B. NASA Response to Panel Annual Report, March 1988

The NASA response was dated September 16, 1988 and in accordance with the Panel's letter of transmittal, NASA was requested to respond to Section II, "Findings and Recommendations" and to the "Open" items noted in Section IV.D, "NASA Response to Panel Annual Report, March 1987."

As noted here, "open" indicates actions may have been taken but are not to the point where the action can be considered completed. "Closed" indicates no further action on the part of the ASAP is necessary.

	SUBJECT	STATUS
A.1.a.	Support new organizational structure for both programs and the SRM&QA operation	CLOSED
A.1.b.	Keeping the Administrator informed of program status and activities of note	CLOSED
A.1.c.	Use of the STS where human presence in space is needed for mission success	CLOSED
A.1.d.	Reevaluation and recertification workload and prevention of human error at KSC	OPEN-- Monitor
A.2.	Methodology and implementation for conduct of FMEA/CIL/Hazards Analyses. Prioritizing of items	OPEN-- Monitor
A.3.a.	MLP prelaunch loads and launch loads	CLOSED
A.3.b.	Instrumentation/Inspection of recovered SRM/SRBs	CLOSED
A.3.c.	NASA to continue to have clear and uniform policies for Shuttle processing	CLOSED
A.3.d.	Clear, unambiguous launch commit criteria	CLOSED
B.1.a.	SR&QA (Code Q) Risk Management directives and directions for manned and unmanned programs	CLOSED
B.1.b.	The dangers of complacency	OPEN-- Monitor

B.1.c.	SR&QA NMIs and Handbooks for risk assessment	CLOSED
B.1.d.	Study of potential design-induced human errors	OPEN--Monitor
C.1.a.	SRB aft skirt structural concerns	CLOSED
C.1.b.	Establish criteria for nominal joints and flawed joints as part of CEI specification	CLOSED
C.2.	N/A	
C.3.a.	Orbiter OV-102 Strain gauge calibration	OPEN
C.3.b.	Orbiter structural inspection and maintenance	CLOSED
C.3.c.	Shuttle Computer Upgrade	CLOSED
C.3.d.	APU turbine wheel blade cracking concerns	OPEN--Monitor
C.4.	SSME certification testing time at 109% RPL	CLOSED
C.5.a.	KSC STS launch processing working environment as affected by schedules and mod work loads	OPEN--Monitor
C.5.b.	Human resource problems at KSC to match work load including worker morale and productivity	OPEN--Monitor
C.5.c.	Launch frequency (manifest) concerns	OPEN--Monitor
C.5.d.	Concerns regarding General Purpose Computer memory read/write procedures (gmems) at KSC	CLOSED
C.5.e.	Procedures for approving late software changes at JSC/KSC	OPEN--Monitor
D.1.	Space Station Computing Systems	OPEN--Monitor
D.2.	Crew Emergency Rescue Vehicle activities	OPEN--Monitor
D.3	EVA/Space Suits for Space Station	OPEN--Monitor
E.1.	X-Wing lessons learned regarding development of key technologies and structuring R&D programs	OPEN--Monitor
E.2.	X-29 flight test program	CLOSED

E.3.	Flight recorders placed in training and administrative aircraft	CLOSED
E.4.	Aircraft Operations and Safety Management	OPEN-- Monitor

The following items were holdovers from the March 1987 annual report and responded to in Dr. Fletcher's letter dated September 16, 1988, page 29-37. A number of these were discussed again in the March 1988 annual report and are carried over into the status report noted previously. As such they are considered "closed" here.

Pg. 29	B.1.	Extra Vehicular Activities (EVA)/Space Suits	Closed See D.3.
Pg. 30	B.2.	Space Station Organization/Management	Closed
Pg. 30	C.1.	Orbiter Structure/Brakes	Closed
Pg. 31	C.2.	STS Operations	Closed See C.5/A.1
Pg. 31	D.1.	Shuttle Management	Closed See C.5/A.1
Pg. 33	D.2.	Space Shuttle Systems	Closed See C.1/C.3/C.4
Pg. 34	D.4.	Safety, Reliability, Quality Assurance	Closed See A.1/A.2/B.1
Pg. 35	D.5.	Space Station Program	Closed See D.1/D.2/D.3
Pg.37	D.6.	Aeronautics	Closed See E.1-.4

NASA

National Aeronautics and
Space Administration

Washington, D.C.
20546

Office of the Administrator

SEP 16 1988

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

Dear Joe:

The enclosure contains our detailed response to the Aerospace Safety Advisory Panel (ASAP) Report of 1987. In accordance with your letter, we have responded to Section II, "Findings and Recommendations" and to the "OPEN" items noted in Section IV.D, "NASA Response to Panel Annual Report, March 1987."

The ASAP has done its usual excellent work during 1987. We believe your activities and specific recommendations play an important part in reducing risk in NASA's manned flight programs. We concur with the vast majority of the recommendations and, in most instances, are implementing corrective action.

We thank you for your valuable contribution and look forward to your comments in the 1988 report. As always, your recommendations are highly regarded and receive the full attention of our senior management personnel.

Sincerely,

James C. Fletcher
Administrator

Enclosure

NASA'S RESPONSE TO THE

AEROSPACE SAFETY ADVISORY PANEL

ANNUAL REPORT
FOR 1987

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 re-establishment 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. (p. 3)

NASA Response: The Associate Administrator (AA) for Safety, Reliability, Maintainability, and Quality Assurance (SRM&QA) is on an equal organizational basis with the top program officials within the Agency. The AA also has access, both on an as required and on a regularly scheduled basis, with the other top management officials within the Agency. Additionally, requests for resources, both budgetary and personnel, are given careful and deliberate consideration. NASA is committed to providing a vigorous and independent oversight and review function through the Office of Safety, Reliability, Maintainability and Quality Assurance. This capability has been developed and is in place. NASA's long range plans include the maintenance of this established capability and the continual strengthening of the SRM&QA functions within the Agency.

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. (p. 3)

NASA Response: NASA agrees. How well the management system functions is a key element in the assessment of NASA programs. The management system, much like technical or budgetary elements, is being reviewed periodically, with the results provided to the NASA Administrator. Among the management mechanisms in NASA that enable this to occur are the various Management Councils that involve the appropriate NASA Center Directors, and the monthly General Management Status Reviews (GMSR) where the various NASA Associate Administrators report directly to the Administrator. The direction and discipline applied for these reviews ensures that the intent and content of these reviews cover all aspects of technical as well as programmatic problems facing the Agency, the Centers, and programs. All changes in key personnel, management structure and organizations and the status relative to performance, problems, and concerns are continually reviewed as part of the agendas for these reviews. In addition, the SRM&QA organization, Code Q, is strengthening the Agency's audit system capability, which includes the periodic survey and assessment of the Centers' technical and management and reporting systems.

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. (p. 3)

NASA Response: NASA agrees and is working toward this goal. However, the Space Shuttle must be utilized to reduce the current payload backlog. The President's national space policy, which sets forth a long-term balanced and clear cut set of goals, principles, and guidelines, states that the Space Transportation System (STS) will be used to maintain the Nation's capability in manned space flight and to support critical programs requiring manned presence and other unique STS capabilities. The policy also states that the United States' national space transportation capability will be based on a mix of vehicles, consisting of the STS, unmanned launch vehicles and in space transportation systems. NASA strongly supports this policy and is intent upon meeting its objectives. As stated in the response to the 1986 ASAP report, the mixed fleet analysis study has been completed. The resulting plan is currently being implemented for a mixed fleet of launch vehicles. The March 1988 Mixed Fleet Manifest for flights through September 1993 shows 16 NASA and National Oceanic and Atmospheric Administration (NOAA) spacecraft previously planned for the shuttle being reassigned for launching on expendable launch vehicles (ELV's). In addition, some 20 DOD payloads have been off-loaded from the shuttle to ELV's.

NASA also agrees with the need for development of an unmanned heavy-lift vehicle. The Agency is a partner with the Air Force in the definition of an Advanced Launch System (ALS) and is also conducting initial studies of an unmanned, cargo version of the Space Shuttle, Shuttle C.

d. **Findings:** The reevaluation and recertification of all hardware and software systems on the STS has produced an extremely heavy workload 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. (p. 4)

NASA Response: Both NASA and contractor management are sensitive to the need to prevent human error from occurring. Increased discipline has been manifested by additions to manpower in the areas of engineering support to the on-line workforce and additional quality control personnel, with clear direction for increased emphasis on planning and control of work. In the SRM&QA area, the ratio of quality control inspector-to-technicians has been increased in all areas from pre-STS 51-L levels.

Certification and recertification training also continues to be provided for the workforce. NASA, the Shuttle Processing Contractor (SPC), and element contractor management periodically review these programs to assure that each critical discipline area is properly supported. Additionally, the currently budgeted Shuttle Processing Data Management System (SPDMS) is being implemented to lessen the paperwork burden. This automated system will improve the work control system by providing for faster, more accurate problem disposition with appropriate management visibility.

In addition to the above, the NASA Headquarters SRM&QA Office, Code Q, has revised the System Safety Handbook whereby a chapter is devoted to Human Factors considerations and requirements. Code Q will also validate the effectivity of organizational functions, systems and staffing through selected staff assistance surveys. Such overview actions will permit insight for determination relative to existence and application of adequate discipline within the system.

2. Reassessment of Risk

Findings: NASA and the STS contractors have been redoing the Failure Modes and Effects Analysis (FMEA's), Critical Items List (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/Hazards 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/Hazards 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. (p. 4)

NASA Response: (1) As part of the revalidation process for the STS "Return to Flight", the National Space Transportation System (NSTS) Program issued NSTS 22206, "Instructions for Preparation of Failure Modes and Effects Analysis (FMEA) and Critical Items List (CIL)" and NSTS 22254, "Methodology for Conduct of NSTS Hazards Analyses (HA)." The purpose of these documents is to provide consistent methods for the preparation, maintenance, and publication of the FMEA/CIL's/HA's. These documents are being used by the SRM&QA Office to develop NASA handbooks that will provide the Agency-wide guidelines. Drafts of these handbooks have already been prepared, and it is anticipated that the final documents will be issued prior to the end of FY 88. (2) A procedure (NSTS 22491, "Instructions for Preparation of Critical Items Risk Assessment") was developed and issued by the NSTS Program to implement a method of categorizing NSTS failure modes by severity of effect and likeliness of occurrence and prioritizing them from most severe effect to least severe effect. In addition, a method (Memorandum NA2/87-L046, "Implementation of Hazard Prioritization Technique", September 29, 1987) for categorizing Hazards by likelihood of occurrence and severity was also implemented in order to determine a risk index for each hazard. These methodologies are being incorporated into an overall Agency Risk Management Program being developed by the SRM&QA Office. (3) The NSTS Program has developed a new closed-loop accounting system known as the System Integrity Assurance Program (SIAP). A key feature of SIAP is its Program Compliance Assurance and Status System (PCASS). This is a computer-based information system which functions as a database that integrates a number of information systems. FMEA/CIL and Hazards Analyses data are a part of this data base. PCASS has the potential to provide, in near real-time, an integrated view of a number of risk assessment parameters to NSTS Program decision-makers.

