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NASA
National Aeronautics and Space Administration

AEROSPACE SAFETY ADVISORY PANEL

ANNUAL REPORT

COVERING CALENDAR YEAR 1983

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AEROSPACE SAFETY ADVISORY PANEL

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

ANNUAL REPORT

COVERING CALENDAR YEAR 1983

JANUARY 1984

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DEDICATION

The Aerospace Safety Advisory Panel wishes to express its thanks for the contribution to this annual report by Robert D. Rothi. Bob was a consultant to and a member of the Panel from August 16, 1982 to his untimely death November 27, 1983.

All of us came to know Bob as a friend, a colleague, and a sincere, intelligent, practitioner of the engineering art. We remember him as he would have wished, with pleasure rather than sorrow, and extend to his family our sympathy as well as our gratitude for having known him.

INTRODUCTION

NASA AEROSPACE SAFETY ADVISORY PANEL

ANNUAL REPORT COVERING ACTIVITIES FOR CALENDAR YEAR 1983

JANUARY 1984

INTRODUCTION

The NASA Aerospace Safety Advisory Panel has completed its assessment of NASA's safety performance for 1983 and affirms that NASA Headquarters and Center management teams continue to hold the safety of manned flight to be their prime concern, and that essential effort and resources are allocated for maintaining safety in all of the development and operational programs. The Aerospace Safety Advisory Panel continues to have access to NASA management at all levels and has found no difficulty in obtaining available data from any of NASA's policy, development, test or operational activities to assist in the evaluation of safety performance.

During 1983, NASA programs for the operational use of the Space Transportation System and their continuing use of aircraft for training, experimentation, and administrative service demanded the largest share of the Aerospace Safety Advisory Panel's attention, and this report addresses those problems which the Aerospace Safety Advisory Panel believes are in need of focused attention.

In this report, the Panel has listed those conclusions most worthy of NASA management concentration along with our recommendations for action. Following these broad conclusions and recommendations are two sections one of which is a review and closeout of NASA's response to the 1982 Aerospace Safety Advisory Panel suggestions and the other of which offers comments on some broad NASA activities which have had and probably will have an impact on the safety of future systems and their operation. Finally, since the Aerospace Safety Advisory Panel conclusions have been derived from substantial detail investigations of the hardware itself, its testing, and its use, an appendix has been added which includes information on Panel studies and reviews which have contributed to the primary conclusions.

It should be recognized that the transition from R&D flying of the Space Transportation System to its operational use introduces many opportunities for management policies and actions to expedite the achievement of maximum safety. Thus, many of the Aerospace Safety Advisory Panel comments have to do with the management approach to operational status for the Space Transportation System. It appears that much needs to be done before the Space Transportation System can achieve the reliability necessary for safe, high rate, low cost operations.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS AND RECOMMENDATIONS

1. Product Quality and Utility

Conclusion: Although present quality assurance programs are thorough, and documentation extensive, the Panel believes that these conventional approaches could be augmented by more motivational emphasis in the development and production phases of hardware and software. The Panel believes that more emphasis should be placed at the contractor and subcontractor level on design suitability and production quality to complement the present quality assurance programs. This emphasis should include motivation of the entire Space Transportation System (STS) design team now addressing improvements to be certain that operational problems are alleviated through these design improvements and elements of the STS which are difficult to inspect, involve obsolete technology, or require frequent maintenance and replacement are changed.

Recommendation: NASA make a concerted effort to assist contractors and subcontractors to produce the highest quality of product, oriented toward operational suitability. NASA and contractor employees, both design and production, should now be approaching their work on subsequent hardware improvements with operational suitability rather than increased performance as the dominant goal.

2. Shuttle System Main Engine (SSME)

Conclusion: The current design of the SSME, with the exception of the turbomachinery, appears to be suitable, assuming satisfactory completion of the specified acceptance tests, for approximately seven flights at full power level (FPL), i.e., 109% of the original rated power level (RPL). The current high pressure turbopumps at this rating of 109% are, apparently, suitable for only one or two flights at 109% thrust before removal for teardown inspection and possible replacement is required.

The Aerospace Safety Advisory Panel (ASAP) agrees with the prudent decision to limit the operation of these engines to the 104% thrust level as this mitigates but does not eliminate the problems of the engine turbomachines and provides operating margin. The engines have performed well during the 1983 flights at the 104% level confirming the wisdom of selecting this constraint.

The SSME project has adopted a three-phase program to develop a longer life expectancy for the engine. The Aerospace Safety Advisory Panel has reviewed this program and supports and commends this organized approach to SSME improvement.

Recommendation: The SSME program should proceed with full NASA support and resources to firm up the content and planning for SSME improvement and to implement the program and pursue the objectives vigorously. Retrofit of certified improvements during scheduled or unscheduled removals of the engines is firmly recommended. The plans should continue to include the activity on a full redesign of the high pressure turbomachines that was begun this year. The Aerospace Safety Advisory Panel believes this effort to be necessary to achieve the margin of safety required for routine operations and long life of the engine.

As testing to demonstrate margin for operation at the 109% level will involve operation at thrust levels higher than 109%, there will be temptation to increase the Shuttle performance by utilizing higher thrust. The ASAP advises strongly against such a decision. Operational reliability, and the concommitant safety can be achieved only by operating the engines at thrust levels below the maximum demonstrated in a few tests to show that a margin exists.

3. Landing Gear

Conclusion: In a number of previous reports and discussions, the ASAP has suggested that the landing gear on the Orbiter has not been

designed with enough structural and functional margin for repetitive use. The response to the suggestions contained in the 1982 report does not appear to the Panel to have answered the fundamental question of achieving sufficient margins for operational reliability and safety.

Recommendation: A complete structural and mechanical suitability review of the Shuttle landing gear be made by an engineering organization with commercial transport experience for the purpose of suggesting alternative landing gear configurations and setting target margins for structures and the wheels, brakes, and axles. This review should include but not be limited to:

a. The practicality of converting to a four-wheel main gear truck within the present wheel well.

b. The practicality of putting an extended or extendable strut on the nose gear for the purpose of changing the Orbiter ground attitude (more positive angle of attack), thus relieving the main gear roll-out loads.

c. The feasibility of increasing brake capacity by a major percentage (at least 25%).

d. A thorough review of the weak points on the present gear followed by suggestions for beef-up to bring the margins into partial comparability with the margins of modern transport aircraft in the landing mode.

4. Logistics and Maintenance

Conclusions: During 1983 the Aerospace Safety Advisory Panel has observed considerable progress in the areas of logistics, maintenance, supply and support programs intended to avoid launch delays due to material shortages. Suitable directives are being developed to encourage liaison between United States Air Force and National

Aeronautics and Space Administration through a co-ordinating group known as the Integrated Logistics Panel (ILP).

The Aerospace Safety Advisory Panel applauds the award of the Shuttle Processing Contract (SPC) in October 1983 but would welcome a clear definition of its role and responsibilities in the logistics field. Plans for transition of logistics and support activities from Marshall Space Flight Center and Johnson Space Center to Kennedy Space Center are in existence but are proceeding slowly and are not scheduled for completion until 1986.

There is no evidence of a long-term overall maintenance plan for the entire Shuttle system. Additionally, some doubt exists as to whom the ultimate responsibility for logistics really belongs and this is clouding the improving liaison between United States Air Force and National Aeronuatics and Space Administration. This may, in part, be due to the non-existence of a single top authority over combined USAF-NASA logistics. A stronger hand from NASA Headquarters in Washington would probably help. Both recommendations, that is, for the maintenance master plan and the appointment of a "czar" have been made previously by the Aerospace Safety Advisory Panel and valuable time is being lost during which some clarity and resolution could have been introduced into the entire logistics progam.

There appear to be some major voids in the logistics programs as presently envisaged. For example, no mandate exists for exploring the adequacy and suitability of logistics programs for Spacelab, Centaur, Inertial Upper Stage or Payload Assist Module systems.

The payloads can contribute to launch delays just as significantly as the Orbiter if logistical support is not considered as an entire system.

Recommendations:

a. A single authority be established responsible for all logistics systems.

b. An overall maintenance plan be established attempting to provide for at least the next decade.

c. The role of the Shuttle Processing Contractor in the vital sphere of logistics should be cleary defined as soon as possible.

d. Spacelab, Centaur, Inertial Upper Stage, and Payload Assist Module should be included in the logistics plans.

5. Orbiter Structural Loads

Conclusion: The most current structural loads for the Shuttle were derived in 1976/1977 and are called the ASKA 5.4 loads. The meager flight test data that has been acquired to date does not validate the ASKA 5.4 loads. To operate the Orbiter up to its safe strength with confidence, aerodynamic loads in ascent and thermal loads in descent need to be better defined.

Recommendation: The Aerospace Safety Advisory Panel recommends that National Aeronautics and Space Administration expedite the derivation of a new set of loads based on the latest wind tunnel and flight data. The Aerospace Safety Advisory Panel further recommends that renewed efforts be made to validate the final derived structural loads with full-scale flight data.

6. Orbiter Landing Speed and Pitch Control

Conclusion: Orbiter flights to date have demonstrated high landing speeds, landing gear loads near the design limits, many brake malfunctions, and a wide scatter in touchdown points.

Handling-quality tests on simulators have verified the sensitivity and inherent instability in pitch control that contribute to the Orbiter's problems.

Excessive landing speed and control sensitivity result in:

a. A continuing potential for a landing accident to occur
b. Limitations on choice of abort sites
c. Risk of destructive brake malfunctions
d. Non-survivable open sea ditchings
e. Lengthy and expensive training programs.

Program management apparently recognizes the above, as evidenced by a reluctance to use the Kennedy Space Center landing strip despite the logistic and turnaround advantages resulting from its use. The ASAP concludes that a major reduction in landing velocity, and an improvement in the apparent stability (and consistency) in pitch control near the touch down point, would substantially improve the operational flexibility and safety potential for the Orbiter.

