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by

AEROSPACE SAFETY ADVISORY PANEL

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INTRODUCTION

During 1980 the Panel, as in the past, has assigned areas of interest to its members. These specific people are responsible for the fact-finding in a given area and at times enlist the aid of other members to help them. As a part of our regularly scheduled fact-finding sessions, we have time to discuss the various facts that the members have ascertained so we can develop a concensus.

In the preparation of the Annual Report the individual members have written the specific sections for which they have been responsible. Our report identifies these sections and the author, although each section does, in fact, represent the opinion of the Panel as a whole.

In the past we have had the subject of avionics. During 1980 this has been encompassed in the hardware and software sections. During this year, experience with the "black boxes" has matured and did not seem to warrant a separate treatment. The matter of interest from an avionics point of view is the software and treatment of changes. There are changes occurring but they are under the control of the Configuration Board and are being handled properly.

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1. SUMMARY CONCLUSIONS

The Panel has spent the major portion of its time and effort in 1980 on safe readiness of the Shuttle for its first flight, STS-1, now scheduled for the spring of 1981. The year has been one of intensive test, review, and simulation. This activity has uncovered some new areas of concern and narrowed others, but it is safe to say that the Shuttle has passed the knee of the maturity curve.

The Shuttle's first flight will provide a variety of data that should substantially reduce many of the uncertainties and wide variations in predictions now confronting the designers. However, work is still underway and any prediction of readiness must be contingent on this planned work being successfully accomplished. There is, in our opinion, one particularly important item and that is the successful completion of the flight readiness firing. We also have our constant caveat that time must be allowed for the astronauts to adequately train for and absorb any late changes.

The Panel is optimistic that these reservations will not turn out to be constraints or unduly delay the present flight schedule.

The readiness of the Shuttle for the balance of the flights in the initial series is strictly a function of the lessons learned as the series progresses. Each of these flights expands the flight envelope and challenges the system more than the previous flight in determining the capabilities and limitations of the system. For instance, the center of gravity for the first flight is very narrowly limited and can only be expanded into a more useful range by experimenting with variations in the initial flight series. This progressive series requires that the reduction and analysis of data be accomplished between flights so that lessons learned can be applied. In addition to data analysis, extensive inspections must be accomplished after each of the early flights. This careful program will outline the limitations, if any, of the Shuttle as a transport system and point out the areas of improvement necessary in the final operational vehicle to provide the mission capability and turn-around time necessary.

For some years we have been disturbed by the impact of funding economies on the NASA approach to STS-1 issues. While this is not directly related to safety, it may create an environment in which the best solutions to problems are not always pursued and may result in the acceptance of more risk than necessary. As a project such as the Shuttle is inevitably ahead of the state of the art, it is impossible to know if, in fact, a minimum risk program has been achieved, hence, it is equally impractical to quantify the Panel's present assessment. We do, however, unanimously feel that such assessments be as definitive as it is feasible to make them. Accordingly, the Panel has these recommendations:

(1) Pioneering programs such as the Shuttle must be conservatively defined and adequately funded at the start and throughout life in order to insure a timely and satisfactory conclusion with a minimum of risk and maximum cost effectiveness.

(2) Sufficient time must be scheduled between flights of the initial test series to analyze data and implement the changes indicated to upgrade the safety for each subsequent critical test.

(3) Insure that the eventual operational organization is involved in the definition of any "product improvement" program for the operational Shuttle.

(4) Define early and implement those long term developments necessary for the operational Shuttle; for instance, uprated engines for more demanding missions.

(5) Develop and implement a more effective method of assuring quality control, particularly with respect to routine as well as new and unusal materials.

1980 has been a year of intensive activity on the part of the program and scrutiny and review by outside groups. During this process, many questions have surfaced and been explained or acted upon. The engine has matured and we now know how to effectively attach tiles. Consequently, the rate of changes has subsided somewhat. The Panel is comfortable with what it sees for STS-1 and is happy that its recommendations this year are general, not technically specific.

2. NASA REVIEW SYSTEM

The Aerospace Safety Advisory Panel was established by Congress in the aftermath of the Apollo 204 tragedy to provide NASA and Congress with an independent assessment of the acceptability of risk associated with NASA's space and aeronautics programs, particularly those involving manned flight. As this and prior annual reports indicate, the Panel takes its responsibilities seriously. We believe that NASA responds in a similar way to the Panel's findings and recommendations. We would not hesitate to declare that a program involved an unacceptable degree of risk if that was our collective judgment.

Nonetheless, even the most diligent panel of outside experts cannot substitute for a conscientious, rigorous, and well-designed system of review maintained by NASA itself. In the case of the Space Shuttle, as in all aerospace endeavors, risks ultimately will be judged on the basis of criteria established, interpreted, and enforced by the program itself, culminating in the final readiness reviews conducted by NASA's top management. Panel members will also participate in these final reviews.

On the basis of frequent meetings throughout the Shuttle's development, touching all major areas, the Panel believes that the first manned orbital flight will occur only when NASA's top management is convinced that the level of risk is acceptable. The review system has been designed to permit NASA management access to a breadth of informed opinion on the status of all major systems. There is every reason to believe that serious reservations held by any management level would be brought to top management's attention and carefully evaluated. It is noteworthy that in key areas of Shuttle development, such as the main engine and thermal protection system, more rigorous performance criteria have been substituted for the initial standards in response to development problems. This has been done even though these new criteria were likely to result in further program delays. Of course, this is no guarantee against a catastrophic failure but it reveals an attitude of mind and commitment to safety that should be welcomed--as well as expected--by Congress and the public.

In making this judgment as to the adequacy of NASA's review procedures, the Panel feels compelled to offer a further observation on the funding and management philosophy that has characterized the Shuttle program since its inception and that makes it considerably more difficult to maintain this "safety-first" commitment. From the moment of its inception, the Space Shuttle program has been seriously underfunded and its "success-oriented" or "success-dependent" schedule, a direct outgrowth of this underfunding, has been consistently too optimistic. The technological difficulty of designing and building a reusable space vehicle, while appreciated fully by Shuttle managers and engineers, has never been fully comprehended by either Congress or the public. The initial claim that the Shuttle would be constructed with "off-the-shelf" technology was both uninformed and regrettable.

Two areas of Shuttle development--the main engine and the thermal protection system--have generally vied with each other for the dubious distinction of being the "long pole in the tent." It is striking, however, that the Panel in its continuing reviews has encountered few development areas that have been able to adhere to anything like the initial budget or schedule. In reality, the Shuttle program is a tent filled with long poles, including such critical areas as software development and testing, crew training, flight controls, launch processing, structural adequacy, as well as the main engine and thermal protection system.

This fact suggests to the Panel that initial funding and schedule commitments were seriously in error. It is difficult to ascertain ultimate responsibility or motivation for this situation. Some critics will point to the Office of Management and Budget and the White House in the Nixon, Ford, and Carter Administrations as major contributors by keeping an unrealistic, indeed arbitrary, lid on Shuttle development funding. Others will point to NASA management for acquiescing too readily to these unrealistic limitations. Still others will say that Congress should have been more alert to the funding and schedule problems, even though Congress has consistently voted whatever funds the respective Administrations have requested. It is undoubtedly true that NASA management and Shuttle contractors could have done a better job of using the resources that were available. It is to the credit of NASA's current team, up to and including the Administrator, that they have insisted, against constant and recurring criticism, that the Shuttle systems be fixed and past omissions be corrected whatever the budget or schedule impact -- all in the interest of a reasonable STS-1 risk. In the end, it is less important to affix ultimate "blame" for the present situation than it is to recognize and act on the lessons of this unhappy experience. What are these lessons?

First, unrealistic budgets and schedules place an extraordinary and potentially dangerous burden on program managers to cut corners in a way that could jeopardize safety. As one veteran of the space business observed to the Panel: "The system encourages managers to be unrealistic." It speaks well of the Shuttle program management that they have not allowed this to impact safety.

