a. Status of Engine Reconfiguration

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

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

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

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

(1) <u>HPFTP First Stage Blade Cracks</u>

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

(2) <u>HPFTP Second Stage Firtree Face Cracks</u>

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

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

(3) HPOTP First Stage Shank Cracks

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

(4) HPFTP Coolant Liner Maximum Pressure

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

(5) HPOTP Bearing Ball Temperatures

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

(6) HPOTP Bearing Failure

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

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

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

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

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

b. SSME FMEA/CIL Reassessment

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

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

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

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

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

Table IV
SSME FAILURE MODE SUMMARY

(September 1987)

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

Table V

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

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

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

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

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

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

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

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

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

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

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

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

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

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

c. SSME Hazard Analyses

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

d. Additional Comments

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

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

5. Launch, Landing and Missions

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

Table VI
LIST OF CURRENT SSME HAZARDS

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

D. Space Station Program

1. General

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

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

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

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

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

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

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

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

2. Computing System

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

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

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

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

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

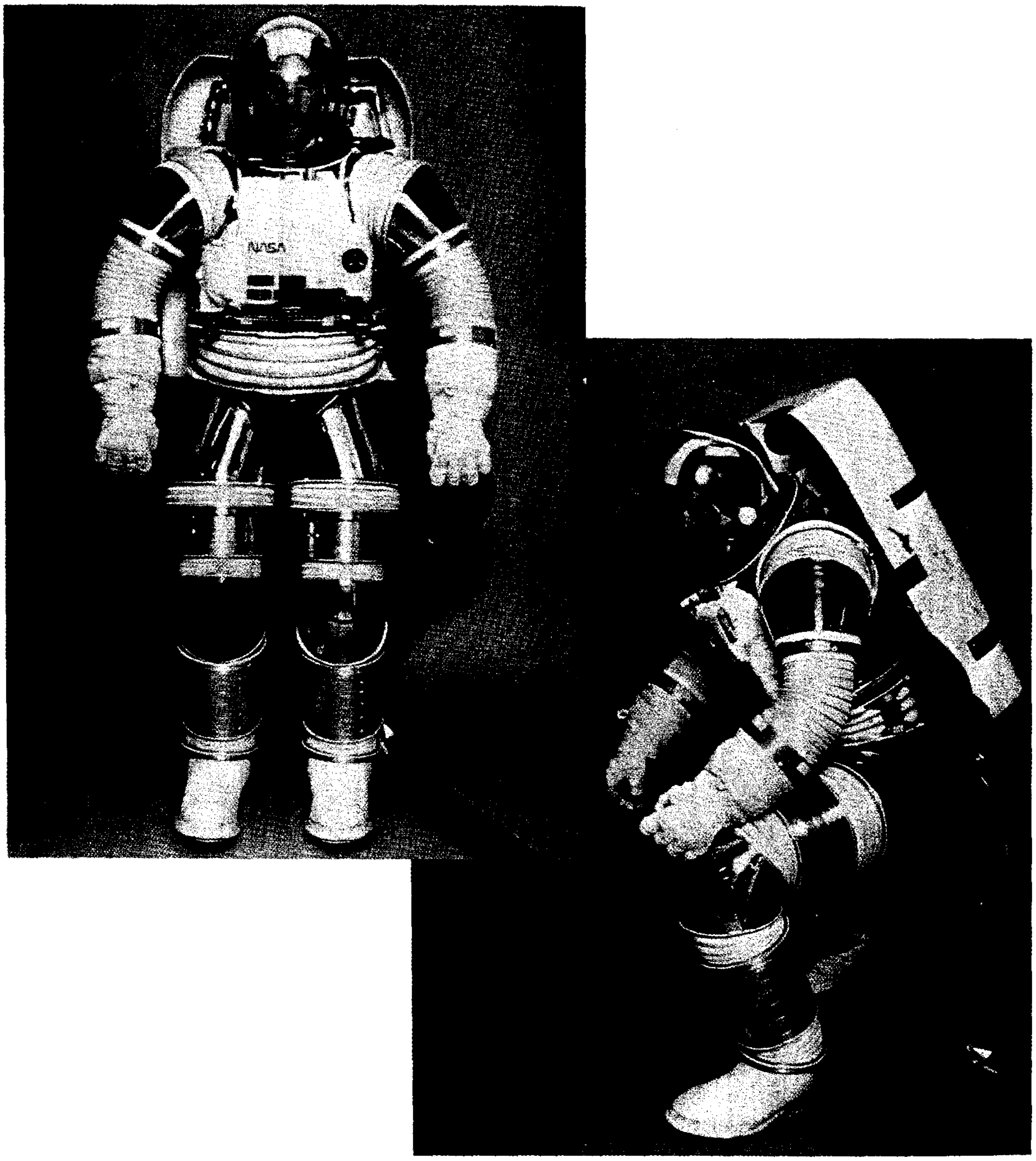
Based on the STS history, Space Station management must maintain an awareness that technical decisions made by senior management require full knowledge of the implications of those decisions. An example is data communications, in which a full appreciation of the timing associated with the various standards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

