59T

annual report to the nasa administrator by the aerospace safety advisory panel

part II – space shuttle program

section 1–observations and conclusions

(NASA-TM-82248) ANNUAL REPORT TO THE NASA ADMINISTRATOR BY THE AEROSPACE SAFETY ADVISORY PANEL. PART 2: SPACE SHUTTLE PROGRAM. SECTION 1: OBSERVATIONS AND CONCLUSIONS (National Aeronautics and Space G3/16 N81-16115 Unclas 43428

june 1975

ANNUAL REPORT TO THE NASA ADMINISTRATOR

by the

AEROSPACE SAFETY ADVISORY PANEL

PART II - SPACE SHUTTLE PROGRAM

Section 1 - Observations and Conclusions

June 1975

PREFACE

This year's Annual Report from the Aerospace Safety Advisory Panel has been divided into two parts. The first part, dated February 5, 1975, covered the Apollo Soyuz Test Project. This part, Part II, covers the Panel's efforts on the Space Shuttle program.

The Panel has been conducting reviews of the many aspects of the Shuttle since September 1973 and considers this year's Shuttle report to be the second in a continuing series of reports. Reviews to date indicate that NASA is proceeding in a reasonable manner to develop a technical basis for confidence in crew safety. This judgement is based upon confidence in (1) the review system which evaluates the adequacy of mission requirements and whether the design approach meets them, (2) the suitability of the test program to qualify Shuttle hardware/software, (3) the assessment of hazards and their resolution, and (4) the development process for subsystems critical to crew safety.

CONTENTS

1.0 INTRODUCTION

1.1 Objective

The objective of the Panel's review of the Space Shuttle Program has been to evaluate whether the program is proceeding through a reasonable process to develop a responsible level of crew safety. Confidence in crew safety implies confidence in such areas as:

(a) NASA and contractor management systems, including policies, practices and procedures for the development of critical systems, subsystems and integration of the program elements.

(b) Technical development status of critical systems, subsystems and interfaces.

(c) Test program to qualify Space Shuttle elements (Orbiter, External Tank, Main Engines, Solid Rocket Booster, Ground Support Facilities).

(d) Identification and resolution of hazards.

(e) Mission operations and contingency planning.

1.2 Panel Activities

Since its last report the Panel has held detailed discussions with the contractors for the Orbiter, Space Shuttle Main Engines, and External Tank as well as with subcontractors for such critical subsystems as the Orbiter Thermal Protection Subsystems and the Main

Engine Controller. We have had repeated discussions with the Shuttle Program and Element Project Managers at the NASA Centers. In addition, the Panel has physically examined the available Shuttle hardware, fabrication and assembly facilities and test areas.

A summary of the agenda for these fact-finding activities is provided in Attachment 1. The Panel also had a great deal of supporting documentation made available to them as required.

In addition to the on-site activities mentioned above, the Panel has from time-to-time requested additional information to update or clarify specific individual interests. An example of this material is presented in Attachment 2.

2.0 OBSERVATIONS

2.1 Management

In general the Panel found that the organizations and management systems implemented by NASA and its contractors for each of the Shuttle elements are adequate and appropriate for the current stage of the development program. Of particular note were significant changes in management of the Main Engine project and its critical Controller. These changes appear to have strengthened these management systems.

Since the Shuttle is currently in the development phase, there are a number of technical management challenges to be met and resolved. Others will no doubt arise as the program evolves towards the operational phase.

An immediate need is to strengthen the Shuttle integration function, particularly within NASA and to assure for the effective conduct of the "check and balance" role necessary to successful systems integration. Examples are the performance/cost/schedule tradeoff studies and the planning of element and integrated test programs. The current management system for Avionics hardware and software, particularly on the Orbiter vehicle, should be reviewed by senior program management to assure that capability is available to deal with the complexities of Shuttle avionics. The current integration effort appears to be effective in the critical areas of definition, documentation, and control of hardware interfaces whereas organization and management interfaces may require further attention.

The numerous Shuttle Panels and Working Groups, established to bring all the available technical talent to bear on the day-to-day design and development problems, appears to be effective in supporting NASA and contractor technical decisions and review requirements.

The Panel feels a strong audit system is needed to check on day-to-day operations as well as a system for providing program management the opportunity to review risk assessment in a timely manner. Safety data must be made available early enough to be considered in the design and test decisions.

2.2. Shuttle Program Elements

2.2.1 Orbiter

Although the Orbiter generally is proceeding in a satisfactory manner, certain critical areas have yet to be baselined. Among these are the Thermal Protection Subsystem, Avionics System, and External Doors which must be reviewed in the very near future.

Manufacturing procedures appear comparable to those observed on prior spacecraft production. The Panel has not visited subcontractors but there is a continuing need to monitor them.

