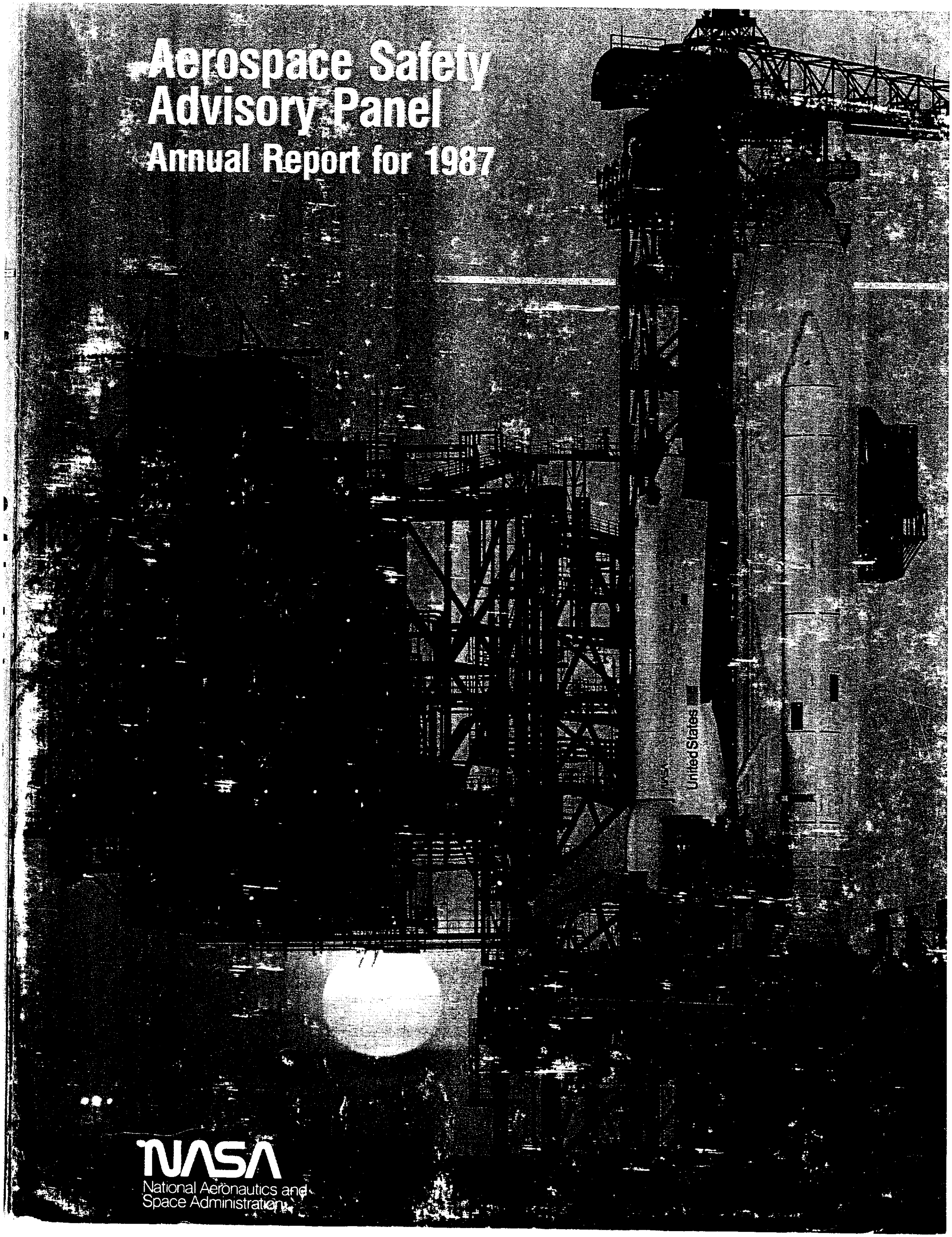
Aerospace Safety Advisory Panel

Annual Report for 1987



NASA

National Aeronautics and
Space Administration

Aerospace Safety Advisory Panel
Annual Report for 1987

March 1988

Aerospace Safety Advisory Panel
NASA Headquarters
Code Q-1
Washington, DC 20546

NASA

National Aeronautics and
Space Administration

Washington, D.C.
20546

Reply to Attn of: Q-1/ASAP

Dr. James C. Fletcher
Administrator
National Aeronautics and Space Administration
Washington, DC 20546

Dear Dr. Fletcher:

The attached document is the Aerospace Safety Advisory Panel's (ASAP) annual report to the NASA Administrator for 1987. This report provides you with our findings and recommendations regarding the National Space Transportation System (NSTS), the Space Station, aeronautical projects and other areas of NASA activities. The period covered is from February 1987 through February 1988. This letter provides an overview of ASAP's findings and recommendations. The ASAP requests that NASA respond only to Section II, "Findings and Recommendations" and to the "open" items noted in Section IV.D "NASA Response to Panel Annual Report."

The effort associated with the Space Transportation System (STS) recovery program following the Challenger accident is one of the greatest tasks NASA has undertaken. The future of U.S. space activities and the recovery of this country's leadership in space is greatly dependent on the successful restart of Space Shuttle flights. The main focus of the Aerospace Safety Advisory Panel during this past year has been on the monitoring and advising of NASA and its contractors on the many facets of their efforts leading to a well-managed, reduced-risk restart of the Space Shuttle flight activities. The efforts of ASAP on other programs--such as the Space Station and aeronautical programs (e.g., X-Wing)--have continued and are also reported.

NASA's efforts to achieve a successful continuation of Space Shuttle operations were directed by President Reagan's directive to the NASA Administrator on June 13, 1986, and by the recommendations of the U.S. House of Representatives Committee on Science and Technology Report 99-1016. NASA has followed scrupulously the recommendations laid out in the Presidential Commission Report on the Challenger Accident (the President's letter directed NASA to do this). These recommendations also required that NASA take cognizance of the advice of the National Research Council (NRC) in several areas, e.g., redesign and test of the solid rocket motor and the Failure Modes and Effects Analysis and Hazard Analyses.

It is the belief of ASAP that the current endeavors of NASA will lead to Space Shuttle operations that are safer than those prior to the Challenger disaster. Nevertheless, ASAP still regards the Space Transportation System/Space Shuttle program as an inherently high-risk endeavor. The assessment and management of risk remains as a major and crucially important task for NASA management. If the efforts of NASA are continued in their present manner, the risk of major accidents will have been reduced significantly considering the inherent dangers. The ASAP is concerned, however, about the monumental amount of NASA and contractor resources utilized in these efforts and believes that after this initial response, NASA must find means to evaluate and reduce risk in a more effective manner. A start on this has been made through the development of a NASA Management Instruction and NASA Notice titled "Assurance Risk Assessment Policy For Manned Flight Programs."

The greatest source of risk will be the pressure to meet a specific schedule. The ASAP reiterates "safety first, schedule second." We will continue to monitor the NASA effort to resist pressures to put fixed schedules ahead of achieving proper completion of the work.

<u>Space Shuttle Management</u>

One of the major recommendations of the Presidential Commission was the establishment of a management structure to ensure that the effort involved in bringing the Space Shuttle back into operation was properly directed, and that management was in a position to control and give direction through an effective "up-and-down" communication system.

The Space Shuttle program was reorganized to set up a line organization with all elements of the system reporting to NASA Headquarters. This has been a major step forward. The Space Shuttle program appears now to be managed with a consistent set of directives and with a communication system which should go a long way in preventing failures due to lack of proper understanding or lack of communication. Nevertheless, it would be prudent for Headquarters to re-examine this management system periodically to ensure that it continues to function in the manner intended.

Another major recommendation of the Presidential Commission was that of establishing "...an Office of Safety, Reliability and Quality Assurance to be headed by an Associate Administrator, reporting directly to the NASA Administrator" having direct authority for SR&QA throughout the agency. NASA's response was the establishment of a new and expanded SRM&QA organization throughout NASA. This organization is developing the ability to ensure effectively that safety requirements are properly defined and are subsequently met. To say, however, that the organization is fully effective would be premature.

The certification process needs a thorough review. We believe that certification needs to be done independently and that this can be accomplished within the NASA community if steps are taken to ensure adherence to NASA policy and precept. The latter can be done by the promulgation of firm safety policies by the Administrator. For each program, line management must develop a set of safety goals consistent with the Administrator's policy and which must be approved by him. Once established, these goals (and design precepts) may not be changed or violated by the line organization. The now independent SRM&QA function would actively monitor the program activities and ensure that all requirements are being met. As an independent member of the body that approves certification documents, the SRM&QA organization has the right of veto and appeal to the Administrator over any proposed action with which it does not agree technically.

The establishment of the current SRM&QA organization has already had a positive effect on the Space Shuttle program and has increased the awareness within the Shuttle organization that safety requirements are of the utmost importance. NASA should monitor the efforts in this area for all programs to ensure that policy is being implemented and that deterioration of the effort does not set in. The ASAP considers it one of its responsibilities to assist in this oversight.

As KSC is the end of the "pipeline" for all of the Shuttle hardware and software, the ability to properly process the Shuttle system depends upon a labor-intensive operation requiring close cooperation between managers, engineers, and hands-on personnel. Therefore, we believe that continued, and perhaps greater attention should be given to assuring that Operational and Maintenance Instructions are complete and match the flight and ground hardware and software, and personnel communications are orderly and timely.

Space Shuttle Modifications and Safety Reviews

NASA is well on its way in defining and incorporating necessary changes to the Space Shuttle system elements. This effort should establish a higher confidence level that a successful mission can be performed. This comprehensive effort is one of the most massive reviews of a large aerospace system ever performed. A complete review of all Failure Mode and Effect Analysis (FMEA), Critical Items Lists (CIL's) waivers and Hazard Analyses (HA's) is still underway. There are some inconsistencies in the manner in which the work is being performed by various program elements. There is also some concern that the existing FMEA, CIL, HA and risk retention rationale methodology may be inefficient and perhaps not fully effective in defining all of the elements that ensure safer operation. Nonetheless, this is the system NASA has developed and used to evaluate and manage risk for the Space Shuttle program. A complete review was recommended by the Presidential Commission and NASA is currently fulfilling this requirement. The ASAP believes that this review will be effective in defining the changes in Space Shuttle design and procedures thereby achieving an acceptable level of risk for continued operations. Because this effort is so massive, ASAP is concerned that management may be overwhelmed by the volume of information involved. This is one of the greatest challenges facing NASA management. Completion of this effort is mandatory before first flight of STS-26.

Before the current review process was undertaken, the FMEA/CIL/HA system was not used as intended when changes to ground and flight systems were being considered. Instead of providing the pros and cons and consequences of a proposed change, the retention rationale developed for an existing design was, in effect, used to justify not making a change despite the problems that elicited the proposal for the change. The present review is helping to evolve a more even-handed presentation of these considerations. Steps should be taken to ensure that this practice is incorporated in the methodology and that it is employed in a consistent fashion.

The review of the FMEA, CIL's, and HA's has not revealed a large number of design changes required to comply with NASA design, operation, or certification ground rules. However, the review has revealed several areas where the implementation of design changes critical for safe flight were long overdue. Of the thousands of items contained in the above, to date approximately 260 design changes across the Shuttle System are considered mandatory for incorporation before the STS-26 flight. Some of the most critical design changes are:

1. The solid rocket motor field joints (Challenger accident cause). Requires completion of verification and certification testing and analysis.

2. The solid rocket motor aft segment case-to-nozzle joint. Verification and certification methods and implementation plan must be completed followed by tests and analysis.

3. Space Shuttle Main Engine (SSME) high pressure turbine blade cracks and other anomalies found in the recent past.

4. Oxygen tank pressurization valve (gaseous oxygen at high pressure) in the Orbiter is subject to high-energy impact and possible ignition. A material change has been made with verification activities still in progress.

5. The 17-inch liquid oxygen and liquid hydrogen shut-off/quick disconnect valves in the Orbiter interfacing with the 17-inch lines coming in from the external tank. The new design, approved for use on STS-26, to preclude inadvertent closure during ascent requires completion of the verification program to qualify for flight. There are some concerns with fluid leakage through the new latching mechanism.

6. The solid rocket booster auxiliary power unit speed controls. Verification that redesigned speed controls eliminate the possibility of catastrophic overspeed.

7. Structural load margins on the Orbiter's wings, vertical tail and lower mid-body fuselage areas. The present ASKA 6.0 (Automatic System for Kinematic Analysis) loads analysis data is nearing completion. However, current indications are that some structural margins are below design criteria. Without further flight loads data, the Space Shuttle could be limited to flight in reduced upper wind conditions (reduced flight envelope) which in turn could seriously hamper operations in those periods of the year where statistically there are greater wind velocities, e.g., winter quarter.

8. Landing/deceleration modifications to Orbiter and landing site facilities at primary and secondary landing sites. For example, brake and gear improvements, deceleration chute.

9. Crew escape provisions during flight and after ground roll-out. This includes the ability to conduct an actual Return to Launch Site (RTLS) maneuver.

The work to define these and other mandatory changes and then to test and certify them prior to the next flight is proceeding on an around-the-clock basis. Such testing and continuing engineering analyses could indicate the need for more work and design changes. It is the satisfactory completion of this total effort that is mandatory prior to flying the STS-26 mission. The Space Shuttle scheduling of critical milestones must take this effort into account if this work is to be conducted in a manner which ensures that the future flight program will achieve a satisfactory level of safety. This task should be done such that "out-of-sequence" work is minimized and a reasonable use of overtime is programmed. The date that the Space Shuttle stack is planned to be moved from the vehicle assembly building (VAB) to the launch pad, as an example, is very important to good planning because very few modifications should be permitted while the Shuttle is on the pad.

Looking to the future, later programs could do well to reflect upon the Space Shuttle program. Continuing improvements in management, communications and quality assurance systems are necessary if future NASA programs are to develop satisfactorily. The lessons learned on the Space Shuttle program must not be forgotten and must be applied for the guidance of future programs such as the Space Station. The ASAP understands that there are steps being taken by the Associate Administrator for Safety, Reliability, Maintenance and Quality Assurance to do this now and in the future.

Space Station Program

The ASAP activities related to the Space Station program have been at a low level. Now that the Phase C/D contracts have been awarded, ASAP will increase its efforts in this area. However, during this past year, ASAP has focused on the following because early attention is required to avoid later problems in these critical areas:

1. Crew rescue from orbit by independent means. The "crew emergency rescue vehicle" (CERV) should be a part of the initial program requirements, and Space Station designs should take cognizance of this. However, there are two points to be made:

   a. The CERV should not be designed to be used for multiple purposes, e.g., a tug or general-purpose vehicle. Simplicity and availability are the keys to its effectiveness and minimum cost.

   b. Funding for the CERV may be prudently delayed until Space Station design itself has matured, allowing enough time to have the CERV available when the station is ready to receive crews in orbit.

2. Orbital debris protection must be considered in light of probability of occurrence and severity of particle impact for each part of the Space Station. At the same time, a continuing risk assessment program should be in place to determine the acceptability of the risk based upon an agreed-to set of criteria.

3. Maintenance and any associated extra-vehicular activities (EVA) must receive priority treatment as a design requirement. This includes the use of space suits applicable to the Space Station environment and overall needs.

4. The long-life design objective of the Space Station demands the recognition of the inevitable occurrence of hardware and software obsolescence. This requires designing for evolution in spite of the possible higher up-front investment.

5. The Space Station computing system requirements as we know them today present a very impressive array of desired capabilities. Systems integration techniques for such large systems are not well understood, and many other large organizations have made very costly errors by grossly underestimating the magnitude of the systems integration problem. In light of the foregoing, the ASAP suggests that NASA review resources devoted to this activity.

6. Space Station must identify program goals for computing system safety and reliability just as is done for other hardware functions.

Aeronautical Management and Programs

The ASAP has two concerns regarding aircraft operations and safety management:

1. The ASAP continues in its efforts to have NASA develop or purchase digital flight/crash recorders for non-research and development aircraft. The ASAP understands there is a funding problem but hopes for incremental funding to resolve this.

2. There should be a review of all written instructions designating responsibilities and authorities of the Headquarters Aircraft Management Office and those of the Safety, Reliability, Maintainability and Quality Assurance organization. The objective of this is to eliminate the confusion associated with the designation of safety responsibilities.

These observations represent an overview of the Aerospace Safety Advisory Panel's views on the more significant aspects of NASA's activities as determined through our fact-finding in 1987 and early 1988. We look forward to meeting with you and your senior management in ASAP's statutory annual meeting and thereafter to keep you apprised of our views on various NASA efforts.

As always, it has been our pleasure to work with the many people at NASA and its contractors and we want to take this opportunity to thank them all.

Sincerely,

Joseph F. Sutter

Joseph F. Sutter
Chairman
Aerospace Safety Advisory Panel

Contents

Contents
(continued)

I. Introduction

The drive toward returning the Space Shuttle to flight status has involved the efforts of not only NASA and its many contractors but also a number of outside groups to ensure a timely, safe and orderly progression toward the STS-26 mission. The Aerospace Safety Advisory Panel (ASAP) is, however, the only continuously operating group dealing with not only the Space Shuttle but all other significant NASA activities involving manned flight. It remains the senior safety advisory group to the NASA Administrator and the Congress.

The role of ASAP is broad because "safety" encompasses many things. A former NASA Administrator provided this description of ASAP's role and modus operandi which remains applicable:

> Where do the ASAP's interests lie? A safety review usually tends to concentrate on the engineering design and quality control aspects of safety. While these are important factors, they do not represent the total necessary for safe and reliable programs. Just as important are manufacturing practices, organizational structures, facilities, and human attitudes. Management approaches--and particularly management's ability to balance schedule, cost, design, development, and testing--often are the most important factors in the total success and safety of a program.

The ASAP has conducted more than 60 fact-finding and participatory sessions during this reporting period of February 1987 - February 1988. In addition to its own fact-finding sessions, ASAP members and consultants have been active participants with National Research Council (NRC) review panels established to examine the Space Shuttle launch rates, the redesign and verification/certification of the Solid Rocket Motor/Booster, and the Space Shuttle Criticality Review and Hazard Analysis Audit Committee. Two members of ASAP are part of the NASA-MSFC Solid Rocket Booster Aft Skirt Structural Review Team reexamining the booster aft skirt and external tank-to-rocket structural interfaces.

As indicated by the Table of Contents of this annual report, a majority of ASAP's time was spent on activities related to returning the Space Shuttle to safer flight for STS-26 and subsequent missions. Less time was spent on the Space Station program since it has been restructured both in management organization and in hardware configuration and was awaiting the awarding of the four major work packages (which occurred at the end of November 1987) for Phases C/D design, development and operations. The activities did, however, suggest the need for added emphasis on the use of lessons learned from other NASA programs. This will be particularly important in the austere budgetary environment in which NASA now finds itself.

The primary areas for aircraft management and operations activities were on the NASA Headquarters policy for aircraft management and safety, its implementation and concerns, and the conduct of the X-Wing research and development project. The ASAP participation in the Intercenter Aircraft Operations Panel and attendance at flight readiness reviews along with individual one-on-one discussions with NASA and contractor personnel were ASAP's principal undertakings in these areas.

With the hiatus in Space Shuttle flights, ASAP placed emphasis on the many facets of the launch processing work at Kennedy Space Center (KSC), which is on the receiving end of everything being done to ensure a safer Space Shuttle program for STS-26 and beyond. In doing this, ASAP conducted numerous face-to-face discussions with NASA and contractor "floor" technicians, inspectors, and test personnel over and above "normal" fact-finding. These "hands-on" people put the hardware into final flight configuration and ensure all is ready for the countdown to launch. These discussions were a continuation of those started in August 1986. To date, some 60 technicians have been involved.

During this past year, ASAP has had the opportunity to provide testimony during congressional hearings and to discuss the last Annual Report (along with NASA's response to it) with members of the House and Senate subcommittee staff (Senate Subcommittee on Science, Technology and Space; Senate Subcommittee on HUD-Independent Agencies Appropriations; and House Subcommittee on HUD-Independent Agencies Appropriations; House Subcommittee on Space Science and Applications).

In today's national climate, it might be well to recall and reflect upon the thoughts expressed in March 1967 by Jim Webb, NASA Administrator at the time of the Apollo 204 capsule fire that took the lives of three astronauts:

> Uncertainty, and therefore risk, is a quality that cannot be eliminated entirely from programs that seek to advance technology and explore the frontiers of science. NASA's programs must be planned and developed with less than full knowledge. This general program characteristic of uncertainty must be coped with by all levels of NASA management and becomes a specific consideration in the planning, development, and operation of each specific NASA program and flight mission. The extent of available resources in the future, the schedules as they will evolve, and the technical advances and breakthroughs are unknown at the outset of the program. Therefore, in a true sense, "risk-taking" by NASA management is inherent in each management decision from inception to completion of a program. The management key is to proceed in these efforts at a known and consciously selected level of uncertainty or risk appropriate to the individual characteristic of each program. Experience sharpens management judgment. The development of management tools to reduce and identify risk stimulates that process.

II. Findings and Recommendations

A. Safe Return to Flight

1. Space Transportation System (STS) Management

a. **Findings:** NASA has responded positively to ASAP's recommendations and those of the Presidential Commission dealing with reorganization of NASA and the National Space Transportation System, including the reestablishment of an independent safety, reliability, maintainability, and quality assurance function.

Recommendations: NASA's top management should continue to support vigorously the new agency and programmatic organizational structure. The Office of SRM&QA should continue to be provided with the management support and resources it needs to carry out its essential oversight and review function in a fully independent and comprehensive manner.

b. **Findings:** In the investigation of the Challenger accident, it was revealed that a breakdown developed in the Shuttle management structure over the course of time. Explanations for this abound. Nevertheless, the view persists that if the management breakdown could have been averted, vital information pertinent to the decision-making process could have reached responsible management in a more timely manner.

Recommendations: Once a management system for a program has been adopted, especially for long-term projects, it would seem prudent for the NASA Administrator to be apprised periodically of its functioning to ensure that changes in personnel and program direction have not resulted in deterioration of the management structure.

c. **Findings:** The STS is a complex system with many R&D-like characteristics. To employ the system so that there is an acceptable level of risk requires much effort and vigilant attention to detail.

Recommendations: NASA should adopt the goal of using the STS only in those circumstances where human presence in space is needed for mission success. Otherwise, access to space should be gained by using unmanned expendable rockets. Given the expected long-term requirements of the Space Station and other space projects of national importance, the need to begin development of an unmanned heavy lift vehicle is clear.

These initiatives should be part of a long-term comprehensive national space policy that sets clear objectives, determines the best way to accomplish these objectives, and then commits the United States to a realistic schedule and budget.

d. **Findings:** The reevaluation and recertification of all hardware and software systems on the STS, has produced an extremely heavy work load related to launch processing including more paperwork, many modifications to existing systems, and a greatly expanded test program.

Recommendations: NASA, the Shuttle Processing Contractor (SPC), and supporting contractors must exercise the most intensive and unrelenting scrutiny to prevent human error from occurring. In particular, the natural tendency to sign off routinely on complex documents approved at lower levels, shortcut test procedures, or otherwise work around nagging problems must be avoided at all costs.

2. **Reassessment of Risk**

Findings: NASA and the STS contractors have been redoing the FMEA's, CIL's and hazard analyses for all elements of the Shuttle system. We found that, although there were great differences in the specific techniques and data management employed by different organizations, the work was thorough and of high quality. Only a limited number of new failure modes were uncovered in the original designs. There were, of course, new modes identified for designs that had changes incorporated or planned. One result of the rework is that the number of Criticality 1 and 2 items increased dramatically. This occurred primarily because of new ground rules as to levels at which components would be addressed.

NASA is considering various techniques for prioritizing the CIL so that the "highest risk" items can receive the highest levels of attention. The ASAP strongly supports this concept. A more definitive prioritization for such risk management purposes would require a more quantitative methodology to establish safety-risk levels.

Recommendations: (1) NASA should take steps to establish uniform methodology for conducting FMEA/CIL/Hazard Analyses for the agency as a whole. (2) In addition to the above, NASA should develop and implement a consistent method of prioritization of items in the CIL so that appropriate attention can be given to the greater risks. (3) Data developed from the FMEA/CIL/Hazard Analysis process should be organized in such a fashion that it provides the deciding authority with information permitting him or her to assess the risk and make informed decisions.

3. **Design, Checkout, and Operations**

a. **Findings:** Mobile Launch Platform stiffness data. The pre-launch and lift-off loads data have been found to be inadequate owing to new Mobile Launch Platform (MLP) stiffness test results.

Recommendations: The Solid Rocket Booster hold-down post, struts and attachments can be instrumented properly and data recorded during static ground tests, firing tests and actual launches. The recorded data should then be correlated with the calculated data obtained from analysis.

b. **Findings:** Flight evaluation, product improvement and ground testing. Valuable and much-needed data should be obtained from the Solid Rocket Booster flight articles, especially the first flight (STS-26).

Recommendations: A comprehensive program of measurement in flight, inspection of recovered motors and assessment of results should be made for each STS flight. The flight evaluation program should provide for design and production evaluation. The hardware from the first several flights can be used in ground tests such as the Joint Environmental Simulator (JES), Nozzle Joint Environmental Simulator (NJES), and Transient Pressure Test Article (TPTA) to obtain valuable data for evaluation of solid rocket motor re-use.

c. **Findings:** Prior to the STS 51-L accident, there was no cross-reference listing between the operational maintenance requirements specifications document (OMRSD) and the critical items list (CIL). Since the accident, an OMRSD/FMEA/CIL matrix has been generated to help ensure that a focus is kept on all critical items in every step of the processing procedure. One of the short comings in the procedures prior to the 51-L accident was the lack of traceability of OMRSD requirements to the operations and maintenance instructions (OMI). An operations and maintenance plan (OMP) is now in use to provide this traceability. A closed-loop requirements accounting system is expected to be in place for STS-26R. This will be a partially manual system for STS-26 but is expected to be fully automated by February 1989.

Recommendations: NASA should continue its efforts to establish clear-cut and uniform policies for the Shuttle Processing Procedures and for the flow of all evaluations top-down as well as bottom-up in a consistent and rational manner.

d. **Findings:** The content and format of the launch commit criteria document are being improved significantly. The format change will make it easier to use. In addition to these changes, the command chain during the countdown has been modified to include a "Mission Management Team" to whom the Launch Director will report. There is a concern that no clear distinction is being made between a "redline" and other criteria whose values are, advisedly, subject to interpretation or evaluation.

Recommendations: Clear, unambiguous distinctions should be made in the Launch Commit Criteria between "redlines" and other parameters monitored during launch operations.

B. Safety, Reliability, Maintainability and Quality Assurance Programs

1. General

a. **Findings:** The restructured SRM&QA organization and operational mode appears to meet the recommendations made by the Presidential Commission, the Congress and the Aerospace Safety Advisory Panel and the internal NASA working groups. The policies and plans promulgated by the Associate Administrator/SRM&QA are being implemented by the NASA centers. There is a new team spirit evolving throughout the SRM&QA world within NASA and its contractors that bodes well for the future.

Recommendations: Official direction, through an appropriate document(s), should be provided to all programs/projects on the decision process for risk decisions. Without such direction for each specific program/project, risk decisions will not be made with a commonly understood and agreed-upon definition of the factors pertinent to the decision. The AA/SRM&QA should ensure that implementation of directed SRM&QA activities are conducted in an orderly, thorough and timely manner to support the various milestones set by program/project offices.

b. **Findings:** NASA has successfully instituted a variety of new procedures and reports to ensure and monitor safety. These are being given much attention in the efforts to resume STS flights. As regular Shuttle flights resume and become more routine, there is a danger of complacency setting in.

Recommendations: Because there is danger of complacency setting in, it is recommended that NASA review and audit the safety assessment process implementation on a periodic basis. Particular emphasis should be placed on the quality of the information reaching decision-makers. A regular review of the process will help managers discriminate between meaningful changes in system safety and unanticipated alterations in the reporting process.

c. **Findings:** New NASA Management Instructions and Notices related to risk assessment and risk management policies are being developed. These instructions provide important new thinking and enabling policies that could lead to a more comprehensive and objective safety-risk management methodology for NASA. As yet, there is no organizational or functional structure for systems safety engineering that could implement effectively such a comprehensive program.

Recommendations: The ASAP recommends that (1) NASA complete NASA Management Instructions and Notices and their implementing handbooks and promulgate them as soon as possible. (2) NASA develop as rapidly as possible a more integrated systems safety engineering functional structure (possibly within the Headquarters SRM&QA organization with similar organizations at the centers).

d. **Findings:** The majority of NASA's safety efforts have focused on hardware reliability and the training and preparation of astronauts and pilots. There are potential safety problems that can arise from human errors at any level of the system because of its inherent complexity.

Recommendations: More emphasis should be placed on the study of potential design-induced human errors.

C. Space Shuttle Element Status

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

a. **Findings:** The SRM existing aft skirt (Fig. 1) failed 14 percent below ultimate design loads in the STA-2B static test. The latest IVBC-3 loads are slightly higher than the loads used in the STA-2B test and the redesigned aft skirt strength is only a slight improvement over the existing aft skirt. Thus, the redesigned aft skirt has not met its objective and the final loads, based on new Mobile Launch Platform (MLP) stiffness data, have not been determined.

Recommendations: Perform a series of tests on an instrumented aft skirt to determine the effect of various combinations of loadings on the stresses in the critical post/weld area. Test the aft skirt to destruction to provide information for variability in loads and material strength between aft skirt units. These test results should provide a basis for determining further action.

b. **Findings:** The unvented field and case-to-nozzle joint designs were chosen to prevent hot gases from reaching the case walls. The non-verifiable bonded insulation and barrier seals in the joints prevent the chamber pressure from reaching the primary O-ring seal and causing erosion or blow-by during motor operation, (see Figs. 2 and 3). There is a remote possibility, under the worst scenario condition, that pressure will reach the primary O-ring seal for the field joint and the secondary O-ring seal for the case nozzle joint, but will not leak enough to cause a catastrophic failure. The criteria and tests now planned should provide the necessary margins in the solid rocket motor for successful restart of Space Shuttle flights, as noted in Figure 4.

Recommendations: Establish the criteria for nominal (non-flawed) joints and flawed joints as a part of the CEI specifications. Conduct a few NJES tests with a flaw to the secondary O-ring seal to assess the radial bolt seals in the case-to-nozzle joins. Conduct a full-duration hot-firing motor test with a flaw path to the primary O-ring seal with pressure transducers at the leak check ports before the first launch.

2. External Tank

Findings: No significant findings.

Recommendations: None

3. Orbiter

a. **Findings:** 6.0 Loads/Stress Analysis. The latest 6.0 loads/stress analysis shows negative margins in structural elements of the wing, vertical tail, mid-fuselage and attachments. The wing loads, vertical tail loads, and fuselage thermal gradients are also considerably larger than for the original design. The panel has repeatedly recommended calibration program for the Orbiter to determine accurate loads.

