is the technical and schedule status of the Inertial Upper Stage (IUS) with regard to supporting the Galileo program?

Dr. Perry: As the planning for the Galileo mission has evolved and the Shuttle performance capabilities have become better defined, we have been faced with increased performance demands which can be most economically achieved by modifications to the IUS. We have currently identified potential IUS modifications which could provide more than 300 lbs. of performance margin above Galileo requirements if all the changes were implemented. The performance improvement options being considered primarily involve structural design changes, i.e., redesign of the airborne support equipment, the equipment support section, and the interstage structure. Also under consideration is using solid rocket motors in lieu of the reaction control system thrusters for third stage spin-up, or going to a three axis stabilized third stage configuration. We are working closely with NASA to select those IUS changes which will satisfy Galileo requirements at the lowest cost. We are confident that the IUS can provide the performance required for the Galileo mission scheduled for 1982.

Since the planetary mission requirements are unique to NASA, necessary funding must also be provided by NASA. Our current estimate of the increase in funding is $20-30 million.

Shuttle Schedule

Question: Have the slips in the Shuttle schedule caused the DOD to switch to any expendable launch vehicle to meet mission requirements?

Dr. Perry: We can accommodate to the revised schedule which NASA now projects for Shuttle development and orbiter deliveries. This NASA schedule projects that the Shuttle will be operational at Kennedy Space Center (KSC) in 1981 and Orbiters 099, 103, and 104 will be available around March 1982, summer of 1983, and late 1984 respectively. This schedule will support our early launches at KSC and our plan to provide an initial operational capability at Vandenberg AFB in December 1983. However, this revised Shuttle schedule reduces the margin in the original schedule relative to DOD payload launches on the Shuttle. We have not switched planned missions from the Shuttle to expendable launch vehicles at this time.

Space Shuttle Funding and Schedule Problems

Question: When was DOD first aware of the recently announced funding problems and schedule slips of the Space Shuttle?

Dr. Perry: Dr. Lovelace advised me on 19 April 1979 that large Shuttle funding and schedule problems were becoming evident. An Air Force representative participated in subsequent NASA internal reviews. On 26 April 1979 Dr. Lovelace met with Dr. Mark and members of my staff and identified the overall magnitude of the problem. Key staff members on NASA and Defense Committees of Congress were immediately alerted to the situation.

Orbiter Fleet Size

Question: Is the DOD prepared to strongly support NASA in budget negotiations with OMB in support of building a 5th Shuttle Orbiter?

Dr. Perry: We believe that the four orbiter fleet will be adequate during the early years of Shuttle operation. However, during the period when FY 1981 and FY 1982 Shuttle funding decisions are being made and orbiter delivery dates finalized, we do intend to work with NASA to be sure that the option for continued production of a fifth orbiter remains open. At this time we cannot project when increases in national Shuttle traffic or possibly loss of an existing orbiter will warrant production of a fifth orbiter.

At such time as the need for a fifth orbiter is clearly established, DOD will fully support NASA in this funding request.

Impact of MILCON Funding Delay

Question: What is the impact of a one year funding delay for construction activities at Vandenberg on the plans for operational readiness at Vandenberg?

Dr. Perry: Delaying the FY80 Military Construction (MILCON) funding for the Shuttle by one year would result in severe impacts on the planned construction program to provide: (1) a Shuttle launch and landing capability at Vandenberg AFB, (2) modifications at the Johnson Space Center (JSC) to provide adequate protection for classified DoD Shuttle missions, and (3) DoD planning for transition of high priority payloads to the Shuttle.

The funding delay would effect a 9-12 month slip in the planned December 1983 IOC for the Vandenberg Shuttle capability. This IOC slip would result in cost increases of between $80-100 million, primarily due to the requirement for sustaining the Vandenberg activation contractor and for adjustments due to inflation. Additionally, the delay would require immediate consideration for procuring additional Titan III boosters to support prime launch requirements presently scheduled for the Shuttle. Costs for the additional boosters could range as high as $180-220 million. Similarly, several NASA missions would be impacted requiring shifts to expendable launch vehicles (ELV) or mission delays. The cost impact to NASA for these missions is currently unknown but would be considerable.