Obviously, there are many areas that we have reviewed and about which we could comment; however, we have decided to identify a few areas most critical to achieving a high order of crew safety. Changes in the design of the Thermal Protection Subsystem to use a "prepared" NOMEX felt on large areas of the Orbiter upper fuselage in lieu of thin tiles indicate a reduced hazard in this critical subsystem. In those areas where tiles and reinforced carbon-carbon are used, the challenge now appears to be installing and inspecting them before each mission rather than in the production of the tiles and nose caps. Installation and inspection problems as to tile-to-tile steps and gaps are expected in meeting individual and multiple tile tolerance requirements. Defining the inspection methods to assure tile internal integrity is currently under study. Test programs on the Thermal Protection Subsystem in high energy thermal and acoustic-vibration environments are continuing.

Many door mechanisms are single failure points. The recent reduction in the number of doors enhances the basis for confidence in crew safety. The Payload doors, including radiators and operating mechanisms, still require further attention. In the light of the Skylab Review Board's recommendations, doors should be treated as operating mechanisms rather than structure.

Development of practical thermal seals in and around moveable aerodynamic surfaces and doors to prevent high heat loads on internal structure and operating hardware during entry present a design and test challenge.

The dynamics of Orbiter separation from the External Tank are complex. A major concern is the design and fabrication of fittings and a command system that will operate in a precisely timed sequence. This will be necessary to avoid any vehicle instabilities or debris impacting the Orbiter.

The Panel suggests that management review once again the following areas to assure there is an adequate basis for confidence in crew safety:

(a) The use of single actuators on the Orbiter elevons.

(b) Decision to use free fall deployment of the nose and main landing gear immediately prior to runway touchdown.

(c) The realism of those Reference Missions 1 and 3 requirements which affect safety because they are drivers on vehicle design.

2.2.2 Space Shuttle Main Engines (SSME)

The Integrated Subsystems Test Bed engine moved through assembly ahead of schedule and the manufacturing personnel at Rocketdyne Division of the Rockwell International Corporation now have a better understanding of what will be required to produce these complex engines. The materials for the critical parts of combustion devices, turbomachinery and heat exchangers and complexity of welds on engine assemblies present potential problems with hydrogen embrittlement. The test firing program will provide needed data on the ability to survive repeated firings at pressures and heat rates not previously experienced.

Analysis indicated that the Space Shuttle may be subject to POGO (structural oscillations) not unlike those experienced by the Saturn V launch vehicles on the Apollo and Skylab programs. A POGO suppressor has been baselined and extensive tests coupled with analysis is currently underway. This requires a closely integrated NASA-Industry team effort.

Experience during the past year with the Controller confirms that the technology of plated wire cores is at the state-of-the-art and there would be many problems to be resolved by a trial and error approach.

Program Management's choice of an improved hydraulic fluid not only reduced the fire hazard but improved performance. There have been no major problems or additional costs associated with this change.

2.2.3 Solid Rocket Booster

The solid rocket motor is basically within th current state-of-the-art of technology and design and fabrication of early units is underway. MSFC, as the Booste. Project Manager, indicates the design and manufacturing of the motor case and propellant are up to expectations. The Panel's interest in the safety of a reuseable booster system is not because of a feeling that the system is inherently unsafe but because some of the inherent penalties of a reusable system, i.e. greater weight and complexity, may well be drivers that affect other parts of the system and result in an overall more complex system with a somewhat lower safety factor.

The Panel in its review has been impressed by the effort that has gone into implementing the reuseable concept.

The areas requiring continuing management attention include:

(a) Design of the remaining components of the SRB assembly, e.g., separation motors, avionics and parachutes.

(b) Reliability of the gimbaling mechanism (thrust vector control).

(c) Reliability of the avionics subsystem.

(d) Recovery, inspection and refurbishment procedures related to their ability to provide confidence in the safe reuse of the booster. This includes the wisdom of reusing electrical circuitry and connectors in signal and control circuits that have been repeatedly immersed in salt water.

(e) Parachute development and proof testing.

(f) Hazards to personnel involved in the water recovery of the booster and parachutes.

(g) Protection of the critical structural members against stress corrosion fractures.

2.2.4 <u>External Tank</u>

The External Tank is the major element in the Space Shuttle system that is expendable. The Panel's interest focused on the disposal problems and on any hazards to the basic Orbiter vehicle.

The External Tank must be made to tumble after separation to assure a predictable reentry footprint. This requirement has generated a set of ground rules for an acceptable disposal system and at the same time also requires:

(a) Creation of a tank tumbling motion within a specified ten to fifty degrees per second.

(b) Prevention of premature tank rupture.

(c) Prevention of recontact with the Orbiter after separation.

