In consideration of public safety, we believe that for the long term, water transportation is preferable to rail transportation. Over the past 10 years, there have been 20 railroad incidents wherein SRM rail cars have been damaged. Fortunately, only 4 of these incidents occurred with live motor segments on the cars, and none damaged the motors. With time, railroad right-of-ways will likely become more congested and public exposure will increase. The availability of water, as well as rail, transportation was a significant consideration in the selection of the preferred ASRM production and test facilities. While barge accidents occur, the consequences of a rail accident could be more severe.

In addition to the aforementioned safety and reliability features of the ASRM, there are policy, programmatic, and procurement considerations that are very important. Starting as early as 1984, NASA began exploring the prudency of recompeting the SRM contract. The STS-51L accident led to more detailed technical and programmatic considerations, which culminated in a report to Congress in March 1987, outlining three options:

- Continue the RSRM contract as a sole source.
- Recompete the RSRM contract.
- Pursue an ASRM through competition.

The Agency and the Congress mutually elected to pursue ASRM to achieve both technical and programmatic benefits, to vitalize the solid motor industrial base, and to provide a realistic competitive environment. Those rationale are as pertinent today (if not more so) as they were in 1987. Through design, production, and operational features, the ASRM will provide enhanced safety and reliability at reduced cost, and enable the Government to recompete the program in the future.

The post STS-51L NSTS redesign activity has eroded an already under-performance Shuttle payload capability. The ASRM is expected to provide a 12,000-pound payload improvement and restore the Shuttle to its full design capability, a factor of no small importance considering the payload backlog, mission model delays, and the increasing mass of deployed payloads such as Space Station.

The need for modern production facilities is no less important than the need for solid motor design improvements. The solid motor industry, by and large, has been slow to modernize manufacturing techniques and facilities, and is characteristically labor-intensive. The ASRM procurement has triggered an industry-wide reevaluation of producibility and productivity. The introduction of automation should greatly enhance the reproducibility from motor to motor. Currently, right- and left-hand booster segments are "match cast" and maintained as pairs throughout their life. This is expensive and has resulted in destacking of both boosters because of a problem in one segment. Destacking and restacking also bring the potential of new problems. The ASRM automation is the only prospect on the horizon of departing from the current practice of "matched casting."

NASA has concluded, reinforced by the findings of the five solid motor contractors, that the extent of modernization required for manned flight safety and cost effectivity support a new, optimized facility rather than the modification and disruption of existing plants. This seems to be borne out by the fact that modernization proposals by the RSRM contractor are comparable to the construction cost estimates for a completely new ASRM production and test facility. Furthermore, once the Government invests in the modernization of a contractor's facility, it must be recognized that it would be prohibitively expensive to so equip another contractor(s) and any benefits of recompetition would be forfeited.

NASA, with industry support, has aggressively studied liquid rocket boosters, and has concluded that the technology is a long way from implementation. An obvious attraction of liquid rocket boosters is the prospect of more flexibility in abort modes. However, since the other Shuttle elements were never designed for abort loads, the effectiveness of liquid boosters might be limited due to the necessity to operate within the constraints of those designs. Also, there are other significant implications of a change to liquid rocket boosters for the Shuttle, necessitating extensive changes to the STS and the supporting assembly and launch facilities, and extensive wind tunnel testing and analyses to recertify the STS.

With regard to postponement of the ASRM procurement, Public Law 100-147-Oct. 30, 1987 (Section 121(d)) provides that failure to complete the ASRM procurement requires:

- Competition to select a qualified second source for RSRM, or
- Recompetition of the current RSRM contract.

Since there is only one facility in the country for building the RSRM, any meaningful competition would necessitate the Government making provision, in a nondiscriminatory way, for prospective competitors to acquire a new facility. Furthermore, to entertain the expense of such a competitive procurement and not incorporate provisions for rectifying deficiencies in the existing motor and/or improvements would be imprudent. Hence, one returns to the ASRM as the sound programmatic decision. The validity of this decision is reinforced by the fact that the extent of design and processing changes envisioned for the ASRM constitute, by law, "significant new procurement." To evolve the current RSRM to an ASRM would, most likely, place NASA in noncompliance with the Competition in Contracting Act.

NASA considers the ASRM to be a soundly conceived, well-considered program that will result in significantly improved safety and reliability; provide an extremely important improvement in STS performance; minimize life-cycle costs; enhance the viability of the SRM industry; and enable the government to be in a position to recompete the program in the future. The alternatives have been considered, and the ASRM is clearly the best approach available. NASA plans to proceed with the ASRM.

4. Logistics and Support

Finding: *A review of the development of the overall logistics and support systems for the STS shows a very satisfactory trend. Full advantage has been taken of the "stand-down time" resulting from the STS-51L accident. Especially noteworthy is the movement of key Rockwell personnel to the KSC area and the enhancement of direct control of the logistics program right up to the launch pad itself. The NASA-KSC logistics organization has made great strides in facilities, equipment and inventory and has been aided immeasurably in this task by protection against having its funds occasionally diverted to other STS areas, as was the case in earlier years. There appears now to be excellent liaison between top management of NASA-KSC and Rockwell-Downey and a real spirit of co-operation is observable at this level which has permeated down to the ranks.*

There are, however, areas still in need of attention: (1) the control of all STS logistics is not centralized at KSC, (2) the repair pipeline turnaround time is much too long to support the program.

Recommendation: Continue the good work. Focus efforts on the need to improve overhaul and repair turnaround time, and the integration of all STS logistics programs in one place - KSC.

NASA Response: The National Space Transportation System (NSTS) logistics program is strongly supporting the NSTS mission. The Kennedy Space Center (KSC) is currently meeting a 99 percentile fill rate for nonrepairables and 90 percentile fill rate for repairable assets. The Orbiter hardware composite fill rate for both repairables and nonrepairables is 98 percentile against a fill rate goal of 90 percentile. The fill rates for Orbiter flight hardware have been improved by both an increase in the range (number of items stocked) and depth (quantity of items stocked) of spare assets at KSC, along with a maximum focus being placed on reducing manufacturing and repair turnaround time. Attendant with these actions has been a major emphasis on transitioning both manufacturing and repair activities to the KSC Shuttle Depot (Rockwell Service Center) located in close proximity to KSC where such actions are technically and economically viable. Further actions have been taken to improve the procurement time for long lead assets and to incentivize contracts for improved repair turnaround time at original equipment manufacturers (OEMs) where transition to the RSC is not viable.

An additional factor in influencing the Orbiter repairable asset fill rate is the ongoing asset modification program. Typically, spare assets are removed from service first for modification and later returned to inventory to support vehicle operations. Thus, the modification program also contributes to reduced fill rates.

As noted in the finding, the repair pipeline turnaround time remains much too long to support the program at the higher launch rates. To resolve this problem, an increase in the stock levels of selected spares has been initiated to compensate for repairable items in the process of undergoing maintenance, either in work or awaiting work. In addition, KSC has a continuing and ongoing program to reduce repair turnaround time to acceptable levels. The key and essential element to this turnaround time reduction is the centralization of repair at the local depot, and numerous actions are underway to achieve this objective.

The increase in range and depth of spares, along with the actions taken to reduce repair turnaround time at the OEMs and through the optimum use of the KSC depot, coupled with the eventual completion of Orbiter Line Replaceable Unit (LRU) modification, are expected to improve fill rates to meet or exceed program goals and, accordingly, provide the required level of logistics support at the higher flight rates.

With regard to the finding that control of all Space Transportation System (STS) logistics functions have not been centralized at KSC, NSTS policy is being revised to include a logistics management responsibility transfer agreement between the design centers and KSC that will result in a schedule for transfer of logistics responsibility to KSC. The Orbiter logistics program, which was transitioned to KSC in 1986, is being supported by a very sound structure that includes KSC Logistics Management; Rockwell International; and Lockheed, the Shuttle Processing Contractor (SPC). Thus, the transition of elements to KSC has been successfully demonstrated. It is the intent of the NSTS program to achieve total STS logistic program integration via transfer of the remaining logistic support programs to KSC. This action will require a program-level review and evaluation of the programs impacted to assure program continuity. All viable logistics management functions will be transferred to KSC with the exception of the responsibility for support of technological opportunities and improvement programs that result in engineering changes. The transfer agreements are tentatively scheduled to be completed in December 1989.

5. Space Shuttle Elements

a. Solid Rocket Motor/Booster (SRM/SRB)

(1) Finding: *The redesigned solid rocket booster is more reliable than those used through the STS-51L mission. A number of significant areas of continuing concern were identified during redesign and testing of the new booster: These included the following:*

(a) the need to eliminate possible voids and blow holes in the polysulfide adhesively bonded case-to-nozzle joint;

(b) a better characterization of the materials used in the internal nozzle ablative composite parts;

(c) the need to prevent the accumulation of slag, which plugs cowl vent holes during tail-off burning, resulting in adverse differential pressure across the nozzle flexible boot;

(d) the need to develop a resilient O-ring material (temperature compatible) for primary and secondary seals in order to eliminate the required field joint heaters; and

(e) the need to conduct a structural analysis in order to determine the criteria for safe reuse of rocket motor case segments.

Recommendation: NASA should develop a program based upon the items listed above and other significant items to improve the solid rocket motors/boosters and further reduce risk.

NASA Response: The Redesigned Solid Rocket Motor (RSRM) Project is developing and evaluating a Product Improvement Program utilizing a block change concept. The justification for the majority of the proposed improvements is enhancement of Safety, Reliability, and Quality Assurance. With respect to the specific five areas of concern listed by the ASAP, the following status is provided:

(a) Blowholes in the polysulfide used to bond the insulation at the RSRM nozzle-to-case joint have been virtually eliminated by improving the processing and assembly techniques in this area. Post-flight inspections of the joints on the first three flight sets (six motors) showed no blowholes. Included in these improvements were controlled rate of assembly to give trapped air time to bleed-off through the vent slots and controlled temperature at assembly to assure proper viscosity of the polysulfide. Action is currently underway to evaluate pulling a vacuum through the vent port during assembly to further expedite the bleed-off of trapped air. Also under evaluation is a metered mixer for the polysulfide that will provide a mix free of entrapped air. A second benefit of the metered mix is that the two-part polysulfide is not mixed until immediately prior to application. This allows for use of freshly mixed adhesive and minimizes the possibility of violating polysulfide pot life. While these changes are being evaluated to possibly improve the design, the need to change is not currently judged a necessity. First, the probability of blowholes has been shown to be very low; second, the effects of a blowhole have been demonstrated via flaw testing of simulators and of a full-scale, full-duration motor firing to be inconsequential.