3. Design, Checkout, and Operations

a. **Findings:** Mobile Launch Platform stiffness data. The prelaunch and liftoff 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 posts, 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. (p. 4)

NASA Response: The prelaunch loads have been revised to incorporate the new MLP stiffness test results and the revised Solid Rocket Booster (SRB) aft skirt math model. These include the results from the MLP - 1/2 stiffness tests. The liftoff loads, which are less affected by the new MLP stiffness test results, utilize the earlier MLP-3 stiffness data. The combined load, designated DCR-2, are the loads being used to certify and clear the Shuttle vehicle, including the SRB hold-down posts and struts for launch. The SRB hold-down posts and struts have been instrumented for the first three flights. Data recorded during the structural qualification test of the aft skirt (STA-3) ground tests, completed on April 1, 1988, are being correlated with calculated data. Data from the flight readiness firing (FRF) test and subsequent launches will be correlated with previous data.

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 SRB 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. (p. 5)

NASA Response: An inspection plan for the retrieved SRB/SRM hardware is being implemented which involves personnel from Marshall Space Flight Center (MSFC), Kennedy Space Center (KSC), United Space Boosters, Inc. (USBI), Morton Thiokol, Inc.

(MTI), and the Shuttle Processing Contractor (SPC). Documents have been prepared to define the inspections to be performed, and distinguish between nominal and anomalous conditions. Development flight instrumentation is currently planned for the first three flights. There currently are no plans to utilize the returned hardware from the first several flights as test articles. However, there are plans under consideration to conduct a multiple cycle hydroproof test, with periodic disassembly and measurement of dimensional changes, to assess reusability, and to conduct flight support motor static firings to validate ongoing production. Consideration is also being given to Multiple Cycle Testing of the aft skirt, under prelaunch load conditions.

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 shortcomings 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. (p. 5)

NASA Response: NASA is continuing its efforts to have clear and uniform policies for shuttle processing procedures and evaluations. NASA and its contractors are expending major efforts to properly identify, document, and cross reference all shuttle critical items in the CIL, OMRSD, OMI's and OMP. These documents have all been thoroughly reviewed, revised, and reformatted for that specific purpose, and matrices allow tracing a CIL item throughout the series. Closed-loop OMP - OMI - OMRSD Accounting has been initiated and is in place supporting STS-26R KSC processing. The complete automation of this system is in process and on schedule to be partially available for STS-26 and completed by February 1989. This system will provide for uniform implementation of policy and create a greater awareness of the critical portions of shuttle processing and facilitate problem identification, resolution, and anomaly evaluations. The PCASS system will also be used to track and provide the status of Criticality 1 & 1R hardware problems.

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. (p. 5)

NASA Response: The Launch Commit Criteria have been thoroughly reviewed by all concerned elements of the shuttle program to remove all ambiguous and unnecessary guidelines and leave only clear and concise criteria. Except for some introductory material about the document and general information on crew restrictions, only true "redlines" remain. These true "redlines" have no built-in margins and are intended for countdown holds, shutdowns, or recycles, depending on the phase of the count. All of the "redlines" that can be automated are being automated. The automation stops the countdown (clock) when any "redline" (limit) is reached prior to T-31 seconds, to allow a considered decision by the appropriate experts and program management on whether to proceed with or terminate the countdown, or take an alternate course. Encountering a "redline" after T-31 seconds leads to a shutdown and/or recycle of the launch countdown.

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 commonly understood and agreed upon definition of the factors pertinent to the decision. The AA/SRM&QA should ensure the 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. (p. 6)

NASA Response: The risk management NMI's and NHB's, as discussed in Section B.1.c on the next page, provide direction on the risk disposition decision process, which is the central function of risk management. These directives and handbooks will be applicable to all programs. As appropriate, they provide for qualitative analyses with likelihood and severity treated categorically, and uncertainty reflected in the potential variability of the categorizations. They also provide for quantitative analyses with likelihood and severity combined in numerical risk estimates, and uncertainty expressed as numerical distributions of the possible variations in the estimates.

The development of the Risk Management Program Plan for each program is a program management responsibility. Guidance is provided in the NMI's and the NHB's, and the Safety Division (QS) Risk Management Program Manager provides additional assistance in the development of the plan and its implementation, as required. The Risk Management Program Manager in Code QS also supports or participates in program risk management assurance activities designed to provide oversight of the program's risk management process. Code Q will, through its audit, oversight, and independent assessment charter, provide personnel and resources to ensure that the programs properly implement the risk management program plans.

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 the system safety and unanticipated alterations in the reporting process. (p. 6)

NASA Response: The Office of SRM&QA is well aware of the dangers of complacency and its impact on the safety of the various programs. One of the principal functions of the Deputy Associate Administrator for System Assurance is to establish and implement an audit/oversight function that will determine the SRM&QA acceptability and posture of each program. Program trade-offs and engineering decisions, vis-a-vis their effects on safety, are key elements to be reviewed, as well as the safety data that was generated to support these decisions.

The expanded audit process and methodology, with plans and schedules, are being developed with the support of the NASA Headquarters Code Q support contractor. Audits will take place on a regular and/or as needed basis. Audit teams will consist of SRM&QA personnel from Headquarters, the Centers, support contractors, and outside experts in selected disciplines. The reporting systems and decision-making processes will be incorporated into the audit checklists to ensure that alterations to management systems and changes to reporting procedures are recognized with changes being properly assessed. Additionally, the Safety Division, QS, will continue to monitor the degree of implementation of the Agency safety policies by means of its own assistance visits and assessment/reviews. A training course is also being developed for personnel who will participate in audits, reviews, and surveys to assure effectiveness of the audit system.

Maintaining the safety awareness and motivation of the workers at the floor level is also critical to the prevention of complacency and maintaining the safety assessment process. In support of this, the Safety Division is developing an Agency level Safety Awards Program that will provide top level recognition to project groups, facility groups, or individuals who have demonstrated superior safety performance.

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). (p. 6)

NASA Response: (1) NMI 8070.4, "Risk Management Policy for Manned Flight Programs," was promulgated on February 3, 1988. NMI's are also in draft and under review on risk management for unmanned programs and for research and technical facilities. These NMI's will identify, in general terms, the roles of qualitative and quantitative risk assessment in support of risk disposition decision-making. The NMI's also reflect recognition of the need to tailor these roles to specific applications, in accordance with appropriateness criteria that are related to the significance of the risks of concern, the information available for risk assessment, and the resources required for assessment and integration of results.

NHB's are also being developed to aid in the implementation of the processes defined in the NMI's. A draft NHB on risk management program tools and techniques is currently under review. An NHB on risk management program roles and responsibilities has been developed, and a draft is currently available. The first NHB is a compendium of advanced qualitative and quantitative risk assessment and risk decision-making methods. The second NHB delineated the functions and interfaces of program and facility management, engineering, system safety, and other Code Q elements. It further delineates the roles and responsibilities in risk management assurance. The primary role of program and facility management is recognized, as is the role of system safety in risk management support. The key role of oversight and special technical assistance in risk management assurance is particularly noted.

In addition, a two-volume Safety Risk Management Program Plan has been published. It serves as a basic information source on risk management program objectives, rationale, and basic methodology.

(2) NASA Code QS has recently completed filling the system safety organizational structure. When combined with the system safety portion of the Code Q Support Contract, awarded in February 1988, adequate resources are available to implement the risk assessment and risk management policies being developed. System Safety has completed an initial draft of the NMI defining the NASA System Safety Program and has a final draft of the revised System Safety Handbook (NHB 1700.1 Vol. 7) ready for review and coordination. In addition, other NHB's in the various system safety technical areas are nearing the final draft stage. The current schedule aims for completion and issuance of these documents in August 1988.

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. (p. 7)

NASA Response: NASA Code QS is already providing additional emphasis on identifying and, when possible, preventing by design the potential safety problem areas arising from human errors. One chapter of the revised System Safety Handbook is devoted to Human Factors, Considerations, and Requirements. Continued emphasis will be applied towards incorporating these concerns into contract statements of work or as overall applicable contract requirements. Review of appropriate progress will be conducted during design and safety reviews to ensure that design takes into consideration human factors requirements. Additionally, Code QS intends to validate the effectiveness of the multiplicity of discipline products and interfaces generated within the highly-matrixed SRM&QA organizational functions through selected staff assistance surveys.

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. (p. 8)

NASA Response: The structural qualification test of the aft skirt (STA-3) was completed on April 1, 1988. The test was planned to apply loading to a maximum of 150 percent limit load, or to failure, whichever occurred first. The test results were that the aft skirt was continuing to carry increasing loads at 146 percent of limit when the test was terminated. Failure initiation began at 132 percent of limit with skin panel to thrust post weld cracking. A large amount of test instrumentation data were gathered, which is currently under evaluation.

In addition, aft skirt instrumentation will be located at some of the same locations in the thrust post weld areas as on STA-3, during the FRF and the first three flights, to correlate actual stresses during firing to the STA-3 test. Also, plans for tests of multiple load cycles on the aft skirt are under consideration to demonstrate useful life.

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 joints. 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. (p. 8)

NASA Response: These recommendations have been implemented. The criterion for non-flawed joints, contained in the CEI specification, was established to be no erosion or blow-by of the primary O-rings. Where flaws are incorporated to assure combustion gases reach the primary O-ring, the criterion is not contained in the CEI specification, but rather in program directive documentation, and is one of fail safe (i.e., no leakage from the joint). Tests with flaws to assure combustion gases to the secondary O-ring seal were conducted on one Nozzle Joint Environmental Simulator (NJES) test and the Transient Pressure Test Article (TPTA) test TPTA 2.2 which was completed on May 17, 1988. A full scale static test with a flaw path to the primary O-ring of one field joint and of the case-to-nozzle will be conducted with the Production Verification Motor (PVM-1) firing in late August 1988. Pressure transducers at the leak check ports will be included in the test.

