COLUMBIA

ACCIDENT INVESTIGATION BOARD

Note: Volumes II – VI contain a number of conclusions and recommendations, several of which were adopted by the Board in Volume I. The other conclusions and recommendations drawn in Volumes II – VI do not necessarily reflect the opinion of the Board, but are included for the record. When there is conflict, Volume I takes precedence.

Report Volume V

Appendices G.10 – G.12

October 2003

On the Front Cover

This was the crew patch for STS-107. The central element of the patch was the microgravity symbol, µg, flowing into the rays of the Astronaut symbol. The orbital inclination was portrayed by the 39-degree angle of the Earth's horizon to the Astronaut symbol. The sunrise was representative of the numerous science experiments that were the dawn of a new era for continued microgravity research on the International Space Station and beyond. The breadth of science conducted on this mission had widespread benefits to life on Earth and the continued exploration of space, illustrated by the Earth and stars. The constellation Columba (the dove) was chosen to symbolize peace on Earth and the Space Shuttle Columbia. In addition, the seven stars represent the STS-107 crew members, as well as honoring the original Mercury 7 astronauts who paved the way to make research in space possible. The Israeli flag represented the first person from that country to fly on the Space Shuttle.

On the Back Cover

This emblem memorializes the three U.S. human space flight accidents – Apollo 1, Challenger, and Columbia. The words across the top translate to: "To The Stars, Despite Adversity – Always Explore"

The Board would like to acknowledge the hard work and effort of the following individuals in the production of Volumes II – VI.

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Chapter 2	*Columbia*'s Final Flight
Chapter 3	Accident Analysis
Chapter 4	Other Factors Considered
Part Two	**Why the Accident Occurred**
Chapter 5	From *Challenger* to *Columbia*
Chapter 6	Decision Making at NASA
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Appendix H.10	June 12, 2003	Washington, DC

Reader's Guide to Volume V

Volume V of the Report contains appendices that were not cited in Volume I. These consist of documents produced by NASA and other organizations, which were provided to the Columbia Accident Investigation Board in support of its inquiry into the February 1, 2003 destruction of the Space Shuttle *Columbia*. The documents are compiled in this volume in the interest of establishing a complete record, but they do not necessarily represent the views of the Board. Volume I contains the Board's findings, analysis, and recommendations. The documents in Volume V are also contained in their original color format on the DVD disc in the back of Volume II.

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Volume V

Appendix G.10

Detailed Summaries

- Rogers Commission Report
- ASAP Report
- SIAT Report

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G.10 Past Reports Review

1.0 Past Reports Overview

The Columbia Accident Investigation Board was very interested in how other independent review boards had evaluated the Space Shuttle Program. A number of previously released reports were reviewed for relevance to the Columbia accident. At the highest level the Board looked at what general areas each of the reports had covered. These were broken up into nine categories, and most reports concentrated in a small subset of these areas. This evaluation provided the Board with insight into how NASA had previously responded to criticisms from independent evaluations, and also assisted the Board in determining how to frame new Findings and Recommendations for the strongest impact. The following table provides a general overview of the content of more than 45 previous reports.

Past Reports Review *1 of 3*

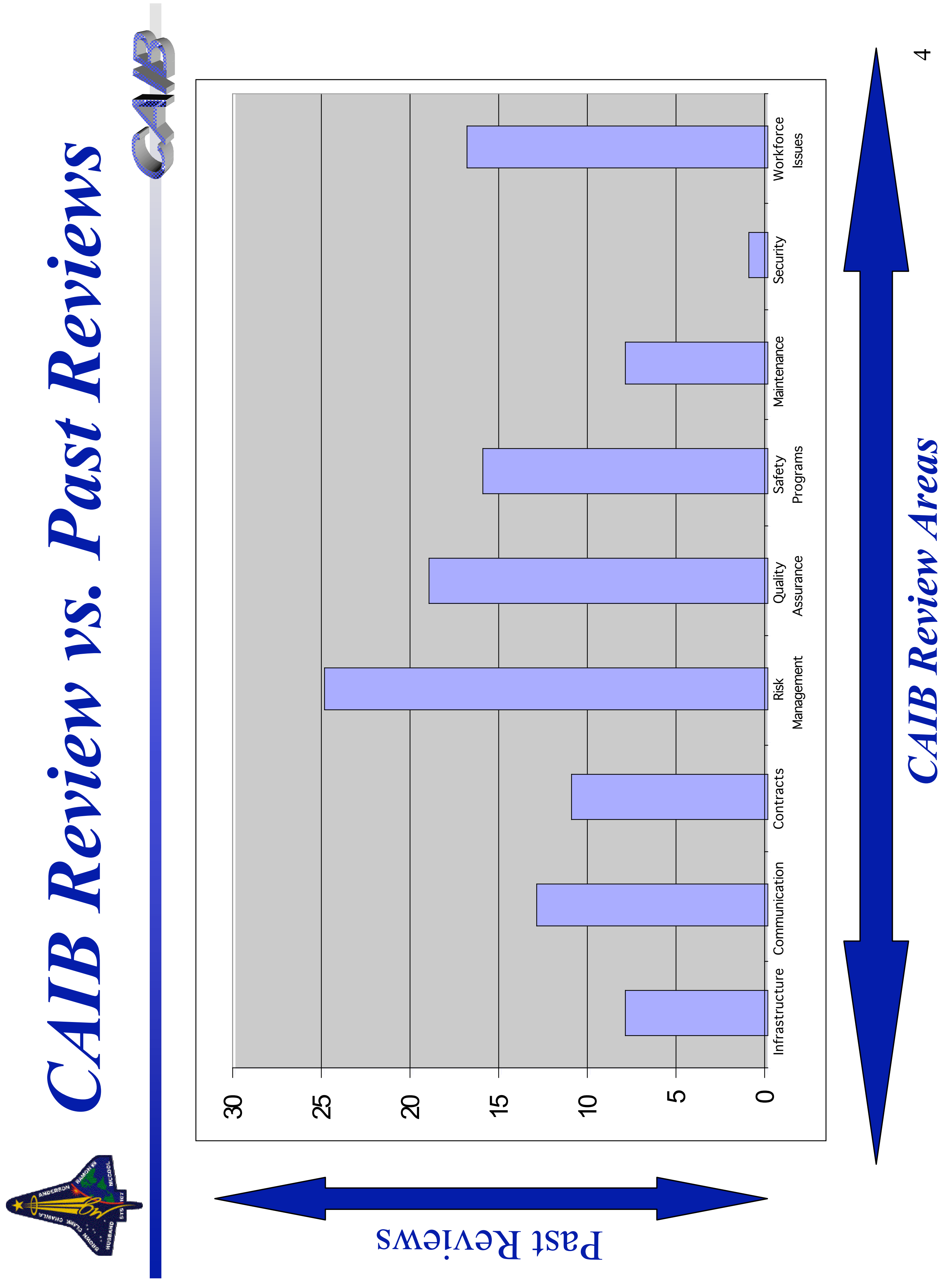
	Infrastructure	Communication	Contracts	Risk Management	Quality Assurance	Safety Programs	Maintenance	Security	Workforce Issues
Rogers Report – 1986	●	●	●	●	●	●	●		
STS-29 Prelaunch Assessment – 1989				●					
"Augustine Report" – 1990		●	●	●			●		●
Paté-Cornell Report – 1990				●	●				●
"Aldridge Report" – 1992				●					
GAO: NASA Infrastructure – 1996	●								●
GAO: NASA Workforce Reductions – 1996	●								●
Super Light Weight Tank Independent Assessment – 1997				●	●				
Process Readiness Review – 1998				●			●		●
S&MA Ground Operations Report – 1998					●				
GAO: NASA Management Challenges – 1999		●	●	●					
Independent Assessment JS-9047 – 1999				●					
Independent Assessment JS-9059 – 1999				●					
Independent Assessment JS-9078 – 1999		●					●		
Independent Assessment JS-9083 – 1999					●				
S&MA Ground Operations Report – 1999					●	●			

Past Reports Review *2 of 3*

	Infrastructure	Communication	Contracts	Risk Management	Quality Assurance	Safety Programs	Maintenance	Security	Workforce Issues
Space Shuttle Independent Assessment Team – 1999			●	●		●	●		●
Space Shuttle Ground Operations Report – 1999						●			
Space Shuttle Program (SSP) Annual Report – 1999						●			
GAO: Space Shuttle Human Capital & Safety – 2000						●			●
Independent Assessment JS-0032 – 2000					●				
Independent Assessment JS-0034 – 2000	●								
Independent Assessment JS-0045 – 2000					●				
IG Audit Report 00-039 – 2000			●						
NASA Independent Assessment Team – 2000		●		●	●	●			●
Space Shuttle Program Annual Report – 2000	●		●	●		●			
ASAP Report – 2001	●		●	●		●	●	●	●
GAO: NASA Critical Areas – 2001				●					
GAO: Space Shuttle Safety – 2001									●
Independent Assessment JS-1014 – 2001		●		●	●	●			
Independent Assessment JS-1024 – 2001		●			●				●

Past Reports Review *3 of 3*

	Infrastructure	Communication	Contracts	Risk Management	Quality Assurance	Safety Programs	Maintenance	Security	Workforce Issues
Independent Assessment KS-0003 – 2001		●			●				●
Independent Assessment KS-1001 – 2001			●	●			●		
Workforce Survey-KSC– 2001				●	●				●
Space Shuttle Program Annual Report – 2001		●		●					
SSP Processing Independent Assessment – 2001				●	●	●			●
ASAP Report – 2002	●		●	●	●	●			●
GAO: Lessons Learned Process – 2002		●							
Independent Assessment KS-1002 – 2002					●				
Selected NASA Lessons Learned – 1992-2002		●		●	●	●	●		●
NASA Navy Benchmarking Exchange – 2002		●	●	●		●			●
Space Shuttle Program Annual Report – 2002	●			●		●			
ASAP Leading Indicators		●		●		●			
NASA Quality Management System – 2003					●				
QAS Tiger Team Report – 2003					●				
Shuttle Business Environment – 2003			●						


CAIB Review vs. Past Reviews
CAIB
0
5
10
15
20
25
30
Infrastructure
Communication
Contracts
Risk Management
Quality Assurance
Safety Programs
Maintenance
Security
Workforce Issues
CAIB Review Areas
Past Reviews
4

2.0 Detailed Report Summaries

In addition to the general overview, many previous reports – particularly from the annual Aerospace Safety Advisory Panel (ASAP) evaluation – were analyses in more detail to determine if there were consistent trends in how NASA dealt with external criticisms. The following table lists the Findings and Recommendations from a long list of advisory panels that have reviewed Space Shuttle operations. The last column details NASA's response to the Finding or Recommendation, if it was publicly released.

The table does not contain every Finding and Recommendation made in the reports that were analyzed, only those that seemed to have particular relevance to the NASA organization and culture as it affected STS-107. Many detailed technical recommendations that addressed specific hardware issues are not listed (and almost all were corrected by NASA in a timely manner), and recommendations that were not directed at the Space Shuttle Program are also not listed.

Independent Assessment Team *(Chartered by)*	**Date of Report**	**Finding**	**Recommendation**	**NASA Response**
Aerospace Safety Advisory Panel (*NASA Charter)*	March 2003	**Finding 02-1:** Many problems have not been discovered until late in the prelaunch sequence. In all of these cases, checkout, test, and inspection procedures were properly performed. The potentially hazardous discrepancies were not detected earlier because the test and inspection requirements did not dictate more specific or more stringent screening.	**Recommendation 02-1a:** Through proactive review, revalidate and revise the criteria for critical ground and flight systems recertification.	
			Recommendation 02-1b: Based on the findings and technical information garnered from the recertification process, validate and update the maintenance, test, and inspection requirements.	
Aerospace Safety Advisory Panel (*NASA Charter)*	March 2003	**Finding 02-2:** The growing Backlog of Maintenance and Repair (BMAR) and the change to Full Cost Accounting (FCA) may put infrastructure vital to safe operations at risk.	**Recommendation 02-2:** Reduce the BMAR on critical infrastructure as quickly as possible to ensure that this infrastructure remains safe and capable of supporting NASA's missions.	
Aerospace Safety Advisory Panel (*NASA Charter)*	March 2003	**Finding 02-3:** NASA has not established a guiding principle for locating safety organizations within its organizational structure. Unlike the DOD and industry, NASA's safety organizations are integrated into the assurance organization rather than into systems engineering.	**Recommendation 02-3:** Through appropriate management action, define an Agency-wide safety organizational structure—one that separates system safety engineering from system safety assurance.	
Aerospace Safety Advisory Panel (*NASA Charter)*	March 2003	**Finding 02-4:** NASA's safety policy direction is well formulated, but the Panel has observed that safety tends to be a comprehensive activity only late in the	**Recommendation 02-4a:** Consider integrating safety into systems engineering to support system development and sustaining engineering and supporting system safety assurance through an	

Independent Assessment Team *(Chartered by)*	**Date of Report**	**Finding**	**Recommendation**	**NASA Response**
		only late in the development cycle after design is complete, and occasionally only after an incident or mishap.	assurance through an independent reporting channel from the safety organization to the mission assurance organization.	
			Recommendation 02-4b: Establish independent funding mechanisms and appropriate authority, responsibility, and accountability for these new safety units.	
Aerospace Safety Advisory Panel (*NASA Charter)*	March 2003	**Finding 02-5:** NASA personnel do not view appointments to safety organizations as a positive career move.	**Recommendation 02-5:** Require that managers of major NASA programs and projects have experience in safety organizations.	
Aerospace Safety Advisory Panel (*NASA Charter)*	March 2003	**Finding 02-6:** NASA's application of root cause analysis appears to be inconsistent across the Agency and across programs.	**Recommendation 02-6a:** Continue the effort that has begun to assess the state of root cause analysis performed by NASA and its contractors. Provide the training and resources necessary to resolve any deficiencies.	
			Recommendation 02-6b: Explore the causes of cultural or contractual impediments, and devise ways to change the culture from a fixing orientation (identifying and eliminating deviations or symptoms of deeper problems) to a learning orientation in which both cultural and organizational factors are included in the search for the source of problems.	
			Recommendation 02-6c: Establish an oversight process for reviewing the root cause analyses and the resulting recommendations for all major failures or incidents.	

Independent Assessment Team *(Chartered by)*	**Date of Report**	**Finding**	**Recommendation**	**NASA Response**
Aerospace Safety Advisory Panel (*NASA Charter)*	March 2003	**Finding 02-7:** The shift to FCA in FY 2004 could negatively impact the ability to sustain safe and reliable operations.	**Recommendation 02-7:** Identify the impact of the implementation plans for FCA with respect to safe and reliable operations during and after the transition. Ensure that programs (including maintenance and modernization of hardware and software), personnel, infrastructure, and contractor services essential to safety are adequately funded.	
Aerospace Safety Advisory Panel (*NASA Charter)*	March 2003	**Finding 02-8:** The orbiter program is making progress in incorporating Engineering orders (EO) into engineering drawings.	**Recommendation 02-8:** Identify drawings that are critical to flight safety, update them to include all EOs, and keep them current.	
Aerospace Safety Advisory Panel (*NASA Charter)*	March 2003	**Finding 02-9:** Although progress is being made, there is no commitment to implementing crew escape capabilities for all regions of powered flight.	**Recommendation 02-9:** Complete the ongoing studies of crew escape design options. Either document the reasons for not implementing the NASA Program Guideline of Human Rating (currently in review) or expedite the deployment of such capabilities.	
Aerospace Safety Advisory Panel (*NASA Charter)*	March 2003	**Finding 02-10:** The Cockpit Avionics Upgrade (CAU) is making excellent progress toward meeting its objectives. The flight crews interviewed by the Panel were enthusiastic and unanimous in support of the effort. The Panel believes that Increment II must be completed in order to realize significant safety improvements in Shuttle operations.	**Recommendation 02-10:** Provide ongoing funding for the CAU through Increment II so that continuity between the two phases can be maintained.	
Aerospace Safety Advisory Panel (*NASA Charter)*	March 2003	**Finding 02-11:** The Cockpit Avionics Upgrade (CAU) project has not completed a credible hazard analysis. An orbiter hazard analysis including the CAU has not been planned.	**Recommendation 02-11:** Perform risk assessments and hazard analyses, both internal to the CAU and from the perspective of the entire orbiter, to confirm that there are no input error conditions that could result in flight crew actions	

Independent Assessment Team *(Chartered by)*	Date of Report	Finding	Recommendation	NASA Response
			detrimental to crew, mission, or vehicle safety.	
Aerospace Safety Advisory Panel (*NASA Charter)*	March 2003	**Finding 02-12:** Certain failure conditions may lead to conflicting data across display panels [of the CAU].	**Recommendation 02-12:** Through analysis, assess the probability of conflicting data among display screens. Confirm through simulated flight experiments that flight crew are able to identify information conflicts, that they are able to ascertain correct parameters, and that they can correct these errors without undue impact to flight safety or operations.	
Aerospace Safety Advisory Panel (*NASA Charter)*	March 2003	**Finding 01-18:** Funding cuts threaten to eliminate all effort on maintaining and updating surveillance and modeling of the orbital debris population as early as October 2002. [Actually in the ISS section, but directly applicable to SSP.]	**Recommendation 01-18:** Reexamine the decision to eliminate this important function and assure that the core MMOD effort is continued.	**NASA Response: Concur 01-18:** OSF is seeking to identify all users/stakeholders of the current Orbital Debris Program and identify appropriate program content and long-term Agency funding source(s) to ensure that NASA retains the capability for compliance with the Agency's Orbital Debris Policy for NASA missions. **Panel Assessment: Recommendation 01-18 is continuing.** The content of the Orbital Debris Program was adjusted in response to the budget reduction without increasing the risk to NASA missions. The program is currently funded by the two major users of the output - Space Shuttle and ISS. However, continued program funding is not resolved in the upcoming FY 2004 conversion to FCA.

Independent Assessment Team *(Chartered by)*	**Date of Report**	**Finding**	**Recommendation**	**NASA Response**
Aerospace Safety Advisory Panel (*NASA Charter)*	March 2003	**Finding 01-6:** The safety of NASA's human space flight programs will always be dependent on the ability of a skilled, experienced, and motivated workforce.	**Recommendation 01-6:** Accelerate efforts to ensure the availability of critical skills and to utilize and capture the experience of the current workforce.	**Panel Assessment: Recommendation 01-6 is continuing.** This issue will require aggressive action for the foreseeable future.
Aerospace Safety Advisory Panel (*NASA Charter)*	March 2002	**Finding 1:** The current and proposed budgets are not sufficient to improve or even maintain the safety risk level of operating the Space Shuttle and ISS. Needed restorations and improvements cannot be accomplished under current budgets and spending priorities.	**Recommendation 1:** Make a comprehensive appraisal of the budget and spending needs for the Space Shuttle and ISS based on, at a minimum, retaining the current level of safety risk. This analysis should include a realistic assessment of workforce, flight systems, logistics, and infrastructure to safely support the Space Shuttle for the full operational life of the ISS.	**Response (from 2002 ASAP Appendix)**: Concur: Both Shuttle and ISS Program Operating Plans (POP) identify the total resource requirements necessary to retain and improve safety risk. The development of these plans involves assessments from all organizations and receives the highest level of NASA management review. NASA management maintains a safety first decision process and will continue to be vigilant in developing as much operating margin as possible. The Office of Space Flight has recently initiated an assessment to address Space Shuttle fleet capability to fly safely until 2020. This assessment includes an analysis of workforce critical skills, flight systems upgrades, logistics and supportability, and any infrastructure upgrades requirements necessary to meet this goal. Any comprehensive assessment to support ISS beyond 2020 would occur in the future.
Aerospace Safety Advisory Panel (*NASA Charter)*	March 2002	**Finding 2:** Some upgrades not only reduce risk but also ensure that NASA's human space flight vehicles have sufficient assets for their entire service lives.	**Recommendation 2a:** Make every attempt to retain upgrades that improve safety and reliability, and provide sufficient assets to sustain human space flight programs.	**Response (from 2002 ASAP Appendix)**: Concur 2a: NASA and its contractors have continued to maintain and improve on the excellent safety practices and processes and as such, safety has not been compromised. Comprehensive analyses have identified potential upgrades projects that can further reduce risk if fully funded.

Independent Assessment Team *(Chartered by)*	**Date of Report**	**Finding**	**Recommendation**	**NASA Response**
				Examples of needed long-term supportability upgrades that are not currently funded include the Orbiter's communication and tracking system, components of the Orbiter's data handling system, and the SRB avionics subsystem. Every attempt is being made to apply available resources to the more promising areas of improvement.
			Recommendation 2b: If upgrades are deferred or eliminated, analyze logistics needs for the entire projected life of the Space Shuttle and ISS, and adopt a realistic program for acquiring and supporting sufficient numbers of suitable components.	**Response (from 2002 ASAP Appendix)**: Concur 2b: Long-term supportability analysis continues on a periodic basis between Orbiter, Logistics, and SMA. Most recent orbiter/logistics summit updated the supportability issues list in November 2001. SSP hardware element managers and SSP logistics managers have implemented a continuing supportability assessment analysis which is intended to maintain cognizance of potential supportability issues and to develop mitigation actions.
Aerospace Safety Advisory Panel (*NASA Charter)*	March 2002	**Finding 3:** Much of the Space Shuttle ground infrastructure has deteriorated and will not be capable of supporting the Space Shuttle for its realistic service life.	**Recommendation 3:** Revitalize safety-critical infrastructure as expeditiously as possible.	**Response (from 2002 ASAP Appendix)**: Concur 3: Human space flight is greatly dependent upon a capable ground infrastructure. The ISS and SSP management have worked closely with Center Directors in identifying the facilities, GSE, training, and test equipment necessary to continue and improve human space flight. As funding becomes available, it is applied to those areas having the greatest risk benefit.
Aerospace Safety Advisory Panel (*NASA*	March 2002	**Finding 4:** NASA is considering closing or deactivating some training and test facilities in an effort to economize.	**Recommendation 4:** Perform a detailed full life cycle safety and needs analysis including consideration of critical skills retention before making closure	**Response (from 2002 ASAP Appendix)**: Concur 4:Any consideration for training or test facility closure will be based upon an appropriate

Independent Assessment Team *(Chartered by)*	**Date of Report**	**Finding**	**Recommendation**	**NASA Response**
Charter)			decisions.	risk assessment that considers their significance to the readiness level of the crews or the vehicle.
Aerospace Safety Advisory Panel (*NASA Charter)*	March 2002	**Finding 5:** Space Shuttle privatization can have safety implications as well as affecting costs.	**Recommendation 5:** Include in all privatization plans an assessment by safety professionals of the ability of the approach to retain a reasonable level of NASA technical involvement and independent checks and balances.	**Response (from 2002 ASAP Appendix)**: Concur 5:All privatization discussions to date have included direct participation by the NASA Headquarters, Center, and SSP Safety organizations. A fundamental ground rule of any privatization option is that it must include the proper checks and balances as well as healthy tension between design and operations and include a value added independent assessment process. Current plans include numerous independent reviews of privatization concepts that will be structured to include safety professionals.
Aerospace Safety Advisory Panel (*NASA Charter)*	March 2002	**Finding 6:** The safety of NASA's human space flight programs will always be dependent on the availability of a skilled, experienced, and motivated workforce.	**Recommendation 6:** Accelerate efforts to ensure the availability of critical skills and to utilize and capture the experience of the current workforce.	**Response (from 2002 ASAP Appendix)**: Concur 6: Capturing the experience of the current workforce by continuing to hire and train young engineers is vital to the long-term safety of the Space Shuttle Program (SSP). NASA, USA, and the State of Florida have developed the Aerospace Technician Certification program, which provides a 2-year curriculum (4-year program in development) towards a space quality standard. Similar certification programs are in work for other aspects of SSP work. A Mentoring Program, focused on further development of technical and managerial skills, is also in place. The Prime Contractors have various hiring, training, and mentoring programs to facilitate skill development

Independent Assessment Team *(Chartered by)*	**Date of Report**	**Finding**	**Recommendation**	**NASA Response**
				and retention. The International Space Station (ISS) is early in the operational phase and has sufficient NASA civil service personnel to assist in the training and mentoring of new Boeing engineers. Further documentation is readily available on key subsystems and some hardware is still being procured. This will also allow an opportunity for new Boeing engineers to learn ISS systems in detail. In summary, this is an excellent time in the ISS program history to transfer and train new personnel and set in place a lower sustaining cost structure.
Aerospace Safety Advisory Panel (*NASA Charter)*	March 2002	**Finding 7:** Mishaps involving NASA assets are typically classified only by the actual dollar losses or injury severity caused by the event.	**Recommendation 7:** Consider implementing a system in which all mishaps, regardless of actual loss or injury, are assessed by a standing panel of independent accident investigation specialists. The panel would have the authority to elevate the classification level of any mishap based on its potential for harm.	**Response (from 2002 ASAP Appendix)**: Concur 7:NASA NPD 8621.1G defines a mishap as any unplanned occurrence or event resulting from any NASA operation or NASA equipment anomaly. Current human space flight problem reporting systems require reporting and analysis of all operational or equipment anomalies against criteria that includes addressing the potential for significant loss of life or assets. At this level, the investigative experts are the engineers, managers, and maintainers of the equipment. If an actual mishap were to occur, the Mishap Investigation Team (MIT) would be the first response. All members of this team have had accident investigation training and the Chairman has completed the NTSB accident investigation school and USC Aviation

Independent Assessment Team *(Chartered by)*	**Date of Report**	**Finding**	**Recommendation**	**NASA Response**
				Safety curriculums.
Aerospace Safety Advisory Panel (*NASA Charter)*	March 2002	**Finding 8:** There is no requirement for Mishap Investigation Boards (MIB) to include individuals specifically trained in accident investigation and human factors.	**Recommendation 8:** Adopt a requirement for the inclusion of accident investigation and human factors expertise on MIBs.	**Response (from 2002 ASAP Appendix)**: Concur 8: NPD 8621.1G states that it is NASA's policy to conduct NASA mishap investigations, using NASA MIBs, with properly trained personnel. At the Space Shuttle Program level, this has been implemented through the assignment of the Mishap Investigation Team. All members of this team have had accident investigation training and the Chairman has completed the NTSB accident investigation school and USC Aviation Safety curriculums.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 2002	**Finding 9:** The first increment of the Cockpit Avionics Upgrade (CAU) has significant potential for long-term Space Shuttle risk reduction and provides a platform for still further improvements.	**Recommendation 9:** Maintain the previously planned funding to expeditiously implement the CAU.	**Response (from 2002 ASAP Appendix)**: Concur 9: CAU is currently adequately funded and authorized through PDR. Due to budget pressures NASA has reduced CAU funding to include only CAU Increment 1, which does provide key safety improvements. Increment 2 will be implemented on a deferred schedule using available sustaining engineering resources.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 2002	**Finding 10:** Orbiter wiring inspections have shown instances where redundant wiring is carried in the same wire bundle.	**Recommendation 10:** Expedite efforts to route redundant wires in separate wire runs.	**Response (from 2002 ASAP Appendix)**: Concur 10: Orbiter project is currently expediting the separation of redundant wires. All that can be accomplished during a normal flow at KSC are being scheduled and those that cannot will be implemented during the vehicles next modification period.

Independent Assessment Team *(Chartered by)*	**Date of Report**	**Finding**	**Recommendation**	**NASA Response**
Aerospace Safety Advisory Panel *(NASA Charter)*	March 2002	**Finding 11:** Little definitive action has been taken to correct and preclude continuing the undesirable situation of excessive unincorporated EOs in the orbiter engineering drawings.	**Recommendation 11:** Expeditiously reduce the number of the drawing changes currently outstanding.	**Response (from 2002 ASAP Appendix)**: Concur 11: Orbiter project is currently working to reduce the number of outstanding drawing changes. The project is prioritizing the drawing updates based on criticality, complexity, and traffic. The highest priority tile drawings have been completed and other subsystems will follow.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 2002	**Finding 12:** Space Shuttle logistics will face increasing challenges from vendor issues including closures, mergers, relocations, and changes in capability.	**Recommendation 12:** Continue to emphasize to all suppliers the importance of timely reporting of all significant business and organizational changes that could affect Space Shuttle logistics.	**Response (from 2002 ASAP Appendix)**: Concur 12:The Space Shuttle Process Control Working Group has been instrumental in communicating to the contractors and suppliers the importance of change control and notification. The Logistics departments continue to interact with the suppliers on a daily basis and have had good success with suppliers providing notification of changes. Several supplier conferences have been held at the Project level to reinforce this message. On January 23–24,2002,the SSP held its first Program-wide supplier conference in which this theme was communicated and reinforced by top management.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 2002	**Finding 13:** Deferring the OMMs intensifies the risk that scheduled safety upgrades will never be completed, thereby further increasing the life cycle safety risk of operating the Space Shuttle.	**Recommendation 13:** Incorporate deferred safety-related modifications in the affected orbiters expeditiously. This should not be accomplished at the expense of other safety or operational upgrades, or the prudent maintenance of the Space Shuttle system and its infrastructure.	**Response (from 2002 ASAP Appendix)**: Concur 13: Orbiter project is currently incorporating a number of safety-related modifications and has placed priority on many proposed safety and risk reduction modifications.

Independent Assessment Team *(Chartered by)*	**Date of Report**	**Finding**	**Recommendation**	**NASA Response**
Aerospace Safety Advisory Panel *(NASA Charter)*	March 2002	**Finding 14:** It is reasonable to utilize the same engineering and technician workforce for routine Space Shuttle processing and OMDP work at KSC, since the work content is similar. Planning and management functions, however, differ significantly between line processing and heavy maintenance activities.	**Recommendation 14:** Designate separate, appropriately experienced management teams for the regular processing and OMDP work at KSC. These teams must be well coordinated, since they will be drawing on the same workforce.	**Response (from 2002 ASAP Appendix)**: Concur 14: The Orbiter Project has established an OMDP Management Plan, which designates a separate Orbiter management team for OMDP.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 2002	**Finding 18 [Space Station, but applicable to SSP]:** Funding cuts threaten to eliminate all effort on maintaining and updating surveillance and modeling of the orbital debris population as early as October 2002.	**Recommendation 18:** Reexamine the decision to eliminate this important function and assure that the core MMOD effort is continued.	**Response (from 2002 ASAP Appendix)**: Concur 18: Office of Space Flight is seeking to identify all users/stakeholders of the current Orbital Debris Program and identify appropriate program content and long term Agency funding source(s) to assure NASA retains capability for compliance with Agency Orbital Debris Policy for NASA missions.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 2002	**Finding 19:** The terrorist attacks on September 11 emphasized the need for increased security of all national assets, including NASA's computer systems. Since many of these systems safeguard the lives of astronauts and cosmonauts and the safety of valuable international assets, it is crucial that security vulnerabilities be fully understood and closely managed.	**Recommendation 19a:** Accelerate the schedule of penetration exercises to gain greater insights into computer security vulnerabilities; determine if further threat analysis should be conducted; review all vulnerabilities; and ensure that plans are adequately formulated to mitigate these vulnerabilities and that work is proceeding to prevent critical systems from being compromised.	**Response (from 2002 ASAP Appendix)**: Concur 19a: The Agency and Center IT security program is a risk-based management and acceptance process. The program continues to evolve to incorporate and facilitate tools and metrics for greater insight into security vulnerabilities. Currently the Centers perform quarterly vulnerability scans and metrics that are reported to the Agency. The vulnerabilities found are reviewed and worked through a defined process. Mission Critical systems external interfaces such as those of the JSC Mission Control Center with the JSC Institutional Network are included in these quarterly assessments. We

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				will continue to work to improve this process and capability as new technologies and tools become available.
			Recommendation 19b: Accelerate the schedule for the implementation of triple Data Encryption System (DES).	**Response (from 2002 ASAP Appendix)**: Concur 19b:The change to incorporate the triple DES has been negotiated with the contractor; a probabilistic risk assessment associated with losing S-band communications is being conducted prior to Program implementation.
NASA Office of Safety and Mission Assurance *(NASA Charter)*	31 October 2001	Under the sampling conditions (survey population, four orbiter in-flow, skill mix, staffing levels, experience level, etc.) and recognizing inherent sampling error and questionnaire limitations, the IAT finds that overall workplace induced stress does not appear to be a present safety concern. Based on the results of this assessment and the two previous assessments of USAGO workforce capability, the IAT reaffirms the previous finding that USAGO has established the capability to safely accomplish an evenly spaced flight rate of up to seven flights per year.	**Recommendation 1:** NASA KSC SSP management should commit to conducting independent workforce surveys on a periodic (e.g., semi-annual) basis. While the current survey represents only a snapshot in time it could serve as the starting point for periodic surveys that track workforce attitudes and perspectives regarding workplace satisfaction and safety. Future survey planning should consider sampling that includes all members of the workforce (including those individuals with zero WTD) as well as a wide range of questions addressing workplace factors that are recognized correlates to occupational safety and stress.	
NASA Office of Safety and Mission Assurance *(NASA Charter)*	31 October 2001	Skill-mix and training/certification imbalance imposes greater demands and stress on fully qualified (Level-1) workforce.	**Recommendation 5:** USAGO should continue to assess and manage skill mix/training issues to more effectively and safely meet workload demands. The IAT recommends that the NASA/USA refine and implement the Workforce Flexibility Model as a viable means to address skill mix,	

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			numbers, and training/certification imbalances.	
NASA Office of Safety and Mission Assurance *(NASA Charter)*	31 October 2001	Reported unsafe activities and/or conditions - a number of the individuals interviewed reported knowledge of unsafe activities or conditions in Space Shuttle ground operations.	**Recommendation 8:** NASA KSC SSP and USA management must redouble their efforts to improve workforce understanding and acceptance of Structured Surveillance as an important and necessary safety control process. The idea of structured surveillance as a means to maintain stable, capable, and controlled critical processes remains an excellent and essential concept for implementing checks and balances within the scope of a performance based contract.	
Aerospace Safety Advisory Panel *(NASA Charter)*	February 2001	**Finding 1:** The current planning horizon for the Space Shuttle does not afford opportunity for safety improvements that will be needed in the years beyond that horizon.	**Recommendation 1:** Extend the planning horizon to cover a Space Shuttle life that matches a realistic design, development, and flight qualification schedule for an alternative human-rated launch vehicle.	**NASA Response (Goldin, 24 May 2001):** Code M - Concur: It is prudent to assume that the Shuttle will continue to support human space flight well beyond the current planning date of 2012, probably at least until 2020. Industry and NASA studies indicate that there will not be a compelling case for funding, developing and certifying a Shuttle replacement system for human space flight until late in the next decade. Therefore, NASA is actively assessing further safety improvements, beyond the current suite of planned and funded upgrades, which may be implemented in the Shuttle within the next 5-7 years and which could significantly reduce the operational risk of the Shuttle for many years of continued operations.

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Aerospace Safety Advisory Panel *(NASA Charter)*	February 2001	**Finding 2:** There is no in-flight crew escape system for the Orbiter other than for abort below 20,000 feet during a controlled glide.	**Recommendation 2:** Complete the ongoing studies of crew escape design options and implement an improved system as soon as possible.	**NASA Response (Goldin, 24 May 2001):** Code M - Concur: The Space Shuttle Program (SSP) concurs with the recommendation and is investigating enhanced crew escape capability with the objective of making significant strides in reducing crew risk for vehicle failures, which result in the loss of the orbiter vehicle. A Crew Escape Study has been initiated to reexamine Space Shuttle crew escape options.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 2001	**Finding 3:** Redundant hydraulic lines for the three orbiter hydraulic systems are not adequately separated to preclude loss of all hydraulic power in the event of a single catastrophic failure of adjacent hardware.	**Recommendation 3:** Provide the same degree of separation of redundant critical hydraulic lines as is given to redundant critical electrical wiring.	**NASA Response (Goldin, 24 May 2001):** Code M - Concur: Orbiter hydraulic systems utilize and will continue to implement the same considerations and degree of redundant system separation as is given redundant critical electrical wiring. Primary consideration is system placement such that a single catastrophic failure environment does not exist. Emphasis is placed on precluding events that may propagate from one function to another. Hazards associated with arc tracking can propagate to another wire in close proximity and therefore have influenced electrical wiring physical separation requirements. Hydraulic line hazards such as leakage or rupture cannot propagate to an adjacent hydraulic line. Extensive Failure Modes and Effects Analysis I Critical Items List (FMWCIL) and Hazard Analyses of the Orbiter systems and operational environment have not identified any credible single failure modes which would result in the loss of hydraulic power. Neither system is protected against

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				extreme externally induced events such as those that DOD separation requirements address.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 2001	**Finding 4:** The ongoing effort to improve the work paper used at KSC by incorporating outstanding deviations and clarifying and simplifying the work instructions is proceeding well. Some lesser effort has been focused on improving the vehicle engineering drawings and reducing the engineering orders (EOs) they contain.	**Recommendation 4a:** Continue vigorous efforts to upgrade the work paper, even as the flight rate increases, in order to maintain the positive momentum that this worthwhile initiative has generated.	**NASA Response (Goldin, 24 May 2001):** Code M - Concur: Upgrading the paperwork continues to be a primary strategic initiative. The implementation of enhancements aimed at "work paper "Deviation" reduction continues to show positive results. The IPP (Intranet Provided Procedures) has enabled the technician to select and work paper that has been pre-approved by engineering, and other initiatives such as MAXIM0 are moving processing toward a more paperless work environment. All these initiatives combine to continue vigorous upgrade to the work paper quality while reducing the labor to achieve these gains.
			Recommendation 4b: Focus additional effort on updating vehicle engineering drawings with the objectives of incorporating as many EOs as possible and assuring the clarity of all information.	**NASA Response (Goldin, 24 May 2001):** Code M - Concur: Each SSP project has configuration control to minimize the number of EOs before engineering drawings are updated. Additional focus will be implemented on improving engineering drawings. For example, the tile drawings, which are complex high-use drawings, have been updated to incorporate their EOs and this process will be applied to other highly complex, high-use drawings on the vehicle. Additionally, the Space Shuttle Program is embarking upon a one-year pilot program to convert orbiter vehicle 2D drawings to 3D digital drawings which if

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				implemented would incorporate all of the outstanding EOs.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 2001	**Finding 5:** The KSC facilities, ground support equipment, and test and checkout gear to support Space Shuttle processing and launch operations continue to age. The status of the potential readiness of these essential assets has been projected, but there is no detailed, funded plan to ensure that this aging infrastructure can safely support the Space Shuttle for its likely operational life.	**Recommendation 5:** Develop a detailed plan and budget to maintain and upgrade the KSC assets that are essential to the safe operation of the Space Shuttle for its reasonably expected flight life so that an appropriate infrastructure life extension program can be implemented.	**NASA Response (Goldin, 24 May 2001):** Code M - Concur: Infrastructure support and upgrades requirements for the KSC facilities, ground support equipment, and test and checkout equipment arc well defined and are updated yearly The SSP initiated an Infrastructure Revitalization Team to develop a detailed plan to upgrade the infrastructure at all element sites, in addition to KSC, for identified life through at least 2012. Infrastructure remains a top program initiative and significant investment is needed. Since there were no new initiatives funded from the FY 02 budget process, other programs within Human Space Flight are being considered to support infrastructure requirements.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 2001	**Finding 11:** The critical skills challenge faced by NASA and its contractors in the Space Shuttle and ISS programs continues despite resumption of active recruiting of experienced and new employees.	**Recommendation 11:** Provide more effective incentives to retain employees with critical skills in such areas as Information Technology and Electrical/Electronic Engineering. Continue active recruiting of experienced and "fresh-out" employees, using appropriate incentives when necessary.	**NASA Response (Goldin, 24 May 2001):** Code M - Concur: Both NASA and its contractor management teams have recognized the challenges of competing for critical skills in today's work environment, and have begun focused development of organizational assessment programs with emphasis on skills maintenance. These programs are targeted to include multiple tools and approaches (such as pay incentives, cross training, mentoring, formal career development planning, etc) to maintain the appropriate balance of experienced skills as well as a continuous revitalization through the

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				steady introduction of recent graduates. NASA has established fresh out goals at OSF Centers, used recruitment or relocation (signing) bonuses when necessary to attract quality hires at all levels, and authorized the payment of more competitive salaries in critical skill areas.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 2001	**Finding 12:** NASA's recent hiring of inexperienced personnel, along with continuing shortages of experienced, highly-skilled workers, has produced the challenge of training and integrating employees into organizations that are highly pressured by the expanded Space Shuttle flight rates associated with the ISS. There is no systematic effort to capture the knowledge of experienced personnel before they leave. Stress levels within the workforce are a continuing concern.	**Recommendation 12a:** Provide active mentoring and other career development incentives to bring new employees to full productivity as rapidly as can be accomplished with safety remaining paramount. Expand resources and delivery methods available to Agency level training programs to enable greater participation at Center and program levels.	**NASA Response (Goldin, 24 May 2001):** Code M - Concur: NASA and its contractors have made significant enhancements in the employee training and development arena. NASA civil servants now have individual career development plans tailored to meet their specific needs, including both hands on experience and appropriate training and education. Significant emphasis has also been placed on employee development with an Agency wide Leadership Development Initiative, a more systematized mentoring program, and increased usage of computer based training. The need to monitor stress levels and provide coping strategies has received considerable attention in all organizations, with significant progress made in this area. NASA has also recognized the importance of capturing the corporate knowledge in our aging workforce and transferring it to the next generation. Code F - General Response: NASA concurs with the recommendation(s). NASA and its contractors have made significant enhancements in the employee training and

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				development arena. Several NASA Centers have implemented individual career development plans for their workforce, or for specific segments and occupational categories. These workplans enable management and employees to plan and implement formal training initiatives, career development assignments, and job rotations which enhance current and future performance. Many Centers have also examined their need for leadership development, and have implemented new training initiatives designed to address these needs and requirements. More systematized mentoring programs and increased usage of computerized training have been implemented within the Agency. The need to monitor stress levels and provide coping strategies has also received increased attention across the Agency, with significant progress being made in this area. Code F - 12a: NASA concurs with the recommendation. As a result of beginning to hire new employees and fresh-outs, the NASA Centers have instituted, or have begun to revitalize, various orientation and other training programs designed to assimilate new employees into the workforce and provide mentoring and career development guidance. Many programs also include the requirement for specific types of training (e.g., technical or administrative), and include both on-the-job and developmental experiences over a period of time. Components in many

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				Centers' training programs also provide for guidance to supervisors in designing a training plan or individual development plan, providing mentoring and coaching, and evaluating work products and progress. The goals of these programs are to aid in the smooth and effective integration of new employees into the Center and Agency workforce by: providing a continuing and accelerated learning process: providing employees a way of identifying with the Center by understanding its mission and values; providing interaction with more senior staff and leaders; and providing opportunities to develop relationships with peers. At the Agency level, efforts are being initiated to establish a network of experienced practitioners who can provide mentoring and access to expertise in project management. At the Agency level, resources have been requested to enable NASA to expand the delivery methods being utilized to develop the workforce. Specific emphasis will be placed on the development of e-learning alternatives that can be accessed at all locations and levels, and increasing the ability to expand participation levels across the Agency. In addition, new capabilities are being developed to facilitate learning within intact teams, delivering tailored content directly to a project team at the point in time specific training is needed. In addition, some Centers have also increased their resources

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				available for training, and are instituting Center specific initiatives based upon Center needs. In addition, learning organization tools and methods being introduced in pilot projects within NASA are increasing organizational understanding, motivation, buy-in, and results. Examples of new initiatives include web-based course delivery and partnerships with universities for academic training.
			Recommendation 12b: Continue efforts, in partnership with NASA contractors, where appropriate, to provide hands-on experience.	**NASA Response (Goldin, 24 May 2001):** Code F - 12b: NASA concurs with the recommendation, and a primary emphasis in developing the workforce will continue to be reliance on valuable on-the-job experience. In addition, the NASA Academy of Program and Project Leadership is in the process or revising its career model to enable an expansion of the identification of experiential development. NASA's Professional Development Program also provides a combination of formal training, briefings, and developmental assignments within and outside the Agency.
			Recommendation 12c: Establish processes that capture the knowledge of experienced personnel before they leave or retire.	**NASA Response (Goldin, 24 May 2001):** Code F - 12c: NASA concurs with the recommendation. Several efforts are underway to more effectively capture the "lessons learned from experienced personnel nearing or at retirement. In addition, the NASA Academy of Program and Project Leadership has initiated a series of "Knowledge Sharing forums and has initiated an area on its website for

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				knowledge sharing and lessons learned. An emphasis is being placed on making maximum use and sharing of the experience of employees and managers both while they are still at NASA and after their retirement. Various avenues are being explored for access to this expertise both within NASA and gaining access to the knowledge base of those who leave the Agency. With regard to sharing knowledge within the Agency, NASA has also revised its Fellowship program to include a planned reentry requirement. The reentry plan requires individuals returning from longer-term University programs to identify with their management how their new learning will be shared within the Agency and how it will be applied strategically.
			Recommendation 12e: Implement an evaluation of the processes used to develop new hires into productive members of the workforce.	**NASA Response (Goldin, 24 May 2001):** Code F - 12e: NASA concurs with the recommendation. Centers will be evaluating systems and processes for developing their new hires, assimilating them into the workforce and sharing best practices.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 2001	**Finding 13:** Recent downsizing and limitations on hiring have produced a workforce with aberrations in normal career development patterns and a potential future shortage of experienced leadership.	**Recommendation 13:** Develop and implement a long-term workforce plan, focused on retention, recruitment, training, succession, and career development needs, with at least a five-year time horizon that will ensure the availability of competent and experienced leaders. Also provide a strengthened capability in organizational development.	**NASA Response (Goldin, 24 May 2001):** Code F - Concur: NASA concurs with the recommendation. The recent experience with downsizing, coupled with Agency concerns about and aging workforce, demonstrate the importance of long-term human resources planning. In 1998, under the auspices of the Chief Engineer's Office, the Agency conducted a core capability assessment that focused on the physical and staffing needs of the

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				Enterprises and Centers of Excellence. This, and other similar activities, while very helpful, resulted in tactically-oriented decisions related to solving near-term human resource issues. The Agency is now embarking on a follow-on strategic resource planning activity, based on Centers' future vision and mission, taking into account workforce and facilities needed. This activity, led by the Associate Deputy Administrator, involves the active participation of the Enterprises and Centers and support from the Office of the Chief Financial Officer, the Office of Human Resources and Education, and the Office of the Chief Engineer. The result will provide a plan for each Center that links staffing, funding resources, mission and activities, and core competencies and will enable them to focus on recruitment, retention, training, succession and career development tailored to their individual circumstances. Once this activity has been completed, the Office of Human Resources and Education will continue to work with the Center Human Resources Directors to assess the impacts of demographic trends. Together the Human Resources community will develop plans that ensure that the Agency has the requisite staffing, training, career development, and recruiting and retention tools and programs necessary to support

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				the Agency mission. In addition, the Office of Human Resources and Education has been actively engaged, with input and support from the Enterprises and Centers, in a number of activities and initiatives to renew and revitalize the NASA workforce. These range from activities to recruit, retain, and continue development of a highly capable workforce today to endeavors to ensure a future source of highly qualified talent in the science, math, and technology disciplines needed to carry out the Agency mission over the long term. With respect to recruitment, the Agency is committed to marketing NASA as an "employer of choice." In order to be competitive with other employers, NASA recognizes that it must have a continuing presence on college and university campuses. The more than 140 on-cam pus recruitment trips scheduled for this coming fall and spring 2002 are typical of this presence. In addition, the Agency will continue to utilize the Presidential Management Intern Program and student employment programs as sources for entry-level hires. NASA will also continue to promote the Internet as a recruitment tool and to work collaboratively with professional organizations (i.e., National Association of Colleges and Employers and National Academy of Public Administration) in an effort to

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				remain competitive. Our NASA Centers utilize various hiring authorities that enable them to offer starting salaries above the minimum rate of a grade. The use of recruitment bonuses by the Centers to attract the "best and the brightest" has also increased significantly in the recent past. The number has increased more than 300% from FY 1999 to FY 2000 (from 20 in FY 1999 to 69 in FY 2000 and 14 in just the first quarter of FY 2001) - a trend that we fully expect to continue because of an increasingly competitive job market and high cost of living surrounding some of our Centers. In addition to these ongoing efforts, NASA will continue to be innovative in it recruitment efforts. We are implementing new automation tools, i.e., a position description management software package and two staffing software packages to improve the effectiveness and timeliness of the hiring process. We are enhancing the Agency's human resources websites to make them more responsive to applicant information needs. Further, we are developing new qualification requirements for cooperative education students in order to more effectively recruit. Additional non-permanent employment options are being pursued where they are practical and the Agency is working with the Office of Management and Budget (OMB) and the Office of Personnel

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				Management (OPM) to facilitate new employment options. The Agency has a new five-year plan for the employment of people with disabilities and will develop other outreach efforts designed to maintain a diverse workforce. A new National Recruitment Team, based at Headquarters, is currently being established to develop new Agency-wide recruitment strategies and tools to meet NASA's current and future hiring challenges in attracting and retaining a world-class, highly technical and diverse workforce. This team will facilitate and complement the Centers' recruitment efforts; collaborate with the Institutional Program Offices and Functional Offices; enhance relationships with universities; eliminate duplication of efforts; and facilitate targeted diversity and disability recruiting. The retention of a highly skilled workforce is equally vital. While the use of retention allowances has more than doubled from 5 in FY 1999 to 12 in FY 2000 (and 7 in the first quarter of FY 2001), this rate of usage has been impacted by downsizing and restructuring efforts in recent years and the continuing need to offer targeted buyouts to deal with our skills imbalances. NASA will continue to assess the skills of its workforce and restructure as necessary through buyout and early out retirement incentives to assure that NASA has the necessary

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				skills for present and future mission success. In addition, we continue to emphasize quality of work-life initiatives such as alternative work schedules, family friendly leave programs, part-time employment and job sharing, telecommuting, dependent day car and employee assistance programs. Promoting safety in the workplace, providing effective awards, recognition and stimulating work will enhance job satisfaction and foster retention. In the arena of developing competent and experienced leaders, in the last 18 months NASA conducted a leadership study and created a model to align development of our leaders to the NASA Strategic Plan and Strategic Management System. The study included benchmarking, working with universities, and the results of interviews of over 500 NASA/JPL employees performing in leadership roles from team lead to executive senior leader. This model provides a roadmap of skills and competencies for effective NASA leadership and is being used to respond to the training and developmental needs of the workforce. As part of NASA's strategy to prepare our next generation of leaders, there are several long-term developmental processes in place at both the Center and Agency level. These include the Senior Executive Service Candidate Development Program, the Professional Development Program, partnerships with

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				academia to provide fellowships in leadership and project management development, and Center-specific development programs. In addition, the curriculum for developing project management leaders is being reviewed to ensure that appropriate skills and competencies are developed. In the area of organization development, one of the features, which will be enabled by an increase in training resources, is the ability to provide intact team support. By providing developmental intervention to teams, NASA will be able to contribute to improved performance of teams, as well as better prepare individual team members for future opportunities. NASA is also engaged in a strategy to develop employees in the theories, methods and tools of learning organizations. Pilots are showing that these skills enhance motivation, communication, and understanding of complex systems. Several Centers have also increased their organizational development resources and capacity and are offering facilitation services to their organizations. The Agency is also looking at ways to help assure a future pipeline of talent from which the NASA and others can draw. FY 2001 marks the pilot year of the new NASA Undergraduate Student Research Program. This Agency-wide program was developed to extend and strengthen NASA's

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				commitment to educational excellence and university research, and to highlight the critical need to increase the Nation's undergraduate and graduate science, engineering, mathematics, and technology skill base. The Undergraduate Student Research Program will also build a national program bridge from existing NASA K12 Education Program activities **to** NASA Higher Education Program options that encourages and facilitates student interest in future professional opportunities with NASA and its partner organizations. Such opportunities might include NASA career employment: temporary assignment: undergraduate and graduate co-op appointment; or contractor positions.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 2001	**Finding 14:** While NASA has made major changes to emphasize the need to utilize IV&V on safety critical projects, the technology is not well understood by program managers and other relevant NASA personnel.	**Recommendation 14:** Develop an appropriate user-centered course and require software assurance awareness training for all levels of management to help them become more cognizant of the IV&V processes and the value IV&V brings to a final product.	**NASA Response (Goldin, 24 May 2001):** Code AE - Concur: As the report points out, NASA has indeed made major changes to emphasize the need for IV&V on mission critical software. The software IV&V policy, criteria, and process for evaluation of projects is in place and being followed. The Office of the Chief Engineer has presented pertinent information to all Center Directors, emphasizing the importance of IV&V, and communicating the expectation that IV&V and the IV&V policy be incorporated in Center processes. The Goddard Space Flight Center has been making presentations about the policy, criteria, and process in greater detail to other levels of management including program and project managers whose projects meet the criteria for IV&V or

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				independent assessment by the IV&V facility. In addition, the Office of Human Resources and Development is planning the update of existing training in Verification and Validation, and Test and Evaluation to include IV&V and the appropriate application of the same.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000	**Issue 1:** NASA must support the SSP with the resources and staffing necessary to prevent the erosion of flight-safety critical processes.		**SSP Response (Abbey/Dittemore, 21 June 2000):** The Office of Space Flight (OSF) has recently conducted workforce reviews of staff workload and skill deficiencies at its Centers and programs, with particular emphasis on the SSP. Findings of these reviews, coupled with those of external groups such as the SIAT and the Aerospace Safety Advisory Panel (ASAP), led to the decision to terminate downsizing. All four OSF Centers, JSC, KSC, MSFC, and SSC, are in the midst of large-scale efforts to replace skill losses and increase the number of entry-level professionals. NASA has a plan in place to hire over 500 new employees in fiscal year 2000. Although only a portion of these new employees will be dedicated to the SSP, this action will help fill some of the most critical skill shortages, enable us to stabilize our flight safety skills resources, and build our cadre of future leaders. It is imperative that sufficient resources, including new hires, be dedicated in support of the SSP. Beginning in fiscal year 2001, the plan is to replace future losses on a one-for-one basis.