(b) Activity in this area is underway. The Marshall Space Flight Center (MSFC) Materials and Processes (M&P) laboratory, along with MTI, are conducting a program to better characterize the carbon cloth phenolic (CCP) that is used as an ablative material in the RSRM nozzles as well as in many other applications outside the RSRM program. A Nozzle Technology Program is also underway to investigate the effects process variables have on the ablative performance of CCP. A CCP Data Base Program has been started to gather data on CCP from numerous sources. MTI has implemented many improvements in the manufacturing processes and, as a result, the defect level has been substantially reduced. The internal nozzle parts from the first three flights and static test motors QM-6, QM-7, PVM-1, and QM-8 (10 successive motors) have shown no anomalous conditions.

(c) MTI has a nozzle cowl vent hole test program in progress utilizing the technical evaluation motors (TEMs). This test program is attempting to define a vent hole configuration that will resist slag accumulation and resulting adverse differential pressure build-up in the boot cavity area of the nozzle, yet not introduce other adverse effects such as heat damage to the flex bearing or its protective cover. One test (TEM-02) has already been conducted that included enlarged vent holes, erodible plugs in standard size vent holes, and Teflon-sleeved vent holes.

(d) During the RSRM redesign, tests were conducted on many different O-ring materials to determine which material would best meet all field joint seal requirements. Despite the necessity to maintain O-ring temperature above 75 degrees Fahrenheit at RSRM ignition, the fluorocarbon material best met all requirements, including resiliency, sealing performance, producibility, compatibility with established lubricants and overall toughness. Subsequent full-scale ground testing has completely confirmed acceptable sealing performance characteristics. Although flight experience to date--due to the total effectiveness of upstream sealing redundancies--has not directly challenged O-ring sealing capabilities, all flight data measurements tend to confirm adequate seal designs. Therefore, there is currently no active program to develop a new elastomer, or other type seal, that would provide adequate overall dynamic response for temperature requirements below 75 degrees Fahrenheit. Design enhancements are being evaluated to include a proposal to develop and implement an improved RSRM O-ring material to eliminate the requirement for field joint heaters.

(e) The criteria for safe reuse of a case segment is established. Each segment is subjected to a hydroproof test of 1.12 times the maximum expected operating pressure and then undergoes nondestructive evaluation to certify that it is acceptable for the next reuse. However, completing an analysis to verify that the case segments are capable of 19 reuses is a different and very complex matter, and is currently being addressed by both MTI and MSFC.

(2) **Finding**: *The booster aft skirt failed on STA-3 static structural test article at 128% of limit load. This is below the required factor of safety of 140% (1.4 over limit load).*

Recommendation: Perform tests to determine the effect of various loadings and provide fixes needed to meet the original design requirements.

NASA Response: The aft skirts are instrumented with 120 strain gages on each booster, some of which are located in the thrust post weld areas as on the STA-3, which allows a correlation of actual stresses during stacking and launch to the STA-3 test. The data have been recorded during the Flight Readiness Firing (FRF) and is currently in place for the first six launches. The Solid Rocket Booster (SRB) project is proposing six additional flights to gather the necessary data to support decisions on potential design changes. These strain gages are also used to measure the stresses induced in the welds during the booster stacking processes to assure that a minimum factor of safety (F.S.) of 1.28 is maintained. Reconstructed loads from the actual data from the first three flights have indicated a F.S. of about 1.36.

One approach being considered as a potential for improving the factor of safety is inducing a compressive preload into the critical welds by biasing the spherical bearing interface between the aft skirt and mobile launch platform during initial stacking operations. The compressive preload will increase the capability of the critical welds, which failed in the STA-3 test due to tensile stresses. A maximum bias was attempted during STS-30 buildup, but was aborted because of rotation of the aft skirt shoe. The project plans to further test this concept on the Transient Pressure Test Article (TPTA) at the Marshall Space Flight Center. The data gathered during stacking of the first three flights, and the aborted attempt indicate that a lower bias value probably will give the desired results. The full-scale TPTA hardware will be used to further develop this concept rather than risk flight hardware and flight schedule by attempting this during flight hardware buildup.

b. External Tank (ET)

Finding: *There have been numerous failures of various sensing devices for liquid levels, temperature and pressure on both the hydrogen and oxygen tank systems. Many of these measurements are used in launch commit criteria and are required during flight.*

Recommendation: NASA needs a coordinated effort to resolve the cause of these many sensor problems and should take the necessary actions to remedy this situation.

NASA Response: In general, the majority of the sensor and transducer failures occurred during acceptance testing procedures (ATPs) that have served the intended function of detecting failures before installation of the transducer in the External Tank (ET). Several of the failures have been isolated cases and have been caused by personnel error or improper testing procedures. However, most of the failures have been attributed to contamination during fabrication which is considered inherent to the manufacturing process. Therefore, failures of this type are considered to be a consequence of normal production fallout.

Most of the sensor/transducer problems have involved the liquid oxygen (LO_2) and liquid hydrogen (LH_2) ullage pressure transducers. The typical failures have been cases where the transducer exhibited erroneous readings, high contact resistance/signal dropout, or electrical noise. These failures occur most often during vendor ATP, with contamination of the transducer internal mechanism identified as the probable cause. Although the contamination is considered inherent to the manufacturing process and these occasional failures have been considered to be normal production fallout, additional inspection requirements have been added to the fabrication process. The transducers must pass ATP at the vendor to ensure that there are no defects at the time of delivery. Operational/functional testing of the transducers is performed when the transducers are installed at the ET assembly facility. Procedures at the launch site require verification that the transducers are operating properly. There are four LH_2 ullage pressure transducers (three are used in flight, and one is a spare). Switchout of a failed transducer with the spare can be accomplished throughout propellant loading up to T-10 seconds. A similar switchout also can be performed for the four LO_2 ullage pressure transducers. A different type of ullage pressure transducer that eliminates the contamination and resistance contact problems is currently in qualification testing. This transducer will eliminate the failure modes experienced by the present transducer design, and is expected to be qualified by late 1989.

Failure of the ATP resistance test has been the most frequent problem reported on the LH_2 and LO_2 level sensors. Again, these failures are expected as a natural result of the sensor design and production process, and any sensor failing ATP would not be a candidate for ET installation. To reduce the number of ATP failures, numerous process changes and additional inspection requirements have been implemented. Of the 680 liquid-level sensor systems that have flown, only 4 have failed. Three of the four hydrogen depletion sensors would have to fail "wet" simultaneously to cause SSME failure. Frequency of temperature sensor failures has been much lower than those encountered on other ET sensors/transducers and these sensors are not used as control indicators during flight.

A program is being planned that will assess NASA's current capability in providing reliable instrumentation. Given the numerous failures in this area (most occurring during ATP), a recommendation is under serious consideration to establish a central expert instrumentation group that would develop all of NASA's sensor hardware.

c. Orbiter

(1) **Finding**: *Upon completion of the 6.0 loads/stress analysis it was determined that negative margins of safety existed in the Orbiter structure. In order to launch STS-26 and subsequent missions, it was necessary to reduce the design flight envelope to such an extent that the probability of launch was considerably below the original target of 95%.*

Recommendation: If NASA desires to attain the originally specified high probability of launch they should implement the identified structural modifications (structural area of the wings, fuselage and vertical tail).

NASA Response: The allowable flight envelope was revised at the Design Certification Review in March 1988; that certification was derived from 6.0 loads/stress analysis. The scope of the analysis used in certification included 60,000 structural components and 30 major structural elements including the wing, vertical tail, and mid-fuselage. Further analysis results indicate that the majority of the orbiter structure has positive safety margins and constraints have been defined for critical structures (wings, tails, aft fuselage, OMS pods, and wings leading edge) to ensure positive safety margins. Since launch probability can degrade due to constrained structure, structural modifications are being made as program requirements dictate.

Currently, NASA is assessing their latest structural analysis and identifying load cases that should be replaced with more realistic loads data. The Space Shuttle Columbia (OV-102) was instrumented on previous flights to collect wing pressure distributions. These instrumented flights will continue to improve the data base used to certify the math models used for wing load prediction. In addition, the Space Shuttle Atlantis (OV-104) is being instrumented with accelerometers on the tail and wing area to measure flutter and buffet loads that are experienced during Max Q. Upon completion of the STS-26 analysis update and subsequent instrumented flights, NASA will have a much better data base to reduce conservatism in predicted structural capability.

Major modifications have already been accomplished on all vehicles in the past particularly to improve the load-carrying capability of the wings. Future modifications, if required to improve margins of safety as a result of ongoing 6.0 loads analysis and new flight data, will involve more complex modifications and may require a major vehicle down period to accomplish. Completion of the design/analysis is expected toward the end of 1989.

(2) **Finding**: *The current General Purpose Computer (GPC) flying on the Orbiter is built upon very old, outdated technology and is a limiting factor in Shuttle operations (due to memory limitations, among other things). It will be increasingly difficult to maintain because parts for the older technology will become increasingly difficult to obtain. The GPC needs to be upgraded as soon as possible. NASA has been working on a replacement central processing unit for at least 5 years now, and use of the new processor is still not scheduled until 1990. The sooner that the upgrade is completed, the sooner advanced applications programs can be placed in the computer system.*

Though the new GPC has been tested extensively in the laboratory, there are no flight tests scheduled for the new processor.

Recommendation: NASA should plan at least one flight test with the new GPC's carried as a test payload and used throughout the flight in a test mode. The computers should be used in as close to an actual flight mode as possible, including sensor inputs if that can be done, except, however, that the new GPC's should not be in line with any actual control outputs. This test should be performed and the upgrade completed as soon as possible.

NASA Response: The new General Purpose Computer (GPC) is scheduled for first flight on STS-41 in October 1990. Design work for the new GPCs began in January 1984. Confidence and validation of the GPCs are being performed using special versions of software, Operational Increments 9A and 9B (OI-9A/9B). These tests will tentatively be completed by March 1990. The actual flight software (OI-8F) will be verified during the 5-month period from April to September 1990. Prior to April 1990, the new GPC will undergo 1,000 hours of burn-in, 200 hours of redundant set time, and 2,000 hours of quality set time. Installation of the new GPCs in the Space Shuttle Atlantis (OV-104) will begin in May 1990.