The disposal system selected will not only have to meet the technical ground rules but also the cost and weight constraints.

Insulation material used on the external surface of the tank, as well as its configuration, is of significance in that outgassing and ablative products could adversely affect the Orbiter's Thermal

Protection Subsystem properties. Formation of ice/frost on the tank and fittings could present a hazard to the Orbiter during launch.

A potential hazard results from teflon insulated wire routed through the liquid oxygen tank to various tank sensors. A special set of tests and analyses are being run under so-called "worst case conditions" to determine the risk involved. The Panel has requested that other methods or materials be investigated to see what other possibilities are available regardless of the outcome of the above mentioned test and analysis program.

2.2.5 Ground Facilities

The launch and landing aspects of the Shuttle Program were recently reviewed by the Panel at KSC, and are an extension of the operations' reviews conducted earlier. KSC's role on the Apollo and Skylab programs has provided excellent insight into the requirements for Shuttle facilities and ground support equipment. Trade-offs between costs and safety for ground support equipment require continuing management attention. The Panel will also continue to monitor these trade-offs.

2.2.6 Test Program

The Panel's questions fall mainly in the area of the proposed flight test program, i.e., the Approach and Landing Test and the first six developmental orbital flights. The Approach and Landing Test program may include as many as eleven low altitude flights launched from the Boeing 747 carrier aircraft modified for this purpose. During such flights there are separation effects to consider that may affect crew safety. Shuttle elements will be tested together for the first time during the first vertical flight and as a result additional hazards may be revealed. Therefore, as the flight test planning evolves, management will need to give priority attention to:

(a) The risk versus the data obtained in the Approach and Landing Test.

(b) Role of the crew in the control loop during the landing phase.

(c) Analyses, procedures and training for contingencies including abort, ditching and landing accidents, including the impact on design requirements.

(d) Proper role for range safety.

(e) Development of an integrated hazard analysis of the first flight that would give management a comprehensive profile of the risks and the alternatives.

The Ground Test Program as presented to the Panel appears to meet the qualification/validation requirements of the individual elements and the total integrated system. Continued study of the ground test program and its relationship to the flight test program is necessary to assure an orderly and timely approach to total system verification.

2.2.7 Range Safety

The Panel has not reviewed the impact of the range destruct system but feels that its interface with the Booster or Orbiter systems must be spelled out because it can well become a part of the software as well as the hardware system. Such questions as when and how does it override the computer and manual control is an important factor in planning and design.

3.0 CONCLUSIONS AND RECOMMENDATIONS

3.1 Generally, the management system is adequate for the current state of development.

3.1.1 Systems integration management needs to strengthen its "check and balance" capability.

3.1.2 The management system for avionic hardware and software should be reviewed by senior program management to assure it is adequate for the indicated complexity of the program.

3.1.3 It is important that senior program management review both the scope and results of safety analyses to reinforce early resolution of risks. Similarly, attention should also be given to the scope and results of technical management audits to assure that such systems as described to the Panel are being applied properly. Two examples are Configuration Management and Material Control.

3.2 The development of the Orbiter system is proceeding as scheduled. Manufacturing procedures appear comparable to those used on prior spacecraft programs.

3.2.1 The design and quality control for the doors, Thermal Protection System penetrations and thermal seals should be closely monitored by management to assure that the reliability necessary to satisfy safety will be achieved.

3.2.2 The procedures, instructions and training requirements for installation and quality control of the Thermal Protection System components should be reviewed by program management to assure the aero/thermodynamic requirements are met.

3.2.3 Free fall deployment of landing gear may introduce safety problems. Therefore the use of a positive system for rapid extension of landing gear should be considered.

3.3 The major challenges of significance for crew safety on the Space Shuttle Main Engine are materials behavior under severe environments, weld integrity, POGO suppresion and engine Controller performance and reliability. Therefore the results of the test program will be critical to developing confidence in these areas.

3.4 The major challenges on the External Tank of safety significance are thermal insulation, ice formation, the use of teflon electrical wire insulation in the liquid oxygen tank and provisions for control of reentry.

3.5 The Solid Rocket Booster is in an early stage of development. Critical areas must be monitored closely for the earliest possible detection and resolution of problems to assure that trade-offs provide for the maximum Shuttle system safety. Such areas include recovery and re-use of the booster.

3.6 The program in assuring the cost effectiveness of its requirements for ground support equipment needs to assure safety receives appropriate attention.

3.7 The program is in the period of defining the detailed requirements and plans for major development and flight testing.

Plans for ground testing appear adequate. Safety-related testing should be monitored to insure it is carried through as planned. The interactions between the Orbiter, External Tank and Solid Rocket Booster, including separation dynamics are complex. Analyses based on ground testing should be thorough enough to maximize confidence in safe development flights.