Recommendation: NASA Headquarters should request Langley Research Center (LaRC) to review the "state of the art" in canard configured aircraft, and prepare briefings to the Aerospace Safety Advisory Panel and NASA Headquarters on the advantages and limitations of canard configurations as applied to the Orbiter. In parallel, Johnson Space Center (JSC) should be asked to explore the practical problems of installing controllable canards on the Orbiters for use in landing.

7. Shuttle Processing Contractor (SPC)

Conclusion: Although it is too early to reach any definitive judgments as to the operational effectiveness of the Shuttle Processing Contractor (SPC), Lockheed Space Operations Company, the planning, preparation, and initial actions during the transition period take account of concerns raised by the Panel in earlier reports. To date, Lockheed has been generally successful in hiring

key personnel of contractors which have been responsible for processing operations. It is important that this success rate be maintained among the contractors--Rockwell International, Martin Marietta, United Space Boosters--whose final transition dates occur after STS-11 in early 1984. In addition, National Aeronautics and Space Administration can assist the Shuttle Processing Contractor in carrying out its responsibilities through such actions as moving toward a unified logistics system, acquiring an adequate number of spares, defining major and minor overhaul sequences, developing coordinated launch schedules for Kennedy Space Center and Vandenberg Air Force Base, and consulting closely with the Shuttle Processing Contractor on major hardware acquisitions and enhancements that relate to Shuttle processing. The Aerospace Safety Advisory Panel will continue to monitor closely Lockheed's assumption of these critical processing responsibilities.

Recommendation: National Aeronautics and Space Administration should clarify as rapidly as possible its internal organizational arrangements that will support routine operation of the Space Transportation System. Such organizational clarity will be a major factor in achieving the objectives noted above and in assisting the SPC.

8. Safety of Flight Operations

Conclusions: Nineteen hundred and eighty-three was a significant year in the evolution of flight safety for the aircraft used at the National Aeronautics and Space Administration Centers. Flight safety has received considerable attention at the highest levels. The revitalization of the Intercenter Aircraft Operations Panel (IAOP) and the many constructive recommendations from the ECOsystems International Inc., and internal reviews should be effective in enhancing safety of flight operations. Still lacking are:

a. Effective communication both up and down the management chain, on flight safety matters, from Headquarters to the flight operations level at the centers

b. A "Director of Flight Operations" or the equivalent in NASA Headquarters

c. An appreciation at the Headquarters level of the role of human factors in aviation accidents

d. An update of Headquarters aircraft and flight operations policies and management instructions.

Recommendations: A "Director" or "Chief" of Flight Operations should be identified and should be the focal point of flight safety matters in NASA Headquarters.

This "Director" should serve as a channel of communication from the branch flight operations level at the Centers to whatever administrative level that is necessary to fully resolve a flight safety problem.

National Aeronautics and Space Administratation Headquarters through the "Chief of Flight Operations" and the Intercenter Aircraft Operations Panel should complement the supervision of flight operations with studies and educational programs aimed at the human factor problem in aviation accidents and assure that appropriate policy documents are issued by Headquarters to meet operational safety needs.

PROGRAM ASSESSMENT

PROGRAM ASSESSMENT

Product Quality and Utility

Together National Aeronautics and Space Administration and the Aerospace Safety Advisory Panel have concerned themselves with the effectiveness of the "Product Quality Assurance Program" and its adequacy to support the safety performance of the manned space flight program. During the history of the STS development a body of procedures, reports and records has grown up that defines in detail the route to be followed in the manufacture of already designed hardware. The pattern developed does not always result in suitable hardware. Another product of the system has been a documented history that will allow later analysis to pinpoint the cause after failure has occurred. This paperwork system and its implementation is massive and hence costly but it is not clear that it directly affect hardware adequacy. In a recent review of quality assurance held at Marshall Space Flight Center covering contractors and subcontractors, hundreds of deviations from prescribed product assurance procedures were reviewed. In spite of these deviations, all contractors stated that there had been no hardware impact. Now that the hardware task is becoming more one of replacing and fixing, it is important to put emphasis on the development engineering needed to insure that equipment that has been found wanting either in suitability or life under operational conditions is properly designed for operation. The achievement of appropriate operational design and the motivation of workers to produce to that design are essential to make traditional quality assurance programs worth the cost.

The ASAP did not perceive sufficient emphasis on directing actual worker attention to those things that, in fact, affect the quality of the work to be done. There is no intention here to imply that the whole body of product quality assurance is not valuable but we believe that it should be complemented by more attention to operational engineering and to the production system itself to insure that each

piece of hardware produced is as near perfect as possible and that it is of an appropriate design for the operational era. Quality assurance does not make hardware--a worker does, and quality assurance is only one of his tools. It should be remembered that STS elements for the most part come from small production, not mass produced items which are susceptible to more automated quality controls. Product quality for such small production is basically a function of the producing organization not the quality assurance organization. Thus, a product of integrity demands:

- Suitable design
- Proper tools and instructions
- Worker education
- Worker motivation

The first of these factors is in a large part a result of the engineering which reflects experience and management dedication to operational utility. The second quality assurance factor is the provision of proper tools, fixtures, and jigs calibrated to the extent necessary. Inspection equipment should be available as necessary and all prints and procedures must be current and explicit. It might help if a given worker had only the paper of importance to his job. Large data packs all of which do not concern the individual worker tend to obsure the importance to him of the few pieces of paper relevant to his particular task.

The third factor, worker education, is more important than most people realize. The majority of the workers on NASA projects either in engineering or production are conscientious, qualified, and intelligent people who want to do a good job. Every effort must be made to acquaint them with the importance, use, and characteristics of the equipment they are working on and the critical parameters that must be controlled. For instance, in some cases cleanliness may be simply good housekeeping and in other cases, such as hardware exposed to propellants or oxygen, it may be absolutely vital. The worker should know why certain procedures are demanding if he is expected to

produce a perfect product. Astronauts make visits to production facilities and this certainly motivates people. It might also be in order to have some of NASA's key engineering personnel conduct in-plant seminars on specific equipment and specific qualities it must have to do its intended job.

Finally, worker motivation beginning with the engineer is a difficult but rewarding task. The proper communications and communicators serve both an educational and motivational purpose. Quality circles are a useful technique so long as they do not produce unauthorized or untested changes in hardware or procedures. Along another line the worker must not depend on the inspector for quality; the inspector must simply confirm the worker's performance. The worker determines the quality of the product and each worker must be carefully reminded of this time and time again.

A new factor in product quality now faces NASA design and production practitioners who must produce reliable replacement hardware--particularly electronic. The designs of most of the Shuttle components are at least 10 years old and as industry has progressed new developments and design concepts have produced better and more reliable products. This coupled with difficulty in the reproduction of older style units, suggests that design change may be essential in achieving functional reliability. The problem that this aging poses for the Shuttle is that NASA cannot allow changes in design or substitutions in components without requalification of the hardware and a very comprehensive consideration of the effects of the change. It would seem to be in order for the Centers to determine in advance the extent of obsolescence, cost versus reliability improvements, the "delta" qualification requirements necessary for such updated equipment and establish a prioritized plan for determining the equipment to be replaced by that containing more modern technology.

Flight Readiness Review Changes

The Panel feels that in light of experience the Flight Readiness Review (FRR) process could be restructured to save some resources and, importantly from a safety point of view, to place the FRR operational decisions in the operations organization.

Panel members have participated in the majority, if not all of the Flight Readiness Reviews either in person or through telecons. These reviews have historically involved senior NASA management, senior program managers, numerous contractor managers, and with the pre-FRR Center meetings, almost the entire Space Transportation System (STS) mid-management population of NASA and their contractors. This effort is costly not only in travel and time but from the standpoint that a large number of senior people will not be doing other urgent things. With time and experience such priorities should have changed. As the operation becomes more routine, safety is enhanced by organizational clarity and the motivation produced by more precise definition of responsibilities.

The Aerospace Safety Advisory Panel feels that it is time for the STS Flight Readiness Review process to be restructured. We suggest a format for the change only to stimulate discussion and accelerate decision. We feel that the Centers should continue to hold their "pre-FRR" meetings and generate a Center readiness position. This should identify current problems, new risks, changes in old risks and other factors affecting readiness. We further suggest that the decision responsibility for flight readiness be delegated to the designated Director for Shuttle Operations wherever NASA decides to locate him, at Kennedy Space Center, at Johnson Space Center or at NASA Headquarters, Washington, D.C. after consultation with the Center Directors. We feel that such change would be more effective in the majority of the operations and would improve the motivation and quality of the NASA organization and its contractors.

Shuttle Processing Contract (SPC)

NASA's decision to consolidate under a single contractor all ground processing and launch and landing services, including operation and maintenance of associated ground systems, is a major step in the direction of achieving a genuine operational space transportation system. The scope of the Shuttle Processing Contractor's (SPC) responsibility is broad, including the processing of individual STS elements (Orbiter vehicle including main engines, external tank, solid rocket boosters), integration of these elements in preparation for launch, performance of on-line cargo integration and interface validation, and operation and maintenance of facilities and equipment required for processing, launch, post-launch, landing and de-servicing of the Shuttle vehicle. The activities of twelve (12) contractors are being consolidated under the SPC.

In September 1983, NASA awarded the Shuttle Processing Contract to the Lockheed Space Operations Company. The Lockheed team also includes Grumman Technical Services, Inc., Morton-Thiokol, Inc., and Pan American World Services, Inc.

Assigned individuals from the Panel have monitored the activities leading to the selection of the Lockheed team and will continue to follow the contract's implementation. It is essential that the important objective of achieving a more cost-effective operation (an operational space transportation system) not be permitted to introduce unacceptable risks to the Shuttle crew or the vehicle system itself. In striving for this proper balance between desired cost-effectiveness and acceptable risk, there is the initial challenge of the SPC accepting and carrying out the many technically demanding responsibilities of twelve (12) separate contractors, many of whom were developers of the STS elements. There is also the longer-term challenge of maintaining rigorous attention to detail and quality when the STS operation becomes more routine, the flight rate increases, and cost-control pressures intensify. How the initial challenge of

transition is approached will more than likely lay the groundwork for solving the longer-term problems associated with truly routine operations.