Because an extensive amount of flight data has been collected from previous missions, the new GPC can be placed in a test environment with a data flow that is identical to an actual flight environment. The processing speed of the new GPC is significantly faster than the old GPC. Therefore, to synchronize both GPC systems on an actual flight would be extremely difficult if not impossible. In addition to the software modifications needed to test both GPCs running in parallel, alteration of the Shuttle avionics bays and data bus wiring to accommodate both GPC systems would be required. Ground testing of the new GPCs is sufficient to ascertain performance and reliability characteristics and is certainly more cost-effective, considering the additional modifications that would have to be made to test both GPC systems in an actual flight mode.

d. Space Shuttle Main Engines (SSMEs)

Finding: *The engines used for the successful STS-26 flight incorporated 39 changes. Extensive certification testing was carried out on these changes with excellent success on all of the most critical items with the exception of the HPOTP bearings. The data indicates that the various cracking problems in the turbopump blades have been resolved. Limited testing on a large-diameter throat engine (0208) showed major reductions in various engine stress environments. A two-duct (versus current three-duct) hot gas manifold power head was completed and made ready for testing at year end. A complete structural audit, a detail assessment of all key welds on the engine, and a thorough failure trend analysis were also completed in 1988. Evaluation of a reliability model for the SSME was continued.*

Recommendation: The contractor should continue work to provide a high pressure oxygen turbopump (HPOTP) bearing having better margins to prevent failures due to wear and to provide longer cycle life. The two-duct power head and the large throat combustion chamber should be vigorously pursued and certified as rapidly as possible.

NASA Response: NASA fully concurs with the need to improve high pressure oxygen turbopump (HPOTP) design and is currently progressing down two paths to assure success. At Rocketdyne, the current pump (which is limited to a single flight per overhaul) is involved in the Block I Improvement targeted at pump and turbine end bearing improvements as well as jet ring modifications. These changes should allow 5,000 seconds (8 to 9 flights) between overhaul. The Block II improvements, which should yield a 7,500-second pump (13 to 14 flights), are targeted at the main impellar, turbine nozzle, and improved bearing wear. Concurrent with this activity is the alternate turbopump development effort at Pratt & Whitney. This HPOTP should see initial component testing in August 1989 and engine-level testing in January 1990. Since crystal blades are baselined for the alternate turbopump development program (Phase II+), NASA is targeting the first ground test on E-0209 in April 1989. Due to other program priorities and funding constraints, the two-duct development and certification testing has been deferred until FY 92/FY 93 with fleet implementation leading to a first flight in FY 95.

The large throat Main Combustion Chamber (MCC) is not currently baselined in SSME planning; however, E-0208, which is in test at Technology Test Bed (TTB), is configured with this feature. This engine will continue to be tested until September 1989 at which time the fully instrumented E-3001 will dominate TTB activity.

e. Launch, Landing, and Mission Operations

Finding: *As the flight schedule picks up in FY 1989, there remains the clear and present danger of slipping back into the operating environment at KSC that helped to contribute to the Challenger accident. At the same time, the need to achieve greater efficiency and cost effectiveness in turnaround procedures is clear. In this situation, NASA's commitment to the operating principle of "Safety first; schedule second" must be retained. If experience of the past is a guide to the future, the pressures to maintain or increase flight rate will be intense.*

Recommendation: NASA must resist the schedule pressures that can compromise safety during launch operations. This requires strong enforcement by NASA of the directives governing STS operations.

NASA Response: NASA and our contractors recognize the complex problem of increasing launch site efficiency while resisting schedule pressures that may compromise safety. Some of the specific actions that Kennedy Space Center has taken include: review of problems caused by human-induced error to ascertain whether additional training, job reassignment, or procedure change is required; and constant review of areas of high overtime/stress for schedule change and reassignment of personnel. In addition, NASA has established formalized training programs designed to reduce the potential for human error. The schedule and scheduling process are constantly reviewed and updated, as necessary, to ensure that all formal protocols are completed regardless of the affect on ability to launch on a specific date. NASA management from the top level through the first-line supervisor exercises constant vigilance to ensure that satisfactory working schedules and environments are maintained at all times in accordance with the operating principle, "Safety First, Schedule Second."

NASA continues to closely monitor workload imposed by the baselined STS flight rate. Manpower levels currently budgeted to support the STS flight schedule have been sized to assure that the processing workload can continue to be accomplished in a safe manner. Both staffing and overtime data continue to be reviewed by top management on a weekly basis to assure rigorous adherence to the overtime policy in Kennedy Management Instruction (KMI) 1700.2.

B. SPACE STATION FREEDOM PROGRAM (SSFP)

1. Management Structure

a. **Finding**: *The Space Station Freedom Program (SSFP) has an extremely complex organizational structure which includes a program support contractor (PSC) with system engineering and integration (SE&I) capability. NASA has not utilized this program support contractor effectively.*

Recommendation: NASA should ensure that the SSFP has a strong, competent systems engineering and integration team with the responsibility and authority to pull all of the various parts of the program together. (P. 6)

__NASA Response__: The Deputy Director, SSFP, has taken action to change the mission of the Program Support Contractor (PSC). Effective May 15, 1989, the principal emphasis of the PSC mission shall be to serve as the Space Station Freedom Integration Contractor. Accordingly, the title of Program Support Contractor is changed to Space Station Engineering and Integration Contractor (SSEIC). The principal tasks for the SSEIC in its role as Integration Contractor shall be restructured to be projectized or "turn-key," with a small proportion of level-of-effort support continuing to the NASA Level II Program Office for smaller, open-ended tasks. A Program Directive will be issued shortly describing the interface responsibilities of the SSEIC, the WP Contractors, and NASA Level III in program integration.

To fully implement the Integration Contractor role, a proposed SSEIC reorganization has been approved.

b. __Finding__: *There are semantic and definitional differences across the international partners and, perhaps, even the work packages. There is also an abundance of new acronyms being used. Some of these are a redefinition of acronyms used on previous NASA programs. As a result, there is great potential for confusion.*

__Recommendation__: NASA should ensure that there are commonly accepted definitions for key terms and acronyms. Where commonality is not possible, corresponding lists should be developed and widely disseminated. Continuing control over this process is required throughout the life of the SSFP.

__NASA Response__: The Space Station Freedom Program (SSFP) Program Requirements Document (PRD) and the Program Definition and Requirements Document (PDRD) control definitions and acronyms used on the program. Although this control currently is not being enforced, there is an active effort by NASA Headquarters to update, consolidate, and standardize the SSFP acronyms and abbreviations (JSC 30235, dated November 26, 1986). Implementation of this SSFP document will ensure the application of commonly accepted definitions for key terms and acronyms. The requirements of the SSFP PRD will be applied to new key terms and acronyms to ensure that they receive common definition for application throughout the SSFP.

c. __Finding__: *Some of the international partners have difficulty following discussions in English at the numerous working meetings. This limits their ability to make contributions and leads to the possibility of misunderstandings.*

__Recommendation__: Interpreters should be available at all meetings attended by international partners who have difficulty keeping pace with the English proceedings. The SSFP should make sure that it has ready access to document translators of sending and receiving meeting minutes, letters of clarification and project memoranda. (P. 6)

__NASA Response__: NASA agrees that communication and good understanding at all times with our international partners is essential to our development of the Space Station Freedom Program (SSFP). English is the common language on the program. At present, NASA does maintain ready access to document translators through our Translation Bureau (Mr. Len Wepasnick/202-755-1075), and written documents are translated on a contract basis. Primary responsibility for on-the-spot spoken interpretation rests with our international partners who are encouraged to provide representatives fluent in English. However, special requests by our international partners for interpretation can be accommodated with sufficient notice. The National Space Development Agency of Japan (NASDA) has solicited support from Hernandez Engineering, which has hired an interpreter/translator to provide language assistance.

d. **Finding**: *The number of interfaces, across which designs must be consistent, is very large. The responsibilities for defining design requirements to span these interfaces are not clear. This may lead, at best, to the need to backtrack in the design effort and, at worst, to the omission of a safety critical element.*

Recommendation: SSFP management should clearly define the interface responsibilities for design definition as soon as possible. This will help ensure that each item is addressed as the design work progresses because the cognizant center, work package or design office will be aware of its role in the definition. (P. 6)

NASA Response: The Space Station Freedom Program (SSFP) Office, Level II, is in the process of clearly stating the Level II design requirements as traceable, verifiable entities in Section 3 of the Program Definition and Requirements Document (PDRD). This will be the basis for a clear flow down of requirements to the Level III design activities. This will also form the basis for clearly identified interfaces between the various design activities. Also, Level II is defining all the detailed tasks that are to be done by Level II. These defined tasks will be assigned as engineering and integration activities to be accomplished by one of the following: (1) the Level II organization at Reston, (2) various NASA Centers under the guidance of the Space Station Integration Manager, and (3) the Program Support Contractor as an integration contractor.

2. Safety and Product Assurance

a. **Finding**: *The level of activity of the SR&QA program for the SSFP appears low considering the complexity of the system design, integration and operational problems. A human factors function is not evident in the program's organizational structure.*

Recommendation: Management should make sure that the resources applied to SR&QA activities are commensurate with the need. An identifiable human factors function at Level II should be established and should be tasked with key relevant issues. The SR&QA activity must maintain its independence of operation and not be subordinated within the program.

NASA Response: The key to an effective SR&QA program is proper organization and adequate staffing. Action has been taken to augment the staffing of the SSFP Safety and Product Assurance function. The authorized staffing level for FY 89 is 19 persons, as opposed to the authorization for 8 persons in FY 88. NASA Headquarters intends to maintain the SR&QA staffing level, which is approximately 5 percent of the engineering staffing. This ratio is derived from tested programs.

The Office of the Associate Administrator for SRM&QA, Code Q, has guaranteed the independence of the SR&QA activity on the SSFP by establishing a unique organizational support relationship with the Program Manager. This is the first time that this has been attempted in the Agency. While the program interfaces are still being worked out, the intent is to ensure that the SR&QA function does not get relegated to a lower tier.