2. External Tank

Findings: No significant findings.

Recommendations: None.

NASA Response: 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 a calibration program for the Orbiter to determine accurate loads. 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. (p. 13)

NASA Response: A plan is in place to add strain gauges to the OV-102 wing, tail, payload bay door, mid-fuselage, and elevons for its next flight (Flight 8) and to recalibrate and reconnect a number of pressure measurements. This plan includes a wing calibration after Flight 8.

Midbody thermal measurements are being installed on OV-104 (Flight 3) to collect and substantiate the 6.0 thermal data. These will be operational on the next flight. Tile temperature measurements are being added for the next OV-102 flight. The quantity of measurements will be determined by the KSC work flow and the shuttle budget in FY 1989.

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. (p. 13)

NASA Response: A plan was developed in April 1986, which defined the structural elements of the orbiter that should be inspected and how/when the inspections should be accomplished. Pan American Airline personnel contributed significantly from their commercial experience. These requirements have been baselined in the Operational Maintenance Requirements Specifications Document (OMRSD) and are being implemented on each of the Orbiter vehicles.

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. (p. 13)

NASA Response: Program Requirements Control Board Directive #S40167R2 established the 5/0 configuration as the National Space Transportation System (NSTS) baseline configuration for all flights of the upgraded General Purpose Computers (GPC's) on the Space Shuttle. There is currently no consideration being given to changing that decision. Consideration is being given to flying a new GPC in an on-orbit test configuration to exercise its functional capability. In addition, the Spacelab program has implemented the new GPC into their baseline program, which is currently scheduled to fly before the new GPC's are installed in the orbiter. These latter two steps should provide for assurance of the new GPC 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. Futher 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. (p. 14)

NASA Response: There are currently two efforts underway to resolve the APU turbine wheel blade cracking issue. The near term approach involves extensive testing, analysis, and mapping of turbine wheel cracks in order to develop criteria for flying the existing configuration. This will define acceptable limits for blade cracking and an acceptable number of hours of "run-time" and APU starts before a wheel should be replaced.

The long-term approach is underway for the design, development, and production of a new configuration turbine wheel, which will eliminate the concerns associated with such cracking. Once developed, the new turbine will then be phased into the fleet (approximately 1990).

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. (p. 14)

NASA Response: While no 109 percent flight requirement currently exists, 27 percent of all certification testing is done at 109 percent to demonstrate margin. The contractor is continuing the effort to increase the useful life of the SSME blades and bearings. The certification program for the SSME blade improvements is complete and additional blade life tests will be completed prior to first flight (STS-26).

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 vigilance 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. (p. 14)

NASA Response: NASA and its contractors have recognized that the complexity of STS launch processing can induce human error, and that there are risks associated with schedule pressure. The actions cited are intended to mitigate the possibility of such errors. As an example, SRM&QA management has taken a major step to this end by forming a Personnel Initiatives Panel (PIP). The purposes of the PIP are as follows:

(1) identify organization problems, recommend corrective action, and provide a means of communication up to all levels of management;

(2) establish the SR&QA function as an aggressive contributor for the overall team;

(3) promote a workforce that is manned with quality people who are dedicated to superior performance and the pursuit of excellence; and

(4) develop a comprehensive program to attract, develop, motivate, and retain the best professional talent available.

By adhering to these tenets, NASA feels that the "safety first" belief can best be instilled in every worker.

KSC policy is in place to assure that overtime is carefully monitored and controlled, and that worker fatigue due to excessive overtime does not contribute to errors during processing. Additionally, recently approved manpower increases, along with initiatives to increase operational efficiency, are serving to improve the working environment.

b. **Findings:** Capacity to handle workload. 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.

Recommendations: High priority should be placed on resolving human resources problems at KSC in order to strengthen the workforce and reduce the likelihood of human error. (p. 14)

NASA Response: NASA and its support contractors are committed to resolving human resource issues. Adequate contractor staffing levels are currently planned and budgeted to meet the demands of the STS flight manifest. This plan will require contractor overtime, and does not include any contingency that requires extra critical skilled manpower for extended periods, such as for large TPS modifications or repairs.

For NASA Civil Service manpower, the recent freeze impacted buildup. The current complement, after factoring in NASA/KSC attrition and the partial allocation of additional hiring allowed, is not considered by KSC to be adequate to meet the processing demands for FY89 and subsequent years. This subject is under continuing review by NASA management.

Worker morale continues to improve as the resumption of shuttle flight draws near. KSC continues to sponsor forums wherein the workers can participate indirect interchanges with both NASA and contractor officials. The KSC Center Director, General Forrest McCartney, advocates and participates in the "walkaround" philosophy and talks informally with workers at all levels. This approach by KSC's senior management has done much to stimulate positive morale and teamwork spirit. NASA sincerely feels that making workers aware of, and part of, current plans and policies is a helpful mechanism to boost morale.

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:

- NASA has not consistently documented software design rationale.
- 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 anomalous conditions arising during flight. Any proposals to reduce training time should be thoroughly reviewed. (p. 15)

NASA Response: The process of changing shuttle software is a rigorous, disciplined, well documented process. Software changes are defined on software CR's by members of the NASA requirements community. These are documented as changes to requirements documents that are under the rigorous configuration control of the Shuttle Avionics Software Control Board (SASCB) chaired by the manager of the NSTS Engineering Integration Office. No part of any software requirements document can be altered without the approval of this board, and only after a thorough review and concurrence by the requirements community. After a review by the community, the CR is formally presented to the SASCB, discussed, and dispositioned. The entire proceedings are tape recorded and documented along with the presentation materials in the minutes of the SASCB. The implementation of the approved requirements is documented and maintained in detailed design specifications, the IBM maintenance specification, the Operational Increment User's Guide, and the Program Notes and Waivers Document. Additionally, the engineering design community has, since STS 51-L, undertaken an effort to document the design rationale associated with each mission's unique design data parameter. This will include the history, limits, constraints, and trends for each parameter, as well as the interrelationships of the parameters with each other and with any other significant flight characteristic. We feel that the above constitutes a thorough and complete documentation of design and implementation rationale for the shuttle flight software.

Shuttle crew procedures development involves a combination of astronauts and operations and engineering personnel. The knowledge base required to develop effective procedures is extensive and multi-disciplined. It requires detailed knowledge of the complex vehicle, the wide range of operating environments, as well as the capabilities of the astronauts. Approval and validation of crew procedures involves formal reviews and simulator checkouts. Additionally, baselined shuttle crew procedures are exercised extensively during simulations. We believe that the majority of the human factors considerations are found during procedures validation and during the extensive exercises and procedures usage in the simulators. Moreover, crew procedures personnel, with established interfaces in the human factors group in spacecraft design, are pursuing methods to improve human factors aspects in procedures development. The guidelines and expertise developed in this activity are extended to the procedures developed in real time.

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

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 onboard 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 reverifying a gmem after it has been made. (p. 15)

NASA Response: NASA agrees with the ASAP concern regarding General Purpose Computer (GPC) memory read/write procedures (gmems) and has always treated requests for approval of such changes with a high degree of caution. From the outset, the Shuttle Avionics Software Control Board (SASCB) has required that any gmem that is considered for application be brought to the SASCB as a Change Request (CR) and be reviewed and concurred upon by the software requirements community before it can be applied. Once approved by the SASCB, the gmem is thoroughly verified by the development contractors. Except for a few gmem procedures that may be required in times of critical situations, the rationale and procedure for a gmem is reviewed in real time and reverified in the Shuttle Avionics Integration Laboratory (SAIL) for the specific vehicle and software configuration existing at the time of application. The SASCB chairman must then approve the "gmems" request in real time before it can be applied. In addition, operations personnel verify that the intended change was made by monitoring the memory contents before and after the application of the gmem. The effectiveness of their careful approach is evidenced by the fact that there has never been an error attributable to an in-flight gmem. Following STS 51-L, the NSTS Engineering Integration Office canceled the approval of all gmems procedures in effect at the time, requiring that the operations community resubmit those gmems procedures which were felt to be required for STS-26 for approval by the SASCB. This precipitated a thorough review of those procedures.

There is a second class of shuttle software memory changes called Table Maintenance Block Update (TMBU) that is restricted to a limited area of software memory, which contain constants that define the limits for onboard crew alarms and consumable calculations. The onboard software performs error checking on the actual contents of the change and will not execute the change if the address specified is outside the TMBU sections of memory. This class of change has been made much more frequently during the Shuttle Program than the above mentioned gmems class. Four errors have occurred during noncritical flight phases and can, in general, be attributed to the manual generation of these changes. Several precautions have been implemented to preclude future errors. These precautions include:

(1) modification to onboard software to perform error checking of the address contained in the change;

(2) development of a ground program which automates and performs error checking on generation of these changes; and

(3) external verification of the ground program.

Finally, in addressing software requirements for future software releases, the SASCB will give high priority to those changes that eliminate the need for gmem and TMBU procedures.

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. (p. 15)

NASA Response: NASA shares this concern about the risks involved in making late changes to the software and treats all such requests with great caution. Only absolutely mandatory changes are considered. Once approved, late changes, whether they are data value updates or code modifications, are put through the same review, development, testing, and verification process by the development and verification contractors as changes implemented in the normal development cycle. Standard checklists, automated process control, thorough testing procedures, formal reviews, and sign off at each process step, assure the same safety and quality for late changes. NASA and its software development and verification contractors have always insisted on taking sufficient time when making late changes to ensure that quality and safety are not compromised. In some instances, duplicate teams have performed parallel processes in order to reduce the risk of human error.

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. (p. 16)

NASA Response: The first computing system concern addressed the apparent under estimation of the complexity of the Space Station Program Office (SSPO) software integration task. In this area, the Space Station Program (SSP) recognized early that the distribution of the very complex SSP software development responsibility to our four prime development contractors, consistent with their distributed hardware responsibilities, would create a difficult software integration problem. Consequently, and as a result of a thorough review of resources allocated to the computer/software integration task, NASA has contracted with Lockheed Missiles and Space Corporation to develop a common Software Support Environment (SSE) for the program. The SSE will bridge the gap between the diverse software development, test, and integration procedures, practices, and tools. Each development organization is required to develop and test its software within a specified computer facility (Software Production Facility) which hosts the SSE provided procedures and tools.