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				In addition, the recruiting strategy is to emphasize the identification of critical skill shortages and make those the top hiring priorities. The goal is to hire 50 to 70 percent of new personnel at the entry level in an effort to revitalize the workforce with high-caliber, recent graduates. To allow some of the best junior- and mid-level personnel the opportunity to broaden their functional experience, the SSP has created rotational opportunities at several Centers where they can gain experience at the program level. This early exposure to the significant operational and programmatic management challenges will enable them to enhance the flight safety critical process skills in the near term, and will better equip them to serve in leadership roles in the future.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000	**Issue 2:** The past success of the Space Shuttle program does not preclude the existence of problems in processes and procedures that could be significantly improved.		**SSP Response (Abbey/Dittemore, 21 June 2000):** The SIAT noted, "the SSP must rigorously guard against the tendency to accept risk solely because of prior success." The SSP wholeheartedly agrees. Regular senior management meetings are conducted that specifically address the issue of complacency and the inherent risk to the SSP relative to process and procedure change. A specific focus on process control has been established to increase the awareness throughout the SSP on changes that could increase the level of risk. A Process Control Implementation Plan, developed in cooperation with each of the major prime

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				contractors for the SSP, has been established that addresses the issue of process control at all levels of the NASA, contractor, vendor, and supplier product chain. A process control video has been developed for wide distribution throughout NASA and the contractor/vendor/supplier community to emphasize the importance of process control and to significantly increase the awareness of management and the workforce. Additionally, the SSP conducted a Program Manager's Review (PMR) in March 2000 where risk management was the sole topic. SSP senior management (NASA and contractors) participated and reviewed the risk management procedures that are utilized by each of the prime contractors. Emphasis was placed on the need for improvement and continued adherence to sound risk management principles. The SSP recognizes the critical importance of maintaining the rigor in planning, analyses, test, and execution that has been the strength of NASA and the space program. A continual emphasis on the SSP's primary goal, to fly safely, will be maintained to strengthen and increase the awareness of the management team and the workforce.
Space Shuttle Independent Assessment Team	7 March 2000	**Issue 3:** The SSP's risk management strategy and methods must be commensurate with the "one strike and you are out" environment of		**SSP Response (Abbey/Dittemore, 21 June 2000):** The foremost priority of the SSP is safety. This priority has extended to all aspects of the program with

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(NASA Charter)		Space Shuttle operations.		emphasis on public, crew, workforce, and asset protection. The program has accepted added cost and provided schedule relief in numerous situations in order to reduce safety risks. Emphasis on safety as the top priority has been implemented across all program elements, prime contractors, subcontractors, and suppliers. The SSP implements extensive risk management processes as documented in National Space Transportation System (NSTS) 07700. As a result of the SIAT, a section of NSTS 07700 will be dedicated to documenting the program's risk management plan (refer to response to SIAT recommendation #19). The SSP is a strong supporter of independent review processes such as the ASAP and considers knowledgeable review to be invaluable. The program has chartered several independent reviews utilizing technology expert representation. All findings and recommendations are reviewed and dispositioned by the SSP or appropriate organization. The SSP has taken many steps to ensure an appropriate risk management strategy, and will continue to strive for improving these processes (refer to response to SIAT recommendation #22). While the current risk management processes provide a focus for the program to succeed in safe and successful missions, the continuous recognition of and sensitivity to the unforgiving

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				environment of the Space Shuttle operational profile must always accompany even these disciplined processes.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000	**Issue 4:** SSP maintenance and operations must recognize that the Shuttle is not an "operational" vehicle in the usual meaning of the term.		**SSP Response (Abbey/Dittemore, 21 June 2000):** Safety is the number one priority of the SSP and is regularly reinforced throughout the workforce. Additionally, there is an emphasis on continual improvement of the Space Shuttle system; improvement in safety, improvement in efficiency, improvement in processes, etc. Ample evidence exists that demonstrate the SSP's commitment to safety as its highest priority goal (i.e., fleet standdown due to vehicle wiring issues, launch delays to allow time to understand and resolve technical issues, etc.). Safety "first" is a culture that exists throughout the SSP. The SSP agrees that the Space Shuttle is not a typical "operational" vehicle. As evident in the responses to the SIAT recommendations in this document, the SSP realizes the importance of maintaining rigor and conservatism in vehicle maintenance and operations. Refer to responses to SIAT Issue 2, Issue 5, and category 2 recommendations #3, 4, 5, 6, 10, 15, 26, 28, 32, 35, and 38 for additional detail on the conservatism and checks and balances in place for maintenance and operations procedures. These procedures are periodically reviewed. In addition, comprehensive

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				reexamination of maintenance procedures is in work as a result of the SIAT. Because of the nature of vehicle processing that does from flight to flight, it is reasonable to allow a certain level of standard repairs and "fair wear and tear" repair activities to exist. Standard repair, "fair wear and tear" specifications, and preapproved problem dispositions are used only for recurring conditions where the risks are well understood and acceptable. The "fair wear and tear" specification is a released engineering document that addresses cosmetic damage to hardware and allows the reflight of hardware with such damage under specified conditions, approved by engineering. Standard repairs are preapproved by the Program Material Review Board (PMRB) as delegated by the SSP Manager. The PMRB clearly defines the criteria that govern the use of such repair procedures. Adequate training on the use of these procedures and specifications is provided to the workforce.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000	**Issue 5:** The SSP should adhere to a "fly what you test/test what you fly" methodology.		**SSP Response (Abbey/Dittemore, 21 June 2000):** The SSP adopted a "fly what you test, test what you fly" verification methodology at the program's inception as the best approach for ensuring safe and successful operations. However, the extreme and complex environments coupled with their synergistic effects, which are experienced by a reusable spacecraft, did not allow for full-scale

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				vehicle or component testing to their operational limits. Therefore, the SSP baselined requirements for certification and verification by test and/or analysis, which are documented in the SSP Master Verification Plan (MVP), NSTS-07700-10-MVP01. The Space Shuttle used flight and ground test data to verify models and analytically predict performance at operational boundaries. For testing, either actual or representative flight hardware components were tested under the most realistic operational conditions achievable. Software was also thoroughly tested in avionics laboratories that contained equivalent or simulators of real flight computers and flight control hardware. Prior to first launch, a rigorous verification process was conducted by the program to assure that the flight vehicle, its components, and the associated or analytical were properly or analyzed simulation models tested to all the defined requirements. The program continues to use this same verification process for any significant redesign. The SSP originally implemented and continues to use a configuration control process that assures that flight hardware, software, and associated models remain consistent with this test-verified certification. Postflight data acquisition, data review, correlation with analytical simulations, and postflight inspections/systems testing of the hardware help to ensure that the systems maintain this test-verified

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				certification. The SSP used available ground and flight test data to characterize the Space Shuttle system performance and to certify the Space Shuttle for flight. Systems dispersions/uncertainties are used in designing the flight and the commit-to-flight processes to ensure safe margins during all flight phases. This preflight and postflight information is reviewed today prior to each Space Shuttle flight. It is natural that hardware and software changes have taken place in the 20 years since the original Space Shuttle certification. These can be classified as planned and unplanned changes. Planned changes are proposed, developed, and accomplished by the SSP to improve Space Shuttle safety, performance, or to account for obsolescence. Space Shuttle Main Engine (SSME) Block II, blanket thermal protection system (TPS), super-light-weight external tank (ET), and software operational increments (OI) upgrades are examples of planned Space Shuttle changes. Typically these types of changes go through the same rigorous testing, verification, and certification processes that the original Space Shuttle hardware went through during its development. Unplanned changes are primarily due to manufacturing defects of new or replaced parts or insufficient performance or failure of existing hardware.

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				These types of changes are typically very minor, and engineering judgments, supported by analyses, are made as to the extent of the required testing, reverification, and recertification requirements. All available information is used in this decision process for the safety of the Space Shuttle and its crew.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000	**Issue 6:** The SSP should systematically evaluate and eliminate all potential human single point failures,		**SSP Response (Abbey/Dittemore, 21 June 2000):** Operation of the Space Shuttle involves an extensive dependency on managers, engineers, technicians, operators, and crew personnel to perform their jobs in an efficient and accurate fashion. Various performance integrity techniques are employed to provide for assurance in executing these activities. The SSP utilizes a high degree of documented procedures and processes which are configuration controlled by the various program and project elements. These requirements flow down into specific maintenance and inspection criteria and are the basis for technician certification requirements and processes. Quality assurance techniques such as inspection, witness, surveys, and audits provide additional checks of performance accuracy. The SSP has had an extensive effort focused on increasing workforce awareness of process control, stamp warranty, and technician certification. In general, the focus has been to drive out the root cause of human error versus reliance on inspection programs. Forums such as the

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				Incident Error Review Board conduct analysis on maintenance issues and utilize various human factor analysis techniques to drive out contributing factors of human error. The establishment of the Process Control Forum, Chief Engineer Council, and the establishment of the SSP industrial engineering initiative have all been structured to provide for systematic evaluation and elimination of all barriers to error-free performance. Management review processes such as the Preventive/Corrective Action Review (PCAR) have been implemented to provide systematic review and evaluation of performance indicators in a proactive approach. A Government Mandatory Inspection Point (GMIP) represents a point in the flow process in which the work stops and a Government representative performs an observation or measurement. Often, a series of GMIPs were executed in a single flow process and ultimately led to a final checkout or inspection that verified system performance. In many cases, these intermediate inspections were redundant. This drove the program elements to reconsider the assignment of GMIPs and led to the formation of a specific analysis process to use in the evaluation of GMIPs. The SSP established criteria against which existing GMIPs would be reviewed and redundant GMIPs removed. The resultant reduction of GMIPs was based upon

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				technical justification utilizing established criteria. Extensive reviews of inspection requirements have been conducted over the years, and the SSP continues to utilize lessons learned to evaluate inspection requirements.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000	**Issue 7:** The SSP should work to minimize the turbulence in the work environment and its effect on the workforce.		**SSP Response (Abbey/Dittemore, 21 June 2000):** The workforce study conducted by SIAT members at KSC was confined to a small sample of workers. Although the survey raised legitimate concerns, the results of the study, particularly the magnitude of the concerns, may not necessarily be representative of the workforce in general. The issues raised by the study were known by NASA, United Space Alliance (USA), and the ASAP, who collectively believe that morale and focus have improved since the impact of the 1998 reduction in force. Nevertheless, NASA and USA took the SIAT concerns seriously, and USA initiated several actions to better understand the status of workforce morale and focus to correct open issues and improve morale and workforce focus. These actions included: • USA increased the number of face-to-face "skip level" meetings wherein senior managers meet with employees two or more levels below them in the chain of command to get direct input on issues of concern. These

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				meetings are held by the Space Flight Operations Contract (SFOC) Program Manager, the Associate and Deputy Associate Program Manager (APM) of Ground Operations (GO), and by the direct reports to the APM of GO. • USA commissioned Lord & Hogan, an independent consulting firm with experience in conducting workforce analysis, to administer an operational stress inventory and analysis. Lord & Hogan contacted the SIATto ensure the research instrument used would be endorsed by SIAT. The Lord & Hogan study included worker response to questionnaires, analysis of the responses, and follow-up focus group meetings to gain additional insight into concerns and issues. • USA established a management team to review the inputs from the "skip level" meetings and the Lord & Hogan survey. This team has recommended specific actions to resolve issues. USA management will follow through with a corrective action plan that implements the recommendations. • USA strengthened their communication

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				process with the establishment of a formal Leadership Council communication process. This council identifies information that should be communicated to the workforce, standardizes the messages, provides talking papers to managers, and flows the information through appropriate channels to ensure both "need to know" and "nice to know" information is provided to the workforce. The council has a feedback loop to measure the effectiveness of communication; thereby, continually improving the process. The issues raised by the SIAT study also were raised in the "skip level" meetings and in the Lord & Hogan survey. The results of the Lord & Hogan survey were very positive and showed that the USA employees in Florida were in the normal range compared to other companies in all categories of stress and coping behaviors. USA currently is conducting a similar study of its workforce in Texas and intends to conduct follow-on studies in both Florida and Texas in approximately 2 years as a comparison to the new baseline. The Space Shuttle launch schedule is expected to

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				increase to seven flights per year in 2001 and beyond. It is imperative that the SSP have the capability to safely meet that schedule. To assure that the program will continue to safely meet the manifest, USA is taking steps to improve the capability of the workforce in Florida. Actions include: • Hiring additional workers in GO and logistics to provide a workforce that is equivalent to the workforce that safely processed, launched, and recovered eight flights in 1997. This change from the continuous pressure to downsize since 1992 should have obvious positive morale effects. • Changing the Florida organization to align with processes in order to conduct work more efficiently and reduce the total workload. Initially, implementation of this "high performance organization" activity could induce stress, as does most change. The reorganization requires continuous communication and leadership from the initial stages throughout implementation of this reorganization to ensure the workforce remains focused on safely processing, launching, and recovering Space Shuttles. Although not specifically

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				mentioned as part of this issue, the morale and focus of Boeing's Palmdale workforce is an ongoing concern for NASA, USA, and Boeing. This concern comes mostly because the orbiter maintenance down (OMDP) periods are spaced with several months between the end of one and the beginning of another. The spacing leaves Boeing's Palmdale workforce with periods of very little Space Shuttle related work. This has caused and will continue to cause periodic reductions-in-force and rehiring. Boeing has taken several actions to mitigate the effects of this periodic work including: • Initiatives to increase Palmdale's non-SFOC work to provide additional opportunities for the workers. • Improvements in Boeing's Palmdale facilities to enhance work spaces, including better lighting, new equipment, refurbished work spaces, and adding a cafeteria. NASA and USA are extremely sensitive to workforce issues and are taking positive steps to ensure improvement. Continual monitoring of the workforce morale and focus is an SSP and USA priority.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000	**Issue 8:** The size and complexity of the shuttle system and the NASA/contractor relationships place extreme importance on understanding, communication, and		**SSP Response (Abbey/Dittemore, 21 June 2000):** The SIAT identified a number of recommendations relative to communication and information handling that are being addressed by the SSP as part of the SIAT response

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		information handling.		activity. The SSP continually emphasizes the importance of communication and has established processes, systems, and forums that facilitate information transfer and open discussion of issues and concerns. Weaknesses identified by the SIAT will be addressed.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000	**Issue 9:** Due to the limitations in time and resources, the SIAT could not investigate some Space Shuttle systems and / or processes in depth.		**SSP Response (Abbey/Dittemore, 21 June 2000):** The SSP considers the work associated with knowledgeable independent review processes to be invaluable to the continued success of the SSP. Relative to the SIAT, all SSP elements have thoroughly reviewed the SIAT report and have conducted internal reviews based upon the reported observations. A special PRCB was held to discuss implementation plans in response to the SIAT recommendations. The PRCB included all SSP elements to ensure maximum participation and dissemination of the information. Specific action items, as discussed in this report, were assigned to the SSP or SSP elements, as appropriate. In addition to the SLAT, USA has formed an independent team comprised of Lockheed, NASA, Boeing, and independent safety and human factors experts to review the maintenance practices related to orbiter processing. Additional reviews to examine other SSP elements will be considered. The SSP has been a strong promoter of independent review processes and has

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				financially supported and participated in numerous reviews. Numerous review processes, which are independent of the SSP, exist today. These include, but are not limited to, the ASAP, NASA Inspector General (IG), Government Accounting Office (GAO), National Research Council (NRC), Program Management Council (PMC), Center Systems Management Offices, and the (Headquarters/Code Q) Independent Assessment Office. In addition to these, NASA Headquarters, NASA Centers, and the SSP have chartered independent reviews on occasion to investigate specific topics or issues.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 1-1.** The reliability of the wire visual inspection process should be quantified (success rate in locating wiring defects maybe below 70% under ideal conditions).	**SSP Response (Abbey/Dittemore, 21 June 2000):** Initial qualitative assessments indicated approximately 70-80 percent of the wire defects are found during the first inspection. The remaining 30-20 percent of defects are found during the second inspection. Subsequent to the STS-103 pre-FRR, quantitative analysis at Palmdale indicates 86 percent of the defects are found during the first inspection with the remaining 14 percent found during the second inspection.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 1-2:** Wiring in OV-102 at Palmdale should be inspected for wiring damage in difficult-to-inspect regions. If any of the wires checked are determined to be especially vulnerable, they should be rerouted, protected, or replaced.	**SSP Response (Abbey/Dittemore, 21 June 2000):** Stringent inspection criteria were established to determine which vehicle areas must be inspected prior to flight of that vehicle. These criteria were approved at the STS-103 pre-FRR. In addition, an end-to-end wiring inspection of OV-102

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				at Palmdale is underway. These inspections include difficult-to-inspect regions. Wiring which is vulnerable to damage will be reported to the Space Shuttle Vehicle Engineering Office (SSVEO) to determine whether rerouting, additional protection, or replacement of the wiring is appropriate. To date, the OV-102 detailed wiring inspections have not identified any conditions which invalidate our basic inspection criteria for the other vehicles in the fleet.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 1-3:** The 76 CRIT 1 areas should be reviewed to determine the risk of failure and ability to separate systems when considering wiring, connectors, electrical panels, and other electrical nexus points. Each area that violates system redundancy should require a program waiver that outlines risk and an approach for eliminating the condition. The analysis should assume arc propagation can occur and compromise the integrity of all affected circuits. Another concern is that over 20% of this wiring can not be inspected due to limited access; these violation areas should as a minimum, be inspected during heavy maintenance and ideally be corrected.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The same stringent inspection criteria were used to determine whether inspections of these 76 areas were appropriate prior to flight. Fifty-eight of the seventy-six areas were inspected on OV-103 prior to flight, based on these criteria. The 18 remaining areas were not inspected because the risk of damage during the inspection was greater than the benefit. The 18 remaining areas were inspected on OV-102 at Palmdale prior to the flight of OV-103. These inspections found no exposed conductor and no Kapton damage. In addition, all of the Palmdale inspections completed prior to STS-103 confirmed that the KSC inspection criteria were valid. The SSVEO presented a plan addressing the criticality 1 circuits located in the 76 criticality 1 areas to the PRCB on May 18, 2000. Preliminary estimates indicate approximately 80 percent of the waivered conditions can

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				be modified to separate system wiring. These modifications are planned to be implemented at the KSC during flow processing operations or during the vehicle orbiter major modifications, whichever is most appropriate. The remaining 20 percent can not be modified due to space limitations. These conditions will continue to be waived.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 1-4:** The Space Shuttle Program should review all waivers or deferred maintenance to verify that no compromise to safety or mission assurance has occurred.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The SSP completed an extensive review of open waivers in January 2000. Waivers to SSP critical documents were reviewed to determine the quantity and quality of the waivers and the health of the waiver process. Currency of waiver rationale, technical validity, and potential for a requirement change were reviewed. The review concluded that although the waiver process is healthy, a periodic review of the waiver data base is appropriate.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-1:** NASA should expand existing data exchange and teaming efforts with other governmental agencies, especially concerning age effects.	**SSP Response (Abbey/Dittemore, 21 June 2000):** Several initiatives to expand data exchange and teaming efforts with the Federal Aviation Administration (FAA) and Department of Defense (DOD) are currently underway. The SSP has initiated conversations and planning with the Department of Navy and Wright-Patterson Air Force Base to take advantage of initiatives already in place and to coordinate a list of working groups and forums involving multiple Government aerospace agencies. The SSP

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				will participate in these forums and identify SSP points of contact. The SSP will document assignments and involvement in these forums and identify an appropriate SSP forum for reporting and dissemination of information obtained from the working interfaces. To address recommendation 31, the SSP will specifically identify wiring related working groups and establish the appropriate level of participation. The Manager, SSP Safety and Mission Assurance (SMA) has been appointed as the NASA representative to the Wire Safety Research Interagency Working Group chartered by the Office of Science and Technology Policy. In addition, the SSP established contact in mid-March with the chairman of the Aircraft Wiring and Inert Gas Generator (AWIGG) Working Group and established communications with the team. Membership rosters were exchanged and both the SSVEO and USA sent representatives to the May 15-19, 2000, meeting to further establish points of contact and exchange information. Formal membership and identification of specific SSP representatives will be documented.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-2:** A formal Aging and Surveillance Program should be instituted.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The SSP currently has a strong System Integrity Assurance Program (SIAP), which includes consideration of all possible failure mechanisms including the

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				effects of aging, maintenance, or exposure. The SIAP requirements of NSTS 07700, Volume XI, were reviewed to ensure that current requirements are structured to incorporate effects of aging and handling on system integrity. The SIAP addresses requirements and responsibilities to ensure that the flight and critical ground systems retain their design performance, reliability, and safety. One key objective of the SIAP is to develop methods to maintain the quality, integrity, and discipline of the SIAP process over the life of the program. Specifically, SIAP paragraph 1.7.2.1 requires the projects and elements to monitor comprehensive maintenance, inspection, time/age/cycle, and refurbishment requirements to assure that their hardware retains design reliability, safety, and performance. Any effort associated with fair-wear specifications are required to comply with this. As a result of the SIAT, all program elements and projects are reviewing the SIAP requirements and specific implementation to meet these requirements. The SIAT makes reference to the "Aging Aircraft Program" in which NASA participates. It is not practical for the SSP to establish a similar program unique to the Space Shuttle, however, it is appropriate for the SSP to ensure results of recent investigations and

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				concerns associated with aerospace systems are incorporated within the SIAP process. The assignment of key points of contact (reference category 2 recommendation #1) will facilitate this dissemination of information from these conferences.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-3:** NASA and USA quality inspection and NASA engineers should review all CRIT 1 system repairs.	**SSP Response (Abbey/Dittemore, 21 June 2000):** KSC, JSC, and MSFC reviewed the process for review and signature of criticality 1 system repairs. Criticality 1 systems are defined as functional criticality 1 and 1R systems per the applicable failure mode and effects analysis/critical items list (FMEAJCIL) documentation. "Repairs" are material review (MR) items used to repair a design-released part. All MRs, regardless of criticality, are treated as "out-of-family." For orbiter systems, NASA system engineers (SE), USA GO; and Boeing Launch Support Services must sign all KSC GO MR dispositions regardless of criticality. Items that may be first time occurrences or out of the ordinary are thoroughly discussed within the appropriate Prevention/Resolution Team (PRT). The PRT consists of system experts at KSC, JSC, the design Center, and vendors. The PRT technically reviews the problem and agrees to the resolution. The NASA SE must be completely satisfied that all requirements are met and that the MR was properly processed prior to concurring to the repair. The

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				PMRB must review all orbiter MRs on hardware with failure mode criticality 1, 1R, 1S, 2 or 2R. The GO PMRB membership includes NASA and contractor engineering and quality representatives. All NASA Shuttle Logistics Depot (NSLD) component MR repairs, regardless of criticality, are reviewed and signed by USA quality, NASA quality, and Boeing NSLD engineers who are authorized MR board members. NASA engineering is involved in the repair of all orbiter flight hardware through the Problem Reporting and Corrective Action (PRACA) Corrective Action Request (CAR)/Sub-CAR) process and PRTs. Hardware at the NSLD is dispositioned for the NSLD PMRB approval per NSTS-07700, Volume IV, Section 4.3.2.9 and Appendix Z. PMRB membership includes NASA and contractor engineering and quality representatives. Requirements for Government quality inspections are documented in the Quality Planning Requirements Document (QPRD). Currently, Government quality inspections are required on final verification of configuration changes but not on MR repairs. As a result of the SIAT, a QPRD review is being performed by NASA quality personnel to ensure the proper level of inspection is documented. USA NSLD quality engineering worked closely with NASA quality

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				personnel to eliminate unnecessary NASA inspection points. Current NSLD metrics by NASA quality personnel shows no increase in findings since the reduction. The SSME Project, Solid Rocket Booster (SRB) Project, Reusable Solid Rocket Motor (RSRM) Project, ET Project, and JSC Space Shuttle Customer and Flight Integration Office also reviewed the MR repair process. The review concluded that the NASA and contractor engineering and quality personnel do review and process MR repairs. Based on the current process and past activities/data, NASA engineering does review all criticality 1 repairs and is compliant with the current NASA requirements. NASA will be required to approve changes to the QPRD, which specifies contractor and NASA inspection points. NASA KSC quality personnel are currently reviewing the QPRD to determine if any additional NASA quality inspection points are required.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-4:** The failure of all CRIT 1 units should be fully investigated and corrected without waivers.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The SSP nonconformance process requires the investigation of safety critical systems failures and also considers the possibility of similar failure modes in other systems. It is the policy of the SSP to return all flight and ground hardware and-software to "print" per Section 1D506, Nonconforming Articles and Materials, of NSTS 5300.4

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				(1D-2). Furthermore, the investigative results of the failure and the proposed corrective actions are exposed to a wide scope of technical, project, and program reviews via the PRCB process. A waiver is used only after the design project and SSP management team review of corrective action options has resulted in concurrence that a "return to print" option is not mandatory and safety is not compromised. The nonconformances are recognized by the identification of variances from the SSP design and certification requirements (i.e., NSTS 077001Volume X, Flight and Ground Specification) or variances to form, fit, or function specifications in project level end item specifications. Finally, the SSP description of the integrated process for elevating and resolving problems is given in NSTS 07700, Volume XI, SLAP. Per Certification of Flight Readiness (CoFR) requirements, at each FRR all SSP elements are required to have verified that all applicable hardware and software meet all SSP baselined requirements for certification and redundancy. Any deviations, whether through disposition of replacement, repair, or "fly as is," must have had prior approval by the PRCB via the SSP waiver process. These items are also reviewed at the appropriate flight FRR. NSTS 07700, Volume IV, Section 4, directs all SSP elements to submit to the PRCB (for approval prior to

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				implementation) all proposed hardware or software dispositions which impact baselined program risk, redundancy, or certification requirements. Approval by the SSP Manager results in the development of a waiver to the applicable SSP requirements with the attendant documentation providing the technical rationale for flight acceptability and flight effectivity.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-5:** All testing of units must be minimized and documented as part of their total useful life. Similarly, maintenance operations must be fully documented.	**SSP Response (Abbey/Dittemore, 21 June 2000):** Testing of hardware life cycle, repair, and replacement items is controlled at KSC by established documentation and procedures. Efficient processing of the Space Shuttle components is a goal of the contractor and Government employees at KSC. Standard processing time is carefully monitored and appropriate justifications for performing nonstandard tasks on flight hardware, ground support equipment (GSE), and facility items alike must be provided. Currently, no testing of flight hardware is performed without authorization and documentation. Established Operations and Maintenance Requirements Specifications Document (OMRSD) requirements, PRACA, Test Preparation Sheet, or program level chits authorize testing of flight vehicle hardware and GSE. All of these documents currently have appropriate checks and balances that ensure only required work is performed. OMRSD

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				requirements conform to the MVP and test for failures modes defined by the FMEA/CIL. OMRSD reviews are periodically held with the goal of improving testing techniques. Per design Center recommendations, time and cycle requirements are levied on sensitive flight hardware items to protect their available lifetimes. OMRSD files also contain specific line replaceable unit (LRU) retest sections that guide the KSC engineer when determining the amount of systems retest required. GSE and facility items are tested only as directed by the appropriate group and must also have authorizing documentation.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-6:** The SIAT recommends comprehensive re-examination of maintenance and repair actions for adequate verification requirements (e.g., visual, proof test, or green run).	**SSP Response (Abbey/Dittemore, 21 June 2000):** The SSME Project, SSVEO, ET Project, RSRM Project, SRB Project, KSC GO and SSP Systems Integration have addressed this recommendation. All elements except SSVEO have completed their assessment and implementation-of any necessary corrective actions. SSVEO is scheduled to complete a review of NSTS 08151, Intermediate and Depot Maintenance Requirements Document (IDMRD) maintenance and Boeing Reusable Space System standard repairs by July 28, 2000. A schedule for implementation of any corrective action will be established as part of this review. All other elements have reviewed their repair/maintenance testing procedures and determined that processes and appropriate testing are in place to verify adequacy of any repairs. The

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				SSME Project determined, during the course of this review, that one type of nozzle tube repair had inadequate verification testing specified. The specification was revised to require acceptance test hotfire or proof testing prior to flight. All nozzles with this type repair have since been tested.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-7:** Human error management and development of safety metrics, e.g., Kennedy Space Center Shuttle Processing Human Factors team, should be supported aggressively and implemented program-wide.	**SSP Response (Abbey/Dittemore, 21 June 2000):** Human factors principles are being aggressively incorporated into ground processing at KSC. The Shuttle Processing Human Factors Team and the newly formed USA Industrial Engineering and Human Factors Department were staffed to implement human error and process management. Both entities are already working hand in hand to share data, resources, and expertise to develop human factors concepts. With the formation of the USA Industrial Engineering and Human Factors Department, the essential building blocks for this program are now in place. We will continue to improve by increasing the number of trained investigators, improving training, and enhancing data capture and trends analysis capability. As a supporting tool, the Tap Root analysis software is being investigated for use throughout USA to help implement a program wide root cause analysis process. The tool would not only be used by human factors team investigators but also by trained individuals throughout

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				the Space Shuttle management team (NASA & USA) to add more structure to root cause assessments and help implement better corrective actions. The joint USA and NASA KSC Shuttle Processing Human Factors Team is currently supporting several initiatives. These initiatives include the Work Instruction Task Team, which provides guidelines and training on effective procedure authoring and the Industrial and Work Space Design Team recently chartered to ensure human factors principles are incorporated into the concurrent engineering and ground system design processes. Both of these initiatives will have program wide effects in operations, maintenance, manufacturing, and design. A cross-functional team including human factors professionals has been established to review the Incident Prevention Board (IPB) process and make improvements to both the investigative process and identification and defining of effective corrective actions. The corrective action verification and effectiveness (CAVE) program is in place to verify corrective action effectiveness. This program will ensure that the recommendations of the industrial engineering and human factors team and the corrective action engineering group are implemented in a timely manner and that the actions taken were effective in

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				preventing or correcting occurrences. The SSP has established a quarterly PCAR where each program element presents their preventative and corrective actions and metrics. Some current activities of the Industrial Engineering and Human Factors Department are performance of on-site process analysis during critical tasks and continuation of development and deployment of human factors related training. USA has also begun to conduct training/outreach to the workforce in their monthly "tailgate meetings," and has reinstated the "Time Out" newsletter, which focuses on human factors issues. The SSP established a specific focus on industrial engineering (IE) and established an IE team that will include human factors in their activities. The focus of the IE team will be to identify specific improvements to the vehicle and/or GSE designs and processing procedures that will result in reduced risk to the workforce, increased maintainability, reduced risk of collateral damage, and an improvement in the overall processing of the hardware and vehicle systems.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-8:** Communications between the rank and file work force, supervisors, engineers and management should be improved.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The USA contractor has taken aggressive actions to improve the communication between the workforce and senior management including biannual briefings from the Chief Executive Officer

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				(CEO), weekly Leadership Council Meetings at the management level, weekly SSP Manager Meetings, and weekly Employee Meetings conducted by directors and supervisors. Additionally, the USA Program Manager has reemphasized the "management by walking around" activity where management has significantly increased the amount of time spent out of the office visiting employees at their respective work sites. This has been especially emphasized at KSC for both the engineering and technician workforce. Meetings between senior management and 20-30 employees, without other management present, are routinely being conducted to get a better understanding of workforce issues and to receive feedback directly from the employees. Although the SIAt recommendation was more specifically targeted for the KSC workforce, the SSP has reemphasized the importance of communication between senior management and the workforce at all sites, both contractor and NASA. "All hands" meetings are routinely being conducted to communicate the SSP message on goals and objectives, to review "hot topics," to address current issues and concerns, and to obtain employee feedback on specific SSP activities.

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Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-9:** NASA should expand on the Human Factors research initially accomplished by the SIAT and the Air Force Safety Center. This work should be accomplished through a cooperative effort including both NASA and AFSC. The data should be controlled to protect the privacy of those taking the questionnaires and participating in interviews. Since major failures are infrequent occurrences, NASA needs to include escapes and diving catches (see Appendix 3) in their human factors assessments.	**SSP Response (Abbey/Dittemore, 21 June 2000):** As a continuation of the human factors research performed by the AFSC, USA hired an independent consultant, Lord and Hogan, to administer the occupational stress inventory and assess the results. A group of 700 USA GO employees were selected to participate in the survey and 589 were completed. Lord and Hogan also conducted face-to-face interviews of 95 participants in focus groups to validate the data and identify other issues. The survey results clearly indicated USA employees experience about the same amount of stress as employees in other industries. The focus groups indicated that USA employees believe that USA is focused on safety at all levels within the organization but USA needs to address workload, training, and other issues for the increased flight rate. These findings are consistent with the earlier ASAP findings. While the overall results are positive, USA is evaluating the detailed data to determine areas where it can improve and is addressing specific issues raised by the focus groups. A USA Workplace Action Team has been established to review the survey results and recommend proactive measures to help assure that USA can continue to effectively manage the pressures in the workplace as the flight rate increases. In response to program tasking, KSC NASA/USA GO have developed a system

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				to ensure both hardware and processing/safety "escapes" and "diving catches," as identified in the SIAT report, are identified and a risk assessment is performed to determine the appropriate level of reporting and corrective action. Human factors investigators are assigned to mishaps based upon a USA risk assessment score or at the discretion of USA management. All items are evaluated using the established USA risk assessment process and may be assigned as an IPB item. Additionally, the SSP Manager directed that process escapes be reported and tracked similar to in-flight anomalies. Process escapes are presented to the SSP Manager at the quarterly PCAR.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-10:** Maintenance practices should be reviewed to identify and correct those that may lead to collateral damage.	**SSP Response (Abbey/Dittemore, 21 June 2000):** In January 2000, a team was formed to assess hardware damage, provisions, current protection, and any associated issues with collateral damage in the orbiter aft fuselage. The team included Aft Shop (orbiter processing facility (OPF) and Pad), Palmdale, NASA, USA and Boeing subsystem engineering, Rocketdyne, GSE/tool engineering, and human factors personnel. The initial effort concentrated on the aft fuselage due to the hardware criticality and potential for damage. Standard processing, as well as contingency LRU removals, were examined. General safety and human factor concerns were

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				considered. Operational area and (OASIS) data were also reviewed. The team findings concentrated on the following areas: access concerns, areas at risk for collateral damage, potential for wire damage, GSE, LRU GSE, portable lighting, and training. To date, seven orbiter modifications are in work as a direct result of this team. A GSE/platform subteam addressed access andGSE concerns. The subteam has reviewed the maintenance procedures and platform installations and identified the areas of poor access for the horizontal and vertical platform sets. In addition to poor access areas, the team is reviewing the size and weight of the piece parts to help reduce the risk of collateral damage during installation and removal. The team has also documented access requirements for the change out of an SSME in the vertical, along with the fall protection concerns in this configuration. Engineering Support Requests (ESR) were approved for improvements to the horizontal and vertical platform sets (ESR K16789 and K16190) and implementation is in work. An auxiliary power unit (APU) access stand was created for general processing and LRU remove and replace (R&R). A Process Improvement Team (PIT) was also chartered to study maintenance procedures, onetime entry issues, additional training, lighting, and communication concerns. PIT findings have revealed the need for an integrated

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				approach to platform installation, hardware inspection, and protective cover installation. The team is also working with vendors to get improved fixed lighting to reduce the need for portable lighting. In addition, use of battery operated lights is under review. Wireless headsets are also being investigated. A main propulsion system (MPS) vacuum jacket line protection effort was kicked off to prevent line damage during processing. The lines are being protected with "elephant-hide" and a visual barrier ("No Step" ID) as immediate protection. In parallel, shop-aid thermo-foam plastic hardcovers are being designed and fabricated (Test Preparation Sheet SA19-1-629). This effort is in work and is being implemented to a prioritized list (by line damage history and high traffic areas). The methodology used to assess the aft compartment and maintenance procedures to mitigate risk to collateral damage will be employed for the orbiter payload bay and forward fuselage areas. Midbody and forward teams were kicked off and are working in parallel. The teams will continue to be chartered by management and will report back to the IPB for an integrated review and concurrence of recommended change. Based on increased emphasis on minimizing collateral damage, employee awareness was raised through communication and training in areas such as hardware handling and testing, foreign

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				object elimination, contamination protection, and equipment operation. The program will continue to apply these methodologies to other areas of the vehicle and maintain employee sensitivity.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-11:** Shuttle actuator soft goods should be adequately wetted to prevent downtime seepage.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The current orbiter hydraulic system provides the best environment for seal operation to meet tight leakage requirements. The hydraulic system seals are maintained in a wetted environment at all times, including down time, and spare units are maintained on the shelf. The PRACA system data base shows there has not been any component replacement due to seal deterioration related to inadequate wetting. The orbiter currently meets the recommendation. SRB hydraulic LRUs incl;uding the actuators are refurbished after each flight. Following refurbishment, each unit is acceptance tested prior to being returned to stock. Preinstallation and postinstallation leakage tests are conducted on the entire hydraulic system for each SRB. Rigorous system level performance tests, including leakage tests, are done prior to each flight. System seal integrity is further verified at the vehicle level during the Space Shuttle Interface Test. No occurrences have been identified on the SRB program where post installation seal deterioration was related to inadequate wetting of the seal.

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Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-12:** Tank time and cycle data must be carefully logged to ensure safe life criteria are not exceeded.	**SSP Response (Abbey/Dittemore, 21 June 2000):** Time and life cycle life requirements for Space Shuttle flight tanks (ET, hydrogen, oxygen, orbiter maneuvering system (OMS) and reaction control system (RCS) propellant, N2, etc.) are found in OMRSD, File Two, Volume Ill. This file lists age sensitive items by part number. Information includes age and cycle life limits and required actions when life limits are reached. Items related to this file that have associated telemetry are tracked by a system called Time Age Cycle Control System (TACCS). TACCS is a data base that tracks the number of tank cycles by using software that accesses Launch Processing System (LPS) data for tank pressures whenever the vehicle is powered up. If the tank is at a vendor, cycles placed on the tank are recorded in the data pack. When the tank arrives back at KSC the data pack is reviewed and appropriate entries made into the TACCS data base. Any cycles not covered by telemetry and tank cycles at Palmdale are recorded into appropriate work authorization documents (WAD) or engineering logs. TACCS personnel review the WADs and entered data into the data base. Engineering is responsible for transferring tank cycle data from their logs to the TACCS data base. There have been limited instances when the cycle data was not accurately transferred to the TACCS data base. This disparity in cycle data is very small and does not constitute a problem since the number of

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				cycles accumulated to date on the tanks is only about 20 percent of the maximum allowed by the OMRSD. However, the SSP will correct the process to ensure accurate tank cycle data in the TACCS data base. When tanks reach 90 percent of their maximum life cycles per the OMRSD file, the appropriate system representative is notified for disposition. The SIATreport addressed exceeding the total number of hours that the tanks can be kept at flight operating pressure and the tracking of these data. The SSVEO has had a fleet leader program in place since 1978 for the Kevlar overwrap pressurant tanks. Data from this program indicate that tanks will not fail at ambient temperature for 100 years or more. Other orbiter tanks are not kept at flight pressures between flights, therefore, the total time spent at maximum pressure is small compared to their overall life. In addition, the design Center stress analysis group determined that there is no limit to the number of hours that the propellant tanks can remain at flight pressure.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-13:** Critical operations, especially those involving Self-Contained Atmospheric Protective Ensembles, must be staffed with technicians specifically experienced and properly trained with the operations.	**SSP Response (Abbey/Dittemore, 21 June 2000):** USA personnel are required to attend specific critical skills certification classes, based upon the requirements of their particular shop area. This is true for all certifications including self-contained atmospheric ensemble (SCAPE). Personnel must

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				attend and satisfactorily complete specific classes taught by certified instructors. Certifications are tracked and updated by the training department and the individual's specific directorate. On-the-job training (OJT) is often used to supplement certification training. Personnel, under the guidance of their management and an experienced certified senior technician, complete OJT packages. These packages are used in the actual work environment so training is hands on. Each area supervisor verifies that their personnel have the necessary skill and experience level to safely perform specific tasks and assigns them accordingly. Special efforts are made to team an experienced technician with a less experienced technician, until the supervisor feels confident in assigning the less experienced technician to a job without oversight. Cross training at various sites and with various systems is also strongly encouraged. USA and NASA at KSC are confident that only highly trained, certified, and experienced technicians are used in task execution. Standardization of this training for both horizontal and vertical operations is achieved via a "partnered" training plan.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-14:** Fleet Leader testing must be carefully scrutinized to ensure adequate simulation of operating conditions, applicability to multiple subsystems, and complete documentation of results.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The Orbiter fleet leader program evaluation is in work and is expected to be complete in June 2000. Results and recommendations will be reviewed at the

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			results.	will be reviewed at the Vehicle Engineering Control Board (VECB). The current fleet lead testing and status was presented to the VECB in February 2000 along with the recommendation to evaluate additional potential fleet lead testing including fire extinguishers, landing deceleration systems, mechanical actuation hardware, hydraulics, and APUs. Test conditions were examined to ensure the correct test environments are applied to the fleet leader. Fleet leader testing of payload integration hardware has consisted of teardown inspections of two power harnesses and one data harness. The results were presented to the November 1999 PRCB. There was no indication of stress in the insulation as a result of bending, no degradation attributable to hi-pot testing, and no wiring damage hidden by the overbraid which was not attributable to the overbraid damage itself. All major SSME components achieved a fleet leader goal of demonstrating life requirements of 60 missions (7.5 hours operating time). After certification, hardware allowable life is based on 50 percent of the fleet leader operating time. The RSRM Project structured postfire inspection and refurbishment processes to ensure that flight hardware has met, and will continue to meet, all engineering

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				specification requirements. Conditions identified for further review by the postfire inspection activity are dispositioned in a closed loop system, which requires approval for closure by both NASA and contractor senior management. All observations noted during the inspections are entered into a data base for future reference and trending purposes. In addition, the "number of uses" is tracked for each component and compared to the design reuse requirements. This process ensures that requirements are met and identifies when replacement hardware should be procured. Furthermore, these data are presented as part of the CoFR process for review by both NASA and contractor senior management. Subsequent to these inspections, those components intended for reuse are subjected to a rigorous combination of nondestructive evaluation (NDE), proof-test, and inspection to satisfy the safe life requirements. As with the post'fire inspection process, the results of these activities are fully documented to provide a clear pedigree of the hardware intended for flight use. The SRB Project does not utilize a formal fleet leader program because the hardware is disassembled, thoroughly inspected, refurbished, and reassembled after each flight. LRU life is based on qualification of the design (structure LRUs = 40 missions, electronic LRUs = 20 missions, pyrotechnic LRUs = time, etc.).

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				Qualification is based on analysis, test, and/or similarity. LRUs are recertified for each flight by inspection and/or test. Critical functional parameters are trended. Pyrotechnic components are lot certified for a specific length of time by test, and their life is extended by test, if required. A teardown/analysis approach is utilized for evaluation of cables. A small sample of flight cables are withdrawn from inventory and subjected to more extensive testing, including destructive evaluation. The SRB Project continually monitors failures to determine their age/life implications and any associated impact on obsolescence and mission supportability. Fleet leader testing is not utilized in the verification of the ET since the tank is an expendable subsystem of the Space Shuttle. All SSP elements are exercising a fleet leader program, or a similar program, which meets the recommendation.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-15:** Vendor supplied training should be evaluated for all critical flight hardware.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The vast majority of direct vendor training is provided to the NSLD. The NSLD was started in 1986 as a repair depot function to provide timely, cost effective local support to the SSP. The NSLD is currently certified to repair over 3,000 line items. The repair certification requirements are defined in JSC20423, Orbiter Repair Agency Design Activation and Operations Requirement

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				Document. Each time a new piece of hardware was transitioned from the original equipment manufacturer (OEM) to the NSLD, an extremely rigorous certification process was employed. This process included representatives from OEM engineering, NASA JSC systems engineering personnel, Rockwell (now Boeing) systems engineering personnel, NASA quality control personnel, NASA logistics personnel, and NSLD engineering/technicians. The process included transfer of knowledge on the theory of operation/design, detailed teardown/repair hands-on operations, and OEM design and specification documentation. Each piece of hardware, for which the NSLD is the certified repair agency, is considered unique. The requirements for how specific orbiter hardware was/is certified for repair at the NSLD is controlled by NSTS08151, Intermediate and Depot Maintenance Requirements Document (IDMRD), Vol. I, Maintenance Concepts Baseline. Both of these documents are subordinate documents to NSTS 07700. On complex items, training was done at both the OEM's plant as well as the NSLD. Actual certification and demonstration of hardware knowledge, troubleshooting, and repair capability was done at the NSLD. Each one of the individual certifications was video taped for documentation purposes as well as for review (if needed) for complex repairs. OJT

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				training packages were built. These packages mirrored the certification capability demonstration and conform to the requirements of the IDMRD for use in future training of engineers or technicians. KSC GO is limited to performing R&R of LRUs and is trained, certified, and procedure controlled to perform this task. There are rare exceptions where LRU replacements are allowed on the vehicle. For these cases, the design Center must concur with actions. Options include calling in certified vendor/depot support or certifying GO personnel to perform the repair. The former option presents an opportunity for GO personnel to work directly with vendor representatives, presenting a unique learning atmosphere for both parties. The latter option requires vendor and design Center (contractor and NASA) oversight and direct participation in initial training and procedure development for certification of GO personnel. Recertification curriculum is developed for administration by USA Integrated Logistics Technical Training & Development. Program control of this process is assured by documenting allowed repairs in the OMRSD LRU retest table. Changes to this document require PRCB approval.
Space Shuttle Independent Assessment Team	7 March 2000		**Recommendation 2-16:** The true mission impact of a second main engine pin failure (internal engine foreign object debris) during flight, similar to	**SSP Response (Abbey/Dittemore, 21 June 2000):** The need for such an analysis has been eliminated since there are no engines

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(NASA Charter)			that which took place last July, should be determined.	remaining in the flight fleet with deactivated main injector liquid oxygen (LOX) posts. Engine 2048 was the last such unit in the fleet. This unit was returned to the factory for a powerhead replacement. That work has since been completed and the engine returned to the active flight fleet at KSC. (Reference STS-93 In-Flight Anomaly Closure Report: STS-93-E-01). The need for LOX post deactivation was eliminated with design and manufacturing process improvements incorporated during the conversion to the Phase II + powerhead configuration. This non-pinned configuration is the only configuration now flying.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-17:** The SSP should consider more frequent lot sample hot fire testing of the Solid Rocket Booster motor segments at full-scale size to improve reliability and safety and verify continued grain quality.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The SSP requires the RSRM Project to demonstrate all engineering/process changes on a full-scale static test motor prior to incorporation into the Space Shuttle flight program. This is accomplished through the use of a flight support motor (FSM) program conducted at the contractor facility in Utah. This program, presently conducted on approximate 12 month intervals, allows an engineering assessment/confirmation of the numerous analytical models used for nominal motor performance predictions and flight safety considerations of Senior Material Review Board conditions. However, these motors are only intended as substantiation that both the

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				individual and synergistic effects of the proposed changes have no adverse impacts resulting from their incorporation. Studies relative to "Corners-of-the-Box" and/or flaw test parameters have typically been limited to subscale test articles which contain inherent scale-up uncertainties leading to conservative boundary conditions when utilized for analytical calculations. Furthermore, the consideration of flaw testing to verify margins of safety on an FSM static test places some risk to the RSRM Project's qualification/verification resources. Within this context, the SSP concurred with the project's intention to define a full-scale engineering test motor (ETM) that would contain test objectives focused on flaw and margin assessments. The requirements for this test bed are currently being formalized targeting a presentation to the SSP requesting formal authority to proceed. The ETM firing is targeted for September of 2001.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-18:** An independent review process, utilizing NASA and external domain experts, should be institutionalized.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The SSP currently utilizes numerous review processes, which are independent of the SSP. These reviews are performed repetitively, and essentially represent an institutionalized independent process. These include, but are not limited to, the ASAP, NASA IG, GAO, NRC, PMC, Center systems management Offices, and the (Headquarters/Code Q) Independent Assessment Office. In addition to these,

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				NASA Headquarters, NASA Centers, and the SSP have chartered independent reviews on occasion to investigate specific topics or issues. Many of these reviews were chartered prior to key program decisions being implemented. The SSP established a specific independent review process for the upgrades program including the Space Flight Advisory Committee, NASA Independent Program Assessment Office, and (Headquarters/Code Q) Independent Assessment Office. A sufficient number of independent formalizing a regular independent SSP review process. In addition, the Agency and the SSP periodically charter other specific independent assessments such as the SIAT to supplement the basic review processes utilized by the program. While there are numerous avenues for the workforce to voice their concerns, as a result of the SIAT, the program determined that value exists in the establishment of an independent process to draw out workforce issues. USA commissioned an independent consulting firm (Lord and Hogan) to conduct employee surveys on a periodic basis (approximately every 2 years) and has established a baseline as of February 2000. Additionally, an external group consisting of Lockheed, NASA, Boeing, and independent safety and human factors experts was established to conduct ongoing policy, procedure,

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				and best practice reviews.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-19:** NASA, USA, and the SSP element contractors should develop a Risk Management Plan and guidance for communicating risk as an integrated effort. This would flow SSP expectations for risk management down to working level engineers and technicians, and provide insight and references to activities conducted to manage risk.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The SSP implements and utilizes extensive risk management processes. The requirements and processes are documented in NSTS 07700 and the various associated documents. This documentation serves as the risk management plan for the SSP and currently defines and integrates risk management activities across all SSP elements. A SSP PMR was held March 21-22, 2000, which focused on risk management implementation across all program elements. The PMR included participation from all NASA elements and Centers, prime contractors, Defense Contract Management Agency (DCMA), ASAP, and the SIAT risk management evaluators. Presentations included discussions of the various methods utilized by the contractors to involve their workforce and management in risk management processes. It was evident that e4xtensive risk management processes and analytical techniques are implemented across all SSP elements. In reviewing the complexity and diversity of the risk management processes, it was determined that a section of NSTS 07700, Volume I, would be dedicated to the documentation of the SSP risk

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				management processes and requirements. This documentation will include the program's risk management plan and a "roadmap" to existing documentation. The documentation will provide centralization of the various risk management elements incorporated throughout the program and establish a basis for the flow down of SSP expectations for risk management to the various program elements and contractors. It will provide insight and reference to activities conducted to manage risk. While this section is not intended to incorporate the specific requirements and procedures, it is intended to consolidate references to the various SSP risk management activities specified throughout NSTS 07700 and the associated SSP documents. The change to NSTS 07700 is target for implementation this summer.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-20:** Risk assessment matrix and Failure Modes and Effects Analysis should be updated based on flight failure experience, aging and maintenance history, and new information (e.g., wiring, hydraulics, etc.).	**SSP Response (Abbey/Dittemore, 21 June 2000):** Currently, the risk assessment matrix, FMEA/CILs, and hazards are updated based on flight failure experience, aging and maintenance history, and new information. For example, FMEA/CILs and hazards are updated when there is a new failure mode that was not considered previously. The new failure mode may cause a change in the risk matrix or cause a change in criticality. All increases in risk for FMEA/CILs or hazards are briefed at the applicable FRR. Prior to 1991, the SSP had a

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				requirement to include all failure history in the FMEA/CIL. The SSP approved deletion of that requirement on October 3, 1991, to eliminate duplicate information that can be obtained through other sources. This change also reduced the volume of CIL documentation updating and resulted in more efficient use of resources. Examples of information kept in other locations include: 1. Tests: Turnaround checkout testing is maintained in the OMRSD. 2. Failure History: Test failures, flight failures, unexplained anomalies, and other failures experienced during ground processing can be found in the PRACA data base. 3. Operational Use: Standard crew actions are maintained in flight rules and crew procedures. A web-based data warehouse with capability to cross reference CILs, hazards, and problem reports/failure history are under development. This capability should be available within 6 months.
Space Shuttle Independent Assessment Team	7 March 2000		**Recommendation 2-21:** The SSP should revise the risk matrix for probable and infrequent likelihood for CRIT 1R** and 1R* severity to require a greater level of	**SSP Response (Abbey/Dittemore, 21 June 2000):** In the 1995 timeframe, the SSP went through an extensive review of the Space Shuttle MVP with the specific

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(NASA Charter)			checkout and validation.	goal of identifying the appropriate level of checkout and verification while not overstressing the systems due to excessive testing. The team was challenged to find the proper balance between the risk of insufficient testing and the risk of overtesting. The team was a multifunctional SSP team and included safety, reliability and quality assurance (SR&QA) personnel. At one time, all criticality 1R1 and 1R2 systems were fully checked out on the ground. Excessive wear was resulting from this philosophy and on-orbit operations were not being considered in the validation approach. The team determined that on-orbit operating time or the time operating the systems in support of associated systems checkout should be considered in the checkout and validation of performance. This approach has reduced the wear and tear on many of the critical systems and has reduced the amount of system exposure to potentially induced damage. As noted in the wiring investigation, exposure to potential maintenance induced damage needs to be continuously balanced with the degree of ground maintenance and checkout required to verify system performance. To date, no in-flight failures are attributable to lack of ground checkout and validation. Continuous review of validation and checkout procedures is standard

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				practice and a current requirement associated with the MVP. For example, as a result of the OV-104 speedbrake power drive unit end cap found during ground testing at KSC prior to STS-101, an additional ground checkout procedure was added to each Vehicle flow to verify the end cap is properly seated and will not impede system operation.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-22:** NASA Safety and Mission Assurance surveillance should be restored to the Shuttle Program as soon as possible.	**SSP Response (Abbey/Dittemore, 21 June 2000):** NASA and the SSP have maintained an active SMA program and will continue to do so. The execution of these activities have contained two key elements: first, the safety, reliability, maintainability, and quality assurance (SRMQA) engineering; and second, analysis tasks performed in accordance with program requirements and the independent SMA oversight function provided in support of the Office of SMA (Headquarters/Cod.eQ)o NASA Center SRMQAorganizations have continued to be active participants in all aspects of the program. _1_ elements and supporting organizations have also been very active in executing SMA Program related surveillance. The SSP has taken several steps towards assuring a strong SMA program: • In 1996, an SSP position, Manager, SMA, was created

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				which provides a senior management authority associated with SSP SMA policy, requirements, and implementation. • All program elements have undergone training in DuPont Safety, fault tree analysis, root cause analysis, and obtained ISO quality system certification by third party registrar. • Resources for center SRMQA, which at one time were constantly threatened by Center priorities, are now provided directly under SSP funding. The SSP program operating plan (POP) reflects multiyear planning for SRMQA tasks throughout element and SRQA organizations and is fully supported by SSP management. • Supplier surveillance has been maintained through use of delegated tasks to the DCMA by the SSP Manager, SMA. This support has not decreased and has even recently been increased through the direct program funding of $4.5 million to support surveillance of contractor activities

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				associated with the SRB. • NASA implemented Government hiring of SMA personnel at all Centers. • In response to SSP requirements, the prime contractors implemented numerous safety and risk management initiatives. • Flight readiness processes include specific review and verification of SRMQA engineering products. • NASA and contract program elements have maintained an appropriate sustaining engineering function that is continuously involved in evaluation and analysis processes. These efforts are continuously reviewed at program forums such as the SSP Council, PMR, PCAR, and PMC. The Office of SMA (NASA Headquarters/Code Q) has also maintained a substantial SMA surveillance program. In 1996, the (Headquarters/Code Q) Independent Assurance Office located at JSC expanded its charter to include independent assessments associated with the SSP. In 1996, the Associate Administrator of SMA established the Human Exploration and Development of Space (HEDS) Assurance

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				Board-to provide senior NASA management with timely, objective, nonadvocate assessments of program health, status, and relative safety posture. This board meets on a monthly basis with NASA Administrator participation each 6 months and includes participation of the senior Center and program SMA managers. The Pre-Launch Assessment Review is chaired by the Associate Administrator of SMA and provides for independent assessment in support of CoFR. The Office of SMA also conducts process verification audits of the various SRMQA processes as an element of their surveillance activity and participates in numerous program reviews and problem resolution processes. SSP requirements address the various roles and responsibilities of both the SRMQA organizations and program elements in executing the SMA program. These requirements will be reviewed to ensure clarity between the SRMQA engineering activities which are conducted in direct support of the SSP and the independent assurance (IA) activities which are conducted in direct support of the Office of SMA. Organization charts and functional responsibilities will be revised to reflect clear and specific working relationships and responsibilities of these two functions. Specific assignment of individuals will be reviewed and revised to ensure clear and separate

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				reporting responsibilities. This review will be accomplished by August 1,2000.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-23:** The Safety & Mission Assurance role should include: mandatory participation on Prevention/Resolution Teams and in problem categorization, investigation of escapes and diving catches (see Appendix 3), and dissemination of lessons learned.	**SSP Response (Abbey/Dittemore, 21 June 2000):** As a result of this SIAT recommendation, verification that SSP requirements define SRMQA engineering's mandatory involvement and product expectations has been accomplished. Program requirements and processes including anomaly disposition, trending analysis, problem reporting, preventive/corrective action, and mishap investigations were reviewed and were confirmed to require mandatory participation by SRMQA engineering. These functions result in specific program products that are integral components of the problem resolution process. Verification of SMA dissemination of lessons learned was accomplished. Also, Headquarters/Code Q manages the NASA lessons learned data base and provides access to anyone within NASA and the contractor team. This system is active and supported. Products associated with determining safety and mission success involve a number of program elements and supporting disciplines. Safety reporting systems, IPBs, mishap and close call forums, and in/out of family anomaly reviews involve a diversity of program element

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				and contractor functions. As a result of the SIAT, the SSP Manager directed that escapes be treated similar to in-flight anomalies. Therefore, all escapes are briefed to SSP management at the quarterly PCAR. This requirement is applicable to all program elements including SRMQA organizations. The PCAR is conducted as a formal PRCB involving the mandatory participation of all elements including SRMQA organizations.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-24:** The SIAT believes that software systems (flight, ground, and test) deserve a thorough follow-on evaluation	**SSP Response (Abbey/Dittemore, 21 June 2000):** The SSP believes that the flight, ground, and test software systems are of world-class quality as evidenced by the metrics for product error rates. The SSP reviews these metrics on a regular basis and conducts reviews of the element processes and metrics. Flight software processes continue to be better than the industry standards for ISO 9001 and the Software Engineering Institute (SEI) Capability Maturity Model for Software (SW-CMM). Flight software personnel continues to exercise an independent verification and validation (IV&V) assessment throughout the general purpose computer (GPC) and SSME development processes. Software processes and performance have been assessed on numerous occasions (ASAP, GAO, NRC, arid Roger's Commission), with consistent findings of exemplary performance reported by these

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				reviews. While the SSP fully recognizes the complexity and criticality of software systems, the current control and review processes are considered to be rigorous, disciplined and sufficient. The SSP believes a follow-on SIAt evaluation is not warranted at this time.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-25:** Due to time constraints, the SIAT only examined Orbiter wiring; many other systems associated with the Shuttle also have critical wiring. The findings and recommendations in this report are applicable to all Shuttle systems, but unique conditions that may require additional actions.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The SSP held an element wide wiring review at the September 16, 1999, PRCB. This review addressed extravehicular (EVA), cargo integration, Government-furnished equipment (GFE), GSE, RSRM, SRB, ET, and SSME wiring. Subsequent to that meeting,14 follow-up PRCB Actions pertaining to non-orbiter elements were issued, addressed, and closed. The scope of these actions includes wiring inspection status and protection, test plans and checkout procedures, fleet leader approach, engineering standards and requirements, as well as element unique activities such as bend radius life cycle analysis and teflon wiring utilization. The scope of SSP wiring attention has been and will continue to be inclusive of all program elements.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-25:** During the inspection of wiring, several connector issues were also apparent. Loose connector backshells and wire strain relief that can potentially chafe wiring were noted. Under certain conditions loose backshells can compromise electrical bonding between shielding and structure. Movement of the backshell can	**SSP Response (Abbey/Dittemore, 21 June 2000):** The orbiter OMRSD requires a visual inspection of electrical connectors every flow to verify proper mating and backshell attachment. The orbiter MLO303-0014 specification documents the requirements for backshell rework and connector manipulation. A recent

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			also cause chafing between the wiring and strain relief. In either case, these are unacceptable conditions and should be eliminated by periodic inspection and connector design.	investigation of chafing found between wiring and backsheil strain relief arms resulted in an update to this specification to provide additional strain relief. This specification is invoked on connectors with detected damage and connectors susceptible to damage due to configuration or frequent flexing. Backshell integrity is physically verified with every connector mate/demate operation and connector reworked. Payload integration wire harnesses are governed by the same ML0303-0014 specification as orbiter harnesses. A recent update to ML0303-0014, Paragraph 6.3.2.23, addresses added protection at the backshell strain relief tangs, where required, with the use of Mystic 7503 tape. A strain relief tang is used to secure the wires going into the connector to reduce strain on the contact locking mechanism. The wires entering a connector are spot tied to the tang so that any flexure of wire bundle stops tang. This configuration greatly reduces movement of the wires in the connector. The SSME design precludes wire looseness in backshell strain relief clamps. Silicone tape is used to fill gaps around wiring, and overmolds provide exterior protection. Inspection for loose backshells is included in periodic inspection requirements. There has been no comparable SSME failure history of wire damage due to

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				loose backshells. The RSRM Project conducted a review and evaluation of RSRM cabling and wiring. All RSRM cables utilizing backshell connectors are new for each flight. All cables undergo extensive electrical testing/checkout and visual inspection before and after installation. All RSRM cables utilizing backshell connectors are criticality 3. No postfight observations/trends were identified for RSRM cable backshell connectors in the history of the program. RSRMcables and connector designs are robust and reside in well protected, low traffic areas on the motor, therefore, greatly reducing the chance of contact damage. There are no postflight concerns/trends for any cable and connector issues. Current cable and connector inspections and tests are necessary and adequate; no additional inspection requirements/corrective actions have been identified. The SRB Project connector inspections (including backshell connections) are performed at the vendor prior to shipment, at SRB refurbishment operations for reusable cables, again at hardware issue, and then a final visual inspection is performed prior to hardware shipment to GO. SRB cable wiring is verified each flight by removal, refurbishment, inspection, and a series of tests. Cables are insulation resistance, dielectric withstanding voltage, and

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				continuity tested on the electrical bench. After installation, these tests are repeated. Prior to hardware shipment to GO, a visual inspection is performed. For the ancillary cables, these tests are performed by the SRB Project prior to shipment to GO. After installation by GO, these tests are repeated. Planned inspections of ET wiring design confirm correct assembly and installation. During assembly at Michoud, inspections verify the torque value of the connector backshells and the correct thread protrusion, spacing, and bend radius. Movement is controlled with tie-wraps, clamps, and Iockwire. A final inspection is performed for visual damage and proper configuration. ET harness assemblies are not exposed to high traffic areas due to enclosure in cable trays, tank interiors, and protective covers. The ET is not a reusable component of the Space Shuttle. Therefore, connectors are not routinely mated and demated which reduces the risk of improper installation.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-27:** Arc track susceptibility of aged wiring and circuit protection devices that are sensitive to arcing should be evaluated.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The SSVEO has approved a comprehensive test plan to evaluate the arc track susceptibility of aged wiring and circuit protection devices. Arc tracking tests will be performed to obtain a baseline comparison between flown (OV-102) and new orbiter Kapton wire. These tests will be performed with orbiter circuit protection and source configurations using

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				various initiation methods and conditions to determine susceptibility to arc tracking under vehicle conditions. The testing is scheduled to take a year. Results will be presented to the SSP.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-28:** The need to examine wiring in areas that are protected or where damage may be induced by physical wiring inspection should be evaluated. Wiring should be continuously evaluated by conducting extensive electrical verifications on systems. When wiring damage is found in an area previously not examined, the remaining Orbiters should also be inspected	**SSP Response (Abbey/Dittemore, 21 June 2000):** OV-102 is undergoing an extensive wire inspection, which includes all accessible wire on the vehicle during OMDP. Any area where wiring is determined to be inaccessible is being photo documented. Wire inspections on OV-102 include all wire harnesses in the environment control and life support system (ECLSS) bay (high traffic area) and the aft compartment. The inspections include wires protected by convoluted tubing in order to develop an approach for inspecting protected wiring. The results of the OV-102 wire inspections will be used to update the OMRSD for future vehicle OMDP requirements. All safety and mission critical system functions are currently tested every flow per the requirements specified in the applicable OMRSD. OMRSD inspection requirements were updated and clarified to ensure adequate inspections are performed during normal vehicle processing. Standard problem resolution dictates that any findings on one vehicle will be assessed for its applicability to other vehicles, and corrective action will be implemented as required.