Figure 1
STA-2B AFT SKIRT FAILURE

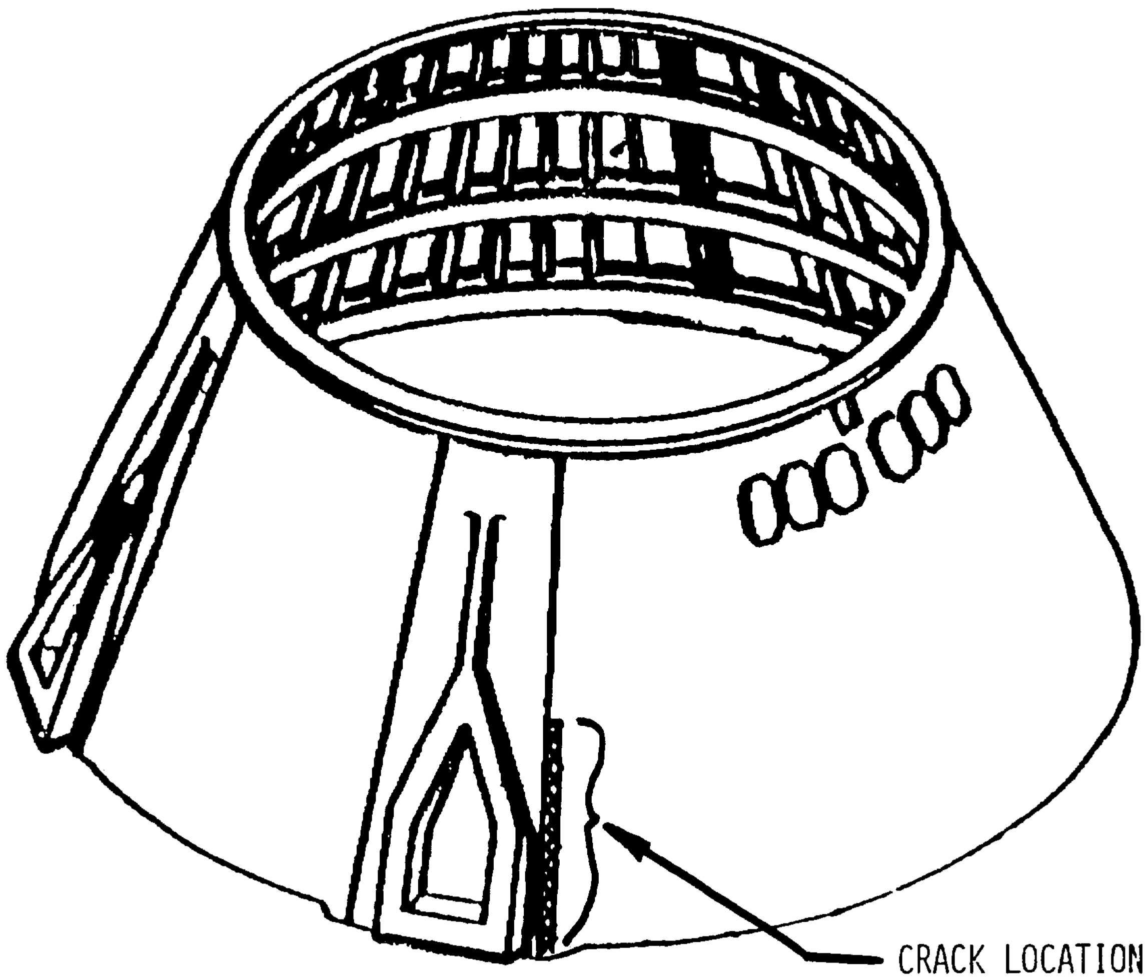
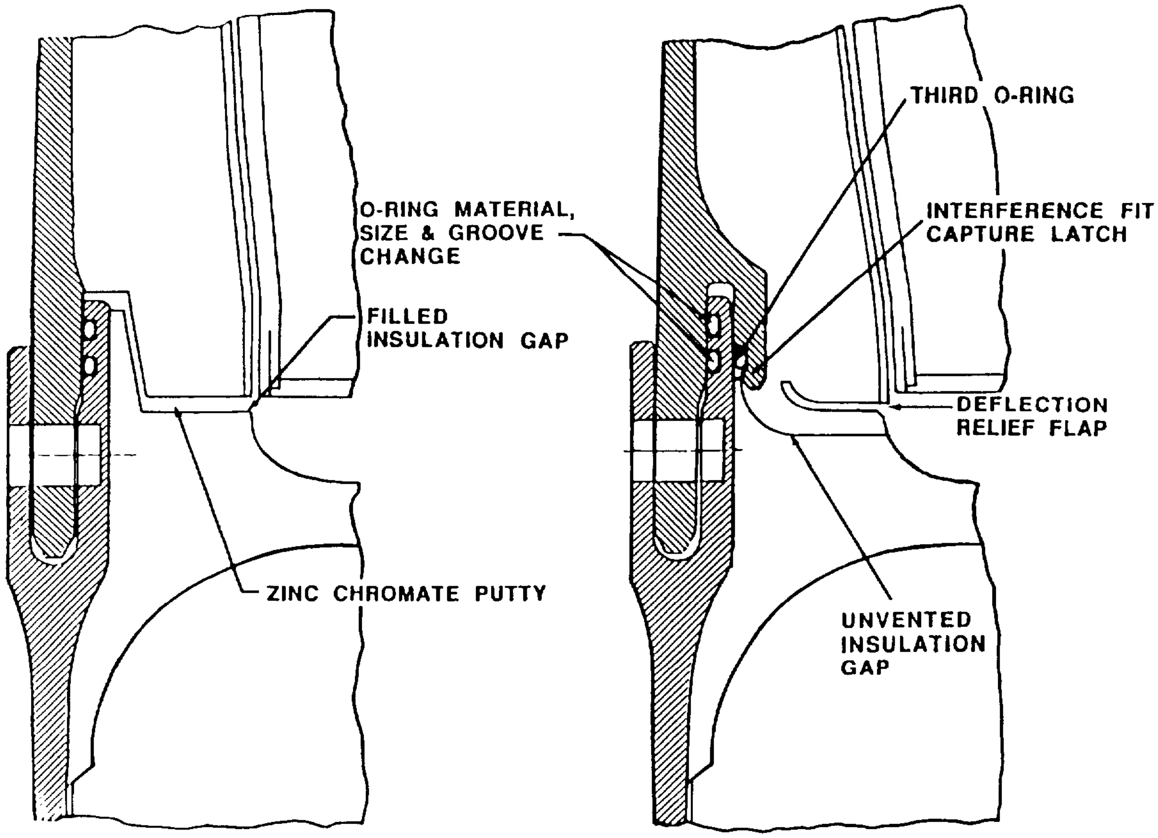


Figure 2

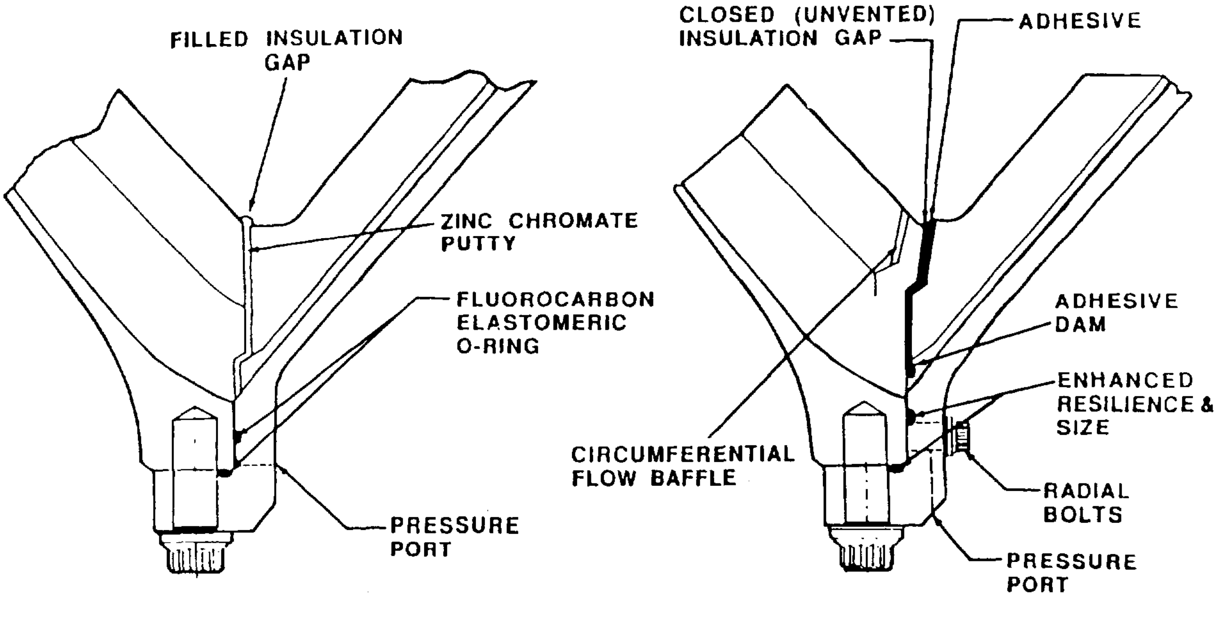
FIELD JOINT METAL AND INSULATION



Original Design **New Design**

Figure 3

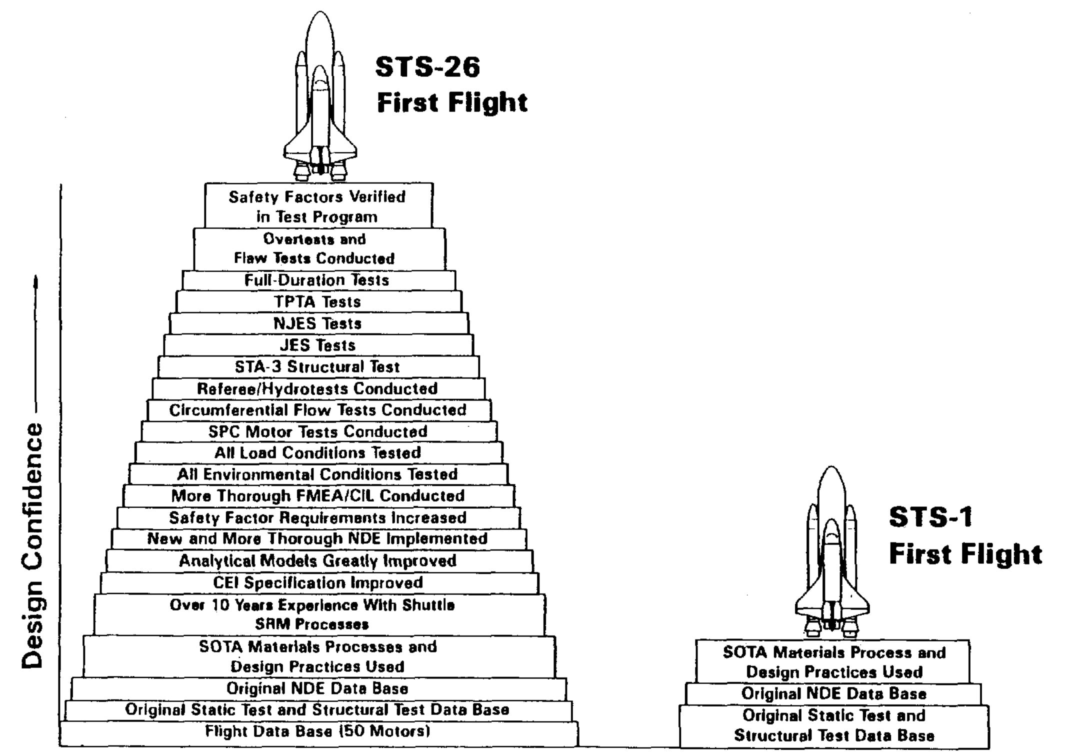
NOZZLE/CASE JOINT METAL AND INSULATION



Original Design **New Design**

Figure 4

Is Total Test Program Adequate for First Flight?



Now it is even more important to determine accurate loads because negative margins have been determined in the 6.0 loads/stress analysis requiring limitations to be placed on the STS operating envelope.

Recommendations: Perform a comprehensive strain gauge calibration program on OV-102 during its downtime so that accurate actual loads can be determined on the wing and vertical tail during flight. In addition, compare stresses and thermal gradients at critical locations in the wing, vertical tail, and mid-fuselage using data from analyses, ground tests, and flight tests.

b. **Findings:** Periodic Structural Inspection and Maintenance Program. The Orbiter structure and thermal protection system is subjected to diverse loads and environments that must meet a long service life. This requires a well-planned periodic inspection and maintenance program to evaluate the structurally significant elements especially in light of the high stresses shown in the stress analysis using the latest 6.0 loads.

Recommendations: The inspection and maintenance program should identify structurally significant items based on safety and economic factors. NASA should develop and publish a plan for periodic inspection and maintenance of the Shuttle's structure. The plan should be developed by cognizant personnel within the Shuttle program, assisted by commercial airline personnel experienced in periodic inspection and maintenance of commercial air transports. The program for periodic inspection and maintenance, when approved, should become a mandatory part of the requirements of each vehicle.

c. **Findings:** Shuttle Computer System Upgrade. The risks associated with human factors and the software testing schedule are likely to substantially exceed those of the hardware.

No hazards analysis that properly studies all factors leading to multiple computer failure has yet been performed.

Recommendations: Before any consideration of overturning the 5/0 (5-new/0-old) decision, a hazard analysis is required. This hazard analysis should include computer reconfiguration procedures and the implications of an increased testing program for a 4/1 (4-new/1-old) configuration.

d. **Findings:** Auxiliary Power Units, (APU's). The ASAP recently was advised of the extent of turbine blade cracking in the APU's. The situation is being explored in depth by the concerned centers as well as by Rockwell International and the Sunstrand Corporation. At this time, a rational explanation as to the cause of such blade cracking has not been made. Further work is being done to understand the cause(s). In addition, some modifications to the turbine blade configuration are being considered. Worst-case situations for failure put this item in Criticality 1 although such situations have a low probability of occurrence.

Recommendations: NASA should review the retention rationale for operation of the APU's in light of the recent history of turbine blade failures to determine its future course of action. NASA should emphasize evaluation of cause and development of possible corrective action for blade cracking on an accelerated basis.

4. Space Shuttle Main Engines (SSME's)

Findings: The engine to be incorporated in the next STS flight and in all subsequent flights will be based on the Phase II engine configuration ultimately planned for certification at 109 percent of rated thrust. A number of significant problems that were identified during development testing of Phase II hardware or as a result of the new FMEA and HA have been resolved during 1987. NASA plans to incorporate about 38 changes in the next flight engines. Of these, 21 are defined as mandatory. The contractor continues to work on the blade and bearing problems. The situation is being controlled by limiting the hardware part life-usage.

Recommendations: The contractor should continue his efforts to increase the useful life of SSME blades and bearings.

5. Launch, Landing and Mission Operations

a. **Findings:** Work Environment at KSC. The work environment at KSC associated with launch processing can induce human error. NASA, the Shuttle Processing Contractor (SPC), and support contractors have generally recognized this fact through such actions as tightened discipline and accountability, improved worker safety programs, strict guidelines to control overtime, better training programs, and the better availability of spare parts and related equipment. However, there are still occasional reports of schedule pressure and the associated potential for error or acceptance of excessive risk.

Recommendations: Top management at NASA and the SPC should exercise continuing vigilence to ensure that a satisfactory working environment is achieved and maintained at KSC. The ASAP's dictum of "Safety first; schedule second" must be observed by each and every person involved in the STS program.

b. **Findings:** Capacity to Handle Work Load. Despite the presence of many skilled and motivated workers at KSC, there still exist problems of recruitment in key disciplines (e.g., data systems, hypergol servicing), retention, training, and morale.

Recommendation: High priority should be placed on resolving human resources problems at KSC in order to strengthen the work force and reduce the likelihood of human error.

c. **Findings:** There were signs that after a series of successful STS missions there was pressure to increase the frequency of missions, reducing the time available for Shuttle Mission Simulator testing. Also, the tracking of the training issues associated with CR's became lax. The staff responsible for flight procedures is very much aware of the importance of its work and dedicated to doing a good thorough job. The formal protocols in place for initiating and tracking change requests (CR's) are also extensive and carefully thought out. Nevertheless, there are areas of serious concern:

- o NASA has not consistently documented software design rationale.

- o The safety of the Shuttle computer system is strongly influenced by the crew procedures used for its operation and reconfiguration.

Recommendations: NASA should take steps to ensure proper documentation of software design rationale.

Human factors considerations should be included in evaluating the ad hoc procedures generated in response to anomolous conditions arising during flight. Any proposals to reduce training time should be thoroughly reviewed.

d. **Findings:** General Memory Changes. The Shuttle software system includes the capability for general memory changes, referred to as "gmems". A ground base can, through telemetry, specify an address in the general memory of the computer and new contents for that address. Changes also can be made from on board the Shuttle. With this mechanism, either program instructions or program data can be altered, but only in controlled ways. General memory changes are made with moderate frequency during Shuttle flights. The protection mechanisms in place seem better than initially reported by contractor personnel, but nevertheless fall somewhat short of full security.

Recommendations: In view of the fact that errors have occurred during gmems in spite of significant precautionary measures, the procedures for making them should be reviewed, and changes for increasing safety sought. Consideration should be given to re-verifying a gmem after it has been made.

e. **Findings:** There has been a practice in the past of allowing very late software change requests, even only days before a flight, that involve flight system constants. When change requests are acted upon this late, there is a potential that normal testing procedures and checks and balances will be less extensive than normal.

Recommendations: The procedures for approving late Software Change Requests should allow for appropriate testing.

D. Space Station Program

1. Space Station Computing Systems

Findings: The complexity of the Space Station computing system is far beyond that of any computer system NASA has yet had to deal with. Systems integration techniques for such large systems are not well understood, and many other large organizations have underestimated the magnitude of the systems integration task. There is concern that NASA is making these same kinds of assumptions.

The requirements documents for the Space Station Data Management System (DMS) state numeric values for a number of important parameters giving neither a rationale for the values chosen, nor a reference to secondary documents containing the rationale.

It appears that the Space Station does not have a formal procedure in place for computing equipment upgrading nor do work packages make such allowances for the future.

Recommendations: Review the resources allocated to the computer/software integration task and ensure that resources are adequate.

NASA should develop a rationale document for Space Station computing requirements. This should include a consistency check between requirements.

NASA's planning should recognize the need for an upgrade plan for both hardware and software. This should include software tools such as compilers.

2. Crew Emergency Rescue Vehicle (CERV)

Findings: There is a good deal of attention being paid to crew safe-haven and crew rescue operations at this time. There appears to be a desire to utilize a CERV as a multipurpose vehicle beyond that required for crew rescue.

Recommendations: There should be a CERV and it should not be designed as a multipurpose machine. Simplicity and availability are the keys to its effectiveness and minimum cost. Fundings for the CERV may be delayed but the requirement for it should be specified now.

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

Findings: Considerable amounts of EVA will undoubtedly be required for maintenance and operation of the Space Station. The current EVA suits used on the Space Shuttle are inadequate for Space Station activities as they require excessive prebreathing time, are not very flexible and are limited in their reusability for multiple EVA's.

Recommendations: The ASAP commends the work now being done and that which has been accomplished on the development of a new EVA suit by both JSC and Ames Research Center. The Panel urges the continued development of a new higher pressure suit that is capable of multiple reuse without requiring major refurbishment and which has greater flexibility in its use.

Target dates for the selection of an appropriate design and its implementation into production should be commensurate with the need for the assembly of the Space Station and its initial operation.

E. Aeronautics

1. X-Wing Flight Test Program Structure

Findings: NASA structured a very comprehensive and safe program for flight testing the RSRA/X-Wing aircraft notwithstanding a major programmatic planning error in that the X-wing program was committed to the full vehicle flight test phase prematurely. Verification of the predicted aerodynamics, structural dynamics and control system design parameters of the full-scale X-wing rotor system were not established by tests prior to the commitment to the complete vehicle flight test program. This resulted in large expenditures of resources associated with the RSRA flight vehicle design modifications, which in turn resulted in the cancellation of the program for lack of resources to solve the rotor system design problems (subsequently discovered). To continue the program without the design changes would have involved high risks.

Recommendations: A high-level technology demonstration airplane panel should be formed to advise in the formation and structuring of X-airplane programs. The initial phase of such programs should concentrate on the design and manufacturing techniques of the components that incorporate the technology challenges. The RSRA/X-wing program can serve as a good "lesson learned."

2. X-29 Flight Test Program Risk Avoidance

Findings: The X-29 flight test program is a credit to NASA. There is no question that safety has been given the highest priority. However, it is noted that the fundamental flight verification objectives that were originally set for the aircraft are somewhat diminished, to a large extent because of the reluctance to expend the relatively few additional resources needed to safely expose the aircraft to the higher risk flight regimes. It also is noted that some risks are inherent in research (X) aircraft flight testing and they must be balanced against the objectives of the program. The fundamental purpose of these programs is to discover and identify unknown problems before making a commitment to the technologies in an operational aircraft. A "very near zero risk" philosophy obviously makes for a safer program but can entail large resource requirements and therefore can seriously impede program implementation. The Nation needs to remain competitive in aeronautics and must be willing to accept some risk to achieve this goal.

Recommendations: A review of the objectives of the X-29 program should be conducted to redefine the flight test program and its resource requirements in order to derive the most benefit commensurate with the more than $150 million that has been invested into the program to date, and also commensurate with <u>acceptable</u> flight safety risks.

3. **Flight Recorders**

Findings: The ASAP has previously recommended that NASA develop a flight recorder that could be used on its administrative and training aircraft so that, in the event of an incident or accident, data would be available for assistance in evaluating the cause of the accident or incident. NASA has not proceeded to implement the recommended flight recorder program.

Recommendation: The ASAP continues to recommend that flight recorders should be developed for training and administrative aircraft.

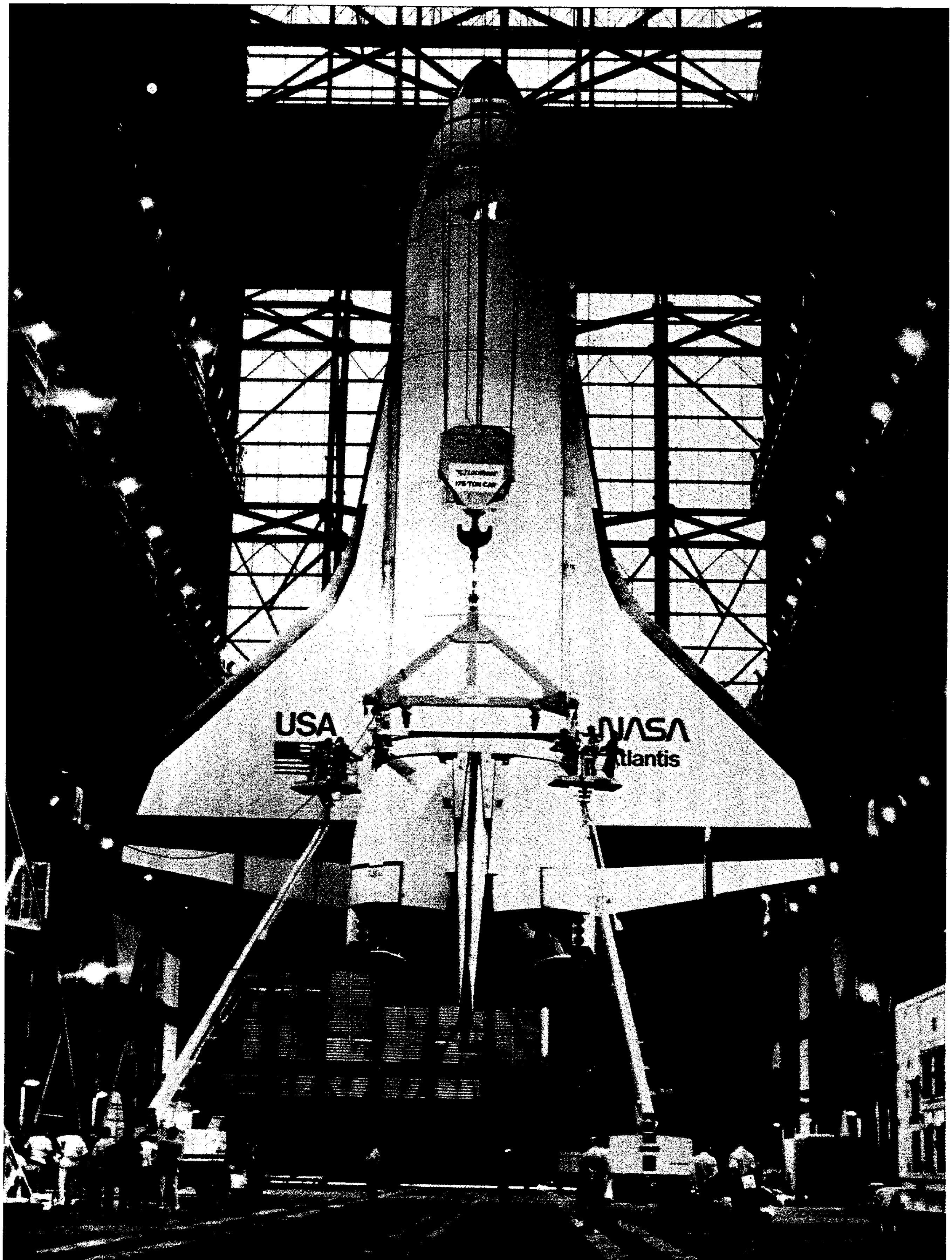
4. **Aircraft Operations and Safety Management**

Findings: Flight operations within NASA continue to be held together by the strong, competent individuals who run these operations at the NASA centers. The Intercenter Aircraft Operations Panel is the bond as well as the mechanism by which coordination takes place among centers and Headquarters.

NASA has a Headquarters Aircraft Management Office which is charged to integrate flight operations and coordinate and establish flight operation policies. The SRM&QA is charged with proper implementation of these policies.

There is not a clear understanding as to who is responsible for what in the area of flying safety. This lack of clarity is evidenced in the less than clear authority which appears to reside in SRM&QA in this area.

Recommendations: Spell out clearly the responsibilities and authorities of the Headquarters Aircraft Management Office and SRM&QA regarding flying safety thereby eliminating the confusion relating to the division of safety responsibilities.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III. Information In Support of Findings and Recommendations

A. Assessment of the Safe Return to Flight Strategy

1. Space Transportation System (STS) Management

NASA has responded positively to the recommendations of the Presidential Commission dealing with the organization of NASA and the National Space Transportation System program management organization. As noted in ASAP's 1986 report, two changes have been of special importance in achieving improvements:

- o The creation of an Associate Administrator for Safety, Reliability, Maintainability and Quality Assurance (SRM&QA), reporting to the NASA Administrator, has established this essential function on an equal footing with other line responsibilities and brought the SRM&QA functions at the NASA centers under the direction of Headquarters.

- o The creation of a Director, National Space Transportation System, reporting to a new Associate Administrator for Space Flight and supported by a Deputy Director for Programs and a Deputy Director for Operations, has established programmatic control by Headquarters and strengthened day-to-day leadership of the Space Shuttle program.

These steps, taken in the aftermath of the Challenger accident, remedied two serious organizational weaknesses: lack of clear direction and accountability in program management and lack of an independent and autonomous safety, reliability, and quality assurance function. With these changes the primacy of NASA Headquarters had been established with the NASA centers carrying out essential, but subordinate, responsibilities.

The ASAP also has found that the new management teams in place at JSC, MSFC, and KSC are functioning effectively. Communications among Headquarters and the centers JSC, MSFC, and KSC, have improved. The Management Council of STS program managers and center directors has been reactivated, leading to a more pronounced sense of teamwork in managing the complex recovery effort. Consequently, "turf" battles between the centers have declined. Although none of these changes, in themselves, will ensure a successful recovery program, they provide the foundation on which a successful program can be achieved.

In addition, the autonomy and independence of the SRM&QA function at Headquarters has been strengthened and is no longer linked by organizational design or management philosophy to STS program management at the centers. In meetings held this past year with ASAP members, the Administrator has demonstrated both his reliance and confidence in the strengthened SRM&QA organization headed by George Rodney. The ASAP strongly shares these views.

The decision to revoke all STS waivers in the aftermath of the Challenger accident and initiate a sweeping review of failure modes and effects, critical items, and hazards has produced an extraordinary amount of data and information that must be evaluated and processed in a valid and reliable way. This process, in turn, has resulted in many design changes to both hardware and software with a corresponding increase in the test program prior to reflight. As a consequence, the complexity of launch processing is greater than ever, placing a much heavier burden on the Shuttle Processing Contractor (SPC), the supporting development contractors, and NASA. The ASAP remains concerned with the capability of these organizations to handle this heavy work load in a manner that leads to an acceptable level of risk.

For example, the preparation of many key documents, such as Shuttle Processing Instruction (SPI's), Operations and Maintenance Instructions (OMI's), Operations, Maintenance, Requirements and Specifications Documents (OMRSD's), Test Preparation Sheets (TPS's), other Work Authorization Documents (WAD's), and Problem Reports (PR's), will continue in the coming months, in some cases right up to the scheduled launch date. These documents are extremely complex (e.g., OMI's average about 200 pages, requiring 15 approvals, and there are 530 OMI's for STS-26.) Interviews held by ASAP members with floor workers at KSC disclosed, for instance, that problems are routinely encountered in carrying out OMI's and WAD's resulting in the need for extensive and continuing rework by design engineers. Sometimes the deviations from approved drawings arising from the resolution of these problems are not recorded promptly (although the SPC is working hard to correct this problem).

This situation of having to deal with a large number of highly complicated actions of this sort, all carried out by humans and thus subject to error or misinterpretation, calls for the most intense and unrelenting scrutiny by NASA management, the SPC, and support contractors. In particular, NASA and the SPC must be alert to all tendencies to shortcut, accept routinely, or otherwise work around the testing and approval processes that accompany this extraordinary work load.

2. Reassessment of Risk

Following the 51-L accident, NASA reluctantly admitted to having followed a "schedule-oriented" and budget-constrained philosophy that fostered the unwise postponement of certain Shuttle modifications (such as those for the SRM field joints) that would have enhanced the safety of the system and, probably, could have avoided the accident.

Stung by the tragedy and, perhaps, over-responsive to the criticisms of the Presidential Commission and other oversight groups, the agency undertook a massive re-evaluation of the safety and risks of each element of the Shuttle and the STS as a whole. It is not at all unusual or unreasonable for an organization like NASA to undergo a prolonged period of technical and philosophical introspection after a tragedy like that of 51-L. The program that it undertook was designed to leave no stone unturned, even if a particular stone had been turned over many times before. As a consequence, the agency finds itself conducting a large number of review activities that consumes massive amounts of manpower both within NASA and the contractor organizations involved in the STS program. Among the reviews being conducted are those of the Failure Modes and Effects

Analyses (FMEA), the Critical Items Lists (CIL) that result from the FMEA and the Hazard Analyses which use as a part of its input the results of the aforenoted analyses. The results of all of these lead to the Risk Analysis whose output is intended to permit decisions concerning acceptability of risks that remain.

Several members of the ASAP have participated in the National Research Council (NRC) committee established to provide independent oversight of the review activity noted above. The findings of this Shuttle Criticality Review and Hazard Analysis Audit Committee (SCRHAAC) are expected to be published by early 1988.

3. Failure Modes and Effects Analyses/Critical Items Lists Review

A FMEA and the resulting CIL are design tools used to identify potential failures in a design and to assess the consequences of such failures. The consequences are categorized in the CIL according to severity. If possible, the design is modified to eliminate the potential failure mode or to provide functional redundancy so as to eliminate a "single-point failure." If it is not possible to make such design changes, procedural steps such as special inspections, special tests, and larger safety factors are incorporated in the manufacturing and operating procedures so as to decrease the probability of occurrence of the particular failure mode. Such steps are documented in the CIL as the "Retention Rationale" which, if approved, permits the design to be used. It must be emphasized that all these steps are intended to precede the manufacture of any hardware and that it is intended to re-visit the process if any modifications to an approved design are proposed.

The so-called "FMEA/CIL" review activity that NASA undertook shortly after the accident involves not only failure mode and critical item identification as described above but includes hazard and risk analysis as well. Many have argued that the latter two items should have been treated separately but such niceties are difficult to observe at this stage, the die having been cast. It would be unwise to interrupt the activity and insist on a more "pristine" approach. The ASAP has chosen to observe and monitor the activity to ensure that it is being carried out as planned and is achieving its objectives.

As of this writing, a large backlog of FMEA/CIL output items exists. There is a reasonable chance that all can be dispositioned in the manner prescribed prior to the date scheduled for the next flight. Program management has expressed confidence that this can be accomplished by the spring of 1988. They cite that these activities have been completed for the External Tank and the SSME, the documentation for the SRM is almost finished and that the activity for the Orbiter is well in hand.

When the so-called "FMEA/CIL" activity was initiated, the STS program office directed that all previous analyses be re-evaluated and that all "waivers" that had previously been granted to permit flying of Criticality 1 and 1R items were canceled and would have to be resubmitted for approval. Changes in the rules for the conduct of FMEA/CIL activities were also instituted. These are shown in Table I and Figure 5. A key change to be noted is the interpretation of a requirement that results in the analysis being conducted at a level lower than the "component." An inherent consequence of this is that the number of "Critical Items" has increased significantly. This could give the

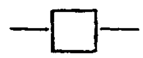
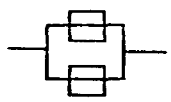
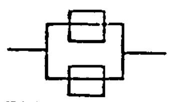
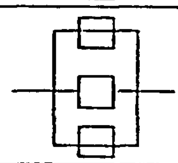
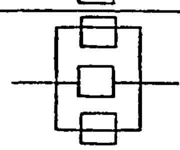
Table I

Major Differences in Pre- and Post-STS 51-L Failure Modes and Effects Analysis/Critical Items List (FMEA/CIL) Activity

SUBJECT	PRE-STS 51-L	POST-STS 51-L
LEVEL OF ANALYSIS	Program required analysis to be conducted to component level.	Program requirements continue to require analysis to component level, however, interpretations have resulted in a lower level detail of analysis.
INDEPENDENT CONTRACTOR REVIEW	There was no independent contractor.	Independent contractors were assigned by each element project office (EPO) to conduct separate evaluations.
INSTRUCTION DOCUMENT	There was no level II FMEA/CIL instruction document. Instructions were controlled individually by project elements.	NSTS 22206, "Preparation of Failure Modes and Effects Analysis (FMEA) and Critical Items List (CIL)," was baselined and a directive issued for each EPO to implement the document in its respective project.
LEVEL I REVIEW	Level I delegated their CIL review responsibility to Level II in February 1984.	Level I is now actively involved in all CIL waiver boards.
CIL BASELINE	CIL's were baselined at Level III and published by Level III.	CIL's are baselined at Level II, and are published and controlled by the Management Integration Office.
LEVEL II PARTICIPATION	Limited "Level II" organization.	Expanded Level II role and organization.
"OPERATIONS" PERSONNEL PARTICIPATION	Reviews did not include Mission Operations Directorate (MOD) personnel or astronaut participation.	Reviews include MOD (new "Operational Use" paragraph) and astronauts. MOD is preparing a cross-reference matrix between CIL and mission rules. Crew procedures which are used to support CIL retention rationale will require Level II approval.
CIL APPROVAL PROCESS	Waiver submittals were limited to changes in critical item redundancy screens.	NSTS 22206 requires resubmittal of CIL waivers for items having changes in retention rationale; i.e., change in future history, inspections, ground turnaround checkout, etc.
LINE REPLACEABLE UNIT (LRU) IDENTIFICATION	LRU identification was not required on CIL pages.	LRU identification is now required. LRU listing will be used by KSC to establish special procedures for the handling of critical hardware.
PRIORITIZATION	Critical items were measured by severity as indicated by criticality.	A CIL prioritization technique was developed to further categorize and prioritize CIL's and will be evaluated for future continued use
FUNCTIONAL CRITICALITY	Functional criticality was not assessed uniformly across all elements.	A more rigorous assessment and determination of criticality assignments was instituted. The evaluation is more thorough and scrutinizing.
FMEA/CIL EXEMPTIONS	FMEA's were not required on wire harnesses, cables, and electrical connectors.	Exemptions were carefully analyzed and reevaluated for effectiveness and correctness. FMEA's are now required on wire harnesses, cables, and electrical connectors.
WAIVER FORMAT	Waivers were submitted by each EPO using its own format.	A standardized waiver format and presentation format were developed by Level II SR&QA for use by each EPO.
"GENERIC" RETENTION RATIONALE CONCEPT	Retention rationale was listed on each page, even if it was repetitive from page to page.	Generic retention rationale for certain classes of hardware were generated and approved by Level II. This resulted in a more efficient use of data and review time.
OPERATION AND MAINTENANCE REQUIREMENT SPECIFICATIONS DOCUMENTATION (OMRSD)/CIL CORRELATION	Critical items were listed within OMRSD under the applicable paragraph number, but there was no baselined cross-reference listing between the OMRSD and the CIL.	OMRSD/CIL matrix was generated. The matrix is required to be housed in front of each applicable subsystem volume of the OMRSD. The master verification plan was revised to regulate checkout of each criticality 1 and 1R item prior to each flight. More stringent adherence to ground turnaround requirements for critical items has been imposed.
GSE REASSESSMENT OF FUNCTIONAL CRITICALITY	Functional criticality assessment and redundancy screens were applied to LRU's and systems, not to individual components.	Reevaluation and application of functional criticality and redundancy screens to components resulted in criticality 1R waiverable items not previously identified.
SIGNATURE APPROVAL	Change request (waiver) was signed on cover page only by requesting organization.	Each page of the CR (waiver matrix) requesting CIL waivers and listing "information only" items is signed by the appropriate element project manager.

Figure 5

NATIONAL SPACE TRANSPORTATION SYSTEM CRITICALITY CATEGORY DEFINITIONS

FUNCTION / LEVEL OF REDUNDANCY	BLOCK DIAGRAM	CRITICALITY CATEGORY: FUNCTIONAL DEFINITIONS		CRITICALITY CATEGORY: HARDWARE DEFINITIONS
LIFE OR VEHICLE ESSENTIAL / NO REDUNDANCY		1 (CIL)		1 (CIL)
MISSION ESSENTIAL / NO REDUNDANCY		2 (CIL)		2 (CIL)
LIFE OR VEHICLE ESSENTIAL / 2 FUNCTIONAL PATHS		1R (CIL)		2 (CIL)
		PASSED SCREEN	FAILED SCREEN	
MISSION ESSENTIAL / 2 FUNCTIONAL PATHS		2R	2R (CIL)	3
LIFE OR VEHICLE ESSENTIAL / 3 OR MORE FUNCTIONAL PATHS		1R	1R (CIL)	3
MISSION ESSENTIAL / 3 OR MORE FUNCTIONAL PATHS		2R	2R (CIL)	3
ALL NON-ESSENTIAL / ALL LEVELS OF REDUNDANCY		3		3

Redundancy "screens" must be addressed for all functionally redundant hardware items. Determination of "PASS," "FAIL," or "N/A" must be given for all functional Criticality 1R and 2R items. Crit 1,2,3 redundancy screens are left blank.