NASA has also defined a Multi-Systems Integration Facility (MSIF) to ensure adequate program-wide software and selected hardware integration testing. The MSIF concept employs a cooperative integration and test approach in which the developers from the diverse software development organizations are also involved in the MSIF test activities under the leadership of Level II and its support contractor. The MSIF will also serve as the flight software load generation facility.

Currently, the program is actively developing the SSE. Because NASA agrees with the ASAP statements expressed concerning the Space Station Computing System complexity, the program has continued to apply high priority resources and support to this critical effort. While it is true that integration techniques for such large systems are not well understood, we believe that SSE and MSIF efforts will provide the structure with which to do the required software integration.

The second area of concern addressed the numerical quantification of the Data Management System (DMS) requirements specifications, stating that they were apparently without adequate rationale and/or traceability to any known requirements source. Although every attempt was made during Phases A and B of the SSP to obtain quantified data storage volume, data processing requirements, and other DMS performance requirements, the information was generally unavailable due to the uncertainty of funding for candidate NASA payloads. We were able to obtain only strawman payload characteristics and manifests which were documented in the Mission Requirements Data Base (MRDB); however, due to funding uncertainties and the absence of formal payload selections by the scientific community, only an estimate of the anticipated needs during the Space Station era were available. For this reason, the DMS has been scoped primarily on the anticipated state of the art of information systems technology in the Space Station era, rather than known quantified user requirements. However, as the program has evolved to the present time, and as the Office of Space Science and Applications (OSSA) has been able to further define its payload manifests and the related DMS requirements, more specificity is being added to the baseline requirements. We expect some, but not all, of these issues to be resolved as a result of the recent Program Requirements Review (PRR). A rationale document for computing requirements and justification for those requirements is evolving as a result of the multiple efforts to define the basic requirements.

The third concern was the lack of apparent procedures for the replacement of computing equipment and/or software. Our current planning on this subject is in two areas. The first is our budget planning for the operational phase of the SSP in which we are planning mainframe computer hardware and support software replacement every 7 years and work station replacement every 5 years.

The second area is establishing evolutionary requirements allowing the program the flexibility to upgrade with advanced technology as it becomes available in the future. We have requirements for the operational Space Station Information System which will require a design to isolate applications software (both flight and ground) from the underlying computing system. This is to promote the migration of ground hardware and software to the flight systems or from facility to facility, and to maximize the flexibility of replacing the flight hardware, as required, during the life of the program. In addition, the work packages have factored advanced automation requirements in their proposals. As the Space Station design matures over the next year, the inclusion of these requirements into work package plans will happen as reviewed and as approved by program management.

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. (p. 16)

NASA Response: NASA agrees with the Panel that an assured crew return capability must be provided for the Space Station crew, and studies have begun to determine the most appropriate means of reaching that goal.

NASA studies to date have been restricted to the fundamental purpose of a CERV, and three Design Reference Missions (DRM's) have been specified, all of which are compatible with the recommendations:

(1) return or support of Space Station crew during interruption of STS launches;

(2) return or protection of Space Station crew from reasonable accidents or from reasonable failures of Space Station systems; and

(3) return or support of Space Station crew during reasonable medical emergencies.

Analyses are continuing and several approaches which could satisfy the DRM's are being considered; the CERV is one of those approaches. Each option considered is being evaluated for its ability to meet the DRM's; its impact on the NSTS, the Space Station, and expendable launch systems; and cost. The assured crew return capability for the Space Station will impact several of the NASA's programs, and all facets must be considered in determining which is truly the most cost effective and reliable concept. As stated, analyses are continuing, and decisions will be documented relative to specific basic requirements, as they are agreed upon between the program and technical elements associated with the programs within NASA.

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. (p. 17)

NASA Response: NASA agrees with maximizing the astronauts productivity where economically feasible and thus has chartered a National Space Transportation System/Space Station Program (NSTS/SSP) commonality working group to review the NSTS and SSP EVA requirements and make a recommendation for the new Extra Vehicular Maneuvering Unit (EMU) design. The goal is to design a common EMU to be used on both programs. NASA plans to develop a space suit that will be operational when Permanent Manned Capability (PMC) is achieved. During the assembly of the Space Station, and during the man-tended phase of operations, the crew will function from the shuttle and will, of necessity, use the current shuttle suit. The EVA timeline delineated for Space Station assembly is extremely conservative. The safety proven Space Shuttle EVA suit is adequate for the early tasks. The safety considerations relative to requirements are complex and the final specifications for the Space Station EVA suits must be adequate when baselined. The NASA strategy, relative to all EVA's and the requirements to meet them, is undergoing continuous analysis.

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." (p. 18)

NASA Response: We agree that key technologies should be developed to the extent practical in the ground based R&T program before commitment to a full vehicle flight test program. The NASA/DARPA X-Wing program was aimed at satisfying a critical national need. DARPA was willing to take unusual programmatic risks to develop the concept within the required schedule, and agreed to provide the necessary resources. Such ventures are within the charter of the DARPA organization. NASA was a logical partner because of its unique management and research skills. The development of several key X-Wing technologies was needed to realize success in what was billed from the beginning as a high risk venture. Some of these technology problems were solved, such as the development of the thick composite stiff blades capable of withstanding high temperatures. Resolution of others, primarily the digital flight control system, was not completed. The development of these technologies was even more difficult than anticipated, resulting in substantial cost growth.

The Aeronautics Advisory Committee has established an Ad Hoc Study Team on Flight Research and Technology. One of the study team tasks is to address the advisability of flight research focusing on proof of concept experimental aircraft. They will also be recommending the timing of when promising advanced technologies should be carried to flight test and subsequent use. Also, the Office of Aeronautics and Space Technology (OAST) is developing a closeout plan for the X-Wing program. The results of the program, including "lessons learned", will be documented.

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. (p. 18)

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 acceptable flight safety risks. (p. 18)

NASA Response: NASA agrees that some flight verification objectives have been diminished as a result of review of flight safety considerations. They are:

a. Flight test demonstration of the existence/nonexistence of a flap-tab flutter mode within the design flight envelope.

This objective has been eliminated due to the large canard torsion loads experienced at supersonic speeds and at high dynamic pressures. The limit is based on 80 percent of the single hydraulic system capability following one system failure. Since the prediction of the single system hydraulic power is not precise, flight beyond this limit would expose the aircraft to the risk of loss due to one failure. Unique, one-of-a-kind hydraulic systems are not considered to be highly reliable.

b. Flight test demonstration of wing divergence boundaries based on tests at maximum dynamic pressures.

Flight tests have shown that a reasonable estimate of the wing divergence boundary can be made with tests performed well below the maximum design dynamic pressure. Flight tests at higher dynamic pressures would improve the correlation between flight test and predicted boundaries, but would only marginally improve the validation of the forward swept wing structural design philosophy.

c. Mid envelope maneuvering.

There is a portion of the flight envelope where the aircraft is restricted in angle of attack (AOA) due to the combined steady state and dynamic buffet loads exceeding the flap-tab link load limits. Objectives have not been significantly compromised due to this limit because high AOA tests can be accomplished at higher altitudes, and high load factor tests can be accomplished at lower altitudes.

d. Evaluation of the flight control system at high dynamic pressures.

Due to the development of new test and evaluation techniques, the evaluation of the flight control system has become routine. Flight conditions have already been flown (M = 0.95, alt. = 15,000 ft.) where the phase and/or gain fell below the already low limit margins. The flight control system gains were modified and tests continued. Repeating this process at higher dynamic pressures offers no new information.

e. A flight test objective recently expressed by the Future Applications Committee is to expand the maneuvering envelope to 8 g's.

It is difficult to ascertain what will be learned by flying to 8 g's, and the programmatic risks associated with such a test are relatively high. The proof load test was only taken to 8 g's, and it is standard flight test practice to only fly to 80 percent of the proof load. In addition, flight test has shown that the aerodynamic loads predictions are not accurate. To fly the aircraft to proof load limits in the face of inaccurate loads predictions is a very high risk policy in light of the questionable technical gains to be achieved.

We believe that the X-29 program has taken a prudent and balanced approach to risks in achieving an early transition of new technologies.

NASA and USAF, with continued DARPA involvement and with consideration of the X-29 program objectives, are conducting a follow on research program using the X-29 aircraft. This program is planned to be completed in 1989. Future plans and objectives will be developed, consistent with overall aeronautical research requirements and consideration for acceptable 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.

Recommendations: The ASAP continues to recommend that flight recorders should be developed for training and administrative aircraft. (p. 19)

NASA Response: NASA is in agreement with the ASAP recommendation. In 1985, the Aircraft Management Office (AMO) contracted with the Flight Safety Foundation to conduct a market survey of available recorders suitable for installation on NASA aircraft. Using information from the survey, the AMO, in coordination with the Intercenter Aircraft Operations Panel (IAOP), has developed an action plan for acquisition and installation of flight recorders in appropriate Agency aircraft. The AMO has requested $2M for funds to initiate this action plan in the FY 1990 budget.

All administrative aircraft have either Flight Data Recorders (FDR) or Cockpit Voice Recorders (CVR) installed. Latest state-of-the-art FDR's were installed in the five

Gulfstream aircraft in 1974. The IAOP's Gulfstream Operations and Maintenance Subpanel recommended, in 1986, that these recorders be replaced with digital FDR's on an attrition basis. The three smaller Kingair aircraft are equipped with CVR's. The Administrative Aircraft Operations and Maintenance Subpanel is studying the feasibility of dual installation of an FDR and CVR on each administrative aircraft. A prototype installation on the LeRC Gulfstream is being evaluated by the Subpanel for possible installation in all 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. (p. 19)

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.

NASA Response: NASA agrees with the intent of the recommendation. The establishment and evolution of the SRM&QA organization at Headquarters may have resulted in apparent confusion concerning the responsibilities for aviation safety of the Headquarters Aircraft Management Office (AMO) and the SRM&QA Office; however, due to a close working relationship, there was no confusion between the two offices. The AMO has historically been responsible for integration of accepted safety practices in aircraft operations and maintenance and, in the past, has been the focal point for incident reporting. With the growth and maturation of the Office of SRM&QA, assignment of incident reporting has become the responsibility of the Safety Division. Consequently, SRM&QA is responsible for all accident/incident reporting and investigation and for safety oversight of aeronautical activities. Action has been initiated by the SRM&QA Office to produce a NASA Management Instruction (NMI) outlining the aviation safety program and responsibilities. The NMI is being developed in coordination with the Aircraft Management Office, and as part of the review process, will be reviewed by the Intercenter Aircraft Operations Panel prior to final publication. The projected completion date for the NMI is late summer 1988.