At JSC, the MILCON funding deferral would delay planned modifications resulting in a 12-18 month slip in our ability to provide adequate security protection for classified DoD missions. The funding delay would require that the security modifications be made at a time when the JSC facility is becoming heavily dedicated to Shuttle operational support--this impact may not be acceptable to NASA because the construction modifications would disrupt computer operations vital to the Space Shuttle flight safety and success. Implementation of the protective modifications at a later date would result in increased costs associated with operations work-arounds, inefficient scheduling, inflation, and could delay launch of classified DoD payloads from Kennedy Space Center (KSC), the first of which is planned for December 1981.

The last major impact resulting from delaying the FY80 MILCON funding is associated with the disruption of our plans to transition high priority payloads to the Shuttle. Some payloads, currently scheduled for early Shuttle launch from Vandenberg AFB, would require redesign for dual launch compatibility (Shuttle and ELV) resulting in increased costs and reduced mission capabilities.

QUESTIONS FOR GEORGE W. JEFFS,
PRESIDENT NORTH AMERICAN AEROSPACE GROUP
ROCKWELL INTERNATIONAL

1. MR. JEFFS, YOU STATED THAT MORE SUBSTANTIAL UNPLANNED EFFORT WAS ADDED TO THE ORBITER PROGRAM IN FY 1978.

   A) WOULD YOU ESTIMATE THE AMOUNT OF UNPLANNED EFFORT WHICH HAS BEEN ADDED TO THE ORBITER PROGRAM IN FY 1979?

      The amount of unplanned effort added to the Orbiter program in FY 1979 is $76 million, as explained in my testimony (p. 116, line 14 through page 117, line 20).

   B) WHAT AMOUNT OF DDT&E WAS DEFERRED FROM FY 1978 TO FY 1979?

      Approximately $65 million in DDT&E effort was deferred from FY 1978 to FY 1979.

   C) WHAT AMOUNT OF DDT&E EFFORT DO YOU ESTIMATE WOULD HAVE TO BE DEFERRED FROM FY 1979 TO FY 1980?

      Approximately $16 million in DDT&E effort probably will have to be deferred from FY 1979 to FY 1980.

2. MR. JEFFS, YOU HAVE STATED THAT THE CONSTRAINED BUDGETING PROCESS HAS RESULTED IN MINIMUM TOTAL PROGRAM EXPENDITURES BUT ALSO THAT MANAGEMENT RESERVES ARE ESSENTIAL FOR REAL-TIME CONTIGENCIES AT THE ELEMENT CONTRACT LEVEL,

   A) WHAT PERCENTAGE RESERVES ARE NEEDED IN THIS PHASE FOR THE ORBITER DDT&E PROGRAM?

      We recently completed reviews with the NASA Space Shuttle Program Office in support of their POP cycle and with the new June 1980 first flight date. We indicated a need for reserves of 20 percent and 50 percent of the baseline work for FY 1980 and 1981, respectively. These reserves should provide funds for anticipated provisioning, anticipated changes, and for resolution of anomolies.

B) WHAT PERCENTAGE CONTINGENCIES ARE NEEDED FOR THE MAIN ENGINE DDT&E PROGRAM? FOR THE MAIN ENGINE PRODUCTION PROGRAM?

A reserve of 10 percent is recommended for unforeseen development problems, spares, and normal change traffic for FY 1980 and 1981. A reserve of 15 percent is recommended for the production program. These contingencies should be added to the baseline POP cost data which we have provided to MSFC.

3. MR. JEFFS, DO YOU FEEL THAT NASA SHOULD HAVE FELT SURPRISED BY THE COST GROWTHS WHICH HAVE OCCURRED?

This question was answered in my testimony (Page 118, Lines 3-25).

4. MR. JEFFS, WHAT WERE THE MAJOR REASONS FOR THE COST GROWTHS WHICH BECAME APPARENT IN THE JULY-SEPTEMBER 1978 TIME FRAME AND RESULTED IN A MEETING AT NASA HEADQUARTERS IN OCTOBER 1978?

