NASA's Response to Comments
made in the
Aerospace Safety Advisory Panel Annual Report
on the Space Shuttle Program
dated June, 1976

Enclosure

- Page 3, Para. 1.I.A.

  Comment: There is no margin in the schedule to accommodate major perturbations.

  Response: Space Shuttle schedules have been developed to provide the proper balance concerning the amount of schedule time that could serve as contingency periods to accommodate development problems. Current Space Shuttle schedules do allow for normal perturbations as have been experienced in some instances to date with no impact to the overall schedule. To maintain large blocks of contingency time would be costly and inefficient. The Shuttle test program is designed to serve as verification of results obtained by other means (e.g., math modelling) so that any major problems will be identified early in the program.

- Page 5, Para. 1.II.A.1

  Comment: Senior management will need to monitor: 1) the ability to meet minimum requirements where there are further reductions or changes in the major test program.

  Response: Our review process insures that senior management is informed on major test program status and changes. This includes periodic reviews with the Program Director and Associate Administrator for Space Flight, and the establishment of ad hoc teams when special reviews are felt to be warranted (e.g., Space Shuttle acoustics testing, structural testing). The Management Council is also apprised of significant issues and used as a review forum for programmatic changes. Finally major test status and requirement changes are reviewed with the Administrator.

- Page 6, Para. 1.II.A.3

  Comment: Senior management will need to monitor the realism of plans and schedules for the remaining tests where there are significant problems so that decisions can be made early rather than under schedule pressure.

  Response: The Shuttle management reviews schedules and program progress on a continuing basis in order to judge their realism and to identify areas where increased attention may be required. We will continue to monitor this activity closely.

- Page 6, Para.1.II.B.1

Comment: An area that warrants review now is the data required from ALT to support a flight readiness decision on the first orbital flights and therefore the current mission planning to obtain these data.

Response: Careful management attention has been applied to (1) identification of the data required from ALT to support a flight readiness decision for the first orbital flights and (2) the ALT flight planning required to obtain these data. This attention is evident in numerous program documents. Volume III, Flight Operations, of JSC 07700, Program Definition and Requirements, relates the ALT objectives to the verification of capability for orbital flight. Space Shuttle Program Directives 5A, Flight Test Requirements, and 34, Mission Evaluation Requirements, are in effect to establish requirements for cross exchange of data. Further, ALT Flight Test Requirements (FTRs) have been developed to state logically the ALT data required to lift specific constraints against the ALT and OFT programs. The implementation of these directives in mission planning will continue to receive full management attention.

- Page 6, Para.1.II.B.2

Comment: An area that warrants review now is the aggregate risk inherent in the "first flight" plan to assure it remains at an acceptable level.

Response: ALT flight operations planning is under constant programmatic review. The risks associated with an individual flight are assessed to a large degree by the Flight Techniques Panel and reviewed by the Flight Crew Safety Panel, the Flight Test Program Panel, the Flight Operations Panel, and the Operations Integration Review and Range Safety Management processes. In particular, the Flight Crew Safety Panel will review all flight test safety issues on a regular basis to include the "first flight" risks. Further, "first flight" plan verifications will be accomplished using the Orbiter aeroflight simulator and the Shuttle Training Aircraft.

- Page 6, Para.1.II.B.3

Comment: The basis for confidence that the structural capability of the 747 tail section will not be overloaded during tailcone off flights and that vibrations will not exceed crew tolerance.

Response: Based on extensive wind tunnel test and analysis by Boeing and Rockwell International, it has been established that the structural capability of the 747 tail section will not be exceeded during tailcone off flights. The situation with regard to 747 crew tolerance is not conclusive. To conclusively establish the acceptability of full length tailcone off flights, it is planned to conduct precursor mated tailcone off taxi and flight tests. The results from these tests will be utilized in making a final decision on whether to conduct the full length tailcone off flights. Safety will be a paramount consideration in the decision.

- Page 6, Para. 1.II.B.4

Comment: The test requirements and plans to give confidence that the landing gear will deploy and lock as required.

Response: Ground tests of Orbiter landing gear deployment will be conducted under simulated flight conditions. In addition to ground tests, it is planned to conduct a deployment test during landing high speed rollout of the mated 747/ Orbiter. The results of the ground and flight tests will be utilized to verify proper Orbiter landing gear deploy and lock prior to Orbiter free flight.

- Page 6, Para. 1.II.B.5

Comment: An area that warrants review now is the plan to have adequate GSE at the proper place to support the ALT program.

Response: All of the GSE required for ALT has been identified and design is approximately 98% complete. As of mid-August, 1976, there are no anticipated problems associated with having ALT GSE in place on time.

- Page 6, Para. 1.II.B.6

Comment: The flight software requirements warrant review so there is an identical flight profile for autoland and manual modes.

Response: ALT software requirements for autoland and the manual control modes have been established so that the pilot and commander will be able to fly the same trajectory as autoland (within the limits of human error). Flight plans are being prepared for compatible trajectories for both the outer $12^{\circ}/13^{\circ}$ and inner 1.5° glide slopes.

- Page 7, Para. 1.II.B.7

  Comment: An area that warrants review now is the provision to allow the crew to adjust the gain of the control system.

  Response: The proposal for pilot control of Flight Control System (FCS) gain was disapproved following detailed management review at the ALT Critical Design Review. The rationale for this decision is discussed in detail in our response to the ASAP suggestion that this proposal be further reviewed (see our response to paragraph 8.0, III. C. of the ASAP Report).