The SRM&QA Office is responsible for establishing the safety program requirements, conducting oversight to ensure implementation, and providing a focal point for aviation safety. The Safety Division, SRM&QA Office has been assigned this responsibility, as well as coordinating all Code Q requirements regarding aviation safety. Aviation safety within NASA remains the responsibility of each level of aircraft management, and the AMO is responsible for implementing the program at Headquarters and ensuring that safety requirements are integrated into all NASA aircraft operations and activities. The IAOP meetings, IAOP reviews of field installations, and the aviation safety officer meetings sponsored by the AMO are among the significant activities that the AMO and the Safety Division participate in, and which contribute to the program.

In addition to the division of responsibilities for aviation safety between the Headquarters Aircraft Management Office and the SRM&QA Office, and the major role of the IAOP, as discussed above, it is extremely important to take note of the fact that the primary responsibility for aviation safety within NASA resides in the organizations that have operational responsibility for NASA aircraft. In recognition of this, Code M, which has the responsibility for the majority of NASA aircraft, has appointed the Chief of the Aviation Safety Office at Johnson Space Center (JSC) as the Aviation Safety Officer for the entire Office of Space Flight. This arrangement has worked very well.

IV. APPENDICES

A. NASA Response to Panel Annual Report, March 1987

The following status is provided in response to those items considered OPEN by the ASAP for prior years.

B. Pressure Suits, Space Station, and Space Debris, letter from Dr. Fletcher to Joseph F. Sutter, January 9, 1987.

1. Extra Vehicular Activities (EVA)/Space Suits

OPEN ITEM: NASA support of the development of an advanced flexible higher pressure suit.

STATUS: NASA agrees with the ASAP relative to their concern as associated with the EVA Space Suits. As previously discussed on page 21, the current status is: NASA plans to develop a Space Station optimized suit that will be operational when Permanent Manned Capability (PMC) is achieved. During the assembly of the Space Station, and during the man-tended phase of operations, the crew will function from the shuttle and will, of necessity, use the current shuttle suit. The EVA timeline delineated for Space Station assembly is extremely conservative and has a safety margin factor of 2 folded into the specific EVA tasks. The safety margin is adequate for use of the safety proven Space Shuttle EVA suit for the early tasks. The safety considerations relative to requirements are complex, and the final specifications for the Space Station EVA suits must be adequate when baselined. The NASA strategy relative to EVA and the requirements to meet them are undergoing continuous analysis.

OPEN ITEM: NASA support of development of necessary data to establish, with confidence, what maximum stay in space should be.

STATUS: The maximum time which a person can stay in space has many complex variables. Major experiences with past EVA on the shuttle, i.e., retrieval of PAMD's with spacecraft and the Leasat repair... although they provide hard data, considerable theoretical and laboratory analyses must still be performed in order to determine all of the subject factors involved. Stay in space has to take into consideration the types of effort being performed, physical capabilities (not only generic but individual personnel characteristics), time already spent in space prior to EVA, consumables available, associated equipment, etc. The progress of these analyses is directly related to the EVA suit requirements definition efforts and is an ongoing activity.

2. Space Station

OPEN ITEM: Space Station ability to meet program objectives in a timely manner within current budget allocations.

STATUS: NASA derived and documented a development plan that did meet the program objectives within the Space Station budget presented to the Congress by the President. The President requested $935M, $2,035M, and $2,756M for development for the next three fiscal years. If Congress presents NASA with a Space Station budget that differs from that requested by the President, obviously the development plan will be changed, and the ability to meet program objectives in a timely manner might be compromised.

OPEN 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.

STATUS: NASA has formed an Advisory Committee within the NASA Advisory Council. This committee, composed of distinguished representatives from NASA's contractor community and from academia, will advise NASA on key management and technical issues. There are retired NASA officials on the committee. In addition, NASA is forming a National Research Council (NRC) Advisory Committee whose function will be to focus on those crucial technical issues that are unique to the Space Station Program, and to advise NASA as to the best approach in coping with these issues.

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

1. **ORBITER**

a. Orbiter structural life certification

OPEN ITEM: An abbreviated conservative analysis should be documented to fulfill the certification program.

STATUS: The Orbiter has completed the 6.0 loads analysis for the OV103 and subsequent Orbiters and will complete an abbreviated analysis for OV102 where structural differences exist. The Design Requirements Review and the Design Certification Review for the structure have been completed and trajectory constraints and day of launch wind conditions have been specified and will not be exceeded. Additional activity includes the trans-Atlantic abort certification and fatigue analysis scheduled for completion in FY 1989. Additionally, a structural inspection on OV103 has been completed, and a Periodic Inspection and Maintenance Plan is in place for all Orbiters.

OPEN 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.

STATUS: A strain gage program for OV102 has been approved for the next flight of OV102, and a wing calibration is planned to be performed after the first return to flight mission on OV102.

d. Brakes and Nose-Wheel Steering

OPEN ITEM: Redesign, tests, procurements still in process.

STATUS: The carbon brakes are currently in qualification, and the first flight hardware is scheduled for delivery in September 1988. Additionally, a landing and deceleration team was formed to review and make recommendations to increase safety margins. The team recommended the addition of a drag chute and the resurfacing of the Kennedy Space Center (KSC) runway. The runway resurfacing has been completed, and the drag chute modification is in the approval cycle.

Design studies are underway to assess full redundancy architecture for Nose-Wheel steering.

2. STS Operations

a. Logistics and Launch Processing

OPEN ITEM: KSC and Shuttle Processing Contractor (SPC) activities regarding burden of work and flight rate.

STATUS: NASA continues to closely monitor the workload imposed by the baselined STS flight rate. Manpower levels currently budgeted have been sized to assure that the processing workload can be accomplished in a safe and efficient manner. Both NASA and SPC management are adhering to the worker overtime policy outlined in Kennedy Management Instruction (KMI) 1700.2. Both staffing and overtime data are reviewed by top management on a weekly basis, and corrective measures are taken when required.

D. Space Transportation System, letter from Dr. Fletcher to Joseph F. Sutter, September 2, 1987.

1. Shuttle Management

OPEN ITEM: Transfer of logistics responsibility from JSC to KSC; appropriate funding; reduce LRU turnaround time.

STATUS: After the orbiter logistics responsibility transferred from JSC to KSC in late June of 1986, KSC Orbiter Logistics Management reviewed and identified all spare hardware requirements and authorized Rockwell International Corporation (RIC) to complete the procurement process. In addition, KSC Logistics has prepared the Orbiter Logistics Management and Budgetary Plan which has been forwarded to Congress. This plan identifies the near- and long-term goals and objectives, management schedules, and associated costs for correcting previous logistical problems and maintaining a high level of supportability for Orbiter processing.

Orbiter Line Replaceable Unit (LRU) turnaround times have received, and continue to receive, NASA management attention. Both KSC and NSTS management receive monthly status on LRU repair turnaround time. This high visibility, combined with the continued transition of Original Equipment Manufacturer (OEM) repair capabilities to the Rockwell Service Center (RSC) Depot, will decrease turnaround times from their current levels and increase KSC's direct control over repair activities.

OPEN ITEM: Consolidation and upgrading of data/information systems, particularly configuration management and launch procedures.

STATUS: NASA and the SPC have been improving the data/information systems as planned. The launch processing Problem Reporting And Corrective Action (PRACA) system has been tied in with the Program Compliance Assurance Status System (PCASS) and is currently transmitting daily reports to NSTS/JSC (PCASS). The existing Shuttle Processing Data Management System (SPDMS I) is being consolidated and improved to phase into the larger SPDMS II. For example, the software for the Auto-GOSS system, which deals with the closed loop OMRSD/OMI procedures, is being rewritten to be more transportable to SPDMS II. SPDMS II has been authorized by NASA, and the SPC has issued RFP's and received bid proposals. An SPC Source Evaluation Board is now in the evaluation process.

OPEN ITEM: Stretching of human resources at KSC (particularly overtime policy).

STATUS: The overtime policy established by the "KSC Maximum Work Time Policy" (KMI 1700.2, dated May 13, 1987) cited in detail in NASA's response last year remains in place. As Shuttle return to flight activities have increased, NASA management continues to adhere to this policy. Overtime data are reviewed weekly by the SPC and NASA. NASA KSC operating Directorates are responsible for staffing, scheduling, and managing overtime, with the KSC Director of Safety, Reliability and Quality Assurance responsible for oversight.

OPEN ITEM: Launch rate/manifest for Space Shuttle.

STATUS: In the current manifest (Payload Flight Assignments, NASA Mixed Fleet, March, 1988), seven flights are planned in the first year of resumed operations, ten in the second, and nine in the third. With the introduction of a fourth shuttle, the rates increase to eleven and thirteen in the fourth and fifth years. These rates were established by engineering and operational analysis in conjunction with the ongoing budget planning. They are reassessed on a continuing basis in reaction to changing payload requirements and annually as an integral part of the budget process.

NASA has assessed the payloads that are functionally suitable for launch on expendable launch vehicles in terms of the availability and cost of ELV's and the cost and schedule impacts on the affected programs. The result was a significant shift of payloads off the shuttle. The March 1988 Mixed Fleet Manifest for flights through September 1993 shows 16 NASA and NOAA spacecraft previously planned for the shuttle being launched on expendable launch vehicles. In addition, some 20 DOD payloads have been off-loaded to ELV's.

2. Space Shuttle Systems

OPEN ITEM: Redesign of solid rocket motor, certification/verification for flight.

STATUS: The major certification tests for the redesigned SRM are two qualification static firing tests (Qualification Motor 7 or QM7 and Production Verification Motor 1 or PVM1), and one Transient Pressure Test Article (TPTA 2.2) test. The QM7 and the TPTA 2.2 tests are complete, and the test results are satisfactory. THE PVM1 firing is scheduled for late August 1988 and will be completed prior to STS 26R launch. The SRM/SRB Design Certification Reviews (DCR's) were completed with Level III on May 18-19,1988, Level I/II on June 78, 1988, and the AA Review on July 78, 1988.

OPEN ITEM: Provide funds to check OV102 loads based on ASK A 6.0 analyses, check other Orbiters, update Orbiter load indicators/redlines, prepare reports.