Lockheed is presently going forward with transition plans to assume responsibility for the work performed by the previous contractors. To date, the transition is essentially on schedule with assumption of all responsibility at Kennedy Space Center (KSC) to be complete by February 6, 1984, following the launch of mission 41-B (STS-11). Lockheed will be totally responsible for the processing of mission 41-C (STS-13), scheduled for launch in April. At Vandenberg the transition will take significantly longer with initial operational capability scheduled for late 1985.

A critical factor in sustaining processing capability will be Lockheed's success in hiring the key personnel of other contractors. As of early December, Lockheed had made 693 employment offers at Kennedy Space Center and received 672 acceptances. At Vandenberg there have been 132 offers with 108 acceptances. Of significance is the "capture rate" of personnel actively sought by Lockheed due to their individual capabilities. This stands (as of early December) at 99% for employees of Boeing Services International, Computer Science Corp., and RCA Service Company; 84% for Martin Marietta Corp.; and 97% for Planning Research Corporation. It is important that this success rate be maintained among contractors whose final transition dates occur after February 1984. Lockheed estimates that total personnel at Kennedy Space Center will be reduced by about 1030 at the conclusion of the transition period from the nearly 5000 persons initially available. The Aerospace Safety Advisory Panel recognizes that there is a small population of highly critical people who because of their experience and knowledge will be hard to replace, and that Lockheed should acquire them to further assure a successful transition. The Aerospace Safety Advisory Panel will monitor these essential skill areas to determine the degree of success achieved.

A major factor in selection of the Lockheed team was the fully integrated management structure that established clear relationships between the organizational elements of the Shuttle Processing Contractor and the work to be performed. Lines of communication, authority, and responsibility were directly drawn between top management and the organizational elements. Personnel of other team members--particularly Grumman--were (and are) integrated throughout the organization, along with the functional assignment of Vandenberg Air Force Base operations to Morton-Thiokol, Integrated Ground Operations to Grumman, and Program Requirements Analysis to Pan Am.

With the transition period approximately at the half-way point, it is too early to reach any definitive judgment as to the operational effectiveness of the emerging organization. However, it is possible to identify certain features or principles of the Lockheed plan that indicates a recognition of the challenges and problems in both the near and longer-term. For example:

--A recognition, as stressed by the SPC's top management, that maintenance and well-being of the work force is essential to productive and safe operations. High morale among employees and attention to detail must be sustained for the operational life of the space transportation system, no matter how routine and predictable operations become in the later years.

--Creation of an external Safety Advisory Board (modeled in many respects after the ASAP) that will meet at least quarterly to examine all aspects of the SPC's operations from a safety perspective. Direct access to SPC top management is assured. The desirability of direct communication between this new Safety Advisory Board and the Panel was informally discussed in December.

--Recognition of the need for a common logistics system to support operations at both Kennedy Space Center and Vandenberg Air Force Base. SPC management currently views logistics as its most serious and difficult problem. This responsibility is

hampered by NASA's own ambiguity concerning a total logistics, spares, and maintenance program. The SPC has no responsibility for ordering or budgeting spares acquisition. It is also not SPC's responsibility to plan major or minor maintenance "downtime" for Orbiter refurbishment. This must be resolved if the logistics system is to adequately support operations.

--An expressed determination to drive operating decisions to the lowest possible level in order to (1) strengthen responsibility at the hands-on level and (2) take advantage of the expertise and knowledge of those persons actually doing the work. Day-to-Day instructions are not to come from top management.

--Recognition of the lack of commonality among the Orbiters and the related assumption that maintenance and logistics procedures must take these differences into account <u>for the life of the program.</u>

--The decision to work toward zone-type processing of the Orbiter where a particular area is worked completely and closed-out only once, as distinct from the present system of numerous close-outs as individual systems are processed separately. Related to this approach is the objective of assembling all needed instructions and parts in the immediate location or station where the work is to be performed.

--Establishment of direct links between the SPC's planning organizations--Program Requirements Analysis, Mission Management Office, and Software Integration Office--with comparable Level III entities at NASA. These direct communication channels will facilitate technical expertise being readily available and provide channels of information for NASA to observe element performance and share in the decisions to further simplify "turnaround" procedures.

These various organizational arrangements and operating principles will be monitored by the Panel as they are implemented. Nevertheless, they provide evidence at this juncture of a management approach that appreciates the continuing risks and difficulties of Shuttle processing, as well as the opportunities to develop a more efficient and cost-effective operation.

NASA'S Support of the Shuttle Processing Contractor (SPC)

In prior annual reports and in other reports to NASA management, the Panel has emphasized the importance of moving toward an organizational arrangement within NASA that takes account of the special needs of the Shuttle's routine, more nearly commercial type, operation as distinguished from the prior research and development effort. In July 1982 we noted, for example, that a "well-defined and stable organization within NASA to oversee STS operations is the anchor for the SPC." The selection of the SPC and initiation of its responsibilities makes this observation more timely and pertinent than ever.

Last year the Panel suggested that the "organizational arrangement within NASA that is to be responsible for commerical operation of the Shuttle should be determined and announced, even though full implementation of this arrangement might not be feasible for the next several years." The Panel's assessment of the current status of the Shuttle Processing Contractor indicates why this recommendation still merits consideration. For example:

--The interim logistics procedure now in effect essentially continues control of all flight hardware with Johnson Space Center and Marshall Space Flight Center. While this arrangement is appropriate for the immediate period when the SPC is building its capabilities and establishing a confidence level among NASA managers, the time is fast approaching when retention of this control by research and development centers will more than likely

impede processing operations. Planning should begin now for an orderly transfer of this oversight responsibility within NASA to an STS operations entity.

--A comprehensive maintenance plan for the Orbiter is lacking. NASA's Operations and Maintenance Instructions (OMI's) provide maintenance procedures but not a baseline from which risks can be assessed. Preparation of such a plan would undoubtedly be a priority assignment of an STS operations entity, carried out in collaboration with Johnson Space Center, Marshall Space Flight Center and the new Shuttle Processing Contractor.

--Operational problems of some magnitude can be expected for the SPC once the Vandenberg launch facility is activated. For example, conflicts between NASA and the USAF for priority of spare parts and perhaps ground support equipment will have to be resolved if the SPC is to carry out its processing responsibilities on both coasts. Resolution of these problems will be facilitated by the existence of an STS operations entity within NASA.

--Flight schedules at KSC and VAFB should be established that permit the SPC to deploy its human and material resources in a cost-effective manner.

--The SPC should participate in the review process that leads to major hardware acquisitions and enhancements that relate to Shuttle processing activities.

The Panel is encouraged by the approach and apparent organizational and technical capabilities of the SPC. The preparation for this significant step toward achieving a genuine operational space transportation system has been thorough and sensibly carried out. Both NASA and the Lockheed team, along

with the incumbent contractors, have contributed to this generally positive situation. As noted above, however, the Panel will continue to monitor these activities as the SPC assumes its full responsibilities and as the flight rate accelerates.

NASA RESPONSE TO CY 1982 REPORT

NASA RESPONSE TO CALENDAR YEAR 1982 REPORT

The 1982 report of the Aerospace Space Safety Advisory Panel to NASA contained many references to the transition now taking place as the Space Transportation System (STS) approaches operational status. It was tne purpose of these 1982 comments to emphasize to NASA the importance of planning and then creating the organization, and inventory necessary to support the proposed increases in rate of STS launches, safely. A concern with any new system, as important and as complex as this STS, is that the need to satisfy potential customers drives a development into changes to improve performance rather than reliability. In addition, design or procedures simplification may have impact on performance but could have major influence on the cost, time for turnaround, and the safety of operations. The general tenor of NASA's response to the ASAP's 1982 report demonstrated the continuing strong bias of NASA management to spend the limited resources on major performance changes and to relegate changes for reliability and safe reduction of turnaround time to a lower priority. The ASAP hopes that this bias will not continue.

The Panel has reviewed the NASA response and has discussed each element of that response in an effort to deduce our own performance and to plan our future efforts to be more effective. In the following, point-by-point review of the NASA response, we offer some measure of self-assessment:

Recommendation 1 - The program for completing all flight test objectives.

NASA has given us a schedule which should complete the determination of aerodynamic performance, loads, etc., by mission 51-B (STS-20). We still feel that this subject deserves high priority and that flight data are necessary before we fully understand the structural and performance capability of the STS.

Recommendation 2 - Maintaining structural factors of safety.

NASA's outline of how future flight test information will be obtained, and its plan for instrumentation appear to be satisfactory. We concur in principle in the exchange of the Flight Acceleration Safety Cutoff System (FASCOS) to replace the Flight Acceleration Monitor Only System (FAMOS) for engine vibration monitoring.

Recommendation 3 - Single responsible operational logistics organization.

NASA's goal as outlined in SFO-PD-110.5, "NSTS Integrated Logistics Support Policy," is commendable and the ASAP concurs with it in principle but we feel that the time to develop, and the lead time to acquire major spares suggests more emphasis is needed from Headquarters. As will be noted elsewhere, the Shuttle Processing Contract alone does not solve the problem, no matter how capably the SPC contractors perform. Scheduled major and minor repair cycles need to be determined and spares ordered. This is not in the SPC work statement.

Recommendation 4 - Sustaining engineering.

The Panel has not succeeded in presenting a convincing case to NASA to separate this function from the engineering cadre that has accomplished the development and is now engaged in the engineering for performance improvement. We still believe it is timely to make this change.

Recommendation 5 - Hardware/Software certification.