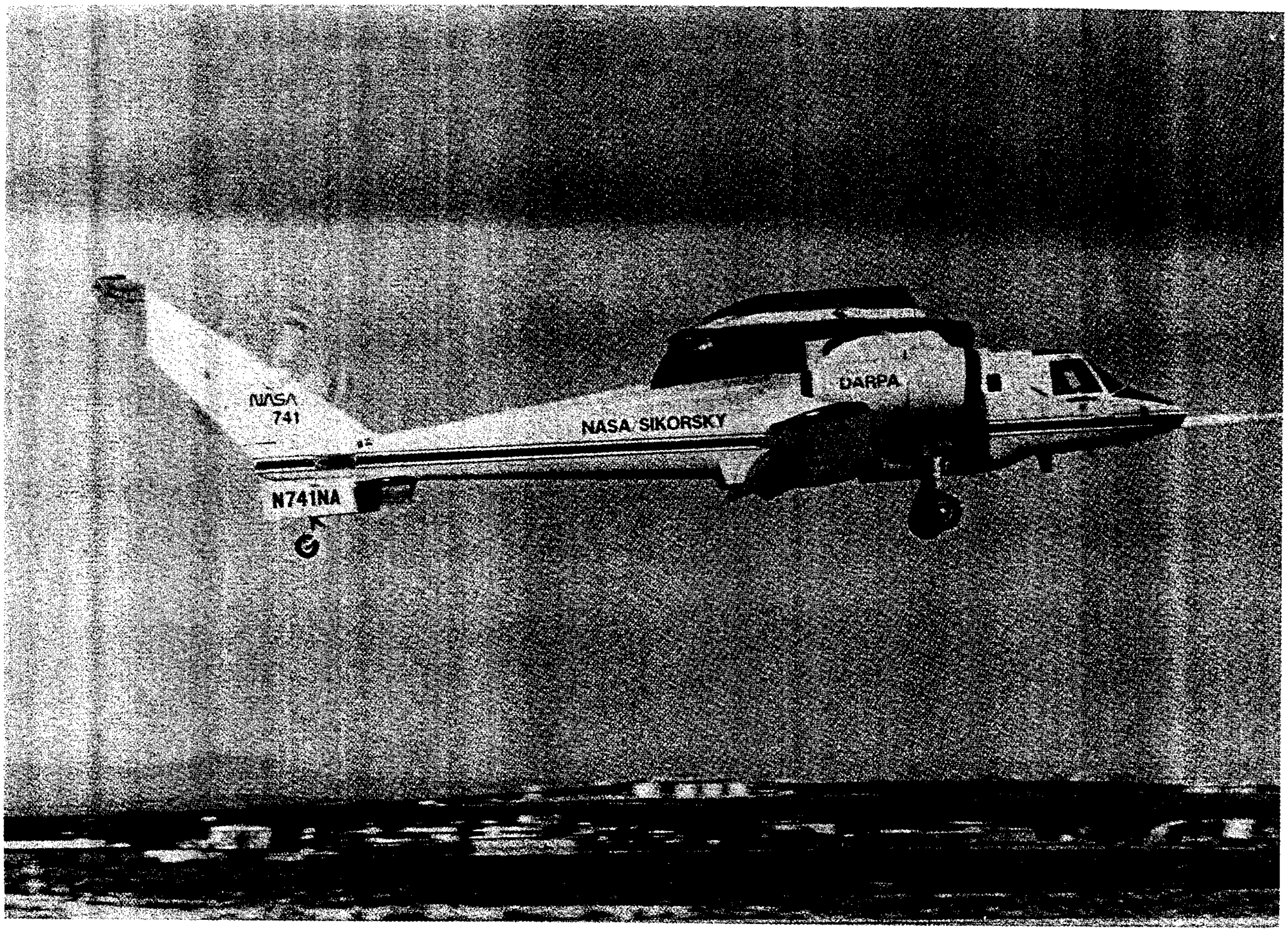
- Space Station program goals for safety and reliability with respect to the computing system.