STATUS: Funds have been provided to verify OV102 certification to the 6.0 loads, and this work is currently underway. Additional discussions associated with the OV102 loads program are on page 12, as associated with the NASA responses to the ASAP 1987 findings and recommendations.

OPEN ITEM: Orbiter 102 loads test program to calibrate strain gauges, etc.

STATUS: The program planning to instrument OV102 for obtaining strain gauge data to verify loads analysis has been approved and will be implemented over the next several flights of OV102. OV102 wing calibration will be performed after the first return to flight mission. Additional discussions associated with the OV102 loads program are on page 12, as associated with the NASA responses to the ASAP 1987 findings and recommendations.

OPEN ITEM: Panel recommends that SSME two-duct hot gas generator and large throat combustion chamber be tested and certified as soon as possible.

STATUS: The two-duct hot gas manifold/large throat main combustion chamber (precurs or engine) is assembled. The test series, which was to begin in the fourth quarter of CY 1987, has slipped to September of CY 1988. The delay is due to continued ground test demonstration of critical operating failure mode margins of the engines, and hot fire acceptance testing of flight engines for STS flight resumption.

OPEN ITEM: NASA and SSME contractor continue development of improved methods of demonstrating critical operating failure mode margins.

STATUS: 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 modes, an extensive ground test program, including margin demonstration test (higher power level, longer duration, and off nominal performance response), has been defined and is being performed. Since the initiation of the extensive ground test program, subsequent to the STS-51L accident, 182 cycles and 62,606 seconds have been accumulated on the SSME's.

OPEN ITEM: Orbiter landing gear system; including brakes, nose-wheel steering, etc.

STATUS: The carbon brakes are in qualification, testing and the first flight hardware is scheduled for delivery in September 1988. The carbon brakes will be installed at the earliest possible time. The landing deceleration team recommended incorporation of a drag chute and the resurfacing of the KSC runway. The runway surface has been completed and the drag chute modification is in the approval cycle. The Nose-Wheel Steering System Redundancy Design Studies are underway to assess full redundancy architecture for nose-wheel steering.

4. Safety, Reliability, Quality Assurance

OPEN ITEM: Development of operating policy for the new SRM&QA offices at Headquarters and at NASA centers.

STATUS: Each Center has established a SRM&QA Director who reports to the Center Director. Within the SRM&QA organization exists a Safety Engineering function that is responsible for implementation of the safety policies established by the Headquarters organization, as well as those established by the Center organization. Over the past year the Headquarters Safety Division has continued to develop and define the roles and responsibilities of the various safety areas and disciplines within the Headquarters Safety Division and at the Centers. While this is an ever-evolving procedure, significant progress has been made in the Systems Safety aspects of the STS, Space Station, and Payload areas. The Associate Administrator (AA) for the Headquarters SRM&QA office, Code Q, has implemented a Headquarters and Center SRM&QA Directors meeting/review which takes place periodically, much in the same manner as the Program Office Management Council meeting. This approach has had considerable results in the development and the providing of operating policy.

OPEN ITEM: Independent review of payload safety.

STATUS: Independent review of the inherent safety of payload components and analysis of the safety implications of potential interactions between payloads has been continued by the JSC and KSC Payload Flight and Ground Safety Panels. Additional emphasis has been placed on this function by management at each of the centers, and is being supported by the various assigned payload safety engineers at the payload developing centers, as well as with additional emphasis and visibility within the Headquarters Safety Division. A Payload Safety Subpanel has been established, chaired by Headquarters, to provide an improved forum for discussion of payload safety related issues, development of Agencywide policies for payload safety, and coordination of potential resolutions to payload safety concerns of general and specific interest.

5. Space Station Program

OPEN ITEM: Use of ELV's.

STATUS: A transportation study by the Office of Space Flight and the Office of Space Station considering the use of the STS and ELV's for the launch and assembly phase of Space Station has been completed. The conclusion of the report was that ELV's were not needed for that phase of the Space Station program. A study for the operational phase of Space Station has now been initiated by the Office of Space Flight and the Office of Space Station to examine:

(1) station logistics requirements for the use of ELV's;

(2) requirements on the Station logistics module design to be consistent with the use of ELV's;

(3) station modifications required to accommodate ELV's; and

(4) station proximity operations requirements to be consistent with the use of ELV's.

As the results of these analyses mature, the results will be factored into the mixed fleet planning to assure availability of adequate transportation systems for the operational phase.

OPEN ITEM: Crew safe haven and life boat, crew rescue.

STATUS: NASA agrees with the Panel that an assured crew return capability should be provided for the Space Station crew, and as discussed on pages 20 and 21, studies have begun to determine the most appropriate means of reaching this goal.

NASA studies to date have been restricted to the fundamental purpose of a CERV, and three Design Reference Missions (DRM's) have been specified, all of which are compatible with the recommendations:

(1) return or support of Space Station crew during interruption of STS launches;

(2) return or protection of Space Station crew from reasonable accidents or from reasonable failures of Space Station systems; and

(3) return or support of Space Station crew during reasonable medical emergencies.

Analyses are continuing, and several approaches which could satisfy the DRM's are being considered; the CERV is one of those approaches. Each option considered is being evaluated for its ability to meet the DRM's; its impact on the NSTS, the Space Station, and expendable launch systems; and cost. The assured crew return capability for the Space Station will impact several of the NASA's programs, and all facets must be considered in determining which is truly the most cost effective and reliable concept. As stated, analyses are continuing and decisions will be documented relative to specific basic requirements as they are agreed to between the program and technical elements associated with the programs within NASA.

OPEN ITEM: Computer system's use of new developments; also use of 32 bit architecture.

STATUS: As discussed on pages 19 and 20 and repeated here for continuity, provisions have been made in the Space Station planning for upgrading computers and/or software systems as improved technology permits. Our current planning on this subject is in two areas. The first is our budget planning for the operational phase of the Space Station Program (SSP) in which we are planning mainframe computer hardware and support software replacement every 7 years and workstation replacement every 5 years.

The second area is establishing evolutionary requirements allowing the program the flexibility to upgrade with advanced technology as it becomes available in the future. We have requirements for the operational Space Station Information System which will require a design to isolate applications software (both flight and ground) from the underlying computing system. This is to promote the migration of ground hardware and software to the flight systems or from facility to facility, and to maximize the flexibility of replacing the flight hardware, as required, during the life of the program. In addition, the work packages have factored advanced automation requirements in their proposals. As the Space Station design matures over the next year, the inclusion of these requirements into work package plans will happen as reviewed and as approved by program management.

Relative to 32 bit architecture and a data bus baseline, the Space Station onboard Data Management System (DMS) is designed for a RAD hard environment and employs current state-of-the-art INTEL 80386 microchip technology. Provision has been made to upgrade the system architecture as technological advances are made. Specifically, plans have been made to utilized the INTEL 80486 chip set when it becomes available. The current bus architecture employs MILSTD 1553 for slow speed (10 MHz) data transmission. This interface is the same as is currently used in the F16 and B1. The American National Standards Institute (ANSI) Fiber (optic) Distributed Data Interface (FDDI) standard for all data transmission.

OPEN ITEM: Use of lessons learned.

STATUS: A draft "lessons learned" document has been prepared. This document will provide guidance to the Space Station Program to utilize applicable lessons learned from the Shuttle 51L mishap. In addition, a newer concept is being explored to create a "lessons learned" action item system in the form of a checklist, which will be tailored for the type of program or system being developed and type of professional discipline involved, and will require action to address the applicable lessons learned in the safety analyses.

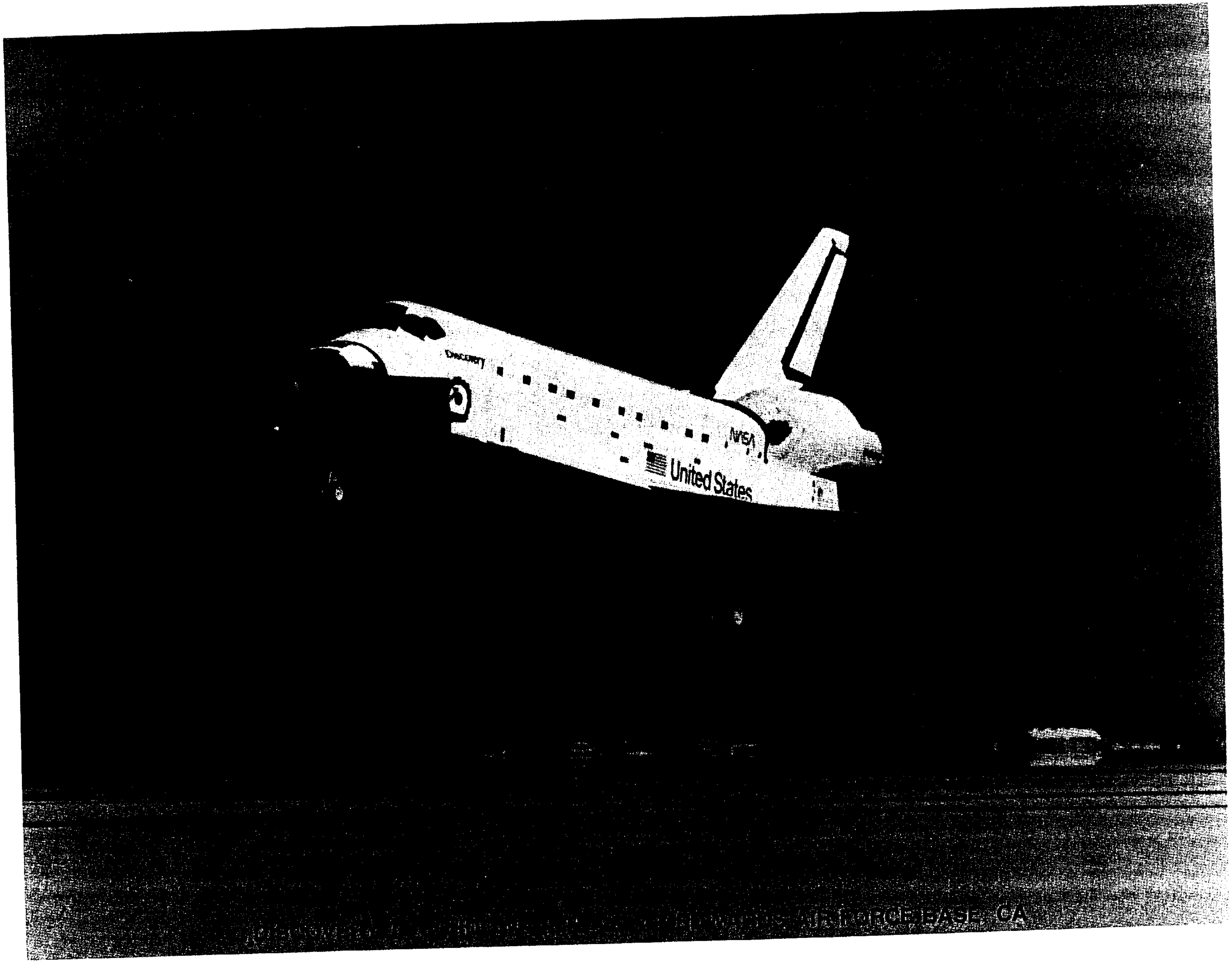
6. NASA Aeronautics

OPEN ITEM: Modification of Grumman Aircraft as Space Shuttle flight simulators.