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Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-29:** Wire aging characteristics should be evaluated, including hydrolysis damage, loss of mechanical properties, insulation notch propagation, and electrical degradation. Testing should be performed by an independent laboratory.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The SSVEO approved a comprehensive test plan to evaluate wire aging characteristics. The evaluation will be performed by two independent laboratories, Barcel and Lectromec, and by Boeing Huntington Beach. Old wire will be obtained from OV-102 and compared to new Kapton insulated wire. Testing will be performed on the flown wire to determine useful life remaining. Testing will be completed in August 2000.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-30:** A database that continually evaluates wiring system redundancy for the current design, modifications, repairs, and upgrades should be maintained. System safety should evaluate the overall risk created by wiring failures	**SSP Response (Abbey/Dittemore, 21 June 2000):** The SSP requirements for routing of redundant systems wiring are documented in NSTS 8080-1. This document specifies that electrical wiring of redundant systems, redundant subsystems, or redundant major elements of subsystems shall not be routed in the same wire bundle or through the same connector with wiring of the other redundant systems, subsystem, or subsystem element. A wire routing assessment was performed in 1994 addressing criticality 1 systems and wire routing violations. This assessment was documented in a report. An update to the report is in work with completion scheduled for October 2000. The report will become an official document baselined by the VECB chaired by the Manager, SSVEO. If a future vehicle modification will result in violation of the criticality 1 redundant wire routing requirements, the VECB will review the

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				proposed wiring and approve or disapprove associated violations.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-31:** NASA engineering should specifically participate in industry and government technology development groups related to wiring. The SAE AE-8 committees (specifically A and D) are excellent forums for identifying wiring issues.	**SSP Response (Abbey/Dittemore, 21 June 2000):** Several initiatives to expand data exchange and teaming efforts with the Federal Aviation Administration (FAA) and Department of Defense (DOD) are currently underway. The SSP has initiated conversations and planning with the Department of Navy and Wright-Patterson Air Force Base to take advantage of initiatives already in place and to coordinate a list of working groups and forums involving multiple Government aerospace agencies. The SSP will participate in these forums and identify SSP points of contact. The SSP will document assignments and involvement in these forums and identify an appropriate SSP forum for reporting and dissemination of information obtained from the working interfaces. To address recommendation 31, the SSP will specifically identify wiring related working groups and establish the appropriate level of participation. The Manager, SSP Safety and Mission Assurance (SMA) has been appointed as the NASA representative to the Wire Safety Research Interagency Working Group chartered by the Office of Science and Technology Policy. In addition, the SSP established contact in mid-

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				March with the chairman of the Aircraft Wiring and Inert Gas Generator (AWIGG) Working Group and established communications with the team. Membership rosters were exchanged and both the SSVEO and USA sent representatives to the May 15-19, 2000, meeting to further establish points of contact and exchange information. Formal membership and identification of specific SSP representatives will be documented.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-32:** Wiring subjected to hypergolic contamination should be replaced since high pH fluids are known to degrade polyimide type wire insulation.	**SSP Response (Abbey/Dittemore, 21 June 2000):** Orbiter wire is not exposed to hypergolics as part of planned operations. Current inspection procedures would detect this condition. The only credible scenario, which could result in wire exposure to hypergolics, would be in the case of a leak. If exposure occurs, the standard problem resolution process would dictate that the wiring be thoroughly inspected for discoloration and physical damage. If exposure and damage has occurred, the wire is removed and replaced.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-33:** The current quality assurance program should be augmented with additional experienced NASA personnel.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The KSC SMA office is in the process of augmenting the existing workforce. Twenty-five quality specialists were hired to work in the SSP at KSC. Six existing, experienced NASA inspectors will augment the in-line processing effort by transferring from the Assembly and Refurbishment Facility.

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				In addition, three SMA engineering slots for the SSP (including one for checkout and launch control system (CLCS)) will be filled later this year. SMA will continue to evaluate resource requirements and work with Center management to prioritize their needs for future years.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-34:** Technician/inspector certification should be conducted by specially trained instructors, with the appropriate domain expertise.	**SSP Response (Abbey/Dittemore, 21 June 2000):** All required training, including recurring training, is tracked by USA and the qualification and certification sign-off system (QACSS). The training requirements are specific to the hardware, the processes, and the procedures used at KSC. The instructors, who train the hands-on personnel, represent the most knowledgeable individuals in their field of expertise. The selection process for instructors focuses on their education and training experience. A new instructor is assigned to an experienced, qualified instructor who is certified in the appropriate subject matter. The new instructor is mentored until signed-off by the experienced instructor and the manager. The instructor carries the certifications that he or she teaches. A senior instructor or their manager periodically observes instructors in their presentations. Students evaluate instructors at the end of each course and may evaluate at any time during the course. Course audits are conducted for courses tied to certifications at least every 3 years. However, course audits may be conducted at any time.

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Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-35:** The SIAT recommends an evaluation of depot repair documentation be performed to determine if the transition process attained a necessary and sufficient set of vendors for each Line Replaceable Unit, Shop. Replaceable Unit, and special test equipment.	**SSP Response (Abbey/Dittemore, 21 June 2000):** A project team was chartered to perform an evaluation of the certification process for identifying and obtaining documentation for transition of LRUs, shop replacement units (SRUs), and special test equipment (STE) to the NSLD. During certification, the NSLD works with the design Center and the OEM to establish a baseline of required repair documentation. The number of requests for vendor data and work stoppages due to lack of documentation was evaluated to determine whether sufficient vendor repair data are available. There is an average of 500 requests for documentation each week to the NSLD Technical Documentation Center. NLSD personnel and other SSP elements submit requests. Only a small percentage of these Evaluations of the NSLD work metrics indicate well requests are unable to be filled. Stoppage below 1 percent are due to lack of documentation. These factors indicate that sufficient documentation is available from the vendors. In those rare cases where NSLD repair documentation is not available, there is a process to obtain data by working with the design Center and USA procurement. Reasons for data not being available include increased repair capability after original certification (e.g., nonrepairable hardware must

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				be repaired due to obsolescence), lost or misplaced data, and limited documentation for STE. If the vendor still supports the program for documentation maintenance, USA procurement will contact the vendor and obtain the proper data. If the vendor or documentation is not available, the design Center will develop and release equivalent documentation through established authorization processes. For those cases where a vendor no longer supports the SSP, an alternate data maintenance agency is designated. All of the OEM's documentation is obtained, indexed, and maintained by the design Center that is designated as the "data maintenance" agency.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-36:** Teamwork and team support should be enhanced to mitigate some of the negative effects of downsizing and transition to Shuttle Flight Operations Contract. Most immediately needed is the provision of relief from deficits in core competencies, with appropriate attention to the need for experience along with skill certification. Further development of the use of cross-training and other innovative approaches to providing on-the-job training in a timely way should be investigated.	**SSP Response (Abbey/Dittemore, 21 June 2000):** Additional hiring is in progress by USA to meet the seven flights per year manifest with particular emphasis on critical skills and core competencies. Over the past 3 months, USA has hired approximately 164 people in the engineer, software, technician, and inspector categories at KSC. Over the same time period, approximately 64 were lost due to attrition. By the end of June 2000, USA expects to have an appropriate number of personnel to support the seven flights per year manifest. The experience level of the new hires is balanced. In addition, cross-training and certification levels are expanding in

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				Florida.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-37:** Work teams should be supported through improved employee awareness of stresses and their effect on health and work. Workload and "overtime" pressures should be mitigated by more realistic planning and scheduling; a serious effort to preserve "quality of life" conditions should be made.	**SSP Response (Abbey/Dittemore, 21 June 2000):** Following the initial concerns voiced by the SIAtabout the morale in Florida and possible effects on safety, USA commissioned an independent consultant, Lord and Hogan, to administer the occupational stress inventory. This inventory included an in-depth survey of the Florida workforce on the subject of stress and safety and face-to-face interviews of participants in focus groups. The results were remarkable for two reasons. First, the response rate to the survey was exceptionally high. Second, the responses showed USA to be well within expected norms compared to many other companies. USA is in the process of conducting the same survey for the Texas workforce. Both NASA and USA are sensitive to the "quality of life" environment of employees. Metrics and other management tools will continue to be used to emphasize this factor in management planning.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 2-38:** The inspection procedures of the Shuttle main engine high-pressure fuel lines and valves to find cracks should be reviewed. Currently, Columbia is at Palmdale and the vehicle is available for inspections of the main propulsion lines to verify whether this potentially serious problem exists.	**SSP Response (Abbey/Dittemore, 21 June 2000):** During the design of the orbiter's MPS hardware, materials were selected specifically for their resistance to hydrogen embrittlement. Hydrogen induced damage is not a concern in the low temperature/low pressure MPS. Nearly all high

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				pressure/high temperature components use "A" rated materials. Exceptions have been approved by the materials and process group based on their review of the specific stress environment for that item. To date, there have been no problems in the MPS hardware attributable to hydrogen embrittlement. In 1991 and 1996, the GH2 temperature probe and flow control valve, respectively, were inspected down to the individual piece part level and there was no evidence of hydrogen embrittlement. Since orbiter MPS materials were selected to preclude hydrogen embrittlement and it has been verified in limited inspections that no hydrogen embrittlement has occurred, a detailed, comprehensive, invasive inspection will not be performed (the configuration does not permit 100 percent inspection, even if desired). While hydrogen embrittlement is not a concern for MPS hardware, detailed inspections of all hardware removed for failure analysis will continue to look for signs of hydrogen embrittlement such as cracking and fatigue. These inspections will provide a periodic check for the onset of any potential failure mechanism, including hydrogen-related damage.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-1:** Standard repairs on CRIT 1 components should be completely documented and entered in the Problem Resolution and Corrective Action system.	**SSP Response (Abbey/Dittemore, 21 June 2000):** All repairs (standard and nonstandard) are entered into either the Problem Reporting and Corrective Action (PRACA) system or lower level nonconformance systems per Space Shuttle Program (SSP) requirements; all require resolution,

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				corrective action, recurrence control, and accommodate trending, tracking, and risk mitigation. Additionally, a requirement is being added program wide to assure that all standard repair (SR) dispositions are uniquely coded in a consistent manner across the existing systems to provide easy access to the SR data base. The PRACA Evaluation Team (PET) will address this issue and recommend PRACA enhancements or structure changes as required. Additionally, the SSP will review program requirements pertaining to disposition and recording of SRs on criticality 1 components.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-2:** The criteria for and the tracking of standard repairs, fair wear and tear issues, and their respective FMEA/CILs should be re-examined.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The SSP criteria for SR's are contained in NSTS 5300.4(1D-2), Safety, Reliability, Maintainability, and Quality Provisions for the SSP, Section ID506. An SR is approved by a Material Review Board (MRB) to repair a nonconformance condition that shows a history of repetition and does not return material/hardware to drawing configuration. Space Shuttle MRBs and Program Material Review Board (PMRB) are authorized by NSTS 07700, Volume IV, Section 4.3.2.9, to disposition repairs per the process identified in NSTS 5300.4(1D-2), Section ID506. Any disposition, including SRs, by the MRB of a nonconformance affecting criticality 1 or 2 failure modes must be submitted to the

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				PMRB with an impact/no impact statement regarding the critical failure modes. If critical items list (CIL) waiver retention rationale for the hardware is affected, the disposition must be approved by the Program Requirements Control Board (PRCB). Fair wear and tear (FW&T) criteria for flight hardware are defined by the design Center and specified in the design drawings. FW&T items are parts or equipment exhibiting minor or cosmetic external defects generally attributed to handling or usage. All dispositions under SR or FW&T criteria are verified by the design project for compatibility with the certified operating environments applicable to the hardware item. All projects have data systems and procedures in place for documenting approved SR's and FW&T items. Criteria for tracking the occurrence of nonconformances, including those dispositioned as SR's, are defined in NSTS 08126, PRACA System Requirements. Currently no dedicated data field is assigned in PRACA for SR closures, and a text search must be made within the closure field to identify those nonconformances dispositioned as SRs. The SSP currently has an action in work to readdress the NSTS 08126, PRACA System Requirements, across the program per Shuttle Independent Assessment Team (SIAT) recommendation. In addition,

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				initiatives are in work that will enable electronic and query of SSP PRACA data (established per NSTS 07700, Vol. XI) by all SSP elements via the Shuttle Flight Operations Contract (SFOC) Advanced Data Acquisition and Management (ADAM) Data Warehouse. This action will be closed by verifying with each SSP element project that: (1) Documented procedures and instructions exist for defining SRs and FW&T items; (2) Procedures and data systems exist for tracking the occurrence of SR's and FW&T items within the project; (3) Procedures and criteria are in place for elevating to the PMRB dispositions involving hardware classified as criticality 1 or 2, and elevating to the PRCB dispositions affecting CIL retention rationale. This verification effort is expected to be completed by October 2000.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-3:** The SIAT recommends comprehensive re-examination of maintenance and repair actions for adequate verification requirements (e.g., visual, proof test, or green run).	**SSP Response (Abbey/Dittemore, 21 June 2000):** The Space Shuttle Main Engine (SSME) Project, Space Shuttle Vehicle Engineering Office (SSVEO), External Tank (ET) Project, Reusable Solid Rocket Motor (RSRM) Project, Solid Rocket Booster (SRB) Project, KSC Ground Operations (GO), and Space Shuttle Systems Integration Office have addressed this recommendation. All elements except the SSVEO have completed their assessment and implementation of any

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				necessary corrective actions. The SSVEO is conducting a review of NSTS 08151, Intermediate and Depot Maintenance Requirements Document, maintenance and Boeing Reusable Space Systems (BRSS) SRs. Implementation of any corrective actions will be established as part of this review. All other elements have reviewed their repair/maintenance testing procedures and have determined that processes and appropriate testing are in place to verify adequacy of any repairs. The SSME Project determined, during the course of this review, that one type of nozzle tube repair had inadequate verification testing specified. The specification was revised to require acceptance test hotfire or proof testing prior to flight. All nozzles with this type repair have since been tested.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-4:** The avionics repair facility should be brought up to industry standards.	**SSP Response (Abbey/Dittemore, 21 June 2000):** United Space Alliance (USA) is continuously evaluating initiatives in the area of safety, testing, repair, manufacturing, and facility improvements at the NASA Shuttle Logistics Depot (NSLD). The NSLD received the Occupational Safety and Health Administration's Standard of Excellence Star facility certification in 1997. Test equipment is being upgraded on a continual basis. Automated test stations and commercial off the shelf (COTS) test equipment are utilized where appropriate, and computer systems have been rehosted to newer

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				platforms. Examples of upgraded automated test equipment are for the heads up display electronics and orbiter cabling/crew compartment wiring special test equipment (STE). The STE is currently being evaluated at the NSLD for upgrade potential with priority placed on supportability improvements. Expert systems are a consideration in the equipment upgrade process. Tracking of equipment failures and causes are documented in logbooks and the data are a consideration in the upgrade process. Troubleshooting and failure analysis plans for in-flight hardware failures are documented on a Corrective Action Report (CAR)/sub-CAR and are thoroughly discussed within the appropriate Problem Resolution Team (PRT). The PRT is a combined effort between system experts at KSC, NSLD, the appropriate design Center (JSC/MSFC), and vendors that allows technically complete, coordinated resolution of problems, including failure trends and causes, at the "hands on" level. In the area of environmental controls, USA has instituted a strong campaign at the NSLD to help reduce potential electrostatic discharge (ESD) damage to flight and nonflight hardware (ESD safe floor wax, ESD safe binders, smocks, liners, etc), made electrical grounding improvements throughout the

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				facility, and upgraded the power drops and lighting in the Avionics Lab. Installation of an injected humidifier system in the avionics area has been approved, and implementation is currently in work. Other initiatives under consideration are power shut-off switches in the event of technician distress and use of insulated safety mats at workstations.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-5:** Selected areas of staffing need to be increased (e.g., the Aerospace Safety Advisory Panel advised 15 critical functional areas are currently staffed one deep).	**SSP Response (Abbey/Dittemore, 21 June 2000):** The Office of Space Flight (OSF) has recently conducted workforce reviews of staff workload and skill deficiencies at its Centers and programs, with particular emphasis on the SSP. Findings of these reviews, coupled with those of external groups such as the SIAT and the Aerospace Safety Advisory Panel (ASAP), led to the decision to terminate downsizing. All four OSF Centers, JSC, KSC, MSFC, and SSC, are in the midst of large-scale efforts to replace skill losses and increase the number of entry-level professionals. NASA has a plan in place to hire over 500 new employees in fiscal year 2000. Although only a portion of these new employees will be dedicated to the SSP, this action will help fill some of the most critical skill shortages, enable us to stabilize our flight safety skills resources, and build our cadre of future leaders. It is imperative that sufficient resources, including new hires, be dedicated in support of the SSP. Beginning in fiscal year 2001,

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				the plan is to replace future losses on a one-for-one basis. In addition, the recruiting strategy is to emphasize the identification of critical skill shortages and make those the top hiring priorities. The goal is to hire 50 to 70 percent of new personnel at the entry level in an effort to revitalize the workforce with high-caliber, recent graduates. To allow some of the best junior- and mid-level personnel the opportunity to broaden their functional experience, the SSP has created rotational opportunities at several Centers where they can gain experience at the program level. This early exposure to the significant operational and programmatic management challenges will enable them to enhance the flight safety critical process skills in the near term, and will better equip them to serve in leadership roles in the future.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-6:** The SIAT recommends that the SSP implement the Aerospace Safety Advisory Panel recommendations. Particular attention should be paid to recurring items.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The SSP seriously considers all ASAP recommendations and responds in a timely fashion to those within program authority. The SSP provides to NASA Headquarters management, through an established review/assessment process involving Center review, a thorough and comprehensive input for use in the development of an overall NASA agency response to all ASAP recommendations. These SSP inputs provide the current status of activities implemented to address the specific issue and/or the needed implementation actions and plans to address

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				each ASAP recommendation. It should be noted that specific implementation of ASAP recommendations is not always possible by the SSP, as the issues often deal with Agency-wide issues (such as manpower levels) or integration complexities with external influences that are beyond the immediate control of the SSP. The SSP, while striving to implement appropriate recommendations, must deal with and address solution complexity, implementation time, and the availability of resources all within the framework of successfully carrying on the continued operational responsibilities and development commitments of the SSP. In all cases, the ASAP is well informed and briefed on the circumstances surrounding their recommendations. All recommendations are tracked, and the ASAP readdresses each year those issues/concerns that it considers open from the previous year, thereby, invoking an appropriate new/updated response through established processes.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-7:** The SIAT believes that Aerospace Safety Advisory Panel membership should turnover more frequently to ensure an independent perspective.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The following paragraph is the ASAP response to this recommendation. It is important to note that this text is taken directly from of the ASAP's "Plan for Assessment and Replenishment of the Membership of the Aerospace Safety Advisory Panel." "The ASAP is chartered to provide independent safety

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				oversight of NASA's programs and day-to-day activities, particularly those related to human flight. In order to cover adequately the range of activities in which NASA engages, the Panel needs a highly experienced and technically diverse corps of members and consultants. The historical effectiveness of the Panel has stemmed in part from the continuity of its membership. Even for experts in the aerospace industry, it takes a significant amount of time to become familiar with the NASA programs, their management and technical personnel and how the programs are managed and operated, The primary recruitment goal of the ASAP is therefore to identify the best possible members and consultants in each needed discipline who are likely to remain with the Panel for a significant period. The exception to this is for consultants recruited only for a specific, unusual task that is not expected to endure or recur."
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-8:** The root cause(s) for the decline in the number of problems being reported to the Problem Resolution and Corrective Action system should be determined, and corrective action should be taken if the decline is not legitimate.	**SSP Response (Abbey/Dittemore, 21 June 2000):** All the SSP elements reviewed their PRACA data to determine if their project experienced a decline in problem reports (PRs) and, if so, to determine the root cause. The SRB Project and the ET Project have not experienced declines but have seen steady or increased report activity tracing back through at least 7 years of PRACA history. The RSRM Project, SSME Project, and the SSVEO have experienced declines in PRACA reports

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				over at least the last 5 years. The RSRM Project, through increased technical understanding, design improvements, and tighter process controls, has experienced a continual decrease in reportable conditions. As the requirements for identifying reportable conditions has remained unchanged and the noted trend understood, no corrective action is under consideration at this time. The RSRM Project is extensively involved in postfire data evaluation and trending. The postfire anomaly data base and trending data bases extend the requirements for documentation to an additional level of detail. Although the problem reporting frequency to PRACA has decreased over time for the RSRM Project, the intensity and detail of the postfire evaluation and potential problem tracking has not diminished. The SSME Project has seen a decline since 1993and ascribes this in part to clarifications in 1993, 1998, and 1999 of their PRACA problem reporting criteria (the Unsatisfactory Condition Report (UCR)). The SSME Project attributes most of the downward trend to block engine improvements and effective response to issues and problems. The data on UCR's can be sorted by failure type and by component to a high degree of granularity, substantiating that their decline is attributed to effective implementation of

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				corrective actions. The SSVEO reviewed the decline in their PR's and attributes this to several legitimate factors. In 1994, KSC GO was authorized to use FW&T specifications, which allows acceptance of "cosmetic nonconformances" without remedial action and the attendant PR. There has also been a series of Memorandums of Understanding (MOUs) implemented for the SSVEO to reduce the number of problems reported to the design Center. These are utilized by the SSVEO technical community to document certain types of recurring hardware problems that are well understood by the design team and for which some type of corrective/remedial action has already been identified and approved. Both FW&T specifications and MOU implementation correlate with a corresponding decline in PR's. The SSVEO also cites that vehicle level testing has been reduced with each revision to the Operations and Maintenance Requirements and Specifications Document (OMRSD). As vehicle design, configuration, and processing techniques have matured, less modifications are being performed resulting in less overall problems. The SSVEO has initiated an internal study of the incoming PRs to determine if there is a significant reduction from any one of the reporting sites that would indicate where the reduction is primarily

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				originating. This study will be completed by September 2000. The PET is also investigating this issue across all the elements and will verify these initial assessments and recommend process changes if deemed necessary. It should be noted that with the observed decline in PRACA PRs, there has also been a corresponding reduction of inflight anomalies (IFA), which would indicate to the SSP an overall improvement of the Space Shuttle system.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-9:** The root cause(s) for the missing problem reports from the Problem Resolution and Corrective Action system concerning Main Injector Liquid Oxygen Pin ejection, and for inconsistencies of the data contained within the existing problem reports should be determined. Appropriate corrective action necessary to prevent recurrence should be taken.	**SSP Response (Abbey/Dittemore, 21 June 2000):** A detailed search and review of the PRACA data base revealed 10 of the 12 engines that experienced ejection of liquid oxygen (LOX) post pins were documented in PRACA. The two omissions (engine 0006 in 1980 and 0110 in 1981) occurred before the baseline release of PRACA system requirements in 1982. The limited search capability in PRACA hindered the SIAT's ability to perform a comprehensive search. Criticality categorization differences assigned to SSME PRs (known as UCRs) and differences in interpretation of the event by the report generator contributed to the inconsistency observed in the finding. One interpretation assigned criticality based on the consequences associated with failure of the LOX post that was pinned (criticality 1 or 1R) and not the observed consequences of the LOX post pin ejection (benign or criticality 3). Rocketdyne has a handbook on UCR procedures and conducts

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				training and monthly audits of the system. The UCR form has evolved over time with additional fields created to standardize part identification and failure source. The UCR handbook and the training will be revised to ensure coding consistency and the form will be reviewed to consider if additional fields could further clarify and standardize the information recorded. The PET is also addressing advanced software improvements and data base management techniques that will aid consistent, complete data entry and enhance the search/trending capabilities of PRACA..
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-10:** A rigorous statistical analysis of the reliability of the problem reporting and tracking system should be performed**.**	**SSP Response (Abbey/Dittemore, 21 June 2000):** After discussions with the author of this recommendation, Dr. Tina Panontin, a plan was developed for a rigorous statistical sampling of the problem reporting and tracking system. A statistically significant sample of PRs (~900 total) spanning the last 5 years for the vehicle, Government furnished equipment, MSFC, and KSC PRACA systems will be analyzed by the JSC, MSFC, and USA quality organizations. A standardized statistical methodology will be developed to assure consistent analysis across the PRACA systems. The corrective actions applied to the sampled reports will be evaluated for effectiveness and any errors found in the review will be categorized and assessed for significance. The plan to accomplish this

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				will be presented to the PRCB in 2 months
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-11:** Reporting requirements and processing and reporting procedures should be reviewed for ambiguities, conflicts, and omissions, and the audit or review of system implementation should be increased.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The SSP established a PET in February 2000. The team includes members from all SSP elements, projects, the SSP Office, and the Ames Research Center (ARC). The PET addressed this recommendation, as well as the findings from all PRACA audits completed over the past year. A review of program-level requirements has been completed. The revised requirements will be published in September 2000. All SSP project and element offices will follow up with a review of their PRACA requirements and processes to ensure compliance with the revised SSP requirements. The PET provides periodic status to the program at the PRCB. In addition to completing the PRACA requirements review, the PET will determine appropriate changes to improve the software systems for data entry, trending, and analysis. This PET will investigate utilizing state-of-the-art data base designs and techniques. To support this effort, the ARC established a pilot project investigating improved PRACA system automation and state-of-the-art data base design. Software upgrade review and implementation is schedule for completion in August 2001.

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Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-12:** The SSP should revise the Problem Resolution and Corrective Action database to include integrated analysis capability and improved problem classification and coding. Also, improve system automation in data entry, trending, flagging of problem recurrence, and identifying similar problems across systems and sub-systems.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The SSP established a PET in February 2000. The team includes members from all SSP elements, projects, the SSP Office, and the Ames Research Center (ARC). The PET addressed this recommendation, as well as the findings from all PRACA audits completed over the past year. A review of program-level requirements has been completed. The revised requirements will be published in September 2000. All SSP project and element offices will follow up with a review of their PRACA requirements and processes to ensure compliance with the revised SSP requirements. The PET provides periodic status to the program at the PRCB. In addition to completing the PRACA requirements review, the PET will determine appropriate changes to improve the software systems for data entry, trending, and analysis. This PET will investigate utilizing state-of-the-art data base designs and techniques. To support this effort, the ARC established a pilot project investigating improved PRACA system automation and state-of-the-art data base design. Software upgrade review and implementation is schedule for completion in August 2001.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-13:** All critical data bases (e.g., waivers) need to be modernized, updated and made more user friendly.	**SSP Response (Abbey/Dittemore, 21 June 2000):** An activity to convert critical data bases from the mainframe environment to web based user interfaces was initiated in FY98. The SFOC ADAM Data Warehouse is

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				ADAM Data Warehouse is being utilized as the central repository using a web-based interface for searching and retrieving critical data. Currently, the SSP PRACAs, IFAs, critical hardware list, hazard reports, and time/age/cycle applications are completed and data are refreshed at least every 24 hours. The waivers, Space Shuttle integration accounting status system, launch commit criteria (LCC), and ClL will be incorporated into ADAM by December 2000. The completion of this activity will result in the data bases being updated and more user friendly.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-14:** There are a number of cryogenic fluid mechanical joints and hot-gas mechanical joints that represent potential risks that should therefore be examined in detail.	**SSP Response (Abbey/Dittemore, 21 June 2000):** All cryogenic and hot gas joints currently receive extensive and continuing attention. This attention comes in the form of inspections, leak checks, problem trending, statistical process control (SPC) evaluation, and root cause problem resolution. The end result is that all hot gas and cryogenic joints are carefully monitored and controlled to ensure that the configuration flying is identical to that certified. Processes, inspections, and trending are in place to ensure proper installation and proper configuration. Furthermore, the projects have and are enhancing monitoring to identify trends in joint performance and manufacture before the trend becomes a problem. The Space Shuttle uses a variety of hot gas and

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				cryogenic joints. Many of these joints are not disturbed from flight to flight; a very small number are replaced with each launch. All joints were recertified during return to flight. A rigorous technical review, a review by the program manager, and a structured approval process assure modifications to the certified configuration receive proper engineering and management attention. Final approval for changes is received at the PRCB. There have been no significant changes to these systems from that certified for return to flight. The process for management review is documented in the NSTS 07700 documents. The SSP PRACA system is used to record and trend problems associated with Space Shuttle hardware including the hot gas and cryogenic joints. For all elements of the vehicle there has been no adverse or unusual problem activity associated with hot gas or cryogenic joints. All problems are reviewed in detail at the project level for trending and root cause solutions. For each flight, the entire vehicle, including the hot gas and cryogenic joints, undergoes comprehensive checkout and flight preparation as outlined in the OMRSD. The OMRSD and LCC are under program configuration control to assure appropriate and consistent testing of all equipment before launch. Testing and checkout of the

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				joints are different depending on the particular system but include inspections, pressure checks, hot fires, and leak tests as appropriate. The SSP, as well as the individual elements, employs a system of audits and inspections that ensure new hardware is manufactured in accordance with the requirements. While most of the cryogenic and hot gas joints are not changed on a routine basis, some very critical joints are new for each flight. It is very important that process drift or other inadvertent changes do not result in changes to the certified configuration of the joints. SPC, inspections, and process audits are routinely accomplished and reviewed to identify process changes or out of family occurrences and assure component compliance with engineering requirements. Each of the elements was asked to review their program for any unique criteria associated with their joints. The SSVEO has undertaken an effort to review all orbiter main propulsion system (MPS) and power reactant storage devices CILs. The intent is to ensure that failure modes are still accurate and that CIL retention rationale is still valid. All problems are documented in PRACA. The only significant PRACA entries concerning MPS leaks were associated with hydrogen leaks resulting in the scrub of STS-35 and STS-38 (1990). These problems resulted in an improvement to

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				the 17" disconnect components and have resulted in significantly reduced instances of "measurable hydrogen leakage. The SSME Project uses a fleet leader process so that flown configurations never exceed 50 percent of the fleet leader experience. Engines to be flown are first run in their final configuration. In addition, the engines undergo an extensive array of leak testing to ensure joint integrity. Routine inspections are accomplished to assure manufacturing compliance with engineering specifications. SPC is used in the manufacturing process to identify trends and out of family hardware. The RSRM Project performs extensive examination of the postflight performance of the joints within the motor. Reused components undergo extensive nondestructive evaluation (NDE), proof testing, and inspection to ensure that the components still satisfy engineering requirements. The entire refurbishment and build process undergoes an annual NASA Engineering Quality Audit (NEQA) to assure process integrity. SPC is one of the tools used to monitor and highlight changes in the build process. Independent review teams are used to review process and out of family occurrences. The SRB Project has only hot gas joints associated with the hydraulic power unit. These

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				joints undergo visual inspections and pressure decay tests to identify any leakage. Each new configuration is hot fired in its flight configuration to assure joint integrity. Routine management review of trends and problems is used to identify areas for special attention. The ET Project has a process that reports nonconformances and problems to the management level for review and action. SPC is currently in place at some areas within the assembly process but is being more fully implemented even at the subcontractor level.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-15:** All internal Foreign Object Debris (e.g., pins) occurrences during the program should be listed, with pertinent data on date of occurrence, material, and mass. The internal Foreign Object Debris FMEA/CILs and history should be reviewed and the hazard categorized based on the worst possible consequence.	**SSP Response (Abbey/Dittemore, 21 June 2000):** To address this recommendation, Rocketdyne reviewed SSME design-generated foreign object debris (FOD). The design FOD analysis accounts for some degree of normal wear and tear, postulates internal sources such as breakage or loose pads, and analyzes the ensuing consequences. As stated by SLAT, Rocketdyne has an aggressive FOD-prevention program at their manufacturing and assembly plant that addresses other FOD sources. After reviewing all design-senerated FQD in the program history (169 analytical cases), all had the correct failure modes and effects analysis (FMEA)/CIL and hazard assessment. All engine components were reviewed and a data base was created that includes FOD source, failure date, material, mass, disposition, FMEA/CIL or hazard reference, correct

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				criticality assigned (yes/no), and a descriptive comment. All UCRs and material reports were reviewed for design-generated FOD and documented in this data base (over 1,000 entries). Every reported occurrence of FOD in the program requires the original analysis to be expanded and continually adds to the FOD knowledge base.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-16:** Any type of engine repair that involves hardware modification - no matter how minor (such as liquid oxygen post pin deactivation) - should be briefed as a technical issue to the program management team at each Flight Readiness Review. The criticality of a standard repair should not be less than basic design criticality, based on worst-case consequences, and all failures of standard repairs should be documented and brought to the attention of the Material Review Board.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The SSP requires all projects to control report, and review significant modifications, repairs, and process changes. The requirements are contained within the various volumes of NSTS 07700 and referenced documents, namely, Volumes IV and Xl; MVP 01; NSTS 08117; and NSTS 5300.4(1D-2) are the primary sources. These requirements can generally be categorized into information required at program reviews, configuration management (CM), and hardware nonconformance. To address program review requirements, NSTS 08117, Requirements and Procedures for Certification of Flight Readiness, requires that each participating project element identify changes since the last mission at each of the program milestone reviews. There is also a generic requirement for all elements to identify significant changes to the configuration baseline, including vehicle servicing and hardware manufacturing critical processes.

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				The program requirements for CM are defined in NSTS 07700, Volume IV, Book 1, Revision K, Configuration Management Requirements. This document defines the requirements, responsibilities, and procedures for all SSP elements/projects in the application of CM. The requirement for acceptance baseline configuration descriptions states that baseline configuration description shall describe and identify the as-designed configuration with exceptions that reflect the as-built and accepted configuration of an end item. Differences between the as-designed configuration and the as-built configuration must have NASA approved deviations or waivers or PMRB dispositions. Any changes to the acceptance baseline configuration must have the approval of the SSP or delegated program element/project. Configuration control of accepted flight hardware/software, including delegated authority, is defined in Volume IV. After a baseline is established, the process precludes any unauthorized configuration changes to that baseline. A procedure is defined to ensure that each proposed change to the baseline is completely described (including impacts); is thoroughly coordinated, reviewed, and evaluated; and is authorized and implemented in an approved manner. Additional requirements can be found in

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				NSTS 07700, Volume XI, System Integrity Assurance Plan. Generally, hardware repairs that are not returned to print are defined as a baseline nonconformance. Modifications can be defined as baseline configuration changes. The difference between the two is that a modification is a revision to the baseline and a nonconformance is a restricted/limited deviation from the baseline and, based on predetermined screening criteria, may require program approval. Hardware nonconformances are regulated by two program documents. NSTS 5300.4(1 D-2), Section 1D506, provides for repair or dispositio n of nonconforming hardware prior to Government acceptance. After acceptance by the Government, NSTS 07700, Volume IV, Book 1, Revision K, Configuration Management Requirements, Paragraph 4.3.2.9, Space Shuttle Material Review System, is the controlling document. Both documents require the establishment of a material review (MR) process. However, the NSTS 5300.4(ID-2) MR process does not require elevation of nonconformances to the program. It does require elevation to the NASA contracting officer based on specific criteria. For Government-accepted hardware, the Volume IV, Book 1, MR process includes criteria for MR dispositions of

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				nonconformances that must require program approval by the delegated configuration control board which is the PMRB. The SSP also delineates criteria for elevating a nonconformance beyond the PMRB to the PRCB.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-17:** The design and the post Solid Rocket Booster recovery inspection and re-certification for flight should be looked at and analyzed in careful detail by follow-on independent reviews.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The SRB Project has recently accomplished a NEQA. The RSRM Project conducts annual NEQAs at the prime contractor's facility and recently completed an audit in August 2000. These sessions cover a broad range of topics, including the design, recovery, and recertification process. In addition, the RSRM Project has pursued additional independent assessments on this same subject by teams comprised of senior level retired experts from industry and NASA with no significant issues identified. Finally, both projects are presently in the formulation process of establishing independent review teams to accomplish SIAT-type reviews on the individual projects. Team members will again be senior people having extensive knowledge and background experience relative to both Space Shuttle and SIAT-type reviews.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-18:** The inspection and proof-test logic to screen for flaws or cracks in the Super-Light-Weight Tank should be reviewed in light of the reversal in fracture-stress-against-flaw-size between room and cryogenic temperatures.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The super-lightweight tank (SLWT) parent material and welds are made of 2195 aluminum-lithium alloy. The proof test and nondestructive test (NDT) logic used to screen for flaws or cracks in aluminum 2195 was

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				extensively reviewed and accepted by a number of independent review teams. The logic was thoroughly reviewed and approved by the NASA MSFC Fracture Control Board with assistance from experts at other NASA Centers and industry. This topic was also a primary focus of the 1996 ASAP review of the ET Project. An independent verification team, a design certification review board, and the ASAP all concurred that the logic to certify and accept the SLWT was adequate, with full knowledge of the reversal phenomenon. The ET Project discussed the concerns cited in the SIAT report with SIAT member, Dr. James Newman of the NASA Langley Research Center. After this review, and based on the extensive previous reviews, all participants are confident in the NDT and proof test logic used to assure mission success on the SLWT.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-19:** The SSP should explore the potential of adopting risk-based analyses and concepts for its critical manufacturing, assembly, and maintenance processes, and statistical and probabilistic analysis tools as part of the program plans and activities. Examples of these analyses and concepts are Process FMEA/CIL, Assembly Hazard Analysis, Reliability Centered Maintenance, and On Condition Maintenance.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The SSP utilizes numerous analytical techniques and processes to determine and manage risk. Program requirements contained within NSTS 07700 specify the use of analytical methods in all aspects of program execution. SPC, process FMEA, hazard analysis, reliability centered analysis, and other techniques are implemented to various degrees across all program elements. The SSP has continued to explore the potential adaptation of various

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				quantitative risk analysis (QRA) processes. The System Safety Review Panel, with representatives from all program elements and safety, reliability, and quality assurance organizations, will review current probabilistic risk assessment/QRA techniques being utilized and determine an approach which maximizes value to risk management. The development of a QRA program standard and an implementation approach will be provided in the February 2001 timeframe. This will include methods of CM of integrated models, interface responsibilities, technical/managerial review processes, and processes for determining threshold decisions. With this information, a final evaluation of value-added will be conducted and the final recommendation presented to the SSP PRCB by April 2001.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-20:** Failure analysis and incident investigation should identify root cause and not be artificially limited to a sub-set of possible causes.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The SSP history demonstrates extensive experience and success in the conduction of failure analysis. These analyses are typically driven to the lowest practical level of potential cause for review. However, the SSP has taken steps to ensure that training syllabuses associated with failure analysis and root cause analysis have had increased emphasis placed on the importance of thorough root cause determination. Within the last year, SSP management level, team lead level, and analyst level personnel have attended root cause analysis training. The majority of contractor

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				employees have also received similar training as part of their ISO certification process. The SSP will verify that program elements have received root cause and failure analysis training by December 2000. Emphasis on accuracy of root cause analysis and clarification of the definition of cause at the lowest level responsible for the problem are being incorporated within the current revision to NSTS 08126 (SSP PRACA requirements) which is planned to be implemented by November 2000.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-21:** Software requirements generated by Shuttle system upgrades must be addressed.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The SSP believes it is meeting the intent of this recommendation. For each new Space Shuttle system upgrade, a review of existing software systems will continue to be accomplished to ensure the proper tradeoffs are performed to correctly integrate the new systems into the existing Space Shuttle architecture. All software modifications will utilize the mature, proven processes that have delivered safe, robust flight software in the past. Software changes identified will be scheduled for implementation, verification, and installation in a timeframe consistent with the installation date of the new Space Shuttle system upgrades. Workforce augmentation and training are planned to support upgrade driven software development, minimizing impact on the current operational software efforts. The SSP is assigning the responsibility for management of these internal software requirements to the appropriate upgrade project's

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				organization. The SSP is confident that this approach will address upgrade driven software modifications without adding undue risk to the program or crew.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-22:** Enhanced software tools should be considered for potential improvements in reliability and maintainability as systems are upgraded.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The SSP will continue to implement reliability and maintainability enhancements through the use of new/revised software tools and methods both to existing systems and in new platforms. The Space Shuttle flight operations contractor's standard software maintenance processes continually evaluate process improvements, including enhanced custom tools and COTS tools through formal methods. Recent improvements include conversion of data bases from hierarchical to relational, special risk analysis tools/methods, and reconfiguration data generation enhancements. As part of the cockpit avionics upgrade (CAU), the flight software contractor (USA) is examining current processes, procedures, and tools for potential improvements in productivity while maintaining or improving reliability and maintainability. Specifically, CAU is evaluating COTS real time operating systems, software development environments, and display generation tools for use in, and development of, the new command and display processor flight software. The SSP is confident that the use of these COTS products will improve reliability and maintainability without adding risk to the

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				program.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-23:** An assessment of using lower fatigue-crack-growth thresholds and their impact on fracture critical parts or components needs to be reviewed to establish life and verify the inspection intervals. Retardation and acceleration model(s) should be used to assess the type of crack-growth history under the Orbiter spectra.	**SSP Response (Abbey/Dittemore, 21 June 2000):** NASGRO fracture mechanics analysis is the methodology and computerized tool used for all vehicle life predictions and inspection intervals. The crack growth threshold is a test derived quantity that is one of many terms in the NASGRQ crack growth equation. The NASGRO crack growth rate equation has a number of empirical coefficients, including the crack growth threshold, which is derived so that the equation matches test data. The current NASGRO equation obtains its threshold values according to the standard American Society for Testing and Materials methods. After incorporating the threshold value into the NASGRO equation, the other empirical parameters are derived to conservatively fit the material test data. If the crack growth threshold was lowered, then the other four parameters would be adjusted accordingly to still conservatively fit the material test data. Comparing the new version versus the current version of NASGRO, both would yield nearly identical results for the exact material test data. Retardation and acceleration were intentionally omitted from the NASGRO analysis to provide a more conservative prediction for

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				the vehicle application. The two occur together and are interrelated. Retardation (beneficial to life) is the dominant effect in aerospace applications and will be in effect on a larger number of the cycles than will acceleration. Aerospace industry experience has confirmed that ignoring retardation/acceleration is conservative. Aircraft users of NASGRO have stated that their designs could not tolerate the conservatism of the nonretardation version used on the vehicle. The SIAT concurred that for most aircraft spectra, omitting acceleration is conservative. Flight data have verified that the vehicle spectra is similar to other aircraft spectra and, therefore, does nothave any extreme ordering of cycles that would make it an exception. There has been more than 20 years of NASGRO experience in worldwide applications including the U. S. Navy, the U. S. Air Force, Boeing, Lockheed Martin, Grumman, Sikorsky, Raytheon, and United Technologies Corporation, all with no indication of under-conservative predictions. The SSVEO has high confidence in the current approach used to apply NASGR© analysis to vehicle structural life.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-24:** Assessments of the impact of any new Orbiter flight loads on structural life should continue as responsibility for the Orbiter structure is transferred to the contractor.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The JSC Engineering Directorate, Structures and Mechanics Division (SMD) will actively participate, in a leadership role, in any new design loads cycle for the

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				orbiter. An example of this type of activity would be the recently completed performance enhancement program, which significantly changed orbiter loads during ascent. These changes effected loads, stress, and structural life certification. In addition, SMD will routinely monitor and review the annual Structural Life Tracking Report produced by USA/Boeing to ensure that the orbiter continues to be operated within the certified boundaries for mission life certification. The Structural Life Tracking Report, Boeing document RSS99D0510A, tracks key structural parameters from mission to mission for each orbiter and is published for review every year.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-25:** The Orbiter Corrosion Control Review Board should consider incorporating the framework suggested by the Federal Aviation Administration for Corrosion Prevention and Control Plans of commercial airplane operators into their corrosion database to provide focus to the more serious occurrences of corrosion.	**SSP Response (Abbey/Dittemore, 21 June 2000):** A review of typical corrosion prevention control plans (CPCPs) (DC-9/MD-80/747) revealed that the SSVEO covers the intent of this document by other methods. A CPCP defines corrosion levels as 1,2, or 3, with the requirement that all level 2 or 3 corrosion be reported to manufacturer: Level 1: Corrosion can be repaired within allowable limits SSVEO: Repaired by Standard Repair Procedure (SRP) Level 2: Corrosion is widespread or repair exceeds design limits SSVEO: Requires

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				MR activity; Reported to Corrosion Control Review Board (CCRB) Level 3: Corrosion is a potential airworthiness concern SSVEO: Elevated to Flight Readiness Review special topic A CPCP establishes areas to be inspected, inspection intervals, methods of inspection, methods of repair, and methods for reapplication of corrosion protection. Similarly, the SSVEQ relies on orbiter maintenance and requirements specifications, orbiter maintenance instructions, SRPs, and any resulting PR/MR documentation. The Federal Aviation Administration (FAA) requires that manufacturers and operators maintain a data base showing location of corrosion (level 2 or 3), the parts affected, and the cause of the corrosion. The SSVEO utilizes the PRACA data base that includes all PR/MR activity for corrosion found on the orbiter fleet. In 1996, KSC representatives of the CCRB built a data base by searching for and pulling the pertinent items from the PRACA data base that covered the time period of 1983 through 1996. The CCRB has initiated another PRACA search to update their data base, and this activity

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				should be completed by September 2000. The CCRB also maintains a corrosion data base on a NASA website that includes all significant issues reviewed by the CCRB. The SSVEO meets the recommendation with their existing mechanisms and procedures in place to satisfy the intent of a CPCP, which is to ensure that inspection and maintenance activities are sufficient to support flight safety.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-26:** Hidden corrosion problems require a proactive inspection program with practical and reliable non-destructive evaluation techniques; at this point, this inspection is done on a randomized basis. An assessment of the impact of hidden (or inaccessible) corrosion and the repairs of identified corrosion on the integrity of the Orbiter structure should to be made.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The SSVEO employs a rigorous, systematic, proactive inspection program. The OMRSD specifies areas to be inspected, inspection frequency, and inspection methods. The probability of hidden corrosion under the thermal protection system is considered to be extremely remote. Room temperature vulcanized material has been proven by test and experience to provide an excellent barrier against moisture. However, hidden corrosion in inaccessible areas continues to be a concern. The forward fuselage plenum is a prime example of this difficulty and recent discovery of significant corrosion on OV- 102 Xo 582 frame highlights this problem• An assessment of structural risk in the areas of corrosion found generally high tolerance for corrosion damage in the forward fuselage area. Various new (or improved) NDE techniques are constantly emerging. Promising NDE techniques include enhanced ultrasonic

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				and eddy current techniques, reverse geometry x-ray, and others. However, virtually all techniques require some direct access to the target area. To ensure that the SSVEO is utilizing the full capability of the available NDE technology to address the issue of hidden corrosion, Boeing is establishing a Structures/NDE Task Team to investigate possible methods for inspecting inaccessible areas. The task team will be chartered to identify structural areas currently considered inaccessible, determine which areas warrant further study (based on low margins), investigate possible NDE methods, and attempt to validate the technology at Palmdale during the next orbiter major modification. Where corrosion has been identified, the integrity of the repaired structure is verified via the PRIMR process. SRP or MR documentation defines procedures for removing corrosion using methods that will not damage the material for verifying the dimensions of the repaired area and for restoring the required corrosion protection. Stress analysis " verifies that the remaining material is sufficient or that further repairs (doublers) are required. If appropriate, design changes implemented as corrective action and corrosion prevention compounds are employed. The SSVEO meets the recommendation with existing processes to address general inspection and repair issues and by initiating a task team to address the inaccessible corrosion issue.

