NASA

National Aeronautics and
Space Administration

Washington, D.C.
20546

1030

March 20, 1987

Reply to Attn of: LB/GLR

TO: Distribution

FROM: Gil Roth/Staff Director, Aerospace Safety Advisory Panel

SUBJECT: Errata For Annual Report of the Aerospace Safety Advisory Panel, Report Issued March 11, 1987

The few changes noted below should be incorporated into your copy(s) of the ASAP's annual report: (Changes are underlined)

Page No.	Change
6 Item 8.a.(4)	5/0 should be 4/1
56 Item 4	ditto
8 Item 1	1. The Panel found that three fundamental weaknesses....
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77 last para. 4th line down	Delete the sentence: "The safety engineering function has been basically lumped ....staff-oriented organization." Move the next sentence: "At the present......and quality assurance." and place it as shown below at the end of the paragraph on the top of Page 78 as a separate paragraph: Therefore, on Page 78 before recommendations the new paragraph reads: "At the present time, our perception of the new office of safety, reliability, maintainability and quality assurance, is that it appears to be a staff function with responsibility to define roles, requirements, policies, and organizational structures in safety, reliability, maintainability and quality assurance."
102 2nd para. 3rd line	cryogentic should be cryogenic

NASA
National Aeronautics and Space Administration

AEROSPACE SAFETY ADVISORY PANEL

ANNUAL REPORT

COVERING CALENDAR YEAR 1985

JANUARY 1986

NASA

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Washington, D.C. 20546

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The Aerospace Safety Advisory Panel shares in the nation's grief over the loss of the Space Shuttle Challenger and its heroic crew. Despite this, the Panel believes it is essential for NASA to continue its manned space flight program. The Findings and Recommendations of this annual report were completed prior to the January 28th accident.

AEROSPACE

SAFETY ADVISORY PANEL

ANNUAL REPORT

COVERING CALENDAR YEAR 1985

JANUARY 1986

TABLE OF CONTENTS

I. EXECUTIVE SUMMARY

The level of activity of the Aerospace Safety Advisory Panel was increased somewhat during 1985 in concert with the increased mission rate of the National Space Transportation System, the evolutionary changes in management and operation of that program, and the preparation of the Vandenberg Launch Site; the implementation of the Program Definition Phase of the Space Station Program; and actual flight testing of the X-29 research aircraft. The Panel continued its review of impending unique payload STS missions and NASA's overall aircraft operations. The Panel also responded to a request by the NASA Administrator to assess the safety aspects of the Leasat salvage mission.

This report summarizes the Panel's 1985 work, and enumerates its findings and recommendations for the attention of NASA management. NASA's response to the Panel's 1984 report findings and recommendations is appended hereto (ref. Appendix E).

The Panel wishes to note its appreciation for the continuing excellent support of all government and industry entities contacted, thus enabling the Panel to perform its statutory responsibilities.

Panel Meetings

The full Panel or Panel members conducted 54 fact finding sessions during calendar 1985. Meetings were held at NASA Headquarters, seven NASA Centers, six contractor sites, Vandenberg Air Force Base, and three other locations. In addition, the Panel presented testimony before the U.S. House of Representatives and U.S. Senate, and held other discussions with congressional staff.

Space Transportation System (STS)

The STS performed in a highly credible manner during 1985. It was a period of continuing transition to increased launch frequency, while, at the same time, undergoing a number of organizational and operational responsibility changes (which included numerous key personnel changes). The program team (government and industry) demonstrated its capability to successfully deal with real-time anomalies to plans, and its flexibility to revise, implement, and execute new plans and schedules to accommodate the anomalies. An outstanding example of this was the Leasat salvage mission. Given the operational system complexities and the sheer magnitude of effort required to safely execute each STS mission, the Program achievements during 1985 were, indeed, noteworthy.

Attainment of NASA's goal of 24 STS launches per year remains sometime in the future, challenging the capacities of both physical and human resources. While plans are being implemented to provide the necessary balance of resources, the goal is all the more challenging considering that: (1) a number of flight hardware components are still undergoing development for both performance and reliability; (2) additional "brick and mortar" facilities are required at KSC for orbiter processing and component maintenance; (3) there are ultimate limitations of human resources to compensate for shortfalls in the physical resources (even with extraordinary dedication and effort); (4) sufficient logistics support, in both hardware and systems, lies sometime in the future; and (5) the fact that all of the above are subject to constraints by budgetary allocations. Nevertheless, the Panel believes that a safe and productive STS Program can be carried out if the System's real state-of-the-art and other limitations are recognized and integrated into the program planning and scheduling.

Several elements of the STS are discussed under Section II and expanded upon under Section IV of this report. One which the Panel wishes to note in this section is the uncertainty of the structural strength of the Filament Wound Case (FWC) for the Solid Rocket Boosters (SRBs). Tests and analyses to date leave considerable question as to the strength margins of safety in the transition areas between case segments. Until the issue can be resolved with a high level of confidence, the Panel believes the FWC SRBs should not be used for STS launch (and certainly not for first launch from VLS). A great deal of attention is being given to the issue, including a select committee of the most knowledgeable experts available.

The Panel also wishes to note its support of the NASA/Air Force decision to reschedule the first STS launch from the Vandenberg Launch Site (VLS) until after mid 1986. Good progress is being made in bringing the VLS on-line and the additional time to complete the process will provide for orderly checkout and confirmation of launch readiness for both the site facility and the launch team.

STS - Payload Related Issues

There do not seem to be many payload-related safety issues arising. This would say that all the time and effort spent on payload planning has been well spent and while the system at first glance seems formidable, it is entirely workable as many payloads have proven. The exceptional performance of the astronauts in space in payload emergencies is such that this factor should be recognized in the design of payloads, with for instance, the accessibility to a suited crewman of critical parts of the payload. It also points up the continuing need for a more flexible space suit or alternatively an end-of-arm manipulator to perform the normal hand functions--perhaps both.

Shuttle - Centaur

The Centaur payload is a special case. The Centaur is a complex, massive machine using cryogenic fuel, originally designed for unmanned launch and with a long successful history. The hazards--particularly in an abort situation--of the Centaur to the Shuttle are such that it must be integrated with the Shuttle, rather than being just a payload. This has been a long hard task but seems to be well underway. The remaining problems do not seem to be technical but rather schedule.

Radioisotope Thermal Generator (RTG)

The deployment into space of an RTG requires specific Presidential authorization before launch. There is a mechanism set up to accomplish the risk assessment and in the past the necessary launch permission has been granted. Except for some of the manned abort scenarios, there are no substantially greater risks with the Shuttle Centaur than with previous unmanned launches, both solid and liquid fueled, carrying RTGs in the payload. We do not see an undue safety concern in the use of an RTG on the upcoming Shuttle Centaur flights, in light of the reviews, attention, and consideration that have been given this issue.

Space Station

The Panel continued to monitor the Space Station Program organization, planning, and "Phase B" (program definition and system preliminary design) through 1985. A broadly based effort is well under way, involving NASA Headquarters, four NASA Centers (each with line responsibility), the full spectrum of U.S. aerospace industry in competitive and support roles, and several international partners. Both the program goals and the broad institutional involvement in program execution create very challenging management requirements. The panel foresees management/organizational concepts and arrangements, consistent funding support, and judicious funding allocation as being the key factors in successfully achieving the President's objectives for the Space Station Program. The technologies needed to produce and deploy the Space Station are essentially in-hand (relatively little "new technology" is required compared to the STS Program).

The Panel will continue to monitor the program developments, principally with regard to the resulting effects on system safety. Some of the Panel's current considerations are discussed in Section IV.

Space Junk

The safety concern caused by the presence in space of debris from past launches and satellites is growing but is difficult to characterize, except statistically. This "space junk issue" can only be resolved by international cooperation and action, and such a solution is slow. Efforts to resolve this issue internationally must be intensified before it moves from the concern to the problem condition. Any solution must consider not only the large trackable units but the small debris that represents an unavoidable collision hazard. The Panel would urge NASA through appropriate channels to establish an international consideration of this issue before it becomes a critical problem.

Research Aircraft Programs

State-of-the Art extensions in Aeronautics are being undertaken in the experimental aircraft programs, such as the X-29 (forward swept wing) and X-Wing Rotor Systems Research Aircraft. Panel members with expertise in the related technologies and experimental flight programs are active in program safety assessments. To date the Panel is satisfied that appropriate safety initiatives are proving to be effective. Both programs involve new techologies and complex control systems, with attendant risks, and require a high level of on-going safety emphasis.

NASA Aircraft Operations

While the Intercenter Aircraft Operations Panel continues preparation of operations guideline documents, a void still exists at NASA Headquarters in appointing a qualified management level individual to head up the Aircraft Management Office. The ASAP believes strongly that agency-wide operations and maintenance standards should be established under Headquarters authority and administered through the leadership of an operations qualified manager or director.

II. FINDINGS AND RECOMMENDATIONS

A. Space Transportation System (STS)

1. Orbiter Structural Life Certification

Findings

The wing root fatigue analysis and fracture analysis certification report funding has been stopped without completion of the documentation.

Recommendations

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

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

Findings

Due to the latest flight test results, an arbitrary "collector force" (a force simulating stresses at critical wing locations) will be added to the wing loads which will be used in the final 6.0 loads/stress program. Rockwell will also have to complete the final analysis within an allocated budget and time frame.

Recommendations

The Panel agrees with the arbitrary force approach taken at this time. However, the primary load path structure and thermal protection system analysis should be a stand alone report fully documented and referenced even if the 9/30/87 end date slips. In addition, it is felt that 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.

3. Redlines and Modifications

Findings

Loads analysis from Orbiter capability assessment - Cycle "D" (OCA - D) and "collector load" concept require wing mods (MOD I, II & III, see section IV.D.1.a) on all vehicles.

Recommendations

In order to provide 85% launch probability redlines, the 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.

4. Orbiter Avionics and Software

Findings

Although we have been assured that no changes will be required in the applications software for the new, uprated general purpose computers (GPCs), there remains a nagging concern that this might not be the case. The new computer has new codes and the temptation will be great to use them to "improve" the applications software. To discourage this human foible, the software compiler will not recognize the new codes. For meeting the logistics associated with these new computers the plan is to buy one new computer each year after the initial purchase.

Recommendations

NASA must monitor this most carefully since applications software can be very expensive to change and retest. Discipline with regard to the new computer codes may be more difficult to implement than management thinks...it was tried on the Apollo program with little or no success. The wisdom of procuring one new computer each year may well lead to the same problem with spares found throughout the LRU program, and deserves additional attention, especially with increasing flight rate and the use of "new" computers.

5. Brakes and Nose Wheel Steering

Findings

The STS program has made a great deal of progress in alleviating the brake problems found on nearly all of the first 21 flights. With the activation of nose wheel steering capability, there has been a marked lessening of brake damage during subsequent landings. The decision to proceed with development of the structural carbon brake, and possibly use a fifth rotor to replace the current beryllium rotors and stators, has been made.

Recommendations

Standard use of nose wheel steering is recommended, regardless of the type of brakes. The system performance should also be analyzed to permit increasing nose wheel steering authority as much as practicable in order to maximize crosswind landing capability. The carbon brake design should be pursued as quickly as possible to replace current materials. The resulting configuration should provide manifold improvement in Orbiter landing ground roll control and stopping reliability. Further, the Panel is still hopeful that NASA will seek practical means of reducing Orbiter landing speed.

6. Flight Crew Training

Findings

The Orbiter landing is a critical phase of each STS mission. Flying qualities of the Orbiter are unique due to its configuration, compounding the demands upon the flight crews at this critical time. NASA has recognized this and met the requirements by assignment of skilled pilots who receive extensive hands-on training in ground simulators and Orbiter flight simulator aircraft. The increasing STS mission rate demands an attendant increase in flight crew training. The time available in the present fleet of Orbiter flight simulator aircraft is becoming marginal and can be foreseen as being inadequate to meet future training demands.

Recommendations

NASA must commit the funds in a timely manner to ensure an adequately-sized fleet of training aircraft to meet the flight crew training needs, without reduction or compromise to the Orbiter flight training syllabus.

7. Space Shuttle Main Engines (SSMEs)

Findings

In 1983, a three-phase program was initiated to substantially improve the SSME. However, as a result of severe funding-rate limitations, the program was restructured in 1984 to address only certain improvements to the wear life of various turbopump components (Phase II), plus a limited effort on development of a new hot-gas manifold (Phase II+). Most of the turbopump component improvement work has gone very well during 1985, and these new components will be incorporated into a two-engine Phase II recertification program. This "certification" is planned to demonstrate that the non-turbopump components of the engines are capable of 20 missions (with 40% operation at 109% of rated thrust), and that the high-pressure turbopumps are capable of 5 missions. A three-engine main propulsion-system test (MPT) is scheduled to be performed to assure there are no feed-system interaction problems at 109% operation. The Panel strongly supports this system test as being highly desirable.

The new powerhead manifold will be incorporated in a later demonstration program in 1986, but at the present time there is no approved plan to demonstrate the large-throat combustion chamber, which is necessary to really improve significantly the turbopump operating environments at 109% thrust.

Recommendations

The recertification approach selected by NASA permits different parts of the engine to be "certified" for different flight times. However, since most of the Phase II turbopump component improvements really only address degradation rates of critical components under nominal mission environments rather than increased stress level margins (the exceptions are the decreased High Pressure Fuel Turbine discharge temperatures $\sim 100^{\circ}$ and a 7000 RPM improvement in synchronous whirl margin on the oxidizer turbopump), the Panel recommends that the engine be operated at power levels above 104% of rated power only when mandatory. Also, when engine operation above 104% is necessary, the power level selected be only the value required for the particular mission and not taken all the way to 109% except when mandatory.

The Phase II development and demonstration program should provide a data base for the modified turbopumps which can be used to estimate new Mean-Time-Before-Replacement criteria for the turbo-machinery. The hardware necessary to support this replacement rate should be made available in order to maintain the engine's new certification status and protect flight safety margins.

We further recommend that the "precursor" (future) program improvements be supported at a level such that they can in fact be incorporated as soon as possible into the flight engines. In the long run, such expenditures will be cost effective as they result in more reliable flight engines with lower maintenance costs and a higher availability factor.

8. Solid Rocket Boosters

Findings

The effect of the new launch mount and the filament wound motor case flexibility has been assessed by "Cycle III" loads analysis and found to be similar to the previous calculated "Cycle II-B" loads which gives added confidence to predictions made to date. However, the hold down Solid Rocket Booster calibration confirmation tests will not be available until late Spring of 1986.

Recommendations

The Solid Rocket Booster hold-down bolt calibration tests should be carefully examined at this time to aid in obtaining meaningful final test results. If the calibrated test results differ from that used in the Cycle-III analysis then the prelaunch and lift-off loads for the External Tank and Solid Rocket Booster will be incorrect. This could cause serious problems in meeting launch requirements.

Findings

The filament wound case test article, STA-2, was tested and prematurely failed. However, there were process and design differences between STA-2 and the VLS-1 flight article. The follow-on test STA-2B will be tested to 140% of limit load using a design comparable to the flight test article. Additional full-scale pressure and compression tests are being made to certify the filament wound case design. There is a heavy dependence on analysis and modifications based on a very limited hardware base and a set of design changes resulting from test failures.

Recommendations

Continued analysis and further studies have to be conducted in order to fully understand the failure mode. Additional studies should continue to evaluate membrane/transition lay-ups and coupon specimens. Until the issue can be resolved with a high level of confidence, the Panel believes the FWC SRBs should not be used for STS launch. The Panel would like to be kept informed of the analysis results and of these upcoming tests.

9. Logistics and Launch Processing

Findings

The Shuttle Processing Contractor (SPC), while not yet at its peak, has laid the organizational groundwork and obtained the right sort of personnel during the year. A general assessment indicates very satisfactory progress is being made.