STATUS: JSC has purchased the aircraft for use as a shuttle trainer. Because the aircraft is not required to support the shuttle manifest until the summer of 1991, modifications will not commence until mid 1989. In the mean time, we are considering a program to continue turboprop research.

OPEN ITEM: X-Wing project flight test program. Other comments included under this heading.

STATUS: OAST is developing a closeout plan for the X-Wing Program. Part of the plan will be to document the results of the program through the first three flights which we successfully conducted. This documentation will include lessons learned as recommended by the ASAP.



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C. Panel Activities - February 1988 - January 1989

FEBRUARY

- FEBRUARY 5-6 NATIONAL RESEARCH COUNCIL, SOLID ROCKET MOTOR REDESIGN PANEL, WASHINGTON, DC
- FEBRUARY 10 - CONGRESS, HOUSE SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE (NELSON) DISCUSSIONS RE: SAFELY RETURNING THE SHUTTLE TO FLIGHT STATUS (PREPARATION FOR UPCOMING HEARINGS)
- FEBRUARY 10 - DR. FLETCHER, DISCUSSIONS RE: USE OF PROBABILISTIC RISK ASSESSMENTS
- FEBRUARY 8-11 - AMES RESEARCH CENTER, AERONAUTICAL R&D DISCUSSIONS
- FEBRUARY 16 - US SENATE, SUBCOMMITTEE ON SCIENCE, TECHNOLOGY AND SPACE, HEARING: RETURN TO SAFE FLIGHT STATUS, WASHINGTON, DC
- FEBRUARY 17-18 - PROGRAM DIRECTOR'S MONTHLY REVIEW, OFFICE OF SPACE FLIGHT, JSC, HOUSTON, TX
- FEBRUARY 22 - LEVEL II 1/2 SSME BOARD MEETING, MSFC,
- FEBRUARY 23-25 - COMPUTER HARDWARE/SOFTWARE, VALIDATION AND VERIFICATION, JSC, HOUSTON, TX

MARCH

- MARCH 3-4 - LIFE SCIENCES ADVISORY COMMITTEE MEETING, NASA HQ,
- MARCH 9-11 - DESIGN CERTIFICATION REVIEW LEVEL I/II, LAUNCH AND LANDING SYSTEMS, EXTERNAL TANK AND SSME, MSFC
- MARCH 16 - ANNUAL STATUTORY MEETING WITH DR. FLETCHER, MR. MYERS AND NASA SENIOR MANAGEMENT, NASA HQ,
- MARCH 17 - PROGRAM DIRECTOR'S MONTHLY REVIEW, OFFICE OF SPACE FLIGHT, NASA HQ
- MARCH 22-23 - DESIGN CERTIFICATION REVIEW, KSC, FL

- MARCH 30-31 - NATIONAL RESEARCH COUNCIL, SOLID ROCKET MOTOR REDESIGN PANEL, MORTON THIOKOL, UT

APRIL

- APRIL 6 - SPACECRAFT FIRE SAFETY MEETING, LEWIS RESEARCH CENTER, OH
- APRIL 12-14 - INTERCENTER AIRCRAFT OPERATIONS PANEL MEETING, ATLANTA, GA
- APRIL 21 - SPACE STATION RISK MANAGEMENT REVIEW, RESTON, VA
- APRIL 25 - SPACE STATION PROGRAM REQUIREMENTS REVIEW KICKOFF MEETING, RESTON, VA

MAY

- MAY 2 - SPACE STATION PROGRAM REQUIREMENTS REVIEW, RESTON, VA
- MAY 3 - ROCKWELL, DOWNEY, CA, DISCUSSIONS RE: 6.0 LOADS AND FACTORS OF SAFETY FOR 1.4 FOR 1ST FLIGHT
- MAY 12-13 - SPACE STATION SAFETY SUMMIT, MSFC
- MAY 12-14 - NRC SOLID ROCKET MOTOR REDESIGN PANEL, MORTON THIOKOL
- MAY 17 - SRM&QA INDEPENDENT WORKING GROUP MEETING, NASA HQ

JUNE

- JUNE 6 -
  1) SPACE STATION SRM&QA DISCUSSIONS
  2) ASSURED CREW RETURN CAPABILITY
  3) STS-26 AND BEYOND - ASAP ASSESSMENTS WITH DALE MYERS
- JUNE 7 -
  1) SRM&QA ASSESSMENT WITH G. RODNEY
  2) SPACE STATION ASSESSMENT WITH J. ODOM
  3) ORBITAL DEBRIS BRIEFING
- JUNE 9 - SRM&QA DISCUSSIONS WITH KOHRS, HARLAN, ET AL, JSC
- JUNE 9 - STS/SRM&QA/TREND ANALYSIS DISCUSSIONS WITH G. RODNEY
- JUNE 13-14 - SPACE STATION DISCUSSIONS/RANGE SAFETY REVIEW, KSC
- JUNE 20-21 - SPACE STATION PROGRAM REQUIREMENTS REVIEW, RESTON, VA

JULY

- JULY 6/LIQUID ROCKET BOOSTER, HQS BRIEFING
- JULY 7-8 - SRM/SRB DESIGN CERTIFICATION REVIEW, KSC
- JULY 11-13 - TEST READINESS REVIEW, KSC
- JULY 11-13 - SAE/AIAA JOINT PROPULSION CONFERENCE, BOSTON, MA
- JULY 14 - RISK MANAGEMENT REVIEW, HQS
- JULY 18-21 - STS LOGISTICS SESSION, ROCKWELL INTERNATIONAL, DOWNEY, CA
- JULY 22-23 - NATIONAL RESEARCH COUNCIL, SRB REDESIGN PANEL, IRVINE, CA

AUGUST

- AUGUST 1-5 - SPACE STATION SAFETY SUMMIT, OTTAWA, CANADA
- AUGUST 9-10 - NUCLEAR SAFETY WORKING GROUP MEETING (GALILEO/ULYSSES MISSION)

SEPTEMBER

- SEPTEMBER 6-7 - NATIONAL RESEARCH COUNCIL, SRB REDESIGN PANEL, WASHINGTON. DC
- SEPTEMBER 6 - AERONAUTICS REVIEW, LANGLEY
- SEPTEMBER 7 - LEVEL III SSME FRR, MSFC
- SEPTEMBER 13/14 - STS-26 FLIGHT READINESS REVIEW
- SEPTEMBER 20 - AERONAUTICS REVIEW, LANGLEY
- SEPTEMBER 22 - SSME REVIEW, ROCKETDYNE, CANOGA PARK, CA
- SEPTEMBER 28-29 - AEROSPACE MEDICINE ADVISORY COMMITTEE, ALEXANDRIA, VA

OCTOBER

- OCTOBER 3-6 - AIAA SPACE LOGISTICS SYMPOSIUM, COSTA MESA, CA
- OCTOBER 6-7 - RISK MANAGEMENT REVIEW (JSC/MSFC)
- OCTOBER 18 - SPACE TRANSPORTATION SYSTEM ORBITER & INTEGRATION UPDATE, RI/DOWNEY

- OCTOBER 19 - SPACECRAFT/PAYLOAD SAFETY, TRW/EL SEGUNDO, CA
- OCTOBER 20 - DRYDEN FLIGHT RESEARCH FACILITY
- OCTOBER 27 - RISK MANAGEMENT DISCUSSIONS WITH NASA HEADQUARTERS PERSONNEL

NOVEMBER

- NOVEMBER 1 - SPACECRAFT BATTERY WORKSHOP, GSFC
- NOVEMBER 10 - JSC, COMPUTER SOFTWARE/HARDWARE VALIDATION AND VERIFICATION/SAIL/
- NOVEMBER 15-16 - STS-27 FLIGHT READINESS REVIEW, KSC,
- NOVEMBER 15-17 - AERONAUTICS ADVISORY COMMITTEE MEETING, LaRC
- NOVEMBER 17 - STS LOGISTICS/SHUTTLE PROCESSING REVIEW, KSC
- NOVEMBER 21-23 - SPACE STATION SAFETY SUMMIT, NASA HWS
- NOVEMBER 29/30 - AUTOMATION AND ROBOTICS SYMPOSIUM, ARLINGTON, VA
- NOVEMBER 30/DEC 1, 2 - SPACE STATION AVAILABILITY WORKSHOP, RESTON, VA

DECEMBER

- DECEMBER 6-7 - NASA HQS, MEETINGS WITH NSTS, SSFP AND DR. FLETCHER AND MR. MYERS, CONGRESS, SPACE STATION, SRM&QA
- DECEMBER 13 - ROCKWELL INTERNATIONAL, DOWNEY, CA STS-27 DATA REVIEW

JANUARY

- JANUARY 18-20 - ROCKWELL INTERNATIONAL
- JANUARY 24-27 - NSTS INTEGRATED LOGISTICS ACTIVITIES AT KSC

D. Improvements Recommended for Space Shuttle Elements

The following improvements to the STS elements are recommended for study to ascertain whether they can truly enhance flight and ground safety, and if so, the advisability of implementing such improvements based on prioritizing them regarding safety enhancement and associated cost, schedule and performance impacts. These lists were obtained from NASA centers (JSC, KSC, MSFC) and their prime contractors.