Second, the United States cannot expect to sustain a bargain basement space program. Either a climate of opinion exists among the Executive, Congress, and the public that recognizes the significant costs and benefits of space R&D or it doesn't. If it doesn't, the Shuttle experience suggests the wisdom of not trying to compensate for this lack of support by designing a program where everything is supposed to work the first time it is tried. To say it clearly: don't begin major aerospace programs unless the nation's elected leadership is ready to provide a realistic base of support. Moreover, although it is impossible to prove, the Panel has the strong suspicion that a more realistic budget for the Space Shuttle earlier in the program would have saved money in the long run, as well as produced an Orbiter that now would be well along in its flight test program.

These observations call for what may be an impossible degree of budgetary "realism" in a period of inflation and fiscal restraint. Nonetheless, since a continuation of the "success dependent" funding philosophy entails the potential of eroding, over time, the basic commitment to safety that must characterize the U.S. space program, the Panel believes it is timely and appropriate to express these views.

3. HARDWARE SYSTEMS

Basic Structure

Under "Structural Adequacy" the unique environmental requirements that affect the strength and deformation of the Orbiter structure will be covered. From a functional standpoint, the structure is straightforward and corresponds to good standard practice. Tests have confirmed its adequacy if the thermal protection system fulfills its design goal to keep structural temperatures and gradients within design limits.

It should be noted that attachment of high temperature nonmetallic elements of the structure (leading edges) to the aluminum is a unique and complex problem. Tests have been accomplished, and will continue, to assure the adequacy of these mechanical attachments. Such attachments as well as moving surface seals, and hinge brackets have all been tested within the capabilities of ground test facilities. Based on such tests and through analyses, it is believed that the environment of the planned STS-1 flight can be fully sustained by these orbital vehicle elements.

The unique vibration environment for hold down and launch is severe and preliminary firing of the main engines must be followed by minute inspection where feasible not only of the thermal protection system components but also the flight control system, particularly the surfaces and their attachments, seals, hinges, and actuators.

Doors and Closures

There are several unique and critical door operations that must be successful if the Shuttle is to complete its mission. The first is the closure over the large cryogenic connections (liquid oxygen and liquid hydrogen lines) between the external tank and the Orbiter. This door system is unique in that it must be full open and flat on the bottom surface of the Orbiter and must be locked in this position to survive the severe launch environment. Once separation of the external tank takes place, the compartment and the line terminations must be rotated 180° to fit flush with the belly of the Orbiter with their complement of thermal protection tiles in position to protect the closed door surface during reentry. The closing and locking of this door in the high heat portion of the belly is essential for safe reentry. Indications of closure of this door pair do not follow modern transport aircraft practice for reliability of indication, but the door actuation and locking system appear adequate and a multiplicity of ground tests affirm this adequacy. There is little that the astronauts can do, except "recycle," if the door lock indications show an "unlock" situation thus the reliability of indication may be the least critical element of the system.

The uniqueness of the payload bay doors is their large size (2 doors, each approximately 60' x 10'), which, coupled with their cooling panels and the thermal environment extremes (including orbital soak), impose stringent demands on the locking and hinge systems to achieve positive closure for reentry. The door system incorporates seals and sliding connections between door elements so that, once locked the door structure contributes to the "stiffness" of the body structure in bending and torsion. Since this contribution may be inconsistent due to lock rigging and seal wear, it has been ascertained that Shuttle control margins are adequate even when the "stiffness" contributed by the doors was assumed to be nonexistent. In spite of this margin, it is essential that these doors be locked during reentry. The "locked" indication system has elements of hazard but the system can largely be visually inspected from the aft crew station through a window in the forward wall of the payload bay. This "confirmation" must be included in the crew procedures and training for STS-1 until a more direct system of "doors-locked" is incorporated in the Orbiter.

Power Systems

The three electrical power systems and the three cryogenic powered fuel cells are based on past experience in the Apollo and Skylab programs and careful analysis of potential failures and emergencies. The planned down-moding of the system appears rational and should cover a reasonable series of failure conjectures.

A similar 3-source approach was taken in the case of the hydraulic power needed for Orbiter flight controls, main engine vectoring, landing gear extension, brakes, etc. Three auxiliary power units are installed in the compartment aft of the payload bay. Test experience with these units has been inconsistent. The Panel has repeatedly reviewed progress and investigated Orbiter control on the assumption that one or two of these units fail during a mission. Control appears to be adequate with one failure and possible (with nearly perfect initial entry conditions) with 2 units out. This appears to be a reasonable basis for STS-1 flight.

A similar, but two auxiliary power unit hydraulic system is installed in each of the two solid boosters. This system has a very short mission time in which it must operate which can justify the assumption that dual redundant rather than triple redundant assurance is adequate. An additional hazard that can be rectified in later flights is the fault of the installation where one unit is in the plane of the turbine wheel of the other thereby possibly exposing both units to a failure in one. This is a sufficiently remote hazard that it can be accepted for early test flights but changes should be made in subsequent operational solid rocket boosters.

Separation Systems

Ground testing has confirmed the repeatability of the major separation elements (between Orbiter, external tank and solid rocket boosters) as well as the lack of hazard to the thermal protection systems from any debris. One conjectured hazard during the launch that has not been shown to be inconsequential by ground testing has been the possibility of ice formation on the Orbiter-external tank attachment members of the separation system. This ice, if shed during ascent, could damage the thermal protection surfaces. To eliminate this possibility for STS-1 special precautions are being taken at the launch pad to prevent ice formation which results from fueling with cryogenic liquids. Flight and launch experience will confirm the prevalence of this hazard and may suggest simple ways to avoid it in the future.

Exhaust gas from the booster separation motors on the solid rocket boosters impacting the Orbiter surface is a cause of some concern but the exposure time and impact energy do not appear sufficient to create an STS-1 hazard. Inspection of the thermal protection tile after the STS-1 mission may indicate that this effect is present but the Panel believes that this concern is unnecessarily conservative.

Flight Control Systems

Rudder Dive Brake System

Of all the mechanical systems on the Orbiter required for reentry and landing the Panel believes that the rudder-dive-brake actuation system presents the maximum potential for failure. The "series" nature of the system, its differential gear sets, the singular surface from root to tip all add up to a list of individually critical elements. The failure of any one of these could invalidate the triply redundant hydraulic motor system provided for actuation. Inspection, ground testing, and incorporation of fixes (some of which are in the software) provide sufficient confidence to accept this system for STS-1. However, the Panel believes that there are obvious changes in system concept that should be incorporated before the Orbiter is qualified for routine operation.

Elevon and Body Flap Controls

As a result of a major design review several years ago, the Orbiter design team responded to elevon and body flap control system concerns by reducing the single points of failure that could invalidate the triple redundancy concept of the hydraulic power system. This improvement, coupled with the meticulous simulation and inspection of the present systems reduces the risk during the first test flights to an acceptable level.

Both elevons and body flap use sets of single actuators into which all three hydraulic systems are fed. Thus these individual actuators become single point failure hazards. Such a failure would appear to be remote and a change in this concept is not suggested for the flight test program.

Thrust Vector Controls on Main Engines and Solid Rocket Boosters

As noted previously, the solid rocket thrust vector controls are of a dual redundant type with two power units in each booster supplying the hydraulic power to actuator pistons. The Space Shuttle main engine gimbal controls are similar in that they have a dual redundant power source each from a different combination of the three power units in the Orbiter. This seeming inconsistency in concept where there are three auxiliary power sources but only two are used per engine can be, at least partially, justified by the fact that there is a hydraulic power lock-up mode that maintains a fixed thrust direction in the event of two auxiliary power unit failures thereby leaving the other two engine thrust vector controls to help maintain Orbiter flight direction.

Both vector control systems use single pistons so that failures at the piston actuator system will invalidate the function. A completely independent thrust vector control for each power system should be studied as part of any major improvement program.

A vector control of substantially smaller capacity is used to gimbal the two orbital maneuvering system engine nozzles used for orbit injection and transfer. These also utilize a dual redundant power source from electric motors, each independent of the other driving a screw jack to move the engine nozzle.

Orbiter Roll and Yaw Thrusters

For orbit attitude control and initial reentry attitude control, a number fixed small thrusters forming the reaction control system are used without vector control. It was suggested that these thrusters, when used in the reentry flight phase at low dynamic pressure but high Mach number may have an important impact on the normal aerodynamics of the vehicle that could reduce the effectiveness or increase control demands on the aerodynamic controls. This, though difficult, has now been carefully evaluated in wind tunnels and has been determined to be inconsequential to control of the reentry.