As I outlined in the section of my testimony dealing with 1978 and 1979 program cost visibility (Page 93 Line 12 to Page 94 Line 6), the major reasons for cost growth were unplanned efforts resulting from the incorporation of changes, additional work required to complete subcontractor efforts, particularly in fabricating the TPS tiles and the OMS pods, and additional efforts made necessary by the development and qualification test results.

WHEN DID ROCKWELL FIRST COMMUNICATE THESE COST GROWTHS TO NASA?

The initial element of the cost growth were formally transmitted to NASA in the May 1978 533Q Report, (published in July 1978) and then updated requirements were presented to NASA Headquarters at a formal briefing on 18 October 1978. We informally expressed our concerns on potential 1979 cost growth to NASA at the time we were directed to hold FY 1978 costs at the originally authorized level, and during the summer of 1978 when we were exercising 1978 and 1979 program work content and schedules to establish an initial FY 1979 plan with the NASA Program Office.

5. A) WITH REGARD TO THE TPS INSTALLATION ON ORBITER 102 AT KENNEDY SPACE CENTER, WHAT RATES CAN WE REALISTICALLY EXPECT TO ATTAIN?

The current plan to install 466 tiles per week is based upon an 80 tile per day nominal rate for a six-day week which equates to 480 tiles per week. This plan allows for some greater-than-expected efforts for difficult installations. Initially, during the training and learning process with new personnel added and working in a new facility, the rate was in the range of 40 to 50 tiles per day. This rate has increased to between 50 and 60 per day with over 100 tiles installed on July 10th. It is expected that a 70 to 90 daily rate will be maintained during the major portion of the effort, reducing to between 50 and 60 tiles daily as the installation nears completion.

B) WHEN TAKING INTO ACCOUNT THE EXPERIENCE IN PALMDALE, WHAT IS BEING DONE DIFFERENTLY AT KSC?

At KSC we are employing a higher ratio of supervisors-to-technicians. This change from Palmdale was made necessary by the requirements to manage the installation of individual tiles at a greater rate as well as the more sophisticated logistics needed to support the program at KSC.

6. ROCKWELL HAS MADE A NUMBER OF MANAGEMENT STRUCTURE CHANGES AT KENNEDY SPACE CENTER. IS ROCKWELL SATISFIED WITH THE NASA INTERFACE AND THE DIVISION OF RESPONSIBILITY BETWEEN JOHNSON SPACE CENTER AND KENNEDY SPACE CENTER?

Yes, the management structure changes Rockwell has made at KSC have improved the interfaces and as a result, Rockwell considers them to be working well. Further, the changes made by NASA have clarified responsibilities.

7. WHAT IS ROCKWELL'S BEST ESTIMATE FOR COMPLETING ACTIVITIES IN THE ORBITER PROCESSING FACILITY?

Rockwell's best estimate for completing activities in the Orbiter Processing Facility (that is, internal Orbiter 102 build activities, TPS installation, and vehicle check-out) is November 24, 1979. The "in-vehicle" activity is expected to be finished by the end of September. TPS installation is planned to be completed by November 24th.

8. A) MR. JEFFS, WOULD YOU ELABORATE ON THE TECHNICAL AND SCHEDULE STATUS OF THE MAIN ENGINE PROGRAM?

The development of the Space Shuttle Main Engine is progressing on schedule to support an FMOF of early 1980. The engine has accumulated over 451 tests and 50,000 seconds towards the goal of 65,000 seconds prior to FMOF. As planned, approximately 75,000 seconds will be accumulated by the end of 1979. The formal Preliminary Flight Certification test was completed on June 27, 1979. The test series included 3 calibration tests and 13 certification tests for 5,250 seconds. The most recent problem caused by a failure of a feed duct on the nozzle is under investigation and will be resolved without impact to FMOF. Plans are being analyzed that provide for the start of engine development for the full power level capability in September of 1979 and provide for engine certification at full power level by the end of 1980. The certification of the engine at full power level by the end of 1980 will support the present mission plans being developed by NASA.