The acceptance of human factors as a discipline is being promoted on the program as well as in NASA Headquarters. There has not been an Agency-level Human Engineering function to date. A draft NMI declaring that Code QS will become the Agency sponsor for the task is in the review process. Similar to the Reliability discipline, the engineering work will remain a System Engineering and Integration (SE&I) function; however, the Safety Division (Code QS) and the Space Station Safety and Product Assurance (Code SSQ) will provide oversight.

b. **Finding**: *The Safety Summit process started in February 1988 has shown the potential to make a marked improvement in the depth and breadth of the program's safety function. This process is being conducted despite the lack of a charger, which is needed to formalize its activity.*

Recommendation: The Safety Summit process should be made formal through approval of a charter specifically delineating its functions and responsibilities. (P. 6)

NASA Response: The Safety Working Group conducted by the Space Station Freedom Program (SSFP) Office is a periodic in-person meeting of the Senior System Review Panel that is formally established and organized by the provisions of paragraph 3.2 of the Space Station Level II System Safety Program Plan (DRAFT). The Senior Safety Review Panel is a SSFP-wide panel co-chaired by the Safety and Product Assurance Office, Code SSQ; Program System Engineering and Integration, Code SSE; and Program Utilization and Operations, Code SSU. This panel coordinates the resolution of important safety issues and problems. Biweekly, worldwide teleconferences by the panel are central to the ongoing coordination/assessment and evaluation/problem resolution process. The actions under study by this panel are thoroughly evaluated at the extended conferences called Safety Working Group meetings.

The Safety Panel has never been chartered, because the International Safety and Product Assurance Group (ISPOC) has never been chartered.

New direction on the SSFP has cut the number of panels and boards. However, the Program Director has directed SSFP personnel to use existing organizations and directives to accomplish the program requirements, and the Safety Working Group forum is still an active arm of the program.

3. **Technical Issues**

a. **Finding**: *The SSFP design as baselined still does not include a specific "lifeboat" or crew emergency rescue vehicle (CERV). It is not clear whether NASA has given up on providing this capability or still has the issue under study.*

Recommendation: The Panel has stated previously: "that a single purpose crew rescue vehicle or lifeboat should be an essential part of the Space Station's design."

NASA Response: A Change Request to Level I has been proposed by the Office of the Associate Administrator for SRM&QA, Code Q. The response to date has been to allow the Office of Space Flight, Code M, to define the requirements, and design and implement the system. Code M is scheduled to issue a request for proposal (RFP) for a study to define crew rescue methods during FY 89.

b. **Finding**: *The design philosophy for the caution and warning system (CWS) as embodied in NASA-STD-3000 does not provide sufficient guidance for establishing the precedence that the CWS should have in the design hierarchy. It also dictates a classification system which may not be best for the unique mission of the SSFP.*

Recommendation: The CWS system design should be given primary status among all SSFP signaling and information systems. (P. 7)

NASA Response: The Safety Working Group has been instrumental in initiating an action by Systems Engineering and Integration (SE&I) to establish a C&W "architect." At this time, JSC's DMS/Avionics organization has taken the lead in establishing this functional role. The scope of responsibilities for this "architect" has not been fully developed as yet, but they will include the following:

- Development and review of all C&W requirements at all levels of the program
- End-to-end architecture of the C&W system
- Oversight of the implementation of the C&W design
- Verification of the end-to-end system

Level II will ensure that this important responsibility is fully defined and implemented, and given primary status among all SSFP signaling and information systems.

c. **Finding**: *The Software Support Environment (SSE) being developed as the Station's primary software development tool appears excellent. It does, however, lack a provision for making safety checks of software as it is being developed. The SSE design process also does not include an independent validation and verification (IV&V) of the SSE itself.*

<u>**Recommendation**</u>: The SSE development program should be modified to incorporate <u>both</u> IV&V of the SSE and functional checks of the safety and reliability of the software developed using the SSE.

<u>**NASA Response**</u>: The Software Support Environment (SSE) includes not only the set of tools that will be used for development of all operational software to be used aboard the space station, but also the tools and standards that can be used to check the software for quality and safety. The issue of software safety and reliability is currently being addressed in a change request to SSP 30309, "Safety and Risk Assessment Requirements for the Space Station Freedom Program." The requirements of SSP 30309 will be incorporated into the SSE standards to ensure that software controlling safety-critical functions has an acceptable level of risk since failures, errors, and adverse environmental conditions will occur. The Lockheed Missiles and Space Corporation (LMSC), the prime contractor for development of the SSE, currently employs an independent validation and verification (IV&V) contractor, Science Applications International Corporation (SAIC). This contractor, although employed by LMSC, functions totally independent of the development team and serves as an effective SR&QA check on the system development effort. They will in fact independently validate and verify the software in the SSE.

d. <u>**Finding**</u>: *There have been many good "preliminary" or "quick look" studies performed to support SSFP preliminary design activities. These studies often involve broad assumptions which are used to fix certain items while others are varied. This is an excellent approach. History tells us it is important to document the extent and nature of these assumptions very clearly. This will minimize the possibility that people reading these studies in the future will mistake areas not examined for those examined and excluded as potential problems.*

<u>**Recommendation**</u>: The SSFP management should develop and disseminate a standard policy for documentation of assumptions in preliminary studies. This policy should clearly differentiate among things assumed and not studied, items given a partial examination, and those studied fully.

<u>**NASA Response**</u>: NASA concurs with the recommendation that better tracking procedures of quick-look and preliminary studies should be implemented. Much insight has been gained through "lessons learned" and documentation of findings and recommendations. If similar documentation and/or a data base were to be developed for SSFP quick-look studies, a considerable amount of redundancy and duplication of effort could be eliminated. In the best interests of continuity and productivity, any study whether large or small needs to be documented as a matter of standard operating procedure. NASA will investigate and review what policies and/or management instructions provide requirements for documenting assumptions, conclusions, and any preliminary or quick-look studies. If current policies and instructions do not provide for this requirement, NASA will develop and publish appropriate policies or management instructions that document assumptions in preliminary studies.

e. **Finding**: *It is understood that consideration is being given to expanding experiments or the storage of experimental gear into the nodes. This would make them essentially undifferentiated from the attached modules with respect to safety considerations.*

Recommendation: SSFP management should establish a policy on node use as soon as possible. However, since there will always be the possibility that the nodes will be used for experimental or storage purposes, they should receive the same safety scrutiny as the remainder of the Station.

NASA Response: Consideration is being given to expanding the experiment capability into the nodes. This change is subject to the same ongoing, rigorous safety scrutiny, as is the entire SSFP design including Failure Modes and Effects Analyses (FMEAs), hazard analyses, and human engineering analyses.

All uses of the nodes will be restricted by the requirement for crew emergency egress through the node from any module.

f. **Finding**: *The baseline design does not include a provision for cleanup of hazardous spills in the open cabin area. Prevention of the spills appears to be the sole countermeasure approach.*

Recommendation: The Space Station should include the capability and equipment for the crew to manage and resolve a toxic spill in the open areas and prevent spills from propagating to the remainder of the Space Station.

NASA Response: NASA accepts the recommendation of the Panel concerning the addition of the capability and equipment to enable the crew to cleanup hazardous spills. While there is currently no requirement for "hazardous spill kits," the Space Station Freedom (SSF) Safety and Product Assurance Office, Code SSQ, is preparing a change request to SSP 30000 to require the provision of spill kits for the management of hazardous spills.

g. **Finding**: *There is concern that the use of the current Shuttle space suits will be inadequate to meet the time line required for the erection of the Space Station Freedom.*

Recommendation: NASA should go all-out to develop the new higher pressure suit so that it can be made available for timely use in the construction of the Space Station.

NASA Response: NASA is developing a space station optimized suit that is not planned to be operational until Permanent Manned Capability (PMC) is achieved. During space station assembly and during the man-tended phase of operations, the crew will function from the Space Shuttle. The crew will use the current Space Shuttle suit that has demonstrated excellent glove mobility, much better than is currently afforded by the newer high pressure glove designs. Also, the prebreathing issue raised in previous ASAP findings is eliminated as a requirement because Orbiter Extravehicular Activity (EVA) operations lower cabin pressure to 10.2 psi when the Shuttle 4.3 psi suit is used.

NASA believes that the proven Space Shuttle suit, with improvements and additional life certification tested as required, will be adequate to meet the time line for the erection of Space Station Freedom; and will be a safer, more conservative alternative than a newly developed high pressure suit.

C. AERONAUTICS

Finding: *Review of the safety policies associated with the NASA flight research programs at Langley, Ames, and Dryden indicate good appreciation of the importance of a comprehensive aviation safety program that is closely linked to, but independent of, the flight projects. Whereas there are similar functions and activities being followed by all flight research centers, they operate under different operational procedures and are organized differently. The safety procedures of each center seem to have evolved separately. As an example, the Basic Operations Manual published by Dryden establishes the Chief Engineer as the focal point for aviation safety with the Aviation Safety Officer assigned to the Flight Crew Branch, whereas the Langley Flight Research Program Management document establishes the Chief, Low-speed Aerodynamics Division as responsible for the overall flight research program including aviation safety with the safety officer in a subordinate branch.*

Recommendation: Headquarters should review the flight research policies and procedures of the concerned flight research centers to determine if their existing flight safety procedures are adequate or if it is appropriate to standardize on a NASA-wide set of procedures for conducting flight research.

NASA Response: The flight research policies and procedures of the Flight Research Centers have been reviewed by NASA Headquarters with inputs from the Offices of the Associate Administrator for SRM&QA (Code Q), Aeronautics and Space Technology (Code R), and Space Flight (Code M). Given the diverse nature of aircraft operations within NASA (including research and development, program support, and administrative flights), absolute standardization of airworthiness/operations is neither appropriate nor required. These findings were further validated when presented to the Intercenter Aircraft Operations Panel that includes members from each installation that operates aircraft, representatives from the Headquarters Aircraft Management Office, the NASA Aviation Safety Officer, and advisors from Headquarters Program Office. The Panel has agreed that the Senior Aviation Manager at the Center will be responsible for implementing safety policies associated with NASA Flight Research Programs. These procedures will be delineated in a new Headquarters NMI that is being drafted.

D. RISK MANAGEMENT

a. **Finding**: *In 1988 NASA issued several NMIs and NHBs that provide policies and direction designed to improve the identification, evaluation and disposition of safety risks. In particular, NMI 8070.4 titled "Risk Management Policy for Manned Flight Programs" calls for a risk management process that includes categorization and prioritization of "risks" using qualitative techniques for ratings of the frequency expectation and severity* *of the potential mishaps. The documents also provide for use of quantitative risk analysis to provide a more definitive ordering of risks for purposes of risk management.*

Recommendation: The risk management policies and initial implementing methodologies which have been issued in 1988 need to be evolved further. Practical quantitative risk assessment and other relative risk-level rating techniques should be actually developed. They should then be applied to help define the risk levels of flight and ground systems.