- Page 7, Para. 1.III.A.

  Comment: Give attention to the effectiveness of recent changes in the avionics management approach and the need for a software expert in the Technical Assessment Office as an independent advisor and check and balance.

  Response: The need to augment the Technical Assessment Office with software expertise has been known by management. As soon as qualified personnel can be found they will be added to the staff.

- Page 7, Para. 1.III.B.

  Comment: The management system to assure that contingency abort analyses are given the proper priority now so that changes, particularly, in the software, are being made while there is still the capability for changes.

  Response: The Ascent and Entry Working Group established by the Flight Operations Panel (FOP) provides a focal point for abort analyses. The review and implementation of contingency abort analysis findings are now an active function of the FOP and Operations Integration Review process.

- Page 7, Para. 1.III.C.

  Comment: Give attention to the total or integrated management plan to assure SRB reliability.

  Response: An SRB R,Q&A plan (SE-020-005-2H) has been baselined at level III which constitutes an overall plan of the requirements and controls to ensure high SRB reliability. The overall management system, although the prime responsibility of the Project Office has been designed to ensure that all critical failure modes/hazards and their effects are identified, reviewed and their impact assessed continuously at all program levels.

Above and beyond the normal major milestone reviews, additional activities and controls have been implemented as follows: A special intercenter S,R&QA Panel with appropriate subpanels has been created, joint surveys at all levels are being conducted, CIL's are being baselined to ensure management attention and approval of disposition actions/controls and an overall system level failure reporting and tracking system implemented.

- Page 8, Para. 1.IV.A.

Comment: The selection of a material and its methods of application for the external insulation, so that the program gets the flight performance it needs.

Response: Based on recently completed cryogenic tests, as well as flammability resistance and wind tunnel tests at AEDC the program has baselined CPR-488 compound as the new SOFI for the external tank. Methods of application of this material is the same as that used for the previously used compound (CPR 421).

- Page 8, Para. 1.IV.B.

Comment: Safeguards to protect auxiliary power unit with sea water exposure.

Response: The design requirements for the APU requires the component to have the capability of 20 uses after sea water exposure. As indicated in the ASAP report, we have been very successful in our sea water tests in flushing out the catalytic bed and refiring the gas generator successfully. We are still in the process of conducting sea water immersion tests of the APU and will use the results of these tests to make any required changes to assure compliance with design requirements. Some of the results of the test indicate differences in torque requirements and sealant requirements to prevent water from entering the gear box.

- Page 8, Para. 1.IV.C.1.

Comment: Follow closely the provisions to assure that TPS installation procedures and tools will maintain the required gap and step between tiles and to avoid the problem of an early tripping of the boundary layer.

Response: We agree that this is an area requiring diligent attention and plans and progress are continuously reviewed.

Rockwell and Lockheed, in a parallel effort, are evaluating two simplified approaches for installing TPS tile arrays. These investigations are expected to be completed in September, 1976, and the solution is expected to assure acceptable step and gap control.

Validity of the stringent criteria currently used is subject to reassessment but the final proof will be determined during the early flights, where the trajectories will be tailored to provide adequate margins.

- Page 9, Para. 1.IV.C.2.

Comment: Follow closely the provision to adequately protect vehicle openings during entry with insulation while assuring this insulation will not obstruct the operation of doors.

Response: A minimum of the doors are required to operate prior to reentry. The payload bay doors, vents, umbilical doors and aero sensors are exceptions. Of these, the payload bay doors and vents are located in relatively protected areas and the seal on the payload bay door, which was found to lose its flexibility when cold, is being changed to a design not affected by orbital temperatures. The umbilical doors actuate after ET separation and provisions have been made to cycle the doors and latches independently for trouble shooting on orbit. The seals selected should not be vulnerable to effects of temperature encountered. The landing gear doors and others are closed and sealed prior to launch and no physical change is anticipated in the material which would compromise operation.

- Page 15, Para. 2.II.A.3.

Comment: The staff of engineers in the systems engineering office may need to be increased. Management regularly should review the staffing of the systems engineering office to assure that its capability is appropriate for its responsibilities.

Response: Agree. Some upward adjustments have been made in the staffing of the systems engineering office. More people could be used productively in engineering and integration.

- Page 15, Para. 2.II.A.4

Comment: Most of the directives have to do with responsibilities for monitoring and evaluating Space Shuttle progress rather than specifying how the daily work gets done or how the daily integration decisions are made. Some do not clearly define responsibilities.

Response: The Systems Engineering Office is an organizational element under the Systems Integration Manager and a conventional management relationship exists. Instructions to the technical organizations outside the program office, however, may take different forms depending upon the nature of the direction and the associated impact, but are typically from within the chain of the Level II PRCB, the Systems Integration Review (SIR), or the Technical Manager/Technical Panel area. Responsibilities of each are covered by program directives and need to be considered collectively in defining relationships. For the example cited, daily integration effort is performed by the responsible NASA/contractor organization, as coordinated within the framework of the technical manager/panel structure and under the guidance of the Systems Engineering Office. Issues that need a broader review by nature of the interfaces or technical considerations are brought to the SIR, which is chaired by the Systems Integration Manager, for resolution. Those issues that involve requirement changes, cost or schedule impact, or substantial differences in technical options, are submitted to the Program Manager's Level II PRCB for decision and direction.