Launch rate predictions are still very optimistic in the light of Space Shuttle Main Engine developmental and spares problems, spares shortages of line replaceable units, excessive modification workload, etc. For the next 2 to 3 years, 12 to 15 flights per year appears to be a difficult but attainable goal.

Arrangements for transfer of functions such as sustaining engineering, logistics management, etc., from JSC to KSC seem to be well organized and an orderly, if somewhat slow, transition should eventually result.

Overall safety practices and monitoring systems--especially by the SPC--at KSC are praiseworthy and would appear to do everything reasonable to ensure the safety of operating personnel.

Recommendations

a. NASA management should monitor closely the effects of the recent reorganization at KSC to make sure that it has accelerated and simplified management of launch processing.

b. 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.

c. NASA should continue to give high priority to acquisition of spare parts and to upgrade the reliability (planned life) of hardware, especially items associated with the space shuttle main engine.

d. NASA should explore whether better coordination could be achieved between those persons determining manifests for specific flights and those persons charged with launch processing. In some instances, the combination of payloads has exacerbated the launch processing sequence.

e. Facilities should be provided to minimize turnaround times of the Shuttle and Line Replaceable Units (LRUs).

- o Orbiter Maintenance and Refurbishment Facility (OMRF) building should be authorized.

- o LRU repair facilities should be provided at KSC for all units which can be properly and efficiently handled there.

B. Payload Interface Standardization

Findings

Shuttle turnaround times remain in the forefront of planning for future STS flights. One of the significant factors that affects turnaround-times is the lack of interface standardization among the various payloads carried into orbit. A considerable effort has been expended in the area of standardization and the prime example is the PAM.

Recommendations

There will always be peculiar requirements for special payloads, but insofar as is feasible, there should be increasing effort to preparing and carrying payloads in a standardized fashion.

C. Extravehicular Activities (EVA)/Space Suits

Findings

This year's activities show that EVA will continue to be in extensive use. The Leasat rescue mission is an outstanding example of its use during the past year. Certainly the Space Station will require extensive EVA for its construction and for its operational activities. The current suit continues to function well, despite its limitations. The need remains for a more flexible suit that has the capability of operating at a higher pressure than the current suit.

Recommendations

NASA should continue to support the development of a more flexible, higher pressure EVA suit and fund the development in an appropriate manner.

D. Space Station

Findings

The Space Station organizational structure is quite complex, with roles and responsibilities difficult to discern at times. The system is maturing, while there remains some questions concerning NASA's ability to adequately handle the systems engineering and complete integration of Phases C & D, the hardware and software development and implementation. Integrating a large development effort, such as the Space Transportation System, has been accomplished through an integrating contractor and supporting contractors and NASA has not performed a full integration role before.

Recommendations

NASA should re-examine the resources required to conduct the many facets of the Space Station integration effort to ensure that the organization and human resources are sufficient to properly fill this role, now and in the future.

Findings

The Space Station exists in an essentially benign environment once on orbit when compared to the ascent conditions within the Orbiter payload bay.

Recommendations

NASA should determine possible means to alleviate the payload bay interface environment and design requirements (vibration, accelerations, loads) which drive some of the Space Station element and "user" designs.

Findings

"Build-to-cost" management for the Space Station may involve many of the same or similar activities that confronted the Space Shuttle in its formative days. Looking into such shuttle management and technical activities, and the resultant decisions, could provide Space Station management with an understanding of possible pitfalls to avoid, if not many positive directions to take, thereby preventing inefficiencies in the use of available resources.

Recommendations

NASA should establish a small team composed of current and retired NASA/contractor persons who have first-hand knowledge of the early activities (1972-1976) on the Space Shuttle program. The team should define the "lessons" that can be "learned" in both management and technical areas, including the real possibility of using today's technology to meet Space Station needs.

E. Aircraft Operations

Findings

There is still no head of the NASA Headquarters's Aircraft Management Office. This precludes proper focusing of management's attention upon achieving centralized aircraft operational control. Agency-wide flight operations and maintenance policy and guidelines documents to be used by both Headquarters and the NASA Centers have been slow in being issued.

Recommendations

NASA should appoint, as soon as possible, a qualified operations manager as head of the Aircraft Management Office. Determine methods to reduce the time it takes to obtain review and approval for critical flight operations guidelines and policies which are generated at Headquarters.

III. PANEL PLAN FOR CALENDAR YEAR 1986

Panel Membership

The Panel selected a new member, Dr. Harold M. Agnew, to fill the vacancy which occurred when Herbert E. Grier retired from the Panel. Mr. Grier remains with the Panel as a consultant. Dr. Agnew's experience in managing high risk, high visibility national programs will be of great value to the Panel as it delves deeper into the Space Station Program.

Dr. Harold M. Agnew has been in the forefront of nuclear energy development since the early 1940s. In 1979, he joined General Atomic Company, after serving as Director of the Los Alamos Scientific Laboratory in New Mexico. He retired as President from General Atomic Company on December 31, 1984. Dr. Agnew is, among many other achievements, a Fellow of the American Physical Society and a Fellow of the American Association for the Advancement of Science.

Dr. Norris J. Krone, Jr. has been working with the Panel as a consultant in the fields of aeronautics and structures, particularly with regard to the X-29A and the X-Wing research and development projects which NASA has been working with DARPA. Dr. Krone, a recognized expert in his fields, is currently Executive Director of the University of Maryland Research Foundation.

Panel Activities for 1986

The Panel's areas of interest are those which further NASA program/project technical goals and reduce adverse events associated with meeting those goals. Specifically, one divides such activities into "on-going" and "new" areas of interest.

A. <u>On-Going</u>

1. X-29A Phase II supersonic flight envelope expansion, including maintenance and logistics support, flight test plans, and crew training.

2. X-Wing Rotor Systems Research Aircraft flight readiness process, including software validation, component fatigue tests, powered model testing, and other certification activities.

3. Space Transportation System, with regard to the transition of activities from development Centers and contractors to KSC operators. Safety assurance under conditions of budget reductions and increased flight rate.

4. Space Station, as it moves through Phase B into the development and construction (Phase C & D). Panel effectiveness depends upon early input.

5. A number of supporting areas, such as life sciences, human factors, Extra Vehicular Activities, Aircraft operations, ground support equipment and facilities, and payload interfaces.

B. <u>New</u>

1. Oblique wing research aircraft project.

2. Tether satellite project, as it interfaces with the Orbiter.

3. Orbiter "Heads-Up" ascent mode of flight, attempting to gain additional payload capability.

4. Space debris, as it affects STS and Space Station activities.

5. Safety impacts of any reduction of payload requirements for those who fly on the Shuttle.

6. Hazardous Material Identification and Material Safety Data as required by statute, and its effect on NASA operations.

7. Transfer of appropriate knowledge from outside into NASA programs to enhance safety, reliability, and maintenance applied to a maturing Space Transportation System, and the buildup of the Space Station.

8. Space Station Orbital Transfer Vehicle interfaces and impacts.

9. Orbiter landing/arresting systems to preclude loss of Orbiters due to landing site overruns or side runs.

As requested, the Panel will respond to NASA management and the Congress regarding safety of NASA activities with due regard to public safety at all times.

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IV. APPENDICES

A. PANEL MEMBERSHIP/CONSULTANTS/STAFF

John C. Brizendine (Chairman)
Aerospace Consultant
President of Douglas Aircraft Company (Retired)

Harold M. Agnew
President of General Atomic (Retired)
Director, Los Alamos Labs (Retired)

Richard H. Battin
Associate Department Head
Charles Stark Draper Labs

Charles J. Donlan
Institute for Defense Analysis
Consultant

Gerard W. Elverum, Jr.
V-P/Gen. Mgr, Applied Technology Group
TRW Space and Technology Group

John F. McDonald
Aeronautical Consultant
V-P Maintenance & Engineering
TigerAir, Inc. (Retired)

John G. Stewart
Assistant General Manager, TVA

Melvin Stone
Director of Structural Mechanics, DAC (Retired)
Aeronautical Consultant

Norman R. Parmet
Aeronautical Consultant
V-P Engineering and Quality Assurance
TWA (Retired)

Panel Consultants

Herbert E. Grier
Senior V-P, EGG, Inc (Retired)
Consultant

John P. Reeder
NACA/NASA Chief Research Pilot (LaRC) (Retired)
Consultant

Seymour C. Himmel
Associate Director, NASA Lewis
Research Center (Retired)
Consultant

Norris J. Krone, Jr.
Executive Director
University of Md Research Foundation

Ex-Officio Member

Milton A. Silveira
NASA
Chief Engineer

Staff

Gilbert L. Roth
NASA
Staff Director

B. AEROSPACE SAFETY ADVISORY PANEL

ACTIVITIES CY 1985

DATE	SITE	PERSONNEL	SUBJECT
1/23	Chicago	Parmet	Life Sciences Planning Group
1/18	NASA Hqs	Himmel	Space Shuttle Main Engine
1/29-30	LaRC	Donlan	Orbiter Upgrade (Canards, etc.)
1/31	NASA Hqs	Reeder	X-29A and X-Wing Safety
2/14	NASA Hqs	All	Annual Meeting
2/20	Congress	All	House of Representatives Hearing
2/25-26	Sikorski	Krone, Reeder	X-Wing Review
2/25-27	PAFB, FL	Parmet	NASA Intercenter Aircraft Panel
3/4	ARC	Donlan	STS Studies, Crew Training
3/7	DFRF	Reeder, Donlan, Parmet	X-29 Safety Review, R&D Operation
3/20	JSC	Battin	STS Computers/MDMs/Software
4/2-3	MSFC	All	STS Projects & Special Projects
4/4	NASA Hqs	Roth	STS 51D FRR Telecon

4/16-18	Gen Dyn, CA	Grier	Phase II Centaur Safety Review
4/16-19	DFRF	Krone	X-29A Activities
4/23-25	Columbia, TX	McDonald	Space Station Special Task Team
4/17	RI/Downey, CA	Stone	Orbiter Structure Adequacy
4/24	Sundstrand, IL	Parmet	Current/Improved Orbiter APUs
5/9-10	KSC	Stewart, Parmet	SPC Operations for STS
5/29	KSC	Parmet	Intercenter Aircraft Ops Panel
5/30	JSC	Grier, Himmel, Donlan, Parmet	STS 51-I Leasat Salvage Mission Special Review Team
6/4	Gen Dyn, CA	All	Shuttle/Centaur Mission Safety
6/5	RI/Downey, CA	All	Shuttle/Centaur, Orbiter
6/6	Rocketdyne, CA	Elverum, Himmel, Donlan, Elms, Williams	SSME Status (Phase II,II+ et al)
6/6	Hughes, CA	Brizendine, Grier, Himmel, Donlan, Parmet, Elms, Williams	STS 51-I Syncom Salvage Mission

6/7	VAFB, CA	Parmet	VAFB Activation
6/19-20	JSC	Grier, Parmet, Elms, Williams	STS 51-I Syncom Salvage Mission
6/19-20	VAFB, CA	McDonald	STS System Safety Panel
7/1	Thiokol, UT	Himmel	Accident Investigation Team
7/1	ARC	Reeder, Krone	X-Wing Safety Review
7/2	DFRF	Reeder	X-29A Review
7/18-19	NASA Hqs	Parmet	Life Sciences Advisory Committee
7/22-26	ARC et al	Parmet	Convair 990 Investigation Team
7/30-31	JSC	Parmet, Grier	STS 51-I Salvage Mission
8/1	MSFC	Elverum, Himmel	SSME Ad Hoc Review Team
8/16	NASA Hqs	Elverum, Himmel	SSME Ad Hoc Review Team
8/15	NASA Hqs	Himmel	STS 51-I Flight Readiness Review
8/20	NASA Hqs	Himmel	Propellant Accident Team Report
9/10-11	JSC	All	Space Station, Special STS Topics
9/12	JSC	Parmet, McDonald	STS Safety, Quality Assurance

9/17-19	ARC, DFRF	Reeder	X-29 Activities
9/24-25	KSC	Roth	Level I Centaur Management Review
10/2-4	Sikorski	Krone	X-Wing Safety
10/9-10	KSC	Stewart, Parmet, McDonald	STS Operations en toto, JSC to KSC Transition, KSC/VAFB Efforts
10/23	NASA Hqs	Roth	STS 61A Nose Wheel Steering
10/28-30	JSC	Reeder	Orbiter Concerns, Space Station
10/29-31	TWA, KS	Parmet, Roth	Intercenter Aircraft Ops Panel
11/19	Rocketdyne, CA	Elverum, Himmel	SSME Update
11/19-21	LaRC	Parmet	Aircraft Ops Safety Review Team
11/20-21	Gen Dyn,CA	Grier, Himmel	Centaur Design Certification Rev.
11/21	NASA Hqs	Brizendine, Donlan	Space Station Management Review
11/22	VAFB, CA	McDonald	Level I Design Cert. Review
12/4-5	VAFB, CA	All	Shuttle Operations - USAF
12/10	MSFC	Elverum	SRB/FWC, SSME,Composites
12/11	NASA Hqs	Roth	STS 61-C FRR
12/19	RI/Downey, CA	Stone	Orbiter Systems Update

PANEL REPORT ON SYNCOM SALVAGE MISSION

NASA

National Aeronautics and Space Administration

Washington, D.C. 20546

June 28, 1985

Reply to Attn of: LB/GLR

TO: A/Administrator
M/Associate Administrator for Space Flight

FROM: LB/Staff Director, Aerospace Safety Advisory Panel

SUBJECT: Safety Assessment of the Leasat/Syncom Salvage Mission (STS 51-I)

INTRODUCTION

The Aerospace Safety Advisory Panel was requested to assess the safety of the plans and implementation to salvage the Leasat/Syncom now in orbit on the STS 51-I mission. A preliminary assessment was provided by memo dated June 11, 1985. This report is the Panel's final assessment. There may be further comments as a result of the upcoming mission operations certification review scheduled for July 30-Aug 1 at JSC.

The Panel team included Norm Parmet, Herb Grier, Charlie Donlan, Sey Himmel and Gil Roth with support from Walt Williams and Jim Elms. The following activities were conducted:

May 30	JSC	Hazard analyses, EVA, handling hardware, interfaces
Jun 5	Rockwell	Orbiter operations
Jun 6	Hughes	Leasat failure cause, vehicle state, salvage safety
Jun 19-20	JSC	Phase III Safety Review, hardware DCR

This was, by necessity, a limited review with the objective of ascertaining the adequacy of salvage mission management, Leasat status now and at the time of the mission, hardware design, crew operations, mission rules, risk analyses as they all affect mission safety.

ASSESSMENT

Safety first then mission success are the priorities for the salvage operation. Both NASA and Hughes have explored and reviewed the salvage task thoroughly and appear to have practical and safe plans for its implementation. Mission simulations at both JSC and Hughes facilities have been and continue to be conducted to replicate each task and step to be taken, including contingency modes. To date there is nothing that represents a source of significant concern with regard to safety. It should be safe to proceed with the mission assuming nothing negative arises from the final reviews to affect the safe operation as we see it now.

We would like to re-emphasize the following: (1) mission rules, now in work, must be clear, concise and complete to assure such things as proper checkout of the many electronic boxes in the cabin and no EVA missteps, (2) assure overlap of JSC and Hughes activities so that nothing can drop-through-the-crack. The continuing working group meetings and reviews should assure this, (3) the spacecraft attitude, spin rate and internal state are not fully known, therefore, analyses of these conditions must continue so that their affects on the mission can be factored into the plans and implementation, (4) if the adverse tolerance buildup theory for failure of the Leasat is correct, it illustrates once again how little things can be the cause of major problems, therefore, no matter how simple or mundane a thing is it can not be overlooked.

FAILURE MECHANISM

Having proved by the STS 51-D "flyswatter" operation that the most probable single point failure probably did not cause the Leasat malfunction, Hughes looked carefully into multiple failure scenarios. By analysis and test they found that a dual failure of the Perigee Kick Motor (PKM) separation switches was the most credible failure due to a design deficiency caused by structure warpage and insufficient switch plunger length, see attached figure. In this case the Post Ejection Sequencer (PES) would never be powered. The proposed salvage operation is based on working around the PKM separation switches and providing inhibits and allowing for ground control (not internal spacecraft) of spacecraft activation.