NASA Response: The risk management function is evolving. NASA is vigorously refining the NASA Management Instructions (NMIs) and NASA Handbooks (NHBs) to reflect the latest risk management policy developments. Independent risk assessments are being performed on Galileo and Ulysses payloads utilizing updated risk management methodology. This risk methodology includes the development of credible accident scenarios derived from initiating events that could cause potential mishaps. It incorporates both qualitative and quantitative system response analyses of initiating events induced by hardware or software anomalies malfunction(s), human error, environmental influences, or probable combinations of these factors. Also, the risk assessment methods are being restructured as further development and state-of-the-art knowledge are gained from ongoing risk assessment activities arena. Practical quantitative risk methods and risk-level techniques are being matured by NASA in structured workshop sessions and supporting policies with a view toward incorporation into the risk management efforts in the National Space Transportation System (NSTS), space station, and payload areas.

b. **Finding**: *The Panel has found strong commitment by each of the Center Director Offices to the rebuilding of the System Safety Functions in NASA. They have provided valuable guidance, encouragement and some level of financial support to the difficult restructuring, staffing and new policy implementation activities at their respective Centers. We are concerned that program resource cuts may be beginning to erode the progress which has been made.*

Recommendation: In addition to continuing their good work we believe that additional vigorous assistance is required on the part of each Center Director's Office to assure the allocation of resources that are necessary so that the promising progress toward a truly effective Systems Safety capability does not falter and wither away after a few successful STS flights. The Center Directors must be seen as major champions of safety engineering within NASA.

NASA Response: NASA strongly agrees that a key element to the successful implementation of a NASA-wide Safety Program is the committed support of the Center Directors who must continue to be the champions of safety engineering. To ensure that progress made at the Centers is maintained, the Office of the Associate Administrator for SRM&QA, Code Q, has initiated the following efforts:

(1) A Center Director/Program Manager Safety Awareness Training Program is being developed. This program will address the benefits and cost-

effectiveness of a strong safety program. Also, it will provide information concerning the role and responsibilities of the NASA Headquarters Safety Division, Code QS, in relation to the Centers and Acquisition Program.

(2) The Associate Administrator for SRM&QA conducts quarterly meetings with the Centers SRM&QA Directors to discuss progress and problems relative to their individual programs. Problems of similar scope experienced by more than one Center are addressed together to form a stronger justification base when additional resources are required. Information on advances or successful new initiatives are also exchanged among the Centers SRM&QA Directors.

(3) The equal relationship of the Associate Administrator for SRM&QA with other NASA Associate Administrators provides the level of authority and visibility to proactively resolve any anticipated problems of budget, manning, or lack of safety focus at a Center or on an acquisition program.

(4) Site surveys of Center and program activities by Code QS periodically review the effectiveness of their safety programs. Results of these surveys, positive and negative, are briefed to the cognizant Center Director or Program Manager, as well as the Director of the NASA Headquarters Safety Division. Problems, whether real or perceived, are presented to the Associate Administrator for SRM&QA for appropriate corrective action.

c. **Finding**: *At JSC there is a clear commitment from the Director's level down to implementing the general policies and requirements of NMI 8070.4, and to improving techniques for risk assessment and risk mitigation. We observed that the SRM&QA organization is still not completely staffed. The organization has assembled hazard information that is used in the decisions of whether or not to fly. Whether this same information can be used to identify safety-enhancing changes has yet to be examined.*

Recommendation: Examine the collected data to see if it can be used to identify safety-enhancing changes, and, if so, define these changes. (P. 9)

NASA Response: The review process for National Safety Transportation System (NSTS) safety issues and associated hazard reports, conducted by the System Safety Review Panel (SSRP) and the Levels I and II Program Requirements Control Board (PRCB), results in thorough review of the safety problems involved. As part of this process, recommended changes required for hazard mitigation and/or control are actions levied on the responsible NSTS element(s). Detailed responses and presentations are made to the review boards up to the Level I PRCB, which is chaired by the NSTS Program Director. Therefore, identifying and recommending safety-enhancing changes in response to identified hazards are integral parts of the hazard review process at levels up to and including NASA Headquarters. These changes include: revisions/changes/additions (to Flight Rules and Launch Commit Criteria); improvements in manufacturing, inspection, test, and quality control procedures; and design changes to mitigate or reduce the risk involved (subject to budgetary review and approval by the NSTS Program Director).

d. **Finding**: *At JSC the ASAP was presented a new approach to hazard rebaselining and rating, and a new format for the Mission Safety Assessment report (MSA). The new report is basically a set of evaluated fault trees which identify the potential system mishaps which might result from various hardware or human faults. For STS-26, 25 "significant risk" mishaps were "selected" for evaluation. All items selected had worst-case severity levels of "loss of crew and/or vehicle." All items were also rated as "unlikely," which was the lowest probability rating used in the hazard rating matrix. Thus, the MSA did not address even the relative risk-levels of the selected potential mishaps. However, the system safety organization did not color-code various faults - red, which designates that Improvement is Highly Desirable (IHD). Because all of the items elected for inclusion in the MSA are rated as unlikely to occur and therefore "safe to fly," there remain a large number of undifferentiated items designated IHD.*

Recommendation: The ambiguity regarding risk levels implied by the red color-coded MSA needs to be removed. NASA needs to provide a much more objective (quantitative) and data based risk assessment methodology that will differentiate the "unlikely" events for purposes of assessing the principal contributors to risk on STS and Space Station type programs.

NASA Response: The Mission Safety Assessment (MSA) focuses in more detail on risks considered issues for the current and subsequent launches. Since the ASAP visit, the MSA has been reevaluated and is now considered a program baseline safety assessment to be updated periodically, not mission specific. It is derived from the approved Hazard Report (HR) set, which forms the program baseline safety risk. Renaming of the document is under consideration and the safety community is developing a replacement document that will be mission-specific and unique, the final title of which is not yet determined. It will provide visibility to top management of significant changes or potential significant changes to the baseline safety risk. It will indicate launch constraints and resolved safety risk factors.

Basic requirements for the mission-unique safety risk assessment report need to be changed, and changes to the requirements are being pursued. The requirement for the MSA to be published 30 days prior to a launch is unrealistic as some safety risk data probably will not be achieved in time for consideration in the report as happened on STS-26. It is expected that the new requirement for safety risk assessments will be keyed to milestones such as the Flight Readiness Review (FRR) and the L-2 Day Review, and it will have a format that will permit rapid, last-minute updates.

All risks in the STS-26 were considered "unlikely," but were also more significant than others that had been received at the time of publication. Several HRs were subsequently submitted with a probability of occurrence of "likely," and they have been incorporated in subsequent MSA editions. All the events had the potential of being catastrophic events.

The fault-tree approach presents these basic and conditional events. From this analysis, the MSA evaluated the hazard controls in the design and procedural area (i.e., redundancy, safety factors, launch commit criteria) for possible improvement to further mitigate the risk. The MSA used a qualitative approach to assessing the relative levels of risk. The NSTS safety community is considering changes to the three-level probability of occurrence to provide greater differentiation. Also, future editions of the MSA will use the results of probabilistic risk assessments, when available, to help define the relative level of risk for prioritization.

NASA's effort to identify and quantify risk contributors has proceeded with several different approaches: probabilistic risk assessment (PRAs), individual statistical analyses, and prioritization of Failure Modes and Effects Analysis/Critical Items List (FMEA/CIL) items (system/component coupled with a Criticality 1 failure mode). Relative to the PRA effort, a risk assessment for the Galileo mission [which uses a radioisotope thermoelectric generator (RTG) power source] was conducted. The assessment focused on events leading to breech of the RTG case. Shuttle element risks and individual risk contributors were developed using fault trees, random failure distribution approximations, and Bayesian techniques.

However, none of the above efforts obviate the need for detailed, accurate, and easily accessible data bases containing test and flight failure data. The current Program Compliance Assessment Status System (PCASS) data base contains problem reports on component failures. For analysis purposes, data fields containing the specific FMEA failure mode need to be included to facilitate initial analyses; such an effort is now under consideration. A space station requirement document for a failure history data base is being developed. Apart from individual assessments and development of data bases, a more quantitative approach for identifying and assessing principal risk contributors has been explored using the current hazard analyses as a foundation. In this approach, detailed causes and scenario paths leading to damage states are developed. Likelihoods ascribed to the scenario nodes and, in turn, probabilities are approximated for each potential path and damage state. Examples using auxiliary power unit hazards have been developed. This approach is being evaluated as a quantitative enhancement for hazard assessment.

e. __Finding__: *Functional areas such as system-safety engineering at the Centers appear not to have received the resource support necessary to fulfill their responsibilities. The SRM&QA organizations at the centers appear to be relatively loosely coupled to headquarters.*

__Recommendation__: The various systems safety organizations throughout NASA should get stronger assistance from Headquarters especially regarding financial support.

__NASA Response__: NASA agrees that Center SRM&QA organizations should continue to receive strong support from Headquarters. During fiscal year (FY) 1989, 50 percent of the Headquarters SRM&QA budget is being transferred directly to the Centers. In FY 1990, we plan to increase this to 70 percent. Since January 1986, we have been able to increase the number of civil service and Jet Propulsion Laboratory personnel directly assigned to SRM&QA functions by approximately 39 percent. During that same period, the number of support contractor personnel performing SRM&QA functions has increased by nearly 95 percent. These statistics verify that the Centers have a strong and eloquent voice in Headquarters. As a consequence, NASA feels that within the context of existing Federal Budget constraints, the Center SRM&QA organizations have been well supported.

Center SRM&QA organizations report and are directly responsible to the Center Directors. The Office of SRM&QA functions in a senior staff capacity at Headquarters providing a focal point for NASA-wide SRM&QA activities, programmatic direction, policy formulation, and resources support. The link between Headquarters and field SRM&QA operations is sufficiently strong to provide proactive and vigorous SRM&QA program management.

f. <u>**Finding**</u>: *At MSFC the ASAP found an excellent SRM&QA organizational structure and good progress in staffing it with experienced engineering personnel. As other centers have done, they engaged the services of two contractors to aid in developing the analysis techniques for practical, more quantitative risk assessment and statistical evaluation of data bases.*

<u>Recommendation</u>: MSFC is to be commended for their progress in evolving its SR&QA function and these efforts should receive continuing high-level support.