Screen A: capable of checkout during normal turnaround.
Screen B: loss of the redundancy readily detectable in flight.
Screen C: loss of the redundant hardware items could result from a single credible event, eg., explosion, vibration, shock, etc.

Functional criticality shall be determined by the failure mode effect on the subsystem/mission/crew/vehicle, assuming loss of all redundancy for performing the function.

Hardware criticality (used only for Orbiter and GFE) shall be determined by the worst case singular direct effect of the identified failure mode of a hardware item. This takes into account the availability of redundancy.

(false) impression that the design of the STS is more failure prone than had been previously acknowledged. Obviously, this is more a "paper" problem rather than a real hardware or software problem but the potential for such misinterpretation is real and NASA must take all steps possible to ensure that the public is not misinformed or its resources will have to be expended in defending itself rather than in doing its job.

There is, however, a real problem associated with the rules adopted for the FMEA/CIL review. This concerns the requirement that the scenario used to categorize critical items is to be based on a "worst case" set of circumstances. Application of this rule has led to the identification of several thousand items as "Crit I" (i.e., catastrophic) failure modes. This designation is used despite the fact that there has been an average of two of these "Crit I" failures on each of the flights to date. Everyone is painfully aware of the one "Crit I" failure of the 55 that have been experienced that was, in fact, catastrophic. But the fact that other failures thus categorized did not have catastrophic consequences is indicative of the fact that the criteria employed for such designation are unsatisfactory in that they can direct attention away from the truly catastrophic failure modes.

An obvious approach to resolving this dilemma is a prioritization of the items within CIL categories. This would help to ensure that the more important items receive more intensive treatment. How to accomplish such prioritization in an objective manner is the subject of much debate.

Among the approaches being considered is that of Probabilistic Risk Assessment (PRA) which has been employed in the nuclear industry. This would result in a rating of the Crit I items based on the probability of occurrence. To the extent that a statistically valid data base exists, this is a useful technique. The validity of any probability assessment is based on a statistical analysis of the performance of the item under various conditions. Hence, a large population and many occurrences are needed to provide a suitable data base. For things like electronic and mechanical devices made in large quantity and used widely, probability analysis is an excellent tool. The Shuttle system and, indeed, many of its subsystems and components, does not satisfy the statistical requirements. With only four vehicles and 25 operations, and only unorganized test data, there is no statistically significant data base with which to determine probabilities. Some argue that, without a statistically valid data base, one can assign a probability number based upon the experience and judgment of individuals familiar with the item. This can be done, of course. But this can camouflage the fact that the input is subjective and attribute more credibility to the result than is warranted. It would be better to use an acknowledgedly subjective rating scheme for prioritization than to cloak a rating system in a mathematical purity it does not possess.

Another concern regarding the FMEA/CIL review process is the absence of consideration of the consequences of improper human action such as slow, inadequate or incorrect intervention on the performance of a system. Such human intervention may be accounted for in the Hazard and Safety Analyses. This may be too late in the process as there may be a distinct possibility that such human failings may significantly alter the criticality of a system failure. It is quite conceivable that a Crit 2 hardware failure's consequence can be elevated to Crit I effect because of improper human intervention. It is recognized that examining all such conjunctive failures would be an impossible undertaking. Nonetheless, the ASAP believes that some attention must be devoted to the joint occurrence of hardware and human failures.

The FMEA/CIL review is a good means for introspection. It forces all the groups involved to return to the early stages of the STS design activity and to re-evaluate the design approaches and decisions. It also has the advantage that now actual test and flight experience can be incorporated into the evaluations. Nonetheless, it is imperative that it be recognized that the existence of a process of evaluation is by no means a guarantee that problems of the sort that led to the 51-L accident will all be eliminated. The ASAP has noted in the past that concentration on process rather than product can lead to unwarranted confidence. The key to safety is unremitting vigilance on the part of system designers and managers.

An area that requires particular attention is that of the "Risk Retention Rationale." It can be argued that, in the past, some of the retention rationales have been written so as to justify why a design should not be changed rather than as an objective treatment of the pros and cons of the risks and options. The ASAP suggests that NASA should establish guidelines for the preparation of retention rationales that ensure that a thorough and objective evaluation of the situation will be provided to the individual or body that must decide whether or not to accept a risk or to require the implementation of a design change.

Despite the concerns noted above, comfort can be drawn from the results of the FMEA/CIL re-examination to date. The CIL has increased in size but this can be attributed to the changes in ground rules rather than to the discovery of previously unknown failure modes. The reviews have strengthened the Shuttle system and, coupled with the reorganization and stregthening of the management system, increase the probability of success of the program. The lessons learned in the process should also be a boon to the Space Station program.

One caution must be stated, however. It must be recognized that because of the hardware, software and procedural changes being incorporated, the system requires thorough retraining of both ground and flight crews. A definite cut-off date for changes must be established and observed so that sufficient time for training with the revised systems is available.

4. Hazards Analysis

Hazards analysis is a natural follow-on to a FMEA/CIL activity. Often, the same technical personnel who are engaged in the FMEA/CIL activity are called upon to participate in the Hazard Analysis because of their familiarity with the hardware, software and functional interactions of the several sub-systems that constitute a system like the STS. This is true of the Shuttle program and, as the FMEA/CIL activity is just drawing to a close, the Hazard analyses are in their early stages. A Hazard Analysis starts with an undesired event, such as an explosion, fire or structure failure or an accident scenario and uses FMEA output as source information. Hazard analyses come in many forms as illustrated in Table II.

Table II
HAZARD ANALYSIS

Type of Analyses	Program Phase	Why Used
Preliminary Hazard Analyses	Concept/Design and Development	Allows top-level hazard definition by generic hazard and lends itself to expansion as the program progresses.
Fault Tree Analyses	Concept/Design and Development/Operations	Allows in-depth analysis of sele critical areas and and relationships among events.
Sneak Analysis	Design and Development Phase (When Detail Design Available/ Operations	Allows identification of latent failure conditions that may allow undesired or prevent desired conditions.
Software Hazard Analysis	Design and Development Phase/Operations	Allows independent verification software code implements approve requirement.
Operations Hazard Analysis	Design and Development Phase/Operations	Allows identification of hazardous conditions during operations caused by such things as out-of-sequence operation, omitted steps, and in action of elements.
Mission Level Hazard Analysis	Design and Development Phase/Operations	Allows detail analysis of mission events consider-in hardware, crew/ ground operations, and software actions.
Mission Safety Assessment	Design and Development Phase/Operations	Allows assessment of previously ducted analyses for completeness accuracy, provides analyses and visibility of hazards by mission and event.

For the Shuttle, the hazard analysis guidelines and methodology are provided in a JSC document (No. NSTS 22254) "Methodology for Conduct of NSTS Hazard Analyses." With these ground rules, there will be two inherent differences in the pre- and post- 51-L results. There will be more detail and there will be more hazards whose risks must be assessed before either being accepted or design or procedural changes are determined to be required for alleviation of the hazard or risk. From the material presented to the ASAP thus far, the Hazard Analysis effort appears to be well designed albeit it has "growing pains" similar to those experienced by the FMEA/CIL review. This, too, is a massive effort and will strain the resources of NASA and its contractors. The ASAP will follow the review with great interest.

5. Design, Checkout and Operations

The great complexity of the launch processing function requires a combination of highly trained, highly motivated, and reliable workers--managers, engineers, technicians, quality assurance inspectors--and reliable data management systems. The ASAP has met on several occasions with a broad cross-section of floor workers and has been impressed with their qualifications and dedication. At the same time, ASAP is concerned with their reports of continuing problems of morale in certain areas, the departure of some highly skilled technicians to seek other employment, and the difficulty of finding suitable replacements in some job categories (e.g., hypergols, non-destructive testing). NASA and the SPC are aware of these problems and are working to correct them. However, human resources are critical in achieving a successful return to flight. There is a continuing need to focus on problems, identify areas of weakness, and seek viable solutions.

In the longer run, the issue of human resources is likely to grow more severe. Many persons in NASA express the view that a number of key managers, engineers, and technicians have signed on through the first reflight--STS-26--but will likely retire or go elsewhere to higher paying, less stressful jobs once reflight has been achieved. In this regard, it is worth recalling the number of key retirements or departures that took place at NASA after the success of STS-1. The ASAP has noted this problem in prior reports and underscores it again. NASA, along with many other Federal agencies, continues to suffer from the difficulty of recruiting and retaining highly qualified and highly sought personnel. The Federal salary ceiling and a complicated entrance process into Federal service are major contributing factors to this serious long-term situation.

NASA and the SPC are also carrying out a vigorous program to consolidate and upgrade the many data management systems associated with the STS. In the long term, the Systems Integrity Assurance Program Plan (SIAPP) will provide a data management umbrella for all flight and critical ground systems. This ambitious plan will be implemented through the Program Compliance Assurance and Status System (PCASS) that will be available to Headquarters, all NASA centers, and contractors. Meanwhile, the SPC is developing the Shuttle Processing Data Management System (SPDMS) in a Phase I and Phase II configuration. The goal of SPDMS II (which will not be achieved prior to STS-26) will be to incorporate the many ad hoc data systems that have been created by contractors, NASA, and the SPC to handle discrete parts of the processing function.

In short, those preparing STS-26 for flight will rely principally on existing systems (with some near-term improvements as part of SPDS I) and manual handling of much of the data. The benefits of these improved systems will be realized principally in the post STS-26 period. This situation underscores the importance of human activity in launch processing.

A vital element in reducing the potential for human error in launch processing is the work environment at the Kennedy Space Center maintained by NASA, the SPC, and support contractors. As ASAP has noted in previous reports, it has been deeply concerned about incidents resulting from a lack of discipline, unsafe work procedures, unplanned vehicle modifications, shortage of spare parts, a heavy paperwork burden, lack of effective training programs, and excessive overtime. These and related problems result in working conditions in which human error is more likely to occur.

These problems, in turn, arose principally from excessive pressure to meet an unrealistic launch schedule in combination with inadequate budgets. The unrealistic launch schedule was an outgrowth of the fiction that the STS was an "operational" system, instead of the highly sensitive and unforgiving R&D system that it is and will remain. Excessive schedule pressure inevitably results in a willingness to accept risks that in other circumstances would not be accepted. For this reason, ASAP has emphasized the dictum of "Safety first; schedule second."

NASA and the SPC have clearly recognized these previous shortcomings and are working hard to correct them. Discipline in carrying out work authorizations and job orders has been tightened. An improved worker safety program has been implemented by the SPC. Training opportunities have been expanded in some areas (although the quality of the instruction is not always satisfactory). Spare parts are more readily available when needed (although small items often take an excessive length of time to procure). Strict controls are in place regarding overtime. NASA and SPC managers echo the call of "safety first; schedule second."

The ASAP recognizes and supports these positive steps. But, it is equally necessary to point out another reality: the pressures and the problems of maintaining a desirable working environment will intensify dramatically as the launch date for STS-26 approaches. Indeed, in ASAP interviews conducted in October 1987, several workers cited instances of schedule pressure by first-line supervisors. Thus, the top management of NASA and the SPC needs to exercise continuing vigilance to see that a satisfactory working environment is maintained prior to STS-26 and for the flights that follow. Work procedures and rules must be observed and executed effectively, not perfunctorally, regardless of the effect this may have on NASA's ability to launch on a specific date. The ASAP will continue to monitor this situation closely.

NASA also faces real challenges in implementing hardware and software changes. The mechanism for carrying out this work is another paper jungle consisting of documents called OMRSD's and OMI's, i.e., Operations Maintenance Requirements Documents and Operations Maintenance Instructions, respectively. These documents apply to the launch activity. A similar set of documents--called Mission Rules--govern Orbiter operations at JSC. Once again the amount of paperwork is staggering, but here also the system is in place and apparently working. It would again seem unwise to suggest changing it at this time.

The Launch Commit Criteria, which govern the launch countdown by specifying clearly what conditions must be satisfied to permit a launch, are contained in a document that is undergoing a major revision. The criteria include not only the values of measurements from airborne and ground systems but also structural and flight control capabilities under prevailing wind and weather conditions, landing site conditions (actual and predicted), range safety requirements, communications and data systems readiness requirements as well as crew readiness.

The changes being incorporated arise from the results of the reviews that are being conducted, including the FMEA/CIL activity, system design reviews, and requirements originating from design changes that are being incorporated before the next flight. In addition, other criteria arise from a more stringent enforcement of the requirement that there must be verification that designed redundancy exists and is functional so that two-fault tolerance is present and operational.

The content and format of the Launch Commit Criteria document are being improved significantly. For example, to permit an orderly determination of whether a measurement is valid or the consequence of an instrument failure or malfunction, predetermined alternative means of establishing the state of a parameter are to be given, enhancing the ability to use other measurements to avoid an unnecessary scrub. Also, the action to be taken in the event a criterion is not satisfied is to be included in the document (e.g., call a hold, switch to manual control of a system). This was not standard in the past. The format of the document also is being changed to make it easier to use. For example, schematic drawings will be full page in size so as to be more legible to the systems engineer at a console.

In addition to changes in the criteria such as those noted above, the command chain during the countdown has been modified to include a "Mission Management Team" to whom the Launch Director reports. This team gives permission to proceed into the terminal count (at T-9 minutes) to the Launch Director. At the time of this writing the composition of the team has not been established firmly but is being actively discussed.

In total, the planned changes to the Launch Commit Criteria embody the sorts of revisions that will make a countdown a more exact and disciplined procedure with as much pre-planning for eventualities as can be done rationally. There is, however, a concern that no clear distinction is being made between a "redline" (i.e., a parameter value or range that may not be violated) and other sorts of criteria whose values are, advisedly, subject to interpretation or evaluation. The latter are, inevitably, the subject of what has been referred to as "waivers." This can lead to the (false) conclusion that criteria are being violated capriciously (i.e., that "redlines" are not being satisfied). It is suggested strongly, therefore, that a clear distinction be made, a priori, between true "redlines" and other criteria which are subject to interpretation during a countdown.

B. Assessment of Safety, Reliability, Maintainability and Quality Assurance

We noted in our previous annual report that many changes have been made and are being made to the total NASA and contractor SRM&QA organization and applicable resources. These changes continue today and will, no doubt, continue after the STS-26 mission as the total SRM&QA operation matures and relearns what it must. NASA has gone beyond the Presidential Commission and congressional recommendations to ensure that all that can be done to optimize safety, success, and efficiency is being done and will be maintained as never before. Amplification of these efforts can be found in the NASA Administrator's response to ASAP's annual report of March 1987; see Appendix D-3, page 130.

During this reporting period, ASAP's focus was on:

- The appropriateness and effectiveness of the real-life implementation of the "new" policies and plans.

- The competence and ability of the SRM&QA personnel to meet the challenge of ensuring a safe and successful STS-26 launch processing and mission.

- Top-level management support at NASA and contractors and ability to provide all necessary resources to do the job and meet the expectations of Congress, the public and NASA management itself.

- Interrelationships between the SRM&QA organizations and all those they work with and support, e.g., STS program administration and technical activities as well as NASA center management.

- Special areas of interest such as the treatment of hardware and software certification for flight which is "the law" not just an objective.

Policies, plans, operational manuals and directives, and roles and responsibilities have been documented starting at the Headquarters level, down through each NASA center and to the various major contractors. Most of these documents are in place and being applied including guidelines for FMEA/CIL, hazard analyses, risk management, activity priortization, and so on. Where the need has arisen for additional support due to resource (manpower) constraints or timely execution of activities to better support the STS-26 processing, SRM&QA organizations have contracted with knowledgeable organizations, and have established ad hoc working groups (such as the Quantitative Risk Assessment Task Team). There has been a general separation of ground and flight safety functions so that neither is diluted but both are mutually supporting. For example, at JSC the Test Operations and Institutional Safety Branch establishes requirements for Hazard Analyses to be performed for the facilities, test beds, and test articles using similar methodologies to those used by the branches dealing with flight safety. In addition, similar safety methodology requirements have been imposed on the flight equipment processing contract, the space transportation system operations contract, and engineering support contractors; all key flight-related contractors with major ground operations. As recommended by ASAP, the safety engineering function at all three manned centers report to the Center Director and the function is matrixed into the various programs/projects.

There is concern that the technical capability in certain areas of the SRM&QA structure are not able to fully meet the demands made upon them, e.g., stress analyses and loads applied to the Orbiter. It is also understood that to have an "across-the-board" technical capability would, in many cases be duplicating the program/project efforts. Therefore, the ability to assess the technical activities of those charged with the "doing" is the important thing for the SRM&QA organization. This capability appears to be there.

This leads to the ASAP's belief that NASA needs a stronger integrated systems safety engineering functional structure and to carry out the efforts necessary to really produce what is stated in NHB 1700.1(V1) as: "...the final product of the systems safety effort, namely, an <u>assessment</u> of <u>risks</u>." The ASAP believes this must be a quantitative (objective) assessment of risk levels.

To accomplish the initial part of the assessment of risks for the current Space Shuttle program, a realistic and useful approach would be as follows:

- o Develop a qualitative fault tree analysis.
- o Provide hazard prioritization by qualitative assessment (through a simple probability of occurrence versus severity matrix).
- o Use selected quantitative analyses where data are available.

To develop an objective assessment of risk levels, NASA should require all major programs to carry out the following five actions:

1. Define and get approved appropriate safety-risk level requirements (quantitative) for the total system.
2. Develop safety-risk design criteria for each of the system's elements, subsystems and components consistent with the total system acceptable risk level.
3. Provide specialized system safety engineering support to help the engineering organizations design to meet the allocated safety-risk criteria.
4. Ensure that the safety-risk design criteria are satisfied by the final element and subsystem configurations.
5. Provide designs for safety-criteria validation test programs and associated data analysis methodologies that will support action (4).

These five actions are based on functions supporting the establishment of risk levels, as described in NHB 1700.1 (V3). A special note: When test data and other information says that there is a significant safety risk, the program should get a fix and implement it.

C. Space Shuttle Element Status

1. Solid Rocket Booster (SRB)

a. Solid Rocket Motor (SRM)

The major effort of the SRB redesign has been focused on the joints and nozzle. The unvented bonded insulation joint with case-to-case and case-to-nozzle joint was chosen as the primary method for keeping hot combustion gases from reaching the steel case walls. The integrity of the adhesively bonded insulation joints, however, cannot be verified by test or inspection after assembly and there are not enough qualification tests to establish verification on a statistical basis. The sealing function occurs in the non-verifiable seals upstream of the primary O-ring seals and therefore prevents combustion gases from reaching the primary O-ring seal. The unvented joint design, therefore, never allows the primary O-rings to experience pressure unless flaws exist in the insulation bondline and barrier O-ring seals. The design criteria states that the primary and secondary O-ring seals will not be eroded or exposed to blow-by during operation. It is reasonable to assume that the combination of non-verifiable seals (e.g., insulation seals, barrier seals and interference fit for the field joint), of the joints are extremely reliable. If gas pressure, therefore, does not reach the primary O-rings it will meet the basic criteria stated above.

Under the worst scenario condition of the field joint, assuming an inline series of flaws through the insulation bondline and barrier O-ring, including the work tolerances of the capture feature, the motor pressure can reach the primary O-ring seal but not the secondary O-ring seal.

In the case-to-nozzle joint, there is a possibility that if a flaw extends through the insulation bondline and inline through the wiper O-ring, then the hot gases from the motor may erode the primary O-ring and continue to the radial bolt seals and secondary O-ring seal. In order to ensure high reliability for the case-to-nozzle joint including the radial bolt seals, a few NJES tests are being conducted with a flaw path to the secondary O-ring seal. Results of these tests, so far, are very encouraging.

The proof of the adequacy of the SRM design now depends on the satisfactory results obtained from the 18 instrumented JES, NJES, TPTA flaw tests and one full-duration fault test. In addition to the flaw tests, the four hot firing full duration tests and STA-3 ultimate static test will be used to assess the reliability of the overall SRM redesign. If anomalies do occur, it will be necessary to assess their severity and determine tests and/or design steps to resolve these anomalies.

The ASAP finds that the redesign of the solid rocket motor incorporates desirable improvements over the original and should provide additional margins in the structure for return to flight.

In reviewing the overall list of tests on the SRM presented to the ASAP, one must conclude that the program is thorough and has been carefully planned except as noted in the recommendations, Section II, of this report.

b. SRM Aft Skirt

The aft skirt failure was caused by loads that produce tensile hoop stresses in the post/weld area. The combination of compressive axial loads and inward radial loads were more critical for the second STA-2B test than the first STA-1 test, which was the reason the STA-2B test failed at 14 percent below ultimate load.

Preliminary finite element linear analysis showed that a redesign of the aft ring of the aft skirt would reduce the stresses in the post/weld area to show positive margins at ultimate load. However, the latest finite element non-linear analysis shows that the redesigned aft skirt has an increase in strength of only 4 percent over the existing design.

The IVBC-3 loads that will be used in the STA-3 test are slightly higher than the STA-2B loads which means that the test skirt will not be able to support ultimate loads.

The final loads from the latest MLP stiffness test will probably not be available for the STA-3 ultimate testing. These loads can vary by a few percent in the axial loads to a much larger percentage in the radial loads.

It appears that NASA will have to restrict the flight envelope for lift-off loads until the problem is fully resolved. In the meantime, various tests and analyses should be conducted to evaluate the effect of load variations on stresses in the failed area.

c. Dynamic Loads/Modal Survey

Rockwell provides the loads data to determine SRB strut loads, aft skirt tie-down loads, etc., using the math model data supplied by Morton Thiokol and MSFC, during pre-launch, lift-off and flight loads.

The center segment modal survey test (TWR 16479) was conducted to determine modal characteristics from 2 to 64 hz and provide modal data for dynamic model correlation. The correlation of the center segment modal test results with the pre-test finite element analysis, however, was not good probably due to the representation of propellant dynamic modulus. Propellant dynamic modulus is a function of frequency (hz), age, and bulk temperature which accounts for the lack of correlation regarding the frequency response functions between the analysis and test results, especially for the rigid body modes.

Morton Thiokol will have to analytically determine static and dynamic loading on the SRB during stacking, pressurization, lift-off and flight conditions including information for testing. This requires a 3-d finite element analysis of the entire SRM with segments that are more complicated than just the center section.

Frequency response functions will be required from ground tests and flight tests in order to calculate the necessary data for analysis.

d. **Mobile Launch Platform (MLP) Stiffness Data**

The Mobile Launch Platform (MLP) is being calibrated to determine influence coefficients in order to determine loads at the SRB hold-down posts, struts and attachments.

The ASKA 6.0 loads/stress report will be finished in February 1988. However, the pre-launch and lift-off loads will have to be modified due to the new MLP stiffness results that is not completed.

The accuracy of the finite element analysis used in the 6.0 loads/stress report to determine aft skirt, booster strut, ET and booster attachment loads and stresses depend on updating the various integrated math models.

The lift-off loads used for the STA-3 ultimate strength test will reflect the MLP-2/1 stiffness data provided by Rockwell on December 20, 1987, and not those based on the MLP-3 stiffness data. Obviously, the latest stiffness data has to be evaluated prior to launch.

2. External Tank

No major concerns have surfaced to date.

3. Orbiter

a. 6.0 Loads/Stress Report and OV-102 Calibration Program

The assumption that the STS orbiter structure has the same reliability as commercial aircraft structure is not warranted.

Commercial aircraft structure has been designed to loads and criteria that have been evolved over a period of at least 50 years and verified by data from instrumented flight. The aircraft structure has been thoroughly tested to establish ultimate load strength capability using instrumented ground and flight test results. In addition, commercial aircraft structure is usually critical for fatigue loads which leaves additional structural margins for static strength.

The Space Shuttle will be viable into the next century and may need to be refurbished and the flight envelope expanded at various times. Most of the current crop of Rockwell and NASA engineers will not be available to perform these tasks.

The STS Orbiter structure has not been tested to determine if it can support ultimate loads without failure but has been proof-tested to 1.2 times limit load. However, flight test data has shown that the wing loads and mid-fuselage thermal gradients are larger than the original designs loads and thermal gradients by as much as 20 percent, which means that the static tests in many cases only represent limit load.

The latest 6.0 loads/stress analysis has shown negative margins on key structural elements in the wing, vertical tail, mid-fuselage and attachments. An action team has been formed to assess the effect on the first mission (STS-26), near-term missions and long-term missions. Flight envelope (squatcheloids) will have to be modified with an impact on performance especially due to dispersions of winds during the winter seasons. The loads and thermal gradients used in the ASKA 6.0 analysis should be correlated with those measured during flight on the wing, tail and mid-fuselage structure.

In 1986 approximately 250 pressure gauges were installed on upper and lower wing surfaces of the STS-61 OV-102 vehicle. The pressure gauges were not accurate enough to determine wing loads in flight. This requires a comprehensive ground loads program with adequate strain gauge coverage to ensure accuracy. The program can best be performed on OV-102 during its downtime before flight. This will allow strain gauges to be accurately calibrated and questionable gauges changed before collecting flight data.

Progress on negative margin issues is shown in Table III.

b. Periodic Structural Inspection and Maintenance Program

The Shuttle structure, including the Orbiter airframe structure and thermal protection system, is subjected to aerothermal loads, high Q boost loads, lift-off dynamic loads, shock, vibration, acoustic, flight winds, gusts and other somewhat uncertain environments and must meet a long service life for each vehicle. This requires that a procedure be established to evaluate each portion of the structure by a well-planned program for periodic inspection and maintenance. The inspection plan should be designed to detect crack initiation, early signs of corrosion, manufacturing errors and other anomalies. The inspection/maintenance plan should be developed by the cognizant design engineer, project office, engineering specialists, reliability, quality assurance and flight test. This group should involve engineers familiar with loads, stress analysis, fracture mechanics and design. In addition, the group should bring the full weight of past experience to bear on the program by including commercial airline personnel experienced in the periodic inspection and maintenance practices of airlines.

c. Orbiter Computer Configuration

The current Shuttle computer system uses a set of five computers to operate the vehicle and the experiments on it, four in a redundant configuration for primary computation, and a separate one for backup. During 1986 and early 1987, the question of what configuration of computers to use when the general data processor is upgraded was hotly debated. Though ostensibly the decision has been made to use a 5/0 configuration (five new computers and none of the existing design), the debate has continued. Rockwell and the safety office at the Johnson Space Center favor a 4/1 (four new computers and one of the old computers) configuration, while the software staff at Johnson favors a 5/0 configuration. The ASAP believes that there is not a sufficient basis for selecting between the two alternatives for two reasons:

- o The risks associated with human factors and the software testing schedule are likely to substantially exceed those of the hardware.

Table III
PROGRESS ON NEGATIVE MARGIN ISSUES

	AREA	DISPOSITION	STATUS
O	AFT ET ATTACH	INCREASE PRELOAD (MCR 12236)	CLOSED
O	COMPONENT LOAD FACTORS	REVISED LOADS SCHEDULED	CLOSED
O	MID FUSELAGE THERMAL	ENG'R VEHICLE MOD	CLOSED
O	WING GLOVE FITTINGS	ANALYSIS	CLOSED
O	THRUST STRUCT LUGS MCR 12345	MODIFICATION - IDENTIFIED SHIM	ERB *COMPLETE
O	WING BOX & GLOVE TRUSS TUBES	INSPECT WALL	LEVEL III CCB *6/23/87
O	TAIL/FUSELAGE JOINT	MODS IN WORK	ERB *LATE JUNE
O	MID FUSELAGE/PBD* AERO	ONGOING	ANALYSIS SCHEDULED
O	AFT ET ATTACH FITTING - SIDE BEAM	REVIEW ONGOING	
O	AFT FUSELAGE SHELL OP/THERMAL	REVIEW ONGOING PROBLEM	AP & THERMAL

*ERB = ENGINEERING REVIEW BOARD
*CCB = CONFIGURATION CONTROL BOARD
*PBD = PAYLOAD BAY DOOR

- A hazard analysis that properly studies all factors leading to multiple computer failure has not been performed.

A hazards analysis that includes computer reconfiguration procedures and the implications of an increased testing program (if a 4/1 configuration is adopted) should be made.

d. General Memory Changes

The Shuttle software system includes the capability for general memory change, referred to as "gmems." A ground base can, through telemetry, specify an address in the general memory of the computer and new contents for that address. Changes also can be made from on board the Shuttle. With this mechanism, either program instructions or program data can be altered, but only in controlled ways.

Gmems can be used in two ways: (1) to make changes in the I-loads (initial input) that describe a particular mission, and (2) make a general change to a general location in memory. The first is done routinely as part of every flight prior to launch to set parameters that cannot be predetermined, e.g., wind velocity. The second is rarely done and only after significant approval chains have been followed.

There are a number of protective measures in place to prevent intentional or accidental misuse of gmems. First, all of the anticipated static changes (e.g., I-loads) are described in a table that is examined by the system management software. Any requested change to an I-load is automatically checked against this table to be sure that it is one that is allowed to be changed. Second, the procedure for making a change is as follows:

- The desired data and address are uploaded to the Shuttle.

- The requested data and address are transmitted back to the ground for a manual check that the information was transmitted correctly.

- If okay, a command to execute the change is transmitted to the Shuttle.

If the change is being made by an astronaut from the Shuttle, the same procedure is used, except that instead of transmission to and from the ground, it is to and from a local display. Third, gmems are never made during ascent or descent. They are only made pre-launch or on orbit.

The second category of gmems allows executable code to be changed. Again, there are a number of protection mechanisms. First, the region of memory that contains code is under hardware storage protect. This protect must be explicitly released before a change can be made. When a patch is to be made, the following procedure is used:

- The change is checked out in a ground simulator.

- The change is written to mass memory.

- The change is dumped to ground and checked before it is used.

Also, just hours before a launch, the computer memory is dumped and compared bit by bit with the contents it should contain. Approval of both the flight director and the chairman of the Software Control Board are required before a change in program code can be made.

While there have been no mishaps involving gmems in the primary software system during actual flight to date, errors have occurred during flight condition testing in the simulators.

There has been a practice in the past of allowing very late change requests (CR's), even only days before a flight, that involve flight system constants. Late CR's might arise, for example, from a late payload change that in turn changes the mass properties of the vehicle. When change requests are acted upon this late, the testing procedures and checks and balances are not always as extensive as they would otherwise be. There is one documented case of a malfunction in duplication hardware (copier machines placing additional marks on a page) resulting in incorrect information being supplied to engineering for inclusion in the flight software. Only alertness on the part of an engineer, who noticed that the values supplied did not look right, prevented an error. The full testing program was not used due to the nearness of the flight schedule.

General memory changes are added with moderate frequency during Shuttle flights. The protection mechanisms in place, however, fall somewhat short of full security.

Late Change Requests, after normal testing of the flight software has been completed, have been accepted in the past, and do not go through adequate testing after inclusion. The principal danger here is that they do not have enough "shelf life" to give side effects a chance to surface.

In view of the fact that errors that have occurred during gmems in spite of significant precautionary measures, the procedures for making them should be reviewed, and changes for increasing safety sought. Consideration should be given to re-verifying a gmem <u>after</u> it has been made.

The procedures for approving late Change Requests should be stiffened as much as possible, and additional testing of those allowed should be instituted.

4. <u>SSME</u>

In its 1986 report, ASAP noted that as of November 1986, 25 items on the SSME had been identified that required changes prior to the next Shuttle flight in 1988. A complete new FMEA/CIL and hazard analysis effort was also underway in 1986, with completion scheduled for 1987. It was noted also that the engine contractor, Rocketdyne, was developing methodologies for quantitative risk assessment and safety operating-margin validations. The progress of these important efforts was reviewed by members of ASAP on several occasions during 1987.

a. Status of Engine Reconfiguration

The engine to be incorporated in the next series of Shuttle flights will be based on the Phase II configuration ultimately planned for certification at 109 percent. These engines incorporate many new turbopump components as well as changes related to resolving issues which arose during the Phase II development program, from the FMEA and as a result of rethinking about operational monitoring and constraints. The 1986 report noted that of the 25 problems identified up to that time, which were to be corrected prior to reflight, there were 5 which ASAP believed were the most significant. These were:

- o High-pressure turbopump blade blade cracks
- o High pressure fuel turbopump coolant liner buckling
- o Bearing ball temperatures in the oxidizer pumps (low pressure and high pressure)
- o Main combustion chamber coolant outlet neck cracks
- o 4000 Hz pressure disturbance in the thrust cone/LOx inlet region

Each of these problems was described and discussed in the Appendix of the 1986 report.

In 1987, NASA identified additional changes to be made before the first flight in 1988. The new total of 38 planned changes include 20 of the 25 items listed in the 1986 ASAP report, and 18 additional items resulting from the FMEA/HA and continuing safety evaluations of the SSME. Of these 38 items, NASA considers 21 to be mandatory to certify and incorporate prior to the next Shuttle flight. The status of what ASAP considers the most significant of these items as of late 1987 is as follows:

(1) HPFTP First Stage Blade Cracks

This has turned out to be primarily a dimensional control problem. Rocketdyne has tightened up the tolerances and implemented a more stringent inspection process. Four sets of the blades made to the more stringent standards have been run with the following results (cycles/seconds): #1 - 19/8,000; #2 - 15/6,000; #3 - 10/5,300; #4 - 8/4000. No cracks were detected using dye-penetrant with 70 power magnification. It appears that this is a promising solution but it has been decided to restrict the number of cycles on the flight engines to three prior to flight and inspect the turbine after flight.

(2) HPFTP Second Stage Firtree Face Cracks

The initial fix selected was to shot-peen the blades and gold plate them to resist hydrogen effects. Inspection showed that the shot-peening and gold plating eliminated the downstream face cracks but engendered many "corner" cracks. Subsequently, two "rainbow" wheels (containing approximately 20 each of the following type blades) have been tested: (a) large corner radius/shot peened; (b) Phase II blades, shot peened and gold plated; (c) Phase II blades (i.e., small radius, no shot peening or gold plating). The first wheel was run in six tests aggregating 250 seconds (the cracks are a low-cycle thermal phenomenon) with the following results from SEM inspection: (a) No cracks of any type; (b) 7 corner cracks, no face cracks; (c) 5 corner and 5 face cracks. The second wheel gave the following results after similar tests: (a) No cracks; (b) No corner cracks or face cracks; (c) 1 corner crack and 2 face cracks.

It appears that shot peening supresses the formation of face cracks and that enlarging the radius precludes formation of corner cracks. It is recognized that as yet, only limited data have been obtained and that other factors are apparently involved as indicated by the difference in the results from the two tests. The results with the type (a) blades are encouraging enough to use them for flight. To be conservative it is planned to limit the number of operating cycles prior to flight to 3 and to pull and inspect the pumps after flight. Testing will continue and the plan is to run two wheels with all type (a) blades for 5,000 sec. each and at least 10 cycles each by March 1988.