SAFETY AND MISSION SUPPORT ACTIVITIES

The salvage activities make use of JSC and Hughes designed and built equipment to meet specific demands of Leasat handling and attitude control, vehicle safing, internal system modification, and redeploy. The original STS payload safety requirements based on NASA's NHB 1700.7A were provided and approved December 1983. These requirements have been reexamined and updated June 14, 1985 to meet the salvage mission requirements. Items considered "open" because they are still in work and will be completed by the end of July 1985 are: Hardware Picture Book, Details of Cabin Checkout Box, In-Cabin Checkout Procedures, EVA Operational Procedures, and Completion of Unit and System Test Program.

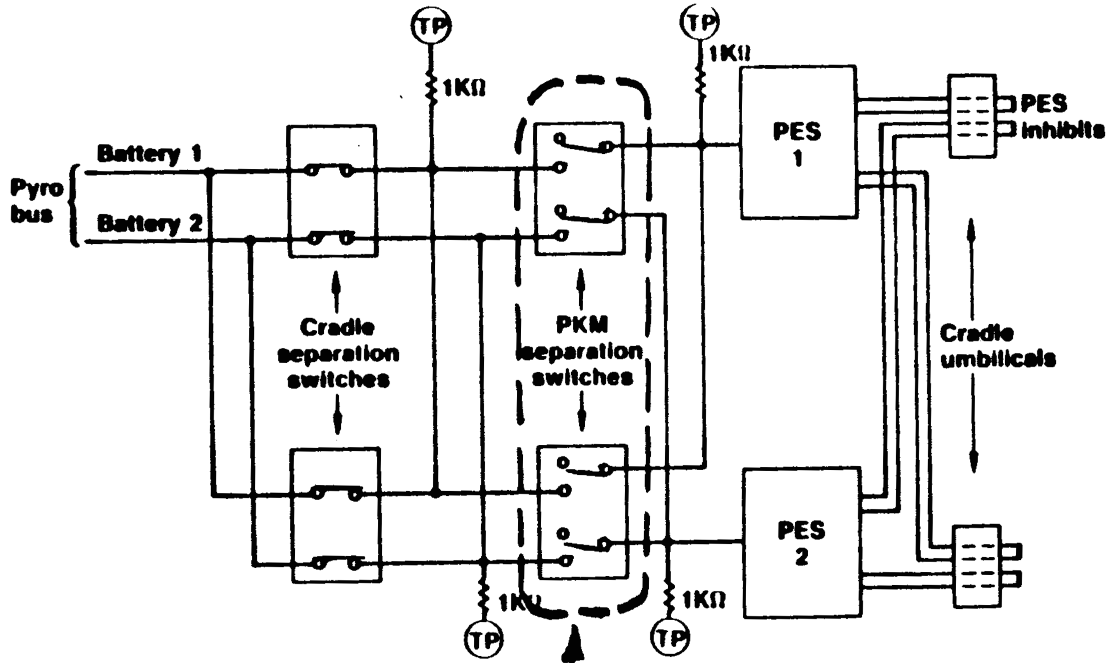
JSC developed procedures for the mission, EVA equipment, crew training and interfacing with Hughes show a thorough understanding of crew/orbiter safety needs. Crew training in 1g and neutral buoyancy facilities at both JSC and Hughes (using Leasat F-5) should preclude complacency between now and the mission, and allows for the necessary "back-out" modes, if such are required.

Visual cues during the salvage operations will provide positive indications of the spacecraft condition, i.e., omni antenna deploy, vehicle spin-up, in addition to any X-band transmissions. Any of these would result in mission abort.

The Hughes built equipment, once installed, will safe the vehicle by (1) locking the separation switch lever in the closed position thereby opening the cradle separation switches, (2) installing shorting plugs to inhibit any internal spacecraft event initiation and allowing only ground commanded initiation, (3) insertion of safe and arm safing pins.

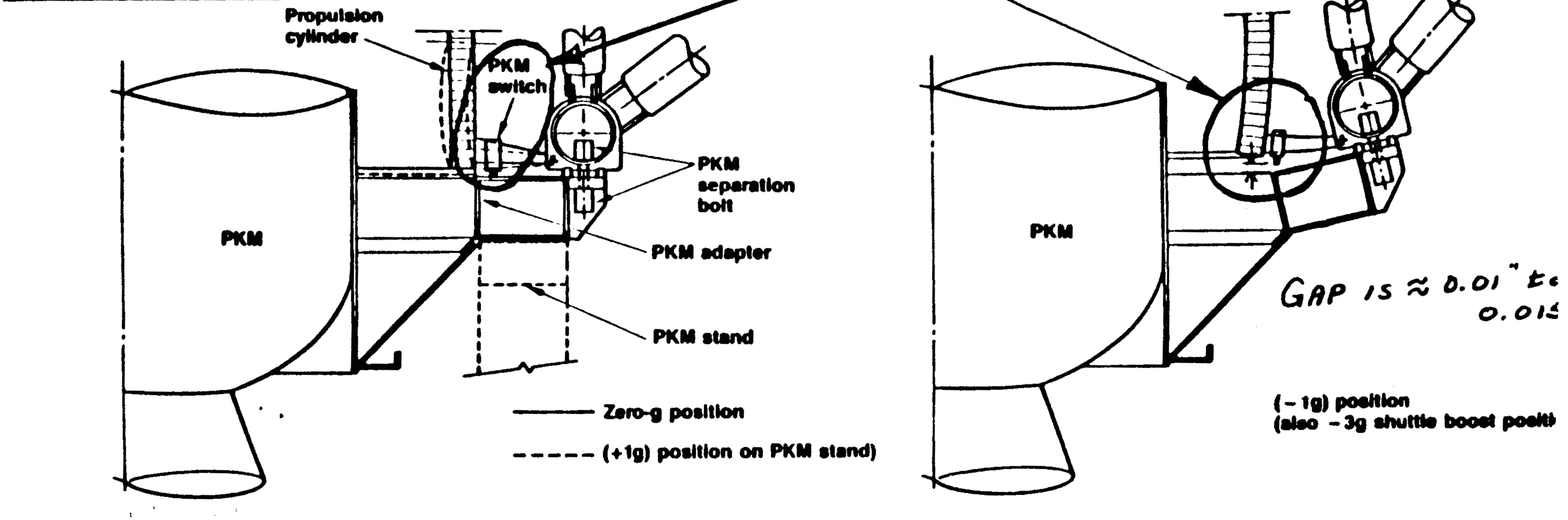
Sneak circuit analyses are being conducted on critical circuits and show no concerns to date. We have been assured that through configuration control that the "as-built" configuration is known. The external configuration is known (unlike the previous on-orbit retrieve/repair missions). Problems associated with on-board propellants (particularly the hypergolics) have been investigated and tests performed. These indicate no safety concerns based on statements made by both JSC and Hughes.

Syncom PES Power/ CURRENT Configuration



FAILURE MODE

Effect of Structural Deformations Upon PKM Switch Actuation



D. FACT-FINDING RESULTS OF CALENDAR YEAR 1985

1. Space Transportation System (STS)

a. Orbiter

There have been surprisingly few crisis-type hardware issues. In fact, the major hardware problem is lack of spares that leads to cannibalization. We have dealt with this separately under logistics.

There is one item, though, that warrants review and that is the fuel cell. The bank of cells is fully redundant in a come-home emergency sense, but the mission power loads are high enough that there is not complete redundancy in a mission-power sense. The basic electric power source should be unquestionable. The fuel cell problems have not been fundamental but seem to have been valves, heaters, and the like. This subject is worthy of review to assure the design of these accessories is, in fact, conservative.

Five areas associated with the Orbiter have received most of the Panel's attention: Structural adequacy, avionics hardware and software, brake/steering behavior, landing handling qualities, and the use of automatic systems (such as autobraking and autolanding).

(1) Orbiter Structural Adequacy and Certification Program

The structural life certification program for the Orbiter has been proven by approximately 33 fatigue, fracture, and acoustic supplemental tests, as well as analysis of outboard elevon/flapper-door/wing portion of the rear spar. The last remaining wing root fatigue and fracture analysis has been started, but will not be completed due to lack of funding at this time. It is recognized that the Orbiter is designed for only 100 missions with a scatter factor of four and approximately a 30,000 PSI tension stress level in the lower wing skin. By examining current available fatigue spectra data one can conclude that the fatigue damage is negligible, fracture damage and acoustic loads small. However, in order to have a complete structural life certification program, a short cut analysis should be made and documented.

The calculated ASKA 6.0 (latest loads/stress program) stresses are lower than the stresses from flight test results at wing strain gage locations AB and A14 for 85% launch probability. At this time, it is not practical to revise aero loads, so an additional loading is applied to the wing, known as a "collector force." This added force simulates stresses at wing locations AB and A14 which appear to be slightly conservative on some of the other wing/carry thru structure. The final ASKA 6.0 loads will contain this collector load. The remaining external loads/internal loads work consists of:

(a) additional landing cases - matrix of sink speed vs gross weight.

(b) replace high Q boost loads with a set of Q loads which include "collector load" increments for wing and carry-thru structure.

(c) internal loads-fuselage side without hatch.

Entry internal loads are expected to be completed by February 1986. However, the remainder of the stress analysis and thermal protection subsystem structural analysis is to be completed on schedule, September 1987. All original sets of loads, including high dynamic pressure

(Q) during ascent, will be used to analyze the fuselage and tail surfaces. The structural thermal gradients used have a high degree of confidence based on flight test results and a significant beef up in the mid-fuselage structure resulted from flight test data.

The final check of the wing loads/stresses will be verified by pressure gages and strain gages applied to the OV-102 vehicle. However, 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.

Since the ASKA 6.0 loads/stress program is to be finished within an allocated budget and time duration, only the primary load path structure (wing, fuselage, tail, and thermal protection subsystem analysis) will be completely documented. Other structural components, e.g., the crew module, will not be well documented.

With regard to redlines and specific Orbiter modifications, it is noted that to meet an 85% launch probability the following modifications are required, based on extrapolation from flight data:

Mod. I. 8 bolts replaced, wing station X = 1307 upper, for all vehicles.
3 bolts replaced, wing station X = 1191 lower, for all vehicles.
Wing station Y = 123, rib cap doublers, for OV-103,104.

Mod. II Wing station X = 1191, external doubler lower for all vehicles.

Mod III (using collector load concept)

o Wing station X = 1249, spar web vert. stiffener	OV-103,104
o Wing station X = 1307, spar web vert. stiffener	OV-103,104
o Add doublers inboard access hole	all vehicles
o Wing station X = 1191, upper cover finger doubler	all vehicles
o Upper surface external doubler	
Proximity of wing station X = 1307	OV-103,104
Aft wing station X = 1307	all vehicles
Inside mid-fuselage carry-thru	OV-103,104
o Wing station X = 1249 access hole doubler	OV-103,104

(Note: These modifications should be the end of any required wing mods. However, there are still two critical items to be evaluated, i.e., the results from the instrumented OV-102 flight test and final 6.0 loads/stress analysis.)

(2) New Avionics Hardware/Software

The Panel has been monitoring three major upgrades for the avionics system of the Shuttle Orbiter--the MMU (Mass Memory Unit), the CPU (Central Processor Unit), and the IMU (Inertial Measurement Unit).

(a) Mass Memory Units

NASA is upgrading the MMUs by adding one card to the tape unit to implement error-correcting codes and to modify the write head--the latter because they have experienced a read-write head wear problem. Several have failed on the ground but fortunately none have failed in flight.

The MMU tape drive is used to change mission phases by loading new programs into the flight computers. The most critical program--namely, the shuttle entry program--is loaded from the MMU into one on-board computer. This load can be, theoretically, accomplished from the ground but the process is slow and has never actually been tried. For a mission abort, the MMU must be used to load the entry program and is, therefore, a critical flight-safety item. Granted, it would require multiple failures (first, an abort, and second, an MMU failure) but the consequences are unacceptable.

The Panel supports the upgrade. However, the cost and schedule (18 months to two years) require NASA's continuing attention.

(b) Central Processor/Input Output Units

Today, each flight computer, consisting of a CPU plus an IOP, uses magnetic core technology and has approximately 104,000 words of 32 bits each. Its speed is 400,000 operations per second. Each box (the CPU and the IOP) weighs 60 pounds and the combination consumes 600 watts of power.

The Panel supports the decision to replace the shuttle computers with those which IBM will be supplying the Air Force for the B-1 bomber (1000 machines) and the F-15 fighter (700 machines). Although IBM would, of course, continue to provide logistic support for the old shuttle computers by keeping a special line open, NASA would be the only customer and the cost to NASA could be unreasonable.

The new computers are smaller, faster, lighter, use less power, and have greater capacity. Each of the new computers weighs 60 pounds (half of the original), provides 256,000 words of memory, executes 1,200,000 operations per second, and consumes 525 watts. With the Air Force as the significant customer, NASA will have logistic support at a fraction of what it would cost if they were to continue with the current shuttle computers.

The NASA versions of the new flight computers are more expensive than those for the Air Force since NASA requires that all parts are to be manufactured in the USA where NASA, through IBM, will be able to directly witness, monitor, and control the processes. This is essential for a flight critical item and it seems odd to the Panel that the Air Force does not demand the same.

Although IBM assures NASA that no changes will be required in the applications software, the Panel recommends that NASA monitor this carefully. Applications software can be expensive to change and retest.

The new computers are scheduled for the middle of 1987 and NASA already has one computer operating in Houston at the IBM laboratory with the new FCOS (flight computer operating system) in place. The old machine has been operating with the necessary software changes to the operating system since January 1985. Now it is in the new computer. NASA has reactivated the GN&C test station to demonstrate the transparency of the new machine to the applications software.

The new computer has new codes and the temptation will be great to use them to "improve" the applications software. To discourage this human foible, the software compiler will not recognize the new codes. The Panel is concerned that this discipline cannot be indefinitely maintained. It was tried without success in the Apollo program.

NASA plans to buy 24 flight and 6 non-flight computers. For logistics, NASA plans to order one new computer each year after the initial purchase. The Panel questions the adequacy of this decision since the lack of spares has always been a significant problem.

(c) Inertial Measurement Units

The upgrading of the IMUs follows a similar pattern. Singer will provide new IMUs with superior performance and at lower cost. The main customer for the new instruments--Bear Claw and the B-1--will provide NASA the opportunity to eliminate the costly dedicated manufacturing line maintained for its use only. Furthermore, these instruments are also expected to be transparent to the shuttle system. In fact, they can even operate as a mixed set--both old and new machines. NASA does not need the improved performance, but will have it as a by-product without changing their specifications.

The new IMU has its own microprocessor which can be an advantage during the prelaunch operation. With the proper software in the IMU processor, any last minute hold-time due to a drifting IMU could be eliminated. Today, as much as 1 1/2 hours of hold-time can occur for such a problem.

The new instruments are lighter--120 pounds versus 175 pounds--and they use less power. The Panel supports the acquisition of this new technology.

(3) Brakes/Nose Wheel Steering

In the Orbiter (shuttle) landing rollout improvement program, the nose wheel steering system has been modified to provide linear response for the first 5 degrees of the 9 degrees total authority with lateral acceleration feedback for smoothing through the general purpose computer (GPC) and is active upon landing. Failure of the GPC results in reversion to the parabolic response direct mode. Results have been satisfactory. However, 9 degrees maximum may not be enough. In the usual case, cross winds are never steady in speed or direction. Thus, the cross wind component will never be known ahead of time for the moment of touchdown or during rollout. Landing wind conditions in case of abort after launch would be the hardest to allow for in planning because of the low probability of such an event and an indeterminate landing site. It is unlikely that winds would be within stated limits at all possible landing sites at any one time. Also, landing procedure calls for off loading the main landing gear by putting the elevons down after nose wheel contact. This, of course, reduces the braking and steering capability with brakes on rollout, and puts greater dependence on nose wheel steering. With these considerations, it would seem that the maximum nose wheel steering angle ought to be increased to 15-20 degrees to deal with high crosswinds, blown tires, inadvertent departure from the hard-surface runway, or a case where drift or skid exceeds the angular limits of the nose wheel, thus leading to possible "groundloop" about the nose wheel. One question remains at this time: Will the nose wheel steering system allow for free-castoring if it goes to a hardover position, that is, a fail-safe, fail-operational condition?