Flight engine delivery has progressed through the successful completion of hot fire testing of two of the three engines. The first engine was delivered to KSC on July 11, 1979 and the remaining two engines of the three making up the first flight set will be delivered later this month.

Three SSME engines are installed in the Main Propulsion Test Article and test no. 6 was conducted on July 2, 1979. The test resulted in a premature cut-off at 20 seconds due to to a failure of a main fuel valve housing. An investigation of the cause of the failure is underway.

B) HAS THE MAIN ENGINE PROGRAM BEEN SUBJECTED TO FISCAL YEAR FUNDING CONSTRAINTS SIMILAR TO THE ORBITER PROGRAM?

As mentioned in the response to Question 2(b), we are subjected to and, as a result, rigorously control expenditures to a fiscal year funding constraint. While we do provide inputs to the NASA Program Operating Plan

(POP) cycle, the initial targets established in that process generally have been less than our projected requirements and adjustments made accordingly.

9. A) WILL THE DDT&E EXPERIENCE MAKE POSSIBLE MORE ACCURATE FUNDING ESTIMATES FOR THE PRODUCTION PROGRAM?

Yes, in fact we have already applied this experience in preparing the funding estimates for the Increment 3 proposal which formed the basis for the cost estimates used in the negotiated contract. This experience includes fabrication of Orbiters 101, 102, 099 and the test articles, subsystems development and qualification tests, and the Approach and Landing Test (ALT) program. The current TPS fabrication and installation experience has been considered in establishing criteria for more rigid adherence to the array installation plan and is forming the basis for improvements in the total TPS system and as an aid in more accurate forecasts of funding requirements for follow on Orbiters. The production program still must be able to accomodate funding changes resulting from the results of the qualification and orbital flight test programs.

B) DO YOU FEEL COMFORTABLE WITH THE CURRENT NASA GUIDELINES FOR FISCAL YEAR FUNDING AND SCHEDULE FOR THE ORBITER PRODUCTION PROGRAM?

We do not yet have firm NASA funding guidelines for the new follow on Orbiter delivery schedule. We are in the process of establishing requirements for revised delivery dates for the follow on Orbiters and this effort will be completed by the end of July. At that time, we will be able to specify firm updated funding requirements.

10. A) MR. JEFFS, WHAT CHANGES HAS ROCKWELL MADE IN AN ATTEMPT TO BETTER ESTIMATE BUDGET REQUIREMENTS AND TOTAL ESTIMATES AT COMPLETION?

Rockwell has made several changes in order to improve our ability to provide earlier visibility of changing fiscal year and total program estimates. We have increased the emphasis and added personnel to our Program Change Impact Board. We have restructed our Material Organization to provide a closer alignment of our cost analysis personnel with our buyers. We have also increased the number of our cost analysis personnel. We have further implemented a subcontract management Budget Impact Tracking System to provide real time notification to the program of change board actions upon subcontractors.

In addition, we have increased our participation with NASA by expanding upon our monthly Performance and Resources Review and increased the Rockwell involvement in the NASA budget planning cycle.

B) HAVE YOU BEEN ABLE TO TEST OR VERIFY THE EFFECTIVENESS OF THESE CHANGES?

It will be a little while before we can fully verify the effectiveness of these changes. I believe that both NASA and ourselves have already seen beneficial results from the changes which are being incorporated into the current FY 1980 and 1981 budget planning cycles of both Rockwell and NASA.

11. IS THE 533 QUARTERLY REPORTING ADEQUATE TO SUPPORT THE DEVELOPMENT OF BUDGET YEAR REQUIREMENTS?

As I stated in my testimony (Page 103, Lines 5-14) and in the answer to question 13, the NASA 533Q report, as modified to include estimates of reserves, is adequate to support the development of budget year requirements up to the last quarter of the fiscal year. We also have made improvements by providing additional fiscal year consolidated funding requirement tables. In addition, we provide updated funding information in the last quarter to support NASA's budget cycle planning. Specific updates to close out the current fiscal year and to verify funding requirements for the next fiscal year are also provided.