Landing Gear

During evaluation of the landing gear system prior to the extensive approach and landing tests, it was determined that the margin of safety in the wheels, bearings, axles, and tires were marginal for the expected Orbiter touch-down weight. In response the program has procured new wheels, axles, bearings, and tires complying with the increased strength requirements. This does not remove one potential hazard noted in the previous review. Having only two wheels per side exposes the system to a probable dual tire failure on one side due to the overload imposed on the remaining wheel of the pair if the other one fails. Strengthening the wheels and tires makes a "first" failure more remote but it may be judicious for the NASA design team to carefully evaluate a gear system with 3 or 4 tires per side.

The extension system of the main and nose gear is a "dual" system with either hydraulic pressure from one auxiliary power unit or a pyrotechnic pressure used to unlock the gear after which the door opens and the gear deploys. Its simplicity is to be commended. It has been exercised during the Approach and Landing Tests on Orbiter 101 and would appear to be entirely adequate for STS-1 and subsequent test flights. All three gear units will extend without power due to gravity and drag, but the time to extend is critical for landing and this final backup system may be too slow.

Environmental Control System

Evaluating the life support system for safety is complicated by the common functions of the environmental controls to provide oxygen and hydrogen to fuel cells, purge of various functional compartments and the common cooling requirements of avionics systems, cabin atmosphere and fuel cell systems. The interdependence of these systems defies analysis of any one system in terms of dual or triple redundancy of the elements. Nevertheless, the many possibilities for down-moding and reducing demands on the system indicate that it is adequate for the test flight program. It is suggested that a more thorough failure analysis of this system will yield suggestions for a more reliable system.

4. STRUCTURAL ADEQUACY OF THE ORBITER

The Orbiter loads have gone through several revisions, with the latest being the internal member loads defined by the Automatic Systems for Kinematic Analysis, 5.4 loads. The mechanical portion of these loads seems to be in good shape. However, questions as to the thermal aspects of the loading conditions still exist. Based on these 5.4 loads, the structural integrity of the Orbiter for the first manned orbital flight, STS-1, except as noted below, is not in question so long as the thermal protection system tiles remain intact through at least the high heating phase of reentry. This is, of course, particularly the case for all black tiles which are subjected to the highest heat loads and temperatures.

A good number of tests have been conducted on Orbiter primary structure components. The second flight vehicle, 099, used as a structural test vehicle, was tested to approximately 100% to 120% of 5.4 design limit mechanical loads and those minor deficiencies which showed up have been corrected. These deficiencies included fittings, brackets, gussets and the like which were beefed-up or added as required. Other than for the forward fuselage, no thermal loads were included in these tests; additional test specimens, consisting of major parts of the overall Orbiter structure, will be tested to ultimate loads (mechanical plus equivalent thermal loads produced mechanically where practical). Some of these tests have been completed and all are expected to be finished by the fall of 1981.

The effects of structural flexibility have been taken into account in the aerodynamic stability and control coefficients used to predict the flight characteristics of the Orbiter during reentry flight.

Wind tunnel tests and analysis indicate the Shuttle is flutter-free up to a dynamic pressure (q) of approximately 1200 psf. The maximum q of any mission is 819 psf. The STS-1 mission will have a worst case q_{max} = 670 psf. We believe that the Shuttle is in good shape with respect to aerodynamic flutter.

The Orbiter 102 Ground Vibration Survey indicated some dynamic coupling between the longitudinal control system and a natural vibration mode of the Orbiter. Further work is being done to resolve this issue before flight readiness review.

A math model of the completely mated launch vehicle is used to analytically predict Pogo stability and the structural response to oscillations in solid rocket and main engine thrusts. This math model was also used to predict the responses to oscillating forces used in the Mated Vehicle Ground Vibration Tests. Correlation between these test results and analytical predictions were not complete. Further work is being done to improve correlation, and the flight readiness firing will provide additional test verification.

Based on 5.4 loads, the thermal protection system appears to be the weak link in the structural integrity of the Orbiter. With the main effort to insure satisfactory performance of the thermal protection system focused on STS-1 capability, the many test and analysis efforts to minimize concerns are progressing well. Extreme care in installation, vigorous testing both off-line and on the Orbiter itself, and careful management review support these efforts. The Orbiter/external tank interface, for example, has been reconfigured using reinforced carbon-carbon material to eliminate tile failure; additional attachment area is provided by cementing the tiles to the "filler-bars." A pyroshock test in the Orbiter/ external tank interface area has been successfully conducted to prove out the new and stronger modification. An item of concern is that some qualification testing of the tile system is late, and "life-testing" will not be completed before STS-1. We also suggest that further work needs to be done to better understand the dynamic characteristics of the Strain Isolation Pad.

Shuttle First Flight (STS-1)

With the first flight scheduled in March 1981, there remain several areas which are of concern:

- o The first concern is that the thermal loading of the Orbiter wings for the STS-1 mission has been defined as Mission 3 which is the most benign of all the design load cases with respect to thermal stresses. The Mission 3 thermal assumptions are not representative of any real mission. Since thermal gradients, in addition to material temperatures, are of great concern, the Orbiter is sensitive to mission profiles. The actual STS-1 gradients appear to be larger than those of Mission 3, which was used for wing assessment. This problem might be alleviated by pre-conditioning the Orbiter, prior to deorbit and entry, to control the initial temperatures and minimize the resulting gradients. However, these resulting gradients could still be more severe than those of Mission 3. Recommended action regarding this concern is addressed later in this section of the report.

- A second concern is that the "real" surface roughness of the Orbiter lower surface (due to tile-to-tile mismatch) can certainly cause increased heating. This, in conjunction with the not fully definable temperatures of the STS-1 mission, may result in overall negative safety margins and possible mid-fuselage lower cover buckling. Analysis of these potential problems is now in process and will be completed prior to STS-1 flight readiness review. A great deal of effort to minimize the step and gap variations has been made, including the use of tile-to-tile gap fillers and again very careful installations.
- A third concern is that the "Abort-Once-Around" condition may be more critical in terms of thermal loading than the two day STS-1 mission. Although this is an emergency condition, it could happen on STS-1. Analyses are in process taking into account both landing and maneuver load factors as they affect overall design margins. The results of these analyses should be reviewed in time to determine their impact on the STS-1 mission.

Based on concerns one and three, the Panel feels that positive plans of action should be implemented as soon as practical to update the thermal structural analysis and resolve the concerns noted above prior to the STS-1 readiness review.

Operational Capability

The effects of differential temperatures (gradients) on the structural integrity of the Shuttle Orbiter will probably require another cycle of analysis after in-flight real-time data becomes available from STS-1. This data will be used to correct and improve the math models currently in use and allow for expansion of the flight envelope for the subsequent missions.

The primary structure of the Orbiter is largely aluminum sheet and stringer construction. The compression strength of this structure is frequently determined by buckling or local crippling at stress levels considerably lower than the compression allowable of the material. Differential temperatures can induce self-balancing tension and compression loads within the structure. The most worrisome of these loads are the compression loads in the sheet and stringer external skins that support the thermal protection system tiles. (Tile structural integrity can be jeopardized by excessive deflections of the supporting panels.) These differential temperatures within the structure are the accumulative result of the heat inputs and outputs that the Orbiter experiences throughout a given mission. Aerodynamic heating rates vary with surface roughness and resultant degree of flow turbulence. Radiation heating in space varies with orientation with respect to the sun. Analytical procedures are complex and require considerable computer time. However, this Panel believes that, before the Orbiter can be committed to routine operation, another round of thermal/structural analysis is desirable to more accurately characterize aero thermodynamic effects and should be done before the present design team is reassigned. The new round of analysis should have an updated data base of heating rates and thermal performance plus updated three-dimensional heat transfer models. The analysis should be done by a closely knit team of structural analysts and heat transfer analysts, the structural analysts providing insight into critical structural loadings in the search for limiting mission scenarios. The Panel feels this additional thermal/structural analysis would allow operational planners to better and more safely utilize the full capability of the Orbiter in future missions, and to promote advanced/better thermal protection systems.

5. PROPULSION SYSTEMS

The development of each of the several elements that comprise the Shuttle propulsion systems has made excellent progress during the past year. Albeit some testing remains to be accomplished, prospects for completion of all testing required for certification for STS-1 by January 1981 are judged to be quite good.