A carbon brake review was conducted by NASA in early December 1985 and resulted in agreement to procure a carbon brake system for the Orbiter and to obtain the system from the current Orbiter brake supplier. There is concern by the STS management about the availability of resources to support the development of the carbon brakes, given the many competing requirements and the projected constrained budget during the 1986 period. The program management considers the development of the carbon brake system to be of the highest priority...and the Panel supports this position as it has in the past.

(4) Landing Handling Qualities

Looking to the future, the concerns with landing handling qualities of the Orbiter which result from the tailless design featuring a low aspect ratio wing and large elevons for longitudinal and lateral control may be corrected through the use of control augmentation devices or surface. This would result in lower landing speeds and improvements in handling qualities. If possible, it would behoove NASA to undertake such a research program with the view of furnishing timely information for future designs of the shuttle type, including possible flight tests of a research-type vehicle at either Ames or Langley Research Centers.

(5) Automation

Automated landings, while still in the program, have not been demonstrated and are not in favor with the current pilot astronauts. They question the system's reliability and prefer a "hands-on" landing capability. However, it would appear that since landings at KSC are deemed mandatory to reduce the turnaround times between missions, the use of the automated system might well be needed to assure meeting the flights-per-year goal. An incongruity appears to exist here in that the launch and ascent portion of the mission is already fully automated and been found to be extremely reliable throughout. The question that arises is: If the flight system for ascent is relied upon, then why not the flight system for landing?

b. Space Shuttle Main Engine

By 1983 there was sufficient data to show that the main engines were being operated near their tolerable margin limits at 104%, and that significant improvements were necessary to permit more than very limited use at the desired 109% of rated power. As reported last year, a three-phase program was defined to address the extensive modifications necessary to improve both operating stress margins and life limiting wear characteristics. Funding constraints in 1984, and continuing in 1985 and for the foreseeable future, have revised the planned program. The restructured program retained the Phase I and Phase II portions to define existing component life and to improve wearout life of the turbo-machinery at both 104% and 109% by decreasing the High Pressure Fuel Turbopump turbine discharge temperature 100°, and by increasing the synchronous whirl margin on the Oxidizer Turbopump by at least 5000 RPM.

The Phase III part of the original program was eliminated and replaced by several other program elements. One of these, labeled Phase II-Plus, will develop and certify a new hot-gas manifold structure. This new manifold will be designed to lower the manifold pressure drop, decrease local peak temperature zones, and improve overall hot-gas flow uniformity.

Additionally, potential engine improvements for the future are being studied in a series of tasks labeled the Test Bed Precursor Program. This activity will develop a single coil heat exchanger, an improved inlet configuration for the High-Power Oxidizer Turbopump, removal of all baffles from the main injector, and a large diameter throat configuration for the main combustion chamber. This will also evaluate further component life extensions by minimizing the start-up and shut-down transient high temperatures.

Beyond these defined but limited tasks to improve known low-margin areas of the existing engine design, there is a new product improvement activity getting underway. This activity will seek new concepts for various critical components or subsystems such as the turbopumps. The objective would be to make major improvements in operating stress margin and/or component wearout life. This long-range improvement activity may involve other rocket engine companies in addition to Rocketdyne. The Panel strongly supports this type of activity because of its leverage on improved reliability at high power levels (109%) and its potential for improved mission performance (>109%).

As of late November 1985, the Phase II program had resulted in many improvements which are now incorporated into the two Certification Engines. Of these, several of the most important are:

- o High Pressure Fuel Pump turbine discharge temperature was reduced about $100^{O}R$.
- o Operating life (no cracks) on both the first and second stage turbine blades of the fuel turbopumps was improved by thermal barrier coatings.

- o A margin of almost 7000 RPM was achieved on the High Pressure Oxidizer Turbopump.

- o "Life" improvements were made in various other components such as liftoff seals, bearings, sheet metal cases, etc.

On the other hand, several of the planned modifications did not work out, particularly on the oxidizer turbopump. As a result, component life limitations still exist in these areas and will continue to present replacement problems. Therefore, engine use at 109% of rated thrust should still be tightly constrained.

Two Phase II engines will run a kind of "composite certification" program. The results of these tests will be to demonstrate "service life" for various parts of the engine, and indicate a replacement-time schedule for the turbopumps, including even replacement schedules for components of the turbopumps. The basic certification program on each engine will be at a mix of 104% and 109% thrust mission profiles. Of the 10,000 seconds of operation (equal to 20 mission durations), approximately 40% will be run at 109% of rated power. It was hoped to demonstrate 5-flight capability on the turbomachinery (10 mission tests for 5000 seconds). However, parts were changed on the oxidizer pumps, and a weld crack repair done on a fuel pump which then subsequently is to accumulate 5000 seconds. Furthermore, the oxidizer turbopump turbine blades will clearly limit usage to well below 5 missions until the two-piece damper blades can be incorporated in a certification extension program.

The Panel's assessment is that the Phase II engines are fully capable of the 109% for the planetary missions. However, the certification groundrules which permit replacements of various components such as turbopumps or blades, etc., during test series result in a somewhat questionable data base regarding true engine "configuration" operating margins and valid mean-time-between-replacement values. This results from the unknown impact of mixing components with various wearlife histories. The Panel still believes, therefore, that operation at 109% should be limited to only those missions where it is mandatory, and that engines be carefully evaluated after such a flight. The MPT runs to date had gone up to 106%. There were no indications of incipient flow instabilities proximate to changes of state or two-phase flow. The JSC engineering staff, after careful review of the data from the earlier tests, feels confident that a 3 point extrapolation in flow rate can be made with confidence. The Panel supports the three-engine main propulsion system tests at the National Space Technology Laboratories (NSTL), which were scheduled to be completed before any flight is carried out at Full Power Levels.

The Panel review and tour of the SSME facility at Canoga Park were very encouraging. The near-term availability of this facility, with its dedicated special equipment, disciplined procedures, and management focus, should improve significantly the timely availability and reliability of future engines and replacement subsystems. However, unless the new hardware is made available to support a more conservative mean-time-before-replacement schedule on the critical components currently showing wide scatter in lifetime, the "cannibalization" and "parts mixing" which now go on will seriously limit the value and effectiveness of this facility.

c. Solid Rocket Boosters

The steel case Solid Rocket Boosters have been performing as expected for each of the Space Transportation System flights conducted this year (1985). There have been component/system anomalies such as the Hydraulic Power Unit (HPU) turbine overspeed on STS 61-C which caused a pad shutdown. Nonetheless the ground launch system reacted properly and the required change-out of hardware was made. Performance (burning time, thrust vs. time, motor pressures) has been close to predicted each flight. SRB recovery systems, with some exceptions, continue to allow for recovery with little damage.

In response to the Panel's recommendation, the solid rocket Motors are being 100% x-ray inspected, on a periodic basis, to assure that the proper propellant process and quality controls are maintained during the case loading.

The filament wound case (FWC) project Design Certification Review (DCR) was conducted November 18, 1985. The first flight will be STS 62-A using the Vandenberg Air Force Base launch pad system, now scheduled for mid-July 1986. There are a number of "gates" to be completed prior to the Flight Readiness Firing (FRF) which takes place at the VLS in June 1986 in readiness for the first launch. Some of the more significant are:

(1) The FWC STA-2 (structural test article) was tested for prelaunch loads and failed at 118.4% of limit load. The failure mode was not properly identified and is receiving further study. However, the load was not applied to take into consideration joint eccentricity nor was the test article representative of the VLS-1 filament wound flight article. There are process design differences between STA-2

and VLS-1, i.e., use of Plastilock, no time limit for tying down helical ends, and use of substrate glass hoops in lieu of graphite cloth.

STA-2B will be conducted with a new skirt, new forward and aft case, and FWC like the VLS-1 flight article. It will be tested to 140% of limit load during April 1986. In addition, the forward dome joint ultimate pressure and line load applied at the joint will be tested during that same time. It is expected that FWC cavity collapse crushing loads will be tested during July 1986. Increased SRB skirt pre launch loads have been properly identified including load alleviation options.

(2) Filament wound case DM-7 firing showed that at about 80 seconds there was significant thrust oscillation. This requires further analysis to determine the cause and whether there would be any impact on actual flight.

(3) A search is underway for an insulation replacement since the use of asbestos is no longer legal. This is a real concern which may alter the known SRM characteristics.

The lift-off loads affecting the Solid Rocket Booster when launched from the Vandenberg site are estimated to be significantly above the "safe limit" at this time. The prediction methods for prelaunch loads and excursions have been validated by reconstruction analysis. The causes of increased Solid Rocket Booster prelaunch loads have been identified as: transient peak bending moment due to SSME ignition, FWC flexibility amplifying dynamic overshoot, and wind and stacking effects. Several load alleviation options have been identified to provide the needed load reduction. Of these, the one selected is to shim the outboard pad support posts that support the total stack through their attachment to the SRB aft skirt. Additional options, such as placarding west wind velocity, are available. It if it decided to change the SSME start sequence to alleviate the SRB laods there might be a requirement for redefinition of payload bay/cargo interface loads as well.

d. External Tank

The External Tank appears to have little, if any, problems in its role as fuel tank for the Space Shuttle Main Engines. The suspected problem with SOFI tank insulation coming off and impacting the Orbiter at liftoff and during ascent has been eliminated through the use of thousands of holes to preclude adverse pressure difference across the insulation.

There are studies looking at reducing the External Tank weight through judicious removal of metal throughout. This work, based on flight data to date, appears reasonable. However, any reduction in design margins must be carefully studied and understood. The possibility of shell buckling must be kept in mind as was done several years ago during a major weight reduction program.

e. Launch Sites/Vehicle Processing/Logistics

(1) VAFB Launch Complex Development (VLS)

The Panel has been observing the VLS development during the year and was present at the Design Certification Review (DCR) Level I Board meeting, and at the earlier Level II and associated Subsystem Safety Reviews. Excellent working relationships between USAF and NASA personnel are apparent and the progressive resolution of developmental problems in the engineering and construction tasks constitute an impressive overall performance.

The Panel notes the delay in the official launch date for STS-62A from March 1 to mid-July 1986 and views this as being very advantageous from the aspects of safety and readiness. The Flight Readiness Firing (FRF) program will serve to resolve many remaining problems and add confidence in launch safety. Two major tasks still require resolution, namely, the system for ensuring safe burn-off of residual hydrogen in the SSME exhaust duct and the verification of actual launch mount loads on the pad, which are being pursued vigorously. Shims have been added at the launch pad SRB hold-down posts to adjust vehicle loads. The hold-down bolt calibration and joint free play tests will be conducted during a pull test of the two SRBs. It is felt that the loads on the compression side will be large enough to give good results; however, the tension side which has combined compression and tension loads may not be large enough for good calibration data. Since combined loads and not uni-axial loads will be applied, it will be difficult to separate out the various load component effects. These tests are scheduled for the end of the first quarter of 1986.

Final integrated loads analyses, Cycle III prelaunch and lift off loads are close to those previously calculated, adding confidence to the predictions.

Problems associated with the very compact nature of the VLS when compared with KSC have been explored, for example, the provision of an ice suppression system to preclude external tank ice-up prior to launch; elimination of possible re-ingestion of exhaust gases into air conditioning and other systems; and analysis of exhaust and flare-off flame temperatures upon the cryogenics storage tanks.

Quality control procedures in construction and systems seem to have adequate attention and there exists great sensitivity towards this subject following some of the criticisms which were aired publicly in the summer of 1984. The comprehensive review and sign-off procedures between NASA and USAF for design certification and operational readiness leave the Panel with the comfortable feeling that considerations towards thoroughness and safety are paramount.

The Program organizational, staffing and personnel, planning, and training elements appear to be sound and providing the needed strengths to achieve program goals. The test program, including the FRF, appears thorough and one which will pay dividends in successful future launches. And, finally, the cooperative teamwork between the USAF and NASA at the VLS is highly evident and, the Panel believes, a great strength in the national space effort. There are two additional observations which the Panel would note: (1) the 7-day work week, success-oriented schedule, which carries certain risks; (2) over the long term of future launches at VLS, orderly success will depend, in large part, upon retention of a stable, experienced launch team. The Panel urges USAF consideration of a personnel assignment policy which will ensure that future capability.

KSC involvement in VLS operations is detailed in the SPC "STS lV. Launch Team Support Plan." It outlines KSC support of VLS and is a commitment of the required resources. The plan calls for regular coordination between KSC and VLS counterparts to the extent that each understands the other's status, problems, and concerns. The SPC is in the process of identifying the required KSC personnel by name. At this stage one can only assume the plan will work as described.

The Panel's continued assessment of the launch processing activities at Kennedy Space Center and preparation for the initial launch in 1986 at Vandenberg Air Force Base includes the long-standing concern with the logistics of the Space Transportation System.

(2) KSC Operations

Last year in its annual report the Panel noted that the Shuttle Processing Contractor (SPC) was struggling to handle the burden of work associated with each mission. Factors associated with these difficulties included: unplanned vehicle modifications, unexpected anomalies, shortage of spare parts, shortage of qualified technicians, heavy paperwork burden, planning and communication concerns, and some lack of hardware reliability. The past year has seen progress in resolving these problems but most of them are still present in some degree and will likely persist for the foreseeable future, thereby limiting the extent of "operational" status the STS is likely to achieve. Specifically:

(a) SPC Performance. The SPC is improving its internal planning and operations through better communication within the SPC operation and with KSC and other NASA centers. Presence of SPC representatives at the centers has helped considerably. Workflow at the VAB and the pad seems under control. However, the Orbiter Processing Facility (OPF) capacity will have to be increased if the projected flight rate for 1987-1988 is to be achieved. Data systems to provide a common base of information around which to schedule the flow are still being developed, for example, all configuration management systems are outside the SPC's control and will remain so for the foreseeable future. Unplanned modifications now require only about 5% to 8% of the processing time, a considerable improvement; however, about 35% of the time is still devoted to responding to unplanned tests or change-outs resulting from flight concerns and anomalies.

(b) Hardware. The major processing problem is still the unpredictability and unreliability of principal flight and ground items, which is not a problem the SPC can address on its own.

(c) Spares. The advent of Atlantis (OV-104) in service means that, in the short term, the spare parts problem will be more difficult since it will be harder to cannibilize needed parts. NASA's spares acquisition is receiving a great deal of attention but the shortages will exist for months and probably years.

(d) KSC and SPC Reorganizations. Both the SPC (in May) and KSC (in October) announced reorganizations and changes in personnel towards the shared objective of evolving a more "operational" organization.

In addition, agreement was reached on shifting responsibility for orbiter sustaining engineering and logistics from JSC to KSC. However, as expected, the shift to a truly "operational" STS will still be gradual and evolutionary.

(e) Flight rate. Given existing constraints--hardware, spares, modifications, absence of data systems, manifesting difficulties--the goal of 18 flights per year is not within reach at present. A more realistic goal is between 12 and 15 per year. The best composite time to date (best time at each facility, OPF, VAB, Pad) is 44 days. KSC hopes to reduce it to 35 days in the near term and, hopefully to 28 days eventually (goal). One fact is increasingly evident: sophisticated payloads result in long occupancy times in the OPF. Centaur, in particular, is very time consuming in this regard. Such facilities as the Orbiter Maintenance and Repair Facility (OMRF) will help ease the load in the OPF.