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Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-27:** Current wire inspection and repair techniques should be evaluated to ensure that wire integrity is maintained over the life of the Shuttle vehicles. Several new inspection techniques are available that use optical, infrared, or electrical properties to locate insulation and conductor damage, and should be explored for use on the Shuttle.	**SSP Response (Abbey/Dittemore, 21 June 2000):** BRSS and the orbiter electrical wiring (OEW) PRT have reviewed orbiter wiring inspection and repair techniques. A new course was developed for all avionics personnel to address wiring inspection and repair methodologies. New repair techniques have been developed, and existing repair methodologies were reviewed and upgraded where necessary. BRSS proposed a plan to the SSVEO Vehicle Engineering Control Board to examine existing and emerging test methods and associated equipment for testing wire integrity. BRSS will work with vendors and developers to determine the effectiveness of test equipment in categorizing damage conditions and identifying degraded insulation properties due to aging wiring. Special consideration will be given to the ability of the test equipment to be used in the vehicle with a minimum of intrusiveness. Additionally, the ARC recently completed a Wire Integrity Research (WIRe) Pilot Study that addressed automated verification and validation of vehicle wiring configuration and automated condition assessment for maintenance. SSVEQ approval of the BRSS plan is pending the recommendations of the Ames WIRe Pilot Study that are expected at the end of August 2000. These two studies will contribute to the continued effort to ensure wire integrity across all the SSP elements.

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Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-28:** All CRIT 2 circuits should be reviewed to determine to what extent redundancy has been compromised in wiring, connectors, electrical panels and other electrical nexus points. The primary concern is that single point failure sources may exist in the original design or have been created by system upgrades or modifications.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The SSVEO has initiated several actions since the STS-93 wiring problem to address wiring redundancy issues. Design changes are being implemented to eliminate single wire criticality 1/1 functions. A risk ranking of electrical criticality 1R2 items for nominal flight and criticality 1/1 items for aborts is being performed to assess which should be targeted for correction first. Interim design solutions are being developed to protect criticality 1R wires and eliminate critical redundancy routing Violations in the fleet. The 1994 Wire Redundancy Separation Study is being updated to include design changes that have occurred since the initial study and assess routing violations for criticality 1/1 conditions. Since criticality 2 circuits do not cause loss of crew or vehicle by definition, they are lower in priority to the 1/1 and 1R2 circuits. The compared criticality criticality SSVEO believes the highest priority is to rectify the compromised redundant criticality 1/1 and criticality 1R2 circuits and will, therefore, continue to focus on the assessment and the implementation of those associated wiring modifications. In the future, when it becomes feasible, the SSVEO will perform an assessment of the criticality 2 and criticality 2R circuits, and based on the results of the assessment, appropriate design changes will be

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				implemented.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-29:** The Shuttle program should form a standing wiring team that can monitor wire integrity and take program wide corrective actions. The team should include technicians, inspectors, and engineering with both contractor and government members. The chair of the team should have direct accountability for the integrity of the Shuttle wiring. One area that should be evaluated is the techniques conductor that has not yet developed into an electrical short.	**SSP Response (Abbey/Dittemore, 21 June 2000):** The OEW PRT has recently been expanded to include additional NASA and contractor representation from the orbiter community. The position of project manager for orbiter wiring has been established and is authorized to direct the PRT tasks. Status is given weekly to the SSVEO. KSC has been tasked by the SSP to expand the scope of the PRT to include all flight elements. A formal charter will be developed with program reporting requirements defined and membership expectations outlined. The OEW PRT is responsible to monitor all orbiter wire integrity issues and recommend corrective actions. The primary emphasis is on process controls, clarification of specifications, preventative wire protection (vehicle and ground support equipment), repair methodology, and wiring installation/modification concerns. This scope will be expanded to cover the entire SSP wiring community. To remain proactive, the SSP provides representation at the Aerospace Wiring and Inert Gas Generator Meetings that address issues with wire integrity across the aerospace industry. The orbiter wiring inspection process was

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				presented at the annual joint Department of Defense/FAA/NASA conference on aging aircraft. NASA ARC is conducting a wire study for the SSP, and BRSS is currently conducting tests to evaluate new inspection equipment that will assist in the detection of potential short circuits. The SSP is also planning updates to program wiring specification, inspection, maintenance, and repair documents to ensure recurrence is minimized.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3I-30:** The long term use of primarily polyimide wiring should be minimized, and wire insulation constructions that have improved properties should be evaluated and compared to the current wire insulation used on the Shuttle program. Alternate wire constructions should be considered for modifications/repairs/upgrades. There are several aerospace wire insulation constructions that can provide more balanced properties.	**SSP Response (Abbey/Dittemore, 21 June 2000):** BRSS performed a study of new wire insulation for potential vehicle uses. Testing was performed over a wide range of criteria comparing vehicle Kapton (polyimide) wiring with six other aerospace wire constructions. After reviewing the test results, the engineering and safety community concluded these alternate wire constructions did not surpass the overall performance of the vehicle's current Kapton wiring. The SSP plans to continue using Kapton insulated wire for vehicle harnesses based on its superior test performance but will continue to evaluate new wiring constructions as they are introduced to the aerospace community.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3L-1:** Where redundancy is used to mitigate risk, it should be fully and carefully implemented and verified. If it cannot be fully implemented due to design constraints, other methods of risk mitigation must be utilized.	**SSP Response (Abbey/Dittemore, 23 October 2000):** The Space Shuttle Program (SSP) reviewed all documentation pertaining to redundancy requirements for flight, payload, and ground support hardware and software. This

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				review verified that the requirements appropriately specify the method for identifying critical functions and hazards, the level of redundancy required to mitigate identified risks, the verification required of the redundancy approach, and the process to address risks that cannot be fully mitigated with redundant design. Every SSP element was involved in this review effort, confirming redundancy awareness and compliance across the program. These program level requirements and associated project level documents are kept current by a formal annual review and audit process. Once risks have been characterized and redundancy measures implemented into the design, a verification of their functionality is necessary. The process for ensuring proper implementation and certification is defined in the Space Shuttle Master Verification Plan. Redundant functional paths or subsystems are designed so that their operational status can be verified prior to each installation into the vehicle or during ground turn-around without removal of line-replaceable-units. Each element defines their system redundancy verification requirements in the Operations and Maintenance Requirements and Specifications Document, and subsequently verifiesthat the requirements have been correctly implemented into technical work instructions. Successful execution of these

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				work instructions for each Space Shuttle mission is verified at the Flight Readiness Review (FRR) via the Certificate of Flight Readiness (CoFR) process. For those situations where resources and design constraints do not permit the full implementation of redundancy requirements, other methods of risk mitigation are utilized per the hazard cause reduction precedence. The risk of hazard is either eliminated by appropriate design measures, prevented by use of safety devices, controlled by use of warning devices, or avoided by using special procedures. Furthermore, critical functions are required to be separated, protected from failure from similar causes, able to be isolated without disrupting redundant functions, and able to be fault-isolated without disconnections. To ensure compliance with all these requirements, the SSP formally directs every element to submit proposed hardware/software changesthat impact baselined program risk, redundancy, or certification requirements to the Program Requirements Control Board (PRCS) for disposition prior to implementation. Hardware or software configuration or performance that deviates from baselined requirements must be submitted by the design element on a waiver for program consideration. A waiver documents the technical rationale for flight

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				acceptability and effectivity, is dispositioned by the PRCB, and, if approved, is subsequently reviewed at the FRR per CoFR requirements.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3L-2:** Serious consideration should be given to replacing the hydrazine power unit with a safer and easier to maintain advanced electric auxiliary power unit for the Thrust Vector Control hydraulic unit.	**SSP Response (Abbey/Dittemore, 23 October 2000):** NASA, United Space Alliance (USA), and Boeing-Reusable Space Systems (BRSS) are working to develop and implement an electric auxiliary power unit (EAPU) to replace the existing hydrazine auxiliary power unit. The overall objectives of the EAPU are to: • Reduce auxiliary power unit (APU) contribution to orbiter catastrophic risk from 30 percent to less than 5 percent. • Reduce APU criticality 1 items and hazards by more than 50 percent. • Increase APU system reliability by at least two orders of magnitude. • Reduce planned APU maintenance operations by more than 50 percent. The phase I feasibility study is complete and the phase II prototype development is in work. The development of phase III preliminary flight hardware is in the process of being authorized.
Space Shuttle Independent Assessment Team	7 March 2000		**Recommendation 3L-3:** Due to obsolescence, Shuttle Reaction Control System propellant valves and propellant flight-half couplings should be	**SSP Response (Abbey/Dittemore, 23 October 2000):** A BRSS study identified an improved reaction control system (RCS)

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(NASA Charter)			replaced with ones that are more tolerant of the oxidizer environment.	pilot operated valve (POV) and received approval from the NASA Space Shuttle Vehicle Engineering Office (SSVEO) to begin qualification testing. The improved POV is designed to be more tolerant of oxidizer-derived contamination by reducing the poppet cage contact area and increasing propellant flow through. The pilot poppet, pilot seat, and main seat materials were also changed to a more corrosion resistant stainless steel. The qualification program will be completed in early 2003, and implementation will be on an attrition basis. The qualification program for the redesigned 1Ainch and _ inch orbital maneuvering system and RCS air-half couplings is complete and certification approval was received from the SSVEO. The redesigned flight-half couplings were made more tolerant of oxidizer-derived contamination by reducing the sliding surface area and changing the poppet material from stainless steel to titanium. Oxidizer exposure tests verified the redesign measures. The redesigned parts will be installed on an attrition basis.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3L-4:** The Problem Resolution and Corrective Action system should be revised using state-of-the-art database design and information management techniques.	**SSP Response (Abbey/Dittemore, 23 October 2000):** The SSP established a Problem Reporting and Corrective Action (PRACA) Evaluation Team (PET) in February 2000. The team includes members from all SSP elements, projects, the SSP Office, and the Ames Research Center (ARC). The

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				PET addressed this recommendation, as well as the findings from all PRACA audits completed over the past year. A review of program-level requirements has been completed. The revised requirements will be published in September 2000. All SSP project and element offices will follow up with a review of their PRACA requirements and processes to ensure compliance with the revised SSP requirements. The PET provides periodic status to the program at the PRCB. In addition to completing the PRACA requirements review, the PET will determine appropriate changes to improve the software systems for data entry, trending, and analysis. This PET will investigate utilizing state-of-the-art data base designs and techniques. To support this effort, the ARC established a pilot project investigating improved PRACA system automation and state-of-the-art data base design. Software upgrade review and implementation is schedule for completion in August 2001.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3L-5:** Inspection technique(s) for locating corrosion under the tiles and in inaccessible areas should be developed. Inspection	**SSP Response (Abbey/Dittemore, 23 October 2000):** BRSS has established a structures/nondestructive evaluation (NDE) task team to investigate possible methods for inspecting inaccessible areas on the orbiter. The task team is chartered to ensure that the SSVEO is utilizing the full capability of the available NDE technology to address the issue of hidden corrosion. The team will identify structural areas

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				currently considered inaccessible, target the low margin areas for further study, investigate possible NDE methods, and attempt to validate the technology at Palmdale during the next orbiter major modification. Various new or improved NDE techniques are constantly emerging. Promising NDE techniques include enhanced ultrasonic and eddy current techniques, reverse geometry x-ray, and others. However, virtually all techniques require some direct access to the target area. The probability of hidden corrosion under the thermal protection system is considered to be extremely remote because room temperature vulcanized material has been proven by test and experience to provide an excellent barrier against moisture.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3L-6:** Consideration should be given to modifying the Shuttle internal hydraulic line routing to the mold line to permit efficient facility hydraulic hose connections.	**SSP Response (Abbey/Dittemore, 23 October 2000):** The SSVEO authorized BRSS to design the relocation of the orbiter hydraulic ground servicing quick disconnects (QD) and landing gear extend/retract QDs to a new panel at the mold line. The modification eliminates the need to carry hydraulic ground servicing equipment into the aft compartment, thereby, reducing potential orbiter damage and improving vehicle turnaround time. The design has progressed through a preliminary design review and BRSS will come to the Vehicle Engineering Control Board (VECB) in October 2000 for implementation approval. Implementation will begin in November 2001, and

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				all vehicles will be modified by February 2002.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3L-7:** Non-intrusive methods of reliably detecting wiring damage should be developed, including those areas no accessible to visual inspection.	**SSP Response (Abbey/Dittemore, 23 October 2000):** BRSS has proposed a plan to the VECB to examine existing and emerging test methods and associated equipment for testing wire integrity. BRSS will work with vendors and developers to determine the effectiveness of test equipment in categorizing damage conditions and identifying degraded insulation properties. Special consideration will be given to minimizing orbiter intrusion with these testing techniques. Additionally, ARC recently completed a wire integrity research pilot study that addressed automated verification and validation of orbiter wiring configuration and automated condition assessment for maintenance.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3L-8:** Quantitative methods of risk assessment (likelihood of failure) should be developed.	**SSP Response (Abbey/Dittemore, 23 October 2000):** The SSP agrees with SIAT that quantitative risk assessment is essential to fly the Space Shuttle safely. The SSP currently utilizes many quantitative techniques to determine and manage risk. Program requirements contained within NSTS 07700 specify the use of analytical methods in all aspects of program execution. Statistical process control, process failure modes and effects analysis/critical items list, fault tree and event tree analysis, hazard analysis, reliability-centered analysis,

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				and other techniques are implemented to various degrees across alt program elements. These methods assess the probability and severity of failures through all mission phases. The SSP has generated a wealth of statistical and analytical data in the last 19 years of flight history and continues to explore the potential adaptation of various quantitative risk analysis (QRA) methods. The System Safety Review Panel (SSRP), with representatives from all program elements and safety, reliability, and quality assurance organizations, is reviewing current QRA techniques and will determine an approach to quantitative risk assessment for the program. To date, several meetings have been held by the SSRP involving the upgrades program, the safety community, NASA Headquarters, MSFC, and KSC to identify and agree on the requirements and priorities of quantitative software packages to support SSP operations and upgrade trade studies. Four software tools have been identified and three expert consultants have assisted the SSP to narrow the choices with the current favorite being a package called Sapphire. USA is working with the program to develop a probabilistic risk assessment (PRA)/QRA center of excellence to assist in the effort. The development of a PRA/QRA program standard and an implementation approach will be provided in the February 2001 timeframe. The SSRP will then determine if a

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				singular program-wide analytical methodology is the right solution, given the diversity and complexity of the SSP. A final evaluation will be conducted with the recommendation presented by the SSRP to the SSP PRCB in April 2001.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3L-9:** Quantitative measures of safety (likelihood of error), including assessment surveying techniques should be developed, e.g., Occupational Stress Inventory and MEDA.	**SSP Response (Abbey/Dittemore, 23 October 2000):** The Incident Error Review Board at KSC is an example of one mechanism in place to assess maintenance process errors. Like the maintenance error decision aid (MEDA) used by the commercial airlines, this board analyzes all contributing elements to determine root cause and to formulate corrective actions. However, this approach is reactive and, much like MEDA, has limitations in that only significant events initiate board reviews. To be proactive, the SSP is aggressively incorporating human factor principles into the flight preparation process. The Space Shuttle Processing Human Factors Team and the USA Industrial Engineering and Human Factors Department were staffed to improve the SSP error management process. The two entities work cooperatively to share quantitative data, resources, and expertise to develop human factor concepts and perform on-site process analysis. Several initiatives underway include the Work Instruction Task Team that provides guidelines and training on effective procedure authoring and the Industrial and Work Space

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				Design Team recently chartered to ensure human factors are incorporated in the engineering and ground system design processes. Both programs will have widespread effects in operations, maintenance, manufacturing, and design. A statistical analysis of the PRACA system is also underway to assess problem report entry and classification errors, with corrective actions to be implemented by the PRACA Evaluation Team. USA commissioned Lord & Hogan, with the endorsement of the Shuttle Independent Assessment Team (SIAT),to administer an operational stress inventory and analysis. The results of the USA workforce surveys in Florida and Texas indicated positive results in the normal range compared to other companies in all categories of stress and coping behaviors. USA intends to conduct follow-on studies in approximately 2 years as a companion to the new baseline. NASA Centers are in the process of conducting various workforce surveys such as the Employee Stress Survey (ESS) and the Performance Evaluation Profile (PEP). These results are compiled and presented to the SSP as a series of measurements. The ESS specifically deals with occupational stress factors and the ability of the workforce to deal with stress issues. The PEP focuses on both industrial and flight safety and serves to evaluate the performance of the safety

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				program. The SSP will evaluate these results and, if necessary, take corrective actions. To further these efforts, the human factor teams will be chartered to develop quantitative measures of human performance and propose plans to address improvements within the industrial engineering for safety initiative currently chartered by SSP directive.
Space Shuttle Independent Assessment Team *(NASA Charter)*	7 March 2000		**Recommendation 3L-10:** Quantitative methods of risk assessment and safety (see above) need to be integrated to develop the ability to perform trade-off studies on the effect of new technology, aging, upgrades, process changes, etc., upon vehicle risk.	**SSP Response (Abbey/Dittemore, 23 October 2000):** The SSP agrees with SIAT that quantitative risk assessment is essential to fly the Space Shuttle safely. The SSP currently utilizes many quantitative techniques to determine and manage risk. Program requirements contained within NSTS 07700 specify the use of analytical methods in all aspects of program execution. Statistical process control, process failure modes and effects analysis/critical items list, fault tree and event tree analysis, hazard analysis, reliability-centered analysis, and other techniques are implemented to various degrees across alt program elements. These methods assess the probability and severity of failures through all mission phases. The SSP has generated a wealth of statistical and analytical data in the last 19 years of flight history and continues to explore the potential adaptation of various quantitative risk analysis (QRA) methods. The System Safety Review Panel (SSRP),

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				with representatives from all program elements and safety, reliability, and quality assurance organizations, is reviewing current QRA techniques and will determine an approach to quantitative risk assessment for the program. To date, several meetings have been held by the SSRP involving the upgrades program, the safety community, NASA Headquarters, MSFC, and KSC to identify and agree on the requirements and priorities of quantitative software packages to support SSP operations and upgrade trade studies. Four software tools have been identified and three expert consultants have assisted the SSP to narrow the choices with the current favorite being a package called Sapphire. USA is working with the program to develop a probabilistic risk assessment (PRA)/QRA center of excellence to assist in the effort. The development of a PRA/QRA program standard and an implementation approach will be provided in the February 2001 timeframe. The SSRP will then determine if a singular program-wide analytical methodology is the right solution, given the diversity and complexity of the SSP. A final evaluation will be conducted with the recommendation presented by the SSRP to the SSP PRCB in April 2001.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 2000	**Finding 1:** The continuing downsizing at Office of Space Flight Field Centers, coupled with the effects of the prior hiring freeze and unplanned departures, has	**Recommendation 1:** NASA must continue to address workforce problems aggressively and establish program priorities that ensure a workforce capable of achieving long-term safe and effective	

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		produced critical skills deficits in some areas, growing workload pressure and stress levels, and a serious shortfall of younger S&Es.	operations. Emphasis should be placed on eliminating critical skills shortfalls and recruiting younger S&Es who can develop into experienced and skilled future leaders.	
Aerospace Safety Advisory Panel *(NASA Charter)*	February 2000	**Finding 2:** The combination of downsizing losses, hiring restrictions, and transition of responsibilities from NASA to contractors, such as USA, continues to limit the opportunities for junior and mid-level NASA managers to gain the operational knowledge and experience required for continued leadership in senior management positions.	**Recommendation 2:** Innovative arrangements between NASA and its contractors to provide entry-level and mid-level NASA S&Es with operational, "hands-on" experience should be strengthened and expanded. Project management training initiatives, such as the Academy of Program & Project Leadership (APPL), must strive to broaden their outreach to management teams and individuals at the Field Centers.	
Aerospace Safety Advisory Panel *(NASA Charter)*	February 2000	**Finding 3:** The Space Shuttle Program Office has instituted a set of Process Control Focus Groups whose goal is to implement "best practice" commonality in change control procedures across all supplier tiers.	**Recommendation 3:** Focus the active and dedicated support of senior management of the major contractors and all their subcontractors on implementing the process control "best practices" as soon as feasible. NASA must be fully apprised of all process changes even if they result in a product that meets requirements.	
Aerospace Safety Advisory Panel *(NASA Charter)*	February 2000	**Finding 4:** Although progress has been made to improve the quality, accuracy, and traceability of the work instructions ("paperwork" used in the processing of Space Shuttle Orbiters) much remains to be done to provide correct and unambiguous procedures. There are still too many unincorporated changes.	**Recommendation 4:** Efforts to improve the quality, accuracy, and traceability of the work paper as well as the timeliness of incorporation of changes to work instructions must be given higher priority by both NASA and USA in a coordinated, systematic effort.	
Aerospace Safety Advisory Panel	February 2000	**Finding 5:** There is no systematic plan to counter obsolescence and assure the availability of adequate facilities, GSE,	**Recommendation 5:** Develop and execute a plan to ensure that all needed support and test-and-checkout facilities and equipment are assured available	

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(NASA Charter)		and specialized test-and-checkout equipment throughout the expected lifetime of the Space Shuttle.	and protected from obsolescence for the maximum foreseeable life of the Space Shuttle.	
Aerospace Safety Advisory Panel *(NASA Charter)*	February 2000	**Finding 6:** Space Shuttle processing workload is sufficiently high that it is unrealistic to depend on the current staff to support higher flight rates and simultaneously develop productivity improvements to compensate for reduced head counts. NASA and USA cannot depend solely on improved productivity to meet increasing launch demands.	**Recommendation 6:** Hire additional personnel and support them with adequate training.	
Aerospace Safety Advisory Panel *(NASA Charter)*	February 2000	**Finding 7:** Due to attrition of experienced personnel, NASA and its contractors are assigning more newly trained personnel to Space Shuttle operations tasks. This has led to concerns in the workforce regarding the qualifications of some newly-assigned personnel.	**Recommendation 7:** NASA and its contractors must ensure that their training, certification, and task assignment processes are such that only suitably qualified engineering and technical personnel are performing Space Shuttle operations. Any training and licensing program to certify new personnel must include both testing of acquired skills and demonstrated proficiency on the assigned task.	
Aerospace Safety Advisory Panel *(NASA Charter)*	February 2000	**Finding 11:** The EVA Project Office has several planned initiatives to ensure the availability of adequate EVA resources to support the ISS and Space Shuttle. These initiatives cover acquisition of materiel, development of procedures, and improved training.	**Recommendation 11:** Expedite completion of the planned initiatives related to the safety of EVA so that maximum benefit can be realized during the upcoming intensive ISS assembly schedule.	

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Aerospace Safety Advisory Panel *(NASA Charter)*	February 2000	**Finding 12:** The funding of the EVA R&T program is not adequate to provide the maximum safety benefit in terms of new equipment and procedures that lower the risk of extravehicular activities.	**Recommendation 12:** Fund a robust EVA R&T program.	
Aerospace Safety Advisory Panel *(NASA Charter)*	February 2000	**Finding 14:** NASA has initiated an agency-wide program to deal with general computer security. Significant parts of NASA's initial plan depend upon the voluntary compliance of system users including contractors.	**Recommendation 14:** Expand the agency-wide security system development work to include less dependence on human compliance with the system. NASA should also require contractors to participate in its security efforts.	
Aerospace Safety Advisory Panel *(NASA Charter)*	February 2000	**Finding 16:** NASA has established an Avionics Upgrade Architecture Team (AUAT) charged with studying Space Shuttle avionics systems and recommending upgrades. The AUAT has conducted a thorough study and developed an excellent Block I upgrade plan that addresses the most serious needs, but as yet it is unfunded.	**Recommendation 16:** Proceed with full funding for the proposed Block I Space Shuttle avionics upgrades as rapidly as possible.	
Aerospace Safety Advisory Panel *(NASA Charter)*	February 2000	**Finding 17:** Part of the AUAT's initial approach is to install three mission computers to augment the existing General Purpose Computers (GPCs). The specific functions to be offloaded from the GPCs to the mission computers have yet to be determined. Eventually, the AUAT plans to consider moving some "Crit 1" functions to the mission computers.	**Recommendation 17:** Do not move any "Crit 1" functions to the mission computers unless memory requirements in the GPC demand it and then only after an appropriate risk analysis is performed.	

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NASA Office of Safety and Mission Assurance *(NASA Charter)*	16 April 1999	The review team evaluated the assumptions, supporting data, and maturity of selected strategic initiatives (fifteen of the twenty-one Phase 2 initiatives) and arrived at an estimated savings of 224 as opposed to the USA/GO projection of 287. This 78 percent-yield (see Chapter 14, Table 14-1) suggests that USA/GO will achieve roughly three-quarters of their goal to increase flight rate capability from 5 flights-per-year to 8 flight-per-year.		
NASA Office of Safety and Mission Assurance *(NASA Charter)*	16 April 1999	The review team estimates that effective implementation of the USA/GO Strategic Initiatives will establish the capability to safely accomplish a steady-state flight rate of up to seven per year. Ultimate verification of processing capability can only be determined after analysis of actual steady-state flow performance.		
NASA Office of Safety and Mission Assurance *(NASA Charter)*	16 April 1999	The team noted that effective implementation has not yet been achieved in the safety-related Structured Surveillance Phase II initiative, where human-factors issues (communication, inspection dynamic, worker acceptance) exist. Increased USA management attention is warranted in this area. The inspection "work review process" must be acknowledged and accepted by the entire USA workforce as a		

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		critical element in assuring flight safety.		
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1999	**Finding 1:** Budget and personnel ceiling constraints on the hiring of engineers, scientists, and technical workers are moving NASA toward a crisis of losing the core competencies needed to conduct the Nation's space flight and aerospace programs in a safe and effective manner.	**Recommendation 1:** Provide NASA's human space flight Field Centers, particularly KSC, JSC, and MSFC, with the budgetary resources and administrative flexibility needed to strengthen their human resource capabilities.	**NASA Response (in 1999 ASAP appendix):** NASA concurs with the recommendation; and, we fully recognize the near heroic efforts at each of our installations that have brought us within striking distance of our downsizing targets. At the beginning of fiscal year 1993, the NASA employment level was 24,900 FTE. As a result of the March 1993 Executive Order to reduce Federal Civilian FTE by 100,000, the NPR recommendations and additional OMB directed cuts in 1994,NASA received an out-year target of 20,906. Additional budget reductions occurred that required us to initiate the Zero Base Review, which was completed in 1995.The ZBR recommended an FY 2000 FTE level of 17,488. Since that time we have carefully managed an FTE reduction to a planned 18,545 FTE for FY 99 and 17,970 for FY 00. Our final "go to" target is now 17,574 FTE for FY 04. Currently 7 of our 10 Centers are at or below our lowest "go to" numbers. To NASA's credit, our accomplishments were achieved without resort to the ravages of a reduction-in-force. Voluntary losses to date include in excess of 4,500 buyouts, 1,300 early outs, and more than 800 intercenter transfers. As a result of the downsizing challenges, we provided relief to the OSF Centers in the FY

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				00 budget process as follows: FY 99-153 FTE; FY 00-110 FTE; FY 01-103 FTE; FY 02-59 FTE; and, FY 03-68 FTE. This relief has enabled the innovative use of temporary and extended term appointments, as well as increasing the number of permanent hires available to fill critical skill positions. In addition, we are currently reviewing their request for additional relief, as identified in the recent Core Capability Assessment (CCA). OSF management has proposed several augmentation and/or hiring models that address both short and long term needs regarding replacement and enhancement of critical workforce competencies. One objective of the current CCA review is to help chart a strategy that will provide the OSF Centers with the requisite flexibility to attract and retain the core competency talent pool necessary to ensure safe mission and program success.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1999	**Finding 2:** Shortfalls in workforce training within both NASA and USA, caused by downsizing and the related difficulty of hiring new people to fill skill shortages, can jeopardize otherwise safe operations.	**Recommendation 2:** NASA and USA should review critical skills training and certification requirements and institute programs to ensure the full proficiency of the workforce and the safety of the products being released.	**NASA Response (in 1999 ASAP appendix):** NASA concurs in the recommendation and, in cooperation with USA, has already reviewed certification requirements for flight controllers, training instructors, and other key operating positions. Training plans and certification requirements for critical positions have been documented and maintained. For example, the management role in launch countdown and landing is supported by a well–defined training and certification plan. NASA and its contractors are continually reviewing critical skills

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				training and certification requirements to ensure controls are in place to validate and ensure employee proficiency. Quality initiatives are being developed to provide improved processes for cross training, automated training tools, inline automated certification validation, and enhancements in the closed loop verification of operators and system operational performance. Meanwhile, training capacity for new employees, both NASA and contractor, has been increased through intensive simulator training at a new USA "training academy." A saturation-type training environment has been designed to improve training at the beginning of the regular certification process and produce employees better qualified for critical process work. In training and orientation programs, NASA emphasizes the priority of safety and the responsibility of employees to voice their concerns about inadequate assurances of safe products.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1999	**Finding 3:** The combined effect of workforce downsizing, the recent hiring freeze, and the SFOC transition, especially at KSC, has raised the possibility that NASA senior managers in the future will lack the necessary hands-on technical knowledge and inline experience to provide effective insight of operations.	**Recommendation 3:** NASA should develop and promulgate training and career paths, with a special focus on providing hands-on technical knowledge and experience, so that NASA's future senior managers will possess the range of skills and experience required for effective insight of the SFOC.	**NASA Response (in 1999 ASAP appendix):** NASA concurs in the recommendation and is intensifying and refocusing its efforts in training and in support of career development at all levels. At the operating level, NASA managers are instructed to plan and to take advantage of all opportunities to obtain operational experience through audit, surveillance, and other interfaces to provide hands-on experience to NASA personnel.

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				(list with lots of detail omitted) Additionally, employees are provided cross training and specialized training as needed and strongly encouraged to take advantage of program related training. The key to developing future generations of senior managers is to provide hands-on experience, with progressively more responsible assignments through one's career. Both NASA and the contractors continually seek improvements in the succession planning and preparations for the next generation of supervisors and managers. Special consideration is given to assuring that broad training and hands-on operational/technical job assignments and opportunities are consciously addressed for promising candidates for future senior management positions. NASA's training philosophy also emphasizes on-the-job work experiences supplemented by classroom instruction, participation in outside academic programs and industry through assignments in such private sector organizations as Boeing, Newport News Shipbuilding, and USA. At the agency planning level, the training budget has provided for an increase of 20% for the Office of Space Flight from FY1997 through

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				FY2000.Current agency Program Operating Plan (POP) guidelines call for funding training at 2-3.25% of salary levels, an extremely generous ratio for government and rivaling progressive private sector organizations. The NASA Academy of Program and Project Leadership (APPL) is building on ten years of educational and developmental activities and is striving to facilitate the flow of current knowledge and techniques to the full engineering and science workforce. APPL is making available information and automated tools on-line and seeking to develop expert systems. APPL is also working directly to support intact teams with information and techniques and attempting to better organize case studies and archives into a more effective knowledge base. The APPL program is also adding an Accelerated Leadership Option to the Project Management Development Process (PMDP) which will enable NASA engineers to obtain a Master's of Science in Engineering and Management degree from MIT.APPL is continuing and expanding a multifaceted program of classroom work, developmental work assignments, and dissemination of information and guidance. Finally, NASA is well along in an update of its Leadership Development Model;

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				documenting the technical, managerial, and executive competencies required to direct the work of the agency through the foreseeable future. This model will guide the scope and emphasis of training and development programs, including a new approach to succession planning, to ensure that NASA's leaders at all levels have the knowledge and skills to meet their responsibilities.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1999	**Finding 4:** It is often difficult to find meaningful metrics that directly show safety risks or unsafe conditions. Safety risks for a mature vehicle, such as the Space Shuttle, are identifiable primarily in specific deviations from established procedures and processes, and they are meaningful only on a case-by-case basis. NASA and USA have a procedure for finding and reporting mishaps and "close calls" that should produce far more significant insight into safety risks than would mere metrics.	**Recommendation 4:** In addition to standard metrics, NASA should be intimately aware of the mishaps and close calls that are discovered, follow up in a timely manner, and concur on the recommended corrective actions.	**NASA Response (in 1999 ASAP appendix):** NASA agrees with the recommendation. In addition to standard metrics, NASA is intimately aware of the mishaps and close calls and is directly involved in the investigations and approval of corrective actions. Current requirements contained in various NASA Center and contractor safety plans include procedures for reporting of mishaps and close calls. These reports are investigated and resolved under the leadership of NASA representatives with associated information being recorded and reported to NASA management. NASA is intimately aware of and participates in the causal analysis and designation of corrective action for each mishap. Additionally, NASA performs trend analysis of metrics as part of the required insight activities. Definitions relating to "close call" have been expanded to include any observation or employee comment related to safety improvement. Close call reporting has been emphasized in contractor and

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				NASA civil servant performance criteria and a robust management information system is being incorporated to monitor and analyze conditions and behavior having the potential to result in a mishap. Various joint NASA/contractor forums exist to review, evaluate, and assign actions associated with reported close calls. As an example, the KSC NASA Human Factors Integration Office leads the NASA/Contractor Human Factors Integrated Product Team (IPT) in the collection, integration, analysis, and dissemination of root cause and contributing cause data across all KSC organizations. The KSC Human Factors IPT is also enhancing the current close call process which includes tracking of mishaps with damage below $1000 and injuries with no lost workdays. The SSP has revised it's Preventive/Corrective Action Work Instruction to include mandatory quarterly review of close call reports. Several initiatives are in place to increase awareness of the importance of close call reporting and preventive/corrective action across the SSP and the supporting NASA Centers and contractors. Under this new approach to close call reporting, a metric indicating an increase in close call reporting and preventive action is considered highly desirable as it indicates an increased involvement by the workforce in identifying and resolving potential hazards. Care is taken in over

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				emphasizing the number of close calls reported as a performance metric to prevent reluctance in reporting. NASA is working hard to shift the paradigm from the negative aspects of reporting close calls under the previous definition to being a positive aspect of employee identification of close calls under the new definition.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1999	**Finding 5:** A principal cause of Space Shuttle processing errors is incorrect documentation ("paperwork").	**Recommendation 5:** NASA and USA must place increased priority on determining error sources, causes, and corrective actions for inadequacies in the documentation on which Space Shuttle processing is based and develop a management system that drastically reduces the time that it takes to incorporate paperwork changes.	**NASA Response (in 1999 ASAP appendix):** NASA concurs with the recommendation. NASA and USA have established metrics to identify the types of errors and error sources in the processing documentation. During daily interface, NASA and USA discuss these metrics and perform causal analysis to identify the need for corrective action. For critical procedures, USA has implemented a check and balance in the work instruction generation process to increase the procedure quality before it is worked. Additionally, NASA and USA have an initiative to reduce the complexity of work procedures, increase the procedure standardization, and reduce the time for paperwork generation for work not requiring engineering disposition. More importantly, USA is developing, as a high priority, a paperless system. Specifically, the Ground Operations organization at KSC is implementing an integrated on-line system that ensures total process rigor and mitigates the potential for human error in accomplishing space flight work. This

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				system incorporates recognized "best practices" for authoring work documents including on-line review and approval, and the ability for authors to automatically update and incorporate work document deviations. Required checks and balances are inherent in the system to maintain the integrity, safety and quality of both flight and ground work performed. Work documents will clarify user understanding by incorporating enhanced explanations with in-line graphics, sound and video where required. The goal of this activity is to ensure that a properly certified person, utilizing the right work instructions, has safely accomplished all required work.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1999	**Finding 6:** While spares support of the Space Shuttle fleet has been generally satisfactory, repair turnaround times (RTAT) have shown indications of rising. Increased flight rates will exacerbate this problem.	**Recommendation 6:** Refocus on adequate acquisition of spares and logistic system staffing levels to preclude high RTATs, which contribute to poor reliability and could lead to a mishap.	**NASA Response (in 1999 ASAP appendix):** NASA concurs with the recommendation. During calendar year 1998,RTAT's for both the NASA Shuttle Logistics Depot and the original equipment manufacturer fluctuated, but at year's end, the overall trend was downward through concerted NASA and vendor efforts. These efforts are aimed at providing better support at the current flight rate and for higher flight rates in the future. Logistics is working to find innovative ways to extend the lives of aging line replaceable units (LRUs) and their support/test equipment. Logistics has initiated the Space Council (an industry group with 11 other company executives addressing such topics as verification reduction, ISO compliance, and upgrades) to

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				assure the supplier base continues its outstanding support to the SSP. Examples of LRUs being evaluated and enhanced include: Star Trackers, auxiliary power units, inertial measurement units, multifunction electronic display system (MEDS),Ku-band, orbiter tires, and manned maneuvering units. NASA/KSC Logistics and USA Integrated Logistics have made progress on a long-term supportability tool. The tool will provide information, including historical repair trend data for major LRUs, RTATs, and "what if" scenarios based on manipulation of factors (e.g., flight rate, turnaround times, loss of assets, etc.) to determine their effect on the probability of sufficiency. This will be a tool, not a substitute, for human analytical decision making.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1999	**Finding 7:** NASA aircraft used for both Space Shuttle operations and astronaut training are increasingly out of date and, in several respects, may be approaching the unsafe. This is noticeably so in the case of the Shuttle Training Aircraft (STA) and the T-38 aircraft.	**Recommendation 7:** Continue to execute and accelerate as much as possible the current plans for the modernization and safety assessment of astronaut training aircraft.	**NASA Response (in 1999 ASAP appendix):** NASA believes that the current aircraft used as astronaut training aircraft are maintained in a safe condition. NASA remains committed to safe operation of all the training aircraft. Measures to ensure that the NASA T-38s and STAs used for astronaut training are maintained in a safe configuration and in good material and structural condition are in place. (lots more T-38 detail omitted) NASA will continue to evaluate new programs and seek new initiatives to meet the requirements as they

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				evolve, such as adding avionics for compatibility with the future free flight concept in the air traffic control system. STA: NASA has four STAs and one spare Gulfstream II (GII) that will be modified into an STA when it is either required by the Shuttle flight rate or in the event that one of the four STAs becomes unusable.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1999	**Finding 8:** The use of simulated Space Shuttle launch and flight operations for training and rehearsal has proven to be an effective technique for enhancing safety and efficiency and is especially valuable in the case of special or rarely performed procedures or after a long hiatus of effort.	**Recommendation 8:** Simulation-based training should be included in difficult or infrequent Space Shuttle operations whenever feasible. This type of training is especially needed after there has been a significant hiatus in performing an operation.	**NASA Response (in 1999 ASAP appendix):** NASA concurs with the recommendation. NASA and USA have beneficially increased simulation-based training at KSC. The pursuit of a separate simulation training room and simulation team will allow NASA and USA to further increase the number of simulations that can be performed each flow. Additionally, KSC will use the new collaborative engineering environment to enhance simulation capabilities.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1999	**Finding 18:** The EVA project lacks sufficient operational assets to meet unplanned contingencies. There are no spare Extravehicular Mobility Units (EMU). Only five U.S. Simplified Aid for EVA Rescue (SAFER) flight units will be available to meet a requirement to maintain three units on orbit. In addition, only four Russian SAFER units are planned.	**Recommendation 18:** To meet contingencies that are almost certain to arise, additional EMU's and SAFER units or their critical long lead components should be procured as soon as possible.	**NASA Response (in 1999 ASAP appendix):** NASA concurs with the ASAP recommendation. With respect to the EMU, the inventory of life support system (LSS) hardware will be 14 (13 Class I and 1 Class II) by October 1999.Exceedences to our supply begin in 2000. In order to achieve a 90 percent probability of sufficiency, NASA must increase its inventory by two LSSs. NASA plans on addressing this issue within the Program Operating Plan (POP) 99.We plan to upgrade the current

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				Class II LSS to Class I and upgrade the certification unit to Class II. This will increase our inventory to 15. NASA also plans to go forward with the recommendation to procure an additional LSS to achieve 16 LSSs. (lots more LSS detail omitted) With respect to the USA SAFER, NASA concurs with the ASAP recommendation on obtaining critical long lead components. In fact, the majority of the long lead components have already been procured. These components are expected to support the USA SAFER flight units for their 7-year life. NASA can normally support the requirement to maintain three USA SAFER flight units on orbit with five flight units in service. The current rotation plan utilizes two of the flight units to accommodate rotation of back-to-back missions where the turnaround time is approximately 1 month. With one flight unit out of service, four USA SAFER flight units can be rotated to maintain three units on orbit for 92 percent of the flights per the International Space Station (ISS) assembly sequence dated February 22, 1999.The remaining 8 percent of the flights can also be supported with contingent coordination ahead of time to reduce the turnaround time from approximately 1.5 months to approximately 1 month. (lots more SAFER detail omitted)

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Aerospace Safety Advisory Panel *(NASA Charter)*	February 1999	**Finding 25:** The NASA Standard Initiator (NSI) on a SAFER unit tested on STS-86 on October 1, 1997, did not activate because of a marginal design of the activating power supply. As a result, the unit could not function. The certification testing for the firing circuit did not identify the power supply inadequacy. Also, an inadequate NSI emulator was used for most of the original SAFER certification (qualification) and acceptance tests.	**Recommendation 25a:** The design and implementation of flight systems critical to safety and mission success should, at least, provide redundancy for system startup.	**NASA Response (in 1999 ASAP appendix):** NASA concurs with the ASAP finding that the NSI drive circuit of the USA SAFER was marginal in its design to the point where the drive circuit failed to activate the NSI during a demonstration on STS-86.The failure was due to lack of margin within the subsystem to drive the NSI and not due to lack of redundancy (a backup subsystem) to the subsystem. Adding redundancy (a backup subsystem) to drive the NSI would not resolve the lack of margin as both the primary and backup subsystems would still fail to drive the NSI without sufficient margin. This condition was addressed by addition of a new NSI circuit with increased margin to fire the NSI on demand. In addition the new NSI contains redundant components where possible. The USA SAFER is categorized as emergency hardware and is designed for use only after the EVA crewmember had inadvertently separated from structure due to a tether failure or a tether disconnection. The combination of the tether and USA SAFER provide a functional redundancy to each other and a fail-operational system, which can sustain one failure in the tether (functional after one failure) and still retains the capability to continue with the EVA. A subsequent failure of the tether (two failures) and a functional USA SAFER provide a fail-safe system,

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				which still retains the capability to successfully terminate the mission by using the USA SAFER to bring the inadvertently-separated EVA crewmember back to safety. Once the USA SAFER is needed to perform self-rescue in its role as the fail-safe device, its failure to perform due to any reason would result in loss of the EVA crewmember. Because the USA SAFER is to provide the fail-safe capability, as the functional redundancy to the tether, it was designed as a single-string system. As such, redundancy was not required for all subsystems and components. Adding redundancy to the activation subsystem alone would not increase the probability of saving an inadvertently separated crewmember since other critical subsystems (propulsion and mechanism) are still single-string. NASA will evaluate redesigning the next generation be fully redundant in critical functions.
			Recommendation 25b: All NASA Centers should review the design requirements for reliable activation of the NSI and assure they are adequate to be communicated to their suppliers, especially those who are responsible for the design of firing circuits. All designs currently using NSI's should be reviewed to assure that the firing circuits are adequate and have been appropriately tested.	**NASA Response (in 1999 ASAP appendix):** NASA agrees with the ASAP recommendation. The new USA SAFER NSI circuit employs the capacitive discharge approach which has been well proven by the SSP. Peer reviews were held to evaluate the new circuit design, and a series of tests were performed with the complete flight circuit. Also, the Engineering Directorate's Pyrotechnic Subsystem Manager performed a comprehensive review of all known uses of the NSI to ensure an acceptable design existed and that appropriate

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				certification/ acceptance tests had been accomplished. Lastly, a User's Guide (JSC-28596) for the NSI was developed to assist developers in selecting the appropriate NSI, designing the appropriate NSI drive circuit, and testing the complete NSI subsystem.
			Recommendation 25c: Qualification tests of safety-critical equipment must use flight-quality hardware. Any exceptions must require high-level program approval.	**NASA Response (in 1999 ASAP appendix):** NASA concurs with ASAP recommendation to use flight-quality hardware to support qualification testing. The new USA SAFER circuit certification was completed with the successful firing of 15 flight NSIs consecutively.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1999	**Finding 29:** The Space Shuttle General Purpose Computers (GPC) are outmoded and limit the ability to incorporate necessary software changes and hardware upgrades.	**Recommendation 29:** NASA should begin the process of replacing the Space Shuttle GPC's. As part of this effort, NASA should also modularize the flight software.	**NASA Response (in 1999 ASAP appendix):** The Space Shuttle Program is addressing the finding and recommendation identified by the ASAP. A review of the GPC and its flight software was performed in April 1998. Based on current estimates on GPC mean time between failures, the flight hardware and spares are expected to be available through at least 2016 (and likely significantly later). The flight software estimate on memory availability and usage has projected that memory capacity would be expected to reach its limit in the 2005-2006 timeframe. A software architecture strategy as part of the overall SSP avionics upgrade effort is being developed which will mitigate the memory capacity concern. This strategy will partition the critical software such as flight control and guidance from software that

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				requires periodic change. The result of this partition would allow those stable software functions like flight control to remain within the current GPC's while allowing those functions that frequently change to be migrated to a newer computer technology. The offloading of the software functions such as display processing and systems management from the current GPCs should permit current GPC memory capacity to remain acceptable through at least 2020. Additionally the software subject to frequent change would be located within a system, which will be designed to be more easily reconfigurable than the existing system. In summary, a supportability concern does not exist for the current GPCs. Continued use of the existing GPCs and their established processes will maintain high levels of safety. Software partitioning involving the offloading of software functions to a more flexible system will provide sufficient memory availability for future GPC software changes. This approach will provide an evolutionary and a migration path to full GPC upgrade if it is later required.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1999	**Finding 30:** There is no formal requirement that dependent Space Shuttle I-loads be recalculated or checked when an I-load patch is to be uplinked.	**Recommendation 30:** NASA should create a dependency matrix of all I-loads. Furthermore, it should assess its Space Shuttle and ISS procedures and ensure that they are all fully documented.	**NASA Response (in 1999 ASAP appendix):** NASA believes that we already meet the intent of the recommendation. Flight Operations processes and documentation ensures proper I-load change implementation for all flight design I-loads, including uplinkable I-loads. These procedures include positive verification that the selected or uplinked values do not violate subsystem,

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				element, or integrated vehicle certification and that the update meets mission requirements. I-load dependencies are verified as part of the certification assessment. Procedures for verifying I-loads to be uplinked vary. In some instances uplinked Iloads change vehicle response in a way that impacts several of the remaining I-loads; i.e., Day-of-Launch I-load Update (DOLILU). Those verification assessments include an analysis which uses a high fidelity computer model to simulate integrated vehicle response to the new I-loads. These simulations include models of the onboard flight software of sufficient detail to verify that all applicable I-load interactions are assessed. In other cases, specific I-load dependencies are evaluated. A number of flight design uplinks involve an uplink of values that are generated and verified days or sometimes months before launch. These I-loads include vehicle navigation, targeting, and abort parameters. Verification procedures for these I-loads are identical to that used during the normal flight design template. For all cases, procedures clearly specifying verification requirements including specific I-load dependency evaluations, as applicable, are in place and under configuration control.
Aerospace Safety Advisory Panel *(NASA*	February 1999	**Finding 31:** Present plans depend on human procedures to achieve lockout to prevent inadvertent or	**Recommendation 31:** NASA should use a computerized authorization to achieve lockout of commands to actual hardware from anyone not	**NASA Response (in 1999 ASAP appendix):** NASA concurs with the ASAP recommendation. The CLCS Project will undertake a study

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Charter)		unauthorized access to actual hardware when using the new Checkout and Launch Control System (CLCS).	authorized to issue such a command in CLCS.	with the Shuttle engineering community to determine how these lockouts could be implemented. The results will include a preliminary set of requirements for CLCS and other systems, such as the Shuttle Data Center and Simulation Systems, an operational risk assessment for implementing these changes, and a rough order of magnitude cost assessment for implementing these changes. The study will be completed in a timely manner so that implementation can be accomplished in time to avoid extensive revalidation of CLCS application software. Progress reports will be presented to the ASAP during their CLCS review meetings.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1999	**Finding 32:** NASA does not have a plan in place to deal with the problem of maintaining the many commercial off-the-shelf (COTS) software development tools used in its programs.	**Recommendation 32:** NASA should develop a general strategy and provide program wide guidelines for addressing the maintenance of COTS tools.	**NASA Response (in 1999 ASAP appendix):** NASA concurs with the finding that no program-wide plan exists addressing the maintenance of COTS software development tools. A programmatic action has been assigned to develop the usage requirements for COTS/modified off-the-shelf software including the associated development tools. These guidelines will document maintenance and selection guidelines to be used by all of the applicable program elements.
NASA Office of Safety and Mission Assurance *(NASA Charter)*	27 October 1998	The review team could not determine whether or not USA-proposed process improvements will achieve efficiencies necessary, in the time required, to support increased manifest demands in mid-to-late 1999.		