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

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

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

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E. Aeronautics

1. RSRA/X-Wing Flight Test Program

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

2. X-29 Technology Demonstration Flight Program

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

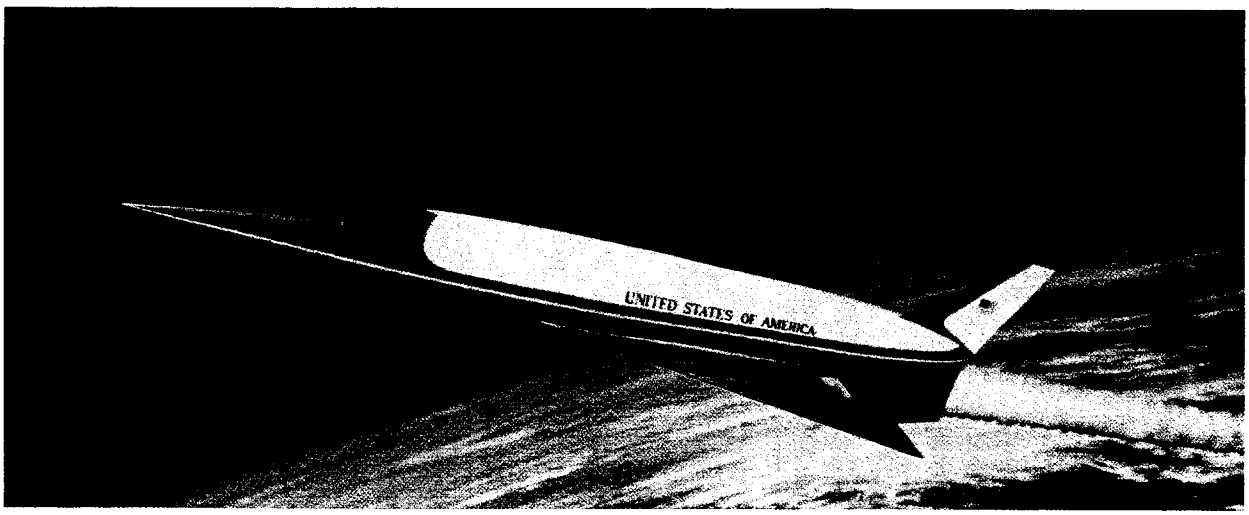
The flight envelope has not been totally explored as the maximum design dynamic pressure (the q corresponding to M=1.07 at sea level) has not been reached. This is the most critical corner of the flight envelope from a structural dynamic and a flight control standpoint. Demonstration of the ability to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

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

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

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

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



IV. Appendices

A. Panel Membership

AEROSPACE SAFETY ADVISORY PANEL

CHAIRMAN

JOSEPH F. SUTTER
Former Exec. VP, the Boeing Co.
Aerospace Consultant

DEPUTY CHAIRMAN

NORMAN R. PARMET
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GERARD W. ELVERUM, JR.
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TRW Space and Technology Group

NORRIS J. KRONE
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University of Maryland
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JOHN F. McDONALD
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Aerospace Consultant

JOHN G. STEWART
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Tennessee Valley Authority

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CONSULTANTS

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Consultant

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NASA HQ, 453-8971

MONICA BOWIE, Secretary
NASA HQ, 453-8971

B. Panel Activities Calendar Year 1987

CALENDAR YEAR 1987 ACTIVITIES

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

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

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

November 12-13	MSFC	Aft Skirt Review Team
November 17-19	LeRC	NASA Aeropropulsion Conference
November 23	MSFC	TSS Program Status Review
December 1	Seattle, Wash.	Auxiliary Power Unit/Hydraulic Power Unit Concerns
December10-11	Ames Reseach Center	X-wing briefings
December 16	HQ	Space Station-Computer Software/Hardware Testing and Validation Programs
February 5-7	JSC	NRC Solid Rocket Motor Redesign Panel
February 16	U.S. Senate	STS-26 Processing Status and Expectations