(3) Logistics Management

The logistics management responsibility transfer to KSC should be complete by 1988 with JSC retaining control of flight software and avionics, aero loads and thermal analysis and major system upgrades. A KSC/RI Downey contract will be executed on or about January 1986 putting the new arrangements for logistics and sustaining engineering into effect. Included in this program is a plan for RI to develop full TPS shops at KSC by March 1987 using Lockheed and RI tile-making techniques.

The entire spares program is being "restructured" to comply with budget restraints. The premise here appears to be that, since the spares provisioning was actually structured for 24 flights/year, it can be tailored downward for 15-18 flights/year with minimal effect until 1991. A significant element of this restructuring is the use of planned cannibalization and the identification of high-value critical spares items.

A continuing and full-blown effort is needed to upgrade Line Replaceable Units (LRU's). Many LRU's today continue to create serious logistic problems because of extremely limited lives and/or a degree of unreliability. These situations may, in the long run, limit turnaround times and thus the number of flights per year. In the case of extremely high risk designs, NASA should plan ahead by early budgeting of funds for product improvement programs instead of waiting until serious problems exist.

The Panel understands that limited budgetary allocations are forcing another assessment of spares procurements. Today, cannibalization is a prime means by which many spares are provided. Today, STS 103 is the major "spare parts bin." Because of deferral of initial flight out of Vandenberg, this vehicle is being cannibalized of LRU's to use on other vehicles. What crisis will develop in six months when these units are needed for first flight out of Vandenberg?

Finally, there has to be a minimum allocation of spare units to permit the planned number of flights. Reducing the allocation of spares to fit the budget is going at the problem backwards. If, however, this sort of action becomes a fact of life, then realistic planning should be accomplished to establish the number of missions that can realistically be flown based on such curtailments. The number of missions should be based on real capability.

An SPC safety awards program has been instituted and various mishap, incident and safety alert programs have been established. Safety alert programs exist in each directorate and a suggestion program has been implemented. Some 4,000 SPC employees have now received safety indoctrination and training. A corporate level Safety Advisory Board has been working with KSC and VAFB organizations to further assure STS safety.

2. Shuttle/Centaur

It is quite apparent that the problem of mating the successful Centaur (an unmanned design) with the manned Shuttle was underestimated by everyone. The extent of the changes to Centaur to be compatible with the redundancy and safety requirements of the manned Shuttle are such that new qualification and certification testing is required in many component and subsystem cases. This testing is occurring late in the program and may well be the most critical problem in meeting the schedule. The lateness, it turns out, is not so much a result of technical problems but rather of the initial decision to treat the Centaur as a payload, independent of the Shuttle. Much of the electronic hardware is late owing to problems with parts like the relays and in acquisition of hi-rel solid state devices (an endemic problem for small lot purchasers). This organizational posture inhibited or delayed the recognition of the magnitude of the system integration task posed by Shuttle-Centaur.

The Panel has followed the technical progress of this program and while there are some current worries, they revolve more around the results of unfinished testing for certification rather than perceived real problems. Our concern really is: can the volume of outstanding work be done in time to meet the schedule? The program is aware of this and appropriate emphasis and the show stopper, if there is one, is the sheer magnitude of the work to be done and the lateness of component and system qualification and verification. This problem has been evidenced in previous reviews but should have subsided by now. It has not. Design changes are still being made, for instance some 20 changes in the ground launch system to shift its philosophy from fail safe to fail operational. This is a worthwhile goal and natural launch system evolution but should not burden the system--if it does--prior to Galileo and Ulysses deadlines.

The system should realize that the old philosophy that technical perfection is more important than schedule has changed with Galileo and Ulysses. Management must now schedule with sufficient margin so that adequate technical peformance can be obtained for fixed schedules. It is the difference between a development program and a transportation system. The case in point is that more than a few systems are to be verified or qualified as a result of the wet countdown on the pad. This simply does not allow any time for corrective measures should problems develop. Program management should prioritize the remaining work so that if necessary items essentially in the "confirm for the record" class can be waived.

There are several technical problems that do not appear to be crises but nevertheless are of concern.

First, some Kevlar fibre used in manufacture of helium bottles on the CISS became streaked with oil as a result of a leaking motor. There is some question as to whether or not there is a degredation of fibre strength as a result. Helium is necessary to drain the Centaur tanks in an abort and in that case a helium tank becomes a single failure point. There are not enough new tanks to change out all the suspect tanks and hence the prudent thing would be to reduce tank pressure somewhat until the matter is resolved. A study is underway to see if margin is available to do this.

Second, the five inch fill and drain valve, also a single failure point, albeit with a long and successful history, has experienced some cracking of the metal lug or tang that drives the valve. The analysis testing and explanations seem to be reasonable and the recommended solution is straightforward and seems to entail no risk. The Panel agrees with the actions taken on the basis of the material presented but it is very late in the program for this type of action.

Third, the central control system uses five control units in a voting system. These units use relay logic involving magnetically latched, multi-pole relays. The complexity is such that there are many--in the tens--relays and the circuit is particularly sensitive to a fault where a relay hangs up in midposition. This can occur if contamination can get in between the poles of the magnetic latching mechanism. A second manufacturer has been located whose commercial relays are of significantly better quality. The relays are physically interchangeable and a sufficient supply is on order to change out all such control unit relays over the next couple of months, but again it is late and test time on the new relay banks will be very limited.

3. Space Station

The Panel recognizes that the Space Station program is in the formative period of development of both its organization and staffing and its architecture and baseline operational concepts. The current Phase B activities covering a 21 month period initiates the contracted activities that will lead to the launch and operation of the Space Station program elements which include the station itself, space platforms, and orbital maneuvering vehicles. Concurrent with the competition for the Space Station definition and preliminary design which leads to a thorough understanding of Station systems prior to hardware development, NASA has begun a technology development program that is to enable the incorporation of the "proper" level of advanced, sophisticated systems aboard the Station.

The Phase B period has two sequential parts, System Definition and Preliminary Design. Space Station management has noted that the following is needed prior to the initiation of Prelminary Design:

a. System Definition which covers the manned core, platforms and man-tended interfaces, allocation of functions/resources to each element, and the international aspects.

b. System Requirements which must be met by the design.

c. Plans, schedules and options/alternatives regarding resource allocations, automation and robotics, logistics, etc.

As a result of the Panel's early reviews of the Station, the following comments are made:

a. The Space Station organizational structure is quite complex with roles and missions and responsibilities difficult to discern at times. There is and will be occasional frustration in coping with the myriad of management prejudices and opinions that exist. The program is coping with and satisfying these multiple requirements. The system seems to be working. A process is evolving for crystallizing decisions that attempt to satisfy user requirements as well as budget concerns.

b. There is some question as to whether NASA is adequately qualified to handle the complete integration of Phases C and D--the hardware and software development. NASA is very good at overseeing conceptual efforts. It has in-house depth of knowledge not to be taken in or misled by others, but integrating a large development effort such as STS and now Space Station is something else. To our knowledge NASA has never performed this role before.

c. Since the Space Station exists in an essentially benign environment compared to the Shuttle ascent and entry environment it may be worth the effort to alleviate the ascent environment requirements which drive much of the design for the Space Station equipment and "user" hardware.

d. Since there are many similarities between the STS and Space Station programs, looking into the "lessons learned" relating to the early days of the Shuttle might better define Space Station actions to preclude missteps. This understanding of possible pitfalls for the Space Station program might include insight as to what <u>not</u> to do, thereby preventing inefficient use of resources (money, people, schedule).

Meeting the Space Station Program objectives within a stringent budget requires early, quick, definitive action on the part of progam management at all levels with emphasis on assuring that system engineering and integration organizations have the responsibilities and authority as reflected in the organizational structure. This assumes a commonality of approach to every critical aspect of the Station by the NASA Centers (e.g., safe haven/rescue, design and operational simplicity, crew support for IVA and EVA, safety threats). The following taken from NASA Contractor Report 3854, June 1985, is instructive:

> "It is interesting to trace the evolution of crew safety philosophy through space programs, and to understand the reasons for this evolution. Table 2-2 illustrates key features of these philosophies or goals. The safety philosophy which was baselined for the crew safety alternative strategies study was consistent with these trends, and is shown in Table 2-3, selected from a few potential philosophies."

TABLE 2-2 EXPERIENCE IN THE DEVELOPMENT OF SAFETY PHILOSOPHY IN SPACE PROGRAMS

PROGRAM	SAFETY PHILOSOPHY	RATIONALE
APOLLO	CREW SAFETY GOAL, .999 ABORT CAPABILITY IN ALL MISSION PHASES BACKUP MODES FOR CRITICAL FUNCTIONS	MANY UNKNOWNS AT TIME WORLD-WIDE EXPOSURE OF PROGRAM
APOLLO-SOYUZ	ABORT CAPABILITY IN ALL PHASES BACKUP MODES FOR CRITICAL FUNCTIONS	PROVEN HARDWARE SINGLE MISSION
SKYLAB	LAUNCH CREW AFTER SKYLAB SUCCESSFULLY ORBITED CREW ESCAPE AVAILABLE BY APOLLO CSM	USE OF EXISTING HARDWARE

SPACE SHUTTLE	ABORT CAPABILITY USING THE ORBITER LIMITED CREW ESCAPE SYSTEM DURING ORBITAL FLIGHT TEST	SPACE PROGRAM MATURITY EMPHASIS ON ELIMINATING OR CONTROLLING THREATS RATHER THAN ESCAPING FROM THEM

TABLE 2-3 SPACE STATION PHILOSOPHY PRECEDENCE

CURRENT OPTIONS	COMMENTS
CAUSE NO DAMAGE WHATSOEVER TO SPACE STATION AND NO INJURY TO CREW	DESIRABLE: COST TRADE
CAUSE NO DAMAGE TO SPACE STATION BEYOND ROUTINE MAINTENANCE CAPABILITY	COST TRADE
CAUSE NO DAMAGE TO SPACE STATION OR INJURY TO CREW WHICH WILL RESULT IN A SUSPENSION OF OPERATIONS	BASELINE PHILOSOPHY

4. Life Sciences

This year's activities have shown that Extravehicular Activities (EVA) will continue to be used extensively. The Leasat rescue mission is an outstanding example of EVA. Certainly the space station will require extensive EVA for its construction and operational activities. The current suit continues to function very well despite its limitations. However, there is a perceived need for a more flexible suit in the future that has the capability of operating at a higher pressure than the current suit and its development should beencouraged so that it can succeed the current suit on an attrition basis.

While it is much too early to be resolved, there has been considerable discussion relating to the makeup of the Space Station life sciences module(s). Discussion has covered separate modules for life sciences and materials research versus separation into noisy and quiet modules. The Life Sciences Advisory Committee (LSAC) currently favors the latter approach. However, decisions in this area are yet to be made. Budgetary constraints will also be a factor in the decision process.

The LSAC notes that there is a lack of knowledge relating to the physical condition of astronauts after long duration flights. They have no hesitation about approving in space duty tours of three months or less. Anything beyond this is subject to question. It is true that the Russians have had cosmonauts in space for seven months, but these men required extensive periods of hospitalization after return to earth. NASA's management must continue to support the efforts of the life sciences group to develop the necessary data to establish, with confidence, what the maximum stay in space should be.

NASA is continuing its suit research activities at Ames with the toroidal metal for arms and legs. Perhaps the way to go is not to change suit pressure but to design these arms and legs as replacment for the current ones. The current glove design which is critical is good to 6+ psi.

5. Research Aircraft

Flight research is essential when technology development on potentially important and promising new concepts cannot be completed using analysis, simulation, and ground tests alone. Factors such as geometric scale effects, handling qualities, flight environment, dynamic behavior, pilot/flying qualities interface, and the interactions among multiple discipline technologies and system components, make flight testing an absolute necessity in the investigation of some technology advances. Two current NASA experimental aircraft programs, the forward swept wing X-29A and the X-Wing Rotary-to-fixed blade, involve such flight research.

a. X-29A Research Aircraft

The overriding objective of the X-29 aircraft is to validate and document the benefits of the Forward Swept Wing concept and its interactive technologies by the most affordable means available. The X-29 flight control system is by far the most technical advanced fight control that has ever been flown managing multiple control surfaces and a large negative static stability margin in subsonic flight.

There was a concern about landing with the analog reversion mode of control after failure of the digital system, since project pilot evaluations of the analog mode in the CALSPAN airborne simulation had shown a strong tendency for a potentially dangerous pilot induced oscillation (PIO) in roll in the landing configuration. Subsequent flight tests in the X-29A at safe altitude using precision formation flying tasks in the analog reversion mode and in the landing configuration showed no problem. The CALSPAN simulation is being revised to reflect flight measured derivatives instead of predicted values.

Installation of a new set of sensors for establishing aerodynamic parameters is complete and allows for the variation of gains of the analog reversion mode for safe expansion of the X-29A envelope into the transonic and supersonic flight regimes. The aircraft has flown transonic/sonic to a Mach number of about 1.03.

The basic divergence avoidance design of the wing structure has been proven by previous analysis and tests. The maximum allowable "g" is currently 6.4 g. The aircraft has been designed for a maximum of 8 g; however, since the wing was not subjected to an ultimate design load test (to destruct), the 80% design limiation has been applied. The flight program of gradually expanding the allowable from 6.4 g to 8 g should be implemented. This will be necessary if the full value of the integrated, advanced technologies are to be tested. The high degree of test instrumentation and the telemetry should allow this expansion to be done safely.

The aircraft is clean and decelerates slowly. Should incipient flutter be encountered inadvertently, for instance, rapid speed reduction would be essential for survival. More generally, if the dual-pump engine-driven hydraulic system should fail, considered an unlikely event unless the engine should stop rotating (freeze), the emergency hydrazine system will drive the pumps for <u>only</u> seven minutes. At the end of that time the controls will "freeze" and the aircraft will diverge longitudinally in a violent manner when in subsonic flight because of its 35% negative static margin. Unless at low speed (low dynamic pressure) in such a case the aircraft may encounter severe adverse structural or crew impacts. To avert such serious consequences speed brakes would enable rapid slowdown to safe structural speeds for ejection or to enable a safe landing on the desert floor if sufficient time remains. Safety considerations suggest that engineering of speed brakes be initiated for possible later retrofit to both X-29A airframes, with installations to follow at a convenient time in the respective programs. Considering the number of new technlogies involved and the fact that the X-29 is a new aircraft, the flights to date have been remarkably trouble free.

b. X-Wing Rotor Systems Research Aircraft (RSRA)

The X-Wing flight investigation project objectives are to develop and demonstrate, in flight, X-Wing rotor design, controls, and pneumodynamics technologies. This is to be accomplished by concentrating on the conversion from rotor to fixed blade activities, by investigating dynamics, performance, and control within a limited envelope, and thereafter to establish a safe envelope and flight procedures for X-Wing research. The approach being followed is basically to:

(1) Design, build and ground test an X-Wing rotor and control system, including supporting research and technology.

(2) Install the X-Wing and Flight Control System in a modified Rotor Systems Research Aircraft (RSRA) and conduct a 40-hour flight test program.

The X-Wing program has been laboring under an overly optimistic schedule. The Program is working on the leading edge of new and complex technologies, such as:

(1) Circulation-control rotor, encompassing pneumodynamics and its intricate system for metering the required airflows at a high sequential rate, as commanded by digital software.

(2) Starting and stopping a lifting rotor in forward flight, eventually without benefit of a fixed wing (looking beyond the RSRA).

(3) Essentially total dependency on very sophisticated digital electronic systems controlling blade-trailing-edge airflow for lift and control, as well as for higher harmonic vibration suppression, superimposed.

(4) Development of slender, composite rotor blades (swept wings when stopped) which are to resist structural flutter and divergence while carrying, internally, air at temperatures of 250-350 degrees Fahrenheit.

The Program schedules have slipped; the first flight in the stopped-rotor configuration is now being scheduled for the first of 1987. Tests with the propulsion systems test bed (PSTB) and the powered "flying" wind-tunnel model are just getting under way, the latter a key to safe and successful flight of the X-Wing.