<u>NASA Response</u>: The achievements of the Safety, Reliability, Maintainability, and Quality Assurance (SRM&QA) organization at Marshall Space Flight Center (MSFC) are recognized and applauded. Also noteworthy is MSFC taking the lead in establishing the management and engineering requirements for Maintainability, which is a relatively new key discipline within the Agency. MSFC and the other Center SRM&QA organizations will continue to receive the high-level support required to ensure their continued viability as effective spokespersons for System Safety, Reliability, Maintainability, and Quality Assurance.

APPENDIX B. OPEN ITEMS FROM 1988 ANNUAL REPORT

A. SAFE RETURN TO FLIGHT

1.d. Space Transportation System (STS) Management

OPEN ITEM: Reevaluation and recertification workload and prevention of human error at KSC.

STATUS: The required reevaluation and recertification of Space Transportation System (STS) hardware and software systems involved in returning the Space Shuttle to flight presented NASA and the Shuttle Processing Contractor (SPC) with a monumental challenge and opportunity. NASA and its contractors are meeting the challenge of returning the STS to operational status by scrupulously following the recommendations and instructions set forth by the Rogers Commissions and other forums.

The Kennedy Space Center (KSC) also has been meticulous in carrying out its duties in accordance with the SRM&QA guidelines and requirements from NASA Headquarters. The NASA and contractor management and work force at KSC believe in the "Safety First, Schedule Second" philosophy. They have developed the mind-set, and the disciplined work and documentation procedures to help avoid human error and danger areas, such as relaxing attention to detail, shortcutting test procedures, or ignoring persistent problems.

A comprehensive testing, training, and certification program has been implemented to acquire and maintain a qualified work force for the STS group operations. Additional personnel have been tested, hired, and trained for the highly technical tasks involved in testing and processing the STS elements for flight, and to augment the safety and quality disciplines. Automated documentation and work authorization systems have been established to lessen the paperwork burden and to assure more efficiency in the work control process. These systems also provide faster and more accurate disposition of problems, appropriate management visibility, and reduced probability of human error.

The Office of the Associate Administrator for SRM&QA at NASA Headquarters, that was established as part of the restructuring process and at the recommendation of the Rogers Commission, has enacted a broad and thorough monitoring/audit process covering all aspects of the SRM&QA discipline in all NASA programs. This process involves developing, disseminating, monitoring, and enforcing policies, quidelines, and procedures for recognition and implementation of SRM&QA concepts and requirements. The SRM&QA requirements and guidelines assure that the SRM&QA philosophy and policies are deliberately factored into all aspects of a NASA program (from concept/design/development to testing/certification/acceptance).

In support of the STS return-to-flight, the Headquarters-level SRM&QA organization has prepared and distributed policy and guideline documents, and long-range plans; provided real-time support to hardware/software development programs; and performed routine and special staff assistance surveys.

Accordingly, KSC has supported this overall SRM&QA effort in the context of its assigned responsibilities by establishing appropriate organizations and staffing; implementing the Headquarters-level policies and requirements; and developing and implementing appropriate local SRM&QA procedures, regulations, and guidelines.

At KSC, the STS recovery and return-to-flight effort have involved a vast number of specific, tangible tasks including the reexamination and overhaul of policies and procedures; redesign, testing, and recertification of hardware and software; assessment and adjustment of management philosophy and organizational structure; safety priorities; documentation systems; and decision-making processes. The tasks also include investigation of personnel factors such as shift work, overtime, and fatigue; as well as less tangible, but equally important, factors such as personnel testing and training, incentives, dedication, morale, and attention to quality.

Each factor in the rebuilding process contributed to the reevaluation and recertification of hardware and software – whether it concerned actual redesign and testing of hardware and software or involved training and qualification of personnel, better documentation systems, strict overtime regulations, or morale of the work force.

Two highly successful STS missions in 1988, one in 1989, and the ongoing successful processing of the next mission attest to the effectiveness of the combined efforts undertaken at KSC to return to flight.

2. Reassessment of Risk

OPEN ITEM: Methodology and implementation for conduct of FMEA/CIL/Hazards Analyses. Prioritizing of items.

STATUS: Based on the National Space Transportation System (NSTS) document NSTS 22206, "Instructions for Preparation of Failure Modes and Effects Analysis (FMEA) and Critical Item List (CIL)," the Office of the Associate Administrator for SRM&QA, Code Q, has developed a NASA Handbook for Agency-wide use. The handbook is NHB 5300.A(1G), "Failure Modes and Effects Analysis (FMEA) and Critical Items List (CIL) Requirements for NASA Space Programs." It is complete and awaiting concurrence of the NASA Headquarters codes. The document NSTS 22254, "Methodology for Conduct of NSTS Hazard Analysis (HA)," is being revised, and a draft is scheduled by mid-1989. The revised NSTS 22254 will provide a consistent approach to hazard analysis. The revision will comply with the following documents being developed by SRM&QA: NMI 8070.4, "Risk Management for Manned Flight Programs;" NHB XXXX, "NASA Risk Management Program: Rules and Responsibilities;" NHB XXX, "NASA Risk Management Program: Tools and Techniques;" NHB 1700.1(V1-B), "Basic Safety Manual (Draft);" and SSP 30309, "Safety Analysis and Risk Assessment Requirements."

The NSTS Program developed and issued document NSTS 2249, "Instructions for Preparation of Critical Item Risk Assessment." This document provides a method of prioritization and categorization of failure modes by severity of effects and likelihood of occurrence. Code Q is developing two documents to be used Agency-wide that address prioritization techniques of CILs for risk assessment: "NASA Risk Management Program: Roles and Responsibilities" and "NASA Risk Management: Tools and Techniques." Additionally, utilizing NSTS 22491 and contractor reports, Code Q developed ranked lists of the "Top 25" most critical CIL items for each Space Shuttle element. Code Q is conducting trend assessments that include examination of problem frequency, current status, resolutions/current control, and recommended action for each CIL item for each Shuttle element.

The NSTS Program developed a computerized accounting system known as the System Integrity Assurance Program (SIAP). A feature of SIAP is the Program Compliance Assurance and Status System (PCASS), which is a computer-based information data base system that integrates a number of information data base systems including: the Integrated Problem Assessment System (IPAS), Hazard Data System, FMEA/CIL System, Closed-Loop Accounting System (CLAS), Requirements Accounting System (RAS), and Programmatic Issues System. PCASS is used primarily to facilitate a closed-loop management system that allows program, element project, and SRM&QA managers (and other users) to determine the status of requirements, problems, trends, risk decision, and critical item action. PCASS and contractor sources are used to baseline risk assessment indicators including Launch Vehicle Reliability, Mission Safety Assessments, Overall Hazard Review, Flight Software Trends, Payload Problem Trends, and Limited-Life Item Trends. These indicators are updated for review prior to each Orbiter flight.

B. SAFETY, RELIABILITY, MAINTAINABILITY AND QUALITY ASSURANCE PROGRAMS

1.b. General

OPEN ITEM: The dangers of complacency.

STATUS: The Office of the Associate Administrator for SRM&QA is continuing to expand the audit process through independent safety assessments to ensure that problems and undesirable trends are identified and communicated to cognizant management levels for proper disposition. A key function in this process is to monitor and provide assessments of all problems that could adversely affect personnel morale and safety awareness or foster an attitude of complacency.

The NASA Headquarters Program Assurance Division, Code QP, is playing a vital role in assuring the National Space Transportation System (NSTS) and associated missions safety and mission success. An example of Code QP involvement is the review of past and ongoing committees' findings on NASA programs to evaluate all launch and flight safety concerns. The dangers of complacency have not been exempt from these evaluations that incorporate a system and decision-making process to include checks and balances to manage system alterations and reporting procedures.

The NASA Headquarters Safety Division, Code QS, Safety Awards Program is being developed to provide top-level recognition of individuals or facility groups who have demonstrated superior safety performance. In addition, the

NASA Quality and Productivity Improvement Programs Office, Code QB, has implemented a program for promoting and evaluating quality and productivity within NASA and its contractor community. This program is dedicated to promoting quality and productivity concepts, techniques, and methodology throughout the Agency.

In cooperation with the NASA Safety Program, the Space Station Freedom Program, and all other Shuttle-related activities, the Manned Flight Awareness (MFA) Program under the cognizance of the Office of Space Flight and the MFA Panel Chairman have been upscaled, realigned, and strengthened in its commitment to mission success and astronaut safety. The primary goal of the MFA Program, considering the impact of STS-51L, has been to revitalize and enhance morale, motivation, and dedication among all NASA and NASA contractor employees associated with the Space Shuttle Program including associated payload activities. All MFA Honoree Program events since STS-51L have included the direct "in-person" staunch support of NASA and NASA contractor top management. Each of these events has included participation by the NASA Administrator and his staff, the Associate Administrator of the Office of Space Flight and other Associate Administrators, Chief Executive Officers of the major aerospace companies supporting NSTS, and members of the astronaut corps. Of note is the fact that these MFA Honoree events have taken place on nonlaunch as well as launch occasions.

Also, the MFA Program is initiating the awards of Flight Safety Awareness Certificates (to be presented by the astronauts) to individuals who identify a safety problem that could precipitate a mishap. Further, the MFA Program has been expanded in scope to include subcontractors, vendors, and payload participants. Astronaut visits and discussions on flight safety awareness and "Safety First, Schedule Second" are being conducted at all NASA and NASA contractor organizations, activities, and facilities both within and outside the NSTS Program. The chain of safety awareness has and will continue to swing full circle in every facet of the NSTS Program.

The audit process, Code QP involvement, the Safety Awards Program, the Code QB Quality and Productivity Improvement Program, NASA Center direct involvement, and the upscaled MFA Program are all dedicated to the elimination of complacency and the preservation of safety awareness in all NASA programs and projects including NSTS.

1.d. General

OPEN ITEM: Study of potential design-induced human errors.

STATUS: NASA Headquarters Safety Division has taken specific steps to reduce human-induced errors. Code QS has developed a draft NASA Management Instruction for Human Engineering that defines the policies and responsibilities for the conduct of a structured Human Engineering Program at all levels of NASA. A draft NASA Handbook has been developed for human engineering in manned space flight systems, software, and facilities that structures the human engineering process. A draft Human Engineering Program Plan for the Space Station Freedom Program has been developed to assist in identifying the various ongoing human engineering efforts and integrating these efforts with the overall Safety Program. The preparation of a Human Engineering/Safety course to be given to Safety Engineers has been funded in an effort to provide awareness of the human engineering issues affecting the Safety Program.