12. A) IS ROCKWELL IN A POSITION TO MAKE FIRM COST AND SCHEDULE ESTIMATES FOR THE PRODUCTION ORBITERS?

B) IF NOT WHEN DO YOU EXPECT TO BE ABLE TO?

On January 30, 1979, the contract document establishing a firm cost and schedule baseline for the production Orbiters was approved by NASA Headquarters. Since October 1978, however, we have been working to a lower annual funding level than was negotiated in the definitive contract. We are in the process of establishing funding requirements for revised delivery dates for the follow on Orbiters. This effort will be completed by the end of July. AT that time, we will be able to establish firm updated funding requirements.

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13. THE 533Q IS CONTRACTUALLY REQUIRED FOR FINANCIAL REPORTING. WHAT MANAGEMENT ROLE HAS THIS DOCUMENT PLAYED IN THE ORBITER PROGRAM?

IS THE 533Q AN ADEQUATE FINANCIAL MANAGEMENT TOOL?

WHAT IS THE BIGGEST WEAKNESS IN THE 533Q REPORTING SYSTEMS?

The NASA 533Q has been used as the basic financial document by which Rockwell reports its time-phased estimate at completion (EAC) to NASA. It is an adequate financial management tool without any real weaknesses. We have learned, however, that the 533Q reports can be more useful by including additional information, not specifically required by the contract, which delineates the contractor's recommended funding reserves.

14. HOW LONG DOES IT TAKE ROCKWELL TO ESTIMATE THE COST IMPACT OF A CONTRACT MODIFICATION?

The time to estimate the cost of a contract modification varies depending upon the sequence of events leading to the issuance of a given modification and magnitude of the modifications.

The majority of the modifications are issued subsequent to submittal of Budgetary and Planning (B&P) type estimates prepared by Rockwell. Such B&P type estimates in some cases are assembled in 1 to 5 days while others require 30 to 60 or more days to prepare, depending on complexity and the extent of subcontractor involvement.

Subsequent to receipt of a contract modification, the preparation of the majority of very detailed firm price proposals generally takes anywhere from 30 to 120 days and involves receipt of formal inputs from all affected contractor functions including definitive work/task statements and required estimating rationale. Sometimes a portion of this time is taken up by evolving a more complete Rockwell/NASA technical definition and understanding of the change. Also the change complexity and subcontractor involvement have substantial bearing on the time span for completion of detailed cost estimates.

HOW MANY MODIFICATIONS HAVE BEEN MADE IN THE ORBITER CONTRACT?

There have been a total of 1120 modifications made in the Orbiter DDT&E contract.

HOW MANY OF THESE MODIFICATIONS HAVE BEEN NEGOTIATED?

747 of these modifications have been negotiated.

SUBCONTRACTS

1. THERE HAVE BEEN MAJOR COST GROWTHS IN THE ORBITER SUBCONTRACTS.

   HOW MUCH OF THIS COST GROWTH IS RELATED TO CONTRACT CHANGES?

   HOW MUCH OF THE GROWTH IS CAUSED BY COST INTERRUPTIONS?

   During the period from May 1977 to May 1979, Orbiter Material & Subcontracts Estimate at Completion (EAC) requirements have increased by $144.3 million for NASA-directed changes and $277.8 million for disruption/schedule shift costs associated with limited fiscal funding.

2. THE COMPETITION FOR AEROSPACE PRODUCTS SUCH AS THOSE PROVIDED BY THE SUBCONTRACTORS IS VERY KEEN. THE AIRCRAFT INDUSTRY HAS A VERY HIGH DEMAND FOR MANY OF THE SAME PRODUCTS. HAS THIS COMPETITION HAD A SIGNIFICANT EFFECT ON THE SUBCONTRACTS?