External Tank

Qualification testing is essentially complete. Final tank flow system functional qualification requires satisfactory completion of the remaining test runs of the Main Propulsion Test program. Most of the aerodynamic fairings for protuberances, etc., have been verified. Difficulty with the adhesion of the wedge fairings for the instrument islands has led to their deletion for STS-1. There is the usual paperwork including deviations/waivers to clean up but there are no outstanding problems at present.

Solid Rocket Booster

All qualification firings have been completed satisfactorily. Only a few component or subassembly tests remain to be accomplished. The motors for STS-1 have been stacked and support the total Shuttle vehicle. A special inspection of the propellant grain for cracks was conducted with satisfactory results. The auxiliary power unit fuel control valve problem associated with leakage of hydroxyzine fuel onto the valve's electrical wiring has been diagnosed and proper steps are being taken to resolove this for STS-1. Further changes will be made for future rocket use.

Orbital Maneuvering System

The Orbital Maneuvering System pod assembly suffered structural failures during the acoustic excitation tests of the pod at 172 db. Several tank supports and other brackets failed. Corrective redesigns were implemented and have been tested for six mission cycles at the qualification levels. The results were satisfactory. Some subassembly tests remain to be completed for certification. These tests should be completed by the end of 1980. Provisions have been made to minimize the problem associated with moisture absorption by the composite graphite/epoxy pod structure by enclosing the system in a cocoon (supported by the Rotating Service Structure) purged withdry nitrogen at all times except during launch day operation. Tanks with strengthened propellant screens are installed for flight.

All other qualification tests for STS-1 have been satisfactorily completed and the Orbital Maneuvering System is essentially ready.

Reaction Control System

This hardware is also in good shape for STS-1. The problems reported in last year's report have been resolved by a combination of hardware and software modifications. All of the changes have been verified by test.

There remains one concern about a possible passage of a bubble of pressurant gas through the propellant tank screens under extreme flight conditions. A combination of analysis and test program is in process to resolve this issue. The present assessment is that for normal flight conditions the tanks are quite adequate but that for the extreme case of a return to launch site abort there may be no margin. This work should be completed by the end of January 1981.

Space Shuttle Main Engine

The main engine has made major strides towards certification for STS-1. The fourth cycle of certification (at 102 percent thrust) is complete. A few remaining component development verification specification tasks (tests) will be completed in January 1981. The engine has shown increasing maturity during all test operations. The engine has been run at 109 percent (full power) for sufficient time to provide confidence that a margin exists and that in an emergency situation the engine could be called on to perform at that thrust level.

The two more significant open problems, viz: the fuel preburner wall burn-through of midyear and the potential overspeed of the high pressure oxygen turbopump during shutdown in flight are fast approaching solution. The preburner liner has been redesigned and tested. A molybdenum insert for further protection has been devised and is in the latter part of its tests. The turbopump overspeed problem solution adopted is to close the prevalves early in the shutdown sequence and to pressurize the oxygen feed lines through the Pogo accumulator during shutdown. Testing completed to date has given encouraging results.

Most of the other problems are those affecting multiple reuse of the engines. Those include such items as spalling of the turbopump bearings, turbine blade cracks, etc. For STS-1 the inspection program keeps these under control. The engine program continues to feel the effects of hardware shortages in testing which does not affect STS-1.

Testing of the full power configuration has begun, and with the Preliminary Flight Certification Tests for STS-1 completed, this is the focus of upcoming main engine test activity.

All told, the engine is in good shape for STS-1 and should be able to support the first flight.

It must be noted that in all the preceding, emphasis has been placed on propulsion systems readiness for STS-1. For subsequent flights additional and more stringent certification requirements must be met and much added testing will be required.

6. THERMAL PROTECTION SYSTEM

During the past year, the Orbiter thermal protection system has had a very rigorous scrutiny and basic problems have been uncovered and, the Panel believes, resolved.

The definition of what the loads on individual tiles were had not been achieved until midyear. This includes both nature and magnitude. Improved and agreed upon analyses were finally achieved so "engineering" could be released. A major problem has been the structural integrity of the brittle tile at the tile-SIP bond line. Earlier attempts at resolving this by a thin plastic or metal laminate were steps in the right direction, but not a solution. The problem has now been solved by densifying the bottom layer of the individual tile itself by impregnating that interface layer with a suspension of fine silica particles. Consequently, if there are tile failures in tension they are breaks in the body of the tile, rather than a parting at the bond line at relatively unpredictable loads.

This definition of loads and the fundamental improvement in the tile structure has been coupled with a much improved application and testing procedure. The application is a monumental task, involving many steps that are labor intensive and must be ofan uniformally high quality. To achieve this, new test equipment, procedures, and traininghad to be developed, and consistently and completely applied. In addition, very detailed records were compiled so that the history and state of each step in the process could be determined. There are some unfinished combined loads tests that must be satisfactorily concluded to verify the load analyses. These tests are in a tight schedule situation. Upon this satisfactory conclusion and after our examination of the painstaking process, the Panel concludes that the thermal protection system will be satisfactory for the Orbiter's first flight, but cautions that time must be made available to properly finish the application.

Before one can predict the future of the thermal protection system, the Panel feels that the experience of the first flight is necessary, for four reasons:

(1) The amount of tile damage due to the flight and, in fact, due to handling after the flight, must be ascertained.

(2) The gap fillers seem satisfactory from a thermal point of view but without some experience their life is unpredictable.

(3) The strain isolation pad on which the tile is mounted is not well characterized, for the reason that the demands on it prohibit the use of many

of the more prosaic structural materials. The net result is that one cannot be sure of its characteristics for reuse until additional tests are made after the first flight. This comment applies only to those portions of the installation that are exposed to high thermal and structural loads and, as such, will most likely affect turnaround time. The present effort to find a better strain isolation pad should be continued and, as noted, should be aided by data from the first flight.

(4) The need to have worthwhile nondestructive evaluation tests of the tiles before and after each mission to assure system integrity.

An additional area of reuse concern is the need for waterproof tiles and capability to do the proper waterproofing upon landing after the STS-1 mission and prior to Orbiter terry back to KSC. This is under review and a waterproofing test program has been started.

The Panel feels that work should continue to look for alternate thermal protection systems, with an emphasis upon a less fragile, more easily maintained system for repeated reuse, e.g., increased tile coating thickness or use of a continuous strain isolation pad instead of "tile footprint + filler bars." However, we do feel that the present system does not pose an undue risk for the Shuttle's first flight.

7. PYROTECHNIC SYSTEMS

The Shuttle requires the use of a large number of pyrotechnic devices for a variety of functions, mainly separation and actuation. It also carries a range safety/destruct package and, of course, the solid rocket booster motors are pyrotechnically-initiated. The ejection seats are also pyro-actuated, as is the initial power assist to the gravity-drop landing gear. The nature of the Orbiter and the Shuttle's stacked configuration is such that these pyrotechnic devices must be installed at different times and all of them must be in place during the checkout phase in the vehicle assembly building and at the launch pad. During that time they are without the benefit of mechanical safe and arm devices, but are electrically disconnected (except the Orbiter fire suppression system).

The Panel has been concerned as to whether or not the differences between NASA's application of pyrotechnics and the traditional ordnance technology maintains the same degree of safety traditionally obtained.

Our investigation started with the NASA standard initiator and its quality control. We found a knowledgeable, competent group of people with an excellent test and record-keeping program that, in our opinion, establishes the quality of the initiator. It should be pointed out that NASA's use of initiators in space represents a small number of units as compared to many ordnance programs and, hence, greater average control is possible in a practical sense.

We have looked at the methods of safing--principally disconnect--and the testing routines to establish the presence or absence of a bridgewire on the circuit. The complexity and makeup of the complete Shuttle to a certain extent dictates the procedures. The procedures, both to safe and to assure that a live initiator is on a circuit when it is needed, impress us as being excellent. The risk of a malfunction, either advertent or inadvertent is acceptable.

The Panel has also reviewed the Range Safety/Destruct Systems and Procedures. We find the system in good shape and the cooperation between NASA and the Eastern Test Range personnel excellent, with a good training and operating program in place. The precautions to prevent inadvertent ignition of the system are satisfactory.