Investigation has begun into the available Human Reliability Assessment Methodologies and Tools for applicability to NASA Programs.

C. SPACE SHUTTLE ELEMENT STATUS

3.a. Orbiter

OPEN ITEM: Orbiter OV-102 strain gauge calibration.

STATUS: The allowable flight envelope was revised at the Design Certification Review in March 1988. Certification was derived from 6.0 loads/stress analysis. The scope of the analysis used in certification included 60,000 structural components and 30 major structural elements including the wing, vertical tail, and mid-fuselage. Further analysis results indicate that the majority of the Orbiter structure has positive margins, and constraints have been defined for critical structures (wings, tails, aft fuselage, OMS pods, and wings leading edge) to ensure positive safety margins. Since launch probability can degrade due to constrained structure, structural modifications are being made as program requirements dictate. In consonance with previous ASAP recommendations, a plan is in place to add strain gauges to the Space Shuttle Columbia (OV-102) wing, tail, payload bay door, mid-fuselage, and elevons for its next flight (STS-28); and to recalibrate and reconnect a number of pressure measurements. This plan includes a wing calibration during OV-102 major modification.

Mid-body thermal measurements are being installed on Space Shuttle Atlantis (OV-104) (Flight 3) to collect and substantiate the 6.0 thermal data. These will be operational on the next flight. Tile temperature measurements are being added for the next OV-102 flight. The quantity of measurements will be determined by the Kennedy Space Center (KSC) workflow and the Shuttle budget in FY 1989. The plan that NASA referenced in 1988 for Orbiter OV-102 strain gauge calibration is being implemented at KSC. Over 200 strain gauges have been installed on OV-102 (Flight 8) currently scheduled for launch on July 1, 1989.

3.d. Orbiter

OPEN ITEM: APU turbine wheel blade cracking concerns.

STATUS: The causes of the turbine wheel blade cracking are not yet fully understood; however, there is a strong correlation between the incidence of blade cracks and the number of hot starts. The blade cracks exhibit the characteristics of high cycle fatigue, possibly due to a combination of the high thermal gradient-induced stresses during hot starts and the excitation of the turbine blade edge resonant frequencies by the hot gas dynamics. Additional testing and analysis using instrumented turbine wheels are continuing to determine the causes and the solutions to the cracking phenomenon.

On the basis of the turbine wheel cracks mapping conducted last year and the correlation with hot starts, the original Auxiliary Power Unit (APU) turbine wheels are limited to 16 hot starts before removal and inspection. Newly manufactured turbine wheels that reflect the latest process changes and controls are restricted to 24 hot starts prior to removal and inspection.

The long-term solution for the turbine blade cracking problems includes a new turbine wheel designed for 75 hours of crack-free life. This corresponds to 50 mission duty cycles and 120 hot starts. The 75-hour turbine wheel design will be phased into the current APUs during the latter half of 1989.

The new 75-hour turbine wheel features a full blade width tip shroud, a lower blade density, and an optimized blade design for the current APU operating conditions. The thicker turbine blade edges combine with the full width tip shroud to raise the blade edge resonant frequencies by a factor of 1.6. The new turbine wheel has a reduction in gas-induced dynamic stress and fuel consumption.

An Improved APU (IAPU) design will be phased into production during the first half of 1990. The IAPU will provide a variety of improvements including the new 75-hour turbine wheel.

5.a. Launch, Landing and Mission Operations

OPEN ITEM: KSC STS launch processing working environment.

STATUS: For factors such as overtime, worker fatigue, worker incentive, safety, and schedule pressure, the work environment continues to be a recognized concern on the part of NASA and NASA contractors. The highly technical and intense work environment associated with all aspects of Space Transportation System (STS) operations is one in which human error is a constant concern because of its propensity to induce human error that might result in danger to the safety of personnel and to flight and/or ground equipment.

Policies, procedures, and guidelines regarding operations methodology, scheduling, and personnel assignment have been and will continue to be devised and put into place. Management authority at all levels is sensitive to any symptoms or indications of potential problems that could, in any way, jeopardize the safety or health of personnel, or the safety and integrity of flight and/or ground hardware. The policy of "Safety First, Schedule Second" is recognized, accepted, and practiced by both NASA and contractor management and workers; it has become second nature in all actions, plans, and decisions regarding STS operations.

Strict policies, for example defining maximum work time for personnel in critical jobs, have been enacted (KMI 1700.2) to assure that conditions of worker fatigue, overwork, or burnout do not become factors that may be detrimental to safety of personnel or equipment, or to quality of work.

Established limitations relative to maximum work schedules for personnel are strictly enforced. A waiver procedure is in place if any critical personnel should be required to work more than certain established maximums, such as: 12 hours per day, 60 hours per week, 7 consecutive days per week, 240 hours for 28 days, and 2,500 hours for 1 calendar year. Policies are already in effect for control and approval of overtime and holiday work for civil service employees (KMI 9610.1C).

5.b. Launch, Landing, and Mission Operations

OPEN ITEM: Human resource problems at KSC to match work load including worker morale and productivity.

STATUS: The human resource factor continues to be a management concern that has been alleviated to some degree by additional hiring, performance incentives, mandatory training, and a concerted attempt by all levels of management to improve morale.

Following STS-51L, a survey was performed to determine present training status and to define long-term training requirements. On the basis of this survey, a comprehensive training program was established and implemented by NASA and on-site contractors, featuring several key methodologies designed to increase the efficiency of the training process. Some of the program features include: pre-employment testing of Space Transportation System (STS) technician applicants, certification training and testing in over 400 STS-related technical subjects, retest after 1 year of certification, computerized record keeping, three-shift training, and a tightly controlled attendance record system. "Learning centers" that locate classroom training in the vicinity of the actual work area were instituted. High volume, high priority work tasks, such as Thermal Protection System (TPS) repair, are accommodated by incorporating special schedules and increasing the size and numbers of courses offered. The launch team undergoes special training and is stand-boarded to assure qualification. Off-site training is provided to assure that visiting technicians meet the local environmental requirements, technical qualifications, and certification requirements. Special training on appropriate technical subjects is provided to personnel performing STS operations activities for off-site locations, such as White Sands and Dryden Flight Research Center.

Overall worker efficiency has been enhanced by the training program, as evidenced by comparison of the number of new jobs with the number of work-related incidents. Worker incentive has been increased by the anticipation of higher job qualifications resulting from the training, as well as by the official certification that is awarded subsequent to training and successful certification testing.

Federal Aviation Administration technical certification testing techniques, methodology, and criteria have been modified/adapted to the unique requirements of the Kennedy Space Center STS technical operations environment. It is reported that the pretested new-hires have a record of learning faster on the job and of accepting more responsibility faster than noted previously.

Overall, worker and management incentive, morale, sense of achievement, and pride in the program have been greatly enhanced by the two highly successful Space Shuttle missions in 1988, and also are evident in the ongoing hardware processing for the next mission scheduled for early 1989. Enthusiasm, pride, and sense of achievement are exhibited by both NASA and contractor management and workers in their demeanor, morale, and dedication. It carries over and is evidenced by a recognizable increase in eagerness, willingness, and quality of work. It has had a tangible, positive effect on the "character" of the work environment.

The contractor and civil service manpower resources are being increased in both number and quality in accordance with policy, requirements, and budget capability.

5.c. Launch, Landing, and Mission Operations

OPEN ITEM: Launch frequency (manifest) concerns.

STATUS: The process of changing Space Shuttle software is a rigorous, disciplined, well-documented process. Software changes are defined on software change requests (CRs) by members of the NASA requirements community. These are documented as changes to requirements documents under the rigorous configuration control of the Shuttle Avionics Software Control Board (SASCB), which is chaired by the Manager of the NSTS Engineering Integration Office. No part of any software requirements document can be altered without the approval of this board, and then only after a thorough review and concurrence by the requirements community. The review and approval process is thoroughly and completely documented through detailed minutes of Board proceedings and incorporation of approved requirements into the detailed design and maintenance specifications, user's guides, and Program Notes and Waivers Document. Additionally, since STS-51L, the engineering design community has documented the design rationale associated with each mission-unique design data parameter. Documentation includes the history, limits, constraints, and trends for each parameter as well as the interrelationships of the parameters to each other and to other significant flight characteristics. NASA believes that this constitutes a thorough and complete documentation of the design and implementation rationale for Shuttle flight software.

The knowledge base required to develop effective Shuttle crew procedures is extensive and multi-disciplined. Development of these procedures involves operations and engineering personnel as well as astronauts since detailed knowledge of the Shuttle, operating environments, and crew capabilities is required. Approval and validation of crew procedures involve formal reviews and simulator checkouts. Baselined Shuttle crew procedures are exercised extensively during simulations. We believe that the majority of the human factor considerations are found during procedures validation and during the extensive exercises and procedures usage in the simulators. Moreover, crew procedures development specialists with assistance from spacecraft designers are pursuing methods to improve the human factors aspects of procedures development. The methodology and expertise developed through this effort are being injected in real-time into the procedures developed for the Shuttle.

Following STS-51L, mechanisms were put in place to ensure that there is adequate training time. A minimum of 11 weeks of Shuttle mission simulator training time is now the standard for NSTS flights. As part of the flight preparation process, each flight is reviewed to determine if additional training time is required. Any reduction in training time from the standard must be approved by the Level II Program Requirements Control Board.

5.e. Launch, Landing, and Mission Operations

OPEN ITEM: Procedures for approving late software changes at JSC/KSC.

STATUS: Late changes to Orbiter Avionics, Space Shuttle Main Engine (SSME) Controller, and Ground Launch Sequencer software can be made. Late changes to the Orbiter Avionics software can be physically implemented via tape or satellite links. Changes to Orbiter Avionics software include modifications to the software program code and program constants or I-Loads; these changes must be formally approved by the Shuttle Avionics Software Control Board (SASCB). Approval by the SASCB often will require a complete test evaluation of the change. As with the Orbiter Avionics software, changes to SSME Controller software include modifications to the software program code and constants; these changes also are generally approved by the SASCB. Occasionally, late changes for SSME Controller software will be submitted to the Problem Review Control Board (PRCB) for approval. Changes made to SSME Controller software cannot be transferred electronically to Johnson Space Center (JSC) or Kennedy Space Center (KSC). Therefore, changes are incorporated on tapes and sent to the appropriate site. Changes to the Ground Launch Sequencer software can be made within 2 hours of launch time. Changes are documented as waivers or deviations from Launch Commit Criteria or File II Operations and Maintenance Requirements of Specifications (OMRS).