(3) HPOTP First Stage Shank Cracks

These blades had exhibited high-cycle fatigue cracks after about 1200 seconds of operation. The solution selected was to employ a two-piece damper that had been in development for some time. These dampers were installed in four blade sets and run for the following aggregate times without any crack formation (cycles/seconds): #1 - 17/8,000; #2 - 10/5,000; #3 - 11/5,000; #4 - 9/4,000. These results are very encouraging.

(4) HPFTP Coolant Liner Maximum Pressure

The problem was the overshoot in pressure differential across the liner during startup. In addition to improved manufacturing controls to minimize weld mismatch, etc., coolant flows were modified by re-orificing. It was not possible to increase the static seal travel capacity because of the limited material available in the housing. With only the first two modifications, a series of tests on seven units showed the pressure differential was reduced by at least 200 psi. Some of these units have been running on the Instrumented Turbopump and thus are producing more detailed information than is available from flight-instrumented machines. It would appear that with the new configuration of orifices, the liners could operate at even the redline temperature with a factor of safety of 1.5. The ASAP will continue to review this item.

(5) HPOTP Bearing Ball Temperatures

In an attempt to resolve the issues as to the temperatures experienced at the surface of the balls, a series of four units were run in a carefully controlled set of tests at 104 percent thrust and then disassembled and inspected. The results were ambiguous; the balls were neither bright and shiny nor were they blackened. Moreover, there was a disparity of effects among the four units. The surfaces of the balls were subjected to microchemical analyses, and, from the species of the material on the surfaces, it was estimated that the surface temperature could have been as high as 1200 degrees Fahrenheit. Comparing these temperatures with auto-ignition data from the NBS, Rocketdyne believes the data indicates a margin of about 500 to 700,F. Tests at White Sands have shown no ignition of the balls. Thus, these surface temperature results provide reasonable evidence that auto-ignition should not be a problem under normal bearing operations. As ASAP observed in the 1986 report: "It is still ASAP's belief that the experiments will be ambiguous at best, and that statistical evaluation of the SSME's entire test and flight history can (and should) be used to make an adequate risk assessment."

(6) HPOTP Bearing Failure

A new problem with the HPOTP bearings showed up in 1987. During the course of testing the highly instrumented HPOTP S/N 0307R4 (internal strain gauges and accelerometers), the internal instruments began to indicate signs of bearing wear (or distress) after about 2500 seconds of operation. Testing was continued until approximately 5800 seconds, when the external instrumentation started to pick up the bearing cage frequency, an indication of bearing wear. Running was continued on to 8200 seconds and the pump was torn down for inspection. It should be noted that the pump passed all the normal post-test checks, i.e., push-pull for the turbine end bearing and torque test for the assembly. On disassembly, the #2 pump bearing cage was found fractured and the races were worn. The balls had rubbed against one another and skidding had occurred. Debris was found consisting of the cage material and the ball material. The #1 bearing was severely distressed; ball diameters had changed, there were dark wear circles on the balls and the races showed wear. It is not surprising that the bearings were considerably worn after 8200 seconds. The concern is that the degree of wear experienced was not detectable from the amplitude of the external accelerometer signal. Another unit (S/N 4101) was put into test and after 4800 seconds temperature and pressure "jumped" and at the same time cage frequency harmonics were picked up. After an additional 900 seconds of running, particles suspected to be bearing material were detected in down-stream ducting.

A decision has been made by NASA to use the bearing configuration that was tested for first flight, and to placard the cumulative operating time based on a wear criterion. The value selected is 2000 seconds at the end of flight. More test data are required to make a maximum run time selection. Also, strain gauge monitoring will be added to the green-run and to the acceptance test as well to provide additional information about wear. Disassembly of the turbo pump after the first flight will be done to inspect the bearings after they have made all the normal shaft travel, torque, and #3 bearing inspections with the engine in place. There are a number of bearing assembly fixes in development for incorporation at a later time.

(7) 4000 Hz Pressure Resonance in LOX Inlet and Thrust Cone Region

This problem involving a structural hydraulic resonance coupling in a local region of the engine thrust cone was also discussed in the 1986 ASAP report. The amplitudes are quite small up to 104 percent of rated thrust, (maximum planned operating value for next flights). During 1987, attempts to eliminate the vibration by external reinforcement in the region were not successful. The next approach is to alter the contour of the trailing edge of the splitter vanes to change the character of the trailing edge vortices and to change the contour of the leading edge to reduce separation on the suction surface of the vanes. These changes are in work.

As stated before, the issue is not the vibration, per se, since it is confined to a small region of engines' head end and does not stimulate any additional structures significantly. The concern is the result of a shift in frequency observed in several engines which has been traced to cracking of the splitter vanes in the inlet tee. The issue could be resolved in several ways. Since engines which exhibit the phenomenon do so from the beginning of their life, they will be screened out and rebuilt in the inlet region. Although this is costly, it is effective.

b. SSME FMEA/CIL Reassessment

The FMEA/CIL work at Rocketdyne and at an "independent" contractor, Martin Marietta in Denver, was completed during 1987. This work was carried out under new ground rules which expanded the number of levels down to which the failure modes for the SSME would be defined. The new rules also required certain structure failures related to leak/rupture of pressure vessels to be included. The new CILs were to include specific critical characteristics related to design, inspection and validation testing, along with explicit failure histories. In addition, for the SSME, all former 2 and 2R critical categories were elevated into the Criticality 1R level. These changes, of course, greatly increased the number of defined Crit 1 and 1R items for the SSME and contributed to making the entire exercise more cumbersome and reviews more difficult.

Rocketdyne divided the SSME into nine subsystems and put special teams on each. The ASAP reviews of their work indicated a very thorough and orderly process which resulted in high confidence that now essentially all of the significant failure modes have indeed been identified. The impact of the new rules can be seen in Table IV which shows data obtained from Rocketdyne on the number of Criticality 1 and 1R items under the old rules (-10) and the new rules (-11).

Because there is yet no objective prioritization process employed by NASA for the CIL evaluations, the large increase in Crit 1 items serves really to deflect attention from truly critical failure modes, and thus may not be improving the real safety-risk management process. It is very difficult to imagine that any quantitative risk assessment of the 384 Crit 1 items would not identify perhaps only 20 to 30 where probability of failure was of significant concern, and where, therefore, the safety-risk should be reduced as soon as practical. Indeed, some of these areas have been singled out and design changes, new inspections, or software changes have been instituted to reduce the qualitative assessment of risks. Table V gives a few examples.

Another important product of the SSME FMEA/CIL rework is the identification of "failures detectable during ascent." Such items will have the following statement included in the CIL retention rationale.

> Failure mode can be detected in real time by the flight control team who will evaluate effects upon vehicle performance and abort capability. Based on this evaluation, the appropriate abort mode or system configuration will be selected. Failure detection cues and associated SSME performance data have been coordinated between the engineering and flight operations organizations with the responses documented in mission flight rules.

Table IV
SSME FAILURE MODE SUMMARY

(September 1987)

	-10 REVISION		-11 REVISION	
	CRIT I	CRIT IR	CRIT I	CRITIC IR
Combustion Devices	7	0	33	4
Pneumatic Controls	3	0	11	6
IGN/Sensors	1	0	5	14
Propellants Valves	16	0	35	11
Actuators	2	2	28	20
Controller	0	3	1	30
Turbopumps	10	0	31	36
Harnesses	0	1	1	51
Ducts & Lines	54	0	239	12
Total	93	6	384	184

Table V

EXAMPLES OF ENHANCEMENTS/DESIGN CHANGES
RESULTING FROM SAFETY REASSESSMENT OF SSME

1. **Added "MCC Ignition" confirm software check at 1.7 seconds**

   - Provide detection for failure to ignite the main chamber
   - Change Criticality from 1 to 1R

2. **Added OMRSD inspection/test requirements to enhance rationale for retention**

   - Transfer tube sheet metal inspection
   - Preburner ASI line clearance inspection
   - Heat exchanger primary tube eddy current test
   - MCC burst diaphragm leak test
   - Nozzle jacket buckling inspection
   - FBP and OPB LOx post support pin inspection
   - Added additional LCCs to prevent Crit 1 failures
   - Failure of oxid dome check valve to open

3. **Spark igniter redesign - igniter case ENDi plated to increase strength to withstand seal leakage**

   - Added software changes to prevent Crit 1 failures (effects)
     - Software change to monitor HPOTP IMSL pressure limit during cutoff
     - Software change to monitor POGO pressure during cutoff
     - Software change to qualify preburner shutdown purge pressure measurements
     - Software change to ensure He supply to POGO is off prior to engine start
     - Software change to qualify LPFP discharge temperature sensors
     - Software change to detect failure of boost pump discharge temperature probe and issue MCF
     - Software change to ramp valve commands in pneumatic shutdown
     - Additional sampling requirements added at subcontractor

There were three other important activities carried out in 1987 to support the reworked FMEA/CIL. These were:

- o Structural audit
- o Weld assessment
- o Failure trend analyses

The structural audit reviewed all of the structural analyses with special emphasis on long-term durability. It re-examined critically the environments, models, assumptions, material properties, fabrication processes and total verification testing. The work was done by an experienced audit team of specialists in various disciplines such as structures, dynamics, aerothermal, heat transfer and materials and manufacturing. When completed, there will be a total of 204 audits, with heavy emphasis on the turbomachinery. The ASAP commends this effort and looks forward to reviewing the results in 1988.

The weld assessment program is likewise a well-coordinated activity with special teams reporting to the SSME Chief Engineer. It is anticipated that any remaining issues not yet adequately dealt with as part of the FMEA/CIL work will be identified in time to implement corrective actions on both field and new units. This will provide enhanced retention rationale for applicable Criticality 1 and 1R items.

The objectives of the failure trend analyses were to examine all test data bases to see if any adverse "trends" could be identified. If discovered, attempts would be made to "quantify" the problems as an aid to managing possible corrective actions. The analyses would be matched to component failure modes and utilize all available data bases of both "failures" and "unsatisfactory conditional reports." This type of analyses, if done using some of the latest statistical methods, would be a very important input element of what should ultimately be a full quantitative safety risk assessment for the SSME. The ASAP believes Rocketdyne is stepping up to this task in a very conscientious way, and we anticipate important results in early 1988.

Finally, a brief comment is warranted on a preliminary attempt at Rocketdyne to produce a determination of the SSME reliability. Clearly, such a quantitative evaluation as is being attempted currently (the likelihood of failure of the SSME at two stages of operation: prior to SRB ignition and after liftoff), would provide an important, if limited, part of an overall SSME safety-risk assessment. The current data is being examined for several power levels (100, 104 and 109 percent) and for two general consequences: shutdown and Criticality 1 loss of life or vehicle. A preliminary review of some initial "results" indicates some questions regarding the methodology. A significant one is validity of the way in which failures are treated after "fixes" are incorporated when they attempt to track reliability limits of liftoff versus total number of engine tests. What is described as a lower boundary, assuming no failures are fixed, is really representative of the engines actual history and does include "fixed" failures in the data base. Rocketdyne and NASA must do much more work on the analysis methodology before one can either believe the indicated overall SSME likelihood of failure or use the process to establish inputs to quantitative assessments of component failure mode risks.

However, the very existence of this effort at Rocketdyne is of enormous significance, and it needs to be supported and further developed by a team of nationally recognized statisticians so that some confidence can be attached to the results. This confidence is necessary in order to then use the component risk assessments to direct and support a viable and cost-effective safety-risk management program for the SSME.

c. SSME Hazard Analyses

The hazard analyses are also being redone for SSME. As of September 1987, there were 27 hazards identified and under qualitative evaluation (see Table VI). Many of these hazards result from the identified modes, and are therefore subject to the same risk of occurrence as the hardware failure. However, since the created hazards could result in various consequences which may or may not be catastrophic, NASA still has no way of in fact establishing a safety-risk level for acceptance of these hazards. Thus, ASAP finds that while a good job has been done of describing the hazards trees and potential events, there is still the issue of establishing an objective basis for hazard risk management in order to reduce the future safety-risk levels in the most focused and effective way.

d. Additional Comments

A heat exchanger leak (an extremely small one) discovered on SSME #2027 caused this engine to be removed and replaced by another for flight. In a December 29, 1987, retest, the engine was fired for 754 seconds with this known leak. There was no increase in the extremely low level of leakage found earlier. It appears to have been an inclusion of material in the basic metal that was the cause of the leak. No other engine has shown such leakage.

There has been some concern about welds within the SSME components over the years. NASA and the contractor have been "working" this problem to ensure that the very complex and difficult welds are made correctly. However, from time to time, problems have occurred and have been resolved. The "mistracking" in the weld around the first stage turbine wheel seal-ring found on one of the high-pressure turbopumps on a test engine following a test firing is being pursued for proper resolution prior to any certification for flight.

5. Launch, Landing and Missions

Comments for this element of the STS are covered in Section 3, "Design, Checkout and Operations."

Table VI
LIST OF CURRENT SSME HAZARDS

1. A1 - External Oxygen Fire
2. A2 - External Hydrogen Fire
3. A3 - Fire, Hydraulic, External
4. B1 - HGM B/T, Rupture, Explosion
5. B2 - FPB Rupture, Burnthrough, Explosion
6. B3 - HEX B/T, Rupture
7. B4 - Main Injection Rupture, B/T, Explosion
8. B5 - MCC B/T, Rupture, Explosion
9. B6 - OPB Rupture, Burnthrough, Explosion
10. B7 - Nozzle Rupture, B/T, Explosion
11. C1 - HPOTP Rupture or Burnthrough
12. C2 - LPOTP Rupture/Fire
13. C3 - Oxidizer Valve Internal Fire
14. D1 - HPFTP Rupture or Burnthrough
15. D2 - LPFTP Rupture/Fire
16. E1 - Avionics Malfunction
17. E2 - Software-Related Effects
18. F1 - Mixture Ratio Error
19. F2 - Off-Nominal Performance
20. F3 - Propellant Depletion
21. F4 - Fail to Shutdown on Command
22. G1 - Thrust Vector Error
23. G2 - EMI Generation
24. G3 - Geysering
25. G4 - Premature Engine Shutdown
26. G5 - Premature Shutdown Second Engine
27. G6 - Overpressure ET Oxygen Tank (HEX)

D. Space Station Program

1. General

As a result of its overview of the Space Station activities and recognizing the current phase C/D situation, ASAP has the following observations:

a. There is a need for an "on-board" method of returning the crew (all or part of it) to Earth. The method or devices to be used should be determined as early as possible so that proper integration of this so-called "crew emergency return vehicle" (CERV) can be accomplished as a part of the total design and operational picture.

b. Space debris and its relevancy to the design, test and operation of the Space Station components and as a system is receiving a great deal of attention. However, the question in ASAP's mind is whether this attention is producing constructive results regarding requirements/specifications, agreements with other spacefaring countries, and any possible methods to reduce the basic problem. The ASAP is reminded of the paint flake that caused an unusually large pit in the Orbiter windshield.

c. Maintenance appears to warrant major consideration in the Space Station design and operation, but ASAP believes not enough attention is being given to this area. Here, ASAP remembers the early days of the Space Shuttle (particularly the Orbiter) when maintenance was touted as next to godliness, but in the end it was not !

d. The use of "lessons learned" appears to be given lip service based on ASAP's early understanding of how Space Station integrated logistics programs are being handled.

e. An initial list of items for further ASAP examination include the following:

- The management structure
- Use of automation and robotics and the safety implications
- The design of the Space Station for use of both ELV's and Space Shuttle
- Design for maintenance and minimizing EVA to reduce impacts on manned safety
- Computer system design, use and evolution and its value in reducing hazards

The ASAP's goal is to determine what plans are real and what is lip service, and how good are the plans themselves. Additionally, lessons learned on the Space Transportation System are available and should be applied on a continuing basis.

2. Computing System

The computing system for the Space Station will be much more complex than anything NASA has flown to date. It will use orders of magnitude more memory and run vastly larger and more complex programs. It will be several times faster, and physically distributed. And, it must evolve through five to ten generations of computer hardware, and introduce new generations of software.

NASA has set many high and likely beneficial goals for the Space Station, e.g., extensive use of artificial intelligence, design for evolution, use of automation and robotics. However, achieving these goals will require a more general design and much greater up-front investment than designing only for the initial operational capability. NASA's requirements documents discuss "design to cost" and note a potential conflict between this approach and the up-front investments needed to achieve longer term goals. There is concern that short-term cost considerations may overcome long-term benefits, force substantially simplified designs, and lead to vastly increased long-term costs and reduced long-term capabilities.

NASA's requirements documents for the Space Station Computing System present a very impressive array of desired capabilities. However, the complexity of this system is far beyond the complexity of any computer system NASA has yet had to deal with. Systems integration techniques for such large systems are not well understood, and many other large organizations have made very costly errors by grossly underestimating the magnitude of the systems integration problem. There is concern that NASA is making these same kinds of assumptions. It will be difficult, if not impossible, to predict accurately the cost involved or design the system to cost.

The requirements documents for the Space Station Data Management System (DMS) state numeric values for a number of important parameters such as communication data rates, processor speeds, error rates, etc., giving neither a rationale for the values chosen, nor a reference to secondary documents containing the rationale. One thus does not know if they are based upon analysis of Space Station tasks, or someone's seat-of-the-pants estimate.

It can reasonably be expected that during the lifetime of the Space Station, five to ten generations of computing equipment will pass, and the Space Station computing equipment will have to be upgraded a number of times. While several people within NASA do have ideas on how these upgrades will be accomplished, there does not appear to be a formal procedure in place, nor does it appear that creating one was part of any of the Space Station work packages.

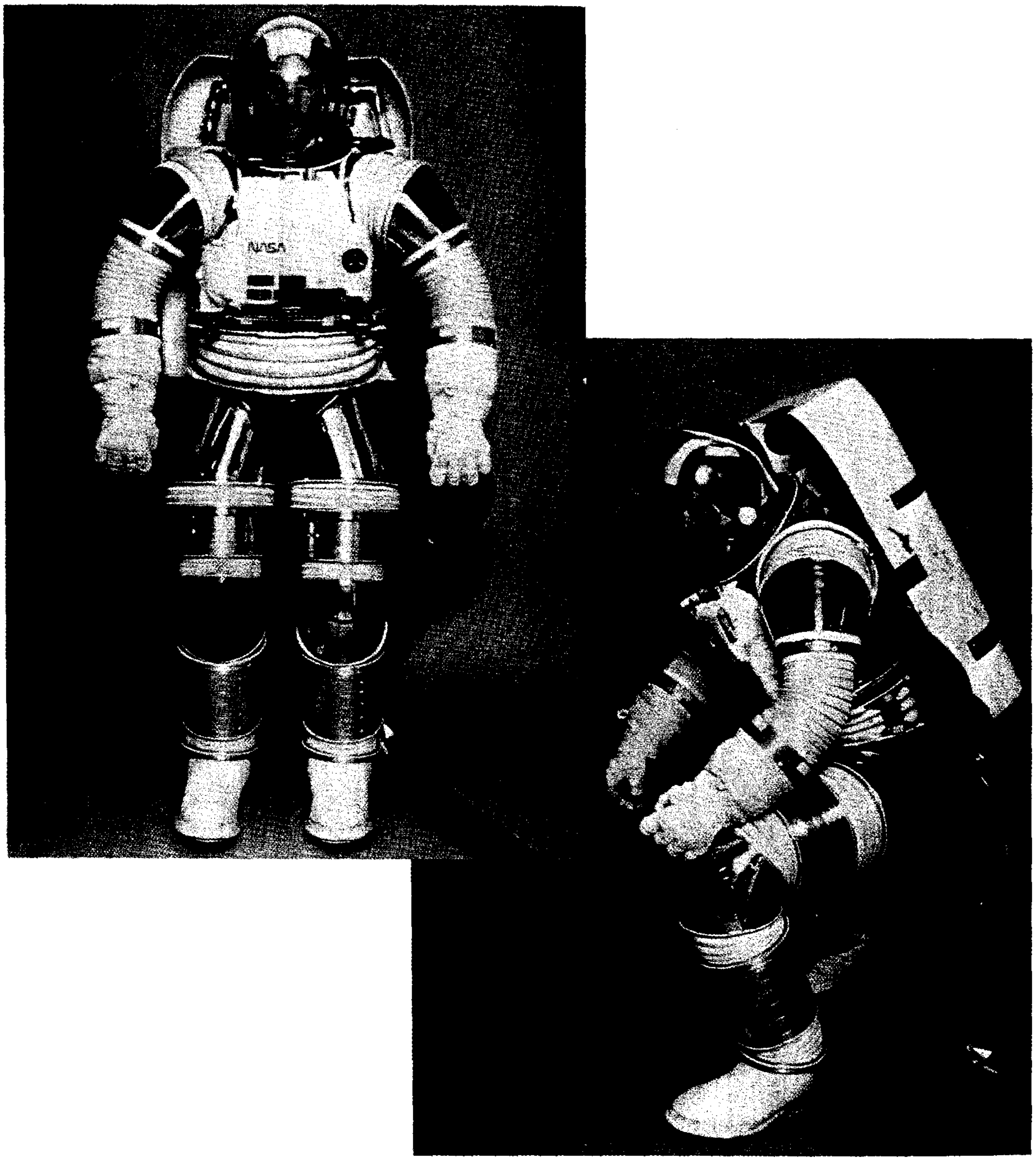
Based on the STS history, Space Station management must maintain an awareness that technical decisions made by senior management require full knowledge of the implications of those decisions. An example is data communications, in which a full appreciation of the timing associated with the various standards is mandatory. Other areas that will require attention are:

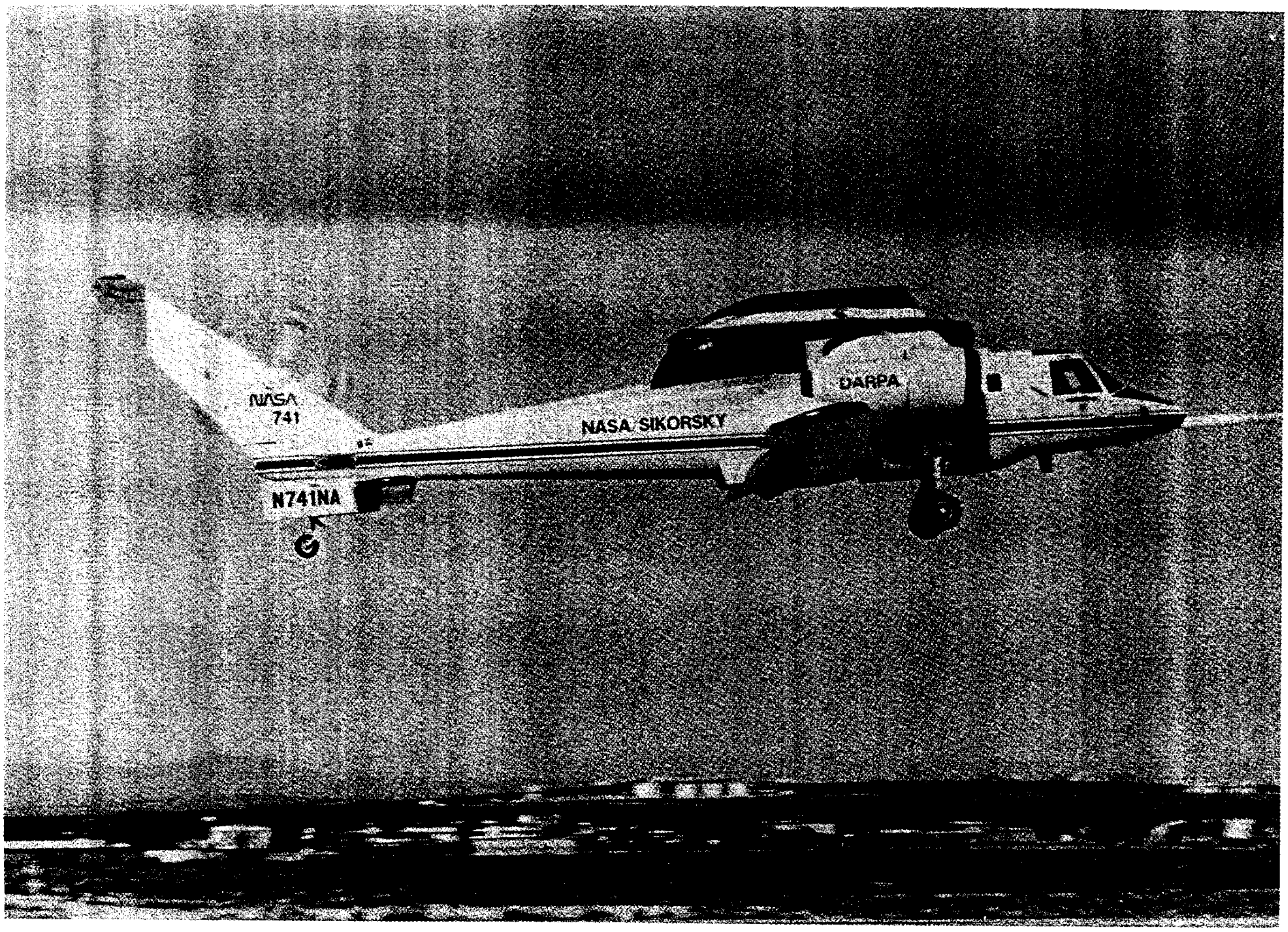
- Space Station program goals for safety and reliability with respect to the computing system.

- Space Station design for long-term objectives, particularly the ability for the station to evolve.

- Development of a rationale document for Space Station computing requirements. This should include a consistency check between requirements, and a extension/upgrade plan for both hardware and software.

- In-depth technology assessment of the automation, robotics, computer hardware and software capabilities for the Space Station. Determine what needs development. Identify areas needing research and development. Examples of needed research might be systems integration techniques and AI software validation methods (no one today can even say what software validation means for some kinds of AI software).

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E. Aeronautics

1. RSRA/X-Wing Flight Test Program

The RSRA/X-wing flight test program received a considerable amount of attention from ASAP during 1987. By the beginning of the year, the program had entered the initial phase (Phase Ia) of the flight test effort and a number of Flight Readiness Reviews (FRRs) were in progress and scheduled. Since the initial flight tests of the aircraft were to be conducted without the X-wing rotor sub-system, and the RSRA X-wing's sister ship had flown successfully, it is the opinion of ASAP that the FRR process was more comprehensive and resource-consuming than was necessary. This is believed true with consideration given for the modifications to the RSRA vehicle and the differences between the RSRA/X-wing and it's sister ship. The ASAP is convinced that NASA was doing everything possible, within their resource limitations, to make the X-wing a safe and viable program.

2. X-29 Technology Demonstration Flight Program

The X-29 flight test program was periodically reviewed by the ASAP during 1987. By the end of the year, aircraft number one (two aircraft have been built) had completed over 150 flights. The principal efforts have been directed towards clearing the aircraft for its maximum speeds, mach number and altitudes, and for gathering data during maneuvering flight. The current flights are aimed at exploring the various maneuvering conditions and evaluating the handling qualities during these conditions. Wind-up turns and asymetric maneuvers are programmed to accomplish this aim. Control law modifications for higher angles of attack are being developed for the high alpha program scheduled for aircraft number two. There are apparent discrepancies in correlating the high and low alpha control laws. The control laws currently installed in the airplane are somewhat timid in their ability to explore the agility and maneuverability capabilities inherent in the basic airframe--especially when one considers the 35 percent negative static margin in the pitch mode.

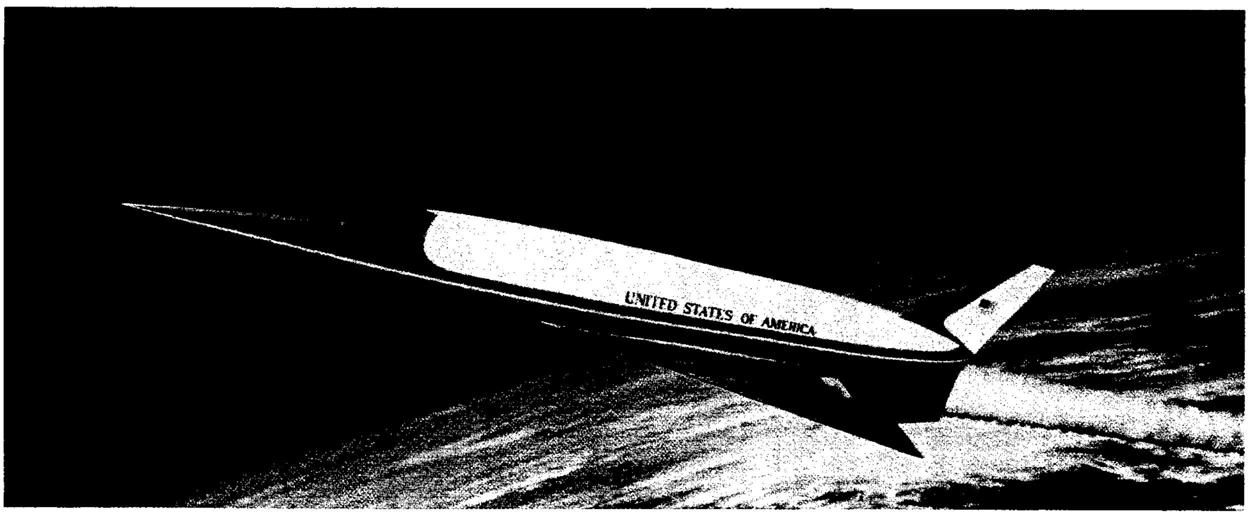
The flight envelope has not been totally explored as the maximum design dynamic pressure (the q corresponding to M=1.07 at sea level) has not been reached. This is the most critical corner of the flight envelope from a structural dynamic and a flight control standpoint. Demonstration of the ability to avoid aeroelastic flutter and divergence at the higher q levels was a fundamental objective of the X-29 flight demonstration program. Also, this regime is the most critical for the flight control system from the standpoint of the phase and gain margins. To date the aircraft has been tested to M=1.1 at 10,000 ft. which corresponds to approximately 70 percent of the design q.

A high-frequency buffet (not severe to pilot) has been encountered during high g turns at angles-of-attack ranging from approximately 7 degrees and higher. The reason for the buffet is not completely understood although there are postulations, and there is some concern that the flaperon linkages could be over-stressed by severe buffeting. Also, the loads on the canard actuators are higher during maneuvering conditions than predicted by analysis and, although there is a theory that this is caused by the canard stalling before the wing, this is another area that requires additional study.

There are no clear plans to expend the effort needed to determine and fully understand the causes for either the buffet or the canard loading problems. As a result, flight safety limitations have been placed on the aircraft's design flight envelope.

3. The National Aero-Space Plane (NASP) Program

The NASP program is aimed at providing a next-generation space transportation system which has been projected to substantially reduce the cost of placing payloads into space. It is a joint NASA/DoD effort with the Air Force assigned as the executive agency. The program schedule calls for the development of a manned technology demonstration vehicle to be flight tested in the mid-1990's. This X-vehicle performance goals are horizontal take-off from and landing on conventional runways, sustained hypersonic cruise in the atmosphere, accelerated flight to orbit in one stage and return, and reusable system that can operate in an airline type of operation. As it will be impossible to provide complete ground test verification of the vehicle's integrated technologies, the initial flights will be answering many technical questions for the first time, and will incorporate many safety issues. It is therefore appropriate that the ASAP monitor the current program activities in order to provide early insight into the safety performance trade-offs that will be critical to the viability of the flight program.



IV. Appendices

A. Panel Membership

AEROSPACE SAFETY ADVISORY PANEL

CHAIRMAN

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Former Exec. VP, the Boeing Co.
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DEPUTY CHAIRMAN

NORMAN R. PARMET
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GERARD W. ELVERUM, JR.
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NORRIS J. KRONE
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CONSULTANTS

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NASA HQ, 453-8971

MONICA BOWIE, Secretary
NASA HQ, 453-8971

B. Panel Activities Calendar Year 1987

CALENDAR YEAR 1987 ACTIVITIES

DATE	SITE	SUBJECT
January 5-6	Kansas City, MO	Computer software/hardware orientation; SRM&QA management status
January 14-16	MSFC	NRC Criticality Review and Hazard Analysis Audit Panel
January 28-30	MSFC	NRC Solid Rocket Motor Redesign Panel
February 4	DFRF	R&D aircraft program status, X-wing, X-29 and other high-performance research aircraft
February 9	HQ	STS Safety Risk Assessment Ad Hoc Committee
February 10-11	Washington, DC	NRC Criticality Review and Hazard Analysis Audit Panel
February 20-26	Ames Res. Ctr.	Computer software/hardware status, STS and simulation/training activities
March 4	HQ	Numerical Risk Assessment and Safety Management
March 5-6	Rockwell, Downey	NRC Solid Rocket Motor Redesign Panel
March 11	HQ	Annual statutory meeting with Administrator, Deputy Administrator, and senior NASA management
March 12	HQ	SRB Ground and Flight Test Program
March 13-14	HQ	Life Sciences Advisory Committee, NASA Advisory Council
March 16	HQ	STS Crew Escape Hardware and Operations
March 17-19	Washington, DC	NRC Criticality Review and Hazard Analysis Audit Panel
March 19-20	MSFC	Tethered Satellite System, Control Dynamics and Operational Safety
March 24-25	MSFC	Aft Skirt Review Team
March 23-26	Denver, CO	NASA Intercenter Aircraft Operations Panel

March 26-27	JSC	Numerical Risk Assessment and Safety Management
April 5-6	Washington, DC	NRC Criticality Review and Hazard Analysis Audit Panel
April 6-8	JSC	SRM&QA Director's Meeting
April 20-22	KSC	NASA/SPC Space Shuttle Launch Processing Operations including "floor activities"
April 22-23	MTI, Utah	NRC Solid Rocket Motor Redesign Panel
April 22-24	JSC	STS and Space Station computer hardware/software and associated human performance issues
April 24-25	Washington, DC	NRC Criticality Review and Hazard Analysis Audit Panel
April 29-30	MSFC	SSME Quarterly Review
May 5-7	Washington, DC	NRC Criticality Review and Hazard Analysis Audit Panel
May 28-29	Washington, DC	NRC Criticality Review and Hazard Analysis Audit Panel
June 1-3	Washington, DC	NRC Solid Rocket Booster Redesign Panel
June 9	HQ	SSME Special Issues/Concerns Management Review
June 8-9	JSC	NRC Criticality Review and Hazard Analysis Audit Panel
June 8-12	DFRF	X-Wing Flight Readiness Review
June 15-16	KSC	SRM&QA Director's Meeting
June 23	Rockwell, Downey	Orbiter structure and loads assessment
June 23-26	NSTL	Program Director's Management Review
June 24-26	MSFC	Tethered Satellite System, Control Dynamics and Operational Safety
July 12-15	JSC	NRC Criticality Review and Hazard Analysis Audit Panel
July 13-16	Rockwell, Downey	STS logistics support and maintenance activities
July 18	Sikorsky Aircraft	X-Wing Flight Readiness and Safety Activities

July 20-23	JSC	STS, Space Station, SRM&QA, hardware/software/crew activities, aircraft operations
August 6-7	JSC	STS, Space Station computer hardware/software status and update
August 12	HQ	STS OMRSD's and OMI's (requirements and procedures for Shuttle launch processing, FMEA/CIL waiver action)
August 20	HQ	Space Station Program Review
August 27	JSC	STS computer hardware/software status
August 31	Dayton, OH	National Aero-Space Plane Update
September 2	HQ	NASA Organizational Review
September 2-4	Ames Res. Ctr.	X-Wing Flight Readiness Review
September 3-4	Washington, DC	NRC Criticality Review and Hazard Analysis Audit Panel
September 15-17	Rockwell, Downey	FMEA-CIL/Hazard Analysis, STS Review
September 17	JPL	Design for hardening computers
September 22	JPL	SSME Probabilistic Risk Assessment Studies
September 22-23	GSFC	SRM&QA Director's Meeting
October 2	HQ	National Aero-Space Plane Update
October 8	HQ	Numerical Risk Assessment and Safety Management
October 21-22	HQ/House/Senate	Sessions with NASA Administrator and congressional groups
October 22-23	HQ	PRCB Level I meeting
October 22-23	MTI, Utah	NRC Solid Rocket Motor Redesign Panel
October 28-29	KSC	NASA/SPC Launch Processing Operations
November 5-7	HQ	Life Sciences Advisory Committee, NASA Advisory Council
November 6	JSC	Space Station - Computer Systems Testing and Validation

November 12-13	MSFC	Aft Skirt Review Team
November 17-19	LeRC	NASA Aeropropulsion Conference
November 23	MSFC	TSS Program Status Review
December 1	Seattle, Wash.	Auxiliary Power Unit/Hydraulic Power Unit Concerns
December 10-11	Ames Reseach Center	X-wing briefings
December 16	HQ	Space Station-Computer Software/Hardware Testing and Validation Programs
February 5-7	JSC	NRC Solid Rocket Motor Redesign Panel
February 16	U.S. Senate	STS-26 Processing Status and Expectations

C. ASAP Proposed Activities for Calendar Year 1988

To meet the increased manned space missions associated with the National Space Transportation System (STS) and the increasing activities related to the Space Station Program, the Aerospace Safety Advisory Panel intends to increase fact-finding in both areas. In the case of the STS, it will focus on the "return to flight" technical and managerial activities, e.g., the Design Certification, Flight Readiness Firing, Flight Readiness Reviews, turnaround between missions and the continued attention to pertinent aspects of Safety, Reliability, Maintainability and Quality Assurance. For the Space Station Program, which is now gearing up to handle a "new" world of manned space flight, the ASAP will focus on the organization buildup, the roles and responsibilities of NASA and its contractors at both Headquarters and the NASA centers, and the foundation both technically and managerial as they affect and promote SRM&QA. In the field of aeronautics, the ASAP will continue to assess the safety integrity of the administrative aircraft program and the R&D projects, the aircraft management policy and implementation of that policy.

