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

National Aeronautics and
Space Administration

AEROSPACE
SAFETY ADVISORY PANEL

ANNUAL REPORT

COVERING CALENDAR YEAR 1985

JANUARY 1986

National Aeronautics and
Space Administration

Washington, D.C.
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103P

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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

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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. On-Going

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. New

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)
Consultant (Retired)

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,

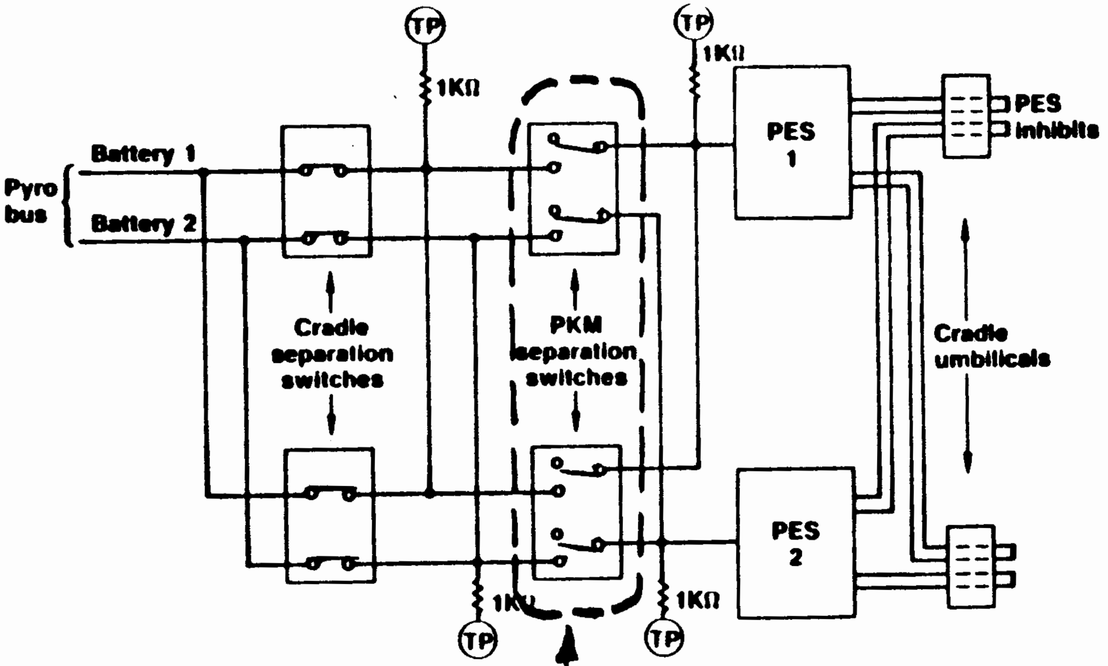
JSC developed procedures for the mission, EVA equipment, crew training and interfacing with Hughes show a thorough understanding of crew/orbiter safety needs. Crew training in 1g and neutral buoyancy facilities at both JSC and Hughes (using Leasat F-5) should preclude complacency between now and the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

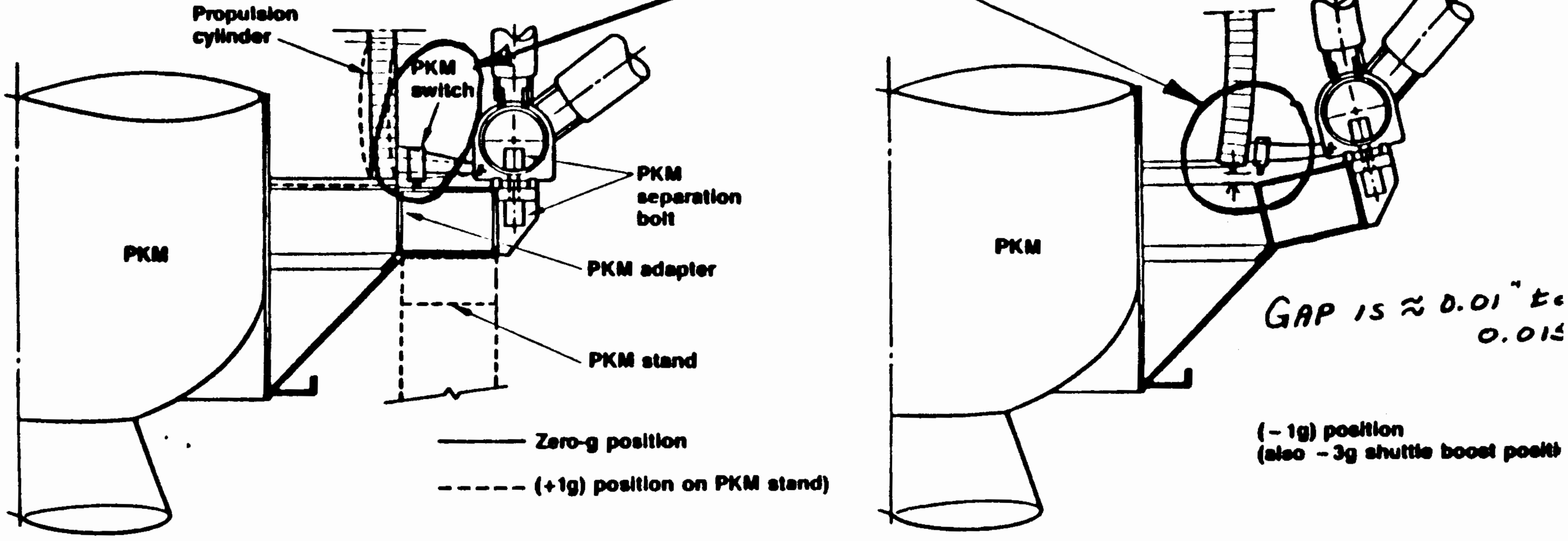
Sneak circuit analyses are being conducted on critical circuits and show no concerns to date. We have been assured that through configuration control that the "as-built" configuration is known. The external configuration is known (unlike the previous on-orbit retrieve/repair missions). Problems associated 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.