- Page 16, Para. 1.II.A.5.

Comment: Work on this (system engineering) plan has been delayed further. If the plan is not to be available in a timely fashion, the management will have to assure that the basic need that required such a document is met in another way.

Response: The system engineering plan consists of engineering master schedules and narrative sections detailing the working process of the responsible technical organizations. The heart of the plan is the schedule of input-output milestone commitments for the systems engineering/integration effort across the program. A conscious decision was made to concentrate on completing the milestone schedules as early as possible and allow the narratives to be developed as resources permit. The schedules have been released and in use since December, 1975. Since that time, improvements in detail definition have been made and updates are periodically incorporated in the master schedules. A System Integration Manager's Review and a Program Manager's Integration Review was instituted to provide for timely discussion of integration and resource issues that come out of the scheduling activity. Most of the narrative sections of the plan have now been completed and the remainder are in review. This delay has not affected the overall purpose for which the plans were intended.

- Page 17, Para. 2.II.A.7.

Comment: Newly established chief engineer at MSFC for the Main Propulsion System was not a member of the Systems Integration Review Panel (SIR) at JSC. The panel believes that he should have direct participation and membership in the Systems Integration Rewiew Panel activities, as well as be a part of the approval cycle for Level II and III documents.

Response: MSFC wrote a letter to JSC (12 November 1975) requesting that Mr. Charles Wood (Chief Eng. at MSFC for the Main Propulsion System) be added as a member of the SIR. JSC answered that the organization concept of the SIR was developed within the context of having a key Level II participant representing each functional area. Mr. Richard Ferguson, of JSC, was designated "Technical Manager for Integrated Propulsion and Fluids" for the area of interest to Mr. Wood. As such, Mr. Ferguson is available to coordinate with Mr. Wood relative to appropriate MSFC inputs to the SIR. In addition, Mr. Wood's name has been included for SIR meetings, announcements, minutes, etc. As such, Mr. Wood has direct input to Mr. Ferguson and the SIR panel for activities pertaining to the Main Propulsion System. Mr. Wood has the same relationship to the SIR panel as Mr. J. R. Thompson, MSFC SSME Project Manager, that is, direct participation in SIR panel activities in his area of interest.

- Page 18, Para. 2.II.B.1. and 2.

Comment: 1. The Panel favors the role of identifying problems so the assessment groups can cover more areas of the program. 2. The Panel suggests that priority be given to safety issues rather than non-safety issues that may seem more pressing.

Response: The assessment groups operate under broad charters and in general, identify, review, and evaluate rather than work a resolution to a problem. Problem solving is the responsibility of the inline organizations. The establishment of priorities is an internal process and reflects the considered judgment of the individual group and particular Center emphasis. Safety issues demand high priority but we would not want to exclude non-safety issues. Periodic reporting to the Program Director and Management Council provides a mechanism for reordering priorities if it is judged desirable.

- Page 20, Para. 2.II.C.1.

Comment: The explosion of a solid rocket booster, a main engine, the external tank, or a reaction control system in all likelihood cause the loss of an orbiter. Thus, all possible measures must be taken to prevent such an occurrence or to provide warning so that such an explosion could be prevented.

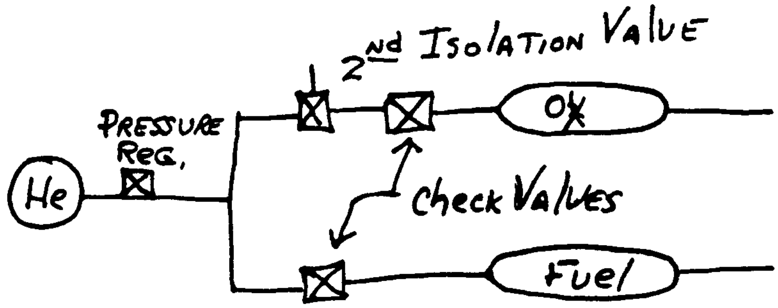
SSME Response: The Hawkins team was chartered to conduct an overall assessment of the Space Shuttle system. Out of this review came a separate "Engine Margin Review" whose objective was to "Reassess the SSME Structural Design". This assessment and structural audit was completed and reported on to the Hawkins Committee as well as to top NASA officials. Any additional reviews should start with reviewing the results of the Hawkins Team and the SSME Margin Review.

In addition, the Critical Design Review (CDR) will be held in September, 1976, which will assess the maturity of the SSME through a review of the design and testing results.

SRB Response: Plans are being implemented which identifies the approaches used, control methods, and procedures to ensure proper quality controls. These plans include identification of all failure modes, effects of these modes, hazard analysis, sneak circuit analyses and other risk assessments that could have a potential failure mode. The results of all these analyses are tracked with a continual assessment of program risks.

In addition to conducting assessment of potential risks to the SRB, specific requirements are imposed on the design to minimize failure modes. For example, these include using proven propellants used in previous solid motor programs, adding extra insulation to prevent the possibility of case burntthrough, and a well defined development and qualification test program which includes 7 motor firings.

OMS Response: The OMS subsystem manager and design personnel met with the ASAP people at the beginning of the OMS POD development effort and adopted the following design/operational features for the OMS design to accommodate all "known" safety requirements: (a) A fire wall is designed into the pod to separate the propellant tanks from the engine proper - it is not a blast wall, however, (b) a second isolation valve was installed in the OX tanks pressurant line between the regulator and the OX tank down stream of the "Tee" junction, which also supplies GN_2 to the fuel tank.