MSFC

A. Solid Rocket Motor (SRM)

1. Submitted Changes

Description	Remarks
Locking feature for nozzle leak leaking check port plugs	Reliability Flight Safety
Design and fabricate foam core systems tunnel	Reliability

2. Recommended Changes

Description	Remarks
One-piece case stiffener rings	Flight Safety Reliability
Non-asbestos motor insulation	Health Safety
Redesign of forward segment grain to permit direct removal of core	Ground Safety
Molded, one-piece o-ring from from second source	Reliability
Nozzle Modifications	
Aft exit cone ply angle	Reliability
New high strength nozzle adhesives	Reliability
Lightning protection enhancement, case, nozzle	Safety
Modify cowl vent holes to prevent plugging by slag	

Incorporate new elastomer and adhesives in flex bearing

More flex boot interply vent holes to avoid exclusion of the vents by contacts with fixed housing

B. External Tank

Description

Plasma arc welding on nine additional weld assemblies

Elimination of non-self-locking standard length thread inserts

Revise design and installation of cable attach clips on LH2 fwd & aft domes

GH2 pressurization line composite fairing

Changes Recommended by Contractor

Description

Add a sensor/monitor device to the facility side of the GUCA to detect a leaking vent valve (GH2)

C. Space Shuttle Main Engine (SSME)

SSME Areas of Future Emphasis

Description

HPOTP

Alternate turbopump development
Bearing modifications and improvements
Bearing and cage improvements
Blade optimization

HPFTP

Alternate turbopump development
Bearing and cage improvements
Sheet metal reduce cracking
Blade improvements - improved Mar-M and single crystal

LPTOP

Bearing improvements

Engine Systems

Elimination of preburner pops
MFV valve leakage and preburner valve(s) operating improvements

Combustion Devices

Two duct manifold development
External HEX
Large throat main combustion chamber (Technology Test Bed evaluation only effort currently authorized)
Single tube heat exchanger

Avionics and Controls

Block II controller
Addition of FASCOS (active redline)
Hot gas sensor improvement (thermocouple)

NOTE: Several producibility items not included

D. Solid Rocket Booster (SRB) Assembly

Recommended Changes

Description

Implementation of parachute ripstops to improve reliability of the deceleration system.

Adaption of an improved APU turbine wheel.

Addition of a radar tracking beam on each SRM to enhance tracking.

Use of booster trowelable ablative (BTA) as component of the thermal protection system. Eliminates use of MTA-1 which contains a carcinogen.

Implementation of a TVC pod which would enhance both TVC system safety and reliability.

Implementation of biasing at the holddown post/mobile launch platform interface to increase the aft skirt ultimate factor of safety.

Redesign of multiplexer/demultiplexer (MDM) to eliminate obsolete components.

Orbiter Vehicles

*1. Structural beef-up of the Tail section, wings, aft fuselage, mid-body/landing gear area. All of these to enhance safety and ability to meet wider flight envelopes and environments.

*2. Auxiliary Power Units (APUs) continue to upgrade so that those items classed as critically 1 and 1R can be shown to have an extremely low probability of occurrence. Metal parts cracking, seals (such as carbon face seals), overspeed control are examples.

*3. Nose wheel steering redundancy (hydraulics, electrical/controls).

*4. Elimination of the problems associated with the use of Kapton wire.

5. Upgrading of the brake system to eliminate landing failures.

*6. Upgrade of the main (currently 17-inch) hydrogen and oxygen valves between Orbiter and External Tank. Eliminate and/or reduce probability of failures of any kind during ascent flight.

7. Upgrade valves and pressure regulators throughout the Main Propulsion System to eliminate leakage and assure proper closing and opening to meet the demanding requirements of the Space Shuttle Main Engine operations.

8. This also applies to the Reaction Control System (RCS) and Orbital Maneuvering System (OMS) . . . see item 7 above.

9. Upgrade the ET/Orbiter umbilical door retention/release latch mechanism, door drive torque limiters on the motors.

10. TPS outer tile study to determine modifications based on flight data with objective of reducing tile weight (overall), attempt to reduce the number of unique tiles, provide carrying plates with reinforced carbon-carbon (RCC) in lieu of tiles where they are damaged on every flight.

11. Increase avionics and software reliability . . . this is abroad spectrum of items looking at those pieces of hardware that are the most safety critical to increase reliability and the enhanced testing of software to eliminate possible "bugs" that can bite you during critical phases of the mission.

*12. Crew escape systems improvements which cover as much of the mission profile as possible. These are either in addition to current methods/thoughts or new items.

13. Enhance the safety of the Remote Manipulator System (built by the Canadiens) such as preventing joint-runaway which can damage the Orbiter.

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*In process or under review

14. Extravehicular Mobility Unit (EMU=space suit) enhancements to assure safety of the crew when doing EVA tasks.

15. RCS nozzle enhancements to prevent material burn-through.

16. A further study to determine hardware and software modifications that would reduce the number of launch commit criteria and launch constraints and reduce their limits (that is widen them) without affecting safety but increasing probability of launch.

17. Examine the Orbiter systems to ascertain possibility of adding redundancy enhancements in safety critical areas.

E. KSC

Description

1. Hypergol exhaust fans control - HMS
2. Resolution of safety and documentation issues on Westinghouse Brazing/Debrazing equipment
3. Install remote CNTL lockout switch
4. MMH, N2H4, NH3 flammable concentration detection cart upgrades
5. Hoist design discrepancies
6. Fire detection/protection for quality tair vans
7. Him "A" card failure - restart command for compressors A & B - Him 237
8. Him "A" card failure - GH2 fire detector remote test command
9. Him "A" card failure - GH2 fire detector remote test command
10. Him "A" cards failure - restart commands for compressors A & B - Him 152
11. Equipment access ramp HB-3 South 10th floor to D-Roof
12. Add platform beneath 186' LVL and method to remove static lanyard cable without removing cable sheave
13. Relocate emergency showers/remove copper plumbing
14. General paging to ESA (3R18)
15. Install paging/area warning system, LC-39 FFD work locations
16. Upgrade flammable concentration detector cart

17. Provide access platform with handrails

18. SSME heat shields & LRU handling

19. LH2 horiz drain line leak (Ref: SYO-0815-001-001)

20. Platform inadequate for handling BI-POD strut fixtures

21. FCSS LH2 hazardous warning system

22. Requirement to heat treat secondary P/L support fittings to control stress corrosion

23. Modify vertical motion system

24. Payload Bay Bridge and Bucket System Mods

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30. Remove ECP/ESP after hoisting system failure

31. OPF target track antenna safing

32. Improve hyper storage tank relief valve protection

33. 30 ton bridge cranes safety lines, handrails and screening mod

34. OPF firex diesels compressed air manual bypass

35. Modification of C70-1226 cabin leak test unit

36. Flow switches

37. OPF scrubbers upgrade (fuel & oxidizer)

38. PGHM LRU platform hoist system modification

39. Over pressure piping connections, sound suppression 36" J pipe replacement

40. Eliminate safety hazard in the RSS hoist machinery room

41. Fix deformed pin hole on lower release mechanism of MLP/TSM

42. Fixed toxic vapor detectors

43. Move FD's to different HIM's

44. HWS-OMBUU gas sampling

45. Pneumatic control valves leak air

46. LC-39 MLP-zero level water spray for hydrazine spill fire protection

47. Authorization & calibration of Raymond Engineering Inc. bolt gage PDX 934

48. OAA critical single failure points

49. OAA critical single failure points

50. FCSS HAZ warning DC power module redundancy

51. MLP HAZ warning DC power module redundancy

52. Removal of wire mesh from SRM segment bottom covers S/N 13 through 24 covers only

53. 3-ton and 5-ton cranes not acceptable for operation, K6-1547

54. Inadequate purge air supply at OPF

55. E-1 HPOTP support beam

56. Elimination of HOSIT critical single failure points

57. Connect 02 sensor to audible/visual alarm in hallway

58. Removal of wire mesh from SRM segment bottom covers S/N 13 through 24 covers only

59. OPF breathing air system

60. Upgrade orbiter emergency alarm system

61. Resolution of safety and documentation issues on Lepel brazing/debrazing equipment

62. Mod PGHM support beams as a result of stress analysis

63. Mod stairs, side 4, PCR

64. Provide remote stop capability on (4) 400 AMP receptacles

65. Upper hinge platform

66. Provide emergency AC power to hydrogen leak detector vacuum pumps

67. Removal of wire mesh from SRM segment bottom covers S/N 13 through 25 covers only

68. Mod PGHM support beams as a result of stress analysis

69. Trolley access ladders for 200-ton cranes

70. OMRF low bay roof safety railing

71. C-hook storage, OPF HB-1 & HB-2

72. OAA white room safety lanyard attachment point structural deficiency

73. Elimination of GN2 from GO2 panel

74. Heating, ventilating and air conditioning (HVAC), OPF

75. HIM redundancy for FCSS leak and fire detectors and vacuum pumps

76. Provide safe access to hammerhead crane machine room

77. Provide safe access to hammerhead crane machine room

78. Eliminate critical one-step commands

79. Platform crossover area needs to be relocated

80. Add ARM/execute command to fuel OX hyper storage tank vent valve

81. SRB AFT skirt GN2 purge panel redundant pressure transducer

82. PCR/canister lightning policy impact

83. Critical helium purge for the hydrogen vent stack at LC-39 pads A & B

84. HIM "A" card review problem

85. Replacement of firex water pumps/motors at pad-A & pad-B

86. Replacement of firex water pumps/motors at pad-a & pad-B

87. Resolution of HIM "A" card review problems

88. VAB extensible platform life lines and tie OFFS

89. VAB vertical door panel life lines

90. Fab/install remote cables & readout distribution box

91. Target track antenna (TTA) rotational limits

92. Provide low flow purge air capability

93. Platforms AP 48, 50 and 93 to provide sufficient working area for SRB inspection and measurements

94. Modification to Diver Operated Plug (D.O.P.)

95. Redesign pressure monitor port fitting stackup on the 8" VJ F/H

96. Eliminate LPS single failure points in the hypergol vapor detection system

97. Modify area warning system to provide control for new areas individually

98. Modify area warning system to provide control for new areas individually

99. Complex F area warning

100. Sample rate change for critical GLS functions

101. Backup HAZ gas detection system for firing rooms #2 and #4

102. Paging and public address system

103. ET LO2/LH2 monitor/pressurization system

104. Modify the design and expedite activation of the TPS P/AW system

105. Communication system support for PHSF service bay and control building

106. Install LH2 leak detector at 8" T-O LH2 flex hose connection

107. Make the 17" QD fire & temp detectors permanent LPS monitored SYS & upgrade the egress route

108. Provide locking device for LRU extendible platform

109. Flow switches

For Further Information
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