A decision was made to equip the early two-man crew Shuttle missions with ejection seats in case of certain emergencies; for instance, the necessity to use the range safety destruct system. A military seat that had high altitude use was chosen and adapted to the Shuttle. This seat, horizontal at launch, is of very limited use early in the launch sequence and, of course, has an upper altitude limit of perhaps 120,000 feet. Additionally, it might conceivably be of use in reentry, under some conditions. Under some deployments, there are high lateral accelerations when the chute opens that may be eased by ballasting to change the center of gravity. If such minor changes improve the performance--fine--but the Panel would caution against major changes that might invalidate the seat's successful history, with insufficient time before flight to requalify the unit.

The initiators for the solid boosters employ a safe and arm device that is conventional in philosophy, and the Panel believes that this critical unit is safe when it should be. The solid rocket motors themselves are a massive pyrotechnic and should an inadvertent ignition of the motor, or one of its segments, occur from any cause a catastrophe would result. The Panel has reviewed the results of an in-depth study of this matter and concurred in a course of action to result in a satisfactory risk, from a safety and a national asset point of view. The Panel has reported separately to the Administrator on this matter.

8. SOFTWARE PROGRAMS

At least a year ago, there was a push to validate the Orbiter software for an earlier scheduled STS-1 launch date. This resulted in verification and change control activities that benefited the flight software. The Shuttle schedule delay has allowed time for the absorption of those changes which have occurred. However, there has been one major area of concern: Orbiter re-entry flight stability and control margins requirements might very well result in some software changes that affect simulation and crew training activities. The program is aware of the seriousness of this and the Panel is confident that only mandatory changes will be made. The Panel harbors a nagging concern about the surprises that can develop from software patches that have not been thoroughly tested. Quite naturally, mission simulations and other test exercises uncover the need for improvements which most easily and quickly are accomplished in computer program changes. However, in a system so complex with sophisticated interdependent components, conflict in the computer logic can arise unless the software modifications are very thoroughly tested. There is potential here for schedule impact.

The amount of software testing in the various facilities, such as the Shuttle Avionics Integration Laboratory and the other simulators, is impressive and the Panel is confident that the flight software will adequately support the Shuttle's first orbital mission.

Another aspect to be considered is the software involved in the Launch Processing System. This system, which is new to NASA's launch activities, is a computer-controlled, automatic implementation of the countdown procedure, which is discussed separately. Development of the software for this system has occurred late in the program and is unique in that test engineers can write their own segments of the total package. Over the last year, the Panel has been concerned about the integration and verification of these various segments and the possibility of unwanted interaction of the various routines that could affect the launch adversely. The Shuttle program has been running very extensive verification tests in the Shuttle Avionics Integration Laboratory facility of the many launch processing and countdown routines. In our opinion, this testing should preclude any malfunctions. Additionally, the KSC Test Director can override the system, at any time and a hardwire emergency capability is provided. Preventing the Launch Processing System from modifying the flight software in the Orbiter under any conditions must continue to be a part of the development work.

We would deem this system to be satisfactory and it will be indispensable in the future routine operation of the Space Transportation System.

9. FLIGHT CONTROLS

The Panel's concern over stability and control on reentry is based on an appreciation of the extremely difficult problem facing the design engineer of the control system. The entry trajectory "window" is tightly bounded by structural and thermal constraints. The ability of the flight control system to guide the Orbiter in that trajectory is complicated by the varying degree of authority of the control means. At low dynamic pressures, the reaction control jets are necessary; as q increases it is necessary to use the lift vector to augment drag calling for roll and angle of attack increases causing both the rudder to be blanked and vorticies shedding from the nose, all of which add to the somewhat uncertain aero effects. Accordingly yaw jets are used well into the aerodynamic region, adding to the uncertainties of possible vehicle interactions.

The derivation of the control equations that govern the signals to the reaction jets and aero surface controls involve several coordinate transformations, consideration of inertia coupling, as well as aero cross coupling, scheduling of the coefficients that vary with Mach No. and dynamic pressure, as well as the gain and lead/lag terms necessary for stability. The design must provide margins that accommodate the variations and uncertainties in the aerodynamic coefficients, structural responses, and control effectiveness.

Inherent in the design are the frequencies of the structural modes of vibration which have been obtained both from an elaborate mathematical model of the vehicle as well as from laboratory tests conducted on a carefully authenticated quarter-scale model. Despite the care and attention of the structural modeling, there exists, in some quarters, an uneasiness concerning the predictability of vibration modes of the actual vehicle. The latest dynamic stability testing at KSC did not lay to rest the concerns of the skeptical. Refinements of the modeling and improved analysis must continue so that no significant discrepancies remain.

Many of the control parameters and gains of the digital flight control system are determined in flight by indirect inference made from navigation information gleaned from gyros, accelerometers and TACAN data. The more conventional air data quantities are not readily available. Research on a direct air data measuring system is underway in NASA. Although it will be unavailable on its current schedule for the first flight, its development, if successful, should be seriously considered for retrofitting at the earliest possible time.

The basic data base for the entry aerodynamics has been the subject of the most extensive investigation possible. Although most experts express confidence in this area, new information on this subject continues to grow. It is essential that when available, these new data should be included wherever appropriate. There is no flight experience at the high Mach numbers and high angles of attack to which the Shuttle will be subjected.

The above complexity raises the question of verification of the control design. Short of actual flight, the only method is that of high fidelity simulation.

10. FLIGHT INSTRUMENTATION

During the past year, the Panel has initiated some studies into Shuttle instrumentation. This very complex vehicle depends heavily on extensive use of transducers and electronics for proper operations and also to collect data that will confirm performance predictions for further flight tests and expansion of flight envelope.

In the conduct of these learning encounters at Johnson Space Center, Kennedy Space Center, and Dryden Flight Research Center (including a complete mission simulation), it appears that adequate information and redundancy is provided by flight instrumentation. Considering the on-board limits in ability to process information, store and/or telemeter aero, temperature, and other airframe data, backup recording capability in the development flight instrumentation might well be increased. The Panel believes, however, this is an acceptable risk for the first flight.

11. CREW TRAINING

The delays in the flight schedule of the STS-1 have provided additional time for crew training. Terminal area energy management flights into Edwards, and into the White Sands strip with the Shuttle Training Aircraft have served to maintain proficiency. The Shuttle Training Aircraft and other inflight simulators have been used to verify and tune control system refinements, such as the pilot induced oscillation suppression filter. Although the simulators have been mainly engaged in flight control design work, the astronauts have participated and contributed to that effort.

A number of simulators are being used to explore a wide range of emergency and contingency procedures. In particular, the technique of "down moding" as a crew option appears to many to be critical for flight safety. The crew is learning to fly the simulator in the down moded configuration and to develop criteria for the circumstances which might dictate its use. For example, in the event of a control problem such as loss of reaction control jets or unexpected variations in critical aerodynamic coefficients which might produce otherwise uncontrollable oscillations, the crew can select a manual mode of flight with reduced control system gains.

Down moding or any such interference with the automatic flight control system is regarded by the crew as an emergency measure only. For the first flight they prefer only to initialize the automatic system and assume the role of display monitoring during the descent through the high Mach number regimes.

The simulator does exhibit some problems which might hamper effective crew training especially in the manual modes. A 350 millisecond delay in the display appears to be more than just an annoyance and contributes also to the difficulties of monitoring entry flight control performance. This problem, which is related to an inherent deviation in the simulator fidelity has been called to the attention of the program.

Elevon oscillations, which are manifested in the simulator, may or may not be characteristic of actual vehicle behavior. Since it is always present, the condition might simply be symptomatic of a simulator hardware problem. In the flight vehicle, the astronauts feel that such oscillations would be intolerable. Potential resolutions are under consideration for application to the simulators as a first step.

The Panel, of course, has had limited observations of the crew training simulators in operation. They are receiving the most competent attention possible as contingency planning causes an expansion of the procedures necessary to cope with emergencies. The crew is experienced as are also the instructors and the Panel feels confident that crew training will be adequate for the First Manned Orbital Flight.