The Sikorsky safety program, supported by experienced engineering from the Sikorsky Executive Safety Committee, now seems to have appropriate emphasis and manpower allocated for avoiding or alleviating problems. Slippage of schedules has and will occur because of the sizeable tasks involved and an optimistic and unrealistic original schedule. However, it is mandatory in this program to proceed carefully and thoroughly, regardless of schedules.

The overall safety program for the X-wing/RSRA has many aspects and organizations. These include the Ames and Dryden safety reviews, the Sikorsky Flight Safety Board, and subcontracted analyses by Boeing (BSI in Houston, Texas) for a Hazard Analysis of the entire vehicle and the Northrop Corporation for fixed wing aeroelastic support. The results of the powered model wind tunnel test, the Propulsion System Test Bed (PSTB) dynamic test and the extensive flight control simulation efforts will form the real foundation for verification of the flight safety of the vehicle design.

The principal airframe restrictions of high speed performance for a forward swept winged aircraft is aeroelastic divergence. On the other hand, aeroelastic flutter is usually the limiter for aft swept winged, high performance aircraft. The X-Wing aircraft is unique in that it has both a forward and an aft swept wing when operating in the fixed wing flight mode and therefore could be limited by either flutter or aeroelastic divergence. The traditional procedure for ensuring the absence of these catastropic aeroelastic phenomena is to first design the structure to withstand the flight loads (a strength design) and subsequently to re-analyze the strength design to detemine the point (dynamic pressure and velocity) where flutter or divergence would occur. If this point is outside of the flight envelope, no further design modification is needed. Otherwise, modifications must be made to add additional stiffness to the strength design. Like other theoretical analysis, there are many assumptions and simplifications inherent to the method used for determining the flutter or divergence point; consequently, if the calculated point is near any point of the flight envelope, it is prudent to build an aeroelastic model of the entire aircraft or possibly of the airfoil surface in question (wing or tail). Due primarily to tail rotor restrictions, the maximum dive speed of the RSRA X-Wing has been set at 300 kts. With the standard aeroelastic safety factor this establishes 345 kts at sea level (the region of maximum dynamic pressure) as the aeroelastic design velocity. Albeit, the aircraft design must not possess either a flutter and a divergence point below this velocity. Indeed, the absence of all instabilities at velocities below 345 kts (a dynamic pressure of 300 lb/ft2) must be established by a combination of wind tunnel and analytic programs.

The RSRA/X-Wing represents the first time that an aircraft has been designed to operate at speeds above the airframe aeroelastic instability point. This requires the active control of the aeroelasticly unstable modes by the flight control system (in addition to the unstable rigid body modes); and therefore, makes it the most complex FCS design ever attempted.

6. NASA Aircraft Operations

The Intercenter Aircraft Operations Panel continues its preparation of guideline documents to serve as basis for management instructions to be issued by Headquarters. This is currently the only practical way in which central direction is provided covering all aircraft operations. This process is extremely slow because of the need to obtain approval of all flight operations chiefs, to coordinate these through a central office in Headquarters and to obtain final approval through the NASA heirarchy. Further, the failure, for another year, to appoint a head of the Aircraft Management Office in Headquarters further slows the approval process. There is a great need for a <u>fully qualified</u> operations manager for this program.

Ideally, there would be a single flight operations entity, reporting directly to the Administrator or Deputy Administrator. This entity would have direct and overall responsibility for all flight operations functions, whether administrative or research and development. Flight operations divisions would be located as they are today and would provide service to the various centers, but would not report to the center. Budgets would be centralized and apportioned in accordance with the needs for routine operations and maintenance. All center projects would then become contracts between flight operations and the specific center.

E. NASA'S RESPONSE TO PANEL'S CY 1984 ANNUAL REPORT

Taking each of the items covered in both the Annual Report and the NASA response to it, the following items are "Closed" or "Open" as noted. Of 20 items, 14 are "closed" and 6 are "open." Those that are "open" are still in work with implementation yet to come. The numbering sequence follows that in the NASA response.

1.0 Launch Processing and Logistics

1.1 CLOSED - Panel will continue overview of KSC (NASA and contractor) manpower ability to meet increasing flight rate while maintaining an acceptable level of safety including effects of "operational efficiencies" through 1988-89 to reach 24 flights per year.

1.2 CLOSED - Continue overview of Orbiter Hardware/Software upgrades (other STS elements as applicable) to assure such modifications/changes do not adversely affect reliability, maintainability and/or safety (and sparing requirements).

1.3 CLOSED - Proposed letter from Jesse Moore to Center Directors and NSTS management indicates, "We must take further action to assure the required increase in the Shuttle flight rate which necessitates a steady reduction in turnaround activities. . . . The change and modification work in the OPF (Orbiter) has been highlighted as the key driver . . ." Panel continue oversight of this concern.

1.4 CLOSED - Operations organization and management discussions.

1.5 a. CLOSED - Use of the term "operational" as applied to the Space Transportation System was addressed in great detail. . . . It is not considered an "airline" by NASA.

b. OPEN - Transition of tasks (particularly sustaining engineering) from JSC to KSC. It was noted that a plan was in process and that Panel should follow the implementation of this transition during 1986-87.

c. OPEN - The following additional points:

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

(2) Review the launch constraints being modified in order to increase launch probability and turnaround mods as well.

(3) Comprehensive maintenance plan supposed to have been released September 1985.

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

2.0 SSME precursor test program to be completed during CY 1985. (OPEN)
Competitive engine (turbopumps) program RFP on the street. (CLOSED) Panel will follow this in 1986.
Phase II and II+ on going. (CLOSED)

3.0 Filament Wound Case follow-up including: Vehicle excursions, lift-off loads alleviation, lift-off drift concerns, flight control stability impacts due to elastic properties, FRF impact on structural adequacy of "single-use" first flight segments (OPEN)

4.1 Results of Rockwell's detailed fracture/fatigue analyses for test article LI-36 (wing/mid-fuselage/aft-fuselage structure being conducted June 85 to January 86. (OPEN)

4.2 Individual Orbiter Delta's and performance capability-structural limitations and load indicator redlines. Follow in 1986 (CLOSED)

4.3 Orbiter Brake Upgrade - Many activities started, some tested, some on-going activities Structural carbon use fail op/fail safe Nose Wheel Steering system vs. current fail safe, etc. Panel follow these in 1986. (CLOSED)

5.0 Development of higher pressure EVA suite. (CLOSED)
Note the following from Beggs' response: "The current Agency posture for further space suit developments will be addressed in the Space Station Phase B requirements definition. These requirements will be evaluated, and a determination will be made as to the acceptability of the current Shuttle system, of an enhanced system or the need for a new high pressure system."

6.0 Orbiter OV-102 in an R&D role with appropriate instrumentation. (CLOSED)

7.0 KSC/VAFB common operations. (CLOSED)

8.0 Shuttle/Centaur to adequately conduct tests within current schedule and the availability of resultant analyses is a concern. (OPEN)

9.0 RTG Safety (First Centaur missions). Maintain awareness. (CLOSED)

10.0 NASA's R&D and Administrative aircraft operations management and policy implementation. Panel continues to monitor. (CLOSED)

NASA

National Aeronautics and
Space Administration

Washington, D.C.
20546

Office of the Administrator

September 25, 1985

Mr. John C. Brizendine
Chairman
Aerospace Safety Advisory Panel
6306 Bixby Hill Road
Long Beach, CA 90815

Dear John:

Enclosed for your consideration is the NASA response to the findings and recommendations provided by the Aerospace Safety Advisory Panel in its Annual Report for 1984.

This year I have also commented on the additional discussions contained in the "Fact Finding" section. Where our positions have been modified from those stated in the past report, I have noted those changes. Comments which specifically address the report's 10 recommendations are submitted in the respective appendices.

The panel's guidance and support is always appreciated. Your inputs have been and continue to be important management tools in the guidance of NASA.

Sincerely,

Original signed by
James M. Beggs

James M. Beggs
Administrator

Enclosure

APPENDICES 1 TO 10, NASA RESPONSE TO THE 1984 ANNUAL ASAP REPORT

APPENDIX 1: LAUNCH PROCESSING AND LOGISTICS

ASAP Recommendation 1.1

NASA management should continue to allocate the human and financial resources required to maintain acceptable levels of safety in what in many respects is still a developmental program from the point of view of the ultimate use of space as well as the maturity of the system.

NASA Response: We believe the level of manpower being applied by the Shuttle Processing Contractor (SPC) at both KSC and VAFB is commensurate with the high safety standards and requirements of a manned space flight program and NASA's overall program goal of evolving the Space Shuttle into a cost effective operation. The maturing, developmental nature of the program is recognized and the essential need for constant safety and quality assurance vigilance is a continuing concern. NASA is committed to continuation of the required resources to maintain an acceptable level of safety.

The number of KSC Shuttle operational personnel remains fairly stable. The number decreased when the SPC came on board early in FY 84 and has remained almost constant for the last year (decreased approximately 1%). We expect it to increase some in the next 1½ years because of additional work stations coming on-line (i.e., Pad B, MLP-3, Logistic Warehouse), and then decrease with operational efficiencies through 1988-89.

The KSC safety policy has not changed since the SPC concept has been implemented. However, the contractor now has responsibility for the implementation of that safety policy with NASA civil servants practicing an oversight and surveillance role. The number of safety personnel actually increased from approximately 35 to 45 under the SPC. This increase was considered necessary as a result of the increased launch processing activity and higher launch rate.

ASAP Recommendation 1.2

Modifications to the Orbiter -- such as main engine, structure, avionics, and brakes -- should be directed at improving reliability, maintainability, and safety as well as achieving additional increments in performance.

NASA Response: I concur wholeheartedly with this recommendation. A large percentage of Orbiter changes are made for these reasons. Examples of modifications which will improve reliability, maintainability and/or safety are the improved APU, IMU, fuel cell, brakes and nose wheel steering. The EEE parts program is also directed at improving reliability for the GPC and IMU. Engine Improvements are discussed in Appendix 2.

ASAP Recommendation 1.3

NASA management should make a concerted effort to identify and prepare for Orbiter modifications prior to commencement of the launch processing sequence. "Freeze point" discipline must be maintained. Unexpected changes and modifications must be held to a minimum if the Shuttle Processing Contractor (SPC) is to achieve the projected flight rate.

NASA Response: Over the past year, the Level 2 and 3 program offices have made concerted efforts to identify and permit preparations at KSC for Orbiter modifications prior to commencement of the launch processing sequence. The Panel is invited to JSC to receive full details on the operation of the system, referred to as the Rockwell BARS (Baseline Accounting and Reporting System). That system provides KSC with computer access to all mods. Mods are identified on a per flight basis as well as a total listing. Changes are prioritized as either mandatory prior to a particular flight or as those which are to be installed at the first available opportunity. A program directive (PRCBD S31730) has been issued which is the implementing document. Copies of the presentation material and the directive are available for review.

ASAP Recommendation 1.4

Vesting overall Shuttle management in an "operations entity" at NASA Headquarters would help achieve acceptable levels of efficiency, productivity, and schedule reliability during this period of "developmental evolution." The Panel has made this recommendation in past years and NASA management is presently examining this and related issues through the Shuttle Operations Strategic Planning Group, the Smylie Committee.

NASA Response: I feel that the Agency is making strides in the direction of an operations entity which the Panel suggests is the proper course to pursue. Since I reported to you last year, the SPC (Shuttle Processing Contractor) is onboard and has successfully launched all vehicles since STS 41C. The contract for operations at JSC is expected to be awarded in January 1986.

With regard to changes at Headquarters, there are several developments that you should be aware of. Within the last year NASA established two groups to study the Space Shuttle's organizational setting and role within NASA. The groups are the Shuttle Operations Strategic Planning Group, chaired by Mr. Ed Smylie and the Shuttle Operations Fencing Team chaired by Mr. Charles Gunn. Copies of the reports from these two groups have been transmitted to the Panel.

The Strategic Planning Group concluded that, for the foreseeable future, the Space Shuttle should continue to be managed and operated by NASA, and outlined several organizational alternatives we are now considering. The Shuttle Operations Fencing Team concluded that the Shuttle operating budgets, organizations, and facilities are now effectively segregated, or "fenced," at each of the operating centers and the consolidation of Shuttle operations contracts (e.g., BOC (Base Operations Contractor), SPC (Shuttle Processing Contractor), STSOC (Space Transportation System Operations Contractor) and FEPC (Flight Equipment Processing Contractor)), plus the evolution from fixed fee to cost incentive contracts, further promotes fencing of the Shuttle from other NASA programs. The Fencing Team, in consonance with the ASAP recommendation, also recognized a need to change the balance between development and operations within NASA Headquarters to place more employees in operations. The Office of Space Flight has reorganized to better focus on requirements, issues, and procedures, which are dominant in operations, as opposed to acquisition and development.

<u>ASAP Recommendation 1.5</u>

NASA management would be well advised to avoid advertising the Shuttle as being "operational" in the airline sense when it clearly isn't. More to the point, however, is the fact that Shuttle operations for the next 5 to 10 years are not likely to achieve the "routine" character associated with commercial airline operations. Given this reality, the continuing use of the term "operational" simply compounds the unique management challenge of guiding the STS through this period of "developmental evolution." NASA should continue to focus on making the STS as efficient, productive and reliable <u>as possible</u>, while the research and development flights are defining the commercial use of space.

<u>NASA Response</u>: National Security Decision Directive (NSDD) 42 states that NASA's first priority is to make the STS fully operational and cost-effective in providing routine access to space. NSDD 144 directed that NASA and DOD jointly define "fully operational and cost-effective" and the specific steps leading to that status. Our definition is provided below, and you will note that nowhere is a reference or an analogy made to airline characteristics. As illustrated elsewhere in this report, I believe we have set in place policies, procedures, practices and processes to make the STS as efficient, productive and reliable as possible, while

balancing the necessity to be cost-effective in the world's marketplace.

Excerpt from NSDD 144

DEFINITION OF A FULLY OPERATIONAL AND COST-EFFECTIVE SPACE TRANSPORTATION SYSTEM

Introduction

NASA's highest priority is to make the Nation's Space Transportation System (STS) fully operational and cost-effective in providing routine access to space. Fully operational means that the STS is ready and available for routine use in the intended operational environment to achieve the committed operational objectives. This means that critical performance capabilities have been verified by flight demonstration; that adequate logistic support for the systems is in place; that the ground and flight processing capabilities are adequate to support the committed flight schedule of up to 24 flights per year with margins for routine contingencies attendant with a flight surge capability; and that the appropriate operational management capabilities are in place. Cost-effective means that the Shuttle provides space services for specific levels of mission capabilities with an effectiveness at least equivalent to the cost of alternative systems. The definition must recognize the unique capabilities of the Shuttle that cannot now be attained by alternative systems. Cost-effectiveness is a function of the unique capabilities required by each category of mission (e.g., launch and deploy, retrieval, on-orbit repair, refuel, assembly, life sciences R&D, and man tended services and applications). As the Shuttle becomes fully operational, its cost-effectiveness in all categories across its full spectrum of space missions can be improved by continued reduction in operating costs.

Joint NASA/DOD STS program capabilities, requirements, and plans for development, activation and operation of the Space Shuttle through the mid-1990's are defined in the NASA/DOD Space Transportation System Master Plan, Part I: Baseline Operations Plan, chartered by the NASA/DOD Aeronautics and Astronautics Coordinating Board. This plan was published in mid 1985 and states:

I. Fully Operational STS

The STS is fully operational when specified levels of capability and maturity have been achieved in (A) Systems Capabilities and (B) Management.