The Panel is pleased that the Chief Engineer's Office is addressing this policy. When it is available for evaluation the Panel will meet with the Chief Engineer. The Panel did not make

clear in its recommendation that it was seeking only a policy, not a summary of what was or was not certified.

Recommendation 6 - Autoland demonstration.

The Aerospace Safety Advisory Panel realizes now that it pressed prematurely for the demonstration of this system. It is obvious that the system is not yet acceptable to the astronauts for full dependence and that a real hazard may exist if the pilots are required to take over from a malfunctioning system late in the landing sequence.

Recommendation 7 - New design for the turbomachinery for the SSME.

NASA's three phase program for improvement and redesign of the power head and its turbopumps is a most thorough response to this problem. The ASAP will follow each phase in the expectation that subsequent Space Shuttle Main Engine (SSME) elements will have enough functional margin to justify repeated use at the 109% thrust level now being tested for certification. This subject is also included in the conclusions and recommendations of this 1983 annual report.

Recommendation 8 - Landing gear integrity.

The ASAP is not satisfied with the response to its 1982 suggestion. An expanded discussion of this element of the STS is included in this, the 1983 annual report.

Recommendation 9 - Structural modifications of Orbiter 102.

NASA must certainly maintain as regular a schedule as possible of useful Shuttle launches and the ASAP recognizes why the suggestion to do full structural modifications on Orbiter 102 became impractical. Elsewhere in this report we have noted our

continuing concern for the structural integrity of the Orbiter at its full payload capability and we are following NASA's flight planning to assure ourselves that adequate placards are in place until the structural loads and strength capability have all been defined.

Other Issues

Automatic entry and automatic braking:

The Aerospace Safety Advisory Panel accepts NASA's response that a complete automatic reentry implies many change in ground control concepts and manual inhibit responsibilities for the crew, and the Panel agrees that the likelihood of incapacitation of the entire crew is remote. Such a response does not cover the more detailed suggestion that automatic gear deployment and auto-braking should be considered to provide redundancy at a critical time.

Role of crew vs. ground control:

NASA response indicates progress toward more autonomous crew responsibilities and the ASAP commends such efforts. Separating the various segments of the operation into launch, on orbit and entry is useful in analyzing crew responsibilities and should be continued. The ASAP included one other phase in its discussions and that was the phase of flight readiness prior to launch. It is the Panel's suggestion that some simplification in procedures, some added confidence in on-board instrumentation, and some time saved might be possible if the cockpit were used as a major readiness check station in much the same manner as the cockpit of a complex airliner or combat aircraft is used.

Safety improvements:

The Panel recognizes that a consistency review of the redundancy of all the systems and backup systems on the STS is a monumental undertaking but we all feel that such a review is both possible and profitable because we believe that simplification of present systems may be the result (thrust vector control of solid rocket nozzles may be a good example).

NASA's response which included a review of the 1200 items on the Critical Item List approaches the Panel's concerns in a different but perhaps equally effective way. It is hoped that a critical item review and presentation can be made to the ASAP in 1984.

Noted elsewhere but worthy of repetition is that the Phase I, II, and III improvement programs in the operational suitability and spares determination for the Space Shuttle Main Engine is an example of a well organized approach to safety consistency. The Panel suggests a similar program for other major subsystems of the STS such as the auxiliary power unit.

APPENDICES

APPENDICES

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2. Upper Stages
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7. Listing of Panel Activities for CY 1983
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Appendix 1

SAFETY OF FLIGHT OPERATIONS

Nineteen hundred eighty-three was a significant year in the evolution of the management of flight safety in NASA aircraft operations.

The good aspects were: (1) the revitalization of the Intercenter Aircraft Operations Panel (IAOP), (2) the reorganization in NASA Headquarters that established the Aircraft Management Office (AMO) as the single office for directives and policy leadership for aircraft operations, and (3) the constructive recommendations from ECOsystems International, Inc. which reinforced many of the previously reported findings of the NASA in-house review teams. An organizational entity such as the AMO could improve what appears to be poor communication from the general management level to and from the flight operations level at the Centers.

The IAOP, through its panels and subgroups, met several times culminating in a full panel meeting at NASA Headquarters in the fall of 1983. The Headquarters staff presented a compendium of the recommendations from NASA in-house reviews, accident and incident reports, and reviews by ECOsystems International, Inc. The meeting closed with an admonition from the chairman to get on with the job of correcting any deficiencies in management for which they had responsibility. As a result of the IAOP work, changes in supervisory procedures and practices have been made at the Center level.

Evidence of poor communication with Headquarters can be deduced from some of the recommendations made by in-house and ECOsystems report--recommendations for the correction of situations that local air operations management had obviously

recognized, and had been unable to correct because of lack of support from higher management levels.

The ASAP has followed "example" relationships between the Centers and Headquarters including direct participation in several accident investigations. Center performance, as observed by ASAP was much improved, yet little commendation and much criticism appeared to be the character of comments from Headquarters. A more permanent Headquarters "focus for flight safety" should alleviate this problem.

Appendix 2

UPPER STAGES

Inertial Upper Stage

The first flight of the Inertial Upper Stage (IUS) from the Shuttle failed to put the Tracking and Data Relay Satellite System (TDRSS)-A spacecraft in the planned geosynchronous orbit. At the end of the IUS second burn, the IUS-1/TDRSS-A stack was in an orbit with a perigee some 7500 n.mi. lower than planned and in an uncontrolled tumble at about 30 rpm. The spacecraft was separated as a result of a command from the ground and, by means of the attitude control system thrusters, was stablized and subsequently raised to the desired orbit.

An intensive investigation was conducted and the multiplicity of anomalies were sorted out. Most of the anomalies were the consequence of a major malfunction. This malfunction was the uncommanded second stage solid rocket motor nozzle displacement that occurred at about 83 seconds into the planned 107 second burn. The IUS control system was unable to regain control of the nozzle positioning during the remainder of the burn despite issuing the command for maximum restoring action and achieving maximum actuator electrical current. After the completion of the motor burn, the nozzle responded to command with correct response. This large deflection of the nozzle caused the observed tumbling.

The investigation concluded that the most probable cause of the malfunction was a failure of the motor "Techroll" joint such that the resultant rapid loss of fluid from the "Techroll" seal lead to the collapse of the seal. In such circumstances, the nozzle would be held in a cocked position by the motor chamber pressure load on the collapsed seal. At the completion of the motor burn the chamber pressure load is eliminated and the

restraining forces on nozzle motion are removed. By making the assumption of such a joint failure it was possible to replicate the flight data in a computer simulation giving credence to the hypothesis.

The exact cause or mechanism of the failure is still under investigation. Evidence to date indicates that a mechanical failure of the seal induced by one or more thermal protection system failures is the most probable cause of the control malfunction. As a consequence, an intensive review of the design and quality assurance provisions for this subsystem has been undertaken. In the absence of evidence of a specific fault leading to the malfunction, it has been necessary to implement a number of design changes to cover the spectrum of possibilities that exists. The changes include providing redundant seals for the fill and bleed ports of the "techroll" seal, providing additional insulation to the thermal protection subsystem to increase the design margin at several locations in the joint area. At the same time tests are being conducted on the original design in an attempt to isolate the cause of the failure. It is anticipated that a redesigned and stringently qualified system should become available by mid-1984.

Centaur

A 2-day fact-finding session covering the Centaur was conducted in mid-July at the General Dynamics Convair Division plant in San Diego, California. This session was the Panel's introduction to the Centaur as a part of the Shuttle program. Most of the organizations involved in the Centaur/Shuttle program provided briefings or had representatives present to respond to questions.

The Centaur program was in the midst of the design phase at the time of the visit. The conceptual designs had been adopted and detailed design was well along. The series of formal design

reviews were scheduled to begin in the last quarter of the year. The test program had been outlined and some of the development tests were in process.

The Panel's principal focus was on the safety implications of carrying a cryogenic propellant rocket stage with pressure-stabilized tanks in the Orbiter payload bay. In general, it appears that the program has identified and attacked the issues involved. Much attention has been given to safety considerations in the design process. The subsystems are being designed to satisfy the safety requirements stipulated for payloads by the Shuttle program. In trying to satisfy these requirements, some of which are more demanding than those imposed on the Shuttle itself, some aspects of the fluid and avionic systems of the Centaur became quite complex. A special review was undertaken to determine if some simplification could be achieved without compromising safety of flight. A Panel member attended a meeting on the findings of this activity and found that a thorough job had been done. There was general agreement that the modified system designs were satisfactory but that some waivers of requirements were required. This is occasioned by the fact that for payloads "damage to STS equipment" is categorized as a "catastrophic failure" regardless of the consequences of such damage. As a failure mode that is classified "catastrophic" is not permitted, additional redundancy is required and leads to the overly complex systems encountered. The issue is being pursued through the required channels.

The Centaur/Shuttle program (Headquarters, JSC, LeRC, KSC) provided detailed responses to Panel questions and comments regarding the Centaur flight and fixed elements and their integration into the Space Transportation System. This continuing dialogue between Panel and program personnel provides a sharing of the results of ongoing studies and decisions reached in those areas that are of vital interest to the Panel.

The Panel will continue to monitor the program actively as it progresses. In particular, we plan to attend the several design reviews, test program reviews and program reviews which are scheduled during the coming year.

Appendix 3

PAYLOADS

With the focus of the Shuttle program shifting from development and flight test to operational use, the Panel has increased its emphasis on the review of the payloads to be transported by the Orbiter. Summary observations on a number of the payloads examined follow.

Orbital Refueling Demonstration

The Panel was represented at the first design review meeting and at the Phase I/II safety review meeting for this project. As would be expected, the focus of safety concerns is the presence of hydrazine in the experiment. Of principal concern are: The possibilities of hydrazine leakage, adiabatic detonation, ullage recompression, exposure of the crew to the propellant etc.