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NASA Office of Safety and Mission Assurance *(NASA Charter)*	27 October 1998	The team noted that opportunities exist to achieve efficiencies in administrative and management processes, which support the core work control/review and change control infrastructure. The strength of USA management leadership and commitment will determine the outcome.		
NASA Office of Safety and Mission Assurance *(NASA Charter)*	27 October 1998	In any event, NASA management must closely monitor implementation of proposed USA process initiatives to assure that a stable infrastructure, capable of handling sustained higher flight rates, is developed. Flight safety will be assured as long as key ground operations processes remain in place. When the ground operations system becomes saturated it will be important to understand how "people in the process" (human factors) respond.		
NASA Office of Safety and Mission Assurance *(NASA Charter)*	27 October 1998	Although no objective evidence was found to indicate that the work requirements would have any adverse impact on safety or quality, the KSC/SMA planning process is not sufficiently mature to provide evidence that the increased flight rate can be supported within current workforce ceilings.	It is recommended that the KSC/SMA organization notify the Office of Safety and Mission Assurance when it has completed the critical process definition effort and the workforce analysis planning. At that time a delta assessment will be performed to assess the completeness of the activity.	
Aerospace Safety Advisory Panel *(NASA*	February 1998	**Finding 1:** Operations and processing in accordance with the Space Flight Operations Contract	**Recommendation 1a:** Both NASA and the SFOC contractor, USA, should reaffirm at frequent intervals the dedication to safety before	**NASA Response (in 1998 ASAP appendix):** The Space Shuttle Program concurs with the ASAP affirmation that safety is our first priority. The

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Charter)		(SFOC) have been satisfactory. Nevertheless, lingering concerns include: the danger of not keeping foremost the overarching goal of safety before schedule before cost; the tendency in a success-oriented environment to overlook the need for continued fostering of frank and open discussion; the press of budget inhibiting the maintenance of a well-trained NASA presence on the work floor; and the difficulty of a continued cooperative search for the most meaningful measures of operations and processing effectiveness.	schedule before cost.	potential for safety impacts as a result of restructuring and downsizing are recognized by NASA at every level. From the Administrator down there is the communication of and the commitment to the policy that safety is the most important factor to be considered in our execution of the program and that restructuring and downsizing efforts are to recognize this policy and solicit and support a zero tolerance position for safety impacts. The restructuring efforts across the Program in pursuit of efficiencies which might allow downsizing of the workforce consistently stress that such efficiencies must be enabled by identification and implementation of better ways to accomplish the necessary work, or the unanimous agreement that the work is no longer necessary, but that in either case that the safety of the operations are preserved. In the case of the restructuring and downsizing enabled by the SFOC transition of some responsibility and tasks to the contractor, the transition plans for these processes and tasks specifically address the safety implications of the transition. Additionally, the Program has required the NASA Safety and Mission Assurance (S&MA) organizations to review and concur on the transition plans as an added assurance. Other Program downsizing efforts have similar emphasis embedded in the definition and implementation of their restructuring, and the S&MA organizations are similarly committed as a normal

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				function of their institutional and programmatic oversight to assure this focus is not compromised. Additionally, the Program priorities of 1) fly safely, 2) meet the manifest, 3) improve mission supportability, and 4) reduce cost are incorporated into almost every facet of planning and communication within both the NASA and contractor execution of the Program. Besides the continuous presentation of these priorities in employee awareness media, the Program highlights their relative order in the formal consideration of design and/or process changes being considered by the various Program control boards. Additionally, these priorities are the focus point for most of the Program management forums such as the Program Management Reviews and SFOC Contract Management Reviews (CMRs). They are specified as the basis for the Program Strategic Plan, as well as the SFOC goals and objectives used by the contractor and NASA to manage and monitor the success of the SFOC. Finally, these priorities are embedded in the SFOC award fee process (which provides for four formal reviews each year). Specifically, the award fee criteria provide for both safety and overall performance gates which, if not met by the contractor, would result in loss of any potential cost reduction share by the contractor. In summary, NASA and all of the contractors supporting the

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				Space Shuttle Program have always been and remain committed to assuring that safety is of the highest priority in every facet of the Program operation. While downsizing does increase the challenge of management to execute a successful Program, process changes, design modifications, employee skills maintenance, and reorganizations are all part of the management challenges to be faced and resolved, and maintenance of the high level of attention to safety in resolving these challenges is recognized by NASA and the contractors alike as not being subject to compromise.
			Recommendation #1b NASA should develop and promulgate training and career paths leading to qualification for senior NASA Space Shuttle management positions.	**NASA Response (in 1998 ASAP appendix):** While it is true that the roles for NASA management and technical personnel are being reduced in number and reshaped to focus on the critical areas of anomalies and changes, these roles and the ongoing role of assessing the contractor's performance against the contract and Program requirements should provide a continued source of trained and capable future NASA senior managers. NASA has an active commitment to development of the skills for senior managers for all functional areas of the Agency, and Space Shuttle Program senior managers are generally products of both their in-line experiences as well as these career development programs. It is anticipated at this time that the roles for NASA personnel and the career development programs which have served NASA well to this point will be sufficient to assure a

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				continuation of highly qualified and capable senior managers in the future. Given the nature of the still evolving definition of the NASA and prime contractor roles and responsibilities for the SFOC operational model, it is reasonable to provide special attention to this concern, and the Program will ensure that specific consideration is given to this concern in the transition plans being developed and implemented by the functional and institutional organizations across the Program.
			Recommendation 1c: NASA should continue to ensure that a trained and qualified Government personnel presence is maintained on the work floor.	**NASA Response (in 1998 ASAP appendix):** NASA/KSC has maintained a physical presence on the work floor since the beginning of the Shuttle Processing Contract and will continue this presence for SFOC, Payload Ground Operations Contract, and Base Operations Contract. NASA engineering, operations, safety, and quality personnel maintain a surveillance and audit presence of overall operations for insight purposes and are formally involved for selected tasks being performed. Presence on the floor monitoring hazardous or safety critical operations has been maintained through the transition to performance based contracting and will be maintained in the future. The frequency and depth of the insight and presence may be adjusted as justified by the results of the contractor's performance, but the value of these checks and balances has long been recognized by NASA and will be maintained. To a lesser degree, this same floor

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				presence is executed at production sites through Resident Office presence and periodic audit and surveillance activities by NASA Center personnel. While there is a focused initiative to minimize Government mandatory inspection points (GMIPs) across the Program, it is mutually recognized by NASA and USA that the criticality of some checks and balances in critical processes demands that some small percentage (10–15 percent) will be maintained on the production and processing floors. This presence also supports the desired training and qualification needs for NASA to remain a smart customer. Finally, there are functional roles anticipated for continued NASA participation, such as flight controllers, astronauts, and launch directors which will also provide a significant avenue for NASA skills maintenance in the long-term management model.
			Recommendation 1d: NASA and USA should continue to search for, develop, test, and establish the most meaningful measures of operations and processing effectiveness possible.	**NASA Response (in 1998 ASAP appendix):** Both NASA and USA recognize the value of meaningful measures of the operational and processing effectiveness for the Program and continually strive to evolve and improve on the measures currently in place. The SFOC Performance Measurement System (PMS) has been a significant development project since the beginning of the contract, continues to take shape as the primary repository for the performance metrics which

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				provide management insight into the cost, and technical performance across the complete contract. Once the system is complete and populated with viable metrics, NASA will validate the system. The goal is to complete the validation by the fall of 1998. Key metrics are reviewed quarterly at the SFOC CMR, and individual functional areas such as flight operations and ground processing use these on a continual basis for their management execution and insight. Additional measures are continually developed at the Program level and within individual functional areas to enhance the understanding of performance trends, and when proven to be effective management tools, these metrics roll into the PMS and/or other forums and products used to manage the Program.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1998	**Finding 2:** The Kennedy Space Center (KSC) has been successfully phasing in the structured surveillance process for safety and quality for some time. The development of metrics using structured surveillance information has lagged data collection.	**Recommendation 2:** KSC should continue to expand the use of structured surveillance and to focus effort on the development of valid and reliable metrics to assess program performance from structured surveillance results.	**NASA Response (in 1998 ASAP appendix):** We concur. The development of reliable metrics with which to measure performance of the SFOC in all areas including safety and quality is progressing at KSC. There are several examples of this. At KSC, NASA Safety has developed a data base for the Space Shuttle Program, revised its surveillance approach, and developed a method by which proper measurements can be evaluated and analyzed in determining safety program management effectiveness and contractual statement of work compliance. These new metrics will enable NASA

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				Safety to more effectively measure contractor performance. The Quality Surveillance Record data base is currently being modified to clarify the method by which deficiencies and observations are counted and to better define failure codes and other data collected. These changes will increase the reliability of the data used to assess program performance and will be implemented in early July. In the interim, the existing data base has been modified and focuses on surveillance data collection for tasks which GMIPs were deleted through the GMIP reduction efforts. KSC has developed an expanded surveillance system that will provide extensive insight into the contractor's overall operation by process analysis. The process analysis program was initiated in October 1997, and there are presently 11 Quality Process Analysts working the pilot program at KSC. This system will provide added insight into the contractor's processes, procedures, and policies.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1998	**Finding 3:** NASA Safety and Mission Assurance (S&MA) auditors at KSC overseeing operations requiring Self-Contained Atmospheric Protective Ensemble (SCAPE) are not certified for SCAPE.	**Recommendation #3:** In order to be in a position to conduct valid safety and quality audits of SCAPE operations, NASA should ensure that personnel involved are certified so that, when necessary, they can observe the tasks while they are performed.	**NASA Response (in 1998 ASAP appendix):** The Space Shuttle Program concurs that safety and quality audits of SCAPE operations be performed. However, KSC's position is that NASA's safety and quality personnel monitoring SCAPE tasks will not be exposed to the additional risk of SCAPE operations as personnel can accomplish monitoring tasks by observing and communicating through the

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				audio and video capabilities of the Operational Intercommunication System and operational television (OTV). All SCAPE tasks are conducted on recorded communications channels that are monitored in the control room, and the majority of tasks are observable on the OTV system. NASA quality and safety personnel have performed those audits for several years without being SCAPE certified.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1998	**Finding 4:** To compensate for skills deficiencies related to staff departures from KSC, both NASA and USA are making extensive use of cross training of personnel, both technicians and engineers. Individuals who have been cross-trained also should have recent "hands-on" experience before they undertake a cross-trained task.	**Recommendation 4:** NASA and USA should develop and use valid and reliable measures of the readiness of personnel to take on tasks for which they have been trained but on which they have only limited or episodic experience. The cross-training program could include a regularly scheduled rotation of duties so that the multiply trained individual has the opportunity to employ all of the acquired skills and knowledge at appropriate intervals.	**NASA Response (in 1998 ASAP appendix):** NASA is in full agreement with the Panel's position that individuals who have been cross-trained also should have recent hands-on experience before performing tasks. The combined NASA/USA training and certification plan identifies those skills that require hands-on training as part of the certification process. Personnel selected for cross-training are required to be certified to perform other jobs in the same family of skills (i.e., mechanical systems, avionics systems, electrical distribution systems). With this knowledge base, those identified for cross-training will be required to meet the same training and performance requirements established for the given task. Performance is measured to verify that the individual has obtained the stated objectives of the instructional tool being used. In the case of hands-on training, the employee is required to demonstrate 100% command of the task being performed. The certification process is controlled by the

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				KSC Certification Board, which operates under approved certification procedures. The Certification Board, chaired by the USA S&MA Director at KSC, approves and implements certification/recertification requirements.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1998	**Finding 5:** The reduction of Government Mandatory Inspection Points (GMIP) at KSC has significantly lagged the downsizing of NASA quality personnel responsible for processing these GMIPs. This has resulted in an expanded workload among remaining NASA quality inspectors and made it more difficult to conduct analyses needed to identify further GMIP reductions. There has been a similar reduction of NASA safety inspectors and engineers at KSC without a commensurate reduction in oversight requirements while, at the same time, the addition of new safety audit or insight responsibilities has taken place.	**Recommendation 5:** Any downsizing of personnel by both NASA and USA should be preceded by the reduction of commensurate workload associated with Space Shuttle processing, such as reduction of GMIPs and NASA safety inspections.	**NASA Response (in 1998 ASAP appendix):** NASA concurs with the recommended approach of reducing the workload in Space Shuttle processing before proceeding with downsizing NASA and USA personnel; however, we have not been as successful in this area as desired. In the downsizing effort implemented in February 1998, USA experienced an unexpectedly high level of voluntary attrition in certain critical functions - an outcome that was predicted by ASAP members and others. Although USA experienced shortages of critical skills and staffing to minimum levels for short periods of time in selected areas, USA and NASA worked together to overcome these deficits and assure that the scheduled missions through STS-91 were safely executed. This was done by a combination of launch schedule relief, back-filling USA shortages with NASA expertise, and re-hiring technical expertise to train and certify USA staff, thus eliminating shortages in critical skills. Evaluation of GMIPs for potential elimination by process engineering and quality engineering staff continues. It is estimated that approximately 6,000 of the original 22,000 GMIPs will

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				remain in place at the end of this effort. This is a level assessed as commensurate with the current NASA quality inspection workforce. NASA Headquarters Office of Safety and Mission Assurance (OSMA) continues to evaluate the situation at KSC regarding NASA and USA workforce reductions by assessing process efficiencies and workload indicators. Indicators of process effectiveness include overtime rates and first-time quality rates. Although the efforts are not yet complete, OSMA anticipates that as GMIPs are reduced overtime rates for NASA quality inspections will drop. Additionally, if the development of process efficiency initiatives by USA are effective, then, when implemented, OSMA anticipates that USA engineering and technician overtime rates will drop and first-time quality rates, based on NASA surveillance sampling, will increase.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1998	**Finding 6:** The Super Light Weight Tank (SLWT) has completed its design certification review, and proof tests on the first tank have been satisfactorily passed. The only remaining test to complete certification of the SLWT is the cryogenic loading test that will be run on the first production tank on the launch pad. The diligent attention that has been given to quality control, particularly to material inspection and weld integrity, has made this program successful.	**Recommendation 6:** NASA should ensure that the current manufacturing and quality control procedures continue to be rigidly adhered to and conscientiously followed in production.	**NASA Response (in 1998 ASAP appendix):** NASA concurs with this recommendation. MSFC and Lockheed Martin Michoud Space Systems (LMMSS), the External Tank prime contractor, periodically perform a NASA Engineering and Quality Audit (NEQA) which focuses on both the processes and the flight hardware. The audit is conducted by experienced MSFC and LMMSS technical and management personnel and the operators and inspectors that actually utilize those processes. LMMSS also performs internal and supplier audits throughout the year. In

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				addition, on-site MSFC Science and Engineering, Safety and Mission Assurance, and DCMC personnel provide continuous insight and guidance through surveillance and limited oversight activities. Finally, adherence to manufacturing and quality control procedures is one of the primary focuses of the on-site government personnel.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1998	**Finding 9:** Support of the Space Shuttle fleet with operational spares has been maintained by the effective efforts of the logistics function. While spares support has been adequate for the current flight rate, any increase in flight rate might not be supportable.	**Recommendation 9:** Although NASA has established programs for dealing with suppliers and bringing additional component overhaul "in house," efforts in these areas need to be continuously reexamined to speed up the restoration and upgrading of line-replaceable units. Such efforts are especially needed to eliminate "dead" time while units are awaiting restoration.	**NASA Response (in 1998 ASAP appendix):** The Space Shuttle Program concurs with the ASAP concerns for the availability of line replaceable units (LRUs). Logistics monitors LRU spares posture through the probability of sufficiency calculations within the LRU data system. This system can be programmed to determine spares requirements for various flight rates. At this time, an appreciable increase in flight rate would be required to jeopardize supporting the Space Shuttle Program with most of the current LRUs. (Lots of detail omitted) Additionally, through the use of industrial engineering principles and work teams, Logistics has taken action to reduce the NASA Shuttle Logistics Depot (NSLD) backlog and increase output for fiscal year 1998. To date, backlog has decreased 8 percent since October 1 by increasing output. These efforts are aimed at providing better support at the current flight rate but are also the type of efforts that will allow higher flight rates in the

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				future.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1998	**Finding 10:** Transition and development of the logistics tasks for the orbiter and its ground operations under the SFOC are proceeding efficiently and according to plan.	**Recommendation 10:** NASA and USA should continue the task of management integration of the formerly separate logistics contracts and retain and expand the roles of the experienced logistics specialists therein.	**NASA Response (in 1998 ASAP appendix):** The Space Shuttle Program concurs with the ASAP philosophy of logistics integration. Integrated Logistics has been successful in integrating Ground Logistics and more recently, Flight Operations Logistics with Orbiter Logistics insight. As new elements are integrated within USA, the sharing of new techniques and best in class practices is occurring. Logistics is recognized as a key member of both the NASA and contractor teams; their input is actively sought on key decisions, and they are members of key decision-making boards and panels.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1998	**Finding 11:** As reported last year, long-term projections are still suggesting increasing cannibalization rates, increasing component repair turnaround times, and loss of repair capability for the Space Shuttle logistics programs. If the present trend is not arrested, support difficulties may arise in the next 3 or 4 years.	**Recommendation 11:** NASA and USA should reexamine and take action to reverse the more worrying trends highlighted by the statistical trend data.	**NASA Response (in 1998 ASAP appendix):** The Space Shuttle Program has recognized the concerns for long-term supportability and is proactively pursuing improvements. Cannibalizations continue to be closely monitored and are well within limits. There have been several concerns during this past year (seals and cryo heater controllers) that are requiring the adjustment of sparing levels. The Logistics organization is aggressively pursuing a solution to specific problems as well as pursuing innovations to keep the rate below the standard. As mentioned in the response to Finding #9, the NSLD backlog is now decreasing as

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				a result of USA action. This should ultimately reduce the repair turn around time for hardware although short term increases can be expected. Other initiatives such as the replacement of unserviceable test equipment at vendors are also in progress. Logistics and Engineering are developing common tools to integrate upgrade actions, resolve supportability issues, and mitigate the loss of repair capability. The Problem Resolution Teams have increased the interfaces with Logistics, Engineering, and management to ensure a proactive and integrated effort in identifying problem areas and identifying solutions. Numerous initiatives are under way. Finally, NASA has funded through Space Shuttle upgrades the prototyping of a new expert logistics system which shows promise in ranking issues according to severity. This data might then be used to assure that limited funding available is used as economically and wisely as possible in order to minimize risk in the most vulnerable areas.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1998	**Finding 19:** The Checkout and Launch Control System (CLCS) program at KSC has not been provided with funding for Independent Verification and Validation (IV&V) that is safety critical for a software effort of this size.	**Recommendation 19:** The CLCS should be provided with adequate funding for software IV&V.	**NASA Response (in 1998 ASAP appendix):** KSC concurs with the ASAP recommendation relative to IV&V funding for the CLCS Project. A Memorandum of Agreement (MOA) was signed on May 5, 1998, between the Software IV&V Facility and KSC, for the performance application of IV&V techniques and methods to the CLCS software. The scope of this

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				memorandum will include performing IV&V on selected catastrophic/critical/high risk CLCS software components. The selected software components will consist of CLCS system software. The specific areas to be analyzed will be system redundancy, command support, data distribution and processing, constraint management, and the safing system related software. The software related to safing includes the Emergency Safing System and those control logic modules associated with safing (some of which may reside within application software). The analysis will consist of requirements, design, code, and test analysis, as applicable for the life cycle of the software being analyzed. The application interfaces with the system software will also be analyzed. In addition, the IV&V Facility will perform system level analysis of the system test plan and system tests performed along with software engineering and integration analysis of the CLCS system as a whole. This MOA is effective from May 1, 1998, until September 30, 2000. The work identified in this MOA will require a staffing level of about 16 full time equivalents (FTEs). This staffing level will be comprised of 15 FTEs from the IV&V contractor located at the IV&V Facility and at KSC. The remaining one FTE will be a civil service personnel. Staffing at KSC

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				will be comprised of eight contractor FTEs with the remainder residing at the Fairmont Facility. The Space Shuttle Program has agreed to fund this effort at $4.5M over the life of the MOA.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1997	**Finding 1:** One consequence of the implementation of the Space Flight Operations Contract (SFOC) is a reduction in opportunities for NASA personnel to maintain detailed, day-to-day work floor interfaces with their contractor counterparts both at space flight centers and major contractor facilities. This could compromise NASA's ability to carry out its assessment function.	**Recommendation 1:** In order to carry out its assessment role, NASA must maintain some physical presence on the work floor at the space flight centers and major contractor facilities. NASA must ensure that the people staffing these surveillance positions are and continue to be appropriately skilled, thoroughly knowledgeable about the Space Shuttle, and sufficiently experienced with both the subsystem they oversee and the total Space Shuttle system.	**NASA Response (in 1997 ASAP appendix):** NASA concurs with the finding and is sensitive to the need to maintain a skilled and capable workforce in both the management and technical functions necessary for Space Shuttle program (SSP) success, and the Agency will work with the contractor in establishing the eventual organizational roles and responsibilities to assure that success. The transition process will be managed at a pace to ensure that necessary skills are maintained within the Government/contractor workforce. The assessment function that NASA will perform in the future Shuttle operations architecture will require the maintenance of a solid skill base within the Agency. NASA will retain the capability to review all anomalies in operations and system performance, as well as all changes to operations and to systems. NASA's role in requirements control will also provide continuous exposure to designs and operations within the program. The participation of NASA engineering and management in the development of Shuttle upgrades will provide further opportunity for the maintenance of an inherent skill base. Finally, there will

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				be functional roles for NASA personnel, such as astronauts, flight controllers, and mission directors, that will provide an avenue for skills development and maintenance.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1997	**Finding 2:** It is not clear how NASA Space Shuttle supervisory personnel will be trained and acquire the experience levels necessary to function effectively in senior management positions when the SFOC is fully implemented and the traditional learning ladder positions are staffed by the contractor.	**Recommendation #2:** NASA should develop and promulgate training and career paths leading to preparation and qualification as potential senior NASA Space Shuttle management.	**NASA Response (in 1997 ASAP appendix):** NASA has an active commitment to the development of the skills of senior managers for all functional areas of the Agency. Space Shuttle program senior managers are generally products of both their in-line experiences as well as the NASA career development programs. It is anticipated at this time that the roles for NASA personnel and the career development programs that have served NASA well to this point will be sufficient to assure a continuation of highly qualified and capable senior managers in the future. Given the evolving nature of the NASA and prime contractor roles and responsibilities for the SFOC operational model, it is reasonable to focus special attention on this issue; the program will ensure that specific consideration is given to management development in the transition plans being developed and implemented across the program.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1997	**Finding 3:** No objective measure has yet been developed, or is likely possible, that can shed significant light on the impact of downsizing on the safety of Space Shuttle operations.	**Recommendation 3:** In the absence of a valid predictive safety metric, NASA should ensure that all functions affected by downsizing and necessary for safe operations are assigned to people who have the knowledge, skills, and time to carry them out.	**NASA Response (in 1997 ASAP appendix):** NASA concurs; all of the contractors supporting the Space Shuttle program remain committed to assuring that safety is the highest priority in every facet of the program. The program recognizes the concerns that downsizing may raise, and it will assure that knowledgeable and skilled individuals are assigned to all

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				critical Shuttle functions, including those being downsized. The plans for the transition of processes and tasks under the SFOC specifically address the safety implications of the transition. As an added assurance, the Shuttle program has required that the NASA Safety and Mission Assurance (SMA) organizations review and concur on the transition plans. Other program downsizing efforts have a similar emphasis on safety embedded in them, and both program management and the SMA management are committed to assure that this focus is not compromised.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1997	**Finding 4:** Post-flight discovery of a wrench and an equipment nameplate in the forward skirt of one STS-79 Solid Rocket Booster (SRB) has heightened concern for the overall integrity of Space Shuttle processing quality assurance procedures.	**Recommendation 4:** NASA, in concert with the several Space Shuttle contractors, should conduct an in-depth review of Space Shuttle processing quality assurance procedures focused on creating a more formal, documented approach to accounting for tools and other material introduced to and removed from flight hardware work areas.	**NASA Response (in 1997 ASAP appendix):** The Space Shuttle program element contractors presented their tool control programs to the Space Shuttle System Safety Review Panel (SSRP) meeting in December 1996. The SSRP reviewed the tool control programs of all the contractors and determined that each of the tool programs was effective for the type of work performed. The SSRP recommended that tool accounting audits be maintained or increased, and that metrics be maintained to assure that each tool control program remains effective. In a letter dated March 20, 1997, the Space Shuttle Systems Integration Office confirmed that NSTS 07700, "Space Shuttle Program Definition and Requirements," requires tool control for only the launch and landing project, and recommended that Volume XI of NSTS 0770 be expanded to include tool control at the manufacturing

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				facilities. A change request to NSTS 07700, Volume XI, adding the program requirement to include tool control at the element manufacturing facilities, was approved by the Program Requirements Control Board (PRCB) on July 10, 1997.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1997	**Finding 5:** NASA plans to operate the Space Shuttle until at least 2012. This will require safety and operational upgrades to hardware, software, and logistics support.	**Recommendation 5:** NASA should complete Space Shuttle upgrades as soon as possible to take advantage of opportunities for earliest risk reduction and operational improvement.	**NASA Response (in 1997 ASAP appendix):** The SSP upgrade strategy is founded on the premise that safety, reliability, and supportability improvements must be made to support human space transportation until a suitable replacement is available. To manage and focus these efforts more effectively, the SSP established the Office of SSP Development on January 16, 1997. The Space Shuttle upgrades program is being implemented from a systems perspective. Upgrades will be integrated and prioritized across all flight and ground systems, ensuring that individual upgrades are compatible and that their impact is assessed across the entire program. A phased approach to the SSP upgrades is already under way. Phase I, to be completed by the year 2000, emphasizes safety and performance enhancements for the International Space Station (ISS) assembly and utilization. Ongoing efforts within all SSP elements are also under way to identify Phase II candidate and Phase III/IV studies. Primary emphasis remains on safety and risk reduction by improving reliability and maintainability, eliminating obsolescent components, and

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				improving vehicle performance. As those upgrade candidates are identified by the program elements, the SSP is committed to expediting implementation to maximize safety and reduce overall program risk.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1997	**Finding 6:** The orbiter Reaction Control System (RCS) thruster valves continue to leak in flight. NASA h as aggressively attacked this problem with some success. Procedural changes have improved thruster reliability, and the incidence of leakage has been reduced but not eliminated.	**Recommendation 6:** Continued attention must be focused on the elimination of the root causes of RCS valve leakage/failures.	**NASA Response (in 1997 ASAP appendix):** Several remedial actions have been and are being implemented as a result of a 1995 tiger team investigation into the causes of RCS valve leakage/failure. This has resulted in many procedural changes and several potential hardware improvement concepts. The procedural changes are reducing the number of in-flight thruster valve failures. Many of the hardware improvements are entering a development testing phase. Examples of procedure and hardware changes include: (examples omitted)
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1997	**Finding 7:** A new gas generator valve module for the Improved Auxiliary Power Unit (IAPU) is currently entering the process of certification. When fully certified, the IAPU with this new valve is planned to be qualified for 75 hours of operation between scheduled teardowns and overhauls (in excess of 10 years at projected use rates).	**Recommendation 7:** Once certification is achieved for 75 hours of IAPU operation, NASA should establish a periodic inspection and test program to assure that IAPUs continue to perform in accordance with requirements throughout their service life.	**NASA Response (in 1997 ASAP appendix):** An IAPU maintenance plan is being developed by the NASA and contractor technical community. Current activity is focused on developing a maintenance specification, evaluating long-term life of elastomeric components, and organizing a parts tracking/usage database. At the conclusion of this effort in late FY 1997, a longterm maintenance plan will be baselined for implementation. Supplementing this to provide long-term service life information is a fleet leader test program at WSTF. The WSTF program is currently

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				scheduled to conclude in FY 1999 and is to demonstrate 75-hour run time and evaluate 10+ year teardown and overhaul time.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1997	**Finding 8:** The Space Shuttle is about to receive two major avionics upgrades - a triple redundant Global Positioning System (GPS) installation and the Multi-Function Electronic Display System (MEDS)- both of which require significant changes to the Primary Flight Software (PFS) and Backup Flight Software (BFS) systems.	**Recommendation #8:** The Space Shuttle program should ensure that both the GPS and MEDS software changes are thoroughly tested in the Shuttle Avionics Integration Laboratory (SAIL) using the normal and enhanced test protocols that have proved to be robust when testing major modifications.	**NASA Response (in 1997 ASAP appendix):** The SSP concurs that all software and hardware changes need thorough testing, and it recognizes the extremely important role that SAIL testing fulfills in the complement of testing for software certification. All Shuttle software or hardware upgrades are assessed to determine integrated verification test requirements. The SSP and its contractors cooperate to produce integrated hardware and software test implementation plans, test requirements documents, and integrated test schedules to assure that the required resources, including SAIL, are available. All these plans are reviewed and approved by the program. Thorough testing of each new capability is then performed and analyzed. This same rigorous process that is used for flight software Operational Increment (OI) updates will be applied to the MEDS, GPS, other Shuttle upgrades, and future software updates.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1997	**Finding 9:**The Multi-Function Electronic Display System (MEDS) in the orbiter is being implemented with display functions and formats that mimic the present electro-mechanical and cathode ray tube presentations. There are significant potential safety and operational benefits from	**Recommendation 9:** The Space Shuttle program should commit to a significantly enhanced MEDS display as soon as possible. The MEDS advanced display working group or a similar multidisciplinary team should be tasked with identifying specific modifications and an associated timetable so that the opportunities inherent in MEDS	**NASA Response (in 1997 ASAP appendix):** The SSP has established an enhanced MEDS program that includes hardware and software enhancements to take full advantage of MEDS capabilities. This includes hardware expansion as well as utilization of inherent MEDS capabilities to provide better displays and improve crew

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		enhancing the amount, type, and format of information shown on the MEDS displays.	can be realized.	situational awareness. Additionally, an SSP Cockpit Upgrade Team is being formed to develop advanced display and application concepts for future implementation into MEDS/enhanced MEDS/future avionics upgrades capability. The Cockpit Upgrade Team will also participate in avionics upgrades discussions in order to anticipate future hardware and software changes and develop advanced cockpit applications to further improve crew awareness and reduce crew training requirements. Initial testing of new applications for enhanced MEDS will begin in June 1997.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1997	**Finding 10:** The Block II SSME development program has proceeded well, except for the Alternate Turbopump Program High Pressure Fuel Turbopump (ATP HPFTP). The HPFTP has suffered significant failures in testing, which were traced to shortcomings in hardware design details. Corrective actions have been implemented on the HPFTP. Block II engine testing has resumed for this major safety improvement.	**Recommendation 10:** Continue the development and certification test programs as originally planned. Accumulate the specified test operating times for the modified ATP HPFTP, and employ the number of test pumps as per the original test plan.	**NASA Response (in 1997 ASAP appendix):** The SSME project is committed to meet the original development and certification plan requirements. The schedule for certification has been adjusted to accommodate comprehensive resolution of the development problems. Scheduled completion of certification testing is now February 1998. As originally planned, the total "hot-fire time" for development and certification will exceed 60,000 seconds, utilizing eight HPFTP units. Certification will be based on two units with 22 tests each, and "hotfire time" of 11,000 seconds per pump or 22,000 seconds total certification time.
Aerospace Safety Advisory Panel *(NASA*	February 1997	**Finding 11:** The schedule for the first flight of the Block II engine has slipped, from September 1997 to December 1997.	**Recommendation 11:** Maintain the full scope of the planned test programs. Assure the availability of test stand A-2 at SSC for as long as it is	**NASA Response (in 1997 ASAP appendix):** The development and certification test programs will be maintained as originally

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Charter)		This schedule is optimistic and contains no slack for future development problems. The schedule also requires continued availability of three test stands at the Stennis Space Center (SSC).	needed for the Block II engine test programs so that three test stands continue to be available.	planned. Test stand availability has been coordinated with other program test requirements to support completion of Block II HPFTP certification testing in February 1998. Three test stands are required only until July 1997 to support this schedule. A mid-May milestone to initiate construction authorization for the July reconfiguration of Test Stand A-1 for X-33 testing will be reassessed based on fuel pump development status at that time. The other two test stands will remain dedicated to SSME testing. After test stand modification, conversion back to SSME test configuration would take approximately 1 month. The first flight of the Block II configuration has been reassigned to STS-91, currently scheduled for May 1998. Due to the development problems with the ATP HPFTP and the associated schedule slips, the SSP has elected to certify an interim Block II configuration, designated Block IIA. Block IIA will consist of Rocketdyne's current HPFTP in conjunction with the other Block II components and will provide the safety and reliability benefits of the large throat main combustion chamber at the earliest opportunity. This configuration will be certified to fly nominal missions at 104% to 104.5% rated power level (RPL) and will maintain the current 109% RPL contingency abort capability.

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Aerospace Safety Advisory Panel *(NASA Charter)*	February 1997	**Finding 12:** The Block II engine will be certified for operation at 109% power level only for abort situations. Accordingly, the test program provides only limited cumulative test time at this thrust level.	**Recommendation 12:** After completion of the current planned Block II certification test program, conduct a certification extension test program that will demonstrate the highest thrust level for safe continuous operation achievable by the Block II configuration. This program should attempt to achieve at least the 109% power level.	**NASA Response (in 1997 ASAP appendix):** The Block II program was developed to "improve the safety, reliability, and robustness of the SSME" by providing lower operating temperatures, pressures, shaft speeds, and other critical parameters. An increase in operating power level from 104% to 104.5% will offset some of the weight gain of Block II. The Block II SSME was never intended to increase Space Shuttle ascent performance or increase payload capability to orbit. However, additional performance has been accepted for a few specific missions at the cost of some of the improved safety margin. There is a commitment that the ISS flights will provide 106% engine power level certification to achieve mandatory critical payloads to orbit. The Block II certification will also provide a 109% intact abort capability, which will allow the vehicle system to better optimize abort scenarios. Implementation recommendations for use of 109% throttle for intact aborts will be made by the Shuttle operations element once certification is complete.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1997	**Finding 13:** Changes in the Pressure Sensitive Adhesive (PSA) and the cleaning agent for the J-flap of the RSRM were driven by environmental regulations. The certification testing for these changes included a Flight Support Motor (FSM) firing without the application of side loads,	**Recommendation 13:** Employ the application of side loads in all future RSRM FSM firings.	**NASA Response (in 1997 ASAP appendix):** The SSP and RSRM project agree with this recommendation when aft field joint test objectives warrant inclusion on an FSM test motor. During Space Shuttle return-toflight RSRM redesign, the assessment of strut loading on the solid rocket motors concluded that the only influence was at the

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		a significant condition for RSRM field joints for which the J-flap plays a role.		aft field joint. The influence on the aft field joint gap openings was predicted to be less than 0.001 inch, roughly an order of magnitude less than the contribution of the internal motor pressures. Side loads were included on two RSRM static test motors (QM-7 and -8) in a comprehensive effort to include every element of flight loading influencing the aft field joint gap openings. Joint gap openings were not measured directly, but the sealing systems performed as expected. Gap openings were measured on the RSRM structural test article-3, where testing showed side loads influence to be less than 0.0005 inch out of a total of 0.0084 inch for aft field joints only. The consideration to include side loads on all future tests would not come without technical penalty. To accommodate the side load forces, the aft test stand must be locked out, and as such, no thrust measurements are obtained. Also, no thrust vector control (TVC) duty cycling is performed during the side load events, which requires modification to the baseline static test duty cycle; for certain test objectives, this is an important requirement consideration. This baseline TVC duty cycle is utilized to allow direct performance comparisons between static tests, primarily associated with nozzle and aft dome materials or components. Therefore, a generic inclusion of side loads on all future FSM tests would require elimination of other test

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				considerations, which, depending on specific test objectives, might be a qualification necessity. In conclusion, the RSRM static test policy includes side loads on full-scale static test motors where there are test objectives associated with the aft field joints, which could be influenced by side loads.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1997	**Finding 14:** There are many material and process changes in work for the RSRM in response to both environmental regulations and obsolescence issues. A vital part of the certification program for these changes is the demonstration of the acceptability of the changes during an FSM firing. At present, FSM firings are scheduled at 2-year intervals instead of the 1-year or 18-month intervals previously used.	**Recommendation 14:** Considering the large number of changes in RSRM materials and processes and the importance of proper simulation of operating conditions in any certification test program, NASA should re-evaluate its decision to have 2 years between FSM firings.	**NASA Response (in 1997 ASAP appendix):** The RSRM project presented an assessment of static test motor frequency to the PRCB on February 27, 1997, and recommended static tests at 1-year intervals. The recommendation was accepted by the PRCB. An initiative is under way to ensure that the maximum possible benefit is obtained from each test.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1997	**Finding 15:** A substantial program effort is under way to eliminate the asbestos used in RSRM manufacture and replace it with more environmentally acceptable (i.e., “asbestos- free”) materials. Although some of the materials tested to date meet specifications, they do not provide as high structural and thermal margins as the asbestos-containing materials.	**Recommendation 15:** To maintain flight safety, NASA should not eliminate the use of asbestos in RSRM manufacture. An environmental waiver should be obtained to continue its use in RSRM insulation, liners, inhibitors, and other motor parts in the event of future regulatory threat to the asbestos supplier.	**NASA Response (in 1997 ASAP appendix):** NASA currently has no plan to introduce nonasbestos-based replacements for asbestos-based components in RSRM production. The RSRM production and flight history are baselined with asbestos-based materials, primarily NBR rubber. Asbestos is also a constituent of liner and adhesives. The production, handling, and disposal processes for these materials are performed in compliance with strict state, Federal, and local controls and regulations regarding asbestos material. There are no currently identified regulations to ban

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				production or use of asbestos materials in the RSRM supply chain. Because there is no existing or pending regulation, pursuit of waivers or exemptions is not applicable at this time. NASA considers it prudent to continue low-level development of possible alternative nonasbestos materials. This reflects NASA's sensitivity to the environment, worker safety and health issues, and the fact that the shelf life of these materials precludes the option to stockpile. This development effort is being carried out to provide limited contingency development at a routine pace. The recommendations by both the ASAP and the RSRM initiatives to find alternative materials are consistent with program policy documented in SSP letter MS 96-071, dated September 16, 1996. The policy seeks to balance flight safety and environmental protection goals.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1997	**Finding 16:** The 2195 aluminum-lithium alloy used in the tank walls and domes of the new Super Light Weight Tank (SLWT) has a lower fracture toughness at cryogenic temperatures than was anticipated in the design. To compensate for this potentially critical short-coming, NASA has limited the pressure used in the full tank proof test and has recognized that acceptance of each SLWT for flight is highly	**Recommendation 16a:** Assure that the acceptance tests of the 2195 material and the quality control procedures used in the manufacture of each SLWT continue to be sufficiently stringent, clearly specified, conscientiously adhered to, and their use unambiguously documented.	**NASA Response (in 1997 ASAP appendix):** The SSP and Marshall Space Flight Center (MSFC) will continue to ensure that material acceptance testing and the quality control procedures used in the manufacturing of SLWTs are of a sufficient quality to validate that each tank is fully in compliance with all program requirements and is safe to fly.

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		dependent on far more stringent quality control of the materials and processes used to manufacture the SLWT than is required for the current external tanks.		
			Recommendation 16b: The criticality of these quality control operations makes it mandatory for NASA to retain buyoff of the results of those fabrication operations and tests that are essential in determining SLWT safety.	**NASA Response (in 1997 ASAP appendix):** The SSP and MSFC will retain NASA approval of the quality control program and changes to that baseline.
			Recommendation 16c: As quality control data on the size of flaws detected in 2195 aluminum-lithium material are collected, they should be used in an updated analysis of the SLWT structure, because it may permit the verifiable spread between flight limit stress and proof stress to be raised above that presently reported.	**NASA Response (in 1997 ASAP appendix):** The simulated service database has been developed from data collected on fracture specimens with flaws that are 0.175 inch long. The data verify a 2.9% positive spread between the flight and proof-test conditions. Using the demonstrated flaw detectability level for our nondestructive evaluation dye penetrant process (0.086 inch long) would increase the spread to approximately 14%. Because of uncertainties, it is NASA's standard policy to use a factor of two on our flaw detectability limit. This methodology provides the proper risk allocation between the nondestructive evaluation capability and proof-test levels. The use of a flaw size of 0.175 inch for the simulated service tests is conservative for the SLWT.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1997	**Finding 17:** Transition of logistics functions under Phase 1 of the Space Flight Operations Contract (SFOC) appears to be taking place smoothly. Key personnel are maintaining	**Recommendation 17:** Continue adherence to established systems, and make maximum use of the inherent capability of the incumbent personnel in the logistics systems.	**NASA Response (in 1997 ASAP appendix):** NASA concurs. The established NASA Logistics Operations continues to monitor the established logistics systems and enhance others in order to maintain insight into the

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		continuity in management techniques and processes.		logistics activity. Both the SFOC contractor and NASA Logistics Organization have retained incumbent key personnel with critical logistics skills to minimize the transitional risks and continue to support the SSP. Currently, the SFOC contractor is studying the horizontal consolidation of like functions and processes. NASA Logistics Operations will monitor the contractor's progress to assure that the logistics systems resulting from this consolidation will be capable, effective, efficient, and, above all, not adversely impacting the safety of operations.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1997	**Finding 18:** Long-term projections suggest increasing cannibalization rates, component repair turnaround times, and loss of repair capability for the Space Shuttle logistics and support programs.	**Recommendation 18:** Take early remedial action to control this potential situation, such as maintaining sufficient spares and extending repair and overhaul capability.	**NASA Response (in 1997 ASAP appendix):** NASA is closely monitoring logistics trends. The areas of emphasis stress long-term logistics support indicators, specifically backlog and repair turnaround. While an increase in repair turnaround time has been noted, vehicle support remains at the same high level. Budget reductions in past years have meant that fewer spares have been produced and less repairs were performed, but NASA and the contractor will continue to manage the process to maintain acceptable levels of support. Presently, logistics performance measurement data do not indicate any adverse trends in cannibalization rates. NASA has directed SFOC management to maintain an emphasis on logistics supportability during the transition of all contract responsibilities. The SFOC

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				contractor has been directed to maintain key personnel with critical logistics skills to minimize transitional risks and provide continuity to Shuttle logistics support. In addition, SFOC is required to develop and submit original equipment manufacturer (OEM) contingency plans for responding to known and potential support issues at effected OEMs. All known supportability threats are tracked and evaluated to determine the associated risk and required actions for resolution. The SFOC has the appropriate processes in place to both monitor and respond to loss of subcontractor capability. The NASA Shuttle Logistics Depot (NSLD) has been certified to make some repairs where there has been a loss of critical supplier capability. The SFOC is also considering consolidating similar work at one vendor so that the NSLD is not the only repair agent.
		Finding 19: Obsolescence of components and systems on the Space Shuttle is an increasing problem threatening critical spares availability.	**Recommendation 19:** Alternative components must be developed and certified, and, where necessary, systems must be redesigned to use available or adaptable units.	**NASA Response (in 1997 ASAP appendix):** NASA continues to identify and coordinate obsolescence issues concerning hardware, special test equipment, vendor capability, and environmental restrictions with the appropriate design center. Each issue is evaluated for logistics impacts, and this information is communicated to or within the design center so that appropriate action can be taken to initiate any required redesigns, modifications, or enhancements. A Kennedy Space Center (KSC) logistics priority list is

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				maintained to communicate logistics' top concerns to design center management. While obsolescence will continue, a team approach to problem identification, prioritization, and resolution appears to be providing effective problem resolution. Additionally, the Shuttle upgrade program is designed to assure that potential problem areas are addressed so as to preclude disruption in meeting manifest requirements.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1997	**Finding 27:** NASA's Agency-wide software safety policy allows projects latitude to tailor their software safety plan for safety-critical software. It does not, however, require projects to obtain center Safety and Mission Assurance (S&MA) approval of the tailored software safety plans nor does it require Verification and Validation (V&V) per se. mile the software assurance standard does mention V&V, it does not require any independence of V&V for safety-critical software.	**Recommendation 27a:** NASA should require approval of a project's tailored software safety plan by both the center S&MA organization and by one administrative level higher than that making the request.	**NASA Response (in 1997 ASAP appendix):** NASA agrees with the intent of this recommendation but believes the requirements for formal system safety program plans and software management plans exist and, with proper and firm enforcement, fulfill the objective of this recommendation. To be sure that these requirements are perfectly understood, the Office of Safety and Mission Assurance (OSMA) will update NSS 1740.13, "NASA Software Safety Standard," to explicitly state that the program/project manager for programs/projects perform an assessment to determine, based on the level of criticality and risk, the scope and level of Independent Verification and Validation (IV&V) to be planned. The results of the assessment will be formally reviewed by Center Safety and Mission Assurance (SMA). The program/project manager, in consultation with SMA, will tailor an approach to ensure that the appropriate V&V requirements are established

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				and implemented. The OSMA will place more emphasis on the implementation and enforcement of these existing requirements. Process verification, recently established in the OSMA, will be used to evaluate and enforce these existing policy and requirements more aggressively. NASA is committed to assuring that required program management plans and any subordinate plans such as software or safety management plans cover the essential requirements for programs where warranted by cost, size, complexity, lifespan, risk, and consequence of failure. Additional changes are being incorporated into NPG 7120.5, "NASA Program/Project Management Guide" (currently under development), to ensure that necessary and sufficient requirements will be fulfilled for programs having software vulnerabilities. SMA organizations at each level are to be a party to these decisions and are to intervene where necessary to assure that proper and clearly documented decisions are made by the appropriate level of management. The Program Management Councils could play a role in adjudicating any issues with the content of program management plans.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1997	**Finding 28:** NASA has put considerable effort into the reorganization of its software activities and has made significant progress. It does not yet, however, have a	**Recommendation 28:** NASA should ensure that there is a clear, universally well-understood, widely promulgated, and enforced NASA Policy Directive on the roles and responsibilities of its	**NASA Response (in 1997 ASAP appendix):** NASA agrees with the recommendation. The July 1996 (draft) program plan for the Fairmont (IV&V) Facility is the contract between Code

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		comprehensive, clear set of roles and responsibilities for various groups within the Agency with respect to software development, safety, V&V, and software process development.	various organizations vis-a-vis software development and safety. Moreover, that Policy Directive should specify organizational roles and responsibilities solely on the basis of technical and administrative capability.	Q and the Facility and will be updated for future funding and delegation of the software assurance program. NASA concurs that the draft plan now contains ambiguities but will be clarified in the next update. The IV&V Facility's reporting structure will be finalized in the upcoming proposed Ames Research Center reorganization. It is anticipated that the IV&V Facility will be moved from under the direction of Code I at Ames and installed as the equivalent of a Directorate in the new ARC organization. The IV&V Facility Business Plan currently defines the roles and responsibilities of the IV&V Facility. NASA Headquarters will establish and document at the policy level the roles in the Agency for all software, including embedded and flight system software. The policies document will explain how the roles and responsibilities of the Agency-wide software efforts mentioned in the finding (e.g., CIO, COE-IT, IV&V Facility) fit together in a synergistic manner within the Agency. The new NPD 2820 will define Agency policy for program/project utilization of the IV&V Facility. The Chief Information Officer, the Chief Engineer's Office, the Office of Safety and Mission Assurance, and the Software Working Group will be responsible for increasing Agency awareness of all the software-related resources, policies, and existing standards. The newly

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				implemented Code Q process verification activity will validate Agency project managers' awareness of software assurance policy and procedures for compliance in software development efforts.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1996	**Finding 1:** Cutbacks in government and contractor personnel and other resources at the Kennedy Space Center (KSC) and the planned transition of tasks from government to contractor workers will create a new mode of Space Shuttle operations. Those involved in day-to-day Shuttle operations and management are in the best position to determine how to maintain the stated program priorities - fly safely, meet the manifest and reduce costs, in that order.	**Recommendation 1:** Additional reductions in staff and operations functions should be accomplished cautiously and with appropriate inputs from the KSC NASA/contractor team itself.	**NASA Response (in 1996 ASAP appendix):** KSC operations continue to focus on the program goals of flying safely, meeting the manifest, and reducing costs, with flying safely being paramount. Teamwork between NASA and its contractors has enabled us to meet program challenges in the past, and we will rely on that same teamwork to meet the challenges of the Space Flight Operations Contract (SFOC) transition. Reductions in personnel will be proportional to requirement reductions as opposed to budget reductions. Requirements reductions which will reduce work content should come from the program as well as efficiencies which are originated at KSC. KSC plans to use a phased methodology to control change and risk. In a partnering relationship, NASA and United Space Alliance (USA) will jointly plan change, implement change, then stabilize and assess the results before making further changes. "Partnering" provides NASA visibility and management insight into the transition process and ensures desired levels of safety and quality are maintained. By implementing a disciplined transfer of mature systems, proven procedures, and experienced personnel into SFOC, we feel that we can

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				accomplish a seamless transition without disturbing the infrastructure that has made this program such a success.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1996	**Finding 2:** Obsolescence of Space Shuttle components is a serious operational problem with the potential to impact safety. Many original equipment manufacturers are discontinuing support of their components. NASA is, therefore, faced with increasing logistics and supply problems.	**Recommendation 2:** NASA should support augmenting the current comprehensive logistics and supply system so that it is capable of meeting Space Shuttle Program needs in spite of increasing obsolescence.	**NASA Response (in 1996 ASAP appendix):** NASA concurs with the finding that current tracking and control systems are providing timely information to deal with logistics problems. With regards to the specific need for better visibility into the subject of obsolescence, it was with that concern in mind that the Safety and Obsolescence (S&O) activity was established as a process for identifying and responding to trends indicative of aging and to identify areas where replacement parts may no longer be available. The S&O process baselined in NSTS 08198 provides a rigorous prioritization approach which factors in the criticality of the systems and nonsafety related risks involved with Shuttle flight and ground processing hardware. This process identifies the most serious problems and generates data used to support requests to program management for correction of the identified concerns.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1996	**Finding 3:** The Return to Launch Site (RTLS) abort maneuver is one of the highest risk off-nominal Space Shuttle flight procedures. A Space Shuttle Main Engine (SSME) shutdown leading to an intact abort is more likely than a catastrophic engine	**Recommendation 3:** NASA should pursue with vigor efforts to minimize Space Shuttle exposure to the RTLS maneuver through all available means.	**NASA Response (in 1996 ASAP appendix):** NASA has and will continue to increase the reliability of the hardware to decrease the probability of any abort and to make operational trades to balance the risks between the available abort modes. The RTLS abort mode is fully certified and has been a

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		failure. Exposure of an ascending Space Shuttle to the risk of performing the demanding RTLS maneuver might be significantly minimized by operating the Block II SSME at higher thrust levels at appropriate times. Certification of alternative Space Shuttle landing approaches for use during contingency aborts and installation of Global Positioning System (GPS) could also contribute to the minimization of RTLS risk (see Finding #5).		requirement throughout the design and certification of the vehicle. Options to improve abort capability, such as increased SSME throttling or utilization of GPS to increase operating flexibility, are continually evaluated. A decision for certifying the Block II SSME intact throttle to 109 percent is scheduled for late 1996. Routinely operating at higher thrust settings may add additional risk, which needs to be evaluated versus RTLS exposure. A review of the GPS implementation schedule is under way. Single-string GPS is in development for three vehicles to gather flight test experience. Software development for three-string GPS is also currently in work. As development and flight testing continues, the GPS contribution to minimizing RTLS risk will be assessed. While the RTLS intact abort mode is certified and is considered to be acceptable, however, improvements to decrease the risks of RTLS will continue to be evaluated. Each flight is designed to meet RTLS constraints, and operational considerations are continually reviewed to ensure that the proper trades are being made to balance risks. While many alternatives have been considered, none can eliminate the requirement for RTLS capability, and, to date, all are predicted to have risk greater than that associated with the current certified abort modes.

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Aerospace Safety Advisory Panel *(NASA Charter)*	February 1996	**Finding 4:** The Range Safety System (RSS) destruct charges have been removed from the liquid hydrogen tank of the External Tank (ET). The risk studies, which supported this removal, also suggested that the RSS charges had to be retained on the Liquid Oxygen (LOX) tank of the ET. It is preferable to omit as much ordnance as possible from flight vehicles to reduce the possibility of inadvertent activation.	**Recommendation 4:** Studies supporting the need for the RSS destruct system on the LOX tank should be updated in light of the current state of knowledge, operating experience and the introduction of the new Super Lightweight Tank (SLWT) to determine if it is now acceptable to remove the ordnance.	**NASA Response (in 1996 ASAP appendix):** Studies have been completed, and the Space Shuttle program has formally eliminated the requirement for an ET RSS and approved removal of ET RSS hardware. Deactivation of the system is planned with a phased implementation of hardware removal on tanks that culminates in a total removal by ET-96. RSS hardware removal may begin as early as ET-87. The first SLWT (ET-96) will not have any RSS hardware installed, thus increasing the Shuttle safety by removing the possibility of inadvertent activation of the tank destruct system.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1996	**Finding 5:** The Orbiter and its landing sites continue to be configured with obsolescent terminal navigation systems. The existing Tactical Air Control and Navigation (TACAN) and Microwave Scanning Beam Landing System (MSBLS) systems are increasingly difficult to maintain, vulnerable and expensive. Continued reliance upon them limits landing options in the event of a contingency abort. Replacement of TACAN and MSBLS with now available precise positioning GPS in a triple redundant configuration would ameliorate and most likely solve these problems.	**Recommendation 5:** Accelerate the installation of a triple redundant precise positioning service GPS in all Orbiters.	**NASA Response (in 1996 ASAP appendix):** The Space Shuttle orbiter project is accelerating the first installation of three-string GPS to the orbiter maintenance down period (OMDP) scheduled for OV-104 in 1998. This improves the date for the last TACAN flight by 2 years, from 2002 to 2000. The FY 1998 OMDP is the earliest date that can be accommodated by hardware design, certification, and flight software development. Software development and hardware installation during the OMDP are the pacing items in bringing the three-string system on line. The requirements to install the wiring, antenna, and control panel modifications for the three-string system have been estimated to be approximately 5,000 man-hours of work on each vehicle. Implementing any change of this size during

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				a vehicle flow in the KSC Orbiter Processing Facility would create prohibitive launch flow impacts, thus relegating the change to OMDP. The single-string system now being implemented for OV-103, -104, and -105 is essential to verifying GPS performance. Plans to thoroughly evaluate and certify the GPS as the primary Shuttle navigational system are being prepared. The additions to GPS flight software necessary to support just the single-string system require the single largest software change since the initial development of the Space Shuttle program. The additional changes to go from single-string to the operational three-string system will be approximately the same size. Production of this software is being given the highest priority. The backup flight software system (BFS) will support the single string-system on STS-79. Primary flight software for the Shuttle is developed in operational increments. GPS software was originally considered for 01-26 in 1994; however, it was necessary to give priority to software associated with payload performance enhancements that enable construction of the International Space Station. A special OI-26B was created to add single-string GPS capability to the primary flight software. 01-27 will be devoted to the three-string system. Meanwhile, NASA is considering utilizing single-string GPS data for additional

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				risk reduction for contingency aborts and emergency de-orbits. Software and hardware improvements and supporting certification will allow for first flight of the three-string GPS in January 1999 on STS-96. The Space Shuttle program continues to investigate upgrades that will minimize the risks of contingency abort modes.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1996	**Finding 6:** Orbiter Reaction Control System (RCS) oxidizer thruster valve leaks are occurring with increasing frequency. More recently, RCS fuel thruster valve leaks have also been observed. Because isolation of leaking thrusters can be implemented by manifold shut off and thruster redundancy is provided, leaking thrusters have not been considered a serious safety hazard. RCS leaks in the vicinity of rendezvous targets such as Mir and the International Space Station (ISS) could, indeed be a serious safety hazard.	**Recommendation 6:** Do what is necessary to eliminate the RCS thruster valve leaks now and in the future.	**NASA Response (in 1996 ASAP appendix):** A comprehensive program to improve thruster reliability and eliminate RCS thruster leaks has been put in place. The majority of oxidizer valve leaks are attributed to the long-term accumulation of nitrates that form in the presence of moisture. The changes fall into three categories: operations improvements, improved maintenance of valves, and design changes. Changes in the way turnaround operations are performed consist of emphasizing the maintenance of the RCS propellant system in a hard-filled/wetted state, improved thermal conditioning to keep the thrusters always above the minimum temperature, and reduction of moisture intrusion into the system. These principles have been incorporated into written procedures at KSC and are currently in use. In addition, a molecular sieve is being implemented at the launch pad to reduce the residual iron and water in the RCS oxidizer. Periodic flushing of thruster and valve passages to remove accumulations of nitrates has been implemented. The thruster flushing essentially returns

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				the thruster to an as- new condition in terms of nitrate accumulation. Thruster flushing has been performed at each OMDP beginning with OV-103 in July 1995. Subsequent intervals for flushing are planned at every other orbiter maintenance down period (OMDP), subject to change based on evolving failure rates from nitrate accumulation. Two design approaches to achieve a more reliable valve have been evaluated, and one has been chosen for implementation. The first design solution proposed was to abandon the current pilot operated valve (POV) in favor of a direct acting valve (DAV). In addition to technical problems involving reliability of required bellows, it was determined that removing and replacing all the oxidizer valves in the fleet was cost prohibitive. It was determined that the cost-effective approach could be achieved by replacing certain internal parts of the existing valve with redesigned parts on an attrition basis. The redesigned parts modify the areas of the current valve that have been shown to be sensitive to nitrate contamination. Examples of design changes are reduction of seal surface contact area, adoption of a conical seal geometry, and a stronger spring with more valve closing capability. In summary, a comprehensive, cost-effective program to improve thruster reliability and minimize leaks

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				has been defined and is in various stages of implementation. The effectivity of various elements of the program will be carefully monitored and the program adjusted according to results.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1996	**Finding 7:** The use of Alumina Enhanced-Thermal Barrier (AETB) tiles with Toughened Uniplace Fibrous Insulation (TUFI) coating on the Orbiter has the potential to enhance safety and reduce life cycle cost.	**Recommendation 7:** NASA should make a thorough study of the potential use of the AETB/TUFI tiles in order to determine if it is cost effective to qualify the tiles for flight.	**NASA Response (in 1996 ASAP appendix):** The use of AETB tiles with the TUFI h as been considered extensively in the last year for use on the Shuttle. AETB/TUFI tiles have been flown as technology demonstrations in support of the X-33 program. These tiles were installed on the lower body flap and base heat shield of the orbiter. Tiles with density of 12 pounds/cubic foot were attached to the body flap. Those attached to the base heat shield had a density of 8 pounds/cubic foot. The use of TUFI coating with the FRCI-12 substrate has been identified as a practical option for certain damage prone areas of the orbiter. Certification of this combination for multiple flights will be relatively inexpensive because of similarity between the current coating and TUFI. However, the weight of FRCI-12 with the TUFI coating excludes its use for large area applications. Weight is a critical parameter as the Space Shuttle program strives for performance improvements in support of Space Station assembly flights. The AETB-12 tile substrate, which is the most mature AETB material, offers few benefits over the current certified FRCI- 12. The

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				AETB-8 shows some promise as it would be weight competitive with the LI-900 configuration. Development of AETB-8 technology continues, but it is not in production. Studies will be performed to determine whether it is cost effective to certify and implement this tile configuration. These studies will determine whether the lower maintenance costs would provide an adequate payback.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1996	**Finding 8:** The SSME has performed well in flight during this year. While some launches were delayed because of problems or anomalies discovered during pre-launch inspections and checkout or development engine test firings at the Stennis Space Center (SSC), such issues were thoroughly and rapidly investigated and resolved.	**Recommendation 8:** Continue the practice of thorough and disciplined adherence to inspection and checkout of engines prior to commitment to flight as well as prompt and thorough resolution of any anomalies discovered.	**NASA Response (in 1996 ASAP appendix):** A disciplined adherence to procedures and a commitment to complete resolution of all anomalies will be maintained.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1996	**Finding 9:** The Block II engine, in near-final configuration, re-entered development testing in mid October 1995. Testing of what had been expected to be the final configuration was begun later that month. The High Pressure Fuel Turbopump (HPFTP) was a principal cause of the late restart of testing primarily because of slips in obtaining some redesigned turbopump components. The remaining time to achieve the scheduled first flight of the Block II configuration is very tight and allows for little, if any, problem correction	**Recommendation 9:** Do not let schedule pressure curtail the planned development and certification program.	**NASA Response (in 1996 ASAP appendix):** The Space Shuttle program and the SSME project are committed to completing the development and certification program of the Block II engine. Current planning supports the utilization of the Block II SSME for ISS missions, but the Shuttle has adequate performance with Block I engines for the initial Space Station flights.

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		during development and certification testing. The improved ruggedness and reliability of this version of the SSME is critical to the assembly and operation of the ISS.		
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1996	**Finding 10:** Post flight inspection of recovered RSRMs from STS-71 and STS-70 identified gas paths leading to primary O-ring heat erosion in joint #3 of the RSRM nozzles. Heat erosion in this joint could compromise Space Shuttle mission safety. NASA stopped all launches until the anomaly was resolved and corrective repairs made.	**Recommendation 10:** NASA should continue to investigate and resolve all potential Space Shuttle flight safety problems in this same forthright manner.	**NASA Response (in 1996 ASAP appendix):** NASA concurs. Anomalies that could compromise Space Shuttle mission safety will be resolved before subsequent Shuttle launches.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1996	**Finding 11:** The schedule for firings of Flight Support Motors (FSM) for evaluating changes made to the RSRM has been stretched out. Now, accelerating obsolescence and new environmental regulations have increased the need for the data supplied by FSM firings.	**Recommendation 11:** Do not further stretch out FSM firings.	**NASA Response (in 1996 ASAP appendix):** NASA concurs with the finding and, based on current funding profiles, plans to abide by the schedule associated with FSM firings.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1996	**Finding 12:** The development of the Super Lightweight Tank (SLWT) using Aluminum Lithium (Al-Li) material entails several unresolved technical issues. These include a low fracture toughness ratio and problems in large scale joint welding. There are also critical structural integrity tests, which are behind schedule. Resolution of these issues could impact the delivery	**Recommendation 12:** Satisfactory resolution of these issues must be achieved prior to SLWT flight.	**NASA Response (in 1996 ASAP appendix):** NASA recognizes the concerns expressed in the findings and recommendations for this item. Appropriate efforts and planning have been implemented within the SLWT project to focus the needed resources on development of resolutions to the issues noted and support delivery of ET-96 to meet the International Space Station first element launch in December 1997.