In the area of Spacecraft Fire Safety, the ASAP is interested in reviewing those programs in support of the STS and the Space Station with emphasis on NASA organizational roles and responsibilities and how they support the manned space flight programs. In particular, based upon information provided recently, there appears to be a fragmentation of the many organizations working in the fire safety field at NASA. With the dearth of resources available to fund everything everyone wants, the ASAP is interested in maximizing the NASA return for its expenditures to ensure fire safety is achieved in the STS and Space Station programs.

D. NASA Response to Panel Annual Report, March 1987

As in each year's annual report, the ASAP takes note of those items considered "open" and those considered "closed," for the latest response as well as prior years. Those listed as "closed" denote that actions planned and implemented have taken place; those called "open" indicate either plans and/or implementation of required activities are incomplete and/or are not well enough known at this time. The numbering sequence follows that found in the NASA letter response.

SUBJECT	STATUS
Status of "open" items reported in Annual Report issued in 1987	
A. Space Transportation System.	
o Space Transportation System Operations Contract (STSOC) at JSC goes into effect January 1, 1986. The ASAP is requested to follow this as they did the SPC at KSC.	CLOSED - Continuing activity
o Review the launch constraints being modified in order to increase launch probability and turnaround mods as well.	CLOSED - Review results noted in this year's annual report
o Comprehensive maintenance plan supposed to have been released September 1985.	CLOSED - System Integrated Assurance Program Plans documented
o Initial lay-in of spares to be completed by October 1987. Status, impact of reduced funding . . . particularly if it affects safety.	CLOSED - Management focus has been ensured
o SSME precursor test program to be completed during CY 1985.	CLOSED - Test program defined and depends upon funding
o Results of Rockwell's detailed fracture/fatigue analyses for test article L1-36 (wing/mid-fuselage/aft-fuselage structure being conducted June 1985 to January 1986.	CLOSED - ASKA 6.0 analysis accounts for this
B. Pressure Suits, Space Station, and Space Debris, letter from Dr. Fletcher to Joseph F. Sutter, January 9, 1987.	
1. Extravehicular Activities (EVA)/ Space Suits.	OPEN - NASA activities ongoing

- o NASA support of the development of an advanced flexible higher pressure suit.

- o NASA support of development of necessary data to establish, with confidence, what maximum stay in space should be.

2. Space Station

o Space Station ability to meet program objectives in a timely manner within current budget allocations.	OPEN
o NASA should establish a small team composed of current and retired NASA/contractor persons to define the management and technical lessons that can be learned from Space Shuttle program and applied to Space Station to preclude missteps.	OPEN

C. Space Transportation System (STS), letter from Dr. Fletcher to Joseph F. Sutter, September 2, 1987.

1. Orbiter

a. Orbiter structural life certification

o An abbreviated conservative analysis should be documented to fulfill the certification program.	OPEN - To be accomplished in FY 1988
o It should be noted that a loads calibration program will not be conducted on the Orbiter wing, but may be required if the flight results are questionable.	OPEN - NASA plans to conduct a loads calibration program on the OV-102 wing prior to its next flight

b. Orbiter Structural Adequacy: "ASKA 6" Loads/Stress Cycle Program

ASAP agrees with the arbitrary force approach taken at this time. However, the primary load path structure and thermal protection system analysis should be a standalone report, fully documented and	CLOSED - ASKA 6.0 data ready for use

referenced even if the September 30, 1987, end date slips. An operating restriction report and strength summary (external loads and vehicle stress) report for each Orbiter should be prepared in order to have quick access to information for making future decisions.	
c. Redlines and Modifications	
To provide 85-percent launch probability redlines, the wing modifications should be made, even if slightly conservative, in some structural areas. Redlines on OV-103 and OV-104 should be specifically examined and changed as required.	CLOSED - Plans completed actions in work, part of activity to return-to-flight
d. Brakes and Nose-Wheel Steering	OPEN - Redesign, tests, procurements still in process
2. STS Operations	
a. Logistics and Launch Processing	
o "NASA should examine the feasibility of developing data systems under management of the SPC, such as configuration management, that will centralize and augment KSC's operational launch capability."	CLOSED - Plans completed, implementation well along
o KSC and Shuttle Processing Contractor (SPC) activities regarding burden of work and flight rate.	OPEN - Panel to follow implementation of NASA SPC Station actions

D. <u>Space Transportation System</u>, letter from Dr. Fletcher to Joseph F. Sutter dated September 2, 1987.

1. Shuttle Management	
o Reorganization of Space Shuttle management. Enforce NMI's and define clearly responsibilities and authority for NASA centers; NASA centers to work as a team.	CLOSED

o The need to appreciate that the Space Shuttle is a system which remains primarily developmental.	CLOSED
o Transfer of logistics responsibility from JSC to KSC; appropriate funding; reduce LRU turnaround time.	OPEN - Continue to ensure appropriate management and congressional attention
o Sustaining engineering at KSC.	CLOSED
o Consolidation and upgrading of data/information systems, particularly configuration management and launch procedures.	OPEN - Panel will continue to monitor to ensure implementation and user-friendliness.
o NASA and contractor vertical and horizontal communications, particularly at KSC.	CLOSED
o Stretching of human resources at KSC (particularly Overtime Policy).	OPEN - assess implementation of current policies
o Growing problem of recruiting and retaining talented engineers and managers.	CLOSED
o Launch rate/manifest for Space Shuttle.	OPEN - Continue to assess capability to meet the NASA defined manifest; assess concerns, if any
o NASA and Congress expectations of "heroic" performance by workers.	CLOSED - See human resources item above

2. Space Shuttle Systems

o Redesign of solid rocket motor, certification/verification for flight.	OPEN - Continue to follow, participate in NRC effort and in-house reviews
o Testing of the SRM in horizontal test stand.	CLOSED

	o Provide funds to check OV-102 loads based on ASKA 6.0 analyses, check other Orbiters, update Orbiter load indicators/ redlines, prepare reports.	OPEN - Continue to follow
	o Orbiter 102 loads test program to calibrate strain gauges, etc.	OPEN - Continue to follow
	o SSME, Panel recommends that the Phase II engines operate below 104% RPL and if practical at no more than 100% RPL.	CLOSED
	o Panel recommends that SSME two-duct hot gas generator and large throat combustion chamber be tested and certified as soon as possible.	OPEN - Continue to follow
	o NASA and SSME contractor continue development of improved methods of demonstrating critical operating failure mode margins.	OPEN - Continue to follow
	o Regarding use of upgraded GPC in the Orbiter: 5-0 versus use of 4-1.	CLOSED - Will follow to ensure appropriate test and safety analyses
	o Orbiter landing gear system; including brakes, nose-wheel steering, etc.	OPEN - Panel will follow, including increased landing weight allowable effects
3.	Space Shuttle Operations	
	o Improvement of KSC work force effectiveness.	CLOSED
	o Space Shuttle logistics	CLOSED - Covered by previous item
	o Maintenance Safeguards program	CLOSED - Covered by previous item
4.	Safety, Reliability, Quality Assurance	
	o Development of operating policy for the new SRM&QA offices at Headquarters and at NASA centers.	OPEN - Panel will review the situation on an ongoing basis

o Independent review of payload safety.	OPEN - Continue to review/assess

5. Space Station Program

o Panel endorses initiative to simplify Space Station design	CLOSED
o Use of ELV's	OPEN
o Crew safe haven and life boat, crew rescue.	OPEN
o Computer system's use of new developments; also use of 32-bit architecture.	OPEN
o Use of lessons learned	OPEN

6. NASA Aeronautics

o Proper level of aircraft policy, management and operations offices.	CLOSED
o Modification of Grumman Aircraft as Space Shuttle flight simulators.	OPEN
o X-Wing project flight test program. Other comments included under this heading.	OPEN - Continue to follow

The material contained in the remainder of the response either expands on the material noted previously which was in the annual report executive summary or adds additional "pieces" to those items. Therefore, Section II, III, IV, V, VI, VII and VIII of the NASA response are not noted as "opened" or "closed."

NASA

National Aeronautics and
Space Administration

Washington, D.C.
20546

Reply to Attn of:

September 2, 1987

Mr. Joseph Sutter
Chairman
Aerospace Safety Advisory Panel
9311 Fauntleroy Way
Seattle, WA 98131

Dear Joe:

Our detailed response to the 1986 ASAP Annual Report is provided in the enclosure. As always, we find the ASAP Report positive and a beneficial activity with respect to NASA programs. From our response, you will find that we are moving to accomplish the vast majority of the Panel's recommendations.

I look forward to your comments and recommendations in the 1987 report, as one measure of the progress which NASA is making, as we continue our recovery activities from the Challenger accident. I can assure you that your suggestions and recommendations will continue to receive senior management attention by NASA.

Sincerely,

Original signed by
Dale D. Myers

for James C. Fletcher
Administrator

Enclosure

NASA'S RESPONSE TO THE

AEROSPACE SAFETY ADVISORY PANEL

ANNUAL REPORT

FOR 1986

I. EXECUTIVE SUMMARY

1. SPACE SHUTTLE MANAGEMENT

ASAP RECOMMENDATION: The Panel finds the recent reorganization of space shuttle management to be a positive step in recapturing or rebuilding a spirit of mutual respect and trust at all levels. The Panel recommends that: a priority objective of the new management team must be to enforce NASA's management instructions and to define clearly the responsibilities and authority of the NASA centers; a willingness of all NASA centers to pull together, to subordinate parochial interests, and to help each other is absolutely crucial if the space shuttle program is to succeed. (p.2, 17)

NASA RESPONSE: We agree. In the Phillips' study, the Crippen report, and in the reorganization of the shuttle management, we have addressed the roles and responsibilities of all levels of management to specify the relationship between the various program offices and centers. NASA Management Instructions (NMIs), Program Approval Documents (PADs) and supporting policies are being reviewed to clearly define the responsibilities and authority of the centers.

The elevation of direct control of the program to Headquarters establishes a programmatic chain that is independent of the NASA center organizations. However, the center directors are responsible and accountable for the technical excellence and performance of each of the National Space Transportation System (NSTS) project elements at their respective centers. Further, the center directors will ensure that their institution provides the required support to the NSTS program.

In addition, the center directors, along with the Associate Administrator, Office of Space Flight (OSF) are working together as members of the OSF Management Council which meets on a scheduled basis to oversee all OSF responsibilities and provide an independent review and assessment of the NSTS program.

ASAP RECOMMENDATION: The Panel finds that NASA and the Congress need to appreciate that the space shuttle is a system which remains primarily developmental with some operational characteristics. It is recommended that NASA needs to emphasize the developmental characteristic or it is likely to miss key elements of the Space Transportation System management challenge. (p.2, 19)

NASA RESPONSE: In the detailed program assessment conducted after the 51-L accident, it has become evident to the top management within NASA that much of NSTS is still in the developmental stage and significant areas of the system will probably remain essentially developmental throughout the life of the program. We agree with the Panel that there is a need to emphasize the development characteristics in order to provide required management oversight and operational awareness. Also, it will be the duty of NASA to work closely with the Congress to come to a mutual understanding of the developmental stage of the system. This will be a critical task to get budget approval in areas of continued development. We seek assistance from ASAP to emphasize in their interface with the members of Congress and their staff the developmental nature of the shuttle system.

NASA has already taken steps to strengthen its development effort on the shuttle program. In the critical main engine program, the single engine test rate has been substantially increased. The new plan calls for an average of 12 tests per month through February 1988, and 10 tests per month through the mid-1990's. This is an increase over the previous plan of eight tests per month through mid-1990 and six tests per month through the mid-1990's.

In the Solid Rocket Motor (SRM) program, it is planned to continue full scale firings of production motors at the rate of one to two per year following final qualification firings. These firings will be used to verify maintenance of critical processes, establish life of reusable components, and qualify any design changes. Another example is in the flight software area where a Level II Software Change Control Board has been set up. This board, made up of high level experts, reviews each proposed software change, determines impact, and approves or disapproves the change.

ASAP RECOMMENDATION: The Panel notes that transfer of part of the Space Transportation System (e.g., orbiter) logistics responsibility from Johnson Space Center (JSC) to Kennedy Space Center (KSC) must be supported with adequate budgets and appropriate authority to: build a sufficient inventory of spare parts, upgrade the Line Replaceable Units (LRUs), and develop an effective program to reduce LRU turnaround time. (p.2, 19)

NASA RESPONSE: Adequate budgets and appropriate authority have been given to KSC to develop an effective program to build a sufficient inventory of spare parts and to reduce LRU turnaround time. NASA logistics is working with Rockwell International (RI) to improve the turnaround times for LRU repair. This program includes establishing a resident office at Downey to coordinate and expedite logistics activities; establishing the Logistics Control Board at KSC to maintain control of LRU repairs and placing management emphasis in the form of contract requirements, such as Data Requirement Documents. Other activities include locating the orbiter logistics contractor next to NASA logistics in the new KSC Logistics Facility for better communication and working relations; holding weekly scheduled interface meetings between RI, Lockheed Space Operations Company (LSOC) and NASA Logistics to review and resolve problem areas; and interfacing with RI/Downey management at monthly progress meetings to review all actions concerning orbiter logistics. In addition, closer working relationships are being established with the new KSC Safety, Reliability and Quality Assurance (SR&QA) Directorate to make it an integral part of the repair process. This should resolve many areas of concern that are caused by communication and documentation problems.

A realistic baselining of new inventory line items has been established and considerable progress has been made in re-establishing inventory levels that dropped below a zero balance due to previous budgetary restrictions. A coordinated analysis has been conducted by NASA, RI, and LSOC of historical cannibalization actions, as well as usage data derived from processing experience. Those LRU's that have been identified to provide adequate support levels have been budgeted and procurement has been authorized with deliveries to begin in FY 1988.

ASAP RECOMMENDATION: The Panel recommends that those elements of sustaining engineering that are directly related to launch processing should be the responsibility of the Launch Operations Center (KSC) and those elements of sustaining engineering that require detailed knowledge of the design and development history of airborne hardware should remain with the design centers, as NASA now contemplates. (p.3, 19)

NASA RESPONSE: NASA agrees that the elements of sustaining engineering related to launch processing should remain the responsibility of the Launch Operations Center (KSC). These include the evaluation of launch base test data, generation and maintenance of test and launch procedures, logistics engineering, quick-look launch phase flight data analyses, design changes to ground support equipment (GSE) and facilities, and troubleshooting of hardware problems. At KSC, this responsibility and work are delegated and under contract to the Shuttle Processing Contractor (SPC) and closely supervised by government employee managers and engineers. The sustaining engineering manpower is being increased to more adequately support these functions.

NASA also agrees that the elements of sustaining engineering related to the design and development of the shuttle flight hardware should remain with the respective design centers and contractors. That concept is being followed. Sustaining engineering is being maintained with the development centers and contractors, who have a resident team from each flight element at KSC in support of shuttle processing (including Rockwell/orbiter, Rocketdyne/SSME, Martin/ET, United States Boosters, Inc. (USBI)/SRB, Thiokol/SRM, Spar/RMS).

ASAP RECOMMENDATION: The Panel recommends that NASA should achieve consolidation and upgrading of STS data/information systems, particularly those related to configuration management and launch procedures. (p.3)

NASA RESPONSE: NASA recognizes the requirement to upgrade the STS data/information systems to assure accurate accounting for configuration and launch processing requirements. A comprehensive relational data base system is being implemented as a portion of the system integrity assurance program plan. The Program Compliance Assurance Status System (PCASS) is being developed to fulfill this requirement and will contain Failure Mode and Effects Analyses (FMEA)/Critical Items List (CIL), hazards analysis, and hardware failure histories in addition to the configuration and processing requirements. This data will reside in or be accessed through a mainframe computer at JSC and be available to all levels of STS management. Our current requirements are to have closed loop accounting for configuration and launch site processing requirements prior to first flight.

ASAP RECOMMENDATION: The Panel finds that although the top SPC and NASA managers are communicating reasonably well, there is a continuing need to communicate even more directly with workers involved in launch processing to assure that there is a clear sense of mission and direction and to benefit from employee initiatives and suggestions during these crucial months prior to first reflight. (p.3)

NASA RESPONSE: NASA and the SPC have instituted a program of frequent periodic meetings with all levels to improve communications and morale. At these meetings speakers from the KSC center directorate, division directors, astronauts, SPC corporate officers and middle managers address audiences of engineers, planners, floor managers and technicians. They are formatted to promote recognition, respect, understanding, and cooperation through all levels and throughout the development and supporting channels of the program. The SPC has also initiated weekly meetings between personnel officers and all directorates, including representatives of salaried, hourly, engineering and floor worker employees. A suggestion box system and quality circles program have been set up to promote communication in the upward and lateral directions. The written forms of communications, such as the operations maintenance instructions and test procedures, have also been thoroughly reviewed and are being improved through revisions. The specific procedures dealing with criticality 1 items are also being reviewed and endorsed by the respective hardware development organization. The paperwork burden is being relieved by computer automation systems, and by increasing the manpower that support the data flow systems, planning, and scheduling activities.

ASAP RECOMMENDATION: The Panel reiterates that NASA and the SPCs need to prevent a recurrence of the condition that developed in 1985 where human resources at KSC were excessively stretched due to launch processing workload and schedule pressures (for example, overtime policy). (p.3, 22)

NASA RESPONSE: Work Time Policy - NASA KSC has established a Maximum Work Time Policy (NMI 1700.2) which requires specific top management (NASA and Contractor) approval for individuals to work:

- In excess of 60 hours in any one workweek
- More than 12 hours in any one workday
- More than 6 consecutive days without one full day off.

Increased emphasis has been placed on the supervisor's responsibility to enforce these policies. The current SPC manpower plan calls for a five percent overall overtime rate in FY 1988 and a minimal rate one percent thereafter. The current plan is to hire more people to lessen the need for overtime. Both NASA and contractor management are committed to closely monitoring workforce utilization and not allowing a situation to develop where excessive overtime is being worked.

SPC Performance - The processing flow timelines have also been evaluated and replanned to allow the work to be accomplished without significant overtime. The workforce is also being increased essentially across the board. Budget support from FY 1988 through FY 1992 has been requested for the improvement and integration of current information systems into an overall Shuttle Processing Data Management System (SPDMS) #II to relieve the heavy paperwork burden. NASA is also continuing to lay in a good supporting complement of spare LRUs to support shuttle flights in 1988 and a rate buildup by 1990. NASA has lengthened the flow timelines and increased manpower in order to reduce the work rate per flow in the Orbiter Processing Facility (OPF). We are also planning/requesting budget support for construction of a third OPF bay from FY 1990 through FY 1992. This OPF bay is to be in addition to the Operations & Maintenance Requirements Facility (OMRF), where airframe/structural inspections and major modifications are to be performed.

Flight Rate - As a result of the NASA assessment of vehicle processing capability and total or content required to return to flight status, the planned and expected flight rate for the shuttle has been reduced. The development of required capabilities to meet NASA objectives indicates a gradual increase in flight rate to 14 flights per year, which will be achieved no earlier than FY 1994. The Office of SRM&QA is tracking key parameters to independently assess if schedule pressure is becoming a potential factor affecting overall performance.

ASAP RECOMMENDATIONS: NASA top management should address the growing problem of recruiting and retaining talented engineers and managers due to inadequate Federal salaries. (p.3, item 8 and p.22, item f, p.58)

NASA RESPONSE: We agree with this recommendation. NASA has traditionally relied on its highly visible mission, work environment, and career advancement opportunities to attract high-caliber scientists and engineers. However, in the past several years, 70 percent of all graduating entry-level engineers have declined NASA engineering job offers. The reason most often given for not accepting these job offers is inadequate salaries and/or benefits. Entry level technical salaries continue to be significantly less in the Federal sector than in private industry. NASA's most recent experiences show that quality scientists and engineers with bachelor's degrees are accepting entry offers in private industry of $26,000 - $29,000; and some exceptional graduates with master's degrees, offers of $30,000 - $34,000. Under the Federal system, NASA can only offer $23,866 and $28,347, respectively.

The Personnel Programs Division, Code NP, has been and will continue to document all data reflecting national recruitment trends and situations. Such data, including specific NASA recruitment and turnover data was recently presented to OMB. NASA management will continue to take every opportunity to give testimony to Congress, OMB, and OPM and to support needed changes to the Federal personnel system. Additionally, Code NP in conjunction with field installation personnel offices has initiated and developed a new personnel concept. This concept, centering around a new pay and compensation package, has the NASA Administrator's support. This new personnel system is needed to strengthen NASA's recruitment and retention posture with private industry, as well as to improve the overall quality of the NASA working environment.

In expressing its concern regarding the salary structure for technical persons within NASA, the ASAP Report stated that: "It appears that in order to progress in terms of salary, people must move into management ranks, making it difficult to keep experienced, highly qualified people in the technical ranks (p.58-9)." We do not agree with this statement. In fact, the opposite is true. NASA employs approximately 6,500 GS-13, 14, and 15 level non-managerial technologists compared to 3,000 management officials at the same grade levels.

It is at these grade levels where the preponderance of technical expertise is found within NASA and where Federal salaries are generally comparable to those in the private sector.

ASAP RECOMMENDATION: The Panel, in an independent review, concurs with the National Research Council (NRC) Panel conclusions on space shuttle flight rates and utilization, that is, an upper limit of 8-10 flights per year with a three orbiter fleet and 11-13 flights per year with a four orbiter fleet. Further, the Panel recommends that the space shuttle be used only where manned missions are deemed mandatory, and expendable launch vehicles should be used for all other missions. (p.3, 4, 23)

NASA RESPONSE: In general, the flight rates projected by NASA are consistent with the conclusions of the NRC Panel. Their four orbiter flight rate of about 12 flights per year was characterized as a reasonable expected sustainable level. The rationale was that four flights per year can be achieved by each orbiter, but that only three of the four orbiters can be relied upon to be available on a continuing basis, due to unexpected problems and related maintenance and inspection requirements. The NRC also concluded that the space shuttle should have the capacity to surge above this sustainable level for short periods of time.

NASA's current planning is based on a gradual buildup to 11 flights per year in the first four years after operations resume, with a later increase to 13 or 14 when the replacement orbiter joins the fleet. The actual flight rates will be adjusted on the basis of operational experience, with appropriate contingency allowances in the shuttle processing schedules to minimize the buildup of launch pressure.

For greater assurance of access to space and to reduce the demands on the shuttle for payloads that do not require its unique capabilities, Dr. Fletcher directed Admiral Truly, Associate Administrator for Space Flight, to conduct a NASA-wide study of a mixed fleet strategy, using expendable launch vehicles to augment the shuttle. The study recommended that Delta, Atlas, and Titan class vehicles be utilized for those payloads that could be launched on ELV's (about 25 percent of the NASA payloads). It also recommended that for the period beyond 1992, NASA, with the DOD, should develop a heavy lift launch vehicle capability to meet the needs of this Nation. Implementation plans for both recommendations are being developed as part of the ongoing NASA planning and budgeting process.

ASAP RECOMMENDATION: NASA and the Congress should no longer expect that "heroic" performance by its workers and its contractors can compensate for funding shortfalls. The sort of heroism that is needed today is the courage to promise no more than can reasonably be expected given the dollars and people available. (p.4, 23)

NASA RESPONSE: The NASA team, both civil service and contractors, are extremely dedicated individuals. We are, however, aware of the problems that are created by excessive overtime and continually attempting to do the impossible. While we do not want to dampen the enthusiasm which made it possible for us to go to the moon and begin man's exploration of space, we recognize that we must be realistic in our planning and must establish goals and objectives which can be accomplished within the funding and manpower constraints and which give first priority to flight safety. Expectations that obviously cannot be met will not be promised.

2. SPACE SHUTTLE SYSTEMS

ASAP RECOMMENDATION: The Panel finds the redesign of the Solid Rocket Booster (SRB) joints is a marked improvement over the original joint design but there may be problems with mating, demating, and reuse. The approach selected entails more risk than one using new forgings that might permit a more sophisticated design but which would delay first shuttle flight. Since the proof of adequacy of the design depends strongly on satisfactory results from a thorough certification test program, the Panel recommends a truly complete definition of the certification program and that the elements of the certification program must relate to the specific design requirements. (p.4)

NASA RESPONSE: The activities planned for the Redesigned Solid Rocket Motor (RSRM) certification are defined in TWR-15723, Rev. 5, Development and Verification Plan for the RSRM, (Volumes I through X) dated 23 March 1987. The planned activities are designed to:

- Support the development of the RSRM design.
- Certify that the RSRM design meets design and performance requirements.
- Provide acceptance test and checkout to assure that deliverable RSRM hardware is manufactured to the certified design.
- Verify that the RSRM hardware, when integrated with other shuttle elements, meets design/performance requirements.
- Verify by flight and postflight analyses and inspection that the RSRM satisfies operational requirements.

The verification program is related to each specification requirement of the Configuration End Item (CEI) specification. The assembly/disassembly of segments is covered by paragraph 3.2.5.1 of the CEI specification.

Mating and demating is accomplished specifically in the following certification tests defined in the D and V Plan Test Summary Sheets:

- TJX-5 Assembly Tests
- TJX-6 Tang Guide Assembly at KSC
- TJX-10 Referee 3A and Hydroproofs (max interference)
- TNX-2.0 JAD Tests Empty and Loaded
- TGX-3 STA-3
- TGX-4 QM-6
- TGX-5 QM-7
- TGX-6 QM-8
- TGX-7.01-7.10 TPTA

- TGX-10 ATA
- TGX-11 PAD Environment Verification
- TGX-12 First Flight

Reuse is not a certification requirement at present. Early assembly certification tests (TJX-10) with maximum interference capture feature hardware were conducted in conjunction with hydroproofs. These referee tests certified the mate, demate, deflection, custom shimming, and rotation of the capture feature RSRM field joint metal design. Each assembly of capture feature hardware throughout the verification program will provide additional assembly/disassembly data to the RSRM program.

ASAP RECOMMENDATION: The Panel agrees with the decision to test the Solid Rocket Motors (SRM) in the horizontal position. In line with this, a second horizontal firing test stand is being constructed that will have the capability to apply simulated flight external dynamic loads. Since there is no way to assure that the tests encompass all possible loading conditions and assembly differences, the Panel recommends that the SRBs and the test stand itself be heavily instrumented to assure that flight-type structural and performance data is obtained as part of the certification program. (p.4, 34, Ref III-6)

NASA RESPONSE: The existing T-24 test facility has capability for 608 channels of instrumentation. The new T-97 facility has the capability for 1216 total channels of instrumentation. QM-7, planned for static test in March 1988 will be the first utilization of this new testing facility in the RSRM Program.

Morton Thiokol Incorporated (MTI) is currently releasing a statement of work to an outside contractor to conduct studies and analysis of the T-97 test stand structure capabilities, to conduct a modal survey vibration test to confirm the analytical predictions of loads, displacements and velocities, and to review the dynamic testing control system.

Detailed test planning for QM-7 will be initiated this fall. Full instrumentation of the test stand, motor and dynamic loading system can be accommodated based on data provided by the outside contractors and use of the facility instrumentation capabilities. Instrumentation selected for each test will be tailored to the specific test objectives for each static firing.

ASAP RECOMMENDATION: The Panel urges NASA to provide funds to: (1) check Orbiter 102 for loads resulting from the latest loads/stress analysis (designated ASKA 6.0), (2) check the other orbiters for ascent and descent loads, (3) update orbiter load indicators and redlines, and (4) prepare appropriate loads/stress summary report. (p.5, 35)

NASA RESPONSE: The tasks summarized above are collectively referred to as the post 6.0 loads studies. The post 6.0 loads studies are part of a number of potential changes and tasks which must be reviewed by Level I/II. The decision as to which changes and tasks are finally approved will be made based on the relative priority (primarily safety) ranking of the individual item and the amount of Allowance for Program Adjustment (APA) (reserve) funds available to support the change requests.

Approval has been given to update the orbiter load indicators and redlines prior to return to flight based on the 6.0 loads/stress analysis results.

ASAP RECOMMENDATION: The Panel urges NASA to have Orbiter 102 undergo a loads test program to calibrate the strain gauges installed so that flight data from these strain gauges may be used with confidence to obtain wing loads in flight. (p.5, 36)

NASA RESPONSE: Obtaining reliable data from the pressure gauges has proven to be difficult. However, accurate knowledge of the pressure distribution over the wings is considered to be very important for the correlation of strain gauge information and the actual wing loading. Consequently, significant emphasis is being given to selecting the best pressure gauges for this application and on understanding how to properly install and calibrate these gauges.

A change request (S40415) is being processed to implement a modified plan to verify the operational capability and performance of the OV-102 wing aerodynamic pressure verification instrumentation system and assure the overall system is adequate to accomplish verification of the IVBC-3 aero data base. The primary elements of this plan are as follows:

- F-104 flight test and lab tests at DFRF
- Ames wind tunnel testing
- OV-102 vehicle instrumentation checkout and verification
- Install 18 additional wing strain gauges for improved strain definition
- Strain gauges influence coefficient testing and calibration
- Detailed definition of test requirements, test support and test data analysis
- Definition of correction factors to apply to STS-61C flight data due to instrumentation irregularities
- Definition of pre- and post-flight checkout procedures on future OV-102 Detailed Test Objective (DTO) flights
- Monitoring of Accent Air Data System (AADS) installation alignment and calibration.

The Level II Program Change Review Board (PRCB) plans to review and decide on implementation of this plan in the near future.

ASAP RECOMMENDATION: NASA conducted an extensive reexamination of the Space Shuttle Main Engine (SSME) during 1986 to identify any safety issues that might have been overlooked and then to establish and validate an engine configuration for use in the upcoming shuttle missions. The Panel finds that the changes being made as a rule do not indicate that there will be any significant improvement in "margin to failure." The Panel recommends that the Phase II engines operate at power levels below 104 percent rated thrust, and if possible at no more than 100 percent rated thrust until these engines have accumulated sufficient flight operating time. (p.5)

NASA RESPONSE: The SSME power level will be limited to 104 percent maximum, except in emergency situations, when the program returns to flight status. An extensive ground test program, including margin demonstration test (higher power level, longer duration, off nominal performance response, and combinations of the above) has been defined and is being performed to demonstrate "margin to failure" at 104 percent power level. Continued testing of improved turbopumps will lead to increased margins.

ASAP RECOMMENDATION: The Panel recommends that the SSME two-duct hot gas manifold and the large throat combustion chamber be tested and certified as soon as possible. (p.5)

NASA RESPONSE: The two-duct hot gas manifold/large throat main combustion chamber (precursor engine) is assembled. The precursor test series to evaluate changes with significant margin gain potential in the hot gas flow environment will begin in the fourth quarter of CY 1987.

ASAP RECOMMENDATION: The Panel recommends that NASA and the SSME contractor continue the development of improved methods for actually demonstrating critical operating failure mode margins and the more rigorous risk assessment analytical procedures. It is recommended that, as part of such procedure, the term "failure" be defined as a violation of any of the governing design criteria for a component rather than as an event such as a structural failure or burn-through. (p.5)

NASA RESPONSE: NASA is continuing development of improved methods for actually demonstrating critical operating failure mode margins and more rigorous risk assessment analytical procedures. For demonstration of critical operating failure mode margin an extensive ground test program, including margin demonstration tests (higher power level, longer duration, and off nominal performance response) has been defined and is being performed. Our test procedures do not require that each and every violation of the design criteria be categorized as a "failure". However, each and every violation does require that an Unsatisfactory Condition Report (UCR) be written and tracked by the SR&QA organization. The UCR must document the discrepancy and can only be closed out with a failure analysis report that addresses cause and corrective action.

ASAP RECOMMENDATION: The Panel findings regarding the use of upgraded computer systems in late 1988 in either the 4/1 (4 new computers plus 1 old computer) or the 5/0 (5 new computers) configuration include the following factors:

(1) The degree of additional safety provided by dissimilar hardware (there already is dissimilar software);

(2) Human factor contributions to risk -- part of the safety provided by computer redundancy is achieved through astronaut training and in flight operations and maintenance procedures performed by the astronauts. This risk difference may well be greater than that in item 1 above.