Much progress has been made since the first design review meeting. Among the changes since the first meeting is the elimination of all catalytic vents of the hydrazine side of the system. Each potential hazard is being analyzed methodically and the design is being scrutinized in a thorough manner to assure that the system meets all NASA safety criteria. One open issue is how to treat the possibility of an astronaut getting his EVA suit contaminated with hydrazine and assuring it is clean before entering the air-lock.

The system design is progressing well. There is a very good team on the job. Much work remains to be accomplished prior to the scheduled flight date. Continued thoroughness of design and safety review coupled with satisfactory completion of the test program is required to reduce the risks to acceptable levels. The Panel will continue to monitor this project.

Spacelab

The Panel was represented in the Phase III safety meetings which were the final safety reviews for Spacelab I. There appeared to be great depth and thorough analyses of payload safety as indicated by the representatives of the participating centers.

It appears to the Panel that the project has been well managed. The matrix format that was utilized was designed to assure that each item was evaluated for individual hazards and the consequence of each such failure on its system. Further, interface analyses had been conducted to assure that each system does not impact adversely on other systems and on the entire payload. Final approval of the results of the review rested with the STS project.

It is suggested that the Panel be kept informed about schedules and plans for such safety reviews at their inception so that it may begin to observe the process as early as possible. With such early involvement, it would be possible to gain a broader comprehension of the payload project and the issues that arise thus permitting the Panel to render a more informed and, therefore, complete assessment.

Appendix 4

EXTRAVEHICULAR ACTIVITY

Suits and prebreathing

Extravehicular activity (EVA) is increasing as the STS project reaches out with new and more sophisticated programs. All EVA has been conducted to date using a 4.3 psi suit. As far as the Aerospace Safety Advisory Panel is aware, all EVA activities have been routine except for the first flight. The current suit, because of its low operating pressure, requires an extensive period of prebreathing of 100% oxygen (up to 4 hours) prior to attempting an EVA from a 14.7 psia cabin. This precaution is necessary to avoid decompression sickness (bends) of astronauts when going EVA.

On mission 41-B (STS-11) the cabin pressure will be reduced from the normal 14.7 psia to 10.2 psia before initiating EVA to acclimate the astronauts to the lower pressure. This allows prebreathing time be reduced to about 40 minutes as well as decreasing the astronaut's susceptibility to decompression sickness.

For the future, research is being conducted on a higher operating pressure suit at 8+ psi. This new suit design is to have much greater flexibility in the shoulder, arm, and leg joints, than that of the current suit. The new design has the capability of greatly reducing or eliminating prebreathing requirements.

It is the view of Aerospace Safety Advisory Panel that as time progresses there will be an increasing need for the higher pressure more flexible suit. While current NASA plans may not require this new design, we can visualize the increasing need for it as missions become more complex and the Air Force begins to

use the STS for its own missions. The ability to go EVA with little or no prebreathing is a big plus. The greater flexibility of the new design when combined with the proven torso of the existing design should decrease workload of the astronaut and reduce his susceptibility to decompression sickness.

We believe that NASA should foster the full development of the higher pressure suit and when fully tested it should become the standard suit for all future EVA activities.

Manned maneuvering unit

This short range versatile spacecraft, the manned maneuvering unit (MMU), has been conceived for use as a controllable platform which can transport an astronaut on a short radius from the Orbiter payload bay to satellites near the Orbiter or to inspect the external surfaces of the Orbiter itself. The purpose for the transportation of the astronaut is to place a member of the crew in a position to inspect, repair, and help retrieve satellites whose orbits can be reached by the Shuttle. Sufficient control power is designed into the MMU to permit the passenger astronaut to use the thrusters on the MMU for controlling the motion of randomly moving satellites and to tow them back to the Shuttle for repair or return to earth.

The concept of the MMU and its systems, along with the operational plans and developed capabilities, was reviewed by an Aerospace Safety Advisory Panel member at the contractor's plant (Martin-Marietta in Denver, Colorado). In addition, the simulator work, the facility, and the training program were also described and shown. Simulator training was assessed along with methods for coupling the astronaut to the Solar Maximum Mission (SMM) satellite. Similarly, the adapter hardware and procedure for attaching the MMU to the payload bay wall was viewed as part of the total description of how the "space-suited" astronaut

mounted the vehicle, detached it from the payload bay wall and reattached it once the mission was completed.

From this individual but thorough review, the Panel notes:

a. The concepts of redundancy for critical systems are consistent, the systems are simple and sufficiently exposed to permit thorough inspection.

b. The cold gas thrust and attitude control system is susceptible to pre-use inspection prior to disengagement from the Shuttle bay wall.

c. The gauge indicating energy available to the thrusters was in a poor position for visual monitoring while the astronaut was secured in the unit's seat. It seemed feasible to move this gauge without destroying the integrity of the systems tests that have been run.

d. The training program has been developed pragmatically along with the unit and appears to be effective. After the first experimental flight with the MMU this program and the formal documentation should be reviewed again by the Aerospace Safety Advisory Panel.

e. It was determined that no "safety" umbilical (tether) is to be used for the first experimental flights and is not contemplated for ultimate operatioanl use. This appeared to introduce unnecessary risk, but the astronaut trainer-director for the program explained that umbilical tangling and snagging represented a hazard judged to be equally severe and that the thruster system of the MMU did not have enough

capacity, even if stuck in "full thrust", to move the passenger out of range of the Shuttle capability for astronaut rescue. Additionally, the "buddy system" provides that a second astronaut in the regular EVA suit will be there.

Based on discussions at the MMU Critical Design Review held November 1983 an additional comment can be made: If, for any reason, there are significant amounts of dust/debris in the payload bay during ground or flight operations, care should be exercised to prevent MMU pneumatic systems from being contaminated which might adversely affect their operation.

Appendix 5

LOGISTICS, MAINTENANCE, SPARES AND OPERATIONS

This discussion is based on three specific activities: (1) General Abrahamson's meeting at Kennedy Space Center in November 1982, (2) attendance at a logistics telecon at Rockwell International, Downey, California, in April 1983, (3) visit to Vandenberg Air Force Base in October 1983. In addition, major events have occurred during 1983 which have direct bearing upon the subject:

a. Creation of the Integrated Logistics Panel (ILP) and commencement of working liaison with Vandenberg AFB. This is noted in a Program Directive, SSPM No. 85A issued by JSC's NSTS Office, March 25, 1983.

b. Issuance of an Integrated Logistics Support Policy (ILSP) for the National Space Transportation System establishing a platform for (a) above.

c. The award to Lockheed of the Space Shuttle Processing Contract (SPC).

The meeting at Kennedy Space Center convened by Gen. Abrahamson on November 9, 1982 was the catalyst for the more vigorous logistics, maintenance and support activities which have gradually evolved during 1983.

The Integrated Logistics Support Policy is commendably detailed with seven appendices: Management policy, spares policy, maintenance and repair policy, logistics support functions policy, ILS milestones, ILS definitions and ILS top level documentation tree. It would appear that a number of management level people in both NASA and USAF are looking to the establishment of the Lockheed-managed SPC as a partial answer to

many logistics problems but, although the ILSP was produced concurrently with the contractor-selection award process, the directive does not cite an SPC role in this arena. It is too early to be able to gauge the effect of the SPC program upon logistics but clearly it must necessarily be heavily involved, at both KSC and VAFB.

With respect to the scope of the ILP task, there is concern that it does not include logistics for the Spacelab, Centaur, IUS and PAM elements. It certainly appears that only a complete system ILS program, that is, including the vital payload elements, would have the desirable result of ensuring that the vehicle launch dates can be met from the support viewpoint.

The issue raised by the Aerospace Safety Advisory Panel in earlier annual reports, namely, that of providing logistics control by a single entity appears to remain for the future. The cooperation and growing cohesion of the USAF-Vandenberg and the NASA-JSC/KSC elements is very encouraging but the co-chairing arrangements of the ILP, necessary as they may be at present, do not make for efficient operation in trying to recover some of the critical time lost over the past three years.

The task of the ILP is greatly complicated by the necessity of trying to match the USAF well-developed organizational and management systems with the equally well-established "three-level" system at NASA. This results in a number of organizational "wiring diagrams," interface and procedural documents, few of which, at this writing appear to be completed.

While the issues of supply of components at the line replaceable units (LRU) level appear to be documented and understood some of the necessary suppliers may not be funded. Progress is most certainly being made in detail components but major units such as the SSME with its critical sub-assemblies still are in need of a good, clearly established master plan.

There is also the logistics aspects of transporting the SRB segments to VAFB which are in need of reinforcement for which the case for a third set of rail cars is being made.

Storage space at KSC for SRB segments is limited (although VAFB seems to be better off in this respect) and there is clearly a need for a study involving a "transportation model" to resolve some of these issues before they become a trans-continental transport crisis. In this general context the critical dependency upon only one B-747 Shuttle ferry vehicle for coast-to-coast movement should be re-examined.

Based upon our observed development of the logistics spectrum over the past year it appears that:

a. Considerable progress has been made in trying to gain control of the logistics problem. Improvements in NASA's interest and organization for Integrated Logistics System and sincere cooperation and coordination by USAF for the projected VAFB operations are certainly showing results.

b. There still appears to be issues associated with who has the responsibility for Orbiter, that is to say between the USAF and NASA. (The Directive says that the Air Force has responsibility for it "on-orbit." This needs clarification.)

c. The "reporting to" functions of the Integrated Logistics Panel (ILP) are still unclear. Should, for example, the ILP report directly to the National Space Transportation System Program Office? Should the ILP functions also embrace logistics aspects of operation and launch instead of being limited as at present to supply and

support tasks? The charter of the ILP, in spite of well-written directives from NASA Headquarters and Johnson Space Center is still unclear.

d. Considerable worry has been voiced throughout the year about the lack of ILP access to the Spacelab, Centaur, Inerital Upper Stage, and Payload Assist Module systems and the question therefore arises: is the ILP intended only to support Shuttle and not the broad spectrum of NSTS which would include these payloads?

e. The USAF view seems to be that they can't see anything in the NASA system at present which could be recognized as a well-developed maintenance, supply and logistics curriculum such as the USAF have developed and refined over the years. On the other hand, it appears that the evolving NASA logistics programs are more suited to the special problems of the small Orbiter fleet than the highly-structured, large fleet concepts of the USAF. Providing a workable accommodation between these two opposing philosophies would seem to be a pre-requisite for the ILP but it must be empowered by directive to be able to bring about such a foundation.

f. The "co-chairing" of the ILP by USAF and NASA is clearly the only arrangement which could be employed at this stage. Perhaps it is too early to establish the function of an overall "czar" of logistics but the difficulties which are beginning to show up from this rather too democratic co-chairing process could probably be short-circuited by the early appointment of a strong top chief with total authority.

g. The role of the SPC in the entire scheme of things needs to be determined and made visible to all concerned as soon as possible if some of the program's aspirations are to be realized.