(c) The OX and fuel fill and drain valves are located on opposite sides of the vehicle (i.e., fill fuel from Rt. POD only and fill OX from Lt. POD only); (d) Shuttle pilots will have caution and warning lights on propulsion panel for identification of low pressure conditions in any of the fluid or pneumatic components of the OMS.

RCS Response: (a) The RCS plumbing and tankage is designed to no-fail limits of structural stresses. (b) RCS - GSE will have vapor detection sniffer capability for personnel safety (pre and post launch). (c) RCS plumbing will be leak checked pre and post launch. (d) Filling and draining criteria same as OMS.

- Page 20, Para. 2.II.C.2.

Comment: SRB or External Tank separation.

Response: The signals which arm and fire the "pyrotechnic" devices for the solids are dual redundant and the pyros are dual redundant. There are no known software contingency techniques to deal with the very remote problem of the failure of the solids to separate.

- Page 20, Para. 2.II.C.3

Comment: In the early flights there will be no Shuttle to perform rescue services, so effort should be made to minimize contingencies which might cause rescue to be needed. These include doors (payload bay doors, or umbilical door) which cannot be closed prior to reentry or the failure of the external tank to separate.

Response: The Space Shuttle is not designed to be dependent upon a rescue vehicle as a contingency backup. Crew safety requirements are the same as for previous programs where no rescue capability existed. Payload bay doors, for example, must be closed prior to reentry. The doors cannot be adequately verified as a system, prior to flight, because of the one "g" environment. Reliability will depend on simple, straight forward design which is amenable to analysis, and component testing. On any flight during which the doors will be opened, EVA capability will be provided, together with the necessary tools, etc. to permit manual closure of the doors by an EVA crewman.

- Page 21, Para. 2.II.C.4.

Comment: Suggested that input and output devices and mechanisms be reviewed to doubly assure no "hard-overs" can exist.

Response: The solids and the main engine gimbal systems are controlled by four port force-sum actuators. The system is being designed to tolerate two consecutive failures. In the remote case of a main "engine out" problem the failed engine will be gimballed in a fail-safe position such that the remaining two can be gimballed through their full authority of $\pm$ 10.5 degrees pitch and $\pm$ 8.5 degrees yaw. Input-Output devices and mechanisms for controlling the engine gimball's are under constant analyses and reviews.

- Page 21, Para. 2.II.C.5

Comment: Adequacy of test and APU system design should be reviewed.

Response: JSC indicated the APU is currently under safety and operational review and will continue to be so until all SSME gimbal and other hydraulic system functions are satisfied.

A turbine wheel scatter shield has been designed into the turbine housing assembly to preclude a category 1 failure from an exploding turbine wheel.

- Page 21, Para. 2.II.C.6

Comment: Loss of pressure in the cabin appears to be a singular and important hazard. There are two cabin air supply systems and three fuel cells which provide cabin air pressure and conditioning. The system must operate for the entire mission and total failure would be fatal. It is suggested that a concentrated review take place seeking once again the strong confirmation that there is a remote enough risk to take. A third air supply system might be feasible and valuable.

Response: We agree that the loss of cabin pressure is a critical and important hazard. There are two general categories of failures which could result in the loss of cabin pressure. One is the loss of pressure by external leaks; the other, by failure of the gas distribution and control system itself. An ancillary high pressure oxygen tank is provided for emergency backup. In the event of excessive external leakage, it will provide an 8 psig cabin pressure for a leak aperature equivalent to a .45 dia. hole for 165 minutes. An incident of such a leak is considered to be remote.

The primary mode of oxygen supply is from the fuel cell power reactant tanks. The nitrogen is stored in four high pressure vessels. Many of the systems components are identical to those of the Skylab which functioned perfectly for 171 days. Other redundant functions and hardware have been incorporated into the Orbiter, such as two stage pressure regulation, crossover manifolds, isolation values and manual controls. Failure mode and effects analyses have identified the most critical hazards and certification/qualification plans have been baselined. We believe the addition of a third air supply would result in unnecessary cost, weight and complexity. We feel the continuing attention to the development and qualification of our present baseline will result in low risk to crew safety and mission success.

- Page 22, Para. 2. II. C. 7

  Comment: Reevaluate Total System

  Response: The controls and the APU systems are three parallel systems. Two APU systems are required to share the load.

- Page 22, Para. 2. II. C. 8

  Comment: "Destruct" decisions for operational flight are needed.

  Response: Decisions regarding employment of a flight termination system during the STS operational time period will not be made for sometime. In the next two years, the joint NASA USAF Range Safety Ad Hoc Committee will be exploring the risk-benefit considerations of planned operations. The involuntary risk must be maintained at a level acceptable to the public and at the same time bear a reasonable relationship to the voluntary risk accepted by flight personnel. We do not expect that decisions in this area will be confirmed until the OFT series is completed.

- Page 23, Para. 2. II. C.

Comment: A similar detail review should be made of the crossover capability which exists on the control system to maintain hydraulic pressure in the event of APU failure with specific focus on the adequacy of maintaining hydraulic pressure in the main engine control valve system. If an APU shuts down there will be an automatic shutdown of that engine being served.

Response: In the event of an APU failure, crossover capability exists to maintain hydraulic pressure in the SSME TVC, elevon actuators and wheel brakes. While crossover capability does not exist for SSME propellant control (due to cost, schedule and weight considerations), mission safety is not compromised. An APU failure would result in the shutdown of one SSME which would result in a safe intact abort case.