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		of the SLWT.		Progress/changes that address these issues since the last Aerospace Safety Advisory Panel review follow. (lots of details omitted)
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1996	**Finding 29:** The Dryden Flight Research Center's Basic Operations Manual (BOM) describes a pro-active attitude toward safety, which is exemplary and worthy of emulation throughout NASA.	**Recommendation 29:** Other Centers and NASA contractors could profit from the use of the Dryden BOM as a model.	**NASA Response (in 1996 ASAP appendix):** NASA agrees that the Dryden Flight Research Center's Basic Operations Manual (BOM) describes a proactive attitude toward safety that is exemplary and worthy of emulation throughout NASA. The Dryden BOM was installed on the Internet 2 years ago and can be accessed from the Dryden home page. This will ensure its availability to other NASA centers and contractors for use as a model in developing or improving their own operations documentation.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1996	**Finding 31:** The Senior Managers' Safety Course conceived and conducted by JSC is an outstanding overview of philosophies, techniques and attitudes essential to a successful safety program.	**Recommendation 31:** A safety course for senior managers similar to the one conducted at JSC should be established at other NASA centers and Headquarters. Consideration should also be given to exporting the course to major NASA contractors and including its elements in managerial training programs.	**NASA Response (in 1996 ASAP appendix):** The Senior Managers Safety Course conducted at JSC has become the benchmark at NASA for establishing enhanced safety awareness at the Center Director level. The Associate Administrator for Safety and Mission Assurance coordinated and promoted the awareness course during presentations on April 9-l 1, 1996, in Houston, Texas, to NASA Center Directors, senior managers, and senior safety, reliability, maintainability, and quality assurance personnel. Attendees highly praised the course and recommended enhancing senior participation by request of the NASA Deputy Administrator. The Deputy

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				Administrator will invite all Center Directors to a second presentation at JSC in the fall of 1996. The goal will be to transport this course using the "train the trainer" concept to each participating NASA center, with the objective of keeping safety and mission success foremost in every NASA operation.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1996	**Finding 32:** NASA's ongoing reorganization and the intention to pass responsibility for Space Shuttle operations to a single Space Flight Operations Contractor (SFOC) have potential safety implications. To this point, other than an effect on morale at the KSC due to uncertainty, no significant problems have surfaced.	**Recommendation #32:** NASA leadership and top management should continue active and detailed involvement in the safety aspects of planning for and over- sight of the NASA reorganization in general and Space Shuttle operations in particular.	**NASA Response (in 1996 ASAP appendix):** NASA's top priority throughout the restructuring process and implementation of the SFOC has been, and will continue to be, maintenance of safety. Safety considerations are currently embedded in the program management processes and will remain so. To help assure this, the Associate Administrator for Safety and Mission Assurance (S&MA) at NASA Headquarters has formed a Human Exploration and Development of Space (HEDS) Assurance Board, which includes in its membership the S&MA Directors of JSC, MSFC, KSC, and SSC and the Shuttle S&MA Technical Manager's Representative (TMR) from the Program Office. The HEDS Assurance Board charter is to monitor program safety implementation and provide guidance through transition to the SFOC. The Lead Center Director (LCD) at JSC has established the position of Associate Director (Technical) with responsibility for overseeing program safety and providing recommendations to the Center Director. (Astronaut John Young currently occupies this position.) The LCD receives weekly SFOC

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				implementation status from the Program Manager as well as monthly program issues reports, which are shared with the Associate Administrator for Space Flight. Additionally, the Program Manager provides status briefings to the OSF Management Council (the Associate Administrator for Safety and Mission Assurance is a member) quarterly or as requested. The implementation of Space Shuttle program streamlining and the SFOC is, therefore, receiving top-level management visibility and guidance on a routine basis. Even so, NASA is being extremely careful in implementing the SFOC. For example, particular attention is being paid to safety considerations at KSC, where the flight hardware will be processed by the SFOC. There, NASA will be instituting an extensive audit, surveillance, and independent assessment of SFOC processing activities that are required to be compliant with existing NASA-approved processes. The KSC management team will be retained as an integral part of the program management structure and will maintain insight into SFOC launch, landing, logistics, and S&MA activities. This team will continue to play a major role in Flight Readiness Review (FRR) activities with full membership on the FRR Board. Finally, we believe execution with the incumbent operations support contractors for the SFOC provides maximum assurance of

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				continuation of safe operations.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1996	**Finding 33:** The plan for Space Shuttle restructuring and downsizing provides that NASA personnel will be involved in the resolution of any off-nominal events which are beyond the operating experience base or "out-of-family." This places extreme importance on the development and implementation of the definition of an out-of-family situation.	**Recommendation 33:** NASA personnel with direct Space Shuttle operations experience should be involved not only in the derivation of the definition of out-of-family but also in the day-to-day decisions on what constitutes an out-of-family event.	**NASA Response (in 1996 ASAP appendix):** The Space Shuttle program management plans to maintain full capability for identifying, evaluating, and resolving all anomalous performance of Space Shuttle systems. To support this objective, the program has developed general definitions of "In-Family" and "Out-of-Family" characteristics for all Shuttle systems and processes, which will serve as performance classification criteria. NASA will use its most experienced and skilled personnel to develop detailed definitions and data bases. With the implementation of the Space Flight Operations Contract (SFOC), the program is transferring responsibility for routine operations activities to the contractor, which will be accountable for classifying performance as either "In-Family" or "Out-of-Family" per the definitions and consistent with well-defined systems and processes performance data bases. The SFOC contractor will be required to report and interface with NASA on a daily basis to ensure that appropriate data are exchanged to identify "Out-of-Family" issues. Additionally, NASA will perform audit and surveillance of the operation using ADVISORY PANEL NASA technical and operations experts. Metrics will be developed that will support the identification of

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				"Out-of Family" issues as well as the health of the processes. For evaluating those issues reported as "Out-of-Family," the program will retain a core team of NASA experts in each area (e.g., KSC ground operations, JSC flight operations, orbiter, flight software, etc.) that will be capable of performing independent assessment of issues and making recommendations to the Program Manager. In this approach, the Program Manager requires these NASA experts to concur in "Out-of-Family" resolutions.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1996	**Finding 35:** While hardware typically gets adequate coverage from the Safety and Mission Assurance organizations at the NASA Centers, there is evidence that software does not.	**Recommendation 35:** The Headquarters Office of Safety and Mission Assurance should examine the depth of the software assurance process at each of the Centers and promulgate NASA-wide standards for adequate coverage.	**NASA Response (in 1996 ASAP appendix):** NASA agrees with the importance of this recommendation. The NASA Software Assurance Standard (NASA-STD-2201-93) promulgates commonality and provides direction on what activities are to be performed for software assurance across the Agency. The NASA Software Safety Standard (NSS 1740.13) was added to the Safety Standards series in 1996. The addition of the software safety standard and guidebook will assist projects to plan and budget for software safety as software increases in criticality and importance in NASA systems. (lots of detail on ISS omitted) One such process to be verified is the software assurance process as it is applied at the center with respect to NASA-STD-2201-

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				93. Process Verification will provide the Agency the confidence that proper skills and personnel exist to adequately perform software assurance for each center. Software assurance has a high priority to be verified within the first year of the PV initiative.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1995	**Finding 7:** The Russian Androgynous Peripheral Docking System (APDS) for docking the Space Shuttle with the Mir uses 12 active hooks on the Space Shuttle side which mate with an equal number of passive hooks on the Mir. The design currently provides no positive means of determining whether any or all of the hooks are secured. NASA has decided it is an acceptable risk to fly the first docking mission, STS-71, without an indicator. Having to rely on the pyros as presently supplied by the Russian Space Agency poses risk because of lack of knowledge relating to the pyros' pedigree and certification. A second contingency demate procedure is available involving the Extravehicular Activity (EVA) removal of 96 bolts at a different interface. Implementing either backup method to separate Shuttle from Mir may leave the Mir port unusable for future dockings.	**Recommendation 7:** NASA should develop an indicator system.	**NASA Response (in 1995 ASAP appendix):** The second APDS unit, which is being procured from RSC-Energia for the second and subsequent Mir missions, also does not have individual structural hook position indicators. The addition of indicators was discussed with RSC-Energia, however, the APDS manufacturing and delivery schedule precluded installation. Johnson Space Center (JSC) and Rockwell engineers have shown, through test and analysis, that there is no threat to crew and vehicle safety for the remote failure case of two adjacent hooks failing to close properly. Combinations of failures that would result in crew injury or vehicle damage are considered to be of remote probability, the risk therefore being acceptable for the Phase I program. The Shuttle program has reviewed the test and analysis results and approved the APDS baseline without position indicators for the Mir missions.

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Aerospace Safety Advisory Panel *(NASA Charter)*	March 1995	**Finding 8:** If the primary system fails, the first backup separation system for the APDS is a set of pyro bolts which disengage the 12 active hooks.	**Recommendation 8:** NASA should emphasize increasing the reliability of the primary mating/demating mechanisms in order to reduce the likelihood of having to use either of the backups. NASA should also obtain an acceptable certification of the supplied pyro bolts. Failing that, NASA should procure fully certified substitute bolts.	**NASA Response (in 1995 ASAP appendix):** The APDS mechanism hardware has been demonstrated by test to fully meet its design environments. Additional detail regarding critical mechanical components was jointly developed by RSC-Energia, JSC, and Rockwell engineering, and analysis of those components has been completed. The analysis supports test results which demonstrate design margin for the life of the Mir program. Additionally, the results for this analysis will be used as a guideline in developing maintenance requirements for future Mir and Station missions, The pyrotechnics, installed in the APDS, have completed a confidence test that was developed by Rockwell and NASA engineering in conjunction with RSC-Energia and with the concurrence of NASA S&MA. NASA is pursuing design improvements of the RSC-Energia bolts for Station missions and is also working on the development of an American-built pyrotechnic bolt. RSC-Energia has not been receptive to the idea of installing American bolts in the APDS; however, assembly schedules do not require a decision until late 1995, and discussions with RSC-Energia are continuing.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1995	**Finding 9:** Significant additional payload mass capability is required to meet the demands of the ISS assembly and supply plans. Much of the needed increase in capacity will be achieved	**Recommendation 9:** Emphasis should be placed on the adequate integration of all of the changes into the total system.	**NASA Response (in 1995 ASAP appendix):** Integration of major changes into the existing Space Shuttle vehicle is receiving emphasis by the Space Shuttle program. The Space Shuttle program has had a system in place for

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		through weight reduction programs on a number of Space Shuttle elements and subsystems. The large number of simultaneous changes creates potential tracking and communication problems among system managers.		many years to integrate all of the changes into the total system. This system has proven effective. The system consists of technical panels, integrated product teams, and control boards. A technical panel exists for each major functional area (e.g., Loads and Dynamics, Thermal). These technical panels integrate and review the technical aspects of the analysis and testing. The functional areas are integrated by the integrated product teams (e.g., Propulsion System Integration Group) and at joint panel meetings. The control boards, at the project and program level, provide a final technical review and integration, and management direction for cost and schedule control. The NASA Element Project Offices and prime contractors are represented on the technical panels, integrated product teams, and control boards, allowing cross communication and input at all levels of the process. There is a System Integration Plan for each of the major performance enhancements that defines the responsibilities of the affected elements, identifies deliverable products and hardware, and defines the system schedule for that enhancement to support the first element launch.
Aerospace Safety Advisory Panel	March 1995	**Finding 10:** The New Gas Generator Valve Module (NGGVM): when certified and retrofitted to the fleet, should mitigate	**Recommendation 10:** NASA should attempt to introduce the NGGVM into the fleet as soon as possible as a safety and logistics improvement.	**NASA Response (in 1995 ASAP appendix):** NASA intends to introduce the NGGVM into the fleet on an opportunity basis. The ground

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(NASA Charter)		many of the problems with the current Improved Gas Generator Valve Module in the Improved Auxiliary Power Unit (IAPU). The NGGVM development program is proceeding well.	logistics improvement.	rule for this plan is to maintain a minimum Kennedy Space Center (KSC) stock level of five spare IAPUs to support any unplanned line replaceable unit removals. Any other IAPUs not required to support this stock level will be shipped to Sundstrand to undergo the NGGVM modification. By leaving this number of spare IAPUs on the shelf at KSC and modifying any units available beyond that, the NGGVM implementation into the fleet can be completed in late 1998 or early 1999. Upgrade and modification of three Auxiliary Power Units currently not used for flight as an expedient to the NGGVM fleet retrofit is not cost effective.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1995	**Finding 11:** The decision has been made to install the entire Multi-Function Electronic Display System (MEDS) in each Orbiter during a single Orbiter Maintenance and Down Period (OMDP). An Advanced Orbiter Displays/System Working Group has been formed to plan for the next generation of MEDS formats and display enhancements.	**Recommendation 11:** NASA should support the Advanced Orbiter Displays/System Working Group and set a timetable for the introduction of enhanced display formats which will improve both safety and operability. It should also maintain its commitment to completing the MEDS installations during a single OMDP.	**NASA Response (in 1995 ASAP appendix):** NASA established the Advanced Orbiter Displays/System Working Group to define next-generation cockpit displays that will take advantage of MEDS data processing capabilities to improve safety and operability. The Government/industry working group is currently defining requirements for enhanced displays as well as a timetable for both evaluation of candidate displays in MEDS testbeds and introduction of new displays into orbiters. NASA identified several advantages to installing MEDS hardware in orbiters during a single OMDP. Current OMDP planning as well as the schedule for first flight of MEDS on each orbiter reflects the single OMDP installation plan.

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Aerospace Safety Advisory Panel *(NASA Charter)*	March 1995	**Finding 12:** The Tactical Air Control and Navigation (TACAN) and Microwave Scanning Beam Landing System (MSBLS) on-board receivers are obsolescent and increasingly difficult to maintain. The MSBLS receivers also have known design problems which can lead to erroneous guidance information if the Orbiter is operating with only two of the three receiver complement. A Global Positioning System (GPS) test is underway on one of the Orbiters using the backup flight software and computer. The use of GPS could replace both the TACAN and MSBLS systems as well as assisting ascent and on-orbit operations.	**Recommendation 12:** Given the potential of GPS to improve safety and reliability, reduce weight and avoid obsolescence and the many existing and potential problems with the use of TACAN and MSBLS, a full GPS implementation on the Orbiter should be accomplished as soon as possible.	**NASA Response (in 1995 ASAP appendix):** The Space Shuttle program is currently reviewing a plan to fully implement the GPS capabilities. The GPS hardware/software implementation plan calls for completing the installation of a redundant GPS hardware capability as early as the year 2000. The software implementation will be completed with delivery of the 0I-27 operational increment by December 1997 with a first flight effectivity in the summer of 1998. The redundant GPS hardware installation will be accomplished during the OMDP for each orbiter.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1995	**Finding 13:** Growth in the requirements for on-board data processing will continue as the Space Shuttle is used in support of Shuttle/Mir, ISS and other future missions. The length of time over which the General Purpose Computer and its software will be able to meet these growing needs effectively is likely inadequate.	**Recommendation 13:** NASA should expedite a long-range strategic hardware and software planning effort to identify ways to supply future computational needs of the Space Shuttle throughout its life-time. Postponing this activity invites a critical situation in the future.	**NASA Response (in 1995 ASAP appendix):** We concur that continued reliance on the Space Shuttle beyond 2005 will demand some major revisions to the core General Purpose Computer (GPC) hardware and software, if for no other reason than the inability to maintain hardware based on early 1980 technology. Such a revision, given the tightly coupled interdependencies of the present core architecture, would logically be accomplished as a major "block" update rather than gradually evolving to a new architecture. The block update approach can also serve to reduce future operations costs by stabilizing avionics hardware and

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				software during the Station assembly era. In accord with that concept, the Space Shuttle program is considering an approach that would freeze the GPC software at roughly the turn of the century, following the incorporation of Station-driven enhancements. That freeze would allow for diversion of engineering resources, heretofore devoted to routinely evolving enhancements, to pursue a true significant block update sufficient to sustain the Space Shuttle past 2020. As the foundation for such a possible architecture, the JSC Engineering Directorate has developed a Reduced Instruction Set Computer (RISC) for high-fidelity emulation of the present GPC. That emulation is capable of real-time bit-level execution of actual object code produced by the HAL/S compiler. It will soon be made available to allow flight software developers a target machine for early development testing. At the present time, such early testing is a premium because of the limited availability of real GPCs. The extension of the emulator concept, as a candidate to replace the actual flight GPCs, is the next logical step. It would preserve critical flight code, thereby minimizing the reverification costs, while still providing a modern platform for growth. In summary, NASA does have the essential formative elements for a long-range strategic hardware and

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				software upgrade effort in work. Existing limited resources and ongoing program activities obviously preclude any definitive strategic planning until completion of the current program-wide restructuring activities. Once those activities are complete, a more definitive plan and schedule, predicated on critical examination of limited available resources, can be developed.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1995	**Finding 14:** The STS-64 mission involved a higher than usual level of windshield hazing which could have led to a situation in which the astronauts' view of the landing runway was obscured. MSBLS and TACAN are obsolescent. There is also the possibility that false indications by MSBLS under certain scenarios could result in an unacceptable risk of a landing mishap. Thus, there is a clear need for early upgrade of Orbiter and support facility autoland equipment and crew flight rules and training improvement.	**Recommendation 14:** NASA should improve the autoland equipment on the Orbiter; for example, replacing MSBLS and TACAN with GPS. In the interim, NASA should ensure that operations and failure modes of MSBLS are fully examined and understood. NASA should also reexamine the training of crews for executing automatic landings, including autoland system familiarization. Astronaut commanders and pilots should discuss circumstances which might warrant autoland use prior to each mission and be prepared for all reasonable contingencies in its operation.	**NASA Response (in 1995 ASAP appendix):** Incorporation of GPS is being pursued as aggressively as funding and technical constraints will allow. The program has approved plans and funding to provide a single-string GPS capability that can be flown in the summer of 1997 as a first step toward TACANIMSBLS replacement. Plans for a full three-string operational system have been approved for 01-27, and detailed costs and schedules are being assessed by the program. The failure modes of the MSBLS have been analyzed and are documented in the program's Critical Item List. The finding made by the ASAP regarding the STS-64 mission, involving a higher than usual level of windshield hazing that could have led to a situation in which the astronaut's view of the landing runway was obscured, is incorrect. The STS-64 orbiter Quick Look Reports states: "Orbiter Windows 3 and 4 exhibited light hazing and streaks were seen on 4." Additionally, the Commander

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				(Richard N. Richards, 4th flight) reports that the window hazing was not unusual at all, typical of what is usually seen, and an excellent view of the runway was obtained at all times during the approach, landing, and rollout phases of the flight. The STS-64 vehicle touchdown parameters were excellent, confirming that the Commander had an excellent view of all visual aids throughout the approach and landing. (These touchdown parameters include touchdown airspeed of 198 knots versus 195 planned, touchdown distance of 2386 feet versus predicted 2505, sink rate at touchdown of 1.0 feet per second, and a threshold crossing height of 20 feet. All parameters are excellent.) Extensive analysis of the orbiter autoland system has been performed by various organizations in NASA, including exhaustive reviews by NASA Safety and Mission Assurance personnel. Those results have been briefed to all levels of NASA management. The Space Shuttle program has not identified/defined any hardware or software change that is necessary to improve the autoland capability. The operational use of the autoland capability remains at the discretion of the mission commander. To educate pilots and commanders on the use of this emergency system, Mission Operations Directorate (MOD) provides a briefing that covers the capabilities and limitations of

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				the autoland system, as well as the contingency cases for which it is a viable alternative (i.e.? both pilots incapacitated, or a highly inaccurate weather forecast for landing). In addition, each crew has a session in the Shuttle Mission Simulator, as well as the Shuttle Training Aircraft where the autoland system is demonstrated and discussed.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1995	**Finding 15:** It has become necessary to execute a partial disassembly of both the engines and turbopumps after each flight because of the accumulation of special inspection requirements and service life limits on components of the current (Phase II) SSMEs. These inspections are performed with rigor and appropriate attention to detail. included in the parameters used in the algorithms that determine engine health.	**Recommendation 15:** In order to control risk, NASA must maintain the present level of strict discipline and attention to detail in carrying out inspection and assembly processes to ensure the reliability and safety of the SSMEs even after the Block I and Block II upgrades are introduced.	**NASA Response (in 1995 ASAP appendix):** NASA agrees with this recommendation and will continue to perform the detailed inspections of the Phase II Space Shuttle Main Engines (SSME) that are currently defined. The postflight inspections of both the Block I and Block II SSMEs will be significantly less in frequency than those for today's Phase II SSME due to the major design changes, especially in the turbopumps. However, the program plans to use the same level of strict discipline and attention to detail in carrying out the new inspection program as it has in the past.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1995	**Finding 16:** The re-start of the Advanced Turbopump Program (ATP) High Pressure Fuel Turbopump (HPFTP) and the start of the Large Throat Main Combustion Chamber (LTMCC) developments were authorized in the spring of 1994. Combined with the ongoing component developments of the Block I engine, this will produce a Block II engine which will contain all of the major component	**Recommendation 16:** Continue the development of the Block II modifications for introduction at the earliest possible time.	**NASA Response (in 1995 ASAP appendix):** NASA agrees with this recommendation. The first flight of the Block I SSME was on STS-70, which was launched on July 13, 1995. The Block II SSME will be available for flight in September 1997.

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		improvements that have been recommended over the past decade to enhance the safety and reliability of the SSME. Both the Block I and Block II programs have made excellent progress during the current year and are meeting their technical objectives.		
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1995	**Finding 17:** In order to provide an engine health monitoring system that can significantly enhance the safety of the SSME, improvements must be made in the reliability of the engine sensors and the computational capacity of the controller. It is also essential to eliminate the difficulties with the cables and connectors of the Flight Accelerometer Safety Cut-Off System (FASCOS) so that vibration data can be included in the parameters used in the algorithms that determine engine health.	**Recommendation 17:** Expand and emphasize the program to improve engine health monitoring. Continue the program of sensor improvements.	**NASA Response (in 1995 ASAP appendix):** The Space Shuttle program is implementing Discharge Temperature Thermocouples as a replacement for the current temperature sensors on the SSMEs. No other health monitoring improvements are funded at this time because the design was not mature enough to make this a cost-effective project.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1995	**Finding 18:** The Block II SSME can improve safety if an abort is required because it can be operated more confidently at a higher thrust level. This will permit greater flexibility in the selection among abort modes.	**Recommendation 18:** NASA should reexamine the relative risks of the various abort types given the projected operating characteristics of the Block II SSMEs. Particular emphasis should be placed on the possibility of eliminating or significantly reducing exposure to a Return to Launch Site abort.	**NASA Response (in 1995 ASAP appendix):** Operating the Block II SSMEs at a higher power level requires completion of two certification activities-the Block II SSME hardware certification and the integrated vehicle intact abort certification (loads, thermal, guidance, navigation and control). Because the internal environments and stresses are significantly reduced for Block II SSMEs, the Space Shuttle program approved certification testing to include log-percent power level for intact abort operations. This allows for the future

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				consideration of increasing the power level for intact aborts to 109 percent pending the results of certification testing. If the increase in power level for intact aborts proves feasible, it would reduce, but not eliminate, exposure to the Return-to-Launch Site abort mode. Performance enhancements vehicle ascent certification environments are currently being developed using 106-percent power level for intact abort operations to improve abort performance and to minimize the risk of design impacts to the Space Shuttle vehicle. A delta certification plan to incorporate log-percent power level for intact abort operations is currently being developed. Implementation of the plan is contingent on a successful Block II SSME test program, the results of vehicle thermal and structural loads trade studies, and the delta certification cost and schedule. Further, even if certification is successful, the decision to utilize log-percent power level for intact aborts will depend on actual flight experience with the Block II SSMEs.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1995	**Finding 19:** The liquid oxygen tank aft dome gore panel thickness of the Super Lightweight Tank (SLWT) has been reduced significantly on the basis of analyses. To stiffen the dome, a rib was added. The current plan to verify the strength of the aft dome involves a proof test only to limit	**Recommendation 19:** The SLWT aft dome should either be tested to ultimate loads or its strength should be increased to account for the uncertainties in extrapolation.	**NASA Response (in 1995 ASAP appendix):** NASA agrees with this recommendation. At the joint NASA and Martin Marietta Aluminum Lithium Test Article (ALTA) Design Review on August 19, 1994, an aft LO2 dome test was added to the ALTA test program. Adding this stability test will permit the aft dome

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		load. Buckling phenomena cannot be extrapolated with confidence between limit and ultimate loads.		to be verified to the ultimate load condition. The as-planned test satisfies the buckling concerns of Finding #19.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1995	**Finding 20:** The structural tests of a segment of an SRB aft skirt in the baseline configuration did not duplicate the strains and stresses previously measured in the tests of the full-scale aft skirt Structural Test Article (STA-3). This suggests that segment testing of the proposed bracket modification to improve the aft skirt's factor of safety may not be valid.	**Recommendation 20:** NASA should reassess the use of the segment test method and reconsider the use of a full scale test article for qualifying the proposed bracket reinforcement.	**NASA Response (in 1995 ASAP appendix):** At the time of the NASA response to the March 1994 ASAP Annual Report, two initial test condition baselining test articles (TA) had been tested to 100- and 70-percent load levels. The TA-1 and TA-3 test loads were analytically derived and validated using empirical data from these tests and STA-3. The TA-3 baseline testing showed excellent correlation with strain response curves measured during the STA-3 test. In addition, a second test article was tested to failure. Strain data obtained from these two specimens was compared to the STA-3 strain data (up to 12%percent loads which was the maximum load level achieved prior to failure initiation during the STA-3 test program). Data from second baseline test, the bracket test, and STA-3 are depicted in the figure below. The strain measurements for the critical weld region for the full-load applications (0 to 12%percent loads) exhibit an average correlation within 8.6 percent and, at 128-percent load levels, the average correlation is within 9.6 percent. (lots of details omitted) In summary, component test results indicate that the external bracket significantly enhances critical weld factors of safety. In addition to

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				providing substantive quantitative verification of existing analytical techniques, the completed evaluation of the test program results has provided no challenge to or indictment of current flight rationale. The resultant potential benefits from introduction of the bracket are limited. The design change has minimal potential for increasing the Shuttle lift-off wind allowables (and associated probability of launch), as other elements are similarly constraining. The elimination of the Advanced Solid Rocket Motor effort precludes near-term concerns for substantially increased skirt loading. The significant component, subscale and full-scale analysis and test, along with individualized measurements of each aft skirt, provide a level of understanding such that no further concerns exist for a demonstrated 1.28 factor of safety in the critical weld area. Therefore, implementation of the bracket is not planned at this time, and the program plans to change the appropriate specification requirement to reflect this factor of safety to avoid repetitive flight by-flight waivers.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1995	**Finding 21:** The effort by the NASA logistics organization and its principal contractors has resulted in satisfactory performance. There remain a few problems, such as a tendency towards increased cannibalization, which still require attention.	**Recommendation 21:** Every effort should be made to avoid cannibalizations, particularly on critical components such as the SSME and the IAPU.	**NASA Response (in 1995 ASAP appendix):** While there were some increases in cannibalizations in mid-1994, continued management attention has maintained an overall decreasing trend in cannibalizations. Close attention to related indicators will continue. There are currently four spare IAPUs on the shelf at KSC. No IAPU cannibalizations have

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				occurred since 1993.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1995	**Finding 23:** There is a plan to consolidate all logistics elements at KSC except Spacelab over the next three or four years. This should unify the entire logistics and supply organization. The realignments are intended to eliminate duplication of effort, gain efficiency in support and materially reduce the cost of operation.	**Recommendation 23:** Proceed as outlined in the NASA plan.	**NASA Response (in 1995 ASAP appendix):** A single organization consolidating all KSC logistics elements was officially established on April 17, 1995. This new organization integrates logistics functions from the Payload Management and Operations Directorate, the Installation Management and Operations Directorate, the Engineering Development Directorate, and the Shuttle Management and Operations Directorate. This new organization, known as the Logistics Operations Directorate, is now proceeding with internal realignments to eliminate duplication, increase efficiency, and reduce costs while improving customer service.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1995	**Finding 29:** The Simplified Aid for EVA Rescue (SAFER) was successfully flight tested on the STS-64 mission. Although designed as a rescue device for an astronaut who becomes untethered, SAFER has demonstrated its potential to assist in other safety-critical situations such as contingency EVAs. Five SAFER flight units have been ordered. Plans are to deploy them on Mir and Space Station as well as to carry them on the Space Shuttle only when an EVA is planned.	**Recommendation 29:** Once the flight units are available, NASA should consider routinely flying SAFER units on all Space Shuttle missions which do not have severe weight limitations, This will permit them to be used for those contingency EVAs in which safety can be improved by giving crew members the capability to translate to the location of a problem to make an inspection or effect a repair.	**NASA Response (in 1995 ASAP appendix):** NASA has considered routinely flying SAFER units on all Space Shuttle missions which do not have severe weight limitations and has decided that it is not required. SAFER was specifically designed to be used to rescue an EVA crewmember who had become inadvertently detached from a structure under the circumstances where the Shuttle could not credibly effect a rescue (for example, during Space Station operations when the Shuttle is either not at the Station or is docked to it). As such, it is

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				classified as an "emergency" device and only needs to be single-string (i.e., zero-fault tolerant). SAFER is not required for other (operational) EVAs. All known, credible, contingency EVAs can be safely accomplished without it. There currently exists an EVA method to get to the External Tank (ET) umbilical doors located on the Orbiter without SAFER, for which each EVA crewmember is briefed prior to flight. Furthermore, the cost of making SAFER operational on all Shuttle flights would be high. To be used as other than an emergency device, significant redesign would be required to make it at least single-fault tolerant. SAFER cannot be stowed on the Primary Life Support Subsystem in the airlock; therefore, special stowage would be required on each flight. Flying two SAFER units on each flight would require stowage for about 8 cubic feet and 200 pounds. Additional EVA training would also be required each time SAFER is flown, regardless of whether or not it is planned to be used. Given the above reasons including the fact that all known, credible, contingency EVAs can be safely accomplished without SAFER, NASA believes that implementing this recommendation is not appropriate at this time.

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Aerospace Safety Advisory Panel *(NASA Charter)*	March 1994	**Finding 5:** The organization and management of Space Shuttle launch operations at Kennedy Space Center (KSC) continue to benefit from a "continuous improvement process" managed by the Shuttle Processing Contractor (SPC). Greater employee involvement, better communications, strengthened employee training and the use of task teams, process improvement teams, and a management steering committee have been major factors in this improvement.	**Recommendation 5:** A strong commitment to achieving "continuous improvement," despite budget cutbacks, should be maintained, at the same time recognizing the paramount priority of safety.	**NASA Response (in 1994 ASAP appendix):** The SPC continues its deep commitment to Continuous Improvement (CI) with over 550 active process improvement teams and 86 percent of their 6,600-person workforce trained in the principles and precepts of CI. The underlying theme of all SPC initiatives is their pledge for the highest level of performance at the lowest possible cost with absolute dedication to safety and quality.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1994	**Finding 6:** More than 1,200 positions have been eliminated by the SPC since September 1991 with only about 22 percent being achieved through involuntary separations. Present reductions have been achieved without an apparent adverse effect on the safety of launch processing. A comparable further reduction has been called for by the end of FY 1995. These additional reductions cannot likely be made without a higher probability of impacting safety.	**Recommendation 6:** KSC and SPC management must be vigilant and vocal in avoiding any unacceptable impacts on safety as a result of cost reductions planned for FY 1995 and beyond.	**NASA Response (in 1994 ASAP appendix):** KSC and SPC management are firmly committed to the precept that safety will not be compromised as a result of cost reductions. Procedures for processing a safe space vehicle have been established and are strictly followed. These procedures are revised only after a thorough review by technical and safety personnel to ensure that safety will not be compromised. Schedule times are flexible; safety requirements are not. As the cost reductions continue, KSC is committed to processing only the number of vehicles that can be completed safely within available resources.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1994	**Finding 7:** Several problems at KSC have been attributed to human factors issues. KSC has recently formed a human factors task force to address these problems.	**Recommendation 7:** KSC should ensure that the human factors task force includes individuals with training and experience in the field. Specific assistance should be sought from appropriate research centers and technology groups	**NASA Response (in 1994 ASAP appendix):** The Management Steering Committee, chaired by the KSC Launch Director, established a CI team to support the Incident Error Review Board (IERB) in

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			within NASA.	assessing human-error factors. This team reviewed the human-factors aspects of the Freon Coolant Loop Number 1 Pump Package incident on OV-105/STS-61 and made nine specific recommendations concerning the incident. A tenth recommendation addressed the need for the team to obtain training in human factors principles. The CI Human Factors Team has since received training on human factors from the Battelle Memorial Institute in a seminar conducted at KSC. Some team members attended a class on incident investigation taught by The Central Florida Chapter of the National Safety Council. The team has subsequently added a new member with extensive experience in human factors from Analex Space Systems, Inc. The team will continue to pursue additional human factors training.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1994	**Finding 8:** KSC has developed a Structured Surveillance Program with the objectives of decreasing overall process flow time, increasing "first-time quality," and reducing cost. The program approach involves reducing the reliance on inspections for assuring quality. Structured Surveillance also is proving valuable as a tool for the effective deployment of quality assurance resources.	**Recommendation 8:** The Structured Surveillance program should be continued and cautiously expanded.	**NASA Response (in 1994 ASAP appendix):** KSC has improved structured surveillance data elements, data collection methods, and metrics for the entire program at KSC (both Government and contractor) and has discussed these improvements with the Panel. To ensure effective implementation of the Government application of the structured surveillance program, the leadership of this effort has been moved up to the directors of the two implementing organizations. These directors co-chair a newly formed control board that manages the generation and modification of the

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				policies, procedures, and training necessary for full implementation of structured surveillance.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1994	**Finding 9:** Thermal damage was noted on the STS-56 (OV-103) elevon tiles. The slumping of the tiles indicated that the tile surface reached a temperature of approximately 1,000 degF. A temperature of this magnitude suggests that the temper and strength of the underlying aluminum structure could have been affected.	**Recommendation 9:** NASA should initiate an analysis to determine the temperature profile of the underlying aluminum structure of the elevens and its possible consequences on the strength of the Orbiter structure.	**NASA Response (in 1994 ASAP appendix):** On STS-56 (OV-103), an alternate forward elevon schedule (part of Center of Gravity Expansion Activities, Detailed Test Objective (DTO) 251) was flown. This was the maximum-up schedule (12 degrees up) ever flown. There was some tile slumping (caused by temperatures exceeding 1500 degrees F) at the center hinge location, but detailed postflight vehicle inspection confirmed that the aluminum structure was neither damaged nor subjected to unacceptable temperatures. Positive Margins-of-Safety have been verified subsequently through thermal design analysis. A redesign has been certified and is currently being installed on all four vehicles. This new design will allow a full-up (16 degrees) elevon without overheating of the underlying structure. Prior to incorporation of this modification, the elevon schedule had been constrained to 7 degrees up.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1994	**Finding 10:** The Shuttle tiles have provided effective heat protection. However, the surface of the tiles is easily damaged and their shrinkage and distortion properties are not as low as desired. A new tile formulation with superior characteristics and possibly lower density is being explored.	**Recommendation 10:** NASA is encouraged to support the development of thermal protection tiles with improved mechanical properties and lower density than the current Shuttle tiles. Autoland in a contingency mode, but do not plan to demonstrate Autoland until a firm requirement mandates a demonstration."	**NASA Response (in 1994 ASAP appendix):** NASA is considering several improvements to the Tile Protective System (TPS). On SIX-51 (OV-105), a tougher tile coating on Fiber Reinforced Composite Insulation (FRCI-12) tiles was flown as a DTO on a few door tiles on the base heatshield. There were no hits on these tiles. However, the DTO will

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				be flown a number of times to obtain a good evaluation of the improvement expected from this coating. This tougher coating will enhance turnaround activities by minimizing tile replacement due to coating damage.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1994	**Finding 11:** NASA has made excellent progress on the engineering of the Multipurpose Electronic Display System (MEDS) for retrofitting Orbiter displays. However, there is no formal program to identify and include the safety advantages possible from a fully exploited MEDS.	**Recommendation 11:** A thorough review of the performance and safety improvements possible from a completely developed MEDS should be conducted based on crew inputs to system designers and researchers. A definitive plan should be developed to determine the schedule/cost implications of such improvements, and, if warranted, implementation should be scheduled as soon as possible.	**NASA Response (in 1994 ASAP appendix):** The MEDS, when operational, will provide a foundation for potential upgrades and enhancements to the current crew displays that will improve safety. The initial MEDS program must be on line in a timely manner to replace aging electro-mechanical devices. The flight crew, mission operations, engineering, training, and safety, reliability, and quality assurance program personnel have all agreed that the "transparency" achieved by designing enhanced displays similar in function and appearance to the current displays is the optimum solution initially. By designing similar but enhanced displays, the impacts for a mixed fleet while MEDS is being installed are minimized in the areas of training and flight software. There is only one single-motion-base simulator, therefore, crews training for MEDS or non-MEDS equipped vehicles will be able to train on displays that are similar to those they will use in flight. Similar display formats do not require any changes to the existing flight software. Once trainers and laboratories are equipped with MEDS, the test beds will be in place to evaluate display

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				upgrades. The next phase of the total orbiter displays-and-controls update activities will be to achieve a world-class state-of-the-art system by expanding the total complement to digital electronics replacing current wiring and switches as practical. Planning for this phase is beginning, but the exact implementation schedule will be dependent on funding availability as well as future human-tended spacecraft planning.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1994	**Finding 12:** The Improved Auxiliary Power Unit (IAPU) has experienced problems that have impacted Space Shuttle processing and logistics.	**Recommendation 12:** A new focus on increasing the reliability of the total IAPU system should be initiated and supported until the identified problems are solved.	**NASA Response (in 1994 ASAP appendix):** To improve Auxiliary Power Unit (APU) reliability, a continuous improvement program has been underway since the STS 51-L accident. Results from this program include the completion of an IAPU "upgrade" project (which eliminated injector tube corrosion, exhaust housing cracking, and some Criticality 1 concerns), a new design for the turbine wheel, an improved APU controller and fuel isolation valve, and the more reliable "Path a" Gas Generator Valve Module (GGVM). These changes have resulted in a greatly reduced rate of APU in-flight anomalies and fewer delays to the Shuttle processing and logistics support activities. Elements of the continuous improvement program not yet complete, but now underway include development of an entirely new GGVM, certification of a new material for the fuel pump thermal isolator, and development of more vibration-resistant thermostats. As the new

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				GGVM is incorporated in the fleet, the APU should be totally certified for its planned 75-hour life capability.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1994	**Finding 13:** In its response to the Panel's last Annual Report, NASA indicated that "The program is reviewing the operational flight rules pertaining to Autoland, we have budgeted upgrades in software and hardware to improve the Autoland functionality, the life sciences organization is collecting physiological data and developing countermeasures to ensure adequate crew performance as the mission duration increases. We are confident with using Autoland in a contingency mode, but do not plan to demonstrate Autoland until a firm requirement mandates a demonstration."	**Recommendation #13:** The focus of Autoland should not be exclusively on long-duration missions. NASA should formulate a complete set of operational procedures needed for emergency use of Autoland, taking into account a full range of operational scenarios and equipment modifications that might be beneficial. These include upgrades to the Microwave Scanning Beam Landing System (MSBLS) receiver group, and installation and certification of Global Positioning System (GPS) capability.	**NASA Response (in 1994 ASAP appendix):** It is agreed that the Autoland system should not be focused just on long-duration missions. Currently, mission planning requirements do not include missions longer than approximately 18 days, including the Space Station program. The entry systems requirements including piloting techniques are continuously assessed for improvements. Autoland backup capabilities as well as heading alignment cone piloting enhancements are being developed and will be incorporated as we continue to implement the flight program. MSBLS/GPS type systems are being considered and will be brought on line as improvements are practical No specific training or procedures are required for the emergency use of Autoland, as the only manual tasks required of the crew in an Autoland scenario (e.g., deploying landing gear, postlanding braking, air data probe deployment, and navigation sensor data incorporation) are identical to those performed in a manual landing. Present flight rules define orbiter and landing-site equipment that must be functioning to perform an Autoland landing. The decision to engage Autoland in a contingency is left to the commander's discretion to protect the safety of the crew.

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				Exact flight rules to define all Autoland engagement criteria exceed the number of failure cases addressed by the current flight rules. A program to expand these criteria would require large resource commitments to develop and is not currently in the planning.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1994	**Finding 14:** The SSME has performed well in flight but has been the cause of launch delays and on-pad launch aborts that were primarily attributable to manufacturing control problems.	**Recommendation 14:** Continue to implement the corrective actions developed by the NASA and Rocketdyne manufacturing process review teams and devise techniques for detecting and/or precluding recurrence of the types of problems identified.	**NASA Response (in 1994 ASAP appendix):** The process audit teams and the NASA and Rocketdyne incident investigation teams have both identified process improvements which either have been or will be incorporated into all areas of the engine program. These process improvements will improve detection and preclude the recurrence of manufacturing control problems in any of our new or recycled hardware and substantially reduce the likelihood of associated problems leading to launch delays or launch pad aborts.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1994	**Finding 15:** "Sheetmetal" cracks in the Phase II (current) High Pressure Fuel Turbopump (HPFTP) have become more frequent and are larger than previously experienced. This has led to the imposition of a 4,250-second operating time limit and a reduction of allowable crack size by a factor of four. Congress has delayed the funding for restarting the development of the alternate HPFTP. This new turbopump design should eliminate the cracking problem.	**Recommendation 15:** Restart the development and certification of the alternate HPFTP immediately.	**NASA Response (in 1994 ASAP appendix):** NASA fully agrees with the recommendation to restart the alternate HPFTP immediately. Congressional authority to restart the program was received on April 14, 1994. The Space Shuttle program (SSP) is proceeding with the restart. The alternate HPFFP will be incorporated into the Block II SSME configuration with first flight scheduled for September 1997.

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Aerospace Safety Advisory Panel *(NASA Charter)*	March 1994	**Finding 16:** The approved parts of the engine component improvement programs, now organized into block changes, are progressing well. The Block I grouping will enter formal certification testing by mid-1994. Progress in the Block II effort is, however, hampered by the delay in restarting the alternate HPPTP development effort.	**Recommendation 16:** Continue efforts to complete all of the Block II development as soon as possible.	**NASA Response (in 1994 ASAP appendix):** NASA fully agrees with this recommendation and is firmly committed to developing and implementing all of the SSME safety improvements, including the Alternate HPFTP and the Large Throat Main Combustion Chamber. Upon completion of these modifications, a significant reduction in Shuttle operational risk will be realized. Initiation of full-scale development testing is currently planned for mid-1995, with first- flight capability scheduled for September 1997.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1994	**Finding l7:** Engine sensor failures have become more frequent and are a source of increased risk of launch delays, on-pad aborts, or potential unwarranted engine shutdown in flight.	**Recommendation 17:** Undertake a program to secure or develop and certify improved, more reliable engine condition sensors.	**NASA Response (in 1994 ASAP appendix):** Improved hot gas temperature-sensing instrumentation is undergoing development testing and is planned for the first flight in FY 1995. A two-step improvement process for pressure and flow measuring instrumentation is also under way. As a first step, a new screening selection process has been developed for immediate implementation to improve sensor quality control. The second step, redesigning and improving sensors, is being implemented as these improvements become available.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1994	**Finding 18:** The SSME health monitoring system comprising the engine controller and its algorithms, software, and sensors is old technology. The controller's limited computational capacity precludes incorporation of more state-of-the-art algorithms and decision rules. As a result, the	**Recommendation 18:** The SSME program should undertake a comprehensive effort to improve the capability and reliability of the SSME health monitoring system. Such a program should include not only improved sensors but also a more capable controller and advanced algorithms.	**NASA Response (in 1994 ASAP appendix):** NASA agrees that the development and implementation of an advanced health monitoring system for the SSME is potentially worth pursuing. A system currently being considered would incorporate more processing capability in an upgraded controller and allow the utilization of

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		probabilities of either shutting down a healthy engine or failing to detect an engine anomaly are higher than necessary.		advanced health monitoring software algorithms. With an improved system of this nature, the probability of shutting down a healthy engine would be reduced while the probability of preventing a catastrophic failure would be increased. NASA is reviewing proposals that would certify and implement this new capability into the Block II SSME configuration.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1994	**Finding 19:** A segment of an aft skirt will be used to test the effectiveness of an external bracket modification in reducing the overall bending stress of the skirt. The validity of using an 11-inch-wide test specimen to determine the effectiveness of the bracket is yet to be demonstrated.	**Recommendation 19:** NASA should evaluate the first specimen test results to see if the strains in the weld area duplicate the strains found when a full aft skirt was tested in the Static Test Article-3 (STA-3) test. If not, another test approach should be pursued.	**NASA Response (in 1994 ASAP appendix):** Tests on three of the four aft skirt test specimens have been completed. The baseline test article (TA-l), which represents the current aft skirt configuration, has been subjected to 100 percent of the developed load case. Based on a thorough evaluation of the TA-1 test data and correlation of the data with STA-3 test results, it is clear that the weld area strain field developed in the TA-1 test article correlates well with the strain field in this same area on the STA-3 aft skirt. This correlation confirms the validity of the test approach being used. The second test article (TA-4) was also in the baseline configuration and was subjected to a maximum load of 70 percent of the developed load case. This article utilized the photoelastic method for determining the strain field as opposed to using the typical strain gage method used on all other articles in this test program. This test verified that the STA-3 strain field could be duplicated on two-separate articles within acceptable limits and that no high strain areas were

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				overlooked during the analytical study of the test article response. The third test article (TA-2), which has an external bracket for the reduction of strain in critical weld region, was subjected to 205 percent of the developed load case with no structural anomalies occurring. Comparisons of the baseline configuration article (TA-1) and the bracketed configuration article (TA-2) were made at 100 percent loads. This comparison demonstrated that there was approximately a 50 percent reduction in the average weld strain in the critical weld region. The baseline configuration article (TA-1) was tested to failure during June 1994. This test defined the weld failure strain for the TA-1 article. Test data obtained from this test is being compared to the results of the 205 percent TA-2 test and the STA-3 test to develop a comparative assessment of the benefit gained by the addition of the external bracket modification If this assessment does not reveal adequate stress reduction, additional testing may be indicated.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1994	**Finding 20:** A small crack was found in the inner wall of a forward Redesigned Solid Rocket Motor (RSRM) casing used for STS-54. Although slightly above the specified minimum detectable size, it was well within the acceptable limits for safe flight. This was the first time that a crack had been found in a	**Recommendation 20:** The X-ray and magnetic particle inspection program criteria should be re-evaluated to assess their ability to detect cracks of the size found.	**NASA Response (in 1994 ASAP appendix):** A single crack was detected during standard refurbishment of the forward segment flown on STS-54. The subsequent investigation determined that an inclusion introduced into the metal during the manufacturing process caused the crack to form during heat treatment of the cylinder. The segment had been flown four

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		forward segment, although cracks have previously been detected in other segments. The crack occurred during the manufacturing heat treatment process because of an inclusion in the parent material.		times prior to detection of the crack. Prior to each of these flights, the cylinder was proof tested, which demonstrated safe life (4 mission cycles) in the membrane region where this crack was found. All areas of the RSRM metal hardware (case, nozzle, igniter) have been reevaluated with respect to critical flaw size and whether proof test, magnetic particle inspection or other nondestructive evaluation methods are required to demonstrate compliance to safe life requirements. As a part of this reevaluation, an RSRM hardware configuration specific magnetic particle inspection probability of detection (POD) study was completed. Prior to this study, crack detection threshold limits were based on industry standards. This RSRM magnetic particle inspection POD study incorporated RSRM specific geometries, physical access, gauss levels, surface finishes, potential flaw types, inspection times, and multiple operators. The results demonstrated that, in the areas of the RSRM hardware upon which magnetic particle inspection is solely relies, the detectable flaw size is smaller than the critical flaw size. Proof test is the method of choice used to demonstrate safe life in the case membrane region, not magnetic particle inspection. X-ray inspection is not used for crack detection in RSRM metal hardware. Magnetic particle inspection capability

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				has been reevaluated and, as a result of an RSRM hardware configuration specific POD study, detection capability versus location is well characterized. In those areas that rely solely on magnetic particle inspection, the detectable flaw size is smaller than the critical flaw size.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1994	**Finding 21:** The Advanced Solid Rocket Motor (ASRM) project has been canceled. Some elements from the ASRM development have possible reliability and/or performance benefits if they were applied to the RSRM.	**Recommendation 21:** Examine the potential applicability and cost-effectiveness of including selected ASRM design features in the RSRM.	**NASA Response (in 1994 ASAP appendix):** The RSRM project has continued to consider ASRM design attributes, as motivated by RSRM flight results, performance goals, obsolescence issues, and cost enhancements. Examples of these are the RSRM project's ongoing initiative to replace metal parts vapor degrease cleaning with an aqueous process and the ongoing initiative to remove asbestos from the primary RSRM insulation material. Both of these obsolescence replacement activities have drawn from previous ASRM activity. There are numerous ASRM design attributes for potential consideration for future adoption in the RSRM. These include, in part, propellant formulation (hydroxyl-terminated polybutadiene), sealing system designs, pressure vessel design and materials, some attributes of the nozzle design and some manufacturing process automation, such as insulation strip winding and Real Time Radiography (RTR) for nozzle and case inspections. At present, the RSRM project is considering incorporation of the previous ASRM RTR system into the RSRM

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				hardware verification process and the use of ASRM manufacturing equipment for nozzle fabrication. Based on collective consideration of the implementation cost impacts and RSRM flight demonstrated hardware performance, no requirements have been established to pursue the ASRM sealing system pressure vessel, or nozzle design attributes. However, future justifications in these areas are possible based on continuing RSRM flight evaluation or increased Shuttle program performance requirements.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1994	**Finding 22:** A chamber pressure excursion of 13 psi (equivalent to a thrust perturbation of 54,000 pounds) occurred in one of the RSRMs of STS-54 at 67 seconds of motor operation. A thorough investigation of the phenomenon was initiated and found that the most probable cause was the expulsion of a "slug" of liquid slag (aluminum oxide) generated during normal propellant combustion. Analyses showed that, even under statistical worst-case conditions, the safety of the Shuttle system is not compromised by such perturbations. Some testing and analyses are still scheduled to complete the investigation.	**Recommendation 22:** Complete and document the investigation, and continue the established practice of monitoring chamber pressures and examining possible remedial actions.	**NASA Response (in 1994 ASAP appendix):** The RSRM project has concluded its investigation and has determined that the generic cause of chamber pressure excursions is the periodic expulsion of liquid slag (aluminum oxide). Slag is produced during normal propellant combustion and is temporarily accumulated in the aft end of the nozzle prior to being "dumped" through the nozzle. The RSRM project has implemented the recommendations set forth by the Panel and has established a program to continue to evaluate multiple parameters that could affect the pressure perturbations. The results and findings of these studies are being reviewed and changes to the processes or specification will be made if it is concluded that they will be beneficial to the program. A very detailed study of many process and material parameters that influence slag formation has been conducted

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				to determine if a statistical correlation exists between these parameters and the pressure perturbations. Examples of these parameters include humidity, time in process, ammonium perchlorate (AP) moisture content, mix times, cast times, viscosity, mechanical properties, and many others. No special causes or process deviations related to pressure perturbations have been identified. Analyses have shown that, under the worst case conditions, the safety of the Shuttle system is not compromised by the pressure phenomenon. The results of this extensive study are currently being documented by Thiokol. Chamber pressures are being analyzed or monitored by Statistical Process Control charts. Eighteen acceptance tests are conducted for each lot of AP. The flight and static test pressure perturbation history is reviewed before every launch. Additionally, several other studies are being conducted to improve the predictability of pressure excursions. Quench bomb tests recorded with high-speed film have been used to identify burn-rate differences in the various propellant mixes. Five-inch diameter spin motor tests are being conducted to evaluate the amount of slag that is generated in a motor. This testing employs a design of experiments to evaluate the effects of ground AP, unground AP, differences in AP vendors, aluminum-particle sizes and vendor differences, particle- size

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				distributions, iron oxide surface area, and several other parameters.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1994	**Finding 23:** A Super Light Weight External Tank (SLWT) has been proposed as a means of increasing the payload performance of the Space Shuttle. The tank would employ structural changes and be made from an Aluminum-Lithium (Al-Li) alloy. The SLWT appears to involve no safety decrement and low technical risk.	**Recommendation 23:** The impact of the SLWT on the total system should be carefully examined.	**NASA Response (in 1994 ASAP appendix):** The External Tank Project and Shuttle program are thoroughly committed to an integrated system approach to the design and development of the SLWT. A systems integration plan to ensure the timely assessment of SLWT effects on the Shuttle system, and to ensure program-wide-managed implementation is currently in development.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1994	**Finding 24:** The Integrated Logistics Panel (ILP), which meets at 6-month intervals to report and coordinate the activities of the NASA Centers and their contractors, is performing a vital service in helping to control the entire Space Shuttle logistics program.	**Recommendation 24:** The ILP should continue to be supported as an effective means of maintaining control and coordination of the entire logistics program.	**NASA Response (in 1994 ASAP appendix):** NASA Centers and contractors continue to support the ILP and related integration activities. All project elements benefit from the exchange of technical data presented at ILP meetings. NSTS 07700, Volume XII, "Integrated Logistics Requirements", the program's requirements for integrated logistics was recently updated, and the ILP provided a focus for this effort. The ILP will continue to serve as the forum for problem solving, technical information exchange, and the appropriate level of control, coordination, and integration of Shuttle logistics support.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1994	**Finding 25:** The Vision 2000 cost-reduction program promulgated in May 1993 includes some major changes in the logistics and support areas.	**Recommendation 25:** All changes that might impair logistics and support functions in the name of cost-cutting should be most carefully reviewed before implementation.	**NASA Response (in 1994 ASAP appendix):** As the program continues to plan for the future, the Vision 2000 approach to the program will remain relevant. The Vision 2000 approach is based on the following two principles: operate within SSP experience and locate

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				decision making near operations. Notwithstanding the advantages these principles offer to the current Shuttle logistics community, the SSP office will remain vigilant and exercise caution when making cost-cutting decisions and changes necessitated by funding reductions.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1994	**Finding 26:** Introduction of the Just-In-Time (JIT) manufacturing and shelf-stocking concept by NASA logistics at KSC is a potentially effective method of cost control.	**Recommendation 26:** JIT should be used with caution and with a thorough understanding of how it may impact the availability of Space Shuttle spares and hardware supplies.	**NASA Response (in 1994 ASAP appendix):** All projects have cautiously considered the JIT method of spares provisioning and are in different stages of planning and implementation. Launch and Landing Project (L&L) has applied the JIT method to manufacturing activity. In addition, L&L is further studying alternative methods of prioritizing repair work which may be applied to JTT repairs at a later date. Operational availability will be uppermost in any JIT implementation decision strategy affecting spares and hardware supplies.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1994	**Finding 31:** NASA's past approach to software development has been to incorporate it within the individual programs, allowing them to determine their own requirements and development, verification, and validation procedures. In the future, as the complexity of NASA's computer systems and the need for interoperability grow, this mode of operation will be increasingly less satisfactory. While NASA has some good software practices, it does not have the overall management	**Recommendation 31:** NASA should proceed to develop and implement an Agency-wide policy and process for software development, verification, validation, and safety as quickly as possible.	**NASA Response (in 1994 ASAP appendix):** A software process action team, sanctioned by the Acting Deputy Administrator and the Information Resource Management Council, is working on Agency software issues including roles, responsibilities, standards, and procedures. The Office of Safety and Mission Assurance is leading the Agency in strategic planning for the Agency-wide software program with a NASA working group consisting of members from Centers, industry, and academia.