Appendix 6

SPACE TRANSPORTATION SYSTEM ELEMENTS

Orbiter Landing Speed and Pitch Control

The Aerospace Safety Advisory Panel has, in the past, called attention to major deficiences in handling qualities of the Orbiter. These deficiencies are well known, highlighted by substantial pitch gyrations during the Approach and Landing Test No. 5 and some subsequent landings. Such control perturbations have been examined by analysis and numerous simulator control explorations. The Aerospace Safety Advisory Panel believes that NASA top management should direct further exploration of the significant benefits to be gained by major changes to improve the pitch control of the Orbiter.

The latest information that the ASAP has found on this problem is a report of the flight control system testing done on the Ames Vertical Motion Simulator (VMS), entitled: "Evaluation of the Space Shuttle Approach and Landing Flight Control System Handling Qualities" by S. D. Griggs, R. J. Grabe, and S. R. Nagel. This study, carefully conducted over a period of several months, by competent engineers and pilots with extensive experience in high performance airplanes and Shuttle simulations, resulted in the following recommendations:

a. Do not replace the current Flight Control System with any of the alternate systems evaluated. Some were found to be slightly better, but not to the extent that a change to the baseline system is warranted.

b. Investigate the feasibility of improving the low speed handling qualities of the Orbiter through airframe modifications, such as the addition of canard surfaces.

Eight different flight control systems were evaluated including software modifications to filters, gains, feedback paths, senor, etc. Ten pilots flew approaches to runways simulating Dakar, Kennedy Space Center, and Edwards Air Force Base. Disturbances were introduced during the approaches to stimulate transients in sensor data, such as changes in radar altitude, in azimuth from the microwave landing system, head/tail winds, and reduced visibility return as in a breakout from low cloud deck. The Heads Up Display (HUD) was not used.

The results show substantial variations in touchdown point, airspeed at touchdown, and vertical speed at touchdown ($\dot{h}$). Different software "improvements" failed to show significant changes; -- and there were a number of "crashes". A "crash" is defined as landing short or long or left or right or with $\dot{h}$ greater than 10 fps.

Pilot comments on the baseline system were:

> "Easy to balloon under stress"
> "If aircraft disturbed, end up hunting for ground"
> "Cannot control aircraft precisely near ground"
> "Lag between rotational hand controller (RHC) and vehicle response causes over control for large inputs and undercontrol for small inputs."

These comments on the performance of the recommended system indicate that there is a basic pitch control problem in the aerodynamic design of the Orbiter.

It appears that the attempt to combine pitch and roll control with lift augmentation by the use of elevons on a delta wing

results in compromises that have penalized both pitch control and lift augmentation.

The pitch control problem arises from the fact that, on the landing flare, to reduce airspeed, the pitch up moment is accomplished on the Orbiter by raising the elevons which inherently decreases lift coefficient with loss of lift, increasing the landing speed. The loss of lift is in response to a control motion that a pilot normally uses to raise the nose and increase lift! In addition, the inertia of the Orbiter is such that the motion of the c.g. lags the control input by as much as two seconds. The lag and apparent lift reversal can induce over control, and, in some cases, severe pilot induced oscillation (PIO).

The use of canard surfaces to provide pitch control would free the elevons to be used for lift augmentation and roll control. The elevons would have to be limited in droop to maintain adequate roll power but in spite of this, the available increase in lift would be most significant. Estimating from a nominal landing speed of 175 knots, angle of attack of 10°, elevon angle of 0_{o}, produces an apparent lift coefficient of 0.41. Using the elevons as landing flaps with a canard trimmer might produce double this lift coefficient with a possible landing speed of 125 knots.

The above increase in lift coefficient is not impractical. The advantages of such a landing velocity reduction are very significant from a <u>safety</u> viewpoint:

a. Stresses on wheels and brakes are reduced
b. The risks of landing at Dakar or other short fields are reduced, opening up many alternate abort sites
c. In the event of ditching in the open sea, the probability of survival would be greatly enhanced.

One of the significant findings in the Ames Vertical Motion simulator tests was an appreciation of the dangers of attempting a high-weight low-speed landing (like an abort to Dakar). If the angle of attack is increased much above 10°, in an attempt to land slowly, the aerodynamic condition is one of "backside of the L/D curve" where the induced drag rapidly decelerates the Orbiter and increases the sink speed.

In addition to the safety aspects of low landing speeds, the avoidance of pilot induced oscillation must be emphasized. To the non-pilot, the term "pilot induced oscillation" is just that: a disturbance that is felt to be controllable and transient. To the pilots who have experienced it, including the astronauts, it is recognized as a potentially uncontrollable instability. The lack of a landing incident to date is a tribute to the skills of the astronauts, and to the carefully planned and executed training program in high performance aircraft, the Shuttle Training Aircraft, and simulators.

Space Shuttle Main Engine

The current year began unauspiciously for the Space Shuttle Main Engine (SSME) with the discovery of leaks in the STS-6 engines and the resultant delays in scheduled flights. There were a number of intensive reviews of the problems and their systems and management implications. Panel members participated in several of these reviews. Corrective actions were devised and implemented. Subsequently, the engines performed essentially as predicted in all the flights this year. During the STS-8 flight an Augmented Spark Igniter line failed during the shutdown sequence. This had no effect on the mission. The cause of this failure has been identified and corrective action implemented.

Because of the very limited life (one or two flights) demonstrated by the turbomachinery during the FPL (109%) certification test program and in the absence of near-term

flights requiring that thrust level, it was decided to limit planned flights to 104% thrust. Such "derating" is a prudent step. Not only does it provide added operating margin for the SSME, it also should result in longer useable life for the turbomachinery. This should mitigate the logistical problems that would be caused by the need for frequent change-out of turbopumps that are operated at 109%.

The SSME project has embarked on a three-phase program to achieve a long-lived, reliable full power load (FPL) engine. The first phase involves conducting certification extension tests at 104% to obtain more data on durability at that thrust level. The second phase comprises the orderly development, certification and incorporation of a set of design-detail modifications aimed at solving some of the problems encountered with the current FPL design. The third phase includes major redesign changes. Among them are: Redesign of the Hot Gas Manifold to eliminate non-uniform flows and accompanying parasitic pressure losses; elimination of injector baffles and shields, and increasing the throat diameter of the nozzle. All of these changes will tend to "unload" the turbomachinery thus providing greater operating margins and, hopefully, extended useful life. Also included in the plan are steps to provide new turbopump designs should the preceding not prove effective.

The Panel supports this organized approach to solving the problems of the SSME. Such a program is necessary to provide a reliable engine for higher-power operation and to reduce the logistic burden of frequent component removals.

The Panel would like to emphasize that it is important to set the objectives of this improvement program in terms of <u>demonstrated margins</u> of stresses, temperatures, loads, etc., rather than primarily in terms of time at a given thrust level. Stipulating margins gives recognition to the fact that time-to-failure curves are extremely sensitive to stress,

temperature, etc., in the vicinity of the ultimate stress limits of materials. This is especially true when materials are operated at the high temperatures that prevail in the SSME.

Having demonstrated such improved margins by, among other things, operating the engine at thrust levels above 109% it is of utmost importance to not fall into the trap of considering the engine to be "rated" for operation at the higher thrust level. What has been accomplished is to have demonstrated that there is a margin for operation at 109%. To operate at the highest level tested would be, in essence, to operate without margin.

The Panel will continue to monitor the progress in the program during the coming year.

Orbiter Structural Integrity

The Orbiter structure was designed to loads that have acquired the name "ASKA 5.1." A later set of loads (now called "ASKA 5.4"), based on revised aerodynamic and thermodynamic data, was used for the most current structural assessment. Flight data analyzed to date (strain gage readings recorded on flights STS-1 through STS-5) have not shown reasonable agreement with predicted strain for the same locations using ASKA 5.4 loads. Even though these initial flights were designed to be as benign as possible, the ASKA 5.4 predicted limit strain on the wing alone was exceeded in:

a. 63 instances during ascent
b. 41 instances during descent

Fortunately, there were no instances where the measured strain exceeded a safe allowable limit strain. The numerous exceedances of ASKA 5.4 predicted limit strains without exceeding safe limit strains could be due to:

a. the ASKA 5.1 loads that were used for design were more severe than the ASKA 5.4 used for assessment in the areas where exceedances were measured

b. larger than minimum margins of safety were accepted and used in the design.

Since flight development was officially concluded with STS-5, the development flight instrumentation installed in OV-102 has essentially been dismantled. There does not seem to be an adequate plan to acquire the in-flight data required to close out the discrepancies between flight and analysis data. Therefore, the following steps should be taken:

a. Vehicle OV-102, which was the most densely instrumented vehicle, should have all DFI (Development Flight Instrumentation) gages reactivated and duplicated on both sides of the vehicle and should have adequate pressure measurements added in order to establish a more complete data base.

b. The initial flights were designed to be as benign as possible. With the flight envelope being expanded with each flight, instrumentation should be required on all vehicles in order to safely monitor future flights.