- Page 24, Para. 2. III. A.

Comment: "Comprehensive review of integrating groups operations should be conducted regularly to insure responsiveness to program needs."

Response: Agree. The integration activity in support of program requirements is highlighted through reviews with the Program Director, Associate Administrator for Space Flight, and selected Management Council topics. Special technical reviews are held in areas where support is critical, and, resource adjustments are made if required. The system integration organization and working relationships are well established but changes are made in panel structure and assignments as improvements are needed.

- Page 24, Para. 2. III. C. and D.

Comment: C. Individuals at the systems integration level at JSC and at Rockwell's Space Division should be given appropriate management responsibility, authority and resources for contingency analysis and planning.

D. Analysis and evaluation of vehicle capability for off-design cases should be done now, rather than later when necessary changes would be prohibitively costly. Staffing needed for this effort should be provided.

Response: Most of the vehicle analysis for off-design/contingency capability has been delayed in deference to design/analysis effort in support of the Critical Design Review (CDR). This is an acceptable approach since no major hardware changes are anticipated to provide for contingency capability. Minor changes could be incorporated after the CDR.

- Page 24, Para. 2.III.F.

Comment: A hazards assessment report should be prepared because of potential hazards to the SRB from aerodynamic environment or failure modes elsewhere in the vehicle.

Response: The significance of potential hazards to the SRB from aerodynamic environment of failure modes elsewhere in the vehicle has been recognized by MSFC in that the SRB FMEA has a list of aerodynamic sensitive elements identified in the appendix, action has been initiated to determine what should be in the SRB vs. systems hazard analyses and a risk management team has been formed to evaluate all hazards identified.

- Page 32, Para. 3.II.B

Comment: Current controller tests appear to have been successful. The controller software programs have progressed a great deal over the past year, but much is to be done.

Response: The PP-2 controller successfully passed vibration testing and shipped to MSFC for acoustic testing at Wyle Labs. Acoustic testing at the predicted flight level of 153 dB was successfully completed in early May without any controller problems. The controller (PP-2) and its associated test and checkout equipment was returned to MSFC where it has been integrated into the Simulation Lab and performing successfully.

The controller, both software and hardware, has been doing an excellent job of supporting engine testing at NSTL. A total of 93 hot fire tests have been conducted at NSTL as of August 18. Sixty-seven (67) tests on stand A-1 using rack mounted controller BT-1 and 26 on stand A-2 (engine 0002)susing engine mounted controller PP-3. We have accumulated over 1300 operating hours on controller BT-1 and 330 hours on controller PP-3 at NSTL. The next controller, PP-4 is scheduled for delivery in mid-November for use in engine testing.

The software design is proceeding on schedule. Software has been doing an excellent job of supporting the engine test program at NSTL. However, Honeywell has expressed concern over the availability of hardware (controllers) to support the software development program, software acceptance testing, engine testing, SAIL program, etc. A task team was established to resolve the problem and to develop a program plan to satisfy all the software requirements.

- Page 32, Para. 3.II.B., Items 1,2,3, 4 and 5

Comment: Status of SSME top priority items

Response: 1. High Pressure Fuel Turbopump - Dr. Fletcher and Dr. Lovelace briefed by Rocketdyne on status August 5, 1976. They are kept updated on a weekly basis.

2. High Pressure Oxygen Turbopump Performance - Testing of a High Pressure Oxidizer Turbopump on Engine 0002 at NSTL showed a performance improvement with the cutback partial-vane impeller (was 20% low; now approx. 5% low). Additional actions are being taken to further improve performance by reducing preburner wear ring leakage and a redesign of the main impeller.

3. The 77.5:1 Nozzle Fabrication - The first 77.5:1 nozzle has been proof tested to rated power level and will be shipped to NSTL the week of August 23, 1976. This nozzle will be installed on engine 0003 (stand A-1) with the first test scheduled for early September. The problems of nozzle jacket distortion during fabrication appear to have been resolved by the process of rehydrosizing after welding.

Work is progressing on designing the additional thermal insulation required as a result of the ascent, OMS, RCS and reentry redefined heat loads. Approximately 140 pounds of insulation and structural "beef up" per engine will be required on selected areas of the nozzle. Convair has been selected to do the materials testing.

4. Hot Gas Manifold Liner Excess Pressure Differential - The hot gas manifold (HGM) liner Δ P had been a concern when the ISTB engine HGM liner Δ P went to 375 psid at 60% power level. However, contamination of the injector (as a result of previous engine problems) was suspected and confirmed. Drilling additional holes in the injector face plate lowered the Δ P to acceptable levels. The Δ P on engine 0002 is well within the requirements (200 vs. 400 psid).

5. Test Program - Turbopump testing has resumed on Coca 1 after an approximate five months lapse as a result of the fire on this stand February 4, 1976. Stability bomb testing of the main combustion chamber is continuing on the Coca 4 Test stand at Santa Susana.

Engine testing continues at NSTL as we test and evaluate the various high pressure fuel turbopump "whirl" fixes. The ISTB engine has been replaced on the A-1 stand with engine 0003 with testing to start in late August.

- Page 36, Para. 3. III. C.

Comment: "What will happen to the 56 hours of engine testing if major problems arise and take extra time to resolve?"