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		policies, procedures, or organizational structure to deal with these complex software issues.		A Software Safety Standard has been completed. Our present plan is to establish this as an interim standard for 1 year at which time it will become a mandatory requirement for newly developed software. The Software Independent Verification and Validation Facility will focus on the Agency software processes for development, verification, and validation in accordance with the Software Strategic plan currently being developed.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1994	**Finding 32:** NASA has consolidated Life and Microgravity Sciences and Applications, including human factors in NASA Headquarters Code U. A space Human Factors & Engineering Program Plan is being prepared to guide future research activities. There remains, however, a clear need for more operational human factors input in both the Space Shuttle and Space Station programs.	**Recommendation 32:** The Program Plan should be expanded to include support of the operating space flight programs to ensure that sufficient human factors expertise is included.	**NASA Response (in 1994 ASAP appendix):** The Life and Biomedical Sciences and Applications Division is committed to developing a new, dynamic Space Human Factors Engineering Program that will integrate human factors knowledge and methodologies into the Shuttle and Space Station programs. Leadership of this program resides within the Environmental Systems and Technology Branch of Code U, which is responsible for directing an integrated Space Human Factors Engineering research and development program. New processes and procedures will be developed to enhance crew training, augment the design of complex automated systems, and use extreme and isolated environments to conduct analog studies. Research programs will continue; however, the primary focus of the program will shift from knowledge acquisition to knowledge application. This shift will extend human factors support to operational areas and emphasize the improvement of processes and

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				products. The Space Human Factors Engineering Program Plan developed in 1993, is being revised to reflect this shift of emphasis, and an implementation plan will be developed to establish and maintain this new focus. Emphasis will be placed on identifying specific, adequate funding for meaningful results, and promoting the added value of human factors through concurrent engineering throughout the Agency. A Space Human Factors Engineering Customer Team, currently being established at Headquarters with representatives from Codes U, M, R, and Q, is being received in -a spirit of cooperation and collaboration. These changes should create a safer and more productive operational environment for all flight and ground activities planned for current and future programs.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1993	**Finding 9:** The Space Shuttle automatic landing system needs only minimal additional analysis and a few system design changes to extend its performance limits and to support a complete definition of flight rules for its use. Cancellation of the detailed test objective for an automatic landing on the flight of STS-53 has further delayed the specification of these capabilities and the appropriate operational role of the automatic landing system.	**Recommendation 9:** Define the requirements and demonstrate the capability for an automatic landing system as soon as possible.	**NASA Response (in 1993 ASAP appendix):** The orbiter currently has a capability for automatic landings, to be used as a contingency when the commander and the pilot are incapacitated or incapable of landing the orbiter using nominal Control Stick Steering (CSS). Certification of contingency Autoland has involved partial flight demonstration; on STS-2, -3, and –4 Autoland (automatic landing) was engaged from 10,000 ft. to as low as 125 ft. Further certification testing of contingency Autoland has not been identified as a requirement. Postflight data from each mission have been

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				reviewed and indicate no instances of unexpected divergence by the nonactive contingency Autoland from the reference trajectory. The requirements for demonstrating an automatic landing on the Shuttle have been developed as part of a DTO. However, this DTO is not currently scheduled. Reasonable mission rules, placards, microwave landing system calibration, and crew training requirements have been identified. Software changes desirable to enhance redundancy management of navigation sensors have been developed, though not yet implemented. Options for automation of landing gear deployment, air data probe deployment, braking, and nosewheel switching have been developed for incorporation in a long-duration orbiter program. We currently have no plan to demonstrate the Autoland System. This policy is the same as not demonstrating a Return to Launch Site or Transatlantic Abort (RTLS or TAL). The policy is not to take any additional risk for demonstration purposes without a firm requirement. As you know, the Office of Space Flight (OSF) is reviewing a crew exchange to preclude pilots from landing on long-duration flights to Space Station which extend beyond the crew's certified capability to land. Additionally, the OSF has developed an on-orbit simulator for practicing landings prior to entry. This

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				will enhance crew performance during landing. In summary, the program is reviewing the operational flight rules pertaining to Autoland, we have budgeted upgrades in software and hardware to improve the Autoland functionality, the life sciences organization is collecting physiological data and developing countermeasures to ensure adequate crew performance as the mission duration increases. We are confident with using Autoland in a contingency mode, but do not plan to demonstrate Autoland until a firm requirement mandates a demonstration.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1993	**Finding 10:** NASA has funded the development and installation of a Multi-Purpose Electronic Display System (MEDS) for retrofit into the Orbiter. This system will replace the conventional electro- mechanical instruments with flat panel displays.	**Recommendation 10:** The inherent operational and potential safety benefits of Multi-Purpose Electronic Display System.	**NASA Response (in 1993 ASAP appendix):** The magnitude of the modifications to the orbiter vehicles to incorporate the MEDS is quite large. This is known to involve removal and installation of flight deck panels, installation of avionic Line Replaceable Unit (LRU) cooling ducts, and installation of new LRU wiring and the LRUs themselves. The nature of these modifications coupled with the subsystem development schedule, testing schedule, and delivery dates of MEDS hardware, warrant installation of the MEDS during orbiter maintenance/interval inspection down periods. First flight is scheduled in the fourth quarter of FY 1996.

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Aerospace Safety Advisory Panel *(NASA Charter)*	March 1993	**Finding 11:** The inventory of Auxiliary Power Units is currently being upgraded to an Improved Auxiliary Power Unit configuration to improve reliability and service life. The upgrade program, however, projects a condition of zero spares in the future due to time limits on some parts.	**Recommendation 11:** NASA should take the steps necessary to preclude a situation of zero Improved Auxiliary Power Unit spares.	**NASA Response (in 1993 ASAP appendix):** The entire orbiter fleet will be upgraded to fly only IAPUs with the completion of the OV-104 Orbiter Maintenance Down Period (OMDP) 1. The spares posture is improving, but cannibalization will continue to be a possibility until all older APUs are upgraded to IAPUs and are available for installation in the field.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1993	**Finding 13:** The results of flight tests on the Orbiter Columbia (OV-102) using pressure and strain gage measurements on the wing showed that the calculated ascent loads on the wing are conservative. Additional flight tests to be conducted will measure the pressure distribution and strains on the wing and tail of OV-102. These data are required to substantiate that the predicted applied and internal loads on the wing and tail are conservative.	**Recommendation 13:** Conduct the planned tests as expeditiously as possible. Particular emphasis should be placed on the loads on the tail.	**NASA Response (in 1993 ASAP appendix):** The Space Shuttle program has conducted a series of structural DTOs flights to collect the pressure and strain gage data on wing loads. Additional DTOs are planned for STS-55 and STS-58. The collected flight data will be used to verify the orbiter aerodynamic data base which has been used in loads analyses. Vehicle loads analyses are expected to be completed by October 1994.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1993	**Finding 14:** The Space Shuttle Main Engine program is doing well and has sufficient spares. However, the engines still require meticulous attention to detail in inspections and tests.	**Recommendation 14:** Continue the vigilant implementation of the inspection and test procedures while design solutions for known weaknesses are being addressed.	**NASA Response (in 1993 ASAP appendix):** The SSME program will continue vigilant implementation of improved inspection techniques and acceptance test procedures. Design solutions, recurrence controls, limitations, and product improvements are addressed routinely to assure and increase operating margins and safety margins.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1993	**Finding 15:** The individual major component improvement programs are making progress. However, a total engine upgrade is being	**Recommendation 15:** The identified Space Shuttle Main Engine design improvements are vital to the reduction of Space Shuttle operational risk. Therefore, NASA should	**NASA Response (in 1993 ASAP appendix):** The identified SSME design improvements are vital to the reduction of Space Shuttle operational risk. Therefore,

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Charter)		delayed because the High Pressure Fuel Turbopump (HPFTP) part of the Advanced Turbopump Program (ATP) is on hold. The highly effective Large Throat Main Combustion Chamber (LTMCC) has finally been made a formal part of the Space Shuttle Main Engine program by NASA but has been denied appropriations by Congress. Schedule disparities among the various component improvements lead to interim certifications of components in engine configurations that will never fly and to unnecessary duplication of certification tests.	reinstate the Advanced Turbopump Program High Pressure Fuel Turbopump development; continue to press for approval of the Large Throat Main Combustion Chamber; and examine carefully the benefits of integrating all the individual modifications into a block change program.	NASA should reinstate the ATP HPFTP development as well as continue to press for approval of the LTMCC, and examine carefully the benefits of integrating all the individual modifications into a block change program.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1993	**Finding 16:** Three Flight Support Motors have been used to date to verify quality and qualify design improvements, reproducibility, and replacement materials for the Redesigned Solid Rocket Motor (RSRM). In the near future, new materials will be needed in the RSRM to replace those eliminated for environmental or safety concerns. It will also be necessary to qualify new vendors to replace those who have left the industry or are no longer willing to supply components for the RSRM.	**Recommendation 16:** To maintain safety and performance, NASA should continue the use of Flight Support Motors for quality control, validation of design improvements, and qualification and verification of new materials, processes, facilities, and equipment.	**NASA Response (in 1993 ASAP appendix):** It is NASA's intention to continue to qualify new materials or process changes incorporated into the RSRM via the FSM program. The next FSM is FSM-4, scheduled for November 1993. The timing of these changes and the subsequent qualification efforts are subject to budgetary constraints.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1993	**Finding 21:** The Kennedy Space Center has begun a pilot Structured Surveillance Program with the objective of increasing the efficiency of the	**Recommendation 21:** Before Structured Surveillance can be fully implemented, it must be carefully evaluated to assure that it is fully supportive of safe flight operations.	**NASA Response (in 1993 ASAP appendix):** The Structured Surveillance program is in the early stages of development with emphasis on maintaining safe flight operations. Operations

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		quality control function in order to enhance launch turnaround processing. This program appears to have great potential.		and Maintenance Requirements Specifications (OMRSs) derived from Critical Items Lists (CILs) or Hazard Report acceptance rationale will continue to have the previous level of quality assurance inspections. Acceptance and installation of Criticality 1 hardware will also continue to have both contractor and NASA inspections. Evaluation of the results of the pilot program indicates increased efficiency of the processing effort and continued effectiveness of the quality assurance activities. We are moving slowly into this program with close management attention to assure safe flight operations.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1993	Finding 23: A new high bay Orbiter Processing Facility (OPF-3) has been opened at the Kennedy Space Center. In addition to advanced support equipment, OPF-3 has vastly improved lighting, which should decrease accident risk and increase productivity.	**Recommendation 23:** NASA should upgrade the lighting in the other Orbiter Processing Facilities as soon as possible to avoid differences across the high bays and maximize safety and productivity.	**NASA Response (in 1993 ASAP appendix):** KSC acknowledges the findings and agrees with the recommendation. Actions are in process to improve the lighting disparities. Because the most significant differences are in platform configurations and light-reflective surfaces, all surfaces that can reflect light on High Bay 1 and 2 platforms are being painted white. The floors in High Bay 1 are also being painted white and those in High Bay 2 are scheduled to be painted white in August 1993.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1993	**Finding 24:** The NASA Shuttle Logistics Depot has great potential for improving repair turnaround times and enhancing the logistics program. At present, however, repair turnaround tunes are still significantly longer than desired due largely to	**Recommendation 24:** The Space Shuttle Program needs to establish a more effective method of moving units through the repair cycle in order to achieve the full potential of the NASA Shuttle Logistics Depot.	**NASA Response (in 1993 ASAP appendix):** The protracted failure analysis times, especially those involving original equipment manufacturers (OEMs), are the most prominent contributors to the long repair turnaround times. Such turnaround times involving OEMs have averaged about

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		protracted failure analysis times.		four times those at the NSLD. The failure analysis capability at the NSLD has been enhanced during the past year. Initiatives are also underway with the Johnson Space Center (JSC) Orbiter and GFE project to improve the overall failure analysis process relative to identification of requirements as well as location where the analysis is performed. The increasing utilization of the KSC NSLD capability for both failure analysis and repair will significantly improve the average repair turnaround time and the overall logistics program in general.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1993	**Finding 29:** At the request of the NASA Administrator, the Panel examined the organizational structure of the Office of Safety and Mission Quality and the counterpart organizations at NASA Centers. The study concluded that the current organizational arrangement provides an appropriate and effective relationship between NASA Headquarters and the Centers.	**Recommendation 29:** Maintain the current organizational structure, but clarify the functions and duties of the Headquarters Office of Safety and Mission Quality and those of Center Directors and, if necessary, issue revised NASA Management Instructions.	**NASA Response (in 1993 ASAP appendix):** The role and responsibilities of the Headquarters Office of Safety and Mission Quality (Code Q) have been realigned as the result of the recent internal NASA Headquarters red team/blue team reviews. Based on the teams' findings, the name of Code Q has been changed to the "Office of Safety and Mission Assurance" to more accurately reflect its function. Other changes have been instituted to streamline the overall activity and realign resources to better support the evolving needs of NASA programs and missions. A NM1 incorporating these changes was signed on April 9, 1993. Although the mandate of the OSMA will continue to emphasize its role as the Agency's "safety conscience," the changes ensure an appropriate and harmonious balance between

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				Code Q's independent program oversight and support functions. The Office will provide an upfront contribution to programs (prevent problems by building in safety, reliability, and quality assurance at the earliest possible stage), focus efforts to manage the quality process for NASA payloads, and increase system engineering/concurrent engineering capabilities, while expanding risk-management capabilities to support program managers in meeting schedule and budget constraints during critical decision making processes. The strategic thrust of the Office over the next 2 years will be to: (1) Integrate SRM&QA requirements at the appropriate stage of a program; (2) Advocate SRM&QA oversight and assessment functions across the Agency; (3) Develop and promote NASA-wide risk-management practices; (4) Maintain a strong contributing SRM&QA presence in NASA programs and operations; and (5) Develop and advance engineering standards and practices.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1993	**Finding 34:** NASA research and test facilities are a national asset, key to the United States' continuing leadership in space and aeronautics. Regrettably, some of the infrastructure is not being adequately maintained, and the development of new, state-of-the-art facilities has been lagging.	**Recommendation 34:** NASA should develop an integrated long-range infra-structure plan that assures the maintenance of existing assets and develops new facilities to continue American leadership in space and aeronautics research and development.	**NASA Response (in 1993 ASAP appendix):** NASA has embarked on a comprehensive study to develop a coordinated national plan for world-class aeronautical and space facilities that meets the current and projected need for commercial and Government-sponsored research and development, and for Government space operations. The plan will be coordinated with the Department of

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				Defense, Department of Energy, Department of Commerce, Department of Transportation, and the National Science Foundation. Industry representatives have been contacted to ensure that private-sector interests are considered. The plan will address shortfalls in existing capability, new facility requirements, and consolidation and phaseout of existing facilities. The development of the Facility Plan will be accomplished by three task groups: Aeronautics R&D Facilities, Space R&D Facilities, and Space Operations Facilities; all three of which are of interest to constituencies in the private sector. The results of the study will be an essential component of our internal planning to improve and continue to maintain our facility infrastructure.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1993	**Finding 36:** NASA has embraced the concept of Total Quality Management (TQM). However, TQM implementation across NASA centers and contractors appears to vary from highly visible and apparently productive efforts to activities that seem to have more form than substance.	**Recommendation 36:** NASA should review its internal Total Quality Management program to assure that it is properly structured as a support function and includes not only motivation, but also appropriate leadership and training for both TQM instructors and hands-on employees.	**NASA Response (in 1993 ASAP appendix):** NASA's Continual Improvement Office (Code T) is currently completing efforts to provide planning for a structured implementation of TQM. Coordination with points-of-contact at each NASA facility and outside industry experts has been conducted, and a NASA-wide Implementation Plan has been written. The plan provides for a phased program to examine established initiatives and approaches at all NASA Centers, benchmark successful activity, coordinate a consensus commitment across NASA, and achieve partnership working arrangement with outside organizations. Contractor/NASA metrics,

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				and an internal/external Supplier Ratings System (SRS) have been developed using the guidelines and selected provisions of the Baldridge Award, President Award, NASA Low Trophy, and other similar criteria. These measures will be used to gauge the performance of NASA's Continual Improvement activities. Overall, this effort will result in a network of leadership, support, and training that meets the strategic goals and directions of the Agency.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1992	**Finding 6:** The results of flight tests indicate that the turbulent flow over the body flap creates a spectrum of hinge moments greater than that used in the original structural fatigue analysis. It also has been determined that an additional load path exists from the flap to the supporting structure. Further, the flap actuators were found to be more flexible than originally assumed. Additional tests are to be conducted to evaluate hinge moments and actuator flexibility.	**Recommendation 6:** NASA should evaluate, as rapidly as possible, the results of the new tests and loads analyses to reestablish the allowable number of flights for the body flap.	**NASA Response (in 1992 ASAP appendix):** Concur. The Space Shuttle Program has baselined a set of loads to account for the increased buffet environment. Additionally, the Space Shuttle Program has implemented a plan to measure loads during missions. Assessments have shown adequate mission life of the body flap for current missions and overall life still is being evaluated. Additionally, the Shuttle Modal Inspection System (SMIS) is being used to track potential damage of the body flap.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1992	**Finding 7:** NASA has developed a Shuttle Modal Inspection System (SMIS) for detecting changes in stiffness in structural/mechanical systems due to factors such as wear or cracking. The SMIS has shown good results when used on the Orbiter body flap and elevon systems (including actuators and supporting structures). However, it is not a	**Recommendation 7:** The SMIS procedure should be used only to augment more conventional NDI methods.	**NASA Response (in 1992 ASAP appendix):** Concur. Successful tests have indicated that the SMIS is a reliable method to detect changes in stiffness and dynamic behavior of the Orbiter body flap, elevon, and rotor speed brake (control surfaces). The SMIS is not intended to replace current inspection procedures but is to supplement standard inspection procedures to help detect early damage in areas

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		complete replacement for more conventional nondestructive inspection (NDI) methods. These conventional methods are capable of detecting cracks in primary structures with a "critical crack length" too small to cause a detectable change in stiffness and hence be measurable by SMIS.		that cannot be inspected. NASA has not deleted any structural inspection requirements documented in the Operational Maintenance Requirements and Specifications Document (OMRSD).
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1992	**Finding 8:** Thermal protection system tiles are inspected for damage after every flight by specially trained and highly experienced inspectors using tactile techniques. These inspectors determine if the tiles are loose and help to identify problems in step and gap. The current procedure is largely qualitative and highly dependent on the skill of the individual inspectors.	**Recommendation 8:** A program to select and train new inspectors should be instituted to ensure the availability of an adequate cadre of qualified inspectors throughout the life of the Orbiters. In addition, further effort should be applied to the development of a quantitative inspection technique.	**NASA Response (in 1992 ASAP appendix):** Concur. NASA has a program in place to train and qualify inspectors to inspect TPS tiles. In addition, quantitative techniques are being investigated to reduce the technique-sensitive characteristics of the current, operator-dependent, inspection techniques. Currently, all new tile inspections require bond verification testing. Any postflight tile suspect bond conditions also are verified along with conducting engineering "deflection" tests. A dozen certified bond inspectors presently are being used to qualitatively evaluate suspect tile bonds. The individuals have been trained on-the-job and consist of contractor and government engineers. The number of trained personnel will remain the same unless unforeseen increases in bond anomalies occur. The Kennedy Space Center (KSC) is actively pursuing the development and implementation of an alternative nondestructive evaluation (NDE) method for performing tile bond

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				verification. Presently, a math model of the tile system is being formulated that will be used to evaluate the abilities of NDE systems being developed by two independent contractors. These NDE systems use vibration imaging patterns correlated to bond discrepancies to identify bond anomalies.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1992	**Finding 9:** The Space Shuttle Program requires both turnaround and periodic major Orbiter overhaul functions.	**Recommendation 9:** Overhaul and major modification efforts should be organizationally and functionally separated from routine turnaround operations because of the different types of planning and management skills and experience required.	**NASA Response (in 1992 ASAP appendix):** The Space Shuttle Program has dedicated Orbiter Maintenance Down Periods (OMDP) at 3-year intervals for the performance of major modifications, structural inspections and other interval inspections. The decision to retain the same organizational structure at the Kennedy Space Center (KSC) for planning and management of both OMDPs as well as turnaround processing is based on the following: (list omitted)
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1992	**Finding 10:** The Space Shuttle design presently includes an automatic approach guidance system that requires crew participation and does not control all landing functions through touchdown and rollout to wheel stop. The present system never has been flight tested to touchdown, but a detailed test objective for such a test is in preparation. The availability of a certified automatic landing system would provide risk reduction benefits in situations such as weather problems after de-orbit	**Recommendation 10:** Future mission plans suggest the potential for significant risk reduction if the present Space Shuttle automatic landing capabilities are fully developed and certified for operational use. System development should include consideration of hardware, software, and human factors issues.	**NASA Response (in 1992 ASAP appendix):** The current autoland system capability is functionally adequate and verified as a backup entry system with some crew participation required. Beginning with STS-53, a two-flight detailed test objective will evaluate autolanding performance through wheel stop. Further, a program study is under way to define the necessary hardware, software, human factors, and system analyses required to support an upgraded autoland system for extended duration Space Shuttle flights where this autoland system could be the

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		and Orbiter windshield damage.		prime mode for entry operations.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1992	**Finding 11:** NASA continued its software independent verification and validation (IV&V) activities during the year. This independent review has demonstrated its value by finding failure modes that previously were unknown. The Safety and Mission Quality organization has taken on greater responsibilities for software safety.	**Recommendation 11:** NASA should continue to support a software IV&V oversight activity. The present process should be reviewed to ascertain whether it can be streamlined. The IV&V oversight activity should include the development of detailed procedures for test generation. NASA should not attempt to duplicate, through IV&V or otherwise, the actual performance of all verification and validation tests.	**NASA Response (in 1992 ASAP appendix):** Concur. The Space Shuttle Program has formally baselined the embedded V&V process and established the requirements in NSTS 08271, Flight Software Verification and Validation Requirements; formally established a V&V policy requiring program elements to adhere to this process; and assigned the SR&QA organization as the independent overseer assuring adherence to this process. The Space Shuttle V&V process includes maintenance of detailed test procedures on many levels for the existing test facilities available to the program. Although the program feels very strongly. that the embedded V&V process is excellent, the NRC has been requested to evaluate the Space‘ Shuttle's embedded V&V process relative to the need for IV&V. NRC's evaluation is in process with planned completion targeted for September 1992. Additionally, NASA plans construction of an IV&V facility in Fairmont, WV in 1992. Methods of improving and streamlining the IV&V process will be studied at this facility. Based on criticality and category of the software to be independently validated and verified, the NASA IV&V activity will permit tailoring to specific software project needs.

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				It is not the intent of these independent activities to duplicate all verification and validation (V&V) tests, but to provide support and consistency to enhance the V&V process.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1992	**Finding 12:** The new Space Shuttle general purpose computer (GPC) apparently has performed well. The Single Event Upsets (SEUs) were no more numerous than expected. Based upon NASA's model of SEUs, the accuracy of the predictions is excellent, and supports NASA's estimate that the probability of an SEU-induced failure is negligibly small. Nevertheless, there still is concern about the eventual saturation of usable memory on the GPC.	**Recommendation 12:** NASA should initiate a small study on alternatives for future GPC upgrades and/or replacements. This should involve other NASA organizations that have been studying computer evolution.	**NASA Response (in 1992 ASAP appendix):** The GPC Error Detection and Correction circuitry cyclically accesses each word in the 256K memory every 1.7 seconds. Because any SEU error is corrected at that rate, there is minimal chance of the memory being "saturated," regardless of the duration of exposure, The same circuitry also generates a count whenever it encounters and corrects such an error, thereby providing corroborating data to compare with the environmental analyses performed to predict SEU rates. The same EDAC architecture is used in the Space Station onboard 386 processors. That processor family also has been selected for the new Space Shuttle Multifunction Electronic Display System (MEDS). It is anticipated that the MEDS will allow future mission-related software growth without directly impacting the flight-critical code in the GPCs. Available usable memory in the GPC appears to be adequate well into the next decade. It is probable that hardware obsolescence will arrive well before practical memory limits are reached. Considerations for GPC upgrades should be initiated in the next 3 to 4 years through the Assured Shuttle Availability (ASA) process.

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Aerospace Safety Advisory Panel *(NASA Charter)*	March 1992	**Finding 13:** The replacement of some requested software upgrades with crew procedures is a matter of serious concern particularly when the functions addressed could be handled with greater reliability and safety by software. The crew already has to cope with a very large number of procedures.	**Recommendation 13:** NASA should conduct a thorough review of all crew procedures that might be performed by the computer system to determine whether they are better done manually by the crew or by the software. Human factors specialists and astronauts should participate.	**NASA Response (in 1992 ASAP appendix):** Concur. As part of the software upgrade process, reviews are held to determine which activities are best shifted from the crew procedures. Astronauts have actively participate in these processes and reviews. Human factors specialists also contribute to this process. The Space Shuttle Program has and will continue to implement flight software automation of crew procedures that are deemed a significant threat to flight safety or mission success due to the level of difficulty. Tasks for which manual procedures are adequate are judged based on the trade-off of value added/implementation risk against other flight software priorities. During the requirements baselining of the last three Operational Increments (i.e., 01-21, -22, -23), a significant number of software change requests were approved that automated existing crew procedures. Examples include (1) single engine auto contingency abort, which defined the automation of vehicle maneuvers following the failure of two Space Shuttle Main Engines; (2) abort sequencing redesign, which automated some of the crew procedure for aborts; (3) Transatlantic Abort Landing (TAL) droop control, which automated crew procedures to keep the vehicle above a minimum target altitude; and (4) Universal Pointing Future Maneuver-Digital Autopilot

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				(DAP) that significantly reduces the crew procedures for selecting the most appropriate DAP configuration to enter from 14 separate entries to a single entry.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1992	**Finding 14:** There are currently a sufficient number of flightworthy engines to provide each Orbiter with a flight set as well as provide an adequate number of spares.	**Recommendation 14:** Maintain this position. level tests have begun for both	**NASA Response (in 1992 ASAP appendix):** Thank you. We intend to maintain a good posture on spare engines.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1992	**Finding 25:** In spite of significant advances over the past year, there is still a need to improve the effectiveness of launch processing at KSC. It is rare when a vehicle is taken to the pad and launched without delays. Subsystem problems sometimes either require rolling the vehicle back to the Vehicle Assembly Building (VAB) or they cause delays at the pad.	**Recommendation 25:** Continue efforts to improve the effectiveness of launch processing operations. Each occurrence of a problem at the pad should be reviewed to determine why it was not caught in the VAB or Orbiter Processing Facility.	**NASA Response (in 1992 ASAP appendix):** Concur. NASA is committed to a series of new initiatives designed to enhance the hands-on accountability of individuals at the task level and improve processing flow. The Space Shuttle Program has requested all Space Shuttle projects to continue striving for efficiencies in the checkout requirements and the implementing procedures at KSC. The Space Shuttle Program recently completed a project-by-project review of the OMRSD requirements. The goal was to eliminate or reduce "vehicle" checkout requirements that were considered redundant testing or over-testing of a system. This is now beginning to appear in the OMIs as efficiencies to operations. A policy that has been put in place by the Space Shuttle Program defers testing of a function until reaching the pad if (1) that function is required to be checked out in an integrated test and (2) the system/component can be reasonably repaired or removed/replaced at the pad. Process reviews and process

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				analyses by the task teams still are being promoted as another technique to improve processing operations.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1992	**Finding 26:** Morale among launch processing personnel at KSC improved over the past year. This most likely is the result of a heightened sense of individual responsibility, improved systems training, and a better supervisory/management approach.	**Recommendation 26:** Continue and expand the approaches that have been successful over the past year.	**NASA Response (in 1992 ASAP appendix):** Concur.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1992	**Finding 29:** Procedures for tracking, analyzing, and providing corrective action for hardware problems arising at KSC are complex and lengthy involving numerous entities. There is no overall coordination effort to ensure that appropriate corrective action is taken.	**Recommendation 29:** The Space Shuttle Program should establish a coordinating function that is responsible for ensuring that proper and timely action is taken by responsible organizations in correcting problems that occur during launch preparation.	**NASA Response (in 1992 ASAP appendix):** Concur. A joint KSC/JSC problem process improvement team chartered by the Space Shuttle Program (SSP) has been formed to analyze the Orbiter discrepant hardware/logistic processing flow. The sequence of events presently required to process discrepant hardware is undergoing assessment to determine how best to streamline and make the system more responsive. Recommended changes are scheduled for presentation to the SSP in mid-1992. In addition, the Space Shuttle Critical Process Improvement Team has completed a review of the current NASA management/ contractor interface relationships for logistics for all Space Shuttle elements. A report identifying issues and corrective actions has been submitted to the Space Shuttle Program.

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Aerospace Safety Advisory Panel *(NASA Charter)*	March 1992	**Finding 42:** Despite acknowledged examples of contributions to aviation safety analyses through human factors research, NASA has not marshalled its resources in this field to study similar problems in spaceflight orbital and ground operations. Efforts in this arena have been stymied by a lack of appreciation of its potential value and the absence of clear guidelines regarding programmatic responsibilities.	**Recommendation 42:** In view of the anticipated increase in manned spaceflight activity during the present decade involving joint Space Shuttle and Space Station activities, NASA human factors resources should be marshaled and coordinated effectively to address the problems of risk assessment and accident avoidance.	**NASA Response (in 1992 ASAP appendix):** Concur. NASA currently sponsors a pilot project at the Kennedy Space Center to determine the value to the safety program of incorporating human factors principles. This project focuses primarily on facility design and acquisition. The Space Station Processing Facility has been selected to serve as a demonstration vehicle. Draft guidelines have been developed and are being tested in the pilot project prior to publication and NASA-wide implementation.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1991	**Finding 1:** NASA has planned to implement the wing/fuselage modifications indicated by the results of the 6.0 load analysis. Modification work has been scheduled for OV-102, and plans are being developed for the remainder of the fleet.	**Recommendation 1:** The implementation of these modifications should be accomplished as soon as possible so that the restricted flight envelope (green squatcheloid) parameters can be safely upgraded.	**NASA Response (in 1991 ASAP appendix):** Concur. Modifications are scheduled for each vehicle's Orbiter Maintenance Down Period (OMDP). The OMDP has been incorporated into the Space Shuttle Program to provide dedicated times for performing detailed vehicle structural inspections, subsystem inspections and internal functional checks as well as modifications. All vehicle modifications will be complete by mid-1993.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1991	**Finding 2:** The uncertainties surrounding crew performance after extended stays in space suggest a need for an alternative to manual landings.	**Recommendation 2:** The Space Shuttle Program should complete the development of a reliable autoland system for the Orbiter as a backup.	**NASA Response (in 1991 ASAP appendix):** Concur. The existing Shuttle autoland system is certified and is a reliable backup for 16-day Extended Duration Orbiter missions. A significant program to collect crew performance data is being undertaken by the Office of Space Science and Applications during flights involving incremental increases of on-orbit duration. Current plans involve flying four lo-day flights and three 13-day flights prior to the first

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				16-day flight. Crew performance data will be evaluated and must be judged acceptable prior to commitment to the next increment of extended duration.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1991	**Finding 3:** With plans to extend Orbiter use well into the next century, it will be necessary to upgrade the Orbiter computer systems several times. The present, rather ad hoc, approach of treating each upgrade as an independent action will be unsatisfactory for the long term.	**Recommendation 3:** NASA should accept the need for an upgrade involving a complete software reverification approximately every 10 years. A study should be undertaken to plan a path of evolution for all future changes in avionics computer hardware and software for the life of the Space Shuttle Program. The study should involve independent assessment to ensure the broadest possible perspective.	**NASA Response (in 1991 ASAP appendix):** Concur. NASA has just completed integrating the Improved General Purpose Computer (IGPC) into the fleet. This upgrading of the orbiter computers included an extensive reverification of the flight software. Integrated testing of the flight hardware and software was one of the milestones in the certification of the IGPC hardware and flight software. In addition, the Shuttle software is incrementally upgraded and released for flight approximately every eight months. These upgrades are validated, verified, and certified through an extensive and thorough process. Future computing capability beyond recent incorporation of the IGPC is under development in the Assured Shuttle Availability (ASA) Program in the Multifunction Electronics Display Subsystem (MEDS). The plan for the subsequent lo-15 years involves maintaining the existing system. Issues involving obsolescence and enhanced performance will continue to be reviewed.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1991	**Finding 4:** The Space Shuttle flight software generation process is very complex. It includes numerous carefully designed safeguards intended to ensure that no faulty software is ever	**Recommendation 4:** NASA should conduct an independent review of its entire software generation, verification, validation, object build, and machine loading process for the Space Shuttle. The goals should be to ascertain whether the	**NASA Response (in 1991 ASAP appendix):** Concur. An independent review has been completed of NASA's entire software generation, verification, validation, object code build, and machine loading process. As part of the

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		loaded. When errors have occurred, or when concerns have been raised about steps in the procedure, new safeguards have been added. The whole process is long, complicated, and involves a plethora of organizations and computers.	process can be made less complex and more efficient.	post-511 activity, NASA contracted with Intermetrics Inc., as the independent verification and validation (IV&V) contractor. NASA is developing a policy to define the scope of our independent oversight activity. To assist in this task, NASA has requested the National Research Council to perform an independent review of the IV&V process to include software generation, object code build, and machine loading.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1991	**Finding 14:** The external tank project is moving along very well.	**Recommendation 14:** Keep up the good work.	**NASA Response (in 1991 ASAP appendix):** Thank you.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1991	**Finding 15:** This past year, NASA management has postponed Space Shuttle launches when technical uncertainties existed, declared a hiatus during the Christmas season and interrupted launch operations until the cause of hydrogen leaks could be determined and resolved. This is clear evidence of NASA management's commitment to the principle of "safety first, schedule second."	**Recommendation 15:** NASA management should maintain this policy even as Shuttle launches become more frequent.	**NASA Response (in 1991 ASAP appendix):** Strongly concur.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1991	**Finding 16:** Reports indicate that launch processing operations at the Kennedy Space Center (KSC) are being carried out with a declining rate of incidents. This is a trend in the right direction since the extreme sensitivity of Shuttle launch processing requires reducing errors	**Recommendation 16:** KSC, the Shuttle Processing Contractor, and associate contractors should continue to make all possible efforts to reduce incidents. However, care must be exercised to ensure that any observed decrease in incident reports is not merely an artifact of the reporting system. In particular, if management's response to	**NASA Response (in 1991 ASAP appendix):** Concur. KSC and the Shuttle Processing Contractor (SPC) are continuing to try to reduce incidents, even beyond the success we have had to date. We are accomplishing this through a network of preplanning, communication, and coordination that encourages everyone to work

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		to the lowest possible levels.	incident reporting is perceived as punitive in nature, the net result may be a suppression of reporting with a resultant reduction in the information available to management on which to identify problems and design remedial actions. Total Quality Management (TQM) techniques can be of great assistance. Likewise, the inclusion of human factors professionals on incident investigation teams can be very beneficial. Therefore, KSC should consider both an enhanced TQM program and a broader use of human factors.	together and understand that they are an essential part of the task at hand. Management takes no punitive action against any worker for incidents unless it is clearly shown that the worker had a preconceived negative intent or makes the mistake repetitively (more than twice). For repetitive errors, the worker is simply reassigned to other tasks and/or retrained. Any repetitive error is automatically evaluated from the human factors viewpoint. It should be noted that human factors concepts have been used throughout the creation and verification of all Orbiter Maintenance Instructions (OMIs) and the initial performances of all tasks involved in vehicle processing. With quality control checks at all levels from planning, engineering, OMI creation, and progressive steps of task team work, we are practicing TQM and reducing incidents. We will continue to use enhanced TQM and a broader use of human factors, as appropriate.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1991	**Finding 17:** There is a perception among some workers at KSC that disciplinary actions for errors are overly severe.	**Recommendation 17:** NASA and its contractors should make every effort to communicate the facts and rationale for disciplinary actions to the work force and involve workers in incident reviews. TQM techniques can be of great assistance. There is simply no substitute for sincere communication between management and labor in dispelling negative perceptions.	**NASA Response (in 1991 ASAP appendix):** Concur. NASA is very concerned about the potential that such a perception may exist. KSC and SPC have instituted a program of vertical and lateral communications that extends from the highest KSC management levels (both civil service and SPC) down through middle management, engineering, and the task team technical floor workers. Practices include weekly meetings at top management levels, daily reviews at middle management and throughout engineering, and per shift (or

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				more) coordination sessions at the task team level. There are also horizontal channels for coordination from hands-on-workers, logistics/supply elements, and support operations. It is continually stressed throughout these channels that disciplinary action for errors will not be severe or punitive unless the errors or incidents result from clearly proven negative intent. All employees are advised of their obligation to come to work fit and able, and to perform the tasks carefully and successfully. Any error is discussed with the responsible employee and efforts made to help him or her understand how to avoid a repetition.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1991	**Finding 18:** There are cases in which recurring waivers are sought and issued for the same subsystem or component on successive Space Shuttle flights. For example, waivers have had to be issued to fly with the tumble valve disabled on the external tank.	**Recommendation 18:** Continuing waivers for the same condition should not be permitted. If it is deemed acceptable to fly repeatedly with a configuration that varies from specifications, the specifications should be altered rather than risk diluting the significance of waivers by making them routine. For example, the underlying specification for the tumble valve could be changed to require its inclusion only on high inclination launches.	**NASA Response (in 1991 ASAP appendix):** Concur in principle. The ASAP is correct in suggesting that there are continuing waivers where the specification can be changed; a good example is the tumble valve. Based on Flight Data for tanks with an active tumble system, the tumble systems were disabled on selected flights based on analysis of External Tank (ET) Rupture Altitude and the corresponding debris footprint. Flight and tracking data were used to determine the correlation between non-tumble system tank trajectories, ET motion, ET Rupture Altitude and the ET Debris Model. Based on these analyses and flight tests, the applicable specification was changed to preclude the necessity for continuing ET Tumble System Waivers. However, it should be pointed out that waiver disposition is never "routine." As outlined above, a request for waivers

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				or to change a specification requires rigorous supporting data (many times flight data) presented through a series of at least three change control boards. Specifications have been, and will continue to be, changed where it is proved that the limits should be revised for all flights.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1991	**Finding 19:** The Mission Control computer support system is quite old, relatively slow, and has monochrome displays primarily of tabular data. The advantages of applying current technology to Mission Control are being explored with the Real-Time Data System at the Johnson Space Center (JSC).	**Recommendation 19:** NASA should embark upon a systematic process to replace the old Mission Control system with one based upon up-to-date computer and human interface system technology.	**NASA Response (in 1991 ASAP appendix):** Concur. Since 1986, NASA has been in a phased process of upgrading the operational elements of the Mission Control Center (MCC) to incorporate advanced technology. This includes the replacement and upgrade of mainframe computers, and the placement over the last 2 years of current generation workstations in the MCC that are capable of using advanced techniques for analyzing and displaying data. These enhancements are part of a comprehensive multi-year plan developed to introduce new technology into the operating environment.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1991	**Finding 24:** Out-of-production, aging, and obsolescent parts are a growing problem.	**Recommendation 24:** Increased emphasis should be given to ensuring the availability of sufficient quantity of up-to-date hardware.	**NASA Response (in 1991 ASAP appendix):** Concur. NASA recognizes the potential problem posed by obsolete parts. KSC has instituted a three-part program to minimize the impact that obsolescence could have on orbiter logistics supportability. The program includes identification of potentially obsolete parts; evaluation of available prevention options; and tracking of obsolescence data, including actions taken. These actions are taken in conjunction with the Assured Shuttle Availability Program. The increased emphasis on

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				parts obsolescence should ensure the ability of KSC to provide up-to-date hardware for orbiter launch processing.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1991	**Finding 25:** There does not appear to be a comprehensive and realistic plan for scheduling and accomplishing major overhaul of the Orbiter fleet.	**Recommendation 25:** To help ensure structural integrity of each vehicle, much greater effort must be devoted to these tasks. A comprehensive program should be developed for the orderly overhaul of Orbiters that are expected to operate into the 21st century.	**NASA Response (in 1991 ASAP appendix):** Concur. The Space Shuttle Program has developed and instituted a plan by which the orbiter vehicles are inspected and modified every 3 years. This plan involves the use of specific orbiter flow periods commonly referred to as Orbiter Maintenance Down Period (OMDP) to perform vehicle structural inspections and modifications. The orbiter structural inspection will verify the integrity of primary structural elements of the vertical tail, flight control surfaces, aft fuselage, mid-fuselage, landing gear, crew module and forward fuselage. Critical elements will be inspected for corrosion, fatigue, deformation and cracks, which would result in reduced structural integrity. Flow periods of 188 days have been allocated for an OMDP. OV-102 is the first vehicle to be scheduled for an OMDP and will begin in FY 91. OV-103 and OV-104 are currently scheduled to begin their modification/inspections periods in FY 92. The Space Shuttle Program will continue to use OMDPs to inspect and modify each orbiter throughout a vehicles operational lifetime to ensure each orbiter's structural integrity and upgrade the systems as required to ensure operations through 2020.

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Aerospace Safety Advisory Panel *(NASA Charter)*	March 1991	**Finding 29:** The use of Fault Tree Analysis and Failure Modes and Effects Analysis techniques proved to be valuable in solving the hydrogen leak problems on STS-35 and STS-38. Their use led to the identification of probable sources of the hydrogen leaks, the probable causes of these leaks, and the nature of the corrective actions needed.	**Recommendation 29:** Use of these techniques for problem resolution should be encouraged throughout NASA. Suitable training programs should be established to ensure proper implementation.	**NASA Response (in 1991 ASAP appendix):** Concur. Fault-tree analysis (FTA) and Failure Modes and Effects Analysis (FMEA) are techniques fundamental to the NASA systems engineering disciplines. They are used throughout system development to enable early identification of problems, and assign hardware and software criticality. Critical Item Lists (CILs) are tabulated by criticality level and require review, resolution, or waiver before flight is approved. FTA is used by the safety organizations to provide top-down analyses of safety-critical problems, while the FMEA is a bottom-up approach that begins at the parts level. Both formal and informal on-the-job training in these techniques is provided.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1991	**Finding 30:** NASA has a TQM program intended to improve quality and productivity within NASA and its contractors. The implementation of the TQM (or its equivalent) concept, however, has been quite variable across the NASA Centers and contractors.	**Recommendation 30:** The principles of TQM have merit when implemented by a dedicated and concerned management. NASA should implement a consistent TQM methodology that ensures adherence to those principles and participation of all levels of the work force.	**NASA Response (in 1991 ASAP appendix):** Concur. NASA's ongoing emphasis on quality and productivity improvement (QPI) began in 1982, with an internal and external focus. In 1986, a special emphasis was placed on the external efforts in recognition that the majority of the NASA budget is allocated to contractors. In fact, Martin-Marietta/Michoud (which was referenced in the ASAP report) was evaluated under the NASA Excellence Award Program and won in 1987 for their quality achievements. In 1989-90, a renewed emphasis was placed on internal QPI programs, while still maintaining our external efforts. In February 1990,

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				NASA formally launched an internal TQM initiative, and recently conducted a NASAwide TQM assessment. We are now planning an internal TQM evaluation initiative patterned after the George M. Low Trophy (NASA's Quality and Excellence Award program) using TQM criteria contained in the President's Award for Quality and Productivity Improvement. NASA top-level management is committed to successfully implementing the TQM program and will be directly involved in formulating strategies for achieving NASA TQM program goals. The TQM Steering Committee, consisting of NASA senior management, will report on the status and progress of TQM implementation at their Fall 1991 meeting.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1991	**Finding 31:** NASA has a management instruction (NM1 8621.1E) that addresses "Mishap Reporting and Investigation." This NM1 includes a specification of board composition. It does not, however, realistically address the need for human factors input in such investigations. It notes that if human factors are thought to be substantially involved, then human factor input is to be sought from a "NASA or resident NASA contractor physician" rather than a trained human factors expert. Also, this NM1 does not require investigation of "close	**Recommendation 31:** Inclusion of a member on the incident/accident investigation board with specific human factors expertise should be given much greater consideration. "Close-call" investigations should be more formalized.	**NASA Response (in 1991 ASAP appendix):** Concur. NASA is investigating the human element in all NASA mishaps. Efforts are currently underway to refine and update NM1 8621.1E. Part of this effort will be the transition of NASA Mishap Investigation Board Membership requirements to the Basic Safety Manual, NHB 1700.1. Consideration will be given to incorporating a requirement to have a Human Factors Engineering professional assigned to a NASA Mishap Investigation Board during this transition. The NASA Headquarters Safety Division is sponsoring a Human Error Avoidance Project at KSC that includes funding for a full-time Human Factors Engineering professional.

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		calls."		This individual will be available to participate in future mishap investigations at KSC. Formalization of the NASA close-call investigation process is also a NASA concern. The update to NM1 862LIE will stipulate investigation of Type A, B, and C mishap-related close-calls as a requirement in the Basic Policy for NASA Mishap Reporting and Investigation. Under the current policy, all close-calls must be reported; close-call reports are evaluated at NASA Headquarters and, when necessary, an investigation board is established.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1990	**Finding 1:** Until November 1989, the two principal manned space flight programs - the Space Shuttle and Space Station Freedom - were managed independently, each under the cognizance of a separate Associate Administrator. Since the Challenger accident, Space Shuttle management has exhibited a noteworthy degree of effectiveness and stability. In contrast, Space Station Freedom management has suffered from a lack of continuity in its top-level personnel. Also, the independent status of both programs created some confusion concerning future operational responsibilities. The recent reorganization of the Office of Space Flight places both programs under one Associate Administrator. This change in NASA	**Recommendation 1:** NASA, the Administration, and the Congress should support the recent reorganization of the Office of Space Flight and allow that office time to accomplish its objective of achieving a unified and cohesive manned space flight program.	**NASA Response (in 1990 ASAP appendix):** NASA concurs with the finding regarding the recent reorganization and establishment of the Office of Space Flight under a single Associate Administrator. All necessary actions have been taken within Space Station Freedom Program (SSFP) elements to ensure the smooth transition of the organization involved so that the goal of a "unified and cohesive manned space flight program" can be achieved.

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		management is a positive step in seeking stability and cohesiveness in manned space flight activity, especially in flight operations and budgetary planning.		
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1990	**Finding 3:** The return-to-flight of the Space Shuttle has been characterized by extensive preflight reviews. The majority of these, including the roll-out, solid rocket booster/external tank mating, and flight readiness reviews have been conducted face-to-face at the Kennedy Space Center. With the increasing flight rate, the travel and scheduling involved in the multiplicity of meetings are becoming a financial and physical burden. Some of the reviews are being shifted to video or telephone conferences. These techniques conserve travel time and budget, but could reduce the effectiveness of the management review process.	**Recommendation 3:** The flight readiness, Launch-2 day, and Launch-1 day reviews should continue to be conducted as face-to-face meetings at the Kennedy Space Center. The balance of the prelaunch reviews for each flow may be conducted as either actual meetings or by remote conferencing techniques. This would depend upon interflight schedules and the number/importance of unique problems or issues associated with a particular flight.	**NASA Response (in 1990 ASAP appendix):** NASA concurs with the recommendation. The Flight Readiness Review, and the Launch-2 Day and Launch-l Day reviews will continue to be conducted as face-to-face reviews at the Kennedy Space Center. For the L-2/L-1 reviews, some JSC support elements (flight directors, weather, etc.) must remain at JSC to support, the terminal count. Therefore, some JSC elements have been supporting, and will continue to support the L-2 and L-1 reviews by telephone. The Level III project reviews, ET/SRB MATE Review, Orbiter OPF Rollout Review, and Launch Site Flow Reviews can be conducted by telephone with proper representation, Detail requirements, formats, and designated face-to-face meetings are contained within the NSTS 7000, Level I, Program Requirements Document, Appendix 8 (NSTS Operations).
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1990	**Finding 5:** Interruptions in Space Shuttle operations for any reason can have serious consequence to the Space Station Freedom assembly. The Panel, thus far, has seen little evidence of contingency planning by NASA for such eventualities. Contingency planning	**Recommendation 5:** NASA should develop a contingency plan that addresses the issues arising from possible interruptions of Space Shuttle operations during the assembly of Space Station Freedom.	**NASA Response (in 1990 ASAP appendix):** NASA concurs and has actions presently underway. All of the Space Station Freedom stages prior to permanently manned capability (PMC) have an orbital lifetime of at least 1 year and generally closer to 2 years in the normal operating altitude. In the case of a Space Shuttle standdown, NASA

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		should extend through all phases of operation. The Panel believes this to be an important area for NASA to emphasize in operational planning.		could boost any of these stages to higher orbits with orbital lifetime of approximately 2 to 4 years, depending on solar cycle. After PMC, an Assured Crew Return Vehicle (ACRV) will be present; and in the event of a shuttle standdown, the crew could be returned via the ACRV and the station boosted to a higher orbit. These results will be reviewed during the Space Station Program preliminary design review in December.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1990	**Finding 12:** Review of the data from postflight inspections of orbiter windows indicates that frequency of damage to the windows is greater than previously believed.	**Recommendation 12:** NASA should consider incorporating thicker or improved glass to enhance the safety margin of the windows as well as implementation of operational techniques such as pre-selecting on-orbit attitudes and entry angle of attack to minimize exposure to debris or thermal effects.	**NASA Response (in 1990 ASAP appendix):** Review of postflight inspections of orbiter window shows that frequency of damage to windows is well within values predicted by Rockwell at the beginning of the program. Thicker windows have been considered in the past as an improvement that would reduce turnaround time for the orbiter. Though improved glass will undoubtedly improve the thermal pane's ability to withstand impacts by reducing the stress on the pane's surface, there always will be a hypervelocity particle that can penetrate the pane. A redundant thermal pane window design may be feasible to incorporate within the vehicle to provide another layer of protection against the risk associated with a failed thermal pane. Vehicle on-orbit operational attitudes that could minimize exposure to debris have been reviewed, though more work needs to be done. Uncertainties in the analysis data presented to date are greater than the risk reduction a different attitude would give.

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				The probability of a particle large enough to penetrate the thermal pane is very small, about 10 to the minus 4 for a 7-day mission. Thus, the risk is small for continuing to operate without attitude restrictions. The effect on the vehicle during entry for the crack and/or loss of a thermal pane is being studied. Entry profiles that could be flown to minimize thermal stresses on a cracked window and surrounding structure will be evaluated once the damaged window study has been completed. Current mission rules require an orbiter entry at a cabin pressure of 10.2 psi for the loss of a thermal pane, thereby minimizing stresses on the remaining panes and window structure.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1990	**Finding 14:** NASA faces a significant problem with respect to its Space Shuttle computers that has not been addressed: a third generation of computers to replace the new computers to be installed in 1991. While it may seem premature to consider a third generation computer before the second generation has been installed, the rate at which computer technology is advancing compels such a consideration.	**Recommendation 14:** NASA should begin planning now for a process of regular upgrades to the Space Shuttle and the Space Station Freedom computers including, perhaps, a transition to the use of a common underlying computer architecture for the two systems.	**NASA Response (in 1990 ASAP appendix):** NASA concurs with this recommendation for the long term but disagrees that this is a near-term issue. NASA believes that efforts currently underway are sufficient to identify and provide any necessary upgrades to the Space Shuttle and Space Station Freedom computing systems. The new Space Shuttle General Purpose Computer (GPC) is scheduled for its first flight on STS-41 in October 1990. Design work for the new GPC began in January 1984, and the first new computers will be flown in late 1990 or early 1991. The calendar time required to design, test, and certify such a man-rated system practically assures that system to be

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				technologically obsolete for most of its operational life. The expected life of the new GPCs is 15 years. Subsequent major changes to the computer system architecture would require revision of the complete avionics package. NASA believes that any consideration of possible further improvements to the GPCs or to the computer system should be an integral part of the Assured Shuttle Availability (ASA) Program. The Space Station Freedom Program (SSFP) is planning for the upgrading of computers and/or software as improved technology permits. This planning, documented in its highest level program document, the Program Requirements Document (PRD), and in its second level requirements document, the Program Definition and Requirements Document (PDRD), is in two areas. First, the SSFP is planning for mainframe computer hardware and support software replacement every 7 years and workstation replacement every 5 years during the program's operational phase. Second, the program is establishing evolutionary requirements allowing the flexibility to upgrade to advance technology as it becomes available. As a result, requirements for the operational Space Station Information System require a design that isolates applications software (both flight and ground) from the underlying computing system, This promotes the migration of ground hardware and

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				software to the flight systems or from facility to facility, and maximizes flexibility for replacement of flight hardware during the life of the program. Transition to the use of a common computer architecture in both the Space Shuttle and Space Station is not considered feasible due to the differences in the underlying design philosophy of the two systems. The Space Shuttle, although relying on five computers (four primary and one backup), is essentially a centralized system fully integrated with the avionics package. Migrating the Space Shuttle computer architecture to some other design, such as that employed by the Space Station, would require the complete redesign of the avionics system. The Space Station, on the other hand, employs a decentralized system utilizing microcomputing technology as its driving force. Additionally, these systems employ radically different operating systems, programming languages, and are subject to different weight and volume constraints.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1990	**Finding 20:** The desire to eliminate the tumble valve has resulted in carrying a waiver for each flight since STS-27. The tumble valve has been disengaged for a number of flights and this has not resulted in External Tank debris footprints outside acceptable limits.	**Recommendation 20:** The program should either remove the tumble valves in their entirety and eliminate the specification requirement or conduct a process by which waivers are no longer needed for each flight.	**NASA Response (in 1990 ASAP appendix):** In all flights where the tumble valve has been activated, the reentry footprint has remained typical of a tumbling tank and outside the geographical limits of 25 nautical miles from United States landmass and 200 nautical miles from foreign land masses. Mission specific analyses are performed to assure that predicted ET

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				reentry footprints are satisfactory and to establish any risk associated with contingency aborts. The tumble valve will be disabled for missions where the footprint is such that the tumble valve is not required. NASA and DOD Range Safety agree the footprint uncertainties pose no risk to adjacent landmarks. When generic certification of ET entries without an active tumble valve is complete, the tumble valve system will be removed. This generic certification is planned to be completed by the end of FY91 and would enable NASA to eliminate this critical flight hardware from the External Tank.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1990	**Finding 21:** There is clear evidence that many of the problems that hampered launch processing prior to the Challenger accident are being addressed such as excessive overtime, lack of clarity in work instructions, shortage of spare parts, and heavy paperwork burden. However, these pre-Challenger problems have not been totally eliminated.	**Recommendation 21:** NASA and the Shuttle Processing Contractor must work diligently to eliminate deviations and errors that still occur frequently in the processing activities. Communications between the Shuttle Processing Contractor middle management and hands-on technicians must be continually improved.	**NASA Response (in 1990 ASAP appendix):** NASA and the Shuttle Processing Contractor (SPC) realize that to safely process vehicles in support of the planned flight rate, occurrences of worker error must be further reduced. To decrease the likelihood of worker fatigue contributing to processing mistakes, the KSC continues to strictly adhere to the overtime policy outlined in Kennedy Management Instruction (KMI) 1700.2. Over the past year, less than 1 percent overtime exceeded the 60 hour/week criteria outlined in the KMI. In May 1989, NASA/SPC formed a joint Processing Enhancement Team (PET) to reevaluate overall processing procedures. Efforts have focused on three major areas. First, the PET is working to assure that the work task preparation is complete, i.e.,

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				all documentation, people, and parts are available when required. Second, the team is working to guarantee that the right people and equipment are available to resolve processing problems as they occur. And third, the PET has found that to enhance processing, standardization is required of planning and scheduling procedures. These representative steps are aimed at clarifying instructions that each worker must abide by in safely completing his task. Availability of spare parts has improved markedly since return-to-flight. The Line Replacement Unit (LRU) fill rate is roughly 89 percent compared to an average of 80 percent prior to STS-51L. The transition of logistics management responsibility to KSC has greatly improved the support posture. Steps also have been taken in this area by placing commonly used items in the OPF to assure availability to workers. Reduction in the amount of, technician downtime has resulted. The Shuttle Processing and Data Management System II (SPDMS II) is the descriptive title for a computer hardware, software, documentation, and processing system that will provide technical and management information support to shuttle ground processing activities. The project will significantly improve the work control system at KSC by providing faster, more accurate work scheduling, tracking, and approval to support the projected flight rate. Initial phases of this project are now

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				being implemented, with continued incorporation planned over the next 2 years. NASA/SPC believes the steps summarized above will mitigate the potential for processing errors. A system has been set up by the PET whereby workers can communicate their concerns and ideas about the specific processing tasks to appropriate directorate representatives. Managers continue to emphasize that safety will not be compromised to meet launch schedules. NASA/SPC remains committed to continue improving workmanship and strengthening communication channels between managers and hands-on technicians.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1990	**Finding 40:** There is a need to monitor the aging and reliability of components as a function of time in service. Typically, monitoring is accomplished with fleet leader statistics. Unfortunately, as presently employed, fleet leader numbers can be relatively uninformative or even misleading. For example, these data do not permit managers to assess whether the fleet leader is representative of the entire system or simply an outlier.	**Recommendation 40:** Statistics on single fleet leaders should be augmented by simple data that identify the distribution of the entire fleet. For items that have been procured in relatively large numbers, this might be expressed as percentages. For relatively unique items, information on the three or four of the oldest and youngest items might be provided.	**NASA Response (in 1990 ASAP appendix):** NASA agrees. Historically, fleet leader statistics were used almost exclusively; however, this is not the case today. The SSME is the only item using a modified fleet leader concept in that it uses multiple fleet leaders to obtain a more representative sample of the fleet distribution. This minimizes the likelihood of a single fleet leader being an outlier. Use of a single fleet leader is atypical rather than typical. Fleet leader information is supplemented by such techniques and data sources as stress analysis, fracture analysis, qualification test results, life limit tests, and additional inspections of critical hardware. The process is no longer restricted solely to the fleet leader statistics.