(3) The impact of the flight schedule on the scope of software testing, or stated conversely, the impact of required software testing (which is larger for the 4/1 configuration) on the flight schedule; and

(4) The additional costs associated with the 4/1 configuration.

The Panel recommends that:

(1) In order to provide greater confidence in the new General Purpose Computer (GPC), it is recommended that the new GPC be flown on several flights as the backup computer before being used as the primary system.

(2) NASA should conduct a study of the human factors aspect of risk associated with in-flight operation and maintenance procedures, particularly changes in procedures and configurations resulting from response to some failure. Included in this should be a preliminary design of the 4/1 procedures and training and an assessment of their impact. (p.6, 7, 54, 57)

NASA RESPONSE: OSF has concluded that the 5-0 upgraded GPC configuration is preferable to the 4-1 option. This decision was reached by trading the unknown increase in system reliability gained by dissimilar hardware against the costs (additional testing, crew training, and software verification). The major threat in the new computer lies in hardware/software interaction in the primary redundant set, rather than a generic hardware problem that would affect all five machines. The additional costs associated with the 4-1 option would dilute the effort applied to hardware/software integration and potentially could detract from the overall system readiness. The Safety, Reliability, Maintainability, and Quality Assurance (SRM&QA) is still assessing the merits of the two configurations.

OSF also concluded that flying an upgraded GPC as the backup computer to gain confidence in the new hardware is not the best overall technical approach. This option does not aid redundant set hardware/software integration, and would create a short-lived intermediate configuration with attendant impacts on facilities, training, software, and testing.

An investigation to determine the benefits and costs of flying an upgraded GPC in a self-contained test bed is being conducted. This project would provide an additional degree of confidence without most of the technical concerns and costs of integrating a single new machine into the flight system.

From the standpoint of the human aspect of risk associated with in-flight operation and maintenance procedures, an intermediate configuration of either four new computers plus one old computer or four old computers and one new computer would exacerbate the problem of developing operation and maintenance procedures, and increase the associated documentation, testing, and crew training. We believe the best approach to minimizing the human aspect of risk is a meticulously planned and executed test and crew training plan for the 5-0 configuration before flight, and that is our baseline plan.

ASAP RECOMMENDATION: The orbiter landing gear system (including brakes and nose-wheel steering) has been a subject of concern to the Panel as noted in its reports since 1981. NASA's response to Recommendation VI of the Presidential Commission's report appears to meet the intent of the Panel's earlier recommendations. The Panel intends to monitor these areas to assure NASA completes its stated action plan. (p.7)

NASA RESPONSE: In accordance with our plans to increase safety margins, many landing gear system modifications have been considered and a number are being incorporated for the return to flight. Others are still being analyzed or tested for possible incorporation later. First flight modifications included the following:

- Brake instrumentation
- Main landing gear stiff axle
- Hydraulic brake module modification
- Thick stator/6 orifice brake assembly
- Main landing gear door retract mechanism
- Main landing gear door booster redesign
- Tire pressure monitoring instrumentation
- Anti-skid electrical power redundancy
- Delete brake pressure reduction
- Modification of control box to balance brake pressures
- Load relief for landing gear

Carbon brake development is proceeding with the Critical Design Review (CDR) scheduled for August 1987. A production set will be delivered April 1988, for the Wright-Patterson Air Force Base (WPAFB) dynamometer integrated test program. Certification is scheduled to be complete September 1988. The carbon brakes will increase abort braking capability by approximately 50 percent.

Nose-wheel steering has been upgraded to fail safe and is under study for further upgrading to fail operational/fail safe. Development tests or studies are being conducted on several potential modifications, including tires with improved wear characteristics and drag chutes. Development tests are planned this summer on the landing gear skid and wheel roll on rim capability.

3. SPACE SHUTTLE OPERATIONS

ASAP RECOMMENDATION: The Panel reviews of NASA and contractor launch processing operations included "one-on-one" interviews with technicians and quality control personnel doing the "hands-on" work. These have shown that recent efforts are steadily improving the effectiveness of both NASA and contractor activities at KSC. (p.7)

NASA RESPONSE: NASA plans to increase its effectiveness in all phases of the processing operation by providing subsystem engineers at the major facilities, e.g., the OPF, VAB, and launch pads. This will provide timely problem disposition by experienced engineers. NASA also plans to increase quality control support. This will improve effectiveness by providing an additional check and balance to guard against unilateral decisions, particularly in critical flight hardware processes.

The SPC has instituted a Quality Awareness Program, the intent being to increase individual awareness of the importance of product and service quality and the need for their personal contribution on the part of the processing team. A permanent group of liaison engineering personnel work directly with the operations and quality personnel during processing activities to provide real-time support to problems themselves or obtain specialized engineering support required for resolution.

To assure processing team effectiveness, SPC engineering emphasizes that it is a service organization designed to support the site operations personnel in accomplishing the total processing job. Engineers are encouraged to review problem troubleshooting plans and corrective actions with site technicians for comments and the approach/workability prior to release of work papers whenever possible. The SPC tries to instill within the process engineers a feeling of total responsibility for their systems processing. This motivates the engineers towards maximum involvement with system operations which necessarily dictates significant interaction with all other processing organizations. The launch support activities by the element contractors have also been augmented.

ASAP RECOMMENDATION: Space Transportation System logistics have improved but there remain some concerns:

- The completion of the procurement of necessary spares.
- Design improvements to LRUs.
- Procedures to control hardware cannibalization between vehicles.
- Establishment of required repair sites for LRUs to improve turnaround time.
- The many activities in support of returning to flight ("recovery"), e.g., hazards reviews, which may require modifications which affect logistics requirements. (p.7, 8, 68))

NASA RESPONSE: Contract NAS9-14000, Schedule L, between RI and KSC has been structured to identify, quantify, authorize, and procure necessary spares. KSC has identified initial and rate spare requirements. The final initial spares procurement was authorized in November 1986. The final rate spares procurement was authorized in February 1987. Lay-in of initial spares is to be completed by April 1989. Delivery of rate spares to be completed by September 1991.

Logistics impacts and required actions are identified as a part of modification/design review procedures. Steps have been taken to assure active planning and implementation participation by logistics agencies by assignment to review/implementation teams and establishment of dedicated organizations/personnel for completion of required activities. As an example, the orbiter brakes are being redesigned which will also result in a redesign of the inner wheel halves. This action has initiated meetings/telecons between JSC and KSC to determine the proper quantity of wheel halves and new wheels to support flight processing, roll around and contingency landing site operations. KSC systems engineers are preparing several operational scenarios, which may result in various quantities of wheels to be procured.

A policy of "no cannibalization" has been promulgated for all KSC shuttle operations and logistics activities. In the event of a mandatory requirement to cannibalize, procedures for justification to and approval by the NSTS Level II PRCB are in place. Level II and contractor management approval is necessary on all actions concurrent with center director review.

All orbiter LRUs have been reviewed to determine the locations for repair. This review has separated the LRUs into two groups; those that will remain with the Original Equipment Manufacturers (OEMs), and those that will be repaired by Depot. The present trend is to establish the Rockwell Services Center (RSC) as a Depot. Rockwell has published a schedule showing the LRU and the date the RSC will be prepared to repair the LRU. This schedule would meet the requirement of having a full Depot repair capability by September 1991. In addition, those LRUs that are to remain with the OEMs will be reviewed to see if it is cost effective and warrants the Depot to repair these items.

Approval of orbiter modifications is the responsibility of JSC. All changes that affect logistics requirements are reviewed and implemented by KSC participating in the mod/design reviews. The changes to logistics requirements, even if they are immediately implemented, may, in some cases, affect the support posture due to long lead times.

ASAP RECOMMENDATION: The Panel recommends that the recommended "Maintenance Safeguards" program being prepared by NASA in response to the Presidential Commission report be documented quickly and its impact evaluated as soon as possible. (p. 8)

NASA RESPONSE: NASA agrees that the "Maintenance Safeguards" program requirements should be documented quickly. A "Maintenance Safeguards" team was established in response to Presidential Commission Recommendation No. 9 and has defined the program requirements for "Maintenance Safeguards" in the System Integrity Assurance Program Plan (SIAPP) which was approved by the NSTS program on March 30, 1987. This plan includes comprehensive requirements to assure that the flight and ground systems retain their design performance, reliability, and safety throughout the life of the program. Each element of the NSTS program is preparing an implementation plan which will define the detailed impacts and will be approved at the program manager level.

4. SAFETY, RELIABILITY, QUALITY ASSURANCE

ASAP RECOMMENDATION: Within the newly established Safety, Reliability, Maintainability and Quality Assurance (SRM&QA) organization, NASA should develop the operating policy for all NASA SRM&QA and have the authority to ensure implementation. At each center there should be a NASA safety engineering function reporting to the center director. This function should be matrixed into the various programs/projects and should be responsible for implementation of safety policies established by the Headquarters organization.

NASA RESPONSE: NASA has significantly strengthened the SRM&QA function both at headquarters and at the field centers. The Associate Administrator for SRM&QA reports directly to the Administrator and is responsible for developing operating policy for the NASA SRM&QA functions throughout NASA. He has the authority to ensure implementation of these policies. Each of the flight centers has a SRM&QA Director who reports directly to the center director. There is a safety engineering function within the center SRM&QA Director's organization. It is our intent to matrix SRM&QA personnel to their line organization for overview and oversight purposes. SRM&QA responsibilities within the programs will reside with the line organizations and they will have their own personnel to accomplish the safety engineering functions within the program/project. Additional personnel may be matrixed between program projects for this purpose to assure full compliance with SRM&QA objectives.

ASAP RECOMMENDATION: NASA should continue to independently review all payload components with regard to their individual inherent safety, and should analyze the safety implications of the potential interactions of payloads in the event of a malfunction of any individual one. (p.8, 26)

NASA RESPONSE: We agree with the recommendation and it is our intent to continue to independently review all payloads for their inherent safety as well as the potential interactions with other payloads in the event of malfunction of any single one.

5. SPACE STATION PROGRAM

ASAP OBSERVATION: The Panel endorses the initiative to simplify the space station design and reduce the extent of manned assembly in orbit using extra-vehicular space suits. (p.9, ref. p.82)

NASA RESPONSE: We agree that the design should be simplified, and will endeavor to do more simplification as we work through the design phase of the program. The amount of shuttle-supported Extra-vehicular Activity (EVA) was reduced by the Configuration Evaluation Task Force (CETF) exercise, and the absolute amount of EVA was reduced as we descoped to define the approved configuration, the revised baseline.

ASAP OBSERVATION: The Panel suggests that expendable launch vehicles of greater performance than the shuttle be included in the launch stable inasmuch as such vehicles may emerge from other national programs. (p.9, ref. p.82)

NASA RESPONSE: As the specific characteristics of approved new launch vehicles become known, the use of such vehicles in either assembly or operation, or both, will be carefully considered. Until the development of such vehicles is approved, we do not know what their performance will be, or when they will be available. Under those circumstances, prudent, conservative program management requires that we plan on using existing, or at least specified, launch systems.

ASAP OBSERVATION: The Panel recognizes that "Safe Haven" and "Life Boat" options are under study in the continuing efforts to define the space station. The Panel suggest that both concepts may be required to satisfy ultimate safety requirements for space station operations. (p.9, ref. p.82)

NASA RESPONSE: We agree that we are not yet ready to make final decisions about "Safe Haven" and "Life Boat" provisions. Both concepts are undergoing further formal study. By the time decisions on one or both of the concepts must be made, NASA must have reached agreement on exactly what are the safety "requirements" to be met.

ASAP OBSERVATION: The Panel is concerned that the computer systems being considered for the space station may not be taking into consideration evaluating changes that will inevitably evolve in the industry in the next two decades. The Panel recommends that the system be designed to allow for the replacement of components as new technology develops. A 32-bit architecture and industry standard bus should be mandatory. (p.9, ref. p.82)

NASA RESPONSE: We also agree that the problem of accommodating for changes in the state of the technological art is not altogether tractable. However, both organizationally and in practice, we have made provisions for folding in new capabilities, new procedures, and new technology. We believe that decisions on the very specific computer system recommendations made by the Panel are neither necessary at this time nor prudent.

ASAP COMMENT: The Panel reiterates an old theme: lessons learned from prior programs must be applied and that such documented material is readily available, e.g., Saturn Apollo, Skylab, Space Shuttle. (p.9)

NASA RESPONSE: Lessons learned from Challenger are being fed back into the safety function at the Headquarters and field centers. Reviews of policy, organization, management, requirements, interfaces and operations in light of lessons learned have resulted in changes and planned changes, not just in product assurance areas, but throughout the STS program. Ground rules for product assurance analyses have been changed and the process for rebaselining them is well underway. Verification and testing procedures have also been tightened. We have activities in progress to identify how lessons learned from other programs, particularly STS, can be appropriately applied to the space station program.

6. NASA AERONAUTICS

ASAP RECOMMENDATION: The Panel recommends that NASA ensure that the level of the Headquarters Flight Operations Management Office and those at the center have proper recognition and ready access to their top management. (p.10)

NASA RESPONSE: We are in agreement with the ASAP recommendation. This recommendation reinforces the recommendations of the Rogers Commission to improve communications and management oversight of critical programs and the Phillips Study to improve institutional management of resources. The Aircraft Management Office (AMO) is the Headquarters focal point for agencywide aircraft operations, management, and operational aviation safety; and these functions necessitate that the office be visible, authoritative, and have immediate access to upper management to ensure that flight operations issues are addressed in a timely and adequate manner. The AMO was established and its functions were significantly enhanced over the past three years to counteract the Administrator's expressed concerns with the effectiveness of the Intercenter Aircraft Operations Panel and the lack of central management and standardization of NASA aircraft operations. The AMO now reports to the Associate Administrator for Management.

ASAP RECOMMENDATION: The Panel recommends that the shuttle flight simulators (aircraft) program be completed in a timely fashion so that astronaut training will not be hampered. (p.10)

NASA RESPONSE: NASA has requested funding in the FY 1989 budget for the 4th Shuttle Training Aircraft (STA) which is required for flight training beginning in June 1990. To meet the STA requirements, we will need to take a GRUMMAN G-II aircraft and perform an extensive, two year modification on the aircraft selected. We are investigating three options to meet this requirement:

1. Convert a G-II administrative aircraft to a STA configuration. This aircraft is being proposed for lease to replace a current NASA G-1 administrative aircraft that requires a service life extension. Prior to modification the proposed aircraft would have to be purchased.

2. Convert the Lewis Research Center Propfan Test Assessment (PTA) aircraft into a STA upon completion of the PTA program. This aircraft is currently under a lease-purchase agreement. Prior to beginning the modification, the purchase option would have to be exercised. The PTA program is scheduled to be completed no later than June 1988, and the aircraft will be available by that time.

3. Purchase a G-II aircraft on the open market and perform the modification on it.

We are evaluating these options and expect to make a decision in the near future.

ASAP RECOMMENDATION: X-Wing/Rotor Systems Research Aircraft (RSRA) incorporates a number of complex analyses, simulator, and test efforts. The Panel recommends that a Flight Readiness Review be conducted after completing these efforts, and that the correlation between them be carefully examined. (p.10)

NASA RESPONSE: Flight Readiness Reviews will be held prior to starting each phase of flight testing. The first series of flights will be accomplished with the rotor off and a review devoted exclusively to rotor-off configurations was held during the week of June 8. Rotor-off configurations have been examined with a powered model in the United Technology Research Center (UTRC) wind tunnel, simulations have been flown by the project pilots in the Ames Vertical Motion Simulator, and analyses have been correlated with available flight test data from the compound RSRA (N740NA). Many of these results were summarized at the June Flight Readiness Review.

ASAP COMMENT: The raising of the vertical center of gravity of the vehicle by some 18 inches as compared with the standard RSRA vehicle. This is having a pronounced effect on the structuring of the flight test program. (p.10).

NASA RESPONSE: The contractor/government team mutually agreed that a prudent approach to flight testing was to increase gross weight and vertical c.g. incrementally using five different configurations. The first three of these configurations are without the rotor and they were briefed and accepted by the Flight Readiness Review Board at the June Flight Readiness Review.

ASAP COMMENT: Aircraft structural divergency prediction from the tunnel tests. (p.10)

NASA RESPONSE: For rotor-off configurations analysis predicts that divergence due to aeroelastic instability would occur well outside of the vehicle's flight envelop (350 kts max.). There were no indications of structural divergency within the planned flight test envelop planned during wind tunnel testing.

ASAP COMMENT: Refinement of the flutter and divergence analyses. (p.10)

NASA RESPONSE: NASA, the contractor, and the subcontractor have refined their flutter and divergence analyses, and these were reviewed at the June Flight Readiness Review. There are no predicted flutter modes or adverse aeroelastic effects for the rotor-off flight test envelop. Refinement and review of these critical analyses will continue for all flight test phases.

ASAP COMMENT: Results from the powered model tests should be correlated analytically with predicated downwash interference. (p.10)

NASA RESPONSE: The accuracy of the initial downwash predictions are considered questionable. All math modeling and simulations have been upgraded to include the measured downwash effects from the wind tunnel tests. More wind tunnel testing is in progress, which will provide additional data.

ASAP COMMENT: The definition of the telemetry requirements with emphasis on software requirements for automatic monitoring. (p.10)

NASA RESPONSE: A detailed flight test plan has been submitted by the contractor that includes telemetry requirements. A go/no go list of instrumentation channels will be established for all flights. There is no contract requirement for automatic telemetry monitoring and the contractor/government flight test team does not believe that such monitoring is necessary or desirable. The Flight Readiness Review Board concurs with this position for the first flight phase, but the subject will again be reviewed prior to testing additional aircraft configurations.

II. SPACE SHUTTLE MANAGEMENT

1. ORGANIZATION

ASAP FINDING AND RECOMMENDATION: The Panel finds the problem of worker morale, especially at KSC, is of special concern. This is a classic problem of organizational and inspirational leadership that cannot be solved simply by changing institutional structures. The Panel recommends that NASA's top management, including the Administrator, Associate Administrator for Space Flight, the STS Director, and the Center Directors, take the lead in recapturing or rebuilding a spirit of mutual respect and trust at all levels. (p. 17, 66)

NASA RESPONSE: NASA and SPC management have instituted monthly meetings at the Orbiter Processing Facility (OPF) which feature members of top management, e.g., General McCartney, in direct interchange with employees. These forums provide the opportunity for the workers to get the "straight story" firsthand--viewed as a key ingredient in improving worker morale. There has also been an increased emphasis on publicizing good performance via in-house printed media. Widespread recognition of achievement and an expanded employee suggestion program are also aimed to improve morale.

NASA's Manned Flight Awareness Program - focusing on the government, contractor, military, and subcontractor employees working together as a team to achieve and maintain astronaut safety and mission success - was reinstituted with an honoree event at KSC in December 1986. This program, along with increased astronaut visits to KSC, plus other NASA centers and contractor facilities as well, is another measure being employed to rebuild team spirit. This participation promotes a personal bond between them and the processing team, reinforcing the awareness of the criticality of performance. The most recent honoree event was held in May 1987, in Washington, DC, and was a huge success. More than 600 people, including 14 astronauts, were in attendance. The next event is scheduled to be held at MSFC in October 1987.

ASAP FINDING AND RECOMMENDATION: The Panel notes that recapturing NASA's self-confidence in managing the shuttle program is crucial to success and requires NASA's leadership to keep in perspective the activities of the many advisory groups, task forces, and panels that have been created in the aftermath of the Challenger accident. NASA has the ultimate responsibility and authority to manage NSTS after giving appropriate consideration to the findings and recommendations of oversight groups. The individuals involved in these review panels, as well as Members of Congress, should recognize that excessive reliance by NASA management on external and internal review groups runs the real risk of destroying NASA's initiative and self-confidence, key elements of success in any human endeavor. (p. 17-18)

NASA RESPONSE: While we appreciate the assistance which we have obtained from the various review groups, we recognize that ultimately the NASA managers and the NASA team are responsible for managing NSTS and making it work. We fully agree with and appreciate the ASAP comment that NASA is accountable for the success of the program.

2. RESEARCH AND DEVELOPMENT VS. OPERATIONAL STATUS

ASAP FINDING AND RECOMMENDATION: NASA, in collaboration with the SPC, should make a concerted push to achieve greater consolidation and upgrading of STS information systems, particularly those related to configuration management and launch procedures. For example, the Problem Reporting and Corrective Action System (PRACA) is not programmed to identify big problems and trends in a timely manner. An improvement in management information will contribute directly to more reliable and predictable launch processing. (p. 19, 20)

NASA RESPONSE: NASA and the SPC are making a major effort to upgrade and integrate the STS information systems related to configuration management and launch processing support. NASA has requested a significant increase in the budget for this effort, extending from FY 1988 through FY 1992, and initiated the activity through the SPC. The PRACA and other processing-related data systems will be improved individually. These and several other processing-related information systems will be interconnected and integrated into an overall Shuttle Processing Data Management System (SPDMS) #II. SPDMS II will provide the hardware, software, data base and computer-to-computer communications for the accurate, efficient and safe collection, manipulation, dissemination and interchange of shuttle ground processing technical and management information. It will also be interconnected with shuttle information systems at other field centers, such as the Program Compliance Assurance and Status System (PCASS) of the System Integrity Assurance Program (SIAP) at JSC. SPDMS II will be initiated in 1988 with initial emphasis on the Operations & Maintenance Requirements & Specifications Document (OMRSD) closed-loop accounting related to returning to flight status. Additionally, SRM&QA is publishing on a regular basis a Significant Problem Report (SPR) which is widely distributed and statused. Other improvements are scheduled to follow which will lead to system maturity.

3. HUMAN RESOURCES

ASAP FINDING AND RECOMMENDATION: The Panel finds that recent layoffs by the SPC of a large number of workers at KSC to accommodate the STS standdown have lost skilled employees who will be needed in 1987 as preparations intensify for a resumption of space shuttle launches. The Panel recommends that the SPC should identify these losses and begin now, locating, recruiting, training and retraining the necessary persons with the skills to support all aspects of these preparations, including modifications to the orbiter and other STS systems that will be identified by ongoing NASA reviews. (p. 21)

NASA RESPONSE: The challenge of restaffing in order to support the first launch in 1988 is well recognized. Plans call for acquiring additional personnel, training or retraining them as the workload dictates, and recertifying them in accordance with job requirements.

During layoff activities, consideration was given to assure the maintenance of appropriate supervisory ratios to support the standdown period work and to retain key personnel for future requirements. Additionally, there is heavy emphasis being placed on reactivation training. This program addresses training for technicians and inspectors in the operational processing areas. NASA feels that the SPC has retained an excellent base on which to build. In addition, it should be noted that to date, in fiscal year 1987, an additional 600 SPC workers have been hired.

ASAP FINDING AND RECOMMENDATION: The Panel finds that uncertainty among SPC workers at KSC as to job security has undermined morale and other management efforts to improve communication and worker participation in launch processing decisions. It is recommended that top SPC and NASA management should personally act to eliminate this uncertainty by dispelling rumors when they arise and leveling with workers as to their future job prospects. (p. 21, 22)

NASA RESPONSE: The post STS 51-L worker environment can be described as one of great uncertainty. This situation was the root cause of morale problems and continued through the phases of the President's Commission, Congressional Committee, NASA Team, and panel investigations, and certainly through periods of workforce reduction. As the NASA organizational and personnel changes have taken place, redesigns have been identified, hardware testing results have been released, work content has been identified, and worker morale has improved.

Both NASA and SPC management policy is to notify, as soon as possible, the workforce of specific directions, actions, or decisions which affect them. To this end, such initiatives as OPF meetings which include members of top management (e.g., General McCartney or E. Douglas Sargent) in direct interchange with the workers have been started.

ASAP FINDING AND RECOMMENDATION: The SPC is expanding training opportunities for workers, but often this training is not focused on meeting the needs of individual workers. Training opportunities need to be linked more explicitly to expanding worker skills to permit longer term career progression. (p. 22)

NASA RESPONSE: A concerted effort is underway to provide training that is tailored to the needs of individual workers. Certification and recertification training, offsite training, and tuition assistance programs are available to the workforce. Cross-training opportunities for numerous individuals, in various disciplines and job assignments have been made available. Since June 1986, the number of workers attending training has risen significantly due to SPC management's increased emphasis to upgrade skills needed to perform critical tasks and processes. To assure that training opportunities are geared towards expanding worker skills, NASA/element contractors/and SPC senior management review training and certification program activities on a weekly basis.

ASAP FINDING AND RECOMMENDATION: The Panel finds there still appears to be some difficulties in communication between top SPC and NASA managers with floor supervisors and workers. The paperwork burden remains heavy. Instructions regarding specific processing operations are often inaccurate or incomplete, leading to inefficient scheduling and potentially to safety problems. It is recommended that top managers need to communicate more directly with workers involved in launch processing to provide a clear sense of mission and direction, as well as to benefit from employee initiatives and suggestions. (p. 22)

NASA RESPONSE: NASA and the SPC have instituted a program of frequent periodic meetings with all levels to improve communications and morale. These meetings rotate speakers from the KSC Center Director, division directors, astronauts, SPC corporate officers, and middle managers for audiences of engineers, planners, floor managers and technicians. They are formatted to promote recognition, respect, understanding and cooperation through all levels and throughout the development and supporting channels of the program. The SPC has also initiated weekly meetings between personnel officers and all directorates, including representatives of salaried, hourly, engineering and floor worker employees. A suggestion box system and quality circles program have been set up to promote communication in the upward and lateral directions. The written forms of communications such as the operations maintenance instructions and test procedures, have also been thoroughly reviewed and are being improved through revisions. The specific procedures dealing with criticality 1 items are also being reviewed and endorsed by the respective hardware development organization. The paperwork burden is being relieved by computer automation systems and by increasing the manpower that support the data flow systems, planning, and scheduling activities. In addition, an independent NASA Safety Reporting System (NSRS) has been implemented for STS.

4. SCHEDULE VS. BUDGET

ASAP COMMENT: Panel members have believed for some time that the space shuttle program has been underfunded and that these shortfalls, in turn, contributed to a Space Transportation System that was incapable of meeting the launch schedule NASA projected prior to the Challenger accident. The present review of Failure Modes and Effects Analysis (FMEAs) and Critical Items List (CILs) will likely generate a number of modifications to the Space Transportation System that will have to be accomplished prior to resuming a flight schedule. It is essential that budgetary concerns not unduly limit the designs and modifications that are needed from a safety and reliability perspective. If funds are not available to accomplish this work due to budgetary ceilings or other fiscal limits, the only acceptable alternative is to stretch out the schedule. (p. 22, 23)

NASA RESPONSE: Safety will not be compromised regardless of whatever budgetary or fiscal constraints might be imposed. If adequate funds are not available, we will make these facts known and make whatever adjustments are necessary to achieve the earliest safe Shuttle flight and ensure that we maintain a realistic flight schedule. We are concerned that stretch outs not only result in increased costs but could actually increase the chances of failure because of the loss of recent experience in operating the system and the potential loss of trained personnel.

1. SOLID ROCKET BOOSTER

ASAP COMMENT - NOZZLE-TO-CASE JOINT: The redesign of this joint incorporates 100 radial bolts, each with a "Stat-O-Seal" under its head. The bolts are intended to reduce the relative motion between the housing and the aft dome. The new design also includes a third (wiper) seal and a second test port, as well as circumferential flow baffles in the insulation.

The addition of the bolts adds multiple potential leak paths and residual stresses in the fixed housing that can reduce the reliability of the joint. The wiper seal bears on insulation rather than on metal. This could limit the pressure that can be employed during leak testing of the assembly.

There are a number of unresolved design questions at this time. Among them are the possibility of hot gas jet impingement of circumferential flow of such gas that could result from an insulation debond, and the ability to disassemble the nozzle from the case without damage to the insulation. Two alternate designs are being considered. One incorporates a metal thermaloc u-seal which maintains contact with the nozzle fixed housing and case aft dome during pressurization. The other concept is to insulate over the case-to-nozzle joint making it a factory joint. This design requires a new "field type" joint in the aft segment case and a redesign of the aft propellant grain. (p. 29)

NASA RESPONSE: The addition of the bolts does add multiple potential secondary leak paths. The bolt stat-o-seal concept, which the igniter/adapter incorporates, has been extremely reliable (i.e., no detectable failures in 57 firings). Hence, the stat-o-seals should not create a joint reliability problem. The fixed housing bolt holes also cause some local stress risers which the RSRM analyses must consider. Properly designed radial bolt holes maintain required factors of safety that will be verified by test.

The reference to the wiper as a "seal" is misleading as its design function is as a wiper to prevent the insulation joint adhesive from extruding into the primary o-ring groove. The combination of the wiper and cured joint adhesive will provide the medium to allow seating of the primary o-ring in the proper direction following the high pressure leak check between the primary and secondary o-rings. The allowable pressure in the wiper to primary o-ring cavity and its effects on the joint adhesive and joint insulation is being assessed both analytically and in Nozzle Joint Assembly Demonstration (NJAD) test article.

Both the jet impingement and circumferential flow issues are under intense scrutiny from two areas. The first area being analytical assessment of the affects of varying flaw sizes and types. As part of this analytical effort, the structural pressurization effects on joint free volumes and flaw sizes are being coupled to the flow/thermal analysis. Another major change in the flow/thermal analysis is the program decision to use the QM-4 nozzle vector duty cycle rather than the combined worst case envelope. The worst case envelope previously used represents the single worst vector degree angle from every potential mission scenario and not a single mission scenario. The analytical model predictions are also being calibrated through a subscale motor test program currently underway.

The second area under scrutiny is the characterization and probability assessment of potential flaws. This is being fed back into the flow/thermal analysis to establish the acceptability determined by meeting either design criteria or fail safe criteria. A key article in potential flaw assessment is the full-scale nozzle joint assembly article currently in work.

The ability to disassemble the nozzle without damage to the insulation is not a requirement. It is a consideration, but not at the expense of reliability and flight safety. The disassembly characteristics are currently being evaluated as part of the NJAD testing.

Reference was made to two alternate design concepts. The first, the thermaloc u-seal, is being actively pursued and will be tested in NJES-5. The second, the case/nozzle factory joint concept, is a concept and is not currently being actively worked. A third concept, a vented interlock insulation with the current baseline metal parts, is being evaluated in subscale test motors. Full-scale mold tooling is inhouse and a checkout fabrication is planned.

ASAP COMMENT - NOZZLE SYSTEM - The existing nozzle seals have performed adequately to date. The new design requirement for redundant and verifiable seals has, however, resulted in a complete redesign of all these seals. All such nozzle internal joints (there are five) are being revised to contain two seals with an intervening seal test port. All of these joints act to close the joint under operating load conditions except for the "number five" joint which acts to close the inboard seal and open the outboard seal in operation.

In addition to internal nozzle joint seal design changes, the ply lay-up angles of the ablator material on the several rings of the nozzle structure are being changed to reduce, if not eliminate, the pocketing erosion that has been experienced in the past. The cure cycle for the graphite composite material employed may have to be changed in order to limit erosion and charring.

The changes being made are many and complex and to validate their suitability requires full-scale, full-duration, hot-firing tests. The number of such tests required to establish confidence in the reliability of these changes will be large and has yet to be established.

Thus, the categorical application of the requirement that all seals be redundant and verifiable to all SRB joints may affect cost, schedule, and inspection procedures and may also reduce inherent reliability. (p. 29, 30)

NASA RESPONSE: The Aerospace Safety Advisory Panel's concern regarding the magnitude of changes approved for the RSRM nozzle has been considered and recently additional full-scale motors have been added to the static test program. To validate the suitability of the RSRM nozzle, it is planned to hot-fire full-scale, redesigned nozzles in a series of RSRM static tests beginning with DM-8, which will include many of the redesigned items. Those not incorporated into DM-8 will be into DM-9 and subsequent. In addition, detailed 2-D and 3-D analyses will support the design selection and validation process, as will subscale laboratory testing.

The following table details the RSRM nozzle features and point of full scale static test incorporation:

POINT OF INCORPORATION OF NOZZLE DESIGN CHANGES

FEATURE	DM-8	DM-9 AND SUBSEQUENT
REDUNDANT AND VERIFIABLE SEALS		
. NEW FIXED HOUSING WITH RADIAL BOLTS AND DUAL SEALS AND LEAK CHECK PORT		X

FEATURE	DM-8	DM-9 AND SUBSEQUENT
. NEW NOSE INLET HOUSING WITH DUAL SEALS, LEAK CHECK PORT, THICKER WEB, MORE MASSIVE STIFFENER RIB AND BONDING SURFACE IMPROVEMENTS (PHOSPHORIC ACID ANODIZATION AND ADHESIVE PRIMER)		X
. MODIFIED THROAT INLET HOUSING WITH DUAL SEALS		X
. MODIFIED FORWARD EXIT CONE HOUSING WITH DUAL SEALS AND LEAK CHECK PORTS (FORE AND AFT)	X	
. AFT EXIT CONE HOUSING BONDING SURFACE IMPROVEMENTS (PAA AND ADHESIVE PRIMER)		X
. REDESIGNED FIXED HOUSING INSULATOR TO COMPLEMENT BONDED CASE TO NOZZLE JOINT	X	
. THICKENED STRUCTURAL SUPPORT OUTER BOOT RING	X	
. THICKENED COWL LINER	X	
. REVISED TAPE WRAP PLY ANGLES IN FORWARD NOSE RING, AFT INLET RING AND THROAT RING	X	
. THICKENED AFT EXIT CONE LINER	X	
. IMPROVED BONDING AND ASSEMBLY PROCESSES		X
. REPLACEMENT OF EA913 WITH EA913 NA		X
. REDESIGNED NOZZLE PLUG	X	

ASAP COMMENT - IGNITER SYSTEM: The thickness of the igniter aft dome case will be increased to eliminate a negative margin of safety. This redesign is the only change that has been deemed mandatory for first reflight by NASA.

In the past, the igniter joint has exhibited primary seal erosion and blowby during the full-scale, hot firings. Test should be made to identify the joint leak paths so corrective action can be taken. (p. 30)

NASA RESPONSE: In considering the subject of erosion/blowby in the igniter during full-scale firings, it is important to identify that the DM-6 igniter experienced the only seal damage (erosion). Soot blowby was identified on the following igniters during post-flight inspection; SRM-11B, SRM-13B, SRM-17A, SRM-17B, SRM-18A.

Engineering determined the cause of the blowby and erosion to be an overfill condition in the igniter inner gask-o-seals. The condition was not detected by the seal vendor due to a faulty inspection method. It was determined that the gask-o-seals used in the above igniters were out of specification tolerance.

The problem became evident on 24 April 1985 when DM-6 igniter was disassembled. This is documented in TWR-14999 (significant program report DR4-4/43).