Response: This becomes a judgement factor depending on engine performance at the time of Final Flight Certification (FFC). If the engine has been performing well during development we would cut back on the program saving both manpower and propellant costs. If, however, we had development problems and arrived at FFC with considerably fewer tests and test seconds than the planned 996 tests and 224,00 test seconds (56 hours) we may have to continue testing and slip the FFC. However, if the most recent testing at that time showed that we now have a good running engine, we could make the judgement that the engine was satisfactory.

- Page 49, Para. 4. III. B.

Comment: The tile material itself appears to be satisfactory from the standpoint of production and processing. However, the program to fully characterize structural capabilities has been delayed.

Response: It is true that the tile characterization program was scheduled for completion in 1976 and that has not been done. The delay stemmed from the hiatus in tile production due to budget constrints. Conservative design values have been developed, however, using experimental material samples instead of the production material. It is planned, of course, to vigorously pursue a full material characterization program to validate the design values used. There is not evidence from preliminary testing that the values used are not conservative.

- Page 49, Para. 4. III. C.

Comment: Concerns associated with the LESS include the ability to maintain required gaps and steps between the RCC segments and the interfacing tiles (concern about early tripping of boundary layer). Additional concerns include mission life capability and cracks on the nose cap shell observed during development testing.

Response: The ability to maintain required steps and gaps at the RCC/HRSI interface is the subject of detailed analytical and test effort. Time related deflection of the RCC, including the contribution from the front spar deflection, is being developed for a range of heating rates for a number of trajectories. Placement of insulation on the front spar, RCC mounting bracketry adjustments and known deflection should allow establishing preflight conditions so that worst case would not exceed the criteria, taking advantage of the more acceptable back facing steps.

The mission life of the leading edge structural systems has been greatly enhanced by the addition of a coating of tetra-ethyl-otho-silicate over the silicon carbide coating. This seals the micro cracks and inhibits the subsurface oxidation. We feel confident from test results that good mission life can be expected.

The crack on the nose cap shell observed during development test was found to be the result of distortions of the test fixture and not a nose cap flight problem. However, the failure does indicate that the nose cap is sensitive to out-of-plane deflections of the bulkhead it is attached to. Analyses are being performed to determine the amount of distortion of the flight bulkhead and its effect on the nose cap.

- Page 50, Para. 4.III.D.

Comment: The ability to adequately protect vehicle openings from the high energy plasma during entry has yet to be proven. This appears to be receiving adequate attention, but may require some redesign effort, prior to the first OFT, which is not comtemplated at this time. This may also serve to expand the current Development Flight Instrumentation requirements.

Response: Of primary concern at this time relative to preventing entry of high energy plasma are the aerodynamic seals an the control surfaces. A number of test articles are currently under construction to assess damage to adjacent structure in the cove areas if a seal were to fail. The tests will simulate progressive failure in arc jet tunnels. A design effort is underway to provide redundant aerodynamic seals instead of the existing ones which might be single point failures.

Other openings such as P/L bay vents and passive vents are located in relatively low temperature areas and provided with heat sink protection where deamed necessary. No plasma injection problem is anticipated on the RCS engine openings.

- Page 58, Para. 5. III

  Comment: A centralization of control of the software in the program would be beneficial.

  Response: The control of the software is centralized in the Orbiter Avionics Systems Office. Mr. A. Aldrich the manager of this office chairs the Software Control Board and reviews all Orbiter software requirements, status of design implementation, problems and solutions.

- Page 58, Para. 5. III. A.

  Comment: A competent, knowledgeable person should be assigned at Program Office level to perform the function of Chief Engineer, Avionics.

  Response: The responsibility for the Orbiter Avionics system (hardware and software) is centralized in the Orbiter Avionics Systems Office since almost all the Shuttle avionics is in the Orbiter.

- Page 59, Para. 5. III. B.

  Comment: The program of testing and simulation of the Avionics system should be given a high priority as it forms an independent verification of the software.

  Response: The ADL and SAIL are the Shuttle Avionics testing and validation facilities. The detailed schedules, plans, problems and proposed resolutions are reviewed by the Orbiter Project Manager at the monthly Orbiter Management Review with Rockwell. Johnson Space Center conducts in-house reviews of both ADL and SAIL test activities.

- Page 59, Para. 5. III. C.

  Comment: Technical assessment group should be supplemented by outside experts in software verification.

  Response: See response for Page 7, Para. 1. III. A.

- Page 59, Para. 5. III. D.

  Comment: Further efforts should be made to more clearly define specific software responsibilities.

  Response: The recent management reporting realignments both in-house at JSC as well as at the software contractor, IBM, strengthen the Avionics System Office control over software development. The Office has responsibility for the total software development effort, requirements generation and design and code implementation.

- Page 71, Para. 6. II. G.

  Comment: Safety Assessment Report for the ALT flights.

  Response: The "preliminary" ALT Mission Safety Assessment Report released in June, 1976, will be updated for the DCR in December followed by a "final" document release in February, 1977, to support the FRR for the first captive flight. An L-2 Addendum is planned to incorporate any significant changes from the FRR to support the first captive flight in March, 1977. This will be followed by an Approach and Landing Addendum in July, 1977, to support that FRR, which will include any significant changes resulting from the capative flights, and finally another L-2 Addendum to update any FRR changes prior to the first approach and landing flight.

- Page 75, Para. 6. III.

  Comment: The final aggregate risk assessment should focus heavily on "what if" questions.