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				Initially, the fleet leader is the prime source of data defining the anticipated fleet distribution. However, as additional devices are built, tested and put into operation additional data becomes available to "temper" the initial judgment of the initial fleet distribution. Information is retained at the contractors on each device and these statistics are compared using in-house studies to guide judgment on retention of items and the flight worthiness of them. These data are reviewed prior to each flight and bear heavily on the decisions to retain/reuse items and on the ultimate launch decision.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1989	**Finding 1-A:** Strengthening the role of NASA Headquarters (Level I) and STS program management (Level II), coupled with tighter management and budgetary controls over NASA's R&D Centers (Level III), has clarified responsibilities within the total STS program and strengthened authority and accountability at all levels. Of special importance is the position of Deputy Director (NSTS) for Operations as the focal point of the highly complex shuttle processing and launch activities at the Kennedy Space Center.	**Recommendation A:** It is essential that this more disciplined management structure - characterized by clear lines of authority, responsibility and accountability - continue in place once the launch rate accelerates in order to support NASA's commitment to the operating principle of "Safety first; schedule second."	**NASA Response (in 1989 ASAP appendix):** NASA agrees. The Space Transportation System (STS) management system is reviewed on a continuing basis to ensure that established clear lines of authority, responsibility, and accountability are effectively entrenched to accommodate planned accelerated launch rates. The Management Councils involving the NASA Manned Space Flight Center Directors and the monthly General Management Status Reviews serve to enhance NASA visibility within the STS program and provide assurance of management strengthened authority and accountability at all levels. Primary emphasis continues to be placed on preventing communication breakdown and ensuring that vital information pertinent to the decision-making process is provided to appropriate levels of management in near real-

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				time, In addition, the Deputy Associate Administrator for Systems Assurance, Code QA, is developing an audit/survey process that will be used to assess the acceptability and responsiveness of the SRM&QA efforts in each NASA program, including the National Space Transportation System (NSTS) program. One of the major purposes of this audit/survey process will be to further ensure that clear, effective, efficient lines of authority, responsibility, and accountability are established and remain in place. Efforts to date have concentrated on: analyzing existing policy documents and their flow throughout NASA; and developing a generic, model survey plan that will be the blueprint for conducting a survey of NSTS Level 2 and Level 3 during the first quarter of FY 1990. NASA has no intention of letting the strengthened Level I, II, and III roles degrade. The operating principle of "Safety First, Schedule Second" will continue as NASA policy.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1989	**Finding 1-B:** The Safety, Reliability, Maintainability and Quality Assurance (SRM&QA) function is now stronger, more visible, better staffed and better funded since establishment of the position of the Office of Associate Administrator for SRM&QA which reports directly to the Administrator. The Panel notes that the incumbent,	**Recommendation B:** Across-the-board budget cuts that jeopardize the recently strengthened SRM&QA function must be denied. Funding to maintain essential safety-related documentation of STS systems must be provided.	**NASA Response (in 1989 ASAP appendix):** NASA agrees that problems such as funding cuts that jeopardize the continuing strengthening of the SRM&QA function must be resolved. Across-the-board budget cuts not only have a debasing effect on Safety, but on all areas of NASA. Management realizes that it is necessary to look at the overall NASA program to evaluate the best and most efficient way to administer

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		George Rodney, is a part of the key decision loops and has established the beginnings of an essentially independent "certification" process within NASA. However, there is recent evidence that budgetary pressures within the Shuttle program are causing project directors to propose budget cuts in various SRM&QA activities (e.g., safety documentation associated with the Space Shuttle Main Engine, such as FMEA/CILs and Hazard Analyses, and oversight of major STS projects).		resources. In several areas, prior major efforts have reduced the outstanding work load so that available resources can be channeled elsewhere for best overall results relating to Safety. For example, in the area of Failure Modes and Effects Analysis/Critical Items Lists (FMEA/CILs) and hazard analyses, a major rebaselining of all hazards was undertaken during the hiatus after STS-51L. The rebaselining effort has been completed; hazard and FMEA/CIL evaluations are now needed only when new hazards are discovered or when configuration changes and new development designs are initiated. This is a considerably smaller effort than during the rebaselining effort, where all existing hazards were revisited and reevaluated. While the hazard FMEA/CIL process is and will continue to be proactive, the quantity of analyses will vary based on design changes to the systems, the elements being deployed, and those hazards that are discovered during operation/evaluation periods. Resolution and documentation of problems associated with hazard analyses and FMEA/CIL findings will continue. However, the backlog of problems and, therefore, the effort is decreasing as problems are resolved. To help identify common funding problems within the Safety community, Headquarters Safety Division, Code QS, convenes a

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				Quarterly Center Safety Directors Meeting. This meeting allows the Safety Community to air safety issues that require additional funding and/or personnel. In addition, the Associate Administrator for SRM&QA periodically meets with the SR&QA Directors from the nine NASA Centers. The agenda at these sessions permits open discussion of problems and issues, such as problems created by funding cuts and reallocation of resources. With the insight acquired through this forum, the problems can be addressed at the Headquarters level, and appropriate action can be initiated with cognizant program managers. This facilitates the resolution of impacts created by funding problems and maintains the vitality of a healthy NASA-wide Safety program.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1989	**Finding 1-C:** Management communications, a necessary component in achieving a successful STS program, have improved, both horizontally and vertically within NASA. In particular, the reinstatement of the Management Council, an entity that fosters direct and regular communication among all top STS managers and center directors, has brought a higher level of awareness of common problems and coordinated action to resolve them. This, in turn, has resulted in better informed and effective design certification reviews	**Recommendation C:** As the flight rate increases, greater attention to maintaining these improved communication channels will be required.	**NASA Response (in 1989 ASAP appendix):** NASA agrees with the need to maintain the improved and strengthened management communications channels. NASA fully intends to maintain the higher level of awareness that now exists in the Space Transportation System (STS) program management structure. NASA also plans to continue the Management Council to foster direct and regular communication, and to ensure better informed and effective assessment of STS program concerns and actions as the flight rate increases.

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		(DCRs) and flight readiness reviews (FRRs).		
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1989	**Finding 1-D:** NASA, along with many other Federal agencies, has suffered through more than a decade of hostility directed toward Federal employees and a related failure to maintain salary comparability at the higher management levels. NASA urgently needs greater flexibility and resources in competing for and retaining the skilled personnel who are required to carry forward the Nation's space and aeronautical programs.	**Recommendation D:** Although the salary comparability question will be settled by the Administration and Congress, NASA should speak out clearly about the increasing costs of the present situation and the specific steps that are needed to once again make NASA careers among the most desirable and respected.	**NASA Response (in 1989 ASAP appendix):** NASA agrees that specific steps are needed to make NASA careers among the most desirable and respected. This has been a priority issue within NASA, and various approaches have been implemented to raise and maintain the professional stature of NASA personnel. However, the monetary reward and/or pay structure are legislated external to the Agency. Competing with industry for top talent, especially in high cost of living areas, is a serious problem. Within the Agency, various career development programs that permit career growth have been implemented. Also, job flexibility programs permit personnel to change positions and jobs horizontally within the Agency, as well as vertically, to gain varied background and experiences. This approach provides new and interesting personal challenges and, at the same time, promotes interest and growth. Training and recruitment programs at both professional and nonprofessional levels also continue as a top priority at NASA Headquarters and the Centers. The NASA Quality and Productivity Improvement Programs Office has as a primary responsibility, the function of finding better

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				ways to stimulate productivity and providing methods and programs for rewarding professional achievement. Recognition for performance is an important factor in retaining the skilled work force. In summary, there is a problem in attracting and keeping professional personnel. The salary base commensurate with responsibility, which is legislated external to the Agency, as well as the uncertainty of funding for existing and new space programs have made attracting and keeping top-level managers and engineers a serious problem. This is an Administration and Congressional issue.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1989	**Finding 3:** NASA's decision to procure the Advanced Solid Rocket Motor (ASRM) is based on the premise that the new motor will benefit from advanced solid rocket motor technology and new manufacturing methods and thus would evolve into a safer and more reliable motor than the current redesigned solid rocket motor (RSRM). On the basis of safety and reliability alone it is questionable whether the ASRM would be superior to the RSRM which has undergone extensive design changes until the ASRM has a similar background of testing and flight experience. This may take as long as 10 years from go-ahead. In the interim, the current design is	**Recommendation 3:** The ASAP recommends that NASA review its decision to procure the Advanced Solid Rocket Motor and postpone any action until other alternatives, including consideration of long range objectives for future launch requirements have been thoroughly evaluated.	**NASA Response (in 1989 ASAP appendix):** The NASA decision to procure the ASRM was made after thorough review of the major factors involved, including an assessment of potential alternative courses of action. Several of the more significant considerations that lead to the NASA decision to proceed with the ASRM Program are discussed below. There have been major improvements in the National Space Transportation System (NSTS) as a whole, and in the RSRM in particular, since the STS-51L accident. RSRM joint integrity is much improved, and the degree of field joint and nozzle-to-case joint rotation during motor ignition has been reduced significantly. However, O-ring expansion is still required

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		the current design is expected to have had over 160 additional firings prior to the introduction of the ASRM. Furthermore, it is not evident why the new manufacturing processes planned for the ASRM cannot be applied to the manufacture and assembly of the RSRM. Consequently, it is not clear to the ASAP why NASA is proceeding with its plan to develop a new and expensive solid rocket motor, especially as there are still many elements of the STS system which, if modified or replaced, would add significantly to the safety of the operation. Furthermore, NASA has not thoroughly evaluated other alternative choices to the ASRM such as liquid rocket boosters.		to preclude hot gas leakage. [The ASAP report (page 4) notes the need to develop a resilient O-ring material for primary and secondary seals to eliminate the required (RSRM) field joint heaters.] The RSRM factory joints do not meet the redundant, verifiable seal design criterion, due to joint rotation. Every feasible precaution, short of complete redesign, has been taken to ensure that all RSRM joints will function as intended, and NASA has high confidence in RSRM joint integrity. However, the RSRM joint designs are not the best concepts now available, and are not optimally tolerant of off-nominal conditions or unanticipated combinations of events. RSRM joint integrity thus remains a concern for the long term. The Advanced Solid Rocket Motor (ASRM) provides a positive solution to joint integrity by incorporation of welded factory joints and mechanical field joints that close upon motor pressurization. The mechanical joint closure criterion applies to & joints (igniter to case, segment to segment, and nozzle to case). The redesign of joints to use face seals rather than bore seals minimizes assembly damage potential and permits visual seal inspection until the final mating. Joint heaters, and their attendant failure modes, are eliminated. Furthermore, it is anticipated that insulation design improvements will further reduce potential debonds

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				and/or leakage paths. Another ASRM design criterion leads to obviation of the Space Shuttle Main Engine (SSME) "throttle bucket" during the maximum dynamic pressure regime with the attendant elimination or reduction of about 175 Criticality l/lR failure modes for the STS. Information gained from actual flight experience has been show-n that the safety factors for water impact loads, internal insulation, and nozzle erosion on the current motors are lower than the original design criteria; these deficiencies are to be rectified in the ASRM. Due to ASRM design innovations, it is anticipated that, relative to the RSRM, Criticality 1 failure modes will be reduced by approximately 30 percent, failure causes will be reduced by approximately 25 percent, and failure points will be reduced by approximately 30 percent. Flight reliability is as dependent upon the method of manufacturing as it is upon design. The current motor manufacturing is highly labor intensive, and historical contractor data indicate that 40 to 50 percent of the encountered defects are workmanship faults. Furthermore, workmanship faults are prevalent in the entire family of solid rocket motor (SRM) failures. These findings led to the conclusion that ASRM should be designed for the prudent automation of manufacturing

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				processes to minimize defects and maximize reproducibility. Short of a major redesign, which would be tantamount to a noncompetitive ASRM procurement, the RSRM will never achieve the aforementioned flight safety and reliability enhancements. Moreover, the ASRM significantly enhances industrial, environmental, and public safety. The ASRM will eliminate all asbestos-bearing insulation and other material applications in favor of equally effective materials that are noncarcinogenic. The manufacturing automation will minimize the exposure of the work force to hazardous operations; and the new production and test facilities will incorporate features for environmental protection in anticipation of ever increasing stringency in environmental constraints. (lots more omitted)
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1989	**Finding 5-E:** As the flight schedule picks up in FY 1989, there remains the clear and present danger of slipping back into the operating environment at KSC that helped to contribute to the Challenger accident. At the same time, the need to achieve greater efficiency and cost-effectiveness in turnaround procedures is clear. In this situation, NASA's commitment to the operating principle of "Safety first; schedule second" must be retained. If experience of the past is a guide to the future,	**Recommendation 5-E:** NASA must resist the schedule pressures that can compromise safety during launch operations. This requires strong enforcement by NASA of the directives governing STS operations.	**NASA Response (in 1989 ASAP appendix):** NASA and our contractors recognize the complex problem of increasing launch site efficiency while resisting schedule pressures that may compromise safety. Some of the specific actions that Kennedy Space Center has taken include: review of problems caused by human-induced error to ascertain whether additional training, job reassignment, or procedure change is required; and constant review of areas of high overtime/stress for schedule change and reassignment of personnel. In

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		the pressures to maintain or increase flight rate will be intense.		addition, NASA has established formalized training programs designed to reduce the potential for human error. The schedule and scheduling process are constantly reviewed and updated, as necessary, to ensure that all formal protocols are completed regardless of the affect on ability to launch on a specific date. NASA management from the top level through the first-line supervisor exercises constant vigilance to ensure that satisfactory working schedules and environments are maintained at all times in accordance with the operating principle, "Safety First, Schedule Second." NASA continues to closely monitor workload imposed by the baselined STS flight rate. Manpower levels currently budgeted to support the STS flight schedule have been sized to assure that the processing workload can continue to be accomplished in a safe manner. Both staffing and overtime data continue to be reviewed by top management on a weekly basis to assure rigorous adherence to the overtime policy in Kennedy Management Instruction (KMI) 1700.2.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1989	**Finding D-1:** In 1988 NASA issued several NMIs and NHBs that provide policies and direction designed to improve the identification, evaluation	**Recommendation D-1:** The risk management policies and initial implementing methodologies which have been issued in 1988 need to be evolved further. Practical quantitative risk assessment and	**NASA Response (in 1989 ASAP appendix):** The risk management function is evolving. NASA is vigorously refining the NASA Management Instructions (NMIs) and NASA

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		and disposition of safety risks. In particular, NM1 8070.4 titled "Risk Management policy for Manned Flight Programs" calls for a risk management process that includes categorization and prioritization of "risks" using qualitative techniques for ratings of the frequency expectation and severity of the potential mishaps. The documents also provide for use of quantitative risk analysis to provide a more definitive ordering of risks for purposes of risk management.	other relative risk-level rating techniques should be actually developed. They should then be applied to help define the risk levels of flight and ground systems. enhancing changes, and, if so, define these changes.	Handbooks (NHBs) to reflect the latest risk management policy developments. Independent risk assessments are being performed on Galileo and Ulysses payloads utilizing updated risk management methodology. This risk methodology includes the development of credible accident scenarios derived from initiating events that could cause potential mishaps. It incorporates both qualitative and quantitative system response analyses of initiating events induced by hardware or software anomalies malfunction(s), human error, environmental influences, or probable combinations of these factors. Also, the risk assessment methods are being restructured as further development and state-of-the-art knowledge are gained from ongoing risk assessment activities arena. Practical quantitative risk methods and risk-level techniques are being matured by NASA in structured workshop sessions and supporting policies with a view toward incorporation into the risk management efforts in the National Space Transportation System (NSTS), space station, and payload areas.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1989	**Finding D-2:** The Panel has found strong commitment by each of the Center Director Offices to the rebuilding of the System Safety Functions in NASA. They have provided valuable guidance, encouragement and some level of financial support to the difficult restructuring, staffing and new policy	**Recommendation D-2:** In addition to continuing their good work we believe that additional vigorous assistance is required on the part of each Center Director's Office to assure the allocation of resources that are necessary so that the promising progress toward a truly effective Systems Safety capability does not falter and wither away after a few successful STS flights.	**NASA Response (in 1989 ASAP appendix):** NASA strongly agrees that a key element to the successful implementation of a NASA-wide Safety Program is the committed support of the Center Directors who must continue to be the champions of safety engineering. To ensure that progress made at the Centers is maintained, the Office of the Associate

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		implementation activities at their respective Centers. We are concerned that program resource cuts may be beginning to erode the progress which has been made.	The Center Directors must be seen as major champions of safety engineering within NASA.	Administrator for SRM&QA, Code Q, has initiated the following efforts: (list omitted)
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1989	**Finding D-3:** At JSC there is a clear commitment from the Director's level down to implementing the general policies and requirements of NM1 8070.4, and to improving techniques for risk assessment and risk mitigation. We observed that the SRM&QA organization is still not completely staffed. The organization has assembled hazard information that is used in the decisions of whether or not to fly. Whether this same information can be used to identify safety enhancing changes has yet to be examined.	**Recommendation D-3:** Examine the collected data to see if it can be used to identify safety enhancing changes, and, if so, define these changes.	**NASA Response (in 1989 ASAP appendix):** The review process for National Safety Transportation System (NSTS) safety issues and associated hazard reports, conducted by the System Safety Review Panel (SSRP) and the Levels I and II Program Requirements Control Board (PRCB), results in thorough review of the safety problems involved. As part of this process, recommended changes required for hazard mitigation and/or control are actions levied on the responsible NSTS element(s). Detailed responses and presentations are made to the review boards up to the Level I PRCB, which is chaired by the NSTS Program Director. Therefore, identifying and recommending safety-enhancing changes in response to identified hazards are integral parts of the hazard review process at levels up to and including NASA Headquarters. These changes include: revisions/changes/additions (to Flight Rules and Launch Commit Criteria); improvements in manufacturing, inspection, test, and quality control procedures; and design changes to mitigate or reduce the risk involved (subject to budgetary review and approval by the NSTS

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				Program Director).
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1989	**Finding D-4:** At JSC the ASAP was presented a new approach to hazard rebaselining and rating, and a new format for the Mission Safety Assessment report &ISA). The new report is basically a set of evaluated fault trees which identify the potential system mishaps which might result from various hardware or human faults. For STS-26, 25 “significant risk” mishaps were “selected” for evaluation. All items selected had worst-case severity levels of “loss of crew and/or vehicle.” All items were also rated as “unlikely,” which was the lowest probability rating used in the hazard rating matrix. Thus, the MSA did not address even the relative risk-levels of the selected potential mishaps. However, the system safety organization did color-code various faults - red, which designates that Improvement is Highly Desirable (IHD). Because all of the items elected for inclusion in the MSA are rated as unlikely to occur and therefore “safe to fly,” there remain a large number of undifferentiated items designated MD.	**Recommendation D-4:** The ambiguity regarding risk levels implied by the red color-coded MSA needs to be removed. NASA needs to provide a much more objective (quantitative) and data- based risk assessment methodology that will differentiate the “unlikely” events for purposes of assessing the principal contributors to risk on STS and Space Station type programs.	**NASA Response (in 1989 ASAP appendix):** The Mission Safety Assessment (MSA) focuses in more detail on risks considered issues for the current and subsequent launches. Since the ASAP visit, the MSA has been reevaluated and is now considered a program baseline safety assessment to be updated periodically, not mission specific. It is derived from the approved Hazard Report (HR) set, which forms the program baseline safety risk. Renaming of the document is under consideration and the safety community is developing a replacement document that will be mission-specific and unique, the final title of which is not yet determined. It will provide visibility to top management of significant changes or potential significant changes to the baseline safety risk. It will indicate launch constraints and resolved safety risk factors. Basic requirements for the mission-unique safety risk assessment report need to be changed, and changes to the requirements are being pursued. The requirement for the MSA to be published 30 days prior to a launch is unrealistic as some safety risk data probably will not be achieved in time for consideration in the report as happened on STS-26. It is expected that the new requirement for safety risk assessments will be keyed to milestones such as the Flight

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				Readiness Review (FRR) and the L-2 Day Review, and it will have a format that will permit rapid, last-minute updates. All risks in the STS-26 were considered "unlikely," but were also more significant than others that had been received at the time of publication. Several HRs were subsequently submitted with a probability of occurrence of "likely," and they have been incorporated in subsequent MSA editions. All the events had the potential of being catastrophic events. The fault-tree approach presents these basic and conditional events. From this analysis, the MSA evaluated the hazard controls in the design and procedural area (i.e., redundancy, safety factors, launch commit criteria) for possible improvement to further mitigate the risk. The MSA used a qualitative approach to assessing the relative levels of risk. The NSTS safety community is considering changes to the three-level probability of occurrence to provide greater differentiation. Also, future editions 'of the MSA will use the results of probabilistic risk assessments, when available, to help define the relative level of risk for prioritization. NASA's effort to identify and quantify risk contributors has proceeded with several different approaches: probabilistic risk assessment (PRAs), individual statistical analyses, and prioritization of Failure Modes and Effects

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				Analysis/Critical Items List (FMFA/CIL) items (system/component coupled with a Criticality 1 failure mode). Relative to the PRA effort, a risk assessment for the Galileo mission [which uses a radioisotope thermoelectric generator (RTG) power source] was conducted. The assessment focused on events leading to breech of the RTG case. Shuttle element risks and individual risk contributors were developed using fault trees, random failure distribution approximations, and Bayesian techniques. However, none of the above efforts obviate the need for detailed, accurate, and easily accessible data bases containing test and flight failure data. The current Program Compliance Assessment Status System (PCASS) data base contains problem reports on component failures. For analysis purposes, data fields containing the specific FMEA failure mode need to be included to facilitate initial analyses; such an effort is now under consideration. A space station requirement document for a failure history data base is being developed. Apart from individual assessments and development of data bases, a more quantitative approach for identifying and assessing principal risk contributors has been explored using the current hazard analyses as a foundation. In this approach, detailed causes and scenario paths leading to damage states are developed. Likelihoods ascribed to the scenario nodes

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				and, in turn, probabilities are approximated for each potential path and damage state. Examples using auxiliary power unit hazards have been developed. This approach is being evaluated as a quantitative enhancement for hazard assessment.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1989	**Finding D-5:** Functional areas such as system-safety engineering at the Centers appear not to have received the resource support necessary to fulfill their responsibilities. The SRM&QA organizations at the centers appear to be relatively loosely coupled to Headquarters.	**Recommendation D-5:** The various systems safety organizations throughout NASA should get stronger assistance from Headquarters especially regarding financial support.	**NASA Response (in 1989 ASAP appendix):** NASA agrees that Center SRM&QA organizations should continue to receive strong support from Headquarters. During fiscal year (FY) 1989, 50 percent of the Headquarters SRM&QA budget is being transferred directly to the Centers. In FY 1990, we plan to increase this to 70 percent. Since January 1986, we have been able to increase the number of civil service and Jet Propulsion Laboratory personnel directly assigned to SRM&QA functions by approximately 39 percent. During that same period, the number of support contractor personnel performing SRM&QA functions has increased by nearly 95 percent. These statistics verify that the Centers have a strong and eloquent voice in Headquarters. As a consequence, NASA feels that within the context of existing Federal Budget constraints, the Center SRM&QA organizations have been well supported. Center SRM&QA organizations report and are directly responsible to the Center Directors. The Office of SRM&QA functions in a senior staff capacity at Headquarters providing a

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				focal point for NASA-wide SRM&QA activities, programmatic direction, policy formulation, and resources support. The link between Headquarters and field SRMLQA operations is sufficiently strong to provide proactive and vigorous SRM&QA program management.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1989	**Finding D-6:** At MSFC the ASAP found an excellent SRM&QA organizational structure and good progress in staffing it with experienced engineering personnel. As other centers have done, they have engaged the services of two contractors to aid in developing the analysis techniques for practical, more quantitative risk assessment.	**Recommendation D-6:** MSFC is to be commended for their progress in evolving its SR&QA function and these efforts should receive continuing high-level support.	**NASA Response (in 1989 ASAP appendix):** The achievements of the Safety, Reliability, Maintainability, and Quality Assurance (SRM&QA) organization at Marshall Space Flight Center (MSFC) are recognized and applauded. Also noteworthy is MSFC taking the lead in establishing the management and engineering requirements for Maintainability, which is a relatively new key discipline within the Agency. MSFC and the other Center SRM&QA organizations will continue to receive the high-level support required to ensure their continued viability as effective spokespersons for System Safety, Reliability, Maintainability, and Quality Assurance.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1988	**Finding A-1-a:** NASA has responded positively to ASAP's recommendations and those of the Presidential Commission dealing with reorganization of NASA and the National Space Transportation System, including the reestablishment of an independent safety, reliability, maintainability, and quality assurance function.	**Recommendation A-1-a:** 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.	**NASA Response (in 1988 ASAP appendix):** 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

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				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.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1988	**Finding A-1-b:** 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.	**Recommendation A-1-b:** 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.	**NASA Response (in 1988 ASAP appendix):** 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,

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				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.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1988	**Finding A-1-c:** 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.	**Recommendation A-1-c:** 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.	**NASA Response (in 1988 ASAP appendix):** 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

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				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 (ELVs). In addition, some 20 DOD payloads have been off-loaded from the shuttle to ELVIS. 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.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1988	**Finding A-1-d:** The reevaluation and recertification of all hardware and software systems on the STS, has produced an extremely heavy work load related to launch processing including more paperwork, many modifications to existing systems, and a greatly expanded test program.	**Recommendation A-1-d:** 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.	**NASA Response (in 1988 ASAP appendix):** 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 work-force. NASA, the Shuttle Processing Contractor (SPC), and element contractor management periodically review these programs to

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				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.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1988	**Finding A-2:** NASA and the STS contractors have been redoing the FMEAs, CILs 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	**Recommendation A-2:** (1) NASA should take steps to establish uniform methodology for conducting FMEA/CIL/Hazard Analyses for the agency as a whole. (2) In addition to the above, NASA should develop and implement a consistent method of prioritization of items in the CIL so that appropriate attention can be given to the greater risks. (3) Data developed from the FMEA/CIL/Hazard Analysis process should be organized in such a fashion that it provides the deciding authority with information permitting him or her to assess the risk and make	**NASA Response (in 1988 ASAP appendix):** (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

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		designs that had changes incorporated or planned. One result of the rework is that the number of Criticality 1I 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.	her to assess the risk and make informed decisions.	preparation, maintenance, and publication of the FMEA/CIL/HAs. 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

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				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.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1988	**Finding A-3-c:** 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 OMRSDIFMEAICIL matrix has been generated to help ensure that a focus is kept on all critical items in every step of the processing procedure. One of the short comings in the procedures prior to the 51-L accident was the lack of traceability of OMRSD requirements to the operations and maintenance instructions (OMI). An operations and maintenance plan (OMP) is now in use to provide this traceability. A closed-loop requirements accounting system is expected to be in place for STS-26R. This will be a partially manual system for STS-26R but is expected to be fully automated by February 1989.	**Recommendation A-3-c:** 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.	**NASA Response (in 1988 ASAP appendix):** 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, OMIs 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.

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Aerospace Safety Advisory Panel *(NASA Charter)*	March 1988	**Finding A-3-d:** 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.	**Recommendation A-3-d:** Clear, unambiguous distinctions should be made in the Launch Commit Criteria between "redlines" and other parameters monitored during launch operations.	**NASA Response (in 1988 ASAP appendix):** 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.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1988	**Finding B-1-a:** 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	**Recommendation B-1-a:** Official direction, through an appropriate document(s), should be provided to all programs/projects on the decision process for risk decisions. Without such direction for each specific program/project, risk decisions will not be made with a commonly understood and agreed-upon definition of the factors pertinent to the decision. The AA/SRM&QA should ensure that implementation of directed SRM&QA activities are conducted in an orderly,	**NASA Response (in 1988 ASAP appendix):** The risk management NMIs and NHBs, 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

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		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.	thorough and timely manner to support the various milestones set by program/project offices.	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 NMIs and the NHBS, 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.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1988	**Finding B-1-b:** 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.	**Recommendation B-1b:** Because there is danger of complacency setting in, it is recommended that NASA review and audit the safety assessment process implementation on a periodic basis. Particular emphasis should be placed on the quality of the information reaching decision-makers. A regular review of the process will help managers discriminate between meaningful changes in system safety and unanticipated	**NASA Response (in 1988 ASAP appendix):** 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

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			alterations in the reporting process.	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

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				groups, facility groups, or individuals who have demonstrated superior safety performance.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1988	**Finding B-1-c:** 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.	**Recommendation B-1c:** The ASAP recommends that (I) 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).	**NASA Response (in 1988 ASAP appendix):** (1) NM1 8070.4, "Risk Management Policy for Manned Flight Programs," was promulgated on February 3, 1988. NMIs are also in draft and under review on risk management for unmanned programs and for research and technical facilities. These NMIs will identify, in general terms, the roles of qualitative and quantitative risk assessment in support of risk disposition decision-making. The NMIs 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 NMIs. 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

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				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.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1988	**Finding B-1-d:** 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 B-1-d:** More emphasis should be placed on the study of potential design-induced human errors.	**NASA Response (in 1988 ASAP appendix):** 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

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				multiplicity of discipline products and interfaces generated within the highly-matrixed SRM&QA organizational functions through selected staff assistance surveys.
Aerospace Safety Advisory Panel *(NASA Charter)*	March 1988	**Finding 5-a:** 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.	**Recommendation 5-a:** 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.	**NASA Response (in 1988 ASAP appendix):** 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

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				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.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1987	**Finding General-1:** The Panel finds the recent reorganization of Space Shuttle management to be a positive step in recapturing or rebuilding a spirit of mutual respect and trust at all levels. The Panel recommends that: a priority objective of the new management team must be to enforce NASA's management instructions and to define clearly the responsibilities and authority of the NASA centers; a willingness of all NASA centers to pull together, to subordinate parochial interests, and to help each other is absolutely crucial if the Space Shuttle program is to succeed.		**NASA Response (in 1987 ASAP appendix):** We agree. In the Phillips' study, the Crippen report, and in the reorganization of the shuttle management, we have addressed the roles and responsibilities of all levels of management to specify the relationship between the various program offices and centers. NASA Management Instructions (NMIs), Program Approval Documents (PADS) and supporting policies are being reviewed to clearly define the responsibilities and authority of the centers. The elevation of direct control of the program to Headquarters establishes a programmatic chain that is independent of the NASA center organizations. However, the center directors are responsible and accountable for the technical excellence and performance of each of the National Space Transportation System (NSTS) project elements at their respective centers. Further, the center directors will ensure that their institution provides the required support to the NSTS program. In addition, the center directors, along with the Associate Administrator,

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				Office of Space Flight (CSF) are working together as members of the OSF Management Council which meets on a scheduled basis to oversee all CSF responsibilities and provide an independent review and assessment of the NSTS program.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1987	**Finding General-2:** The Panel finds that NASA and the Congress need to appreciate that the Space Shuttle is a system which remains primarily developmental with some operational characteristics. It is recommended that NASA needs to emphasize the developmental characteristic or it is likely to miss key elements of the Space Transportation System management challenge.		**NASA Response (in 1987 ASAP appendix):** In the detailed program assessment conducted after the 51-L accident, it has become evident to the top management within NASA that much of NSTS is still in the developmental stage and significant areas of the system will probably remain essentially developmental throughout the life of the program. We agree with the Panel that there is a need to emphasize the development characteristics in order to provide required management oversight and operational awareness. Also, it will be the duty of NASA to work closely with the Congress to come to a mutual understanding of the developmental stage of the system. This will be a critical task to get budget approval in areas of continued development. We seek assistance from ASAP to emphasize in their interface with the members of Congress and their staff the developmental nature of the shuttle system. NASA has already taken steps to strengthen its development effort on the shuttle program. In the critical main engine program, the single engine test rate has been substantially increased. The new plan calls for an average of 12 tests per

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				month through February 1988, and 10 tests per month through the mid-1990's. This is an increase over the previous plan of eight tests per month through mid-1990 and six tests per month through the mid-1990s. In the Solid Rocket Motor (SRM) program, it is planned to continue full scale firings of production motors at the rate of one to two per year following final qualification firings. These firings will be used to verify maintenance of critical processes, establish life of reusable components, and qualify any design changes. Another example is in the flight software area where a Level II Software Change Control Board has been set up. This board, made up of high level experts, reviews each proposed software change, determines impact, and approves or disapproves the change.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1987	**Finding General-8:** The Panel recommends that NASA top management should address the growing problem of recruiting and retaining talented engineers and managers due to inadequate Federal salaries. This is not just a Space Shuttle problem.		**NASA Response (in 1987 ASAP appendix):** We agree with this recommendation. NASA has traditionally relied on its highly visible mission, work environment, and career advancement opportunities to attract high-caliber scientists and engineers. However, in the past several years, 70 percent of all graduating entry-level engineers have declined NASA engineering job offers. The reason most often given for not accepting these job offers is inadequate salaries and/or benefits. Entry level technical salaries continue to be significantly less in the Federal sector than in private industry. NASA's most recent experiences show

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				that quality scientists and engineers with bachelor's degrees are accepting entry offers in private industry of $26,000 - $29,000; and some exceptional graduates with master's degrees, offers of $30,000 - $34,000. Under the Federal system, NASA can only offer $23,866 and $28,347, respectively. The Personnel Programs Division, Code NP, has been and will continue to document all data reflecting national recruitment trends and situations, Such data, including specific NASA recruitment and turnover data was recently presented to CMB. NASA management will continue to take every opportunity to give testimony to Congress, CMB, and OPM and to support needed changes to the Federal personnel system. Additionally, Code NP in conjunction with field installation personnel offices has initiated and developed a new personnel concept. This concept, centering around a new pay and compensation package, has the NASA Administrator's support. This new personnel system is needed to strengthen NASA's recruitment and retention posture with private industry, as well as to improve the overall quality of the NASA working environment. In expressing its concern regarding the salary structure for technical persons within NASA, the ASAP Report stated that: "It appears that in order to progress in terms of salary, people must move into

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				management ranks, making it difficult to keep experienced, highly qualified people in the technical ranks (p.58-91." We do not agree with this statement. In fact, the opposite is true. NASA employs approximately 6,500 E-13, 14, and 15 level non-managerial technologists compared to 3,000 management officials at the same grade levels.) It is at these grade levels where the preponderance of technical expertise is found within NASA and where Federal salaries are generally comparable to those in the private sector.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1987	**Finding General-9:** The Panel, in an independent review, concurs with the National Research Council (NRC) Panel conclusions on Space Shuttle Flight Rates and Utilization, that is, an upper limit of 8-10 flights per year with a three Orbiter fleet and 11-13 with a four Orbiter fleet. Further, the Panel recommends that the Space Shuttle be used only where manned missions are deemed mandatory, and expendable launch vehicles should be used for all other missions.		**NASA Response (in 1987 ASAP appendix):** In general, the flight rates projected by NASA are consistent with the conclusions of the NRC Panel. Their four orbiter flight rate of about 12 flights per year was characterized as a reasonable expected sustainable level. The rationale was that four flights per year can be achieved by each orbiter, but that only three of the four orbiters can be relied upon to be available on a continuing basis, due to unexpected problems and related maintenance and inspection requirements. The NRC also concluded that the space shuttle should have the capacity to surge above this sustainable level for short periods of time. NASA's current planning is based on a gradual buildup to 11 flights per year in the first four years after operations resume, with a later increase to 13 or 14 when the replacement orbiter joins the fleet. The actual flight rates will be adjusted on the basis of operational

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				experience, with appropriate contingency allowances in the shuttle processing schedules to minimize the buildup of launch pressure. For greater assurance of access to space and to reduce the demands on the shuttle for payloads that do not require its unique capabilities, Dr. Fletcher directed Admiral Truly, Associate Administrator for Space Flight, to conduct a NASA-wide study of a mixed fleet strategy, using expendable launch vehicles to augment the shuttle. The study recommended that Delta, Atlas, and Titan class vehicles be utilized for those payloads that could be launched on ELVs (about 25 percent of the NASA payloads). It also recommended that for the period beyond 1992, NASA, with the DOD, should develop a heavy lift launch vehicle capability to meet the needs of this Nation. Implementation plans for both recommendations are being developed as part of the ongoing NASA planning and budgeting process.
Aerospace Safety Advisory Panel *(NASA Charter)*	February 1987	**Finding Safety-1:** The Panel finds that three fundamental weaknesses appear evident. First, there has been a lack of in-line responsibility and authority in the Headquarters organization for establishing policy for the safety engineering function throughout NASA. Second, the elements of the safety functions that have been accomplished at various locations did not include responsibility for defining	**Recommendation Safety-1:** Within the newly established Safety, Reliability, Maintainability and Quality Assurance (SRM&QA) organization, NASA should develop the operating policy for all NASA SRM&QA and have the authority to ensure implementation. At each Center there should be a NASA Safety Engineering function reporting to the Center Director. This function should be matrixed into the various programs/projects and should be responsible for implementation of safety	**NASA Response (in 1987 ASAP appendix):** NASA has significantly strengthened the SRM&QA function both at headquarters and at the field centers. The Associate Administrator for SRM&QA reports directly to the Administrator and is responsible for developing operating policy for the NASA SRM&QA functions throughout NASA. He has the authority to ensure implementation of these policies. Each of the flight centers has a SRM&QA Director who reports directly

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		and controlling the validation and certification programs. Third, there is a conscious lack of quantitative approaches to determine failure-mode probabilities for the purposes of defining acceptable margins, and the relative likelihood of resulting system interactive hazards.	policies established by the Headquarters organization. NASA should continue to independently review all payload components with regard to their individual inherent safety, and should analyze the safety implications of the potential interactions of payloads in the event of a malfunction of any individual one.	to the center director. There is a safety engineering function within the center SRM&QA Director's organization. It is our intent to matrix SRM&QA personnel to their line organization for overview and oversight purposes. SRM&QA responsibilities within the programs will reside with the line organizations and they will have their own personnel to accomplish the safety engineering functions within the program/project. Additional personnel may be matrixed between program projects for this purpose to assure full compliance with SRM&QA objectives.
Rogers Commission *(Presidential Charter)*	6 June 1986		**Recommendation I – Design**: The faulty Solid Rocket Motor joint and seal must be changed. This could be a new design eliminating the joint or a redesign of the current joint and seal. No design options should be prematurely precluded because of schedule, cost or reliance on existing hardware.	**Original Response (Fletcher, 14 July 1986):** On March 24, 1986, the Marshall Space Flight Center (MSFC) was directed to form a Solid Rocket Motor (SRM) joint redesign team to include participation from MSFC and other NASA centers as well as individuals from outside NASA. The team includes personnel from Johnson Space Center, Kennedy Space Center, Langley Research Center, industry, and the Astronaut Office. To assist the redesign team, an expert advisory panel was appointed which includes 12 people with six coming from outside NASA. **Ultimate Result:** The result was the Redesigned Solid Rocket Motor (RSRM), later renamed the Reusable Solid Rocket Motor.

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Rogers Commission *(Presidential Charter)*	6 June 1986		**Recommendation I – Independent Oversight**: The Administrator of NASA should request the National Research Council to form an independent Solid Rocket Motor design oversight committee to implement the Commission's design recommendations and oversee the design effort.	**Original Response (Fletcher, 14 July 1986):** In accordance with the Commission's recommendation, the National Research Council (NRC) has established an Independent Oversight Group chaired by Dr. H. Guyford Stever and reporting to the NASA Administrator. The NRC Oversight Group has been briefed on Shuttle system requirements, implementation, and control; Solid Rocket Motor background; and candidate modifications. The group has established a near-term plan that includes briefings and visits to review in- flight loads; assembly processing; redesign status; and other solid rocket motor designs, including the Titan. Longer term plans are being formulated by the group including participation in the Solid Rocket Motor preliminary design review in September 1986.
Rogers Commission *(Presidential Charter)*	6 June 1986		**Recommendation II – Shuttle Management Structure**: The Shuttle Program Structure should be reviewed. The project managers for the various elements of the Shuttle program felt more accountable to their center management than to the Shuttle program organization. Shuttle element funding, work package definition, and vital program information frequently bypass the National STS (Shuttle) Program Manager. A redefinition of the Program Manager's responsibility is essential. This redefinition should give the Program Manager the requisite authority for all ongoing STS operations. Program funding and all Shuttle	**Original Response (Fletcher, 14 July 1986):** The Administrator has appointed General Sam Phillips, who served as Apollo Program Director, to study every aspect of how NASA manages its programs, including relationships between various field centers and NASA Headquarters. General Phillips has broad authority from the Administrator to explore every aspect of NASA organization, management and procedures. His activities will include a review of the Space Shuttle Office of Safety, Reliability, and Quality Assurance, and to the

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			Program work at the centers should be placed clearly under the Program Manager's authority.	existing Aerospace Safety Advisory Panel. On June 25, 1986, Astronaut Robert Crippen was directed to form a fact-finding group to assess the Space Shuttle management structure. The group will report recommendations to the Associate Administrator for Space Flight by August 15, 1986. Specifically, this group will address the roles and responsibilities of the Space Shuttle Program Manager to assure that the position has the authority commensurate with its responsibilities. In addition, roles and responsibilities at all levels of program management will be reviewed to specify the relationship between the program organization and the field center organizations. The results of this study will be reviewed with General Phillips and the Administrator with a decision on implementation of the recommendations by October 1, 1986.
Rogers Commission *(Presidential Charter)*	6 June 1986		**Recommendation II – Astronauts in Management**: The Commission observes that there appears to be a departure from the philosophy of the 1960s and 1970s relating to the use of astronauts in management positions. These individuals brought to their positions flight experience and a keen appreciation of operations and flight safety.	**Original Response (Fletcher, 14 July 1986):** Rear Admiral Richard Truly, a former astronaut, has been appointed as Associate Administrator for the Office of Space Flight. Several active astronauts are currently serving in management positions in the agency. The Crippen group will address means to stimulate the transition of astronauts into other management positions. It will also determine the appropriate position for the Flight Crew Operations Directorate within the NASA organizational structure.

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Rogers Commission *(Presidential Charter)*	6 June 1986		**Recommendation II – Shuttle Safety Panel:** NASA should establish an STS Safety Advisory Panel reporting to the STS Program Manager. The Charter of this panel should include Shuttle operational issues, launch commit criteria, flight rules, flight readiness and risk management. The panel should include representation from the safety organization, mission operations, and the astronaut office.	**Original Response (Fletcher, 14 July 1986):** A Shuttle Safety Panel will be established by the Associate Administrator for Space Flight not later than September 1, 1986, with direct access to the Space Shuttle Program Manager. This date allows time to determine the structure and function of this panel, including an assessment of its relationship to the newly formed Office of Safety, Reliability, and Quality Assurance, and to the existing Aerospace Safety Advisory Panel.
Rogers Commission *(Presidential Charter)*	6 June 1986		**Recommendation III – Criticality Review and Hazard Analysis**: NASA and the primary Shuttle contractors should review all Criticality 1, 1R, 2, and 2R items and hazard analyses. This review should identify those items that must be improved prior to flight to ensure mission safety. An Audit Panel, appointed by the National Research Council, should verify the adequacy of the effort and report directly to the Administrator of NASA.	**Original Response (Fletcher, 14 July 1986):** On March 13, 1986, NASA initiated a complete review of a1 Space Shuttle program failure modes and effects analyses (FMEAs) and associated critical item lists (CILs). Each Space Shuttle project element and associated prime contractor is conducting separate comprehensive reviews which will culminate in a program-wide review with the Space Shuttle Program Manager at Johnson Space Center later this year. Technical specialists from outside the Space Shuttle program have been assigned as formal members of each of these review teams. AI1 Criticality 1 and 1R critical item waivers have been cancelled. The teams are required to reassess and resubmit waivers in categories recommended for continued program applicability. Items which cannot be revalidated will be redesigned, qualified, and certified for flight. All Criticality 2 and 3 CILs are

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				being reviewed for proper categorization. This activity will culminate in a comprehensive final review with NASA Headquarters beginning in March 1987. As recommended by the Commission, the National Research Council has agreed to form an Independent Audit Panel, reporting to the NASA Administrator, to verify the adequacy of this effort.
Rogers Commission *(Presidential Charter)*	6 June 1986		**Recommendation IV – Safety Organization**: NASA should establish an Office of Safety, Reliability and Quality Assurance to be headed by an Associate administrator, reporting directly to the NASA Administrator. It would have direct authority for safety, reliability, and quality assurance throughout the agency. The office should be assigned the work force to ensure adequate oversight of its functions and should be independent of other NASA functional and program responsibilities.	**Original Response (Fletcher, 14 July 1986):** The NASA Administrator announced the appointment of Mr. George A. Rodney to the position of Associate Administrator for Safety, Reliability, and Quality Assurance on July 8, 1986. The responsibilities of this office will include the oversight of safety, reliability, and quality assurance functions related to all NASA activities and programs and the implementation of a system for anomaly documentation and resolution to include a trend analysis program. One of the first activities to be undertaken by the new Associate Administrator will be an assessment of the resources including workforce required to ensure ad- equate execution of the safety organization functions. In addition, the new Associate Administrator will assure appropriate interfaces between the functions of the new safety organization and the Shuttle Safety Panel which will be established.

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Rogers Commission *(Presidential Charter)*	6 June 1986		**Recommendation V – Improved Communications**: The Commission found that Marshall Space Flight Center project managers, because of a tendency at Marshall to management isolation, failed to provide full and timely information bearing on the safety of flight 51-L to other vital elements of Shuttle program management.	**Original Response (Fletcher, 14 July 1986):** On June 25, 1986, Astronaut Robert Crippen was directed to form a team to develop plans and recommended policies for the following: 1. Implementation of effective management communications at all levels. 2. Standardization of the imposition and removal of STS launch constraints and other operational constraints. 3. Conduct of Flight Readiness Review and Mission Management Team meetings, including requirements for documentation and flight crew participation. Since this recommendation is closely linked with the recommendation on Shuttle management structure, the study team will incorporate the plan for improved communications with that for management restructure. This review of effective communications will consider the activities and information flow at NASA Headquarters and the field centers which support the Shuttle program. The study team will present findings and recommendations to the Associate Administrator for Space Flight by August 15,

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				1986.
Rogers Commission *(Presidential Charter)*	6 June 1986		**Recommendation VI – Landing Safety:** NASA must take actions to improve landing safety.	**Original Response (Fletcher, 14 July 1986):** A Landing Safety Team has been established to review and implement the Commission's findings and recommendations on landing safety. All Shuttle hardware and systems are undergoing design reviews to insure compliance with the specifications and safety concerns. The tires, brakes, and nose wheel steering system are included in this activity, and funding for a new carbon brakes system has been approved. Runway surface tests and landing aid requirement reviews had been under way for some time prior to the accident and are continuing. Landing aid implementation will be complete by July 1987. The interim brake system will be delivered by August 1987. Improved methods of local weather forecasting and weather-related support are being developed. Until the Shuttle program has demonstrated satisfactory safety margins through high fidelity testing and during actual landings at Edwards Air Force Base, the Kennedy Space Center landing site will not be used for nominal end-of-mission landings. Dual Orbiter ferry capability has been an issue for some time and will be thoroughly considered during the upcoming months.

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Rogers Commission *(Presidential Charter)*	6 June 1986		**Recommendation VII – Launch Abort and Crew Escape:** The Shuttle program management considered first-stage abort options and crew escape options several times during the history of the program, but because of limited utility, technical infeasibility, or program cost and schedule, no systems were implemented.	**Original Response (Fletcher, 14 July 1986):** On April 7, 1986, NASA initiated a Shuttle Crew Egress and Escape review. The scope of this analysis includes egress and escape capabilities from launch through landing and will provide analyses, concepts, feasibility assessments, cost, and schedules for pad abort, bailout, ejection systems, water landings, and powered flight separation. This review will specifically assess options for crew escape during controlled gliding flight and options for extending the intact abort flight envelope to include failure of 2 or 3 main engines during the early ascent phase. In conjunction with this activity, a Launch Abort Reassessment Team was established to review all launch and launch abort rules to ensure that launch commit criteria, flight rules, range safety systems and procedures, landing aids, runway configurations and lengths, performance versus abort expo- sure, abort and end-of-mission landing weights, runway surfaces, and other landing-related capabilities provide the proper margin of safety to the vehicle and crew. Crew escape and launch abort studies will be complete on October 1, 1986, with an implementation decision in December 1986.
Rogers Commission *(Presidential Charter)*	6 June 1986		**Recommendation VIII – Flight Rate:** The nation's reliance on the Shuttle as its principal space launch capability created a relentless pressure on NASA to increase the flight rate. Such reliance on	**Original Response (Fletcher, 14 July 1986):** In March 1986 NASA established a Flight Rate Capability Working Group. Two flight rate capability studies are under way: (1) a

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			a single launch capability should be avoided in the future. NASA must establish a flight rate that is consistent with its resources. A firm payload assignment policy should be established. The policy should include rigorous controls on cargo manifest changes to limit the pressures such changes exert on schedules and crew training.	study of capabilities and constraints which govern the Shuttle processing flows at the Kennedy Space Center and (2) a study by the Johnson Space Center to assess the impact of flight specific crew training and software delivery/ certification on flight rates. The working group will present flight rate recommendations to the Office of Space Flight by August 15, 1986. Other collateral studies are still in progress which address Presidential Commission recommendations related to spares provisioning, maintenance, and structural inspection. This effort will also consider the National Research Council in-dependent review of flight rate which is under way as a result of a Congressional Subcommittee request. NASA strongly supports a mixed fleet to satisfy launch requirements and actions to revitalize the United States expendable launch vehicle capabilities. Additionally, a new cargo manifest policy is being formulated by NASA Headquarters which will establish manifest ground rules and impose constraints to late changes. Manifest control policy recommendations will be completed in November 1986.
Rogers Commission *(Presidential Charter)*	6 June 1986		**Recommendation IX – Maintenance Safeguards:** Installation, test, and maintenance procedures must be especially rigorous for Space Shuttle items designated Criticality 1. NASA should	**Original Response (Fletcher, 14 July 1986):** A Maintenance Safeguards Team has been established to develop a comprehensive plan for defining and implementing actions to

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			establish a system of analyzing and reporting performance trends of such items. Maintenance procedures for such items should be specified in the Critical Items List, especially for those such as the liquid-fueled main engines, which require unstinting maintenance and overhaul.	comply with the Commission recommendations concerning maintenance activities. A Maintenance Plan is being prepared to ensure that uniform maintenance requirements are imposed on all elements of the Space Shuttle program. This plan will define the structure that will be used to document (1) hardware inspections and schedules, (2) planned maintenance activities, (3) maintenance procedures configuration control, and (4) maintenance logistics. The plan will also define organizational responsibilities, reporting, and control requirements for Space Shuttle maintenance activities. The maintenance plan will be completed by September 30, 1986. A number of other activities are underway which will contribute to a return to safe flight and strengthening the NASA organization. A Space Shuttle Design Requirements Review Team headed by the Space Shuttle Systems Integration Office at Johnson Space Center has been assigned to review all Shuttle design requirements and associated technical verification. The team will focus on each Shuttle project element and on total Space Shuttle system design requirements. This activity will culminate in a Space Shuttle Incremental Design Certification Review approximately 3 months prior to the next Space Shuttle launch. In consideration of the

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				number, complexity, and interrelationships between the many activities leading to the next flight, the Space Shuttle Program Manager at Johnson Space Center has initiated a series of formal Program Management Reviews for the Space Shuttle program- These reviews are structured to be regular face-to-face discussions involving the managers of all major Space Shuttle program activities. Specific subjects to be discussed at each meeting will focus on progress, schedules, and actions associated with each of the major program review activities and will be tailored directly to current program activity for the time period involved. The first of these meetings was held at Marshall Space Flight Center on May 5-6, 1986, with the second at Kennedy Space Center on June 25, 1986. Follow-on reviews will be held approximately every 6 weeks. Results of these reviews will be reported to the Associate Administrator for Space Flight and to the NASA Administrator.

Only **Findings** and **Recommendations** relevant to the Space Shuttle Program have been extracted from each report.

The Organizations making the reports – and their charters - are as follows:

Aerospace Safety Advisory Panel (ASAP): "The Panel shall review safety studies and operations plans referred to it and shall make reports thereon, shall advise the Administrator with respect to the hazards of proposed operations and with respect to the adequacy of proposed or existing safety standards, and shall perform such other duties as the Administrator may request." NASA Authorization Act of 1968 | Public Law 90-67, 42 U.S.C. 2477

Space Shuttle Independent Assessment Team (SIAT): The Space Shuttle Independent Assessment Team was chartered in September 1999 by the NASA Administrator to provide an independent review of the Space Shuttle subsystems and maintenance practices.