The failure of flight data to validate the current best predictions of structural loads raises serious questions about how the full strength of the Orbiter vehicles can be safely exploited. The Panel views the present situation as follows:

a. ASKA 5.4 loads apparently do not have the correct distribution of aerodynamic forces in the ascent configuration.

b. Current analytical prediction of internal loads and identification of the most critical elements for structural failures are not valid.

c. OV-103, OV-104 and OV-105 wing structure will be more critical than earlier vehicles because of the 800 pounds of structural weight removed in a weight reduction program. The reduction was based on adhering to close margins on ASKA 5.4 loads which, in some areas, were less than the ASKA 5.1 loads used for the original design. Thus, the failure to validate the ASKA 5.4 loads has particular significance for these later vehicles.

d. Future plans include missions that can experience 11% more dynamic pressure (Q) on ascent and 60% higher heating rate on descent than has occurred on STS-1 through STS-5. The best way to prepare to safely fly the most severe mission should be addressed.

Vehicle 6.0 Loads/Stress Analysis

Since the time that the ASKA 5.4 loads were derived (in 1976/1977), both flight and wind tunnel data have been developed that should provide a better basis for generating loads that more closely represent those being experienced by the full-scale flight vehicles. It has been proposed that a new set of loads be derived and used with an updated finite element model to provide a basis for establishing safe structural limits for future flights. This proposed effort has been called the 6.0 Vehicle Loads/Stress Analysis.

The vehicle 6.0 loads/stress analysis would consist of a complete update of the dynamic, thermal and mechanical loads math models that takes into consideration all structural configuration

changes resulting from the OV-103 weight saving efforts and other Shuttle element (ET and SRB) modifications. The followng should also be re-evaluated: aeroheating and thermal gradients, aerodynamic and compartment venting pressure loads, weight distributions, inertia loads, ascent trajectories, and the effects of the redesigned landing gear metering pin. These efforts should be coordinated with the latest wind tunnel and flight test data results in order to establish a new internal loads data base for ascent, descent, and landing conditions. These loads would then be used as a basis for a new stress analysis to establish the operational capability of the vehicle.

The Aerospace Safety Advisory Panel believes that another round of loads analysis of the 6.0 type is necessary in order to safely utilize the full potential of the Orbiter structure.

Filament Wound Case (FWC) For Solid Rocket Boosters

Results of a full-scale hydrotest of two segments of the FWC were reported at the Technical Interchange Meeting at Morton Thiokol, Wasatch Division, on November 16-17, 1983. Full-scale test specimens TFS 2 and TFS 3 were pinned together with proper end closures and external tank/solid rocket booster interfaces and successfully completed hydrotesting on October 21. The test results are as follows:

a. The test ran four maximum expected operating pressure (MEOP) cycles to 1050 psi with a final test to 1478 psi without burst.

b. The fiber strength in TFS 3 was demonstrated to 442 KSI.

c. The factors of safety (F.S) were shown to be:

1.50 Factor of Safety in the membrane for TFS 3
1.42 Factor of Safety in the membrane for TFS 2
1.32 Joint Factor of Safety for All Joints

d. The test specimens show no signs of delamination or wear.

e. All test objectives were met.

Two more full-scale specimens are scheduled to be hydrotested to 140% of maximum expected operating pressure by the middle of January 1984. These tests if as successful as the tests of TFS 2/3, will provide adequate certification of the FWC structural design.

Lightweight External Tank

In last year's annual report the Aerospace Safety Advisory Panel recommended that a nonlinear buckling analysis be performed on the Lightweight External Tank (LWT) structure in the area of the LH_2 tank where maximum compressive stresses are produced by thrust from the Orbiter. This analysis has now been completed by Martin-Michoud, and the method and assumptions have been reviewed and approved by an independent consultant, Mr. David Bushnell, of Lockheed Missiles and Space Company. The results show the LWT to have a 60% margin of safety in compression above the design ultimate load. This will add to the 26.5% margin of safety between the design ultimate load and the design limit load. With these analytical results in mind, the Panel is satisfied the LWT is structurally stable for 109% of SSM rated power level.

Landing Gear Design

For many years the ASAP has been pointing out the inconsistency of the landing gear design loads where the Orbiter has departed from commercial design practice. Normal commercial transport aircraft have built-in margins for the maximum loads expected in landing and braked roll-out conditions since the critical loads are normally refused take-off with braking and a 1/2g turn. Thus comparison with transports show:

	DC-9	L-1011	Orbiter
Max design load equals max stress (% max stress)	100%	100%	--
Braked roll-out (% max stress)	73%	58%	100%
Touchdown at 10ft/sec (% max stress)	71%	34%	--
5ft/sec (% max stress)	--	--	100%
Static load (% max stress)	48.4%	21%	38.7%
Tire deflection (max Ldg Load)	33%	--	66%

In spite of the fact that brake energy (design) has been based on abort landings at 240,000 lbs. there have been actual or incipient brake failures on almost every landing even though landing weights have not yet approached the design maximum valve. A review of the brake energy utilized through STS-5 shows that the pilots have been demanding ever increasing energy. STS-5 used an average of 35.54 millions of foot pounds with a maximum on one wheel of 42.62 millions of foot pounds. This value compares to the maximum energy for emergency use of 55 million foot-pounds and a fuse setting of 42 million foot-pounds, illustrating the marginal capacity of the brakes.

It has been noted by Robert Rothi that the brake pedals require a 75 # force to achieve maximum brake pressure of 1500 psi. This apparently is extremely difficult for the pilot to do consistently because of the long, tiring mission and not applying full force lengthens the stopping distance appreciably. Here is a PRIME situation to incorporate an "autobrake" system. Autobrakes are currently in production use on the 747, DC-10, DC-9, and other airplanes and the systems have been well-developed. Adaptation for use on the Shuttle should be a simple process and would relieve crew workload and result in shorter, consistent stopping distances.

The brakes were initially designed for 3000 psi, but the torque from the carbon-carbon rubbing surfaces peaked so high near the end of the stop on dynamometer tests that B. F. Goodrich, the brake supplier, was afraid of structurally failing the stators and rotors. Hence, the addition of reducers and the reduction of maximum brake pressure to 1500 psi to limit the peak torque.

Repeating again some of the Aerospace Safety Advisory Panel recommendations, it is suggested that NASA:

a. Seriously study the use of a longer nose gear strut or the installation of an expanding nose gear strut to relieve the roll-out loads in landing,

b. Similarly study the feasibility of a 4-wheel truck main gear.

Short of such a major change there are a number of less extensive improvements that NASA should seriously address including:

a. Place the Shuttle main gear tires on a flat surface on individual load cells at the end of a mission

and record variation in load distribution across the Shuttle. It appears that structural deflections on landing must tilt the shock struts outward loading up the inboard tires to higher loads and causing those brakes to absorb more than their proper share of the energies.

b. Move the main tire centerline inward toward the shock strut about one inch and increase the tire size as much as the diametral clearances will allow, maybe H46x17-22, or bigger, with a 5° bead seat.

c. With the larger tire and internal wheel space redesign the brake for greater energy and torque capacity using structural carbon. Support the brake on the axle near the inboard bearing to minimize axle bending.

APPENDIX 7

PANEL ACTIVITIES FOR CY 1983

As in previous years, Panel fact-finding sessions have been conducted on the average of four times per month for 1983. Members and consultants have during this same period visited seven NASA centers and facilities (Ames Research Center, Dryden Flight Research Center, Langley Research Center, Lewis Research Center, Johnson Space Center, Marshall Space Flight Center, Kennedy Space Center) as well as NASA Headquarters, and numerous NASA contractors. Although these have been focused on the Space Transportation System, there have been a number of fact-finding visits aimed at reviewing and assessing aeronautical operations and attendant flight safety. The Panel has, where practical, participated in a number of significant in-house reviews; e.g., Flight Readiness Reviews, various project hardware/software technical meetings, STS Support Activities. Panel efforts have been supported by the Panel Staff Director through in-depth and continuous participation and reviewing of STS and other program/project activities as well as aeronautical R&D and administrative flight safety activities.

The breadth of Panel personal discussions goes from the NASA Administrator and Deputy Administrator to Program Directors on into the subsystem design and test personnel (the "hands-on" people). Beyond this is the Panel's annual report provided to the NASA Administrator, informal meetings with Congressional staffs, and testimony before the appropriate House and Senate subcommittees in January-March period. Where requested, the Panel provides individual support to special review teams such as those looking at the Filament Wound Case for the Solid Rocket Motor, Centaur/Shuttle Safety, and the Shuttle Main Engine Assessment Group.