  Response: The fault tree process, as described in the ALT project safety assessment report, is used as the systematic approach for pursuing "what if" questions. This process is carried through to individual hardware items and the identified safety concerns assessed for each mission phase of the ALT. Emphasis is placed on identifying, assessing and resolving these safety concerns prior to the ALT DCR and the various ALT FRR's.

- Page 82, Para. 7. III

  Comment: "Planned full scale model tests were directly related to 1/4 scale model tests - designed to provide a one-to-one comparison ... The lack of these one-to-one comparisons could have an adverse impact. Management is aware of these reductions and has assessed the risk."

  Response: The GVT program has not been reduced since the early 1975 plan. At that time, the dummy Orbiter was deleted from the full scale program and some undefined test conditions were deleted from the 1/4 scale program. At the same time the balance of the 1/4 scale test conditions were reviewed and some were changed to more nearly give a one-to-one comparison with the full scale tests (e.g., added on Orbiter horizontal test condition and an Orbiter/ET tilt condition).

Other changes to improve the 1/4 scale model program included the addition of a maximum "-q" condition (not in the full scale tests) and the addition of influence coefficient tests. No further changes have been made in the GVT test conditions and the 1/4 scale program still retains the corresponding full scale test conditions.

- Page 83, Para. 7.III.D.2

Comment: There is some indication that test payloads during early OFT are being considered that could interfere with manual back-up for closing payload bay doors. Recommend no such payloads be permitted during early OFT.

Response: We have been mindful of the fact that some payloads being proposed for Orbital Flight Tests could interfere with EVA access to manual payload door closure. We agree with the panel that closure by use of EVA should not be precluded in early OFT. Exactly when this constraint can be relaxed is still under discussion. A definitive drawings of the payload bay volume which must be kept accessible by EVA is under development.

- Page 84, Para. 7.III. Last Paragraph:

Comment: The Panel believes the point of diminishing return must be close for changes in the Ground Test Program. Thus, such changes should be brought to the attention of the Panel as soon as they are defined.

Response: We can do this. The last major change was the deletion of the Orbiter aft fuselage vibro acoustic test at JSC and the transfer of test objectives to MPTA. Additional instrumentation and mass simulations will be incorporated in the test article to obtain the desired data.

- Page 87, Para. 7.III

Comment: The Panel should follow changes and/or reductions planned for support equipment, assuring that NASA reviews of such actions consider all risks involved.

Response: GSE is subjected to the same program management controls as other hardware including flight hardware. This includes conduct of PDR's, CDR's, and change board control activity. The ASAP could review these activities in order to gain confidence in the control of GSE hardware.

- Page 96, Para. 8. III.C.

Comment: The Panel believes that the flight control system, if provided with a cockpit gain variation, would add to the safety of the first flight tests of the Orbiter vehicle. The Panel is aware that the ALT CDR considered this problem; however, we suggest further review.

Response: The ALT CDR Board considered all aspects of the cockpit controlled gain variation question, particularly safety. The alternative suggested by the originator of a similar review item disposition (RID) submitted for the OV101 Delta PDR, to provide a backup system with different gains from the primary system, has been implemented. That action, the well understood subsonic flight regime of ALT, the short flight duration with no violent maneuvers and the extensive landing area available at DFRC all contributed to the decision. Safety representatives participated in the review and in the decision. The Space Shuttle Program Office will review with the ASAP any specific questions the panel may have regarding this subject.

- Page 96, Para. 8. III.D.

Comment: If the Orbiter L/D is to be simulated when it is flown with tailcone on, the Panel recommends that extra caution be employed to assure there is sufficient attitude control available when drag devices are deployed. It is realized that currently such maneuvers are not planned.

Response: As indicated, it is not currently planned to simulate the Orbiter L/D with tailcone on. Should it ever be planned, it will be a mandatory requirement that sufficient attitude control be available to safely simulate Orbiter L/D with tailcone on.

- Page 96, Para. 8. III.E.

Comment: Panel believes it is essential to make automatic and manual landing profiles identical.

Response: Based on many T-38 flight simulations, the profile for the ALT outer glide slope has been established to be $12^{\circ}/13^{\circ}$ for both Autoland and manual. The inner glide slope for Autoland is being reviewed and it appears that it will be baselined at about 1.5°. This will provide a compatible glide slope for Autoland and manual such that the crew will be able to gracefully take-over from the Autoland and fly-in during a visual manual flare and landing. These profiles are being analyzed, reviewed, and will be flight-tested and verified on the Shuttle Training Aircraft.

- Page 102, Para. 9. II

  Comment: Give latest hazard status

  Response: The latest update of the Hazard Summary (based on the July 30, 1976, Hazard Analysis Report) is as follows:

  A. 69 Hazards Identified

  B. 21 Hazards Submitted to NASA for Evaluation

  C. 5 Residual Hazards Proposed for Acceptance

  D. 43 Continuing Hazards Resolved

- Page 102, Para. 9. II last A.

  Comment: Breakdown of Hazards into functional list caused a great deal of cross referencing, etc.

  Response: The functional breakdown of the Hazards List will be reviewed for a more effective and simpler breakdown.

- Page 102, Para. 9. II last B.

  Comment: TPS Flammability problem suggests that a complete review of propellant spillage/leakage may be of value.

  Response: The problem of flammability of the Thermal Protection System due to propellant leakage/spillage has been submitted by MSFC to Level II for tracking and disposition action.

- Page 103, Para. 9. II. B.