D. SPACE STATION PROGRAM

1. Space Station Computing Systems

OPEN ITEM: Space Station Computing Systems

STATUS: As stated in the 1988 report, the design and production of components are divided into four work packages delegated to Marshall Space Flight Center (MSFC), Johnson Space Center (JSC), Goddard Space Flight Center (GSFC), and Lewis Research Center (LeRC). Therefore, the integration of software development is recognized as a demanding task. Lockheed Missiles and Space Corporation (LMSC) continues to develop a common Software Support Environment (SSE) for the entire Space Station Freedom Program (SSFP). The SSE will allow each development contractor to design, develop, and test their software to assure compatibility and integration when operational. The Multi-Systems Integration Facility (MSIF) will be the verification and validation activity where integration and testing will take place under the leadership of Level II and its support contractor. The concept of how to attack the software integration task appears workable and is one in which NASA can have confidence of achieving successful SSFP software/computing systems.

A concern has been expressed relative to the Data Management System (DMS) for the space station: the quantity and scope of data that the DMS will have to handle that has been addressed in Section 8, SSP 30000, the Program Definition and Requirements Document (PDRD); with rationale provided in more detail in SSP 30261, "Data Management System," and JSC 30226, "Technical and Management Information System Functional Requirements Document." More documentation is planned and will be available for the Preliminary Design Review scheduled for Spring 1990.

The recommendation that provision be made for planned upgrades for both hardware and software of the space station computing systems is implemented by provisions of the space station Program Requirements Document (PRD) and the PDRD.

2. Crew Emergency Rescue Vehicle (CERV)

OPEN ITEM: Crew Emergency Rescue Vehicle Activities

STATUS: The Space Station Freedom Program (SSFP) Safety and Product Assurance Office, Code SSQ, agrees that a crew rescue capability is a mandatory requirement on the space station. There is ample medical evidence to support the need for prompt return of an injured or medically disabled crew member, which constitutes sufficient reason for the emergency capability. Additional justification includes conditions that might render space station unhabitable (for example, by debris/meteoroid impact or contamination).

A Change Request to Level I has been proposed by the Office of the Associate Administrator for Safety, Reliability, Maintainability, and Quality Assurance (SRM&QA), Code Q. The response to date has been to allow the Office of Space Flight, Code M, to define the requirement, and design and implement the system. Code M is scheduled to issue a request for proposal (RFP) for a study to define crew rescue methods during FY 89.

3. Extra-Vehicular Activities (EVA)-Space Suits

OPEN ITEM: EVA/Space Suits for Space Station

STATUS: NASA is developing a space station optimized suit that will be operational when Permanent Manned Capability (PMC) is achieved. During the space station assembly and during the man-tended phase of operations, the crew will function from the Space Shuttle. The crew will use the current Space Shuttle suit that has better glove mobility than is afforded by the newer high pressure glove as currently designed. Also, the prebreathing issue raised in the previous ASAP findings will be eliminated since it will not be a requirement when the Orbiter cabin pressure is lowered to 10.2 psi and the Shuttle 4.3 psi suit is used.

NASA believes that the proven Space Shuttle suit, with improvements and additional life certification tested as required, will be adequate to meet the time line for the erection of Space Station Freedom, and is a safer, more conservative alternative than a newly developed high pressure suit.

B. NASA Response to Panel Annual Report, March, 1988

E. AERONAUTICS

1. X-Wing Flight Test Program Structure

OPEN ITEM: X-Wing lessons learned regarding development of key technologies and structuring R&D programs.

STATUS: The program was a high-risk venture from the start, but one with potentially high payoffs. Significant technological challenges included the development of a fly-by-wire quadraplex flight control system, fabrication of large composite blades capable of withstanding temperatures up to 350 degrees Fahrenheit, and resolution of numerous stability and control issues associated with higher harmonics, hub moment feedback, stopped rotor aeroelastic stability, and circulation control aerodynamics.

The program prioritized schedule first, technical second, and cost third. The schedule priority was driven by the Defense Advanced Research Projects Agency, which took the responsibility for cost growth in the development program. Such a schedule-driven program forced the design to press ahead before the requirements were completely known, and led to redesign of work as the requirements become fully known. Had this not been the priority, then cost growth could have been minimized by detailed planning early in the program, progressing serially from preliminary design to detail design with a minimum of parallel effort and redesign due to late design changes.

The matrix staff structure, which brought extensive people resources in the pneumatic/propulsion area from Lewis Research Center and in the rotor area from the Naval Research Laboratory to aid the Ames Research Center project office, proved to be an excellent source of technical talent. However, had NASA had in place a strong in-house supporting research and technology program, the program success would have been greatly enhanced. The ground-based test program including a Propulsion System Test Bed, a hardware in-the-loop simulation, and scaled powered wind tunnel testing, provided an excellent means of identifying problems prior to flight test. Any remaining structural problems would have been encountered prior to flight using these test-beds. The greatest technical challenge to date and, therefore, the most cost growth, was in the flight control system and blowing control laws. A paper written for the 1989 American Helicopter Society Annual Forum entitled "RSRA/X-Wing Flight Control System Development: Lessons Learned" covers the problems of balancing program goals with technical goals, software- and hardware-related problems, safety issues, and system testing.

4. Aircraft Operations and Safety Management

OPEN ITEM: Aircraft Operations and Safety Management

STATUS: Aircraft Operations and Safety Management within NASA remains the responsibility of each level of aircraft management. The NASA Headquarters Safety Division, Code QS, has the responsibility of coordinating Safety, Reliability, Maintainability, and Quality Assurance (SRM&QA) requirements with regard to aviation safety. The Aircraft Management Office (AMO) is tasked with implementing the programs at NASA Headquarters and ensuring safety requirements are integrated into all NASA operations and activities. To this end, both the AMO and SRM&QA Offices have produced new NASA Management Instructions (NMIs) that state Headquarters policy guidance for aviation safety programs and responsibilities. These draft NMIs are undergoing final review within Headquarters and will be presented to the Intercenter Aircraft Operating Panel (IAOP) for final review. This should eliminate any confusion relating to how safety responsibilities are divided between AMO and SRM&QA.

C. AEROSPACE SAFETY ADVISORY PANEL ACTIVITIES
FEBRUARY 1989 - JANUARY 1990

FEBRUARY

8-10 - Aerospace Medical Advisory Committee, NASA Headquarters
14-15 - Risk Management Review, NASA Reston, VA

MARCH

27 - Liquid Hydrogen Tank Review, NASA Headquarters
28 - Annual Meeting with NASA Administrator, NASA Headquarters
30 - Weather Concerns Meeting, NASA Headquarters
31 - Office of Space Flight General Management Status Review

APRIL

3-5 - Advanced Manned Operations, Dallas, TX
11-12 - Space Station Power Systems Review, NASA Lewis Research Center, Cleveland, OH
11-13 - Space Station Safety Summit, NASA Kennedy Space Center, FL
13-14 - STS-30 Flight Readiness Review, NASA Kennedy Space Center, FL
19-20 - Allied Bendix Propulsion Meeting, Alexandria, VA
25-26 - Space Station Review, NASA Reston, VA
28-30 - Aerospace Medical Advisory Committee Meeting, NASA Headquarters

MAY

2-4 - Integrated Logistics Panel, Michoud, LA
2-4 - AIAA Annual Symposium, Crystal City, VA
11 - Senate Subcommittee Testimony (Sen. Gore), ASRM Washington, DC
23-25 - Intercenter Aircraft Operations Panel, Atlantic City, NJ
31-1 - Space Station Work Package #1 Review, NASA Marshall Space Flight Center, AL

JUNE

1 - Orbiter Logistics Support Review, NASA Headquarters
1-2 - Aerospace Medical Advisory Committee, NASA Headquarters
27 - Aircraft Meeting, NASA Dryden Flight Research Facility, CA
28-29 - OSF Program Directors Review, Shepardstown, WV

JULY

6-7 - Plenary Session, NASA Lewis Research Center, Cleveland, OH
10-12 - SAE 1989 Joint Propulsion Conference, Monterey, CA
17 - Space Shuttle Orbiter Mods Review, Rockwell International, Downey, CA
25-26 - STS-28 Flight Readiness Review, NASA Kennedy Space Center, FL
- STS/SS Computer Software Briefing, NASA Johnson Space Center, TX
26-27 - AIAA/NASA Maintainability of Aerospace Systems Symposium, Anaheim, CA
31-2 - Space Station Work Package #2, NASA Johnson Space Center, TX

AUGUST

3-4 - STS Processing and Space Station Activities, NASA Kennedy Space Center, FL
4-6 - STS-28 L-2 and L-1 Day Reviews, NASA Kennedy Space Center, FL
18 - STS Safety Enhancements, NASA Johnson Space Center, TX

SEPTEMBER

5-8 - NSTS PDMR and ASRM Level II Briefing, NASA Marshall Space Flight Center, AL
12-13 - X-29 Flight Readiness Review, NASA Dryden Flight Research Facility, CA
26-28 - Space Station Work Package #3, NASA Goddard Space Flight Center, MD
and
Discussions with Administrator/Deputy Administrator, ASRM Briefing and Congressional Hearing, NASA Headquarters

OCTOBER

2-3 - STS-34 FRR Galileo, NASA Kennedy Space Center, FL
10 - STS-34 L-2 Day Review, NASA Kennedy Space Center, FL
15-17 - Aerospace Medical Advisory Committee Meeting, NASA Headquarters

NOVEMBER

7 - Space Shuttle Orbiter(s) Briefing, Rockwell International, Downey, CA
8 - Space Station Work Packages #'s 2 and 4 Briefing
McDonnell Douglas, Huntington Beach, CA
9 - Space Shuttle Main Engine Briefing, Rocketdyne, Canogoa Park, CA
27 - Space Suits Discussion, NASA Johnson Space Center, TX
29 - Space Shuttle Solid Rocket Booster Project Status Review, National Research Council, Washington, DC

DECEMBER

1 - Space Station Reviews with Associate Administrator for Space Flight and Director, Space Station, NASA Headquarters
14-15 - Solid Rocket Motor Briefing and Plant Tour, Thiokol, Watsach, Utah; and Annual Report Review, Salt Lake City, Utah

JANUARY

11-12 - Propulsion Meeting, NASA Headquarters
24-25 - Annual Report Editing Committee Meeting, NASA Headquarters

For Further Information
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National
Aeronautics and
Space
Administration