APPENDIX 7 CONTINUED

SUBJECT: Panel Fact-Finding Sessions Calendar year 1983

Date	Location	Attendance/Subject
1/28-29/83	KSC	STS-6 Flight Readiness Firing (Elverum/Grier)
2/4/83	Rocketdyne Div.	STS-6 Flight Readiness Firing (Elverum/Grier)
2/8/83	NASA HQ	Annual Meeting, 1982 Activities (Panel)
2/22/83	Hercules Corp.	SRM Filament Wound Case (Hedrick/Rothi)
3/2/83	Congress, DC	Panel Testimony to House of Representatives
3/3/83	KSC	STS-6 Flight Readiness Review (Battin/Grier)
3/16-17/83	KSC	Launch Processing Software/Hardware (Battin)
3/30/83	JSC	STS Program Management/Mission Ops (Hawkins/Grier)
4/4-8/83	JSC	Mission ops, aircraft safety, logistics for STS, Logistics Panel, Space Medicine (Parmet/Davis)
4/6/83	Rockwell, CA	Integrated Logistics Panel, Orbiter (McDonald)
4/14-15/83	General Dynamcis	Shuttle/Centaur Level II Reviews (Hawkins/Grier)
4/19-20/83	MSFC	STS Projects (SSME, ET, SRB), Spacelab, Space Telescope, Filament Wound Case (Panel)

4/21/83	NASA HQ	STS Logistics Programs/Policy (McDonald)
4/27-30/83	Rockwell, CA	Space Shuttle Main Engine/Orbiter (Himmel)
5/25-26/83	NASA HQ	TDRSS Ops, Orbital Communications (Battin/Davis)
5/31-6/1/83	JSC	STS Autoland, Flight Trajectories (Battin)
6/1-2/83	JSC	STS Autoland, RTLS abort, Crew Support (Davis)
6/2-3/83	JSC	Spacelab Safety Review (Parmet)
6/8-9/83	Hercules Corp	Filament Wound Case Status/Problems (Hedrick/Rothi)
6/10/83	NASA HQ	STS-7 Flight Readiness Review (Himmel)
6/14-16/83	KSC	Special SSME Management Review Team (Himmel)
6/27-30/83	ARC	Aviation Safety Inspection Review Autoland Simulator operation (Davis)
7/12-13/83	General Dynamics	STS/Centaur Integration and Ops (Panel)
7/14/83	Rocketdyne Div	Space Shuttle Main Engine (Elverum/Himmel)
7/25-28/83	LaRC	Aircraft operational safety (Davis)
8/11-14/83	JSC	Orbital Refueling Test Program (Parmet)
8/23-24/83	MSFC	Technical Interchange Meeting, FWC (Hedrick)
9/14/83	Martin Marietta,	Manned Maneuvering Unit (Hawkins)

9/13-15/83	NASA HQ	Intercenter Aircraft Operations Panel and NASA Aircraft Operations (Parmet/Davis)
9/28-30/83	KSC	Launch Preparations, Shuttle Processing Contractor transition, Aircraft Ops (Panel)
10/7/83	JSC	STS-1 to -8 Biomedical Symposium (Parmet)
10/18-19/83	JSC	Shuttle/Centaur Fluid Systems Safety Review RTG power supply cooling/control (Elverum)
10/19-20/83	MSFC	Filament Wound Case Technical Interchange Review/Meeting (Rothi)
10/19-20/83	VAFB	Integrated Logistics Panel for STS (McDonald)
10/18/83	Congress, DC	Informal meetings with Senate Staff (Hawkins/Grier)
11/8-10/83	JSC	Manned Maneuvering Unit Critical Design Review Orbiter Brakes, Crew Operations (Rothi/Davis)
11/10/83	MSFC	SSME, ET, SRB Production Quality Readiness Review with contractors/government (Grier)
11/16/83	JSC	Orbital Refueling System Safety Review (Parmet)
11/18/83	Brooks AFB, TX	EVA medical status and testing (Parmet)
11/18/83	NASA HQ	STS-9 Flight Readiness Review (Himmel)

11/30/83	Rocketdyne, Div	SSME 109% Rated Power Level Status (Hawkins/Grier)
12/2/83	KSC	Shuttle Processing Contractor's Status (Stewart)
12/6/83	NASA HQ	Orbital Maneuvering Vehicle, Transfer Orbit Stage, Tethered Satellite and its operations, Inertial Upper Stage status, activities review (Panel)
12/13/83	Nat'l Res Council	Filament Wound Case Special Committee Meeting (Roth)
12/16/83	LeRC	Centaur Critical Design Review (Himmel)

Appendix 8

PLANS FOR 1984

Panel Membership

A number of Panel membership changes are taking place at this time occasioned by events in late 1983. As noted in the front of this report, Robert D. Rothi's passing requires the selection of a new member. Lt. General Leighton I. Davis completed his membership term and has been retained as a consultant to the Aerospace Safety Advisory Panel. Bob Rothi had taken General Davis' position on the Panel. As a result of the selection of the contractor team which included Lockheed and Grumman to perform Space Shuttle Launch and Landing processing at Kennedy Space Center and Vandenberg Air Force Base both Willis M. Hawkins and Ira Grant Hodrick have retired from the Panel. They are remaining with the Panel in a phase-over period to accomplish a smooth transition to new members recently appointed in their stead.

Mr. John C. Brizendine former President of the Douglas Aircraft Company, now an aerospace consultant, has been selected to succeed Willis Hawkins as the new Chairman of the Aerospace Safety Advisory Panel. A brief resume follows:

> John Brizendine completed 33 years with the Douglas Aircraft Company in May 1983 after trying his hand at teaching at the University of Kansas after college graduation. His career included flight test work on a series of high performance research and development, military and commercial aircraft. This culminated in his promotion to Executive Vice President and then President of Douglas Aircraft Company in 1973. John served in the Navy as a Naval Aviator with single and mulit-engine ratings.

Mr. Charles J. Donlan has been selected to fill the vacancy left by Grant Hedrick. A brief resume follows:

> Charles Donlan had 37 years experience in research and development activities with NASA and its predecessor NACA before retiring in 1976. Most of this time was spent at Langley Research Center with the last 8 years spent at NASA Headquarters. Since leaving NASA he has been a consultant to the Institute for Defense Analysis with emphasis on assessing and making recommendations to the DoD on the development of facilities for the space Shuttle operations. His NASA/NACA experience included high speed research aircraft programs and direct involvement with all aspects of manned space flight since the beginning of such programs.

The selection of a candidate to fill the remaining membership position will be made in the very near future.

Panel Activities in 1984

Plans are to continue to focus on a number of aspects of the Space Transportation System as it approaches full operational status, assess the safety implications of upper stages and payloads that interface with the STS and to monitor the safety procedures and practices of NASA's aircraft operations.

Efforts will include at least the following areas of interest and concern:

- Shuttle Processing Contractor progress
- STS logistics and associated operational implementation

- Orbiter
- SSME
- Solid Rocket Boosters
- External Tank
- Launch Processing System at KSC and VAFB

o Vandenberg Air Force Base operations and relationships with KSC

o Upper stages including the Inertial Upper Stage, Centaur, Transfer Orbit Stage, Orbital Maneuvering System

o Filament Wound Case for the STS Solid Rocket Motor

o Payloads and on-board experiments and their integration into the STS, for example:

- Refueling Experiment
- Spacelab
- Tethered Satellite System
- Galileo
- Space Telescope

o Extravehicular Activity (EVA) and its support systems including suits, manned maneuvering systems and life sciences

o Rendezvous and proximity operations in space

o The Solar Maximum Mission spacecraft repair flight

o Space Station

- Certification policy and its implementation including product quality and design suitability, as well as, use of analyses versus tests

- Operational procedures to promote safety in the STS, space station and other programs

- Safety of NASA aircraft operations

AEROSPACE SAFETY ADVISORY
PANEL

AEROSPACE SAFETY ADVISORY PANEL

CHAIRMAN

Mr. Willis M. Hawkins (Retiring Chairman)
Senior Advisor Lockheed Aircraft Corporation

Mr. John C. Brizendine (Incoming Chairman)
Formerly President, Douglas Aircraft Company

MEMBERS

Dr. Richard H. Battin
Associate Department Head
Charles Stark Draper Lab. Inc.

Mr. Charles J. Donlan
Formerly, Deputy Associate Adminstrator for
Manned Space Flight NASA

Mr. Gerard W. Elverum, Jr.
Vice President-General Manager
TRW Space and Technology Group

Mr. Herbert E. Grier
Formerly, Senior Vice President
EG&G Inc.

Mr. Ira Grant Hedrick (Retiring Member)
Presidential Assistant for Corporate Technolgy
Grumman Aerospace Corporation

Mr. John F. McDonald
Formerly, Vice President-Technical
TigerAir, Inc.

Mr. Norman R. Parmet
Formerly, Vice President
Trans World Airlines

Mr. Robert D. Rothi (deceased)
Formerly, Chief Design Engineer
Douglas Aircraft Company

Mr. John G. Stewart
Assistant General Manager
Tennessee Valley Authority

CONSULTANTS

Lt. Gen. Leighton I. Davis
USAF (Ret.)

Dr. Seymour C. Himmel
Formerly, Associate Director,
Lewis Research Center

EX-OFFICIO MEMBER

Dr. Milton A. Silveria
NASA Chief Engineer
NASA Headquarters

STAFF

Mr. Gilbert L. Roth
Staff Director, Aerospace Safety Advisory Panel

Ms. Susan Webster
Advisory Committee Assistant

ACRONYMS & ABBREVIATIONS

ACRONYMS AND ABBREVIATIONS

AMO	Aircraft Management Office
ASAP	Aerospace Safety Advisory Panel
ASKA	Automatic Systems for Kinematic Analysis
DFI	Development Flight Instrumentation
EVA	Extravehicular Activity
FASCOS	Flight Acceleration Safety Cutoff System
FAMOS	Flight Acceleration Monitor Only System
FRR	Flight Readiness Reviews
FPL	Full Power Level
HUD	Heads Up Display
ILP	Integrated Logistics Panel
IAOP	Intercenter Aircraft Operations Panel
IUS	Inertial Upper Stage
ILS	Integrated Logistics Support
JSC	Johnson Space Center
KSC	Kennedy Space Center
LPS	Launch Processing System
LWT	Light Weight Tank
LRU	Line Replaceable Units
LaRC	Langley Research Center
LeRC	Lewis Research Center
MSFC	Marshall Space Flight Center
MMU	Manned Maneuvering Unit
NACA	National Advisory Committee on Aeronautics
NASA	National Aeronautics and Space Administration
NSTS	National Space Transportation System
OMI	Operations and Maintenance Instructions
OV	Orbiter Vehicle
PAM	Payload Assist Module
PIO	Pilot Induced Oscillation
RPL	Rated Power Level

RHC	Rotational Hand Controller
SMM	Solar Maximum Mission
SPC	Shuttle Processing Contract(or)
SRM	Solid Rocket Motor
SSME	Shuttle System Main Engine
STS	Space Transportation System
TDRSS	Tracking Data Relay Satelite System
USAF	United States Air Force
VAFB	Vandenberg Air Force Base
VMS	Vertical Motion Simulator