   This subject is of great concern to Rockwell. About six months ago, we became aware of the growing competition for aerospace products and its impact on the ability of both Rockwell and its subcontractors to meet the schedule of the Space Shuttle production program. As a result, we took action to assess a representative sampling of our major raw material, hardware, and machine shop suppliers. We found that not only had the lead time between order and receipt dramatically expanded, but a capacity problem also will exist in the area of general machining during calendar year 1980. We also found that the cost of gold and other exotic metals such as titanium, inconel, cobalt, chromium, and molybdenum, as well as fabrication costs, have significantly increased during the last year.

   As a result, we placed our orders for in-house requirements early to cope with these capacity and lead-time problems. This information also has been disseminated to all of our subcontractors on the Shuttle program to ensure that they have made adequate provisions in their cost and schedule planning.

3. MANY OF THE SUBCONTRACTS AND EVEN THE PRIME CONTRACTS INCLUDE AN AWARD FEE THAT IS BASED UPON COST CONTROL. MANY OF THESE INDIVIDUAL COMPANIES HAVE HAD FISCAL CONSTRAINTS IMPOSED UPON THEM WHICH EVENTUALLY CAUSED UNANTICIPATED COST GROWTH. CONSEQUENTLY, THEY HAVE BEEN PENALIZED BY REDUCING THE AWARD FEE.

   DO YOU FORESEE ANY MODIFICATIONS IN THE CONTRACTING ARRANGEMENTS?

   No modifications are expected to our existing subcontract arrangements as a result of fiscal constraints. Certain instances exist where award fee is currently utilized as a means to provide incentives to our subcontractors to meet or improve our established fiscal year budget allocations. However, no award fee penalties have been levied against our subcontractors for inordinate cost growth resulting from fiscal year cost limitations. As each subcontractor is evaluated for cost performance, specific consideration is given to funding constraint impact on forecasted costs.

THIOKOL CORPORATION
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Thiokol/GOVERNMENT SYSTEMS

U.E. GARRISON

17 July 1979

Mr. Darrell R. Branscome
Subcommittee on Space Science
and Applications
U. S. House of Representatives
Washington, D.C. 20515

Dear Mr. Branscome,

In reply to your 6 July request, attached are Thiokol's replies to the eleven questions suggested to Mr. Stone during testimony before the Committee on 28 June.

Sincerely,

U. E. Garrison
Director of Marketing
Government Systems Group

/bbc

RESPONSE TO QUESTIONS FROM SUBCOMMITTEE
ON SPACE SCIENCE AND APPLICATIONS
RELATED TO HEARING ON 28 JUNE 1979

1. Question: Recent history of inhibitor, insulation and propellant casting problems (as well as motor segment handling problems) have contributed to cost growth in the program. To what extent do you believe these problems were associated with scaling up to the large motor castings, design flaws or quality control? Do you believe you fully understand those factors at this time?

Answer: The Space Shuttle SRM DDT&E Program includes seven ground test static firings. These are divided into four development tests and three qualification tests. The development tests are intended to find and correct any design or manufacturing problems, including scale-up problems, so that the solution can be incorporated in the qualification motor design and manufacture. The solution to the inhibitor and insulation problems are essentially the normal development process which takes place for any new solid propellant rocket motor, and the size factor, although present, was secondary in nature. The opposite is true for the propellant casting process development. This problem was definitely related to the scale-up characteristics necessary to cast approximately 300,000 pounds of propellant into a 146-inch diameter by thirty-one foot long segment. The problem was solved by changes to the casting tooling.

We all recognize that development activities are necessary to perfect a product design and manufacturing techniques. The normal development activities also include development of inspection methods and tools used for quality control of that specific design. These improvements have taken place on the SRM Project as part of the expected learning experience. We do understand the motor design, the processing methods and product quality control as evidenced by our successful test experience, including the test of Qualification Motor No. 1 in June 1979.

2. Question: What level of Thiokol personnel are working quality control and quality assurance at Thiokol? What is the level of government personnel working quality control and quality assurance at Thiokol?
How do these levels compare with previous solid rocket motor programs?
Do you believe this level is efficient, cost effective and affective in meeting SRB program requirements?