C. ASAP Proposed Activities for Calendar Year 1988

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

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

D. NASA Response to Panel Annual Report, March 1987

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

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

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

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

2. Space Station

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

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

1. Orbiter

a. Orbiter structural life certification

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

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

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

referenced even if the September 30, 1987, end date slips. An operating restriction report and strength summary (external loads and vehicle stress) report for each Orbiter should be prepared in order to have quick access to information for making future decisions.

c. Redlines and Modifications

To provide 85-percent launch probability redlines, the wing modifications should be made, even if slightly conservative, in some structural areas. Redlines on OV-103 and OV-104 should be specifically examined and changed as required.	CLOSED - Plans completed actions in work, part of activity to return-to-flight
d. Brakes and Nose-Wheel Steering	OPEN - Redesign, tests, procurements still in process

2. STS Operations

a. Logistics and Launch Processing

o "NASA should examine the feasibility of developing data systems under management of the SPC, such as configuration management, that will centralize and augment KSC's operational launch capability."	CLOSED - Plans completed, implementation well along
o KSC and Shuttle Processing Contractor (SPC) activities regarding burden of work and flight rate.	OPEN - Panel to follow implementation of NASA SPC Station actions

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

1. Shuttle Management

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

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

2. Space Shuttle Systems

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

o	Provide funds to check OV-102 loads based on ASKA 6.0 analyses, check other Orbiters, update Orbiter load indicators/ redlines, prepare reports.	OPEN - Continue to follow
o	Orbiter 102 loads test program to calibrate strain gauges, etc.	OPEN - Continue to follow
o	SSME, Panel recommends that the Phase II engines operate below 104% RPL and if practical at no more than 100% RPL.	CLOSED
o	Panel recommends that SSME two-duct hot gas generator and large throat combustion chamber be tested and certified as soon as possible.	OPEN - Continue to follow
o	NASA and SSME contractor continue development of improved methods of demonstrating critical operating failure mode margins.	OPEN - Continue to follow
o	Regarding use of upgraded GPC in the Orbiter: 5-0 versus use of 4-1.	CLOSED - Will follow to ensure appropriate test and safety analyses
o	Orbiter landing gear system; including brakes, nose-wheel steering, etc.	OPEN - Panel will follow, including increased landing weight allowable effects

3. Space Shuttle Operations

o	Improvement of KSC work force effectiveness.	CLOSED
o	Space Shuttle logistics	CLOSED - Covered by previous item
o	Maintenance Safeguards program	CLOSED - Covered by previous item

4. Safety, Reliability, Quality Assurance

o	Development of operating policy for the new SRM&QA offices at Headquarters and at NASA centers.	OPEN - Panel will review the situation on an on-going basis

	o Independent review of payload safety.	OPEN - Continue to review/assess
5.	Space Station Program	
	o Panel endorses initiative to simplify Space Station design	CLOSED
	o Use of ELV's	OPEN
	o Crew safe haven and life boat, crew rescue.	OPEN
	o Computer system's use of new developments; also use of 32-bit architecture.	OPEN
	o Use of lessons learned	OPEN
6.	NASA Aeronautics	
	o Proper level of aircraft policy, management and operations offices.	CLOSED
	o Modification of Grumman Aircraft as Space Shuttle flight simulators.	OPEN
	o X-Wing project flight test program. Other comments included under this heading.	OPEN - Continue to follow

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

NASA

National Aeronautics and
Space Administration

Washington, D.C.
20546

Reply to Attn of:

September 2, 1987

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

Dear Joe:

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

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

Sincerely,
Original signed by
Dale D. Myers

for James C. Fletcher
Administrator

Enclosure

NASA'S RESPONSE TO THE

AEROSPACE SAFETY ADVISORY PANEL

ANNUAL REPORT

FOR 1986

I. EXECUTIVE SUMMARY

1. SPACE SHUTTLE MANAGEMENT

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

2. SPACE SHUTTLE SYSTEMS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The Panel recommends that:

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

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

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

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

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

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

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

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

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

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

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

3. SPACE SHUTTLE OPERATIONS

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

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

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

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

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

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

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

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

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

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

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

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

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

4. SAFETY, RELIABILITY, QUALITY ASSURANCE

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

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

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

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

5. SPACE STATION PROGRAM

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

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

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

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

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

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

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

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

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

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

6. NASA AERONAUTICS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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