12. GROUND SIMULATIONS

Recognizing the importance of simulation to the design of the control equations and the verification of the control system, the Panel recommended in 1979 that Johnson Space Center organize a technical management group to coordinate the efforts of various organizations that were engaged in simulations. The Entry Flight Simulation Integration Group was formed and has met monthly this past year. In addition to defining and assigning tasks to the various talented groups available, it has been very effective in "integrating" (cross feeding of information, and engendering appreciation of problems) the separate technical disciplines; i.e., aerodynamics, controls, thermal, structures, and flight operations. The group's charter includes consideration of control problems on ascent, return to launch site and abort-to-orbit and abort-once-around. This work supports STS-1 as well as future missions.

The concentrated work on analysis and simulation of the problems of reentry, and the progress that is becoming apparent, has done much to allay the Panel's concern about the dangers incident to reentry. The control problems during ascent benefit from the availability of great authority from the vectored thrust of the main engines and the orbital maneuvering system.

Ground simulation is a powerful and necessary tool in the design and first time use of the control system; but, not sufficient to fully prove the accuracy and comprehensiveness of the design for operational use. That will come only through the gathering and use of data from later orbital missions. Its other important function is in training of the crews.

13. FLIGHT RULES

The current published Flight Rules (preliminary, Revision C, June 20, 1980, and Revision C, August 27, 1980) have been reviewed. The Panel is impressed by the scope of the contingencies covered, and by the depth of detail provided. It would be presumptuous of the Panel to criticize, or even to suggest modifications to these Rules; inasmuch as the subjects covered are so specialized, and the volumes have been prepared by competent engineers with wide experience in such matters. Mission simulations will exercise these rules under the concerned eyes of the crews. If any inconsistencies are found, or if it becomes desirable to relax some standards, the changes will be subject to careful review under management controls such as Configuration Control Board procedures.

14. LAUNCH PROCESSING SYSTEM

Early in the program it was recognized that the checkout, test and launch of recurring Shuttle flights would require a degree of automation that was new to the space fraternity. As a result, the Launch Processing System was developed around a computer that controls the various checkout and launch functions. The software language for this computer was constructed so that an engineer using the system could write the software for the particular segment of the operation in which he was interested and could then check it out to see that it performed the functions required. These various subroutines are stored in the memory for recall during checkout, when a particular function of the launch process is needed. The integration of such interactive programing must be carefully verified for the overall program to work satisfactorily.

The system consists of a group of consoles, essentially operating in parallel, each of which can call up and initiate any of the routines in the computer during the operation. The memory also includes the launch management program that controls the countdown, the sequential performance of the many subroutines. This management software has provision for manual and automatic holds, as appropriate to the conditions and time periods leading to launch. The ability of many consoles to have control puts a premium on practice so as to achieve strict discipline on the part of the Launch Control Center personnel. It is significant that late in the countdown the control function is restricted to several master consoles, under the cognizance of the Launch Director. The Panel feels that this concentration of authority is good, in that it removes the possibility of people-type failures due to misunderstanding or miscommunication.

Launch Commit Criteria are an integral part of the Launch Processing System which are interlocked in the launch sequence via the software program. The Shuttle is a complex system that has many elements arranged in a redundant fashion to insure reliability. In order for mandatory redundancy to be available in flight, the vehicle as launched must be in the specified condition. To insure this there are--after scrubbing--1,276 measurements or conditions which are monitored during final launch preparations. From T-9 minutes to T-27 seconds their number is reduced to 1,089 which are monitored by the ground launch sequencer which can call a "hold" if any out-of-tolerance condition exists. During the final sequences, T-27 seconds to launch when the automatic redundant set programs take over, there are only 254 automatic-hold measurements or red-lines. These deal primarily with the propulsion systems involving the engine, boosters and the external tank and most are termed "single mandatory" measurements, i.e., measurements with no redundant sensor or data readily available. The remaining 835 parameters are monitored but can not cause an automatic hold. Prior to T-9 minutes any one of the 1,276 parameters can cause a hold. Since many of these measurements present difficulties, we may be getting close to the point where in some cases the Shuttle is more reliable than the systems designed to measure that reliability, and the current Launch Commit Criteria will be hard put to cope with the later Shuttle's routine operational phases.

Better, more reliable instrumentation is a necessity but there are also other things that can be done. For instance, since there is insufficient time to make an infallible analysis of a measurement, go/no-go criteria should be used for late time constraints. Prior to launch, there is also a finite time that a then properly operating, redundant subsystem could be removed from the go/no-go system to allow effective concentration upon the more critical issues. In the Panel's discussions, we have difficulty realizing the effective management of over 1,200 prime measurements some of which are alternate (232) or backup (214) measurements. With current training and special attention paid to the over 800 "must measurements" there is less concern for STS-1. As operational launch preparation time gets shorter, reliance must be placed on fewer primary criteria, because the time remaining is simply not adequate for analysis or comparison and decision.

The Panel's review of the prelaunch operations and landing operations certainly impresses upon us that much work and streamlining must be done before the turn-around time initially envisioned can be accomplished. In light of the proposed two launch sites, in fact, it may be more economical and safer to procure at least one additional Orbiter, so as to give more time for the between-flight processing.

15. LANDING OPERATIONS

After the rigors of reentry, any consideration of the landing operation will seem tame by comparison. However, there are critical functions that must be done properly. Fortunately, the landing is the one phase of the Shuttle's flight that has been actually practiced in the approach and landing tests. This series of flights uncovered a sensitive control characteristic that resulted in a pilot-induced oscillation. This oscillation has been analyzed and a control-gain filter devised to correct the characteristic. This has been extensively simulated and should pose no hazard for the crew.

Both the prime--Edwards AFB--and the alternate landing sites--Northrup strip at White Sands for Abort-Once-Around and KSC for Return-To-Launch-Site--have had the Microwave Scanning Beam Landing System installed and tested. The length of the Edwards and Northrup strips are such that there should be no difficulty due to braking or overruns.

The ground crews that assist the astronauts from the Shuttle after landing and secure the vehicle are from Kennedy Space Center and have had extensive training. The ground support equipment at Edwards and Kennedy is complete. The ground support equipment at Northrup is sufficient to cover the crew egress and to safe the vehicle from hazardous materials.

In light of the preparations and training, the Panel does not expect any troubles to develop during the rollout and postlanding activities.

16. PAYLOADS AND GROUND OPERATIONS

The Panel's focus has been on the preparations for the first manned orbital mission, STS-1, which includes a minimum of what might be called payload, i.e., Aerodynamic Coefficient Identification Package (ACIP), Induced Environmental Contamination Monitor (IECM), and Development Flight Instrumentation (DFI). Consequently, a safety of payloads area has received only a cursory review during this past year. Within this curtailed activity, however, two items have been examined: (1) Level I - Space Transportation System safety policy and requirements and (2) the current status of the European Space Agency's flight and development Spacelab and pallet hardware. In support of upcoming Panel activities, this report outlines some areas we hope to review and assess as the Shuttle system begins its orbital flight test period and sets the stage for the early operational flights.

Basic Space Transportation Operations safety policy is to minimize NASA involvement in payload and attendant ground support equipment design, construction and testing while maintaining an acceptable level of safety. Thus, payloads neither interfere with the Shuttle system itself (particularly the Orbiter) nor adversely affect mission operations. Based on discussions at NASA Headquarters and KSC and a brief review of NASA documentation there is no doubt that NASA has and intends to continue to place great emphasis on payload safety. This through both setting realistic requirements and making available technical support for those who request it. The "Safety Policy and Requirements" document, NHB 1700.7 issued by NASA Headquarters established policy and safety requirements applicable to all STS payloads and their ground support equipment (GSE). Typical implementing documentation for users is the "Space Transporation System Payload Safety Guidelines Handbook" # 11123, issued by JSC. Day-to-day coverage is provided by the STS Payload Safety Review Panel at JSC, established in 1977. This working group assures that safety critical payload subsystems are appropriately verified, and provides confidence in adherence to safety requirements throughout the payload community. A major organizational change to better reflect current and future needs was made at NASA Headquarters: The Office of Space Transportation Operations (operational organization) was established separate from the Office of Space Transportation System (a development organization) without affecting the general roles and responsibilities at the NASA centers. In line with this, the existing Headquarters

Headquarters Reliability, Quality and Safety Office within Space Transportation System organization was set up so it could support both the operational and developmental organizations thus providing continuity between them.