Answer: The number of Thiokol personnel working the quality control and quality assurance areas is related to the level of manufacturing and test activity at any given time. The number typically may be in the range of 200 to 250 personnel. This level is comparable to but somewhat higher than experience on previous solid rocket motor programs. This seems proper in view of the SRM use for manned space flight. We understand that fifteen government personnel are working these areas at Thiokol. The overall effort is effectively and efficiently meeting the program requirements.

3. Question: You indicate on the bottom of page 3, that you were estimating $68.2 million cost in FY 79 and $44.4 million cost in FY 80. Funding limitations now make it necessary to limit FY 79 work to approximately $61 million.
How much cost were you estimating for FY 79 at the beginning of FY 79 (i.e., 1 October 1978)?
Did you know, at that time, the funding levels for your part of the program associated with headquarters mark to Marshall Space Flight Center?
Was your FY 79 program plan adjusted accordingly at that time or should it have been adjusted?
Do you believe that by the start of FY 80, you will know the funding levels for your part of the FY 80 program associated with the headquarters mark to MSFC, which is presumably the basis for the FY 80 budget and budget amendment?

Answer: Our cost estimate for FY 79 as of 1 October 1978 was $65.6 million. We did not know a final funding level for the SRM Project at that time, but we did realize that the overall Space Shuttle Program was in the midst of its development phase and that funding and program plans might have to be adjusted as the fiscal year progressed. The NASA program managers on such a large and complex undertaking must retain some ability to change resource allocation as required by unexpected and previously unknown technical problems. While it would be helpful for an individual contractor to know his funding level at the beginning of the fiscal year, it may not be in the best interests of the total program to allocate all of the resources at that time and to assume that program plans will not change for the next twelve months. We did not change our FY 79 program plan as of 1 October 1978, but we did change it in coordination with the NASA program manager as the fiscal year proceeded. The changes reflected the real time assessment of technical and schedule progress on the SRM Project as compared to the other elements of the Space Shuttle Program.

3. (Continued)

We have been able to meet the defined funding level for the SRM Project for each fiscal year thus far in the development program, and we believe this can be accomplished again in FY 80 by working closely with NASA. As previously described, the allocation of the FY 80 resources will have to be determined by NASA on a program-wide basis.

4. Question: Your present contract for the development phase of the Shuttle program (DDT&E) ends in early 1981. Do you have any concerns with being able to meet the requirements of follow-on procurement?
What actions have been taken to assure that follow-on SRB's will be available to support the Shuttle operational program?

Answer: We have no concerns with being able to meet SRM procurement requirements following the Shuttle development phase provided that production rates and quantities are defined in time to meet long lead needs for materials and components. We believe this will be done; for example, some long lead steel billets for case and nozzle components have been procured. As another example, the development SRM's are being built on "hard" or production type tooling rather than temporary tooling. The tools in our plant and at our vendor plants are immediately usable for follow-on production.

5. Question: Mr. Stone, Dealing with technical performance issues, you state in your text that you "found an unexpected erosion pattern which prompted design change to the inhibitor."

What does that mean?

What are the consequences of this had it not been discovered?

Are you confident you understand this issue?

Answer: The rocket motor case in solid propellant motors is protected from the hot combustion gases by internal insulation which ablates or erodes away as a function of the time of exposure. The total insulation thickness therefore is determined by the exposure time, erosion rate under the gas flow conditions which prevail at that location and the design safety factor. The designer can predict the amount of insulation that will be eroded at a given location in the motor. This prediction is available before a motor is static fired and measurements are made after static firing to compare predictions with actual results, and to calculate actual safety factors. The Space Shuttle SRM is very large, being over twelve feet in diameter and 125 feet long, and there are many hundreds of square feet of internal insulation surface area. After a firing we go through the motor and make a sample inspection at a number of locations to look for any major differences between predicted and actual erosion. When this "quick-look" assessment was made following the static firing of Development Motor No. 2 we didn't see any significant differences from the prediction. As a routine step we always go back and expand the number of measurements to a fine grid so that we look in much more detail. This detailed inspection found more erosion in one local area of one segment than had been predicted. The most probable cause for this was an exposure time which was greater than expected, and this could be caused by the burning propellant surfaces reaching this local area sooner than predicted. Ignition of

5. (Continued)

the propellant surface in this region is controlled by an inert coating called an inhibitor which ablates away during the course of a firing. The time of ignition therefore is controlled by the inhibitor thickness and the results of this static firing showed that the inhibitor thickness should be increased. This was accomplished on Development Motor No. 3 and all subsequent motors thereby correcting the problem.