The Agency continues its evolutionary process of becoming "operational." Great strides were taken this spring when JSC and KSC reached an agreement on definition of center roles and responsibilities for the STS operations era. As stated in the JSC memorandum, dated May 7, 1985,

> "KSC will assume responsibility for the integrity of and sustaining engineering for all certified Orbiter flight hardware, flight readiness certification and Orbiter configuration control. KSC will also be responsible for flight hardware spares and logistics activity. The sustaining engineering responsibility includes the LSSC, which may be an early transition step.
>
> JSC will retain responsibility for development and certification of new or upgraded Orbiter flight hardware. JSC will also retain responsibility for long lead planning for the fleet/manifest, mission analysis, flight software, avionics as a system and the analytical disciplines such as loads, thermal, aero and the like. JSC will continue to provide on-call engineering support as required."

A plan to implement that policy is being developed by KSC.

Discussion of Fact Finding Points for Recommendation 1

The following paragraphs address points raised by the Panel in the "Fact Finding" section of your report.

With regard to the ASAP comment that "there must be no disruption in the operational support adequacy and ability to safely launch and turnaround the Space Transportation System as currently operating," NASA continues to assess methods of reducing turnaround times and optimizing operations. Where a decision is made to reduce or optimize, careful analysis is given to ensure that operational adequacy is maintained and that the safety of the Shuttle during turnaround and launch and landing operations is always maintained.

We concur with the Panel's statement that "Personnel are a key resource and provisions must be made to "feed in" new people to replace, as necessary, those leaving." This has been one of the major goals which I established for NASA.

During FY 84, of the 384 scientist and engineer (S&E) new hires, in NASA, 246 (64%) were at the GS-9 grade or below. This represents a continuation of the "fresh-out" initiatives begun in FY 82. For FY 82-84, 1449 S&E's were hired and 1049 (72%) were at the GS-9 grade or below.

The Panel notes that "traditional organization arrangements, review methodology, handling of payloads, and system certifications cannot remain static but will change with STS maturity and accompanying knowledge and objectives" and that "complacency at any point in the process must be guarded against." NASA is presently seeking an STS Operations Contract contractor to consolidate the Shuttle operations tasks at JSC. The purpose is to improve cost-effectiveness via consolidations of mission operations during the STS operations era while maintaining a high level of technical performance. The contractor will be given considerable latitude in forming and developing an approach based on his unique capabilities and experiences. The STS basic program objective of reliable and economical space transportation is paramount; conformance with the historical "business as usual" approach, typical of development and test programs, is not. We expect this new contractor to begin operation in January 1986.

From an STS cargo processing standpoint, there are a number of enhancements underway or planned that will reduce the handling times of STS payloads. Our customers are encouraged to qualify payloads for flight ready storage in order to minimize their pre-launch time at the launch site. They are also urged to provide an adequate number of personnel to facilitate multiple-shift work as required, so as to minimize stay time.

On a payload-by-payload basis, technical assessments are conducted to determine whether stand alone, simulated mission sequence, or end-to-end testing can be eliminated. A continuing effort is underway at JSC to identify ways to simplify the payload-to-Orbiter interfaces. As interfaces are simplified, payload installation and subsequent check-out procedures will be streamlined, resulting in time savings. Although efforts are being made to minimize or delete unnecessary payload operations, care will continue to be taken to insure that necessary procedures are not neglected.

The ASAP observes (page 39) that "a specific aspect of the management process which bears further attention are the 'Program Freeze Points' and their use. Program freeze points are established at specific intervals during flight processing. Freeze points are defined as those points in time when the design, definition, and content of the cargo, integration hardware/software and flight design, vehicle flight hardware/software, crew activities/stowage and launch site flow are complete. Subsequent to these points, only mandatory changes to the hardware, software or affected documentation are permitted (mandatory changes are those necessary to ensure crew/vehicle safety and/or accomplishment of primary mission objectives). Such freeze points are established for each mission."

The management of "Freeze Points" is receiving significant attention within NASA and the Shuttle customer community. Changes to the design/definition/content decisions made at the

"Freeze Points" are being resisted so that the mission design and planning can proceed in an orderly fashion. The schedule of the Freeze Points is a compromise between the desires of the customers (who would like the "Freeze Points" scheduled as late as possible to allow flexibility in cargo design) and the mission planners (who would like the "Freeze Points" scheduled as early as possible to allow time for mission design). NASA is developing techniques and tools to increase the productivity in the planning efforts and, thus, better support the customers.

"Preparations for contingency landing site (CLS) activities must be planned to meet mission goals and to minimize expenditure of resources which can best be used elsewhere. (Refer to page 37) CLS activities have been planned with a minimum investment of resources but still provide the ability to support Orbiter operations with safe back-up options. It is agreed these resources could be used elsewhere, but where considered essential, the CLS capability has been provided. Particular CLS attention is being given to the missions involving the launch of radioisotope thermal-electric generators.

"Operational efficiency, as measured by such things as turnaround time reduction, hardware increased reliability (increased mean time between failures), increased crew effectiveness and weather predicting, are all part of operations. Since day of launch winds can affect vehicle aerodynamic loads, better trajectory shaping and load reduction can be accomplished with winds as near to T-0 as possible. The actual "doing" part of launch and landing, along with retrieval of SRB's, has been proven through the STS missions to date. However, one area of continuing interest is the impact of flight vehicle and ground equipment hardware and software changes (both generic and mission unique) and procedural changes upon the ground sites, including modifications to the launch constraints or so-called "red and blue lines."

Operational efficiency has been improving, as indicated by the turnaround time improvement from 187 days for STS-2, to a current average in the neighborhood of 55 days; our best turnaround time to date was 50 days for STS 51-B. Efforts are continuing to achieve additional efficiencies in several functional areas. The weather predicting capability is now being improved through the addition of communications, radar, and other equipment. Also, plans are being formulated for more refined, long-range weather predicting improvement through advanced technology surveys, studies, and applications. Changes are being minimized. Winds are measured by Jimsphere down to L-3.5 hours.

The Panel iterates on page 40 that "a complementary area of interest is the pre- and post-flight mission reviews. The Panel notes, as it has in the past (see Annual Report dated January 1982 and January 1983), that the management review processes remain little changed from those used on early missions. With an increased flight rate, maturing systems and hands-on resources, there remains the involvement of a large number of high level management personnel. Changes made to date in this review system have certainly helped but further streamlining should be expected in the future." It should be noted that the reviews conducted and the reports generated in support of the Shuttle missions are undergoing continual evaluation as to their content and requirement. This effort, even in a "business as usual" context, is decreasing as the program matures and there are fewer problems to be reported and coordinated. Efforts have been reduced through abbreviated pre- and post-mission reports, Headquarters mission monitoring and reporting, and follow-up briefings. I am encouraging the Headquarters staff to reduce the amount of required paperwork, as well as their direct involvement, in these activities. However, it must be anticipated that where unique missions are flown, interest and involvement on the part of high level management will continue.

"The Panel (ASAP) has previously recommended that a comprehensive maintenance plan be established partly as a system to prevent interruptions in the launch rate through the 1990 period and beyond, and partly to provide a more rational basis for the current logistics plan which is now underway. While some elements of maintenance planning are evident, there does not yet appear to be a total plan which would include contingencies such as multiple SSME failures or planned withdrawal of an Orbiter for structural fatigue examination or replacement. This sort of maintenance overview may indeed exist and will be examined by the Panel in the future." (Page 40)

The Panel's observations are proper and a comprehensive maintenance plan is being developed by the Johnson Space Center Logistics Office (LG). The estimated release date is September 1985. We welcome your review and comments.

"The SPC in its operations has uncovered some problems; the most serious of which is shortage of spares. Line replaceable units (units designed for rapid replacement) are in short supply and the only alternative is to cannibalize -- that is to remove a working component from another Orbiter and pay back the loan when the part becomes available. This is a costly procedure in terms of manhours and delay, but the safety implications are those of violating a certified system to get the necessary parts. Another significant problem is that of the workload caused by the incorporation of modifications on the Orbiter at KSC. Even though modifications are scrutinized before the decision is made to incorporate them, further controls may have to be instituted, if the launch rate requirements are to be met. The next year or so should see some improvement in logistics and support problems as the SPC program advances satisfactorily."

Although some spares shortages do exist, the requisition fill rates of both flight hardware (FH) and ground support equipment (GSE) are continually improving. The KSC requisition fill rates for November 1984 through February 1985 are:

	NOVEMBER	DECEMBER	JANUARY	FEBRUARY
FH	88.7	90.9	91.8	90.5
GSE	82.2	84.1	85.0	85.5

Our initial lay-in of spares will be completed in October 1986.

"If OV-105 is ever funded, it will have the beneficial effect of providing a standby vehicle in the Orbiter fleet, but at the same time will sop up most of the available production spares thus exacerbating the problems surrounding each individual launch toward the 1990's. The goal is presently some 20 flights per year from KSC and 4 per year from VAFB. There has been a sizable transfer of experienced personnel from KSC to VAFB and we were told that there are about 1200 LSOC people there now." The long lead time between funding and delivery of OV-105 -- if and when it is funded -- will allow adequate lead time for lay-in of supporting spares. A further logistics benefit to the funding of OV-105 would be that "production line spares" would be available to support the entire Shuttle program for a longer period of time than is presently envisioned. This will undoubtedly further improve our spares long-term support posture.

APPENDIX 2. SPACE SHUTTLE MAIN ENGINES (SSME'S)

ASAP Recommendation

The modified improvement program should be pursued vigorously. All reasonable effort should be exerted to develop the new hot gas manifold and to incorporate it at the earliest date feasible. Activity to reduce start and shutdown temperature transients should be added to the "Phase II+" program. Mission planning should continue to consider 104% RPL thrust as the normal operating level for the engines. We will use the 109% RPL thrust capability only for those missions dependent on the higher thrust and as an abort capability.

NASA Response: The precursor test program scheduled to be completed during CY 85 will include a limited test series (7 to 11 tests) with the large throat main combustion chamber designed to reduce turbine temperatures, modification to control valves to ameliorate start transient turbine temperature spikes and a single tube heat exchanger. The test series will include "bomb" tests of the chamber to determine stability margin and to assess the need for baffles or acoustic cavities. Elimination of these stability aids could provide performance improvement in terms of increased specific impulse.

The competitive engine program is structured to provide an alternative approach to engine design improvements/ modifications which improve reliability and safety by increasing operating margin and extending hardware life.

The baseline program consisting of the Phase II and Phase II+ activities is underway with the Phase II certification testing having been initiated in March 1985 and scheduled to be complete in October 1985. The Phase II+ development testing with the new, 2 duct, hot gas manifold is scheduled to start in May 1986. I should note that this program does not include LOX pump redesign which was indicated in last year's response to the Panel.

The baseline program is now just getting into certification testing, and it is premature to speculate how well these improvements will improve reliability maintainability, safety, and performance. Improved life and operating margin is being realized in the development program testing to date. Until these improvements are made, we plan to limit the current engine to 104%.

APPENDIX 3. SPACE SHUTTLE SOLID ROCKET BOOSTER (SRM/SRB)

ASAP Recommendation

An analysis and tests be performed on the filament wound case with the total stack to establish lift-off loads and vehicle excursions considering the lower modal frequencies.

NASA Response: The analysis conducted predicted a flexible filament wound case. The initial quarter scale testing at MSFC showed that the SRB joint free play was a potential source of increased vehicle on-pad excursions. Tests to the full 125% flight load limit will be performed on a flight segment by January 1986.

As test data from FWC hydroproof testing and sag data recorded during the DM-6 static firing became available, it was found that the entire SRB FWC joint area was much less stiff than expected. The DM-7 Static Test confirmed the DM-6 test results. New SRB FWC dynamic math models were constructed by MSFC, and a special analysis effort of the stacked vehicle was initiated to assess the effect of the recorded stiffness in five areas already thought to be marginal. This assessment was completed in late December 1984 with results as follows in the five problem areas:

1. Vehicle on Pad Excursions (FWC, VAFB): Predicted excursions exceed both the ICD and the range of previous tests. The impact of these results is being assessed by KSC. A new series of tests, exceeding the predicted values by 10%, is being planned for the Launch Equipment Test Facility and will include a new "haunch" assembly simulating the VAFB umbilicals. Results will be verified by the "twang" test at VAFB and supported by Structural Test Article testing at MSFC

2. Lift-off Loads: Significant load increases were predicted at the SRB/ET forward attachment and in crew cabin accelerations. The increased attachment loads have been assessed to be within the structural capability of the vehicle, and the effect on payloads of the increased accelerations has been determined to be acceptable.

3. Lift-off Drift: The clearance between the SRB and the facility during lift-off are essentially unchanged, and the minimum four inch exclusion envelope is not violated.

4. SRB Hold Down Bolt Load: An increase of approximately three percent in maximum bolt tensile load, which occurs at the maximum excursion during SSME build-up, is predicted. MSFC has assessed this increase to be

acceptable due to other actions taken to alleviate the bolt load problem.

5. Flight Control Stability Margin: The predicted reduction in the SRB bending mode frequency was determined to be unacceptable. The flight control systems software has been redesigned to insure acceptable margins. These changes will be incorporated for VLS-1.

Because of the lack of actual test data on the FWC configuration, the development of the math model representations used in these studies has been very difficult and uncertain. The DM-6 and DM-7 sag tests were the first chances to assess actual bending stiffness, and resulted in the most significant change. Special measurements during the DM-7 test did confirm the bending model parameters. Since the interim assessment discussed above, several minor changes that do not affect the above problems have been incorporated in the math models, and the next major analysis cycle is underway. This is the final planned set of studies of the Shuttle/FWC combination and is considered to be the primary verification analysis.

Due to the lack of maturity of our understanding of the FWC properties, additional testing to demonstrate the validity of the verification analysis is considered necessary. A test is planned at VAFB using a fully stacked SRB. The currently baselined twang test will be expanded to include sine-dwell, and random survey testing. A special pull test, using the two SRM's on VLS-1, was also recently baselined to evaluate joint free play and bolt load effects.

Completion of the planned analysis activities and the testing identified above will insure that adequate margins exist in these identified. A flight readiness firing would demonstrate adequate margins regarding bolt loads and excursions driven by SSME build-up, but these items must be demonstrated prior to attempting either an FRF or launch.

APPENDIX 4. ORBITER STRUCTURAL LIFE CERTIFICATION AND STRUCTURAL ADEQUACY

ASAP Recommendation (1)

The Panel agrees with the decision to certify these two articles (LI (Line Item) 31 and LI 36) by analysis. A detailed analysis plan for the two test articles should be developed and implemented to fulfill the certification program for 100 missions.

> NASA Response: A plan to analyze the two test articles does exist. The Orbiter vehicle end item specification requires certification of the Orbiter primary structure for 100 missions times a scatter factor of four. Detailed fracture/fatigue analysis has been completed for LI 31, the wing/elevon structure, and the analysis confirms the capability of the structure to be certified in accordance with the specification. Detailed fracture/fatigue analysis for "LI 36," the wing/mid-fuselage/aft-fuselage structure, started in June 1985. Completion is estimated by January, 1986.

ASAP Recommendation (2)

Conduct a systematic review and document the structural differences, safety margins and major logistics impacts for each Orbiter vehicle. In recognition of these differences, baseline the performance envelope for each Orbiter and, as required, determine the trade-offs between any structural/aerodynamic modifications and performance.

> NASA Response: Trade-off studies between structural and aerodynamic modifications and performance have been conducted for OV-103 and 104. The most productive option in terms of performance gain versus mod complexity has been implemented. This option, which strengthens the X0=1365 wing spar and upper rib caps, results in a net payload gain of approximately 4,000 pounds.

OV-102 has been modified based on the 5.4 loads to bring it in line with the rest of the fleet. OV-099 was modified for 5.4 loads prior to delivery while OV-103 and OV-104 were built to the 5.4 loads. Wing leading edge moment ties have now been added to all four orbiters. Mid-fuselage strap (torsional restraints) additions have been completed on OV-099 and OV-102 and will be completed by flight 10 of OV-103 and flight 7 of OV-104.