The following actions have been taken:

- Vendor's inspection method has been corrected and verified.
- All overfill gask-o-seals inhouse were sent to the vendor for refurbishment (new molded seals), and
- Overfill gask-o-seals already installed in motors were re-torqued per TWA-769 to ensure bolt torque relaxation did not occur.

Additionally, properly manufactured gask-o-seals will be evaluated in each of the static tests in the RSRM program.

ASAP FINDINGS AND RECOMMENDATIONS - SRB JOINT REDESIGNS: The Panel recommends that a more complete definition of the certification test program be required in order to determine its adequacy. The Panel also recommends that a concerted effort be made to include additional full-scale, hot firing tests in the final test program plan so as to reduce the possibility of undiscovered weaknesses. Further that during the first year of resumed shuttle flights, the SRBs be heavily instrumented to obtain both structural and performance data and that these data be considered as part of the certification program.

To attain a SRB design with a higher margin of safety for the long-term use with the shuttle, it is suggested that NASA proceed with the development of the "Langley" design (or its equivalent) for the case field joint and the "Hercules" design (or its equivalent) for the nozzle-to-case joint in an aggressive effort. (p. 32, 33)

NASA RESPONSE: The certification of the RSRM is detailed in TWR-15723 (Vol I-X), Development and Verification Plan for the RSRM. This plan includes a number of full-scale, hot fire tests of the RSRM and includes a full-scale motor test at both high and low temperature extremes with applied side loads. The Design, Development, Test & Evaluation (DDT&E) Flight (6) are an integral part of the RSRM certification process. These flights will contain 215 channels of Development Flight Instrumentation (DFI), and three channels of Operational Flight Instrumentation (OFI) for the SRM.

MTI has issued a subcontract to Lockheed to evaluate and analyze alternate joint concepts, including the "Langley" design. Steel billets have also been put on order as schedule protection for this activity. This effort, including reporting, will be completed late this year. Implementation of this or other Block II concepts is dependent upon overall NASA plans for future shuttle development.

ASAP FINDINGS AND RECOMMENDATIONS - SRB TEST FIRING ATTITUDE: The Panel recommends and agrees with the decision to conduct the hot-firing tests of the SRB in the horizontal attitude. The Panel notes that, despite the array of subscale, large diameter, and full-scale tests contemplated, there is no way to ensure that the tests encompass all possible loading conditions and assembly differences. The Panel strongly urges, therefore, that during the first year of resumed STS flights, the SRB's be heavily instrumented to obtain structural and performance data and that these data be considered to be part of the certification program. (P. 34)

NASA RESPONSE: OFI and DFI on the RSRMs for the first (6) flights will include 218 MTI requested measurements per motor (436 per flight), plus an additional 39 MSFC measurements per flight. In addition, there are 108 DFI and 24 heaters sensor measurements recorded prior to lift off. The following table identifies the currently planned OFI, DFI, GFI instrumentation. This is approximately (3) times the measurements installed on the motors for the first (6) flights (STS-1 through STS-6). At least (3) OFI measurements per motor will always be installed to provide actual motor performance. Some of the presently installed DFI measurements may be converted to OFI indefinitely on subsequent flights after the development flights. Most of the DFI will be installed to obtain the thermal and structural loads occurring from flight aerodynamics and aerothermal loads. More valid SRM data should be obtained from these flights over earlier flights since the majority of these measurements were requested and located by MTI to coincide with static test instrumentation.

DEVELOPMENT FLIGHT INSTRUMENTATION (DFI) RSRM 1-6 MEASUREMENT

QUANTITY		MEASUREMENT
LH	RH	FORWARD SKIRT
3	3	Accelerometers ±10g
		FORWARD SEGMENT
3	3	Pressure 0-1000 PSIA (OFI)
1	1	Pressure 0-3000 PSIA
12	0	Pressure 0-10 PSIA (MSFC)
0	3	Accelerometer ±400g (MSFC)
5	9	Strain ± 2K uIN/IN (4 ON RH SIDE MSFC)
5	9	Strain -2K/+6K uIN/IN (4 ON RH SIDE MSFC)

DEVELOPMENT FLIGHT INSTRUMENTATION (DFI) RSRM 1-6 MEASUREMENT

QUANTITY		MEASUREMENT
LH	RH	FORWARD SEGMENT
9	9	Girth -2K/+6K uIN/IN
1	1	Temperature Sensors 0 to 400 F
9	9	Temperature Sensors ± 200 F (GEI)
		FORWARD MIDDLE SEGMENT
2	2	Accelerometer ±10g
10	10	Girth -2K/+6K uIN/IN
4	4	Strain ±2K/+6K uIN/IN
4	4	Strain -2K/+6K uIN/IN
3	3	Temperature Sensors 0 to 400 F
10	10	Temperature Sensors ± 200 F (GEI)
LH	RH	AFT MIDDLE SEGMENT
3	3	Accelerometer ±10g
10	10	Girth -2K/+6K uIn/IN
12	12	Strain ± 2K uIn/IN (4 EACH SIDE MSFC)
12	12	Strain -2K/+6K uIn/IN (4 EACH SIDE MSFC)
3	3	Temperature Sensors 0 to 400 F
6	6	Temperature Sensors ± 200 F (GEI)
		AFT SEGMENT
6	6	Accelerometer ±10g
11	11	Girth -2K/+6K uIn/IN
31	31	Strain ± 2K uIn/IN
31	31	Strain -2K/+6K uIn/IN
17	17	Temperature Sensors ± 200 F (GEI)
		NOZZLE & AFT DOME
4	4	Accelerometer ±10g
9	9	Girth -2K/+6K uIn/IN
15	15	Strain ± 2K uIn/IN
15	15	Strain -2K/+6K uIn/IN
4	4	Temperature Sensors 0 to 400 F
9	9	Temperature Sensors -50 to 750 F
12	12	Temperature Sensors ± 200 F (GEI)
1	1	Continuity

3. EXPERIMENTAL VERIFICATION OF ORBITER FLIGHT LOADS:

ASAP FINDINGS AND RECOMMENDATIONS: The Panel found that data from the pressure gauges installed on vehicle Orbiter 102 cannot be relied upon for predicting wing loads accurately, and therefore, data from the installed strain gauges will have to be used to verify the Automatic System for Kinematic Analysis (ASKA) 6.0 loads/stress analyses. The strain gauges installed on the vehicle have never been calibrated as installed.

The Panel recommends that Orbiter 102 undergo a loads test program to calibrate the strain gauges installed so that flight data from these gauges may be used with confidence to obtain wing loads in flight. This testing should be accomplished during present hiatus in STS flights. (p. 36)

NASA RESPONSE: Please refer to Chapter I, Section 2, p. I-11.

4. SPACE SHUTTLE MAIN ENGINE (SSME)

ASAP RECOMMENDATION: The changes described above primarily address hardware reliability, firmer redlines and configuration control and improved hardware cycle life. In only a few instances will there be any significant improvement in margin to failure. The Panel recommends, therefore, that the Phase II engine be constrained to operate at 104-percent rated thrust or less. Furthermore, it must be noted that a significant increase in operating margin of safety can be achieved by operating a 100-percent rated thrust. It would be prudent, therefore, to operate at 100-percent thrust until the Phase II engines have accumulated significant flight operating time so as to provide a meaningful data base.

The Panel recommends that the two-duct hot gas manifold and the large throat combustion chamber be tested and certified as soon as possible. It is the opinion of the Panel that these changes will produce lower stress environments and improve margins at 104-percent thrust levels.

It is also recommended that the NASA and its SSME contractor continue the development of improved methods for actually demonstrating critical operating failure mode margins and the more rigorous Risk Assessment analytical procedures. It is suggested that, as part of the procedure, the term "failure" be defined as a violation of any of the governing design criteria for a component rather than as an event such as structural failure or burn-through. By way of illustration, crack growth to the point where a calculated stress margin falls below 1.4X should be call "failure" rather than when it reaches the "rupture critical flaw size." (p. 48, 49)

NASA RESPONSE: The SSME power level will be limited to 104-percent maximum, except in emergency situations, when the program returns to flight status. An extensive ground test program, including margin demonstration test (higher power level, longer duration, off normal performance response, and combinations of the above) has been defined and is being performed to demonstrate "margin to failure" at 104-percent power level. Continued testing of improved turbopumps will lead to increased margins.

The two-duct hot gas manifold/large throat main combustion chamber (precursor engine) is assembled. The precursor test series to evaluate changes with significant margin gain potential in the hot gas flow environment will begin in the fourth quarter of CY 1987.

NASA is continuing development of improved methods for actually demonstrating critical operating failure mode margins and more rigorous risk assessment analytical procedures. For demonstration of critical operating failure mode margin an extensive ground test program, including margin demonstration tests (higher power level, longer duration, and off normal performance response) has been defined and is being performed. Our test procedures do not require that each and every violation of the design criteria be categorized as a "failure". However, each and every violation does require that an Unsatisfactory Condition Report (UCR) be written and tracked by the SR&QA organization. The UCR must document the discrepancy and can only be closed out with a failure analysis report that addresses cause and corrective action.

5. SHUTTLE COMPUTER SYSTEM

ASAP COMMENTS: Reliability of new and old General Purpose Computers (GPC) - It seems clear that on paper the new GPC is more reliable than the original, but it does not have the flight testing of the original. All of the problems found in the original GPC have been corrected in both the current versions of the original GPC and the new GPC. If an original GPC is used, it will be a processor that has been in use for several years, not a new production copy of the original design. This has potential for both positive and negative effects. Through its use any initial manufacturing defects have been eliminated. However, as it has been in use for several years, one must question the effects of aging. (p. 55)

NASA RESPONSE: For this new GPC, an Electronic, Electrical, Electromechanical (EEE) parts upgrade regimen imposed tighter process controls and inspections, aimed at correcting reliability problems experienced on the old GPC. However, the new GPC does have some areas that must be actively worked to ensure adequate reliability. For example, the contractor has proposed a high density memory with a radiation damage risk, and a digital microcircuit family for which the manufacturer is still evolving wafer processing techniques. Also, the inspection and process control requirements of the parts upgrade program have necessitated using less experienced microcircuit assembly houses that could be in a learning period during the GPC build. All of these issues are being actively worked by the GPC project and their resolution is a high priority. The ASAP report states that all of the original GPC problems have been corrected in current versions of the original GPC. It is probably more accurate to say that corrective actions have been taken to the extent possible to address parts problems such as particle contamination and electromigration. The actual correction occurred when the suspect parts were designed out in the new GPC. Finally, we feel that the GPC with the new Complimentary Metal Oxide Silicon (CMOS) memory and associated circuitry, does have the potential for substantially improved reliability when fully qualified.

ASAP TECHNICAL CONCERN: The methods of determining and validating the 8,000 I-LOADS that must be defined for each shuttle flight. These constants define the mission to be flown and are as important as the software and computers to the success of a mission. (p. 58)

NASA RESPONSE: This technical concern was intended to indicate one of the topics that ASAP would like to have detailed reviews on at JSC during the coming year. The organization which is to be contacted to set up this review is Mr. Jack Boykin, Code WG, Telephone: 525-6136. (This response has been coordinated with the ASAP Staff Director, Gilbert L. Roth).

ASAP TECHNICAL CONCERN: Implications of proposed flight schedules on flight software testing on the Shuttle Avionics Integration Laboratory (SAIL) facility. In particular, there are concerns that the increased flight schedules will force reduced per flight testing.

NASA RESPONSE: This technical concern was intended to indicate one of the topics that ASAP would like to have detailed reviews on at JSC during the coming year. The organization which is to be contacted to set up this review is Mr. Jack Boykin (software), Code WG, Telephone: 525-6136; and Mr. Frank Littleton (hardware), Code VG, Telephone: 525-2744. (This response has been coordinated with the ASAP Staff Director, Gilbert L. Roth).

ASAP TECHNICAL CONCERN: The methods by which software tests are generated. The quality of the resulting software is highly dependent upon these procedures. (p. 58)

NASA RESPONSE: This technical concern was intended to indicate one of the topics that ASAP would like to have detailed reviews on at JSC during the coming year. The organization which is to be contacted to set up this review is Mr. Jack Boykin, Code WG, Telephone: 525-6136; and Mr. Frank Littleton, Code VG, Telephone: 525-2744. (This response has been coordinated with the ASAP Staff Director, Gilbert L. Roth).

ASAP TECHNICAL CONCERN: The methods by which compiler upgrades are tested. The compilers translate the program written for the Shuttle into the code execute by the computers. (p. 58)

NASA RESPONSE: This technical concern was intended to indicate one of the topics that ASAP would like to have detailed reviews on at JSC during the coming year. The organization which is to be contacted to set up this review is Mr. Jack Boykin, Code WG, Telephone: 525-6136. (This response has been coordinated with the ASAP Staff Director, Gilbert L. Roth).

ASAP TECHNICAL CONCERN: More detail on the redundancy management among the computers, in particular, timing and comparison methods. (p. 58)

NASA RESPONSE: This technical concern was intended to indicate one of the topics that ASAP would like to have detailed reviews on at JSC during the coming year. The organization which is to be contacted to set up this review is Mr. Frank Littleton, Code VG, Telephone: 525-2744. (This response has been coordinated with the ASAP Staff Director, Gilbert L. Roth).

ASAP TECHNICAL CONCERN: General hardware and software support system upgrade policies. It is not clear that NASA has general procedures. In the aftermath of the GPC upgrade, it would be a good idea to examine this issue and encourage NASA to develop suitable procedures. (p. 58)

NASA RESPONSE: This technical concern was intended to indicate one of the topics that ASAP would like to have detailed reviews on at JSC during the coming year. The organization which is to be contacted to set up this review is Mr. Jack Boykin (software), Code WG, Telephone: 525-6136; and Mr. Frank Littleton (hardware), Code VG, Telephone: 525-2744. (This response has been coordinated with the ASAP Staff Director, Gilbert L. Roth).

ASAP PERSONNEL CONCERN: Much of the knowledge of shuttle computer development and operation resides in the corporate memories of the employees who have worked on the system. The age distribution of the employees working on the computer system is of concern. There have been initial inputs that the current staff is heavily skewed toward the older age groups and that there is a dearth of employees in the mid-age group. (p. 59)

NASA RESPONSE: The NSTS organization shares ASAP's concern about aging corporate knowledge of shuttle computer development and operation. An intensive effort is being made to hire and train new college graduates.

ASAP PERSONNEL CONCERN: Some concern has been expressed about pressure from above to state that adequate tests can be performed within budget, whether or not they can be: it is also implied that if individuals do not conform, someone else will be found who will. (p. 59)

NASA RESPONSE: Adequate tests will be run on the GPC hardware and corresponding software. There are a number of organizations at JSC involved in the verification of these items including a Level II Change Control Board and software advocates whose sole job is to ensure proper tests are conducted. The budget will be made to accommodate the required testing.

There will be no improper pressure on individuals to conform. There are clear channels of communication both within the program structure and independently through the SRM&QA organization to ensure that any potential problems of this nature are surfaced and properly addressed. Further, the recently announced NASA Safety Reporting System provides a mechanism for any individual who encounters this type of problem to bring it to the attention of the highest levels of NASA management, with a guarantee of anonymity.

6. ORBITER LANDING GEAR SYSTEM:

ASAP COMMENT: Prior to first reflight, a heavyweight brake dynamometer facility will be assembled and used to verify braking capability. (p. 61)

NASA RESPONSE: The interim thick stator beryllium brakes planned for use on the first reflight have been tested at the Goodrich dynamometer facility. Although not a requirement to verify the interim thick stator brakes at the WPAFB dynamometer facility prior to first reflight, consideration is being given to testing the thick stator at this facility. It is planned to test the new structural carbon brakes at the WPAFB dynamometer facility. The WPAFB dynamometer will be modified to incorporate a full up landing gear assembly for the brake tests.

ASAP COMMENT: Additional areas are being investigated as part of the effort to improve the orbiter braking system. These areas have not, however, been designated as mandatory for first reflight. They include items such as use of an orbiter drag chute, upgrading of nose-wheel steering system, and wheel spin-up devices. Also, landing and roll-out simulations are to be conducted at the Ames Research Center (ARC) flight simulators. The Panel will continue to monitor progress in these areas. (p. 62)

NASA RESPONSE: Potential modifications under study and test include roll on rim, gear skids, tire tread material change, FO/FS nose-wheel steering and the drag chute. These modifications will be presented to the System Design Review Board for decision as to implementation.

The ARC landing and rollout simulations were conducted during the February-March 1987 time period. Over 1,100 runs were made with 15 pilots participating. All simulation objectives were accomplished with results including:

- Nose-wheel steering performance with the updated tire model closely matched last year's performance.
- The anti-skid function released the brake pressure on the two remaining wheels after the two tires were blown. Large braking recovery times (up to 6 seconds) resulted. The contractor is evaluating the system performance in this area and a change request is being considered to reduce the recovery time.
- The simulated drag chute demonstrated significant improvements in stopping distance, brake energies, and main tire load.
- Simulation data is being processed to statistically characterize tire wear versus crosswind.

IV. SPACE SHUTTLE OPERATIONS

1. LAUNCH PROCESSING

ASAP COMMENT: The issue of weather forecasting has been under review for some time as it affects operations at KSC. The need for more accurate and timely weather data, particularly winds aloft and rain, has been apparent and became more apparent as the pace of operations increased. (p. 65)

NASA RESPONSE: In 1984 a Meteorological System Modernization Program (MSMP) was initiated and a joint KSC-AF working group was created to assess the center's operational weather requirements. Over time this group has been broadened to address the full scope of both manned and unmanned weather requirements, with representatives from HQ, MSFC, and JSC.

A major advancement in forecasting capability was realized when NASA procured and installed a Meteorological Interactive Data Display System (MIDDS) at the Cape Canaveral Air Force Station (CCAFS) in 1985. MIDDS provides forecasters with a tool to integrate a multitude of data products (satellite data, winds data, radar imagery, etc.) into a concise format allowing more time to visually analyze dynamic weather systems impact on space operations.

In response to the Shuttle Weather Advisory Panel reports, NASA is implementing a five-year Weather Forecasting Improvement Plan. A cornerstone of the Plan is a study by the National Research Council, beginning in July 1987, to assess the feasibility of instrumenting KSC as a prototype nowcasting facility to ensure that state-of-the-science technology and forecasting methodology are utilized to support the space program. Another noteworthy element of the plan includes the installation of a radar wind profiler in 1987 that will aid in the assessment of winds aloft affecting manned and unmanned launches. In recognition of KSC's unique operational weather requirements, the AF has provided NASA with a weather officer dedicated to support the center's day-to-day needs. In light of the recent Atlas Centaur accident, we are further calculating our lightning requirements and prediction capability.

ASAP COMMENTS: There is a substantial amount of unplanned and previously deferred work at KSC. This is particularly true for the orbiters. This work must be carefully scheduled and accomplished. (p. 66)

NASA RESPONSE: The NASA NSTS management and development contractors have conducted thorough reviews of all previously deferred open work on all flight hardware, GSE, and facilities at KSC for reclassification, replanning, and rescheduling purposes. This was related to the FMEA/CIL, safety, processing requirements and procedures (OMRS/OMI) reviews. The open work, including orbiter and GSE modifications, has been classified as to criticality (for safety), which modifications are mandatory for return to flight status (RTFS), which are required before flight of each element and which modifications can be delayed for how long or for windows of opportunity. These classifications are now being utilized to carefully schedule those modifications required before RTFS, those before each orbiter's first flight, etc. The schedules are being planned to provide adequate time for the available workforce to accomplish the required modifications before the related target launch dates. Of course, modifications which can be further deferred will wait for windows of opportunities for installation between missions as required.

ASAP COMMENTS: Workers often expressed the opinion that training should employ real or equivalent hardware and situations so that the trainee can attain proper understanding of the hardware, software, and procedures. It was also suggested that competent supervisors and/or engineers should give the technical training courses rather than a training staff considered to be unfamiliar with the "real world." (p. 66, 67)

NASA RESPONSE: NASA KSC, the element contractor and SPC management have enhanced the formal courses and on-the-job training with increased simulation. KSC is currently conducting monthly T-20 minute countdown simulations. Included in the current budget request is a launch team training simulation plan (LTTS). This system consists of a firing room simulator (hardware and software) of the shuttle on-board flight system and associated ground support equipment. It will be used for training engineers and support personnel in subsystems operations and integrated shuttle processing scenarios. This integrated training system will better simulate the launch environment and reduce the overall time to train.

All plans for training activities are strictly reviewed by management. Additionally, shop supervisors and systems engineers will be involved not only in instruction, but also in the preparation of course material.

ASAP COMMENTS: The "hands-on" personnel exhibited respect for and reported satisfactory relations with most engineers. There was, however, concern expressed about the lack of experience and/or ability of many of the newly hired engineers. (p. 67)

NASA RESPONSE: There exists an excellent rapport between the engineers and floor workers, achieved primarily through "liaison engineering" personnel who work directly on-the-floor with the operations technicians and quality personnel in response to questions, problems and issues arising during processing. As the workforce is being expanded, "newly hired engineers" are being incorporated through training activities, familiarization roles with the liaison engineers, and practical experience during the RTFS mod and reactivation phase. The SPC and NASA managers feel that this methodical approach is the best way to bring in additional new engineers, determine their capabilities and allow them to develop their familiarity, confidence, and respect of the workers who will eventually implement their plans (instructions).

2. LOGISTICS

ASAP RECOMMENDATION: Establish control of the pipeline for the repair of Line Replaceable Units (LRUs), in particular, as well as for other components. This will probably include the need for a repair depot on-site at KSC. Although it will still be necessary to return certain sensitive units to the manufacturer for repair, the number of such units should be kept to a minimum. (pg. 68)

NASA RESPONSE: KSC shuttle logistics has established controls for the repair of LRUs. These controls include establishing a KSC Logistics Control Board to control repair actions; locating the orbiter logistics contractor next to NASA Logistics in the new KSC Logistics Facility for better communication and working relations, holding weekly scheduled interface meetings between RI, LSOC, and NASA logistics to review and resolve problem areas; and interfacing with RI/Downey management at monthly progress meetings to review all actions concerning orbiter logistics.

In addition, closer working relationships are being established with the new KSC SR&QA Directorate to make it an integral part of the repair process. This should resolve many areas of concern that are caused by communication and documentation problems.

ASAP RECOMMENDATION: Determine, as soon as feasible, the impact of the "maintenance safeguards" program. If there is a financial effect (i.e., increased spares requirements) necessary, budget modifications should be made promptly. (p. 68)

NASA RESPONSE: The program requirements for "maintenance safeguards" was approved as the System Integrity Assurance Program Plan on March 30, 1987. This includes maintenance and logistics requirements. For example, it requires a 90 percent probability of sufficiency for direct support spares. Each NSTS project is currently preparing implementation plans and impact assessments for these requirements. These implementations will be reviewed and approved by the Program Requirements Control Board (PRCB) and will include approval for additional resource allocations.

ASAP RECOMMENDATION: Ascertain the effect of the planned maintenance program on logistics. Make necessary adjustments to spares required. If the maintenance program planning is not yet complete, do so promptly in order that the effect on spares requirements may be known and incorporated into the recovery plan. (p. 68)

NASA RESPONSE: Current maintenance experience and planning have been reviewed as a routine management activity within KSC shuttle logistics activities. Actual experience, as well as projected impacts, are factored into spares quantification determinations to assure availability at the point of need. Real time unanticipated impacts are considered/evaluated for most rapid recovery possible within physical and/or monetary limits.

Spare parts have been ordered to support the implementation of the maintenance/structural inspection program. KSC Logistics, Flight and Ground Project Division is working with systems engineering to establish the schedule, areas of the orbiter to be inspected, and ordering items that will be replaced or have the potential of being replaced.

ASAP RECOMMENDATION: Determine the effects, if any, of the results of the ongoing shuttle design review program (if any) and factor them into logistics planning. (p. 68)

NASA RESPONSE: Logistics impacts and required actions are identified as a part of modification/design review procedures. The logistics program has been represented on the shuttle design review and implementation teams. Also, organizations/personnel have been established to monitor and participate in the completion of required activities. For example, the orbiter brakes are being redesigned which will also result in a redesign of the inner wheel halves. This action has initiated meetings/telecons between JSC and KSC to determine the proper quantity of wheel halves and new wheels to support flight processing, roll around and contingency landing site operations. KSC systems engineers are preparing several operational scenarios, which may result in various quantities of wheels to be procured.

ASAP RECOMMENDATION: Re-examine and assess the logistics targets to ensure that they are compatible with realistic flight rates. (p. 68, 69)

NASA RESPONSE: Since the Logistics responsibility transfer from JSC to KSC, there have been several grass roots exercises done in terms of logistics targets, both technical and budget, to ensure compatibility with the current flight manifest. Immediately after the transition from JSC to KSC in July 1986, and in preparation for the Program Operating Plan (POP) 86-2 budget cycle, KSC performed a bottoms-up assessment of the logistics program. A complete hardware supportability assessment was performed and all hardware required to support the fight rate is on order. Repair and depot requirements were all assessed and sufficient dollars are in the budget to support the technical requirements.

ASAP RECOMMENDATION: Establish a program to determine which components, devices, or parts are no longer available or may become so as a consequence of the supplier going out of business or ceasing their manufacture. Establish an activity to obtain equivalent hardware. (p. 69)

NASA RESPONSE: Requirements have been established within logistics support contractor activities to ensure future sensitivity to aging hardware systems, vendor discontinuance, and/or cessation. Projection of need and prior determination of replacement hardware is an objective which has met with limited success due to unexpected changes in business climates. In some instances, life of the program spares have been procured when prior notice of unavailability can be determined. In other instances, expensive real time redesign and replacement have been necessary. For example, Harris Corporation has made a "life of program" buy of certain solid state devices to be retained for repair parts. This should eliminate costly redesign/requalification of suppliers.

ASAP RECOMMENDATION: Reduce pipeline turnaround times for all critical LRUs. (p. 69)

NASA RESPONSE: Actions underway to improve turnaround time at the OEMs include:

- Streamline repair authorization procedures
- Improved repair scheduling and tracking system being installed
- Repair deferral eliminated
- Proper staffing of essential skills
- Consolidation of repair activities at the RSC
- Improved repair parts lay-in
  - OEMs are being tasked to recommend and procure required parts
  - Rockwell has established a new economic order policy that allows more flexibility for the OEMs.

These actions should help to achieve the desired turnaround times. Use of the RSC Depot will also increase KSC's direct control over repair actions.

3. SHUTTLE FLIGHT SIMULATORS

ASAP RECOMMENDATION: The shuttle flight simulator program requires an additional airplane because the current three airplanes are aging and will soon require major modification. The restart this year of the astronaut mission related training program will require the fourth aircraft in order to maintain the proposed flight schedule. Although this is approved, it appears to be suffering from lack of top management attention.

NASA RESPONSE: NASA has $21.2M in the budget for the 4th Shuttle Training Aircraft (STA). The STA will be ready for training in June 1990. We are investigating two options for the purchase of the aircraft. The first option is to purchase the Lewis Research Center Propfan Test Assessment (PTA) Gulfstream II aircraft. The other option is to purchase the Gulfstream II aircraft on the open market. The cost of the PTA aircraft is approximately $2M lower than an aircraft on the open market. However, there is a question of whether the PTA aircraft will be suitable because of potential structural problems caused by the PTA program. We intend to procure the PTA, but if found to be unacceptable, we will make an open market purchase.

ASAP RECOMMENDATION: NASA Headquarters should ensure that this program is continued and completed in a timely fashion so that astronaut training will not be delayed or restricted. (p. 69)

NASA RESPONSE: NASA Headquarters will continue its program responsibility through funding and direction to assure that the required training is accomplished prior to each shuttle mission. The current funding for the procurement of the 4th STA will enable its delivery in June 1990. Prior to that date, the present fleet of aircraft will provide the necessary training requirements to meet the current scheduled space shuttle manifest.

V. SAFETY, RELIABILITY AND QUALITY ASSURANCE

ASAP OBSERVATION: The objective of a System Safety Program in any enterprise or organization should be to manage such risk to an acceptable level (not zero) throughout the operational life cycle of the system. We believe there are also issues with the basic methodology used to ensure that risks are adequately projected (quantitatively) and then controlled to the levels accepted. (p. 72 and 73)

NASA RESPONSE: The Agency has a major effort underway to improve our risk management and risk assessment programs. Several current case studies are to evaluate the applicability of probabilistic analysis to improve understanding of failure modes. Improvements to trend analysis capabilities have also been initiated.

Systems assurance policies that will establish more uniform criteria for risk assessment are also in development. Risk assessment models that will evaluate in terms of undesired scenarios and their severity, and likelihood, will be required. Management structures and procedures will be revised to include a thorough review of the results of these new risk assessment models at the various decision points. Systems assurance requirements for Project Managers, implementation guides, and a specific Systems Assurance Program Plan for the STS are in draft form and will be available for use in the near future.

ASAP RECOMMENDATIONS: The Associate Administrator for SRM&QA should have full responsibility to establish a total system safety engineering program throughout NASA and be given the authority to assure its full implementation. A system safety engineering organization reporting to the Associate Administrator should generate the overall safety program policies to be followed. It would also define the critical design criteria to be used and the testing program methodology necessary to assure that those criteria have been properly validated. This Headquarters organization would also establish requirements and methods for performing overall system integration hazards analysis and for the generation of quantitative risk assessments tied to controllability of failure mode margins and test and flight results. (p. 73)

NASA RESPONSE: The Associate Administrator for SRM&QA (Q), chartered an Ad Hoc committee called "The STS Safety Risk Assessment Ad Hoc Committee" to review the STS flight centers (JSC, KSC, and MSFC), the STS element contractors, and the major payload centers (GSFC and JPL) and payload contractors in regard to their implementation of the STS safety process. These reviews and discussions indicated inconsistencies in the management approaches at various levels and some confusion whenever system or organizational interfaces were addressed. The committee concluded that these problems were the result of a weak Headquarters safety function and a weak STS safety integration process. As a result of this report and other observations made by the Associate Administrator for SRM&QA, further staffing increases are planned and a reorganization of the system safety activities within SRM&QA is underway. The system safety engineering doing function will still reside in the program at various levels, and the policy and oversight functions will reside in the Headquarters SRM&QA organization and the center SRM&QA Director's organization, which reports to the center director, and by dotted line to the Headquarters SRM&QA organization. These activities are being strengthened by staffing increases and establishing the function at the proper level in the respective organizations. The Associate Administrator for SRM&QA will have the ability to assure proper center support through his involvement during the center budget requirements review. He will assure proper support in the STS program through his policy development and oversight role. Within Code Q, the system safety functions are being brought together under one manager and continue to be under the Safety Division. The function will consolidate Code Q system safety engineering policy and oversight responsibilities in the design and operations areas. Critical safety design criteria and test methodology to assure those criteria have been properly validated will be developed within the System Safety Branch. Several new system safety policy and requirement documents are being developed, including procedures for performing specific hazard analyses and risk management assessment. As we envision it, a system safety training program is a necessary and vital ingredient to assure the program and project managers understand the role, interface, and responsibility of system safety in the decision-making process. An audit plan will be developed, to periodically review the NASA and contractor organizations at all levels. The requirements and methods for performing overall system risk assessment are currently being defined. The quantitative methods applicable to the generation and communication of risk assessment information are being reassessed.

ASAP RECOMMENDATION: Reliability, configuration maintainability, and operations safety engineering should be integral parts of this system safety engineering organization and it would provide policy direction for these functions throughout NASA. The definitions of policies and operating instructions for the quality assurance functions which are a vital part of risk management should also be the responsibility of the Associate Administrator. The policies and implementation directives should be implemented by system safety organizations reporting to the director's office at each NASA center. As appropriate, personnel from these organizations could be matrixed into the various programs. A significant part of NASA funds to be spent in safety areas should be allocated directly to the system safety organizations. This would provide assurance that necessary safety engineering activities can be controlled independently of the funding tradeoff pressures which always exist within programs. (p. 78)

NASA RESPONSE: We do not agree with the suggested amalgamation of various additional disciplines under the system safety organization. System safety over the years has developed into a well-defined technical discipline. We recognize that the application of existing system safety principles within NASA needs improving, and we are actively expanding the caliber and quantity of personnel, both within NASA and our contractors. To broaden the scope of this activity at this time, we believe, would be counter-productive. In the case of operational safety, we have chosen to deliberately highlight it as a separate organizational entity to provide added focus on an element that we recognize as needing significant added emphasis. We plan to continue to treat these as separate functions but strengthen the interaction and coordination between these groups. We agree that the quality assurance functions are a vital part of the overall risk management and these are, in fact, the responsibility of the Associate Administrator for SRM&QA. We believe they can be managed more effectively in a separate organization and we plan to continue to keep quality assurance in the RM&QA Division. At the local level, implementation of system safety policies and directives will be accomplished by the program or project line organizations with review by the center system safety organization which reports to the center director through the Director of SRM&QA at the center. We do plan to matrix the center system safety personnel into the various programs and will do this in a much more disciplined manner so that we can still maintain oversight and review objectivity in the center organizations.

The funding support issue we believe can be handled by the Associate Administrator for SRM&QA's involvement in the center's budget review process, for center support and by his oversight role for programs and projects. We believe we can protect the safety engineering activities from the tradeoff pressures which we agree do exist in the normal course of program operation without a direct funds allocation for the Associate Administrator for SRM&QA.

ASAP FINDING: The Panel recommends that NASA should emphasize development of Non-destructive Evaluation (NDE) techniques for assistance in qualifying critical STS elements. (p. 80)

NASA RESPONSE: NASA recognized the need for special attention in NDE and has had annual NDE meetings with NASA and contractor participation. The November 1986 meeting was directed toward SRM NDE. Also, a more indepth SRM NDE meeting was held at MTI in January 1987 with NASA HQS, LaRC and MSFC participants. One major accomplishment was achieved with the development of an ultrasonic technique to explore propellant to liner debond from outside the SRM steel case. Other NDE techniques are being investigated to inspect areas in the SRM where standard NDE methods are not applicable. NASA has a commitment to expand the NDE program under the Associate Administrator for SRM&QA.

VI. SPACE STATION PROGRAM

1. BACKGROUND

2. MANAGEMENT

ASAP RECOMMENDATION: Reorganizational concepts emphasize that overall program guidance will be centered at NASA Headquarters, Washington, DC, under the space station office directed by the Associate Administrator for the Space Station. Day-to-day direction and control of the program will be conducted by the Program Director who heads the Space Station Program Office (SSPO) located in Washington, DC. Detailed performance of the development activities are assigned to NASA field centers. (p. 83)

NASA RESPONSE: The information on assignment of responsibilities listed in this section of ASAP is not fully accurate. The current status is as follows:

The program office, which is part of the NASA Headquarters organization, has the responsibility to define and provide the station-level requirements, functional partitioning and resource allocations to the systems and elements. It also has the responsibility to perform overall systems engineering and integration, including interface analysis and control between elements and end-to-end systems.