The consequence of this problem had it not been discovered is a decrease in the insulation design safety factor at this location. I want to point out that Development Motor No. 2 had no damage to the motor case, and we have confidence in the corrective action since all subsequent motor firings have shown satisfactory inhibitor performance.

6. Question: Later on in your prepared text you mention "propellant voids." What does this mean? What are the consequences of this not being discovered?

Answer: A propellant void is a "bubble" in an otherwise homogeneous solid propellant grain. There are three potential areas of concern with propellant voids. One is increased pressure in the motor due to an increased burning surface as the flame front moves through a region containing voids. A second item is early exposure of the case insulation due to a more rapid propagation of the flame front through the voids, and, finally, the change in grain surface geometry as the propellant burns could alter the pressure-time (and thrust-time) relationship required by the flight vehicle performance specification.

None of these potential problems have affected the SRM development program since x-ray inspection has been used to detect any troublesome collection of voids. We use a 15-million volt linear accelerator to perform this inspection and the capability is good enough to detect an object no larger than the end of a pencil. As I mentioned, we replaced one segment of the fourth development motor as a result of x-ray inspection, and we then changed the casting tooling prior to manufacturing additional segments. Our changes have produced excellent propellant grains as verified by x-ray inspection.

7. Question: Do you feel confident that all the handling equipment and procedures are worked out satisfactorily?

Answer: Yes, we believe the detailed review of all handling equipment and procedures for critical moves which was initiated in December 1978 and recently completed has worked out problems to a satisfactory degree. We need to bear in mind the fact that we are still in the program development phase -- not the production phase -- and additional experience could lead to further improvements in handling equipment.

8. Question: On page 3, 2nd paragraph of your prepared text, you talk about "bond failures." What does this mean? What are the consequences of the bonding failure?

Answer: Nozzle flexible bearings go through a rigorous series of acceptance tests which verify their ability to withstand operational loads and pressures. Among these tests are tensile "stretch" tests which stress the adhesive bonds between the alternate layers of steel shims and rubber pads which are bonded together to form a flexible bearing assembly. We have experienced some bond failures in recent months during "stretch" tests. I want to point out that this test is an overtest for powered flight conditions since the bearing is basically under a compressive load while the motor is pressurized and tensile stresses exist only near the edges when the nozzle is vectored. Analysis shows that a bond failure would not lead to a motor failure since the bearing is in compression; however, we know from experience that bonds can be achieved which will pass a "stretch" test and we will solve this process development problem.

9. Question: How would you characterize the cost growth associated with the SRB effort? Normal or abnormal development problems? Please elaborate.

Answer: In my opening statement I pointed out that the SRM Project has experienced some technical problems of the type which do occur in development programs. If absolutely no problems were expected, and development tests and design and manufacturing improvements were not required, then the motor could be committed to fixed price production and to flight without any need for development work and ground testing. This, of course, is not the case for the Space Shuttle SRM which is three times the weight and delivers much more performance than any other motor now in existence. Advancements in the state-of-the-art have been required in the design, manufacture and test of this motor. I believe that the problems which have been found and successfully corrected are not unusual when viewed in this context, and the cost is within the range of experience for development programs.

10. Question: Can the Subcommittee use a 15% to 20% DDT&E growth factor as the norm for any large space program undertaken by NASA?

Answer: A space program undertaken by NASA could involve anything from a small scientific payload placed in orbit around the earth to a manned landing on the Moon or Mars or to a launch vehicle larger than the present Space Shuttle. I do not believe that one can speak of normal growth factors separate from a consideration of the magnitude and sophistication of the task undertaken.