An indication of program response to Panel safety recommendations (see Panel's Annual Report 1978) is seen in the recent NASA and ESA agreement that during the Crew Compartment Fit and Function (${}_C2_F2$) review a "safety walk-through" will be conducted as defined in the appendix to PL-ER-0111, dated August 12, 1980, of the "Policy and Procedures for Spacelab Flight Safety Engineering Walk-Around Inspections." This safety walk-through is to be conducted concurrently with the Crew Station Review and the Spacelab Flight Unit ${}_C2_F2$. More specifically, paragraph 2.2 of this document notes: "This inspection Team shall consist of ESA, NASA, and ERNO members as follows:

NASA	ESA	ERNO
Co-Chairman	Co-Chairman	Co-Chairman
Systems Engineering		
Crew Systems		
Aerospace Safety Advisory Panel Representative		
Product Assurance & Safety		

During the Walk-Around Inspection, an ERNO Quality Assurance representative will be required for recording findings to be used in further team discussions and to determine any future corrective actions."

At this point in time the payloads assigned to STS-1 and STS-2 take priority, and are described in Table I. The Panel's payload review activity in the coming year is expected to cover the areas noted in Table II. In addition, if the liquid propellant Centaur vehicle is selected as a possible upper stage propulsion unit for high-orbit payloads the Panel will, of course, include it in its reviews.

TABLE I - PAYLOADS FOR STS-1, STS-2

a) STS-1 Mission

- Aerodynamic Coefficient Identification Package (ACIP) weighing 165 pounds. The ACIP experiment consists of a self-contained package of 3 linear accelerometers, 3 angular accelerometers, 3 rate gyros, signal conditioning and PCM equipment. It is mounted on the Orbiter wing box carry through structure near the longitudinal center of gravity (C.G.).

- The Induced Environmental Contamination Monitor (IECM) weighing 985 pounds. The IECM is used to measure and record (tape and photograph) concentration levels of gaseous and particulate contamination in the vicinity of the payload bay. Mounted on DFI (Development Flight Instrumentation) System Pallet. (Note: Currently not expected to fly.)

- Development Flight Instrumentation weighing 9,015 pounds. Includes pallet, sensors, cooling, and cold plates plus wiring.

b) STS-2 Mission

- Instruments (called OSTA-1 payload)

  - o MAPS (Measurement of Air Pollution from Satellites)
  - o SMIRR (Shuttle Multispectral Infrared Radiometer)
  - o SIR-A (Shuttle Imaging Radar)
  - o FILE (Features Identification Location Experiment)
  - o OCE (Ocean Color Experiment)
  - o NOSL (Nightime and Daytime Optical Survey of Lightning)
  - o HBT (Heflex Bioengineering Test)

- Research Equipment

  - o DFI (Development Flight Instrumentation)
  - o ACIP (Aerodynamic Coefficient Identification Package)
  - o IECM (Induced Environmental Contamination Monitor)
  - o Solid Sorbent Sample
  - o Whole Gas sample bottles (4)
  - o Support Systems for Orbiter Experiments (OEX)

- Tape recorder
- PCM system
- Interface module
- Power control box
- Turning buffer
- Control Panel

TABLE II - PANEL AREAS FOR REVIEW

Level II, III, IV

- Documentation status and their implementation regarding policy and minimum safety requirements for payloads and ground support equipment. Includes actual examples of payload safety operations.
- Discuss payload safety and safety related responsibilities with the specific individuals tagged as "safety responsible" parties and how they actually work with experimenters and others involved in Shuttle payloads, e.g., correspondence, day-to-day contact personal or telephone contact, periodic reviews.
- Contractual aspects of payload safety.
- The safety related documents that an experimenter is expected to provide to NASA including how one checks the authenticity of safety related data, e.g., materials compatibility, use of explosives, electrical isolation.
- KSC safety activities and assurance during launch preparations.
- Self-contained payloads and how they are treated from a safety viewpoint including the implementation of November 4 Federal Register Section # 1214.903 "Conditions of Use" subpart (c).
- USAF/NASA payloads.
- Specific actions taken if hazards are found and what determines such actions.

17. PRODUCT ENHANCEMENT SUGGESTIONS

As in any major program that spans a number of years from concept to fruition the progress in parallel military and commercial programs suggests different techniques and concepts of systems and subsystems that would enhance the safety of the space transportation system. It has been suggested by the Aerospace Safety visory Panel that NASA should initiate a major study to define an improved STS, still based on the present overall concept, to improve the basic system safety but also to improve the reliability of its routine use and reduce the turnaround time between missions. Such a study should not be limited to the following suggestions but these appear to the Panel to have major total positive impact on the usability and ultimate safe performance of the space transportation system.

1. Consistent Approach to Redundancy

Shuttle systems throughout, aerodynamic and engine controls, thrust vector controls, environmental systems, etc., should all be evaluated in the light of best current practice to insure a consistent redundancy philosophy. Such a study may suggest many major changes, all of which should be carefully considered whatever the impact on retrofit potential or cost and schedule. There will be further Shuttle aircraft purchased and they should be at the forefront of the safety state of the art.

2. Thermal Protection System

It has become apparent that long life with repeated exposure to launch and reentry environments is not likely to be reached with the present thermal protection system. Most likely areas of improvement are probably within the Strain Isolation Pad (SIP) system and in the concept of gap fillers. It is believed that the random composition of material in the present SIP layer should be exchanged for a more positively configured flexible layer.

3. Power Systems Concepts

The auxiliary power system now being used has consistently demonstrated a random unreliability. This suggests that an entirely new concept be sought. This investigation should be more extensive than the power generation unit itself--it should include at least:

a. All electric Orbiter.

b. Fixing or programming the nozzles in the solid rocket boosters thus reducing power demands to allow the removal of the auxiliary power units.

c. Sufficient power per unit to fulfill re-entry and return to base without degradation in control capability, even though only one power unit was still operative.

4. Landing Gear

A tire failure at some time is inevitable--a multi-wheel truck or multi-tire wheel should be designed that can sustain a tire failure with only a remote potential for a disastrous "out of control" ground loop or worse.

5. Performance Enhancement

Based on data from initial flight results, a program to enhance thrust for more payload capability should be initiated along with control system changes which will permit major improvements in the permissible center of gravity ranges for routine operation.

6. Solid Propellant Element Handling

Review of ground facilities and erection systems for assembly of the total vehicle with its tank and booster systems revealed that early facility limitations forced NASA into less than the best handling concepts for the solid propellant elements that are assembled at the Kennedy Space Center. Interim procedures and special care programs will suffice for early flights but major remote storage and handling facilities should be provided for the solid propellant elements awaiting assembly or being individually prepared for assembly. Finally, a major study is needed to design element handling systems that minimize or eliminate the hazard inherent in manipulating segments with hoists, particularly in changing segments from the horizontal to vertical position.

18. AERONAUTICAL RESEARCH AND DEVELOPMENT PROGRAMS

The Panel has continued its attention to certain aeronautical research programs. During the past year, our activities in this area were limited to flight test programs of certain new or different aeronautical configurations. Most of the Panel's attention was directed at the following points:

A. Shuttle Controllability--Reentry, hypersonic control and pilot induced oscillation has been an ongoing subject with those who flew the lifting body vehicles as well as those involved from NASA's aeronautical centers. Experimental work has recently been conducted on other high fidelity simulators to gain a further insight into this problem.

B. HiMAT--A much higher risk project involving remotely piloted flight operations. The HiMAT is a very sophisticated machine, both aerodynamically and in its systems. The Panel is confident that management of risks in this program are controlled and that while there is always a possibility of mission failure in this type of project, successful completion is highly probable.

C. Other Special Aeronautical Configurations (DAST, Tilt Rotor) and modified aircraft (F14, F16, F104-F15 Shuttle Tile Tests).

The Panel will continue to monitor safety aspects of aero flight research programs.