  Comment: The effectiveness of the retardant in case of an oxygen leak is questionable.

  Response: The improved ET TPS (CPR 488) compound exhibits improved flame retardant capability. Testing,however, on various samples are still in progress and the effects of an oxygen leak on this material is continued to be tested and studied by MSFC.

- Page 103, Para. 9. II. B.

  Comment: An lengthy exposure to direct solar heating might degrade the integrity of the Thermal Protection System (CPR 421)

Response: Approximately 350 samples of the revised ET TPS compound (CPR 488) will be exposed to various environments. Although some degradation of the TPS surface due to UV can be expected, it is the opinion of the technical experts that it will not affect the thermal insulation properties of TPS.

- Page 104, Para. 9. II. E.

Comment: Tank tests are still forthcoming.

Response: Anti-geyser tests at MMC Denver, have been rescheduled due to funding constraints. Tests will be initiated in September, with an anticipated completion in mid-January 1977.

- Page 104, Para.9. II. F.

Comment: Large cryogenic separation fittings subject to water and nitrogen icing might be troublesome to guarantee a proper disconnect. To date, no ground separation test (even simulated) is planned.

Response: At a recent Separation Mechanical Systems Subpanel meeting (July 26, 1976), RI presented a summary of safety hazards and concerns caused by possible condensation of air or N_2 at the LH_2 disconnect. Also, icing is a problem at both the LH_2 and the LOX disconnects. Condensation of air (cyro-pumping) is a hazard and the icing can cause mechanical problems with umbilicals as well as door mechanisms. RI has investigated several methods of dealing with these problems and is currently working on a purge system for the umbilicals and a combination of insulation and heaters for the mechanisms. Recommendations will be made to the TSR.

- Page 104, Para. 9. III. A.

Comment: Finalized data in all environmental fields will not be available until late in the test program and may result in a costly redesign and sooner or later, performance variations may well result.

Response: Realizing that Space Shuttle system weight margins have been small and performance goals have been high, we have been pursuing several candidate measures for reducing system weight and for enhancing launch performance. These studies are continuing with new candidates being identified. It is expected that all pending weight growth and performance dispersions will be be offset by implementing certain of these measures now under study.

- Page 105, Para. 9.III.B

Comment: Critical mechanical activities like the complex separation of the External Tank and Orbiter will be experienced for the first time under environmental conditions during the first orbital flight. If at all possible, it would be prudent to include an environmental separation ground test in the program. A flight failure can neither be observed nor measured and could well lead to a total loss of the Orbiter.

Response: Separation mechanism requirements stipulate that components and subsystems be qualified to operate and survive in the maximum environmental conditions imposed by Space Shuttle missions. Qualification testing will be conducted at the system level.

For example: Integrated Orbiter/ET umbilical pre-flight verification testing will be conducted with qualified or qualifiable hardware using combined MPS, mechanical systems and avionics components. Tests will be conducted under cryogenic conditions utilizing a flight configuration ET umbilical disconnect mechanism and a flight configuration Orbiter umbilical carrier. Flight loads, vibration and pressure differential will be simulated.

A similar phylosophy will apply to structural separation systems. In addition, the Orbiter/SCA structural attach/separation systems will use the Orbiter/ET system, thus the ALT program will further verify the system prior to orbital flight.

- Page 105, Para. 9.III.C

Comment: It would be advisable to assure suitable limited storage space for these large external tanks.

Response: The KSC VAB project for high bays 2 and 4 will include provisions for processing and storing up to four external tanks. The need for additional storage at KSC was reviewed and is considered not necessary at this time.

- Page 106, Para. 9.III.D

Comment: Suggest that a "Lightning Protection Committee" approve the finalized lightning protection measures.

Response: Testing on the external tank Gaseous Oxygen (GOX) line indicated a potential burn-through problem when covered by TPS (to prevent icing). Currently the design concept is to purge the GOX line to defrost therefore, no TPS is required.

Without TPS, the lightning stroke will be swept across during ascent and tests have indicated no burn-through problem on a 0.02 inch thick stainless steel line. The present design will utilize a .032 inch line for safety margins.

All designs will be tested under simulated lightning conditions (worst case, 50K amps, 2 micro sec rise time). This will provide us the necessary data to support and verify the external tank design. Periodically the Lightning Protection Committee consisting of representatives from the prime contractors and the centers audit the designs for appropriate design implementation and test verification. No additional group or committee appears to be required.

- Page 110, Para. 10.III.A.

Comment: Reconditioning must assure adequate flushing.... possibility of designing plastic cover.

Response: This is currently being "worked" by MSFC, KSC, and Sundstrand. A final procedure for total cat-bed refurbishment has not been agreed upon by the above parties. Salt content, flushing fluids and drying temperatures are still open issues.

- Page 111, Para. 10.III., Last Sentence

Comment: Hazards associated with Shuttle system assembly in the VAB will be included in such surveillance.

Response: A second briefing was conducted for the DOD Explosives Safety Board on July 30, 1976, to provide an update on our planned VAB Shuttle operations. The Board responded in a letter of August 18 indicating it appears that the proposed use of the VAB is satisfactory provided that any undue hazards indicated by the SRM contractor hazard analysis be adequately controlled or eliminated by procedures or facility modifications. We plan to brief the Board on the results of the hazard analysis when it is completed. We will also continue scrutiny of manpower requirements to assure that manloading is the minimum for efficient operation.