With the completion of the modifications stated above, the primary remaining differences between the Orbiter vehicles from a performance/structural viewpoint will be as follows:

a) OV-102 weight is 5,000 pounds greater than the other vehicles, a major contributor being additional flight instrumentation

b) OV-103 and 104 have WTR capability due to upgraded upper surface TPS

c) OV-099 and 104 have Centaur carrying capability

For the near term, structural limitations and load indicator redlines are being provided on a flight-by-flight basis. Long range plans call for the development of a common set of capabilities for all vehicles while taking into account the remaining differences noted above. This will provide the maximum possible launch flexibility in terms of Orbiter vehicle interchangeability, an increasingly important factor as the flight rate increases.

The Panel has expressed concern in the past over Orbiter brakes and the thermal protection subsystem. I have received several briefings on that hardware, in February and May on the brakes and in March on the waterproofing of the tiles. The JSC Director has written Headquarters on July 24, 1985, that they are pursuing a comprehensive and aggressive program to address the landing/deceleration system problems of the Orbiter which consist of a dynamic stability problem and a heat/energy capacity problem. Some key elements of this program are provided below:

1. Provide the changes necessary for routine landings at KSC. The nose wheel steering is being modified to be fail safe, the modifications being accomplished on STS-61A. That will reduce braking requirements by elimination of the need for differential braking for steering.

2. Testing and analysis are being performed to provide increased system damping and balancing of brake puck pressures.

3. A stiffer main landing gear axle is being incorporated. Designs for an automatic braking system and thicker out-board brake stators are underway.

4. We plan to duplicate the brake problems and assess fixes via an analytical and test activity (at Goodrich) and to improve flignt data collection through additional brake instrumentation. Langley is conducting tests to determine the impact of runway surface on brake performance.

5. We have initiated a preliminary design activity for a structural carbon brake system. A PDR is scheduled for September 1985.

6. With the upgrading of the Wright Patterson AFB test facility, the Orbiter strut, wheel, and braking system will be tested with a considerably increased test fidelity.

APPENDIX 5. SPACE EXTRA-VEHICULAR ACTIVITIES (EVA'S) AND LIFE SCIENCES

ASAP Recommendation

NASA should encourage the development of an advanced higher pressure EVA suit to replace the existing unit.

NASA Response: The current Shuttle Space suit has performed excellently since STS-5. All design reach and flexibility requirements have been met and exceed that required for an EVA.

The low pressure suit (4.3 PSIA) maximizes flexibility and glove dexterity but requires prebreathing to eliminate the bends. A higher pressure suit would reduce prebreathe concerns but would sacrifice glove dexterity and increase suit leakage. Of course, the other approach to elimination of prebreathe is reduced cabin pressure. Reduced cabin pressure is the Shuttle's chosen option for bends control.

The current Agency posture for further space suit developments will be addressed in the Space Station B requirements definition. These requirements will be evaluated, and a determination will be made as to the acceptability of the current Shuttle system, of an enhanced system or the need for a new high pressure system. This decision will be made during the FY 1986 or FY 1987 time period.

Key to the decision will be the amount of EVA required and the selected Space Station cabin pressure. The Agency's stated goal is to have one EMU/EVA system, which will satisfy all requirements and be cost effective.

The addition of telemetered data during EVA will reduce requirements for crew call down of data and will expand the metabolic data base for EVA planning. This effort is currently underway and will use the EKG channel on a shared basis with life support system data.

APPENDIX 6. USE OF ORBITER -- 102 IN R&D ROLE

ASAP Recommendation

Orbiter OV-102 is the most suitably instrumented of the Shuttle fleet and should be utilized as a research and development vehicle in addition to its normal mission activities.

NASA Response: NASA agrees with the ASAP recommendation and is actively engaged in a two part data gathering program which will utilize OV-102 as well as the other vehicles in a research and development effort.

One part of the program provides the necessary instrumentation and data to expand the operational Orbiter envelope to its fullest. Data to be gathered as a result of this part of the program includes wing loads, mid-fuselage thermal gradients, compartment vent pressures, WTR launch conditions, brake accelerations and strains, flutter, CG expansion, payload bay environment, and TPS life.

The second part of the program will provide basic data useful to follow-on space vehicles. This part of the program is referred to as the OEX (Orbiter Experiments). The magnitude of the effort can be seen from the enclosed OEX Flight Schedule. The OEX includes the Aerodynamic Coefficient Instrumentation Package (ACIP), the Shuttle Entry Air Data System (SEADS), the Shuttle Infrared Leeside Temperature Sensor (SILTS) and the Shuttle Upper atmosphere Mass Spectrometer (SUMS).

OEX FLIGHT SCHEDULE

FLIGHT NUMBER	41D 14	41G 17	51A 19	51C 20	51B 21	51E 22	51D 23	51B 24	51G 25	51F 26	51I 27	51J 28	61A 30	61B 31	61C 32	51L 33	62A 1	61E 34	61F 35	61G 36	61H 37	61M 38	61J 39	61K 40	61I 41	62B 2	61L 42	71A 43	71B 44	71C 45	71D 46	71E 47
FLIGHT DATE	8/84	10/84	11/84	12/84	2/85	2/85	3/85	4/85	6/85	7/85	8/85	9/85	10/85	11/85	12/85	1/86	3/86	3/86	5/86	5/86	6/86	7/86	8/86	9/86	9/86	9/86	10/86	10/86	11/86	12/86	1/87	2/87
OV-099 CHALL		X		X		X		X		X			X			X			X			X			X				X			X
OV-102 COLUM															⊗			X			⊗			⊗				⊗			⊗	
OV-103 DISCO	X		X		X		X		X		X						X									X						
OV-104 ATLAN												X		X						X			X				X			X		
ACIP/HIRAP		X		X		X		X		X			X	X	X	X		X	X		X	X		X	X			X	X		X	X
SEADS															X			X			X			X				X			X	
SUMS															X						X			X				X			X	
SSO		X		X		X		X		X			X	X	X	X		X	X		X	X		X	X			X	X		X	X
OASIS					NOT FLOWN	NOT FLOWN																										
CSE																																
TGHE																																
TABI																																
DIR BOND																																
SILTS															X			X			X			X				X			X	X
OFO	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
AAPE									X	X				X																		

⊗ DENOTES FLIGHT WITH FULL COMPLEMENT OF OEX EXPERIMENTS

June 1985

APPENDIX 7. KENNEDY SPACE CENTER (KSC) AND VANDENBERG AIR FORCE BASE (VAFB) COMMON OPERATIONS

ASAP Recommendation

Until such time as the KSC and VAFB sites have their own launch crews and dedicated Orbiters, the manifesting or scheduling activity should have a procedure to consider the schedule effects on crews who must travel back and forth. Also, attention must be given to the availability of specific Orbiters that may be required by specific missions. This is particularly critical in those cases where the DOD may be required to ask for an unscheduled launch.

NASA Response: The Agency's present approach is to provide maximum utilization of SPC personnel at both launch sites, and mission planning at both facilities to account for the schedule effects on crews who serve those sites. In the case of early flights from VAFB, launch team personnel from both KSC and the SPC will assist. In addition, consideration is being given to the maximum use of SPC personnel at VAFB for various tasks, such as Orbiter mods, during non-launch periods. In our manifest planning, orbiter use is also being optimized between launch sites with consideration being made for unique DOD requirements. Unscheduled launches will require a review as the need arises.

Discussion of Fact Finding Points

The ASAP observes that "for some substantial startup time -- years not months -- the rate of Shuttle launches from VAFB will be too low to justify the establishment of a complete launch crew that would be inactive for most of the year. The present plan is to use selected military personnel who have had training at KSC as permanent VAFB personnel and at each launch move the rest of the required crew from the NASA ranks at KSC. None of these people have had the opportunity to train at VAFB and hence the crews must be in residence some appreciable time before each launch, most particularly before the first launch at VAFB."

"While this would seem to be a straight-forward scheduling job, it is complicated by two facts. First, the DOD may be required by circumstances to ask for an unscheduled launch on short notice. Second, the Orbiters are not identical from a structural load capability and certain loads may require certain Orbiters. The scheduling problem is not bad if one formally identified it and is aware of the limitations it may impose on the joint operations. A subsidiary but important point is that the launch crews have not trained at VAFB nor has the facility been exercised. The Panel has recommended that an FRF be conducted at VAFB prior to the first launch as a facility and crew certification. A bonus to such a test would be a partial insight

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into the 'twang' effect on the stack under the VAFB hold-down conditions."

The training of NASA/KSC and USAF personnel at VAFB will be achieved through the conduct of an FRF during the processing flow for the first launch at VAFB. The decision to conduct this FRF has been made and scheduling of the FRF and first launch is in process for the first quarter of 1986.

"Common ground support equipment interfacing with the space Shuttle vehicle requires special attention so that consistent functional design and such interface characteristics are rigidly maintained since loss of configuration commonality may occur due to KSC or VAFB programmatic requirements."

We believe that the proper efforts are being exerted to maintain GSE configuration control and commonality. The VAFB and KSC common and mod-common GSE is the responsibility of KSC for design, procurement and delivery to VAFB. Mod-common GSE is the KSC GSE which can be adapted for use at VAFB by design modifications. The common and mod-common GSE at VAFB constitute nearly all of the GSE at VAFB as well as most of the installed equipment which interfaces with the flight hardware at VAFB. KSC is also responsible for preparing and maintaining the OMD (Operational and Maintenance Document) and configuration control of this GSE.

APPENDIX 8. SHUTTLE CENTAUR

ASAP Recommendation

While acknowledging the fact that the issues are being addressed, the Panel urges that the matters of the safety waiver request and the interpretation of specifications be resolved with careful deliberation. The ability to make and incorporate significant design changes for Centaur G' within the time remaining to the planetary opportunity for Galileo is fast diminishing. With the major portion of the Centaur G' qualification test program remaining to be conducted, it would be highly desirable that the Centaur project staff be able to concentrate on insuring that the test requirements are met.

NASA Response: Review and acceptance of waivers to the Headquarters NHB 1700.7A, "Safety Policy and Requirements for Payloads Using the Space Transportation System (STS), are the responsibilities of the JSC Payload Safety Review Panel. It is the responsibility of the Centaur Program Office to determine that those specifications have been met or require a waiver.

There has been concern over the redundancy and design margin of the Centaur Super*Zip separation system, and whether or not the design meets the NHB 1700.7A payload safety requirements. These concerns, of course, apply also to the IUS separation system which uses almost an identical design. Although both systems have completed qualification testing, new data, as a result of some pyrotechnic research work at Langley and margin determination testing at JPL for Galileo, indicate that the design margin may not be as great as originally thought. Additional testing is being performed at Langley to resolve this issue.

With regard to changes, only those which are essential to make the Centaur G' perform its missions are being incorporated. The schedule is extremely tight. A hydrogen tank leak has been experienced and was attributed to a design oversight. A repair has been implemented on the test tank which has been successfully cycle and proof tested. Tank integrity was maintained throughout the 1.4 static loads test and reverification pressure cycle testing. The same fix has been completed on the flight G-prime tanks. The G-vehicle redesign has been baselined and the test vehicle will verify this redesign.

Performance reserves, which were low, have now been reduced additionally by the required tank beef-up for the repair. The use of a portion of the Shuttle Program Manager's reserve is being pursued.

A special Phase II delta safety review was conducted at General Dynamics. Dr. Walter Williams recommended a review by JSC senior management following a special investigation of the Centaur Shuttle integration activity reported in a letter dated Feb. 6, 1985. The special safety review was chaired by Mr. Kohrs of JSC and included senior personnel on the board. No design changes resulted from the review which gives us confidence in the work being accomplished to date.

In terms of documenting the program's hazards based on the safety analysis and the rationale for risk acceptance, the contractor has not performed as well. Publication of the safety reports and the failure modes and effects analyses have been late. The Phase III safety review has been delayed several months because of inadequate preparations for the review. This is being given attention at GDC, and additional manpower is being allocated.

We are equally concerned with regard to the large amount of qualification testing that has to be done and are sensitive to ensuring that the program needs are satisfied by concentrating the appropriate personnel on testing activities. We fell behind the formal qualification largely due to late delivery of electronic piece parts, as the industry in general is experiencing, and due to late planning of hardware deliveries. To preserve schedule, preliminary system testing is being accomplished using prototype hardware. Production hardware will be installed following acceptance testing. Some will be installed at KSC. However, all production avionics should be installed before or during vehicle processing at Launch Complex 36. Qualification hardware is being built after the flight units to avoid disrupting vehicle flow.

Relative to abort mode operational constraints, we are working closely with JSC/RI to identify the various abort modes, the time available to dump propellants, residuals, vent rates, etc. The design driver to date appears to be the late systems TAL (Trans Atlantic Abort). To satisfy the safety constraints, in addition to the Orbiter landing weight c/g (center of gravity) management, we are implementing a vacuum inerting capability, which will reduce residuals to low levels. Testing and analysis are planned to verify this capability. We are also looking at inhibiting GH_2 venting during the critical time of reentry (Orbiter vent door opening to Mach 1) to preclude ingestion of GH_2 into the Orbiter OMS pod, lower mid fuselage, rudder speed brake and body flap).

APPENDIX 9. RADIOISOTOPE THERMOELECTRIC GENERATORS (RTG'S) FOR GALILEO AND ULYSSES MISSIONS

ASAP Recommendation

"The Panel endorses the proposal made by the ad hoc committee that addressed the issue to improve coordination among the organizations involved by appointing a 'single point of contact' on this subject for each organization. Further, the Panel endorses the recommendation to assign prime responsibility for obtaining flight clearance to the science mission center, Jet Propulsion Laboratory (JPL)."

NASA Response: I believe that the appropriate contacts have been designated. Mr. R. Kohrs at JSC is responsible for coordinating the overall Shuttle reliability estimates and interfacing with the Interagency Nuclear Safety Review Panel. Mr. J. Cork of JPL has the responsibility for coordinating activities that will result in obtaining flight clearance. That is a full time assignment for Mr. Cork.

Mr. Kohrs has been actively involved in revising the "Space Shuttle Data for Nuclear Safety Analysis" document, JSC 16087, to include the latest program data. STS failure modes and effects have been given further analysis, and the failure probability estimates are being reevaluated based upon our experience basis.

It should be recalled that JPL coordinates with the DOE, who owns the RTG's, and who has the task to prepare the "Safety Analysis Report" (SAR), which describes the flight risk. The Interagency Nuclear Safety Review Panel (INSRP) prepares the "Safety Evaluation Report" (SER) after reviewing the SAR and then presents their independent evaluation of the risks. The NASA INSRP coordinator distributes the SER for a review by the NASA staff, collects the inputs, and prepares a report on the flight recommendation for the NASA Administrator which is forwarded to the White House staff for flight approval.

More recent testing for the RTG fuel capsules causes us to be more optimistic about the capability of the RTG to survive severe overpressures that are being considered. The shock tube testing at Los Alamos has shown that it can withstand 1800 psi. There have been a number of meetings held in which INSRP and NASA participants have jointly met to review data and share planning. We are in the process of reviewing contingency planning.

APPENDIX 10. NASA AIRCRAFT OPERATIONS

ASAP Recommendation

The Aircraft Management Office, as the Agency focal point for all aircraft operations and related matters, should include, if practical, an aviation safety function. The NASA centers would benefit by a single reporting location at Headquarters.

NASA Response: As the Panel pointed out, progress is being made in centralizing management of aircraft operations. Further, the Panel's specific recommendation that NASA Headquarters include aviation safety management and aircraft operations management in a single office has been accomplished. The Aircraft Management Office has been assigned the additional function of operational aviation safety and, in addition, this particular function has been strengthened by the hiring of two exceptionally qualified individuals in the areas of aviation safety and human factors engineering (human performance). Also as the Panel had recommended, the Centers now have a single reporting location in Headquarters. The Office of the Chief Engineer will continue aviation safety oversight to provide the appropriate audit function. The objective of these adjustments is to clearly separate implementation from oversight. Mr. Parmet met at Patrick Air Force Base in February with the Intercenter Aircraft Operations Panel and sat in on deliberations concerning the implementation of agencywide aircraft operations guidelines. The target date for publishing this document is September 1985.