APPENDIX A

AEROSPACE SAFETY ADVISORY PANEL MEMBERS

Membership of the
Aerospace Safety Advisory Panel

Herbert E. Grier, Panel Chairman
Sr. Vice President, EG&G, Inc. (Retired)
Consultant

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

Leighton I. Davis
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APPENDIX B

1980

PANEL SESSIONS

AND

FACT-FINDING MEETINGS

1980 PANEL SESSIONS

January 16	Annual meeting with NASA Administrator and NASA senior management	Washington, DC
February 7	Testimony before the Senate Subcommittee on Science, Technology and Space	U.S. Senate
March 19-20	First Manned Orbital Flight, STS-1, launch preparations, flight hardware checkout and launch countdown overview. Orbiter 102 hardware/software status.	Kennedy Space Center
May 15-16	Shuttle program overview with emphasis on flight control system, structural loads, avionics and its validation for flight, ground/flight crew training, space suit accident, payloads and Development Flight Instrumentation.	Johnson Space Center
June 18-19	Rockwell International's implementation of their Systems Integration responsibilities. Orbiter and systems status, Safety and Reliability. Solid Rocket Motor handling. STS-1 hardware and software certification and validation.	Rockwell International Corp. Downey, CA
August 21-22	Space Shuttle Main Engine, Solid Rocket Booster, External Tank and the Main Propulsion System projects activities in support of STS-1 and later missions. Range Safety and configuration control. MSFC's support of operations at KSC and DFRC.	Marshall Space Flight Center
October 7-8	Status of STS-1 flight hardware testing Launch Commit Criteria, pyrotechnic operations, range safety system. SRM/SRB handling and processing at KSC	Kennedy Space Center
December 4	Discussions with NASA Chief Engineer concerning current and projected STS-1 issues and their resolution.	Washington, DC

1980 FACT-FINDING SESSIONS
BY
INDIVIDUAL PANEL MEMBERS

January 4	Shuttle Safety, Reliability and Quality Assurance Operations. Orbiter TPS, APU status and problem resolution.	Rockwell International, Downey, CA
January 30-31	Orbiter flight crew simulations training and the fidelity of simulator input/output used at various NASA/contractor locations.	Johnson Space Center
March 3-4	Examination of the Development Flight Instrumentation and Operational Flight Instrumentation as to adequacy of support and real-time use for STS-1 mission.	Johnson Space Center
March 31	Observe and follow HiMAT test flight, data reduction and evaluation of the mission and supporting activities.	Dryden Flight Research Center
April 29-30	Orbiter Flight crew simulations and analytical evaluations of the results to assure reentry stability and control.	Johnson Space Center
May 13	Discussions with project managers on their conduct of research aircraft flight test programs to assure safety of operations.	Washington, DC
May 21	Orbiter-102 Thermal Protection System tile test program, installation and the expected design margins.	Rockwell International Downey, CA
May 29-30	Computer simulation of Shuttle reentry and applicability of additional Draper Laboratory work to the STS-1 Orbiter flight trajectories.	Charles Stark Draper Labs., Inc. Cambridge, MA
July 8	HiMAT program assessment meeting.	Dryden Flight Research Center
July 9-10	STS-1 Flight Rules Review as part of the Flight Readiness Review process.	Johnson Space Center

July 22-23	STS-1 Launch Commit Criterial review as a part of the Flight Readiness Review process.	Kennedy Space Center
July 23	Space Shuttle Main Engine status, problems and their resolution.	Rocketdyne Corp. California
August 6-7	Orbiter-102 reentry stability and control characteristics and the adequacy of the Orbiter flight control system, both hardware and software. Development and use of control equations.	Systems Technolog Hawthorne, CA Dryden Flight Research Center
September 16	STS-1 flight control simulation equations and reentry training results for the $0.9 < M < 6$ region.	Johnson Space Center
September 17-18	DFRC risk management system for their research aircraft projects, results of flight test to date on Orbiter-102 tile system configurations, general support of the Space Shuttle System with emphasis on STS-1.	Dryden Flight Research Center
November 13	STS-1 Orbiter reentry kinematics and adequacy of current trajectory analyses.	Charles Stark Draper Labs. Cambridge, MA
November 13	STS-1 Rollout/Stack meeting prior to move of Orbiter-102 from its processing facility and stacking (mating) with External Tank and Solid Rocket Booster in the VAB. Part of the Flight Readiness Review process.	Kennedy Space Center
November 17	Update on research aircraft projects, STS-1 support operations and review of current flight control simulations.	Dryden Flight Research Center
November 24-25	STS-1 Orbiter reentry flight control discussions to resolve any remaining concerns on stability and control margins.	Johnson Space Center

APPENDIX C

INVENTORY (TYPICAL) OF
PANEL ISSUES AND CONCERNS

TYPICAL ISSUES AND CONCERNS - STS-1

SUBJECT	DESCRIPTION	STATUS
Space Shuttle Main Engine (SSME)	Use of Flight Acceleration Safety Cut-Off System (FASCOS) to protect against turbopump failures. Must not get into position where instrumentation failure produce an SSME functional failure.	Open Panel will review program actions
Orbiter APU	Auxiliary Power Unit (APU) fuel isolation value seal breakage due to pressure surges in the fuel line.	Closed Panel satisfied with program actions
Orbiter TPS	Completion of Combined Loads Operational Tests (CLOT's) will provide certification of total tile system and gap fillers to meet expected environment.	Open Panel will review test results
Orbiter Umbilical Doors	Possible ice impact on these doors during list-off and ascent portion of mission.	Closed Actions planned taken appear adequate.
Mission Operations/ Payload Safety	Assurance that system safety associated with the Shuttle payloads and their interface with the Orbiter are as rigorous as that accomplished for each Shuttle element.	Closed Panel will monito this as a normal part of its review system
Mission Simulations and crew training	Assure that adequate time and thoroughness has been provided to ground and flight crews to meet the demands for STS-1.	Closed Activities to date give this assurance
Orbiter entry stability and control (aeroperformance)	Combinations of loss of roll or yaw thrusters coupled with ineffectiveness of aerodynamic flight control surfaces during the Mach No. 6 to 0.9 regime may cause diverging instability.	Closed Panel will continue to review program actions
Flight Rules and Flight Test Requirements and Launch Commit Criteria	Panel review of the Flight rules, requirements and their application during flight, including: "policy-priority" established to govern downmoding in case of electrical	Closed Activities to date give this assurance

SUBJECT	DESCRIPTION	STATUS
	and hydraulic limitations; data available for post flight analysis for various flight termination points in the mission; LCC scrubdown.	
Orbiter Seat Ejection System	Ejection seat yawing after ejection and the lateral loads on the crew when the drogue chute is opened.	Closed Tests and analyses appear satisfactory
Launch Processing System (LPS) at KSC for STS-1	Validation/testing of the ground and flight software in flight-configuration using (as close as possible) flight-configured hardware.	Open Current testing and the Flight Readiness Firinc will complete this. Panel monitor

TYPICAL ISSUES AND CONCERNS
SHUTTLE OPERATIONAL MISSIONS AND
ORBITER VEHICLES BEYOND ORBITER-102

SUBJECT	DESCRIPTION	STATUS
Shuttle Product Improvement or Enhancement Program	A formal enhancement should be established to assure proper attention to all those items/activities proposed to increase usefullness of the STS. Examples are: - Orbiter Landing Gear. Panel suggests that the main gear configuration be studied to assure adequacy for maximum required payloads, and use of wheel RPM in lieu of weight-on-wheels to initiate the anti-skid system. - Orbiter TPS. Continue to look for alternate, less fragile materials for tile. Alternative SIP materials to enhance the structural capability of the overall system and less negative impact from environmental conditions, e.g., water.	Actions are in process. Panel will monitor as a part of its normal reviews.
Solid Rocket Motor and Booster Processing at Kennedy Space Center	Current processing methods provide an acceptable level of safety. Completion of the ongoing SRM Hazard Study in the spring of 1981 will define any problems and confirm or redirect KSC actions now being planned and/or implemented. Three open items of concern to the Panel are: - Analysis of the effects of cracked propellants on the burn rate and subsequent VAB over-pressurization. - Assurance that risks will be reduced to lowest	SRM Hazard Stud is in process ECD is May 1981 CofF funding is being requested and initial wor has begun on th new storage and handling facilities. Pane will continue to monitor this work.

practical level during STS operations.

- Use of breakover fixtures vs. the current crane and hooks handling methods.

Additionally, the decision to continue to use manned cranes in the VAB rather than remote operated cranes as envisioned for the new SRB handling and storage facilities should be reevaluated in light of the results of the SRM Hazard Study.