For design and development, space station elements and end-to-end systems architecture have been assigned to four "work packages" as follows:

Work Package	Element	End-to-End System
WP-01 (MSFC)	Hab Module Lab Module Log. Module(s) Logistics elements	ECLSS
WP-02 (JSC)	Truss MSS Mobile Base Propulsion Resource Nodes Airlock(s)	Data Management Thermal Control Comm & Tracking Guidance, Nav. & Control Man Systems Assembly & Maintenance
WP-03 (GSFC)	Platform(s) Servicing Facility Attached Payload Accommodations	Servicing
WP-04 (LeRC)	Power Modules	Power Management & Distr.

3. TECHNICAL AND RESOURCE RISKS

ASAP OBSERVATION: From the point of view of space station safety, there are three general categories of space station threats: hardware/software, human performance, and logistics/resupply. In brief it would appear that these are some of the risks:

- Human performance errors should be a major concern of space station design and operation.
- The docking, electrical, flight control, and instrument systems have great potential for adversely affecting space station operations.
- A major logistics/resupply threat is the unreliability of launch vehicles.

The baseline space station program associated with the "build-to-cost" concept is a resource risk.

NASA RESPONSE: The mention of resource risk in connection with "build-to-cost" concept is fairly obvious, and is common with all NASA programs for which we offer a cost estimate early in the life of the program. Other risks listed are associated with other uncertainties in this development program; they make a good starting list of relevant uncertainties. In fact, many of these concerns were addressed in the thoroughgoing cost-commitment review that preceded the program approval for the revised baseline program.

Additional review by the special committee of the National Research Council is currently underway. At the beginning of September 1987, we should have their comments and will be able to respond appropriately.

The entire reconstituted SRM&QA program has as its main objective to identify these types of risks as early as possible and work to eliminate them.

4. SPACE STATION COMPUTER SYSTEMS

ASAP RECOMMENDATION: The space station designs developed over the next 18 months will impact the station's utilization and safety for probably two decades. It is thus particularly important to ensure that the utmost care and planning go into the design. It is, therefore, appropriate for the Panel to investigate the planning. This preliminary report is, therefore, more a statement of principles than a detailed set of findings. The examination of this subject will continue during 1987. (p. 85)

NASA RESPONSE: It has been a primary objective of the space station program to implement the designs of the station systems in a form that is responsive to, or at least consistent with, both the current and foreseeable missions of the station. This approach manifests itself in designs and technology selections which will be modular, adaptable, and changeable without major impacts on users of the station. The approach pervades the entire conceptual design, from computers, ISA, and bus structures, to networks, communications media, and beyond. It is also a primary objective to use, to the maximum extent possible, proven off-the-shelf technology and standardized components and approaches.

The selection of the computer architecture will significantly affect the performance of the on-board systems, in both the IOC and growth phases of the station. In creating the architecture control documents, the Station Program has set performance requirements for the flight systems adequate to meet or exceed current and foreseeable mission requirements. The selection of the specific processor to be incorporated will be made not now, but after Phase C/D contractor selection at the time of the preliminary design review (PDR). The flight qualification status of the systems at that time will weigh heavily in the decision.

If a candidate architecture cannot reasonably be flight qualified in time to be incorporated into the flight systems, its putative benefits are put into serious question and it cannot be used without waiving the standards of good flight system engineering. Other considerations include performance, size, weight, cost, and second-source availability. All things considered, we intend to select the best overall machine. With LAN technology as the communications backbone, the modular systems architecture designs will permit the upgrade of the on-board computational capability as candidate technology matures through the phase of flight qualification.

No specific selection of the computer architecture, ISA, networking protocols, LAN type, or other hardware has yet been made, nor should it be made until the completion of the PDR activity, which is at least a year and a half in the future. As the Panel notes, there may be significant advances in available technology in that time, and we intend to capture the best overall combination in reach at the time of decision, while preserving the avenues for future upgrade.

We believe these same comments apply to the Panel's findings and recommendations on automation and robotics in the space station. (p. 88)

5. LIFE SCIENCES

ASAP RECOMMENDATION: Life sciences probably needs to establish a more effective mechanism within NASA so that it can compete for available funds.

NASA RESPONSE: The space station program agrees with the Panel statement about life sciences activities in NASA. In addition, we note the Panel's concern on page 84 about incorporating consideration of human performance errors in station design. It would appear that not only must the agency be concerned with fundamental physiological well being in the station era and on into the era of planetary visits, it must also be concerned with psychological and psychiatric well being that can determine whether humans aboard the station will be able to function safely and efficiently.

B. THE ROTOR SYSTEMS RESEARCH AIRCRAFT/X-WING FLIGHT TEST PROGRAM (RSRA/X-WING)

ASAP COMMENT: Of primary concern is the raising of the vertical center-of-gravity of the vehicle by some 18 inches as compared with the standard RSRA vehicle. (p. 92)

NASA RESPONSE: The contractor/government team mutually agreed that a prudent approach to flight testing was to increase gross weight and vertical c.g. incrementally using five different configurations. The first three of these configurations are without the rotor and they were briefed and accepted by the Flight Readiness Review Board at the June Flight Readiness Review.

1. FLIGHT READINESS REVIEW

ASAP RECOMMENDATION: The Flight Readiness Review Board (FRRB) is structured in a way that will assure complete and adequate coverage of the X-Wing design activity. Included should be an evaluation and assessment of all data from the various X-Wing test and simulation activities. (p. 93)

NASA RESPONSE: These topics were addressed in the June Review and will be addressed at the Flight Readiness Reviews for each phase of flight testing.

ASAP COMMENT: Adequate correlation of dynamic analysis with the stopped rotor wind tunnels tests is not clear. Also, the plan for showing a wind tunnel/analytic correlation should be improved. (p. 94)

NASA RESPONSE: Flight test data from N740NA has now been correlated with the rotorless configuration at nominal gross weight. A global computer model is now available using both GENHEL (handling qualities) and REXOR (dynamics) for stopped rotor configurations. This modeling is continually updated to incorporate wind tunnel results.

ASAP COMMENT: The structural divergence prediction from the tunnel tests were not conclusive — some differences in the data are not accounted for. (p. 94)

NASA RESPONSE: There were no indications of structural divergence within the planned flight test envelope resulting from the wind tunnel tests. Performance measurements and hub moment measurements without putting grit on the blade surfaces to fix the location of boundary layer transition, did not correlate with the analytical predictions. Satisfactory correlation has been obtained using grit on the blades and making appropriate Reynold's number corrections. It should be noted that these data are not relevant for rotor-off flight testing.

ASAP COMMENT: The flutter and divergence analyses results performed by Northrop need further refinement. It is difficult to address the meaning of the results of the flutter analysis. (p. 94)

NASA RESPONSE: These analyses are continually being refined and now include flexible blades and better dynamic modeling. Neither structural divergence or flutter are predicted to occur within the RSRA/X-Wing flight envelope.

ASAP COMMENT: Various aerodynamic models for downwash interference are being used. Results from powered model tests are not in agreement with predicted analytical model results. (p. 94)

NASA RESPONSE: As previously stated, these initial models were rough predictions and good correlation was not expected. Current modeling is consistent with the measured downwash from the wind tunnel tests.

ASAP COMMENT: Current Northrop controls/dynamic analysis is conducted for 200 kts/2.5 degree angle of attack. The analytic method may not cover 140 kts to 250 kts of the flight envelope. (p. 94)

NASA RESPONSE: The methodology is believed to be valid for the complete stopped rotor envelope, and comprehensive results will be briefed for the proposed envelope for each phase of flight testing.

ASAP COMMENT: Better definition of the telemetering requirements with emphasis on software requirements for automatic monitoring is needed. (p. 94)

NASA RESPONSE: The project office agrees that better definition of the telemetry requirements is needed and we are presently reviewing "do not exceed limits" in order to establish go/no go requirements. As previously stated, there is no requirement for automatic monitoring. Past experience has shown that such monitoring is not desirable when a large number of parameters are involved.

ASAP RECOMMENDATION: There is a need for a well thought-out written plan that describes the expansion of the flight envelope in a methodical manner to ensure avoidance of flutter divergence and tail buffet. The flight data should be correlated with the analytical and wind tunnel test data at each point as the envelope expansion proceeds. (p. 95)

NASA RESPONSE: A written flight test plan is now available for review which covers the rotorless phase of flight testing. It is intended that all math modeling will be continually updated as flight test data become available.

2. PROPULSION SYSTEM TEST BED (PSTB) AND OTHER SIMULATION

ASAP RECOMMENDATION: As a result of drive train problems encountered on the Propulsion System Test Bed (PSTB), additional running time should be allocated to the PSTB. (p. 96)

NASA RESPONSE: The 50-hour drive train endurance run was increased to a 75-hour run that has now been successfully completed. A transmission teardown inspection was performed after the endurance run with no significant anomalies being observed.

4. X-WING SAFETY

ASAP RECOMMENDATION: The Panel recommends that NASA should complete a fault and failure analysis to provide an adequate level of confidence for its use. (p. 97)

NASA RESPONSE: The contractor has provided a comprehensive Failure Mode Effects Criticality Analysis (FMECA) and hazard analysis that has been reviewed by the Project Office. An Operating Hazard Analysis that is being jointly prepared by the contractor and the government will be completed prior to first flight of the aircraft.

D. NATIONAL AERO-SPACE PLANE (NASP) SAFETY CONSIDERATIONS

ASAP COMMENT: A major technical issue is the establishment of an adequate data base and overall validation of the design of the experimental manned transatmospheric research vehicle since the full-scale vehicle cannot be ground tested through the full range of operational flight speeds, Mach numbers, and altitudes. A thorough evaluation of existing ground research facilities, their modernization and upgrading needs, the need for new ground facilities, as well as possible flight research facility options must be established and the corresponding budget requirements defined. (p. 101)

NASA RESPONSE: NASA is in complete agreement with the ASAP recommendations. Phase 2 is specifically directed to the development of the design data base prior to and in support of the decision to proceed to the Phase 3, X-30 design, construction, and flight test. A review of facility capabilities and CoF requirements has been underway since program inception and will continue through Phase 3. This activity supports both NASA's CoF and DOD Milcon planning and out year activity. In addition, at the direction of the NASP Joint Project Office at Wright-Patterson Air Force Base, a panel of flight test specialists from the Air Force Flight Test Center and Ames/Dryden has been established to plan and coordinate development of the X-30 flight testing program.

VIII. STATUS OF "OPEN" ITEMS FROM JANUARY 1985 REPORT AS REPORTED IN JANUARY 1986 REPORT

ASAP ITEM: Space Transportation System Operations Contract (STSOC) at JSC goes into effect January 1, 1986. Panel is requested to follow this as they did the SPC at KSC. (p. 116)

NASA STATUS: The purpose of the STSOC contract was to consolidate numerous support contractors that supported the operation of the space shuttle fleet. At the time of the Challenger accident, Rockwell Shuttle Operations Company (RSOC) was involved in the transition portion of the contract. Due to the expected reduction in operational support, NASA directed RSOC to reduce transition hiring, use RSOC sustaining engineering capability to reduce backlog of facility modifications and discrepancies, and modify training of RSOC personnel by incumbents. After the transition period ended in June 1986, RSOC was tasked to actively participate in the 51-L recovery process to provide support for facilities maintenance, maintain proficiency for flight support, and establish management procedures for reliability and control. Due to major differences in the original Statement of Work (SOW) and current operating requirements, renegotiations are currently underway for the remaining portion of the option period of the contract.

ASAP ITEM: Review the launch constraints being modified in order to increase launch probability and turnaround mods, as well. (p. 116) - Open

NASA STATUS: NASA is reviewing the entire launch commit process, including launch constraints, to ensure safety, efficiency, and clarity. Launch constraints will be as flexible as possible, consistent with a safe operation. Turnaround mods will be reviewed for completeness, understanding, and necessity so that a rapid, safe turnaround of the shuttle may be accomplished.

ASAP ITEM: Comprehensive maintenance plan supposed to have been released September 1985. (p. 116)

NASA STATUS: The "Maintenance Safeguard" plan was not released in September 1985 as planned, but rather the System Integrity Assurance Program Plan (SIAPP) was released in March 1987. Development of the comprehensive maintenance requirements which could be applied to program elements required more time than originally anticipated. The program did proceed with elements of this program prior to the formal release of the SIAPP. The requirement for design center review and approval of launch center procedures was implemented prior to SIAPP approval. Program Compliance Assurance Status System requirements were developed in parallel with the SIAPP development to assure that essential program requirements would be implemented prior to the next flight.

ASAP ITEM: Initial lay-in of spares to be completed by October 1987. Status, impact of reduced funding... particularly if it affects safety. (p. 116)

NASA STATUS: Lay-in of initial spares is to be completed by April 1989. The delivery of rate spares is to be completed by September 1991. A rebaselining of the logistics program occurred in October 1985, and March 1986, which resulted in a completion date of April 1989, for initial lay-in of spares, and September of 1991 for rate spares. Current performance is on target to achieve this plan. All lay-in and rate hardware is on order to support these milestones.

ASAP ITEM: SSME precursor test program to be completed during CY 1985. (p. 116)

NASA STATUS: The precursor engine 0208 is assembled and is scheduled for the first test series to begin October 1987. The precursor program is delayed due to funding and test stand availability.

ASAP ITEM: Results of Rockwell's detailed fracture/fatigue analyses for test article LI-36 (wing/mid-fuselage/aft-fuselage) structure being conducted June 1985 to January 1986. (p. 116)

NASA STATUS: The fracture/fatigue analysis for LI-36 continues to be deferred to FY 1988 due to budget constraints. The primary work to be completed here is to verify the capability of the subject structure to meet its design life of 100 missions times a factor of 4. In view of the limited number of flights to be accumulated on each orbiter by FY 1988, completion of the LI-36 analysis is not considered to be mandatory in the near term. In the interim, a specific structural inspection has been implemented for this portion of the orbiter structure on the flight vehicles.

It is planned to complete and document this analysis in FY 1988 to complete the subject structural fatigue certification program for the orbiter.

ASAP ITEM: Space Station ability to meet program objectives in a timely manner within current budget allocations. (p. 118)

NASA STATUS: A major review of costing estimates was completed in early 1987. As a result of extensive discussions within the Executive Branch and with the Congress, a revised baseline program was established that satisfactorily matched budgets with program requirements. Further review of program costs by a special committee of the National Research Council is now underway, with completion expected by September 1, 1987. Major steps have been taken, consistent with the concerns expressed by the Panel, but some resource risk remains in all development programs until completion.

ASAP ITEM: NASA should establish a small team composed of current and retired NASA/contractor persons to define the management and technical lessons that can be learned from the space shuttle program and applied to space station to preclude missteps. (p. 118)

NASA STATUS: The Space Station Office is making a continuing commitment to gathering the lessons learned from the shuttle program, as is apparent from many of the comments on points raised in this year's ASAP Report. During the first half of 1987, the Space Station Program Office (SSPO) has been in the process of formation. It has been judged preferable to complete the senior level staffing of the SSPO so that those who must take action to avoid missteps will be able to profit by direct interaction with the small group of experienced people recommended in the Report. During the next few months, the formation of the SSPO complement should be completed, the program support contractor will be selected, and the lessons learned can be handed over directly, rather than through the rather more sterile means of a finished document on lessons learned. Additionally, NASA has funded John L. Casey, Incorporated, to prepare a lessons-learned document which can be used by the space station. John L. Casey, Incorporated, will use retired NASA/contractor personnel to assist, including Mr. Richard Smith and Dr. Robert Gray.

ASAP ITEM: ORBITER STRUCTURAL LIFE CERTIFICATION - An abbreviated conservative analysis should be documented to fulfill the certification program. (p. 118)

NASA STATUS: The fracture/fatigue analysis for LI-36 continues to be deferred to FY 1988 due to budget constraints. The primary work to be completed here is to verify the capability of the subject structure to meet its design life of 100 missions times a factor of 4. In view of the limited number of flights to be accumulated on each orbiter by FY 1988, completion of the LI-36 analysis is not considered to be mandatory in the near term. In the interim, a specific structural inspection has been implemented for this portion of the orbiter structure on the flight vehicles. It is planned to complete and document this analysis in FY 1988 to complete the subject structural fatigue certification program for the orbiter.

ASAP ITEM: It should be noted that a loads calibration program will not be conducted on the orbiter wing, but may be required if the flight results are questionable. (p. 118)

NASA STATUS: A change request is being processed which includes the installation of 18 additional wing strain gauges for improved strain definition. The change request further includes provisions for strain gauge influence coefficient testing and strain gauge calibration. The Level II PRCB plans to review and decide on implementation of this plan in the near future.

ASAP ITEM: ORBITER STRUCTURAL ADEQUACY: "ASKA 6" LOADS/STRESS CYCLE PROGRAM - The Panel agrees with the arbitrary force approach taken at this time. However, the primary load path structure and thermal protection system analysis should be a stand alone report, fully documented and referenced even if the September 30, 1987, end date slips. An operating restriction report and strength summary (external loads and vehicle stress) report for each orbiter should be prepared in order to have quick access to information for making future decisions. (p. 118)

NASA STATUS: Stand alone reports will be issued for the primary structure, the tile system, and the leading edge structural system. The schedule for completion of the 6.0 loads/stress cycle is February 1988.

The operating restrictions for each orbiter are contained in JSC Document 08934, "Shuttle Operational Data Book, Volume 1, Shuttle Systems Performance and Constraints Data."

The operating restriction and loads/stress summary reports are to be included in the post 6.0 loads study effort. The post 6.0 loads studies are part of a number of potential changes and tasks which must be reviewed by Level I/II. The decision as to which changes and tasks are finally approved will be made based on the relative priority (primarily safety) ranking of the individual item and the amount of APA (reserve) funds available to support the change requests.

ASAP ITEM: REDLINES AND MODIFICATION - To provide 85-percent launch probability redlines, the wing modifications should be made, even if slightly conservative, in some structural areas. Redlines on OV-103 and OV-104 should be specifically examined and changed as required. (p. 119)

NASA STATUS: The subject wing modifications (Mod Groups 1, 2, and 3) are being made as required and it is planned to have them in place for the return to flight of each orbiter vehicle.

The redlines have been specifically examined based on the accumulated flight data. The wind persistence factors used to account for changes in the launch winds from those measured 3 hours before launch proved to be underpredicting the actual loads encountered. Consequently, the wing persistence factors have been increased and the prelaunch wind measurement will now be taken 2 hours prior to launch. Final adjustments to the load indicators and redlines will be made when orbiter wing pressure distribution are verified on future OV-102 flights.

ASAP ITEM: BRAKES AND NOSE-WHEEL STEERING

NASA STATUS: In accordance with our plan to increase safety margins, many landing gear system modifications have been considered and a number are being incorporated for the return to flight. Others are still being analyzed or tested for possible incorporation later. First flight modifications include the following:

- Brake instrumentation
- Main landing gear stiff axle
- Hydraulic brake module modifications
- Thick stator/6 orifice brake assembly
- Main landing gear door retract mechanism
- Main landing gear door booster redesign
- Tire pressure monitoring instrumentation
- Anti-skid electrical power redundancy
- Delete brake pressure reduction
- Modification of control box to balance brake pressures
- Load relief for landing gear

Carbon brake development is proceeding with the CDR scheduled for August 1987. A production set will be delivered April 1988, for the Wright-Patterson Air Force Base dynamometer integrated test program. Certification is scheduled to be complete September 1988. The carbon brakes will increase abort braking capability by approximately 50 percent.

Nose-wheel steering has been upgraded to fail safe and is under study for further upgrading to fail operational/fail safe. Developments tests or studies are being conducted on several potential mods including tires with improved wear characteristics and drag chutes. Developments tests are planned this summer on the landing gear skid and wheel roll on rim capability.

ASAP ITEM: "NASA should examine the feasibility of developing data systems under management of the SPC, such as configuration management, that will centralize and augment KSC's operational launch capability." (p. 121)

NASA STATUS: NASA and the SPC are making a major effort to upgrade and integrate the STS information systems related to configuration management and launch processing support. NASA has requested a significant increase in budget for this effort, extending from FY 1988 through FY 1992, and initiated the activity through the SPC. The Problem Reporting and Corrective Action System (PRACA) and other processing related data systems will be improved individually. These and several other processing related information systems will be interconnected and integrated into an overall Shuttle Processing Data Management System (SPDMS) #II. SPDMS II will provide the hardware, software, database and computer-to-computer communications for the accurate, efficient and safe collection, manipulation, dissemination and interchange of shuttle ground processing technical and management information. It will also be interconnected with shuttle information systems at other field centers, such as the Program Compliance Assurance and Status System (PCASS) of the System Integrity Assurance Program (SIAP) at JSC. SPDMS II will be initiated in 1988 with initial emphasis on the OMRSD close-loop accounting related to returning to flight status. Other improvements are scheduled to follow, which will lead to system maturity.

ASAP ITEM: KSC and Shuttle Processing Contractor (SPC) activities re burden of work and flight rate. (p. 122)

NASA STATUS: Open - Panel to follow implementation of NASA and SPC station actions. See previous response p. I-5.

SPC Performance - The processing flow timelines have also been evaluated and replanned to allow the work to be accomplished without significant overtime. The workforce is also being increased essentially across the board. Budget support from FY 1988 through FY 1992 has been requested for the improvement and integration of current information systems into an overall Shuttle Processing Data Management System (SPDMS) #II to relieve the heavy paperwork burden. NASA is also continuing to lay in a good supporting compliment of spare LRUs to support shuttle flights in 1988 and a rate buildup by 1990. NASA has lengthened the flow timelines and increased manpower in order to reduce the work rate per flow in the OPF. We are also planning/requesting budget support for construction of a third OPF bay from 1990 through 1992. This OPF bay is to be in addition to the OMRF, where airframe/structural inspections and major mods are to be performed.

Flight Rate - As a result of the NASA assessment of vehicle processing capability and total work content required to return to flight status, the planned and expected flight rate for Shuttle has been reduced. The development of required capabilities to meet NASA objectives indicates a gradual increase in flight rate to 14 flights per year, which will be achieved no earlier than FY 1994.

E. Referenced Memos from Associate Administrator for Space Flight

NASA

National Aeronautics and
Space Administration

Washington, D.C.
20546

Reply to Attn of: M

MAR 24 1986

TO: Distribution

FROM: M/Associate Administrator for Space Flight

SUBJECT: Strategy for Safely Returning the Space Shuttle to Flight Status

This memorandum defines the comprehensive strategy and major actions that, when completed, will allow resumption of the NSTS flight schedule. NASA Headquarters (particularly the Office of Space Flight), the OSF centers, the National Space Transportation System (NSTS) program organization and its various contractors will use this guidance to proceed with the realistic, practical actions necessary to return to the NSTS flight schedule with emphasis on flight safety. This guidance is intended to direct planning for the first year of flight while putting into motion those activities required to establish a realistic and an achievable launch rate that will be safely sustainable. We intend to move as quickly as practicable to complete these actions and return to safe and effective operation of the National Space Transportation System.

Guidance for the following subjects is included:

- o ACTIONS REQUIRED PRIOR TO THE NEXT FLIGHT
- o FIRST FLIGHT/FIRST YEAR OPERATIONS
- o DEVELOPMENT OF SUSTAINABLE SAFE FLIGHT RATE

ACTIONS REQUIRED PRIOR TO THE NEXT FLIGHT:

Reassess Entire Program Management Structure and Operation

The NSTS program management philosophy, structure, reporting channels and decision-making process will be thoroughly reviewed and those changes implemented which are required to assure confidence and safety in the overall program, including the commit to launch process. Additionally, the Level I/II/III budget and management relationships will be reviewed to insure that they do not adversely affect the NSTS decision process.

Solid Rocket Motor (SRM) Joint Redesign

A dedicated SRM joint design group will be established at MSFC, with selective participation from other NASA centers and external organizations, to recommend a program plan to quantify the SRM joints problem and to accomplish the SRM joints redesign. The design must be reviewed in detail by the program to include PDR, CDR, DCR, independent analysis, DM-QM testing, and any other factors necessary to assure that the overall SRM is safe to commit to launch. The type and content of post-flight inspections for the redesigned joints and other flight components will be developed in detail, with criteria developed for commitment to the next launch as well as reusability of the specific flight hardware components.

Design Requirements Reverification

A review of the NSTS Design Requirements (Vol. 07700) will be conducted to insure that all systems design requirements are properly defined. This review will be followed by a delta DCR for all program elements to assure the individual projects are in compliance with the requirements.

Complete CIL/OMI Review

All Category 1 and 1R critical items will be subjected to a total review with a complete reapproval process implemented. Those items which are not revalidated by this review must be redesigned, certified, and qualified for flight. The review process will include a review of the OMI's, OMRSD's, and other supporting documentation which is pertinent to the test, checkout, or assembly process of the Category 1 and 1R flight hardware. KSC will continue to be responsible for all OMI's with design center concurrence required for those which affect Category 1 and 1R items. Category 2 and 3 CIL's will be reviewed for reacceptance and to verify their proper categorization.

Complete OMRSD Review

The OMRSD will be reviewed to insure that the requirements defined in it are complete and that the required testing is consistent with the results of the CIL review. Inspection/retest requirements will be modified as necessary to assure flight safety.

Launch/Abort Reassessment

The launch and launch abort rules and philosophy will be assessed to assure that the launch and flight rules, range safety systems/ operational procedures, landing aids, runway configuration and length, performance vs. TAL exposure, abort weights, runway surface, and other landing related capabilities provide an acceptable margin of safety to the vehicle and crew. Additionally, the weather forecasting capability will be reviewed and improved where possible to allow for the most accurate reporting.

FIRST FLIGHT/FIRST YEAR OPERATIONS

First Flight

The subject of first flight mission design will require extensive review to assure that we are proceeding in an orderly, conservative, safe manner. To permit the process to begin, the following specific planning guidance applies to the first planned mission:

- daylight KSC launch
- conservative flight design to minimize TAL exposure
- repeat payload (not a new payload class)
- no waiver on landing weight
- conservative launch/launch abort/landing weather
- NASA-only flight crew
- engine thrust within the experience base
- no active ascent/entry DTO's
- conservative mission rules
- early, stable flight plan with supporting flight software and training load
- daylight EDW landing (lakebed or runway 22)

First Year

The planning for the flight schedule for the first year of operation will reflect a launch rate consistent with this conservative approach. The specific number of flights to be planned for the first year will be developed as soon as possible and will consider KSC and VAFB work flow, software development, controller/crew training, etc. Changes to flight plans, ascent trajectories, manifest, etc., will be minimized in the interest of program stability. Decisions on each launch will be made after thorough review of the previous mission's SRM joint performance, all other specified critical systems performance and resolution of anomalies.

In general, the first year of operation will be maintained within the current flight experience base, and any expansion of the base, including new classes of payloads, will be approved only after very thorough safety review. Specifically, 109 percent thrust levels will not be flown until satisfactory completion of the MPT testing currently being planned, and the first use of the Filament Wound Case will not occur with the first use of 109 percent SSME thrust level. Every effort will be made to conduct the first VAFB flight on an expeditious and safe schedule which supports national security requirements.

DEVELOPMENT OF SUSTAINABLE SAFE FLIGHT RATE

The ultimate safe, sustainable flight rate, and the buildup to that rate, will be developed utilizing a "bottoms-up" approach in which all required work for the standard flow as defined in the OMRSD is identified and that work is optimized in relation to the available work force. Factors such as the manifest, nonscheduled work, in-flight anomaly resolution, mods, processing team workloads, work balancing across shifts, etc., will be considered, as well as timely mission planning, flight product development and achievable software delivery capability to support flight controllers and crew training. This development will consider the availability of the third orbiter facility, the availability of spares, as well as the effects of supporting VAFB launch site operations.

THE BOTTOM LINE

The Associate Adminstrator for Space Flight will take the action for reassessment of the NSTS program management structure. The NSTS Program Manager at Johnson Space Center is directed to initiate and coordinate all other actions required to implement this strategy for return to safe Shuttle flight.

I know that the business of space flight can never be made to be totally risk-free, but this conservative return to operations will continue our strong NASA/Industry team effort to recover from the Challenger accident. Many of these items have already been initiated at some level in our organizations, and I am fully aware of the tremendous amount of dedicated work which must be accomplished. I do know that our nation's future in space is dependent on the individuals who must carry this strategy out safely and successfully. Please give this the widest possible distribution to your people. It is they who must understand it, and they who must do it.

Richard H. Truly

NASA

National Aeronautics and
Space Administration

Washington, D.C.
20546

NOV 5 1986

Reply to Attn of: M

TO: Distribution

FROM: M/Associate Administrator for Space Flight

SUBJECT: Organization and Operation of the National Space Transportation System (NSTS) Program

This memorandum defines direction for the organization and operation of the NSTS program. This direction has been reviewed by the NASA Management Study Group led by General Phillips and has the approval of the Administrator. This implements the NASA response to Recommendation II (Shuttle Management Structure) and Recommendation V (Communications) of the Presidential Commission on the Space Shuttle Challenger Accident.

A crucial part of our strategy to safely return the Space Shuttle to flight status, as outlined in my memorandum of March 24, 1986 (and later reinforced by the Presidential Commission), has been a reassessment of the NSTS program management structure and operation. On June 25, 1986, in order to form the basis for a careful assessment of the management of the NSTS and required adjustments, if any, I directed Robert L. Crippen to lead a study of NSTS program operation and organization. This study has been presented to me and, subsequently, reviewed with all incumbent managers of the NSTS program through the project level; all involved field Center Directors (Kennedy Space Center (KSC), Marshall Space Flight Center (MSFC), Johnson Space Center (JSC), and National Space Technology Laboratories (NSTL)); and staff members of the Headquarters Office of Space Flight.

Decisions relating to the following program areas have resulted from this deliberation:

- NSTS MANAGEMENT STRUCTURE
- NSTS PROGRAM EXECUTION
- IMPLEMENTATION
- RELATIONSHIP OF THE CENTER DIRECTORS TO THE NSTS PROGRAM

A detailed discussion of each of these subjects follows in this memorandum.

NSTS MANAGEMENT STRUCTURE

Director, NSTS

The position of Director, NSTS, is established. In addition, the Director, NSTS, shall have two Deputies--Deputy Director, NSTS Program, and Deputy Director, NSTS Operations. This triad shall act as a single entity to manage the NSTS program. The Director, NSTS, is at the level of Deputy Associate Administrator and reports directly to me. He will have full responsibility and authority for the operation and conduct of the NSTS program. This will include total program control with full responsibility for budget, schedule, and balancing program content. The Director, NSTS, is responsible for overall program requirements and performance. He shall have sufficient staff/systems engineering support at Headquarters to accomplish this activity. The Director, NSTS, is the approval authority for top level program requirements, critical hardware waivers, and for budget authorization adjustments that exceed a predetermined level.

Deputy Director, NSTS Program

The Deputy Director, NSTS Program, who reports directly to the Director, NSTS, and his senior managers will be Headquarters employees. They are responsible for the day-to-day management and execution of the NSTS program. This includes detailed program planning, direction, and scheduling and STS system configuration management. Other responsibilities include system engineering and integration for the STS vehicle, ground facilities, and cargos. The NSTS Engineering Integration Office, reporting to the Deputy Director, NSTS Program, is established and directly participates with each NSTS project element (Space Shuttle Main Engine, Solid Rocket Booster, External Tank, Orbiter, and Launch and Landing System). The Deputy Director, NSTS Program, will be located at the Johnson Space Center. The JSC Center Director will fully support the personnel and facility requirements of the Deputy Director, NSTS Program.

Deputy Director, NSTS Operations

The Deputy Director, NSTS Operations, a Headquarters employee reporting directly to the Director, NSTS, is responsible for all operational aspects of the missions. This includes final vehicle preparation, mission execution, and return of the vehicle for processing for its next flight. The Deputy Director, NSTS, Operations, will present the Flight Readiness Review (FRR) which will be chaired by the Associate Administrator for Space Flight, manage the final launch decision process, and chair the Mission Management Team (MMT). He will be supported by a small staff located at KSC, MSFC, JSC, and Headquarters. These personnel shall remain employees of their respective Centers but report directly to the Deputy Director, NSTS Operations. The KSC, MSFC, and JSC Center Directors will fully support the facility and personnel requirements of the Deputy Director, NSTS Operations.

NSTS PROGRAM EXECUTION

Flow of NSTS Program Direction and Response

NSTS program direction and response will flow from the Director, NSTS, through the Deputy Director, NSTS Program, to the various Project Managers and vice versa.

In this programmatic chain, the managers of the project elements located at the various field Centers will report to the Deputy Director, NSTS Program. Depending upon individual Center organization, this chain is either direct (such as the Orbiter Project Office at JSC) or via an intermediate office (such as the Shuttle Projects Office at MSFC). The MSFC Shuttle Projects Office is a management integration function and does not preclude direct interaction between the MSFC Project Managers and the Deputy Director, NSTS Program. The Manager, Shuttle Projects Office, located at MSFC, will be a Headquarters employee reporting directly to the Deputy Director, NSTS Program. The MSFC Center Director will fully support the personnel and facility requirements of the Manager, Shuttle Projects Office.

Budget Procedures and Control within the NSTS Program

The NSTS program budget will continue to be submitted through the Center Directors to the Director, NSTS, who will have total funding authority for the program. The Deputy Directors, NSTS Program and NSTS Operations, will each provide an assessment of the budget submittal to the Director, NSTS, as an integral part of the decision process, and their recommendations will be key to the final budget decisions. Following the final budget mark by the Associate Administrator for Space Flight, the Centers will submit a mark implementation plan, reconciling budget and program content, which will also be reviewed and concurred in by the Deputy Directors, NSTS Program and NSTS Operations, then approved by the Director, NSTS.

The Deputy Directors', NSTS Program and NSTS Operations, budgets will be established and managed directly as part of the NSTS budget. Their budgets, although not submitted as part of the Center budgets, will continue to be supported by the Center procurement and financial management organizations.

IMPLEMENTATION

The Director, NSTS, is charged with implementing this direction for the organization and operation of the NSTS program by revising appropriate NASA Management Instructions and program documentation. In addition, the Program Director shall act on the detailed recommendations of the Crippen study, exclusive of the recommendation on Astronauts in Management, which will be acted on by the Associate Administrator for Space Flight.

RELATIONSHIP OF THE CENTER DIRECTORS TO THE NSTS PROGRAM

Responsibilities of the Center Directors to the NSTS Program

As with other programs and projects located at their Centers, the Center Directors are responsible and accountable for the technical excellence and performance of each of the NSTS project elements at their respective Center. Further, the Center Directors will ensure that their institution provides the required support to the NSTS program.

Revitalization of the OSF Management Council

A key element of the ultimate success of the Office of Space Flight is a revitalization of the OSF Management Council. The OSF Management Council will consist of:

Associate Administrator, Office of Space Flight
Director, Marshall Space Flight Center
Director, Kennedy Space Center
Director, Johnson Space Center
Director, National Space Technology Laboratories

The Council will meet on a regular basis, with agendas published in advance, and will oversee all OSF responsibilities, including the NSTS.

Richard H. Truly

For Further Information
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