3.7.1 More information is needed on the risks of Approach and Landing Testing in comparison with the value of information which would be obtained in such flights.

3.7.2 The role of man-in-the-loop, especially during landing, rollout and braking, needs re-examination as the program reaches the point where avionics' capability and limitations are better known.

3 7.3 Contingency analyses especially for aborts, ditching, landing accidents, and range safety should be completed early enough to assure design solution rather than operational work-arounds.

ATTACHMENT 1 - PANEL ACTIVITIES

January 15, 1974	Orbital Maneuvering System	MDAC-East, St. Louis, MO
February 26, 1974	Program Manager's Review of Significant Shuttle Decisions	JSC, TX
May 13-14, 1974	External Tank	Martin Marietta, Michoud, LA
June 5-6, 1974	SSME Quarterly Review	MSFC, ALA
July 16-17, 1974	Shuttle Main Engine Controller	Honeywell, Aerospace Div., FLA
August 22-23, 1974	Orbiter Thermal Protection System	Ames Research Center/Lockheed, CA
September 16-17, 1974	Systems Integration Activities Space Shuttle Main Engine	RI-Downey, CA
October 15, 1974	Orbiter ALT program, Ferry Operations, OFT program, Operations	JSC, TX
January 6, 1975	Shuttle Level II Update Avionics and Their Managment MSFC Update (Teleconference)	JSC, TX
March 3, 1975	Launch and Landing Project	KSC, FLA
April 7-8, 1975	MSFC Systems Activities SRB, ET, SSME Detailed Review	MSFC, ALA
May 5-6, 1975	Shuttle Technical and Management Challenges, Systems Safety, Systems Tests	RI-Downey, CA

ATTACHMENT 2

MSFC RESPONSE TO ACTION ITEMS FROM THE PANEL'S

INSPECTION TRIP OF APRIL 7-8.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
MARSHALL SPACE FLIGHT CENTER, ALABAMA 35812

JUN. [illegible] 5

REPLY TO ATTN OF: SA01

TO: NASA Headquarters
Attn: APA/Mr. Howard Nason

FROM: SA01/Robert E. Lindstrom

SUBJECT: Action Items/Aerospace Safety Advisory Panel Visit, April 7 and 8, 1975

As discussed during the April 8 wrap-up session and in accordance with your correspondence of May 23, 1975, this memorandum is being forwarded to close certain actions as well as provide projected response dates on the remaining actions recorded during the subject visit. We are also addressing several additional actions provided to us by Dr. Mrazek in early May and documented by your May 23 correspondence.

We have provided briefings to Dr. Mrazek on the below items and believe these actions to be closed:

- External Tank anti-geysering test program.

- MSFC sonic boom activities in support of JSC and RI integration efforts.

- Acoustic, vibration, and thermal load data included on element Interface Control Documents.

- Economics supporting recovery and reuse of Solid Rocket Booster.

- Solid Rocket Motor bi-propellant activities.

We will follow-up on the briefing provided to Dr. Mrazek on SRB Recovery System with a written response to the Panel by June 16 on:

- Possibility of premature actuation of the SRB Recovery System and the effects of such an actuation.

- Quality control efforts planned for the SRB Recovery System based on prior Air Force drone recovery system experience.

Enclosures 1 through 10 address our responses to action items on:

- FMEA Critical Items List
- Secondary Structural Items
- Hazard Analysis Status
- 7075-T6 Material
- Teflon Insulated Wire
- Material Management System
- ET Lightning Protection
- Freezing/Breakoff of Condensation -- Damage to Orbiter TPS
- SSME Heat Exchanger Leakage Limits
- SSME Lightning Protection
- Utilization of Teflon Balls in POGO Suppressor Unit

As you can note from our responses, several of these actions are still in the analysis and coordination phase with JSC. Further data will be supplied to the Panel upon completion of this phase. Also at this time, we are still in the process of addressing the differences between MSFC's and JSC's production hardware component acceptance test vibration requirements. We should be in a position to provide this response to the Panel on June 16.

While Mr. Praktish was here for the ASTP pre-FRR, we discussed with him the deferment of the below items to more appropriate groups for addressing the Panel's concerns:

- **SSME Critical Failure Periods during the Ascent/Actions to alleviate resulting problems (JSC/RI).**

- **Safety problems associated with SRB retrieval at sea (KSC).**

As we discussed during your visit to MSFC, the question of critical SSME failure periods relate to vehicle control problems. While we are participating very closely with JSC in this area from vehicle structural limits, etc., the critical time periods are mission/wind dependent and this area should be addressed by JSC. Also, KSC is carrying out the planning and development activities associated with the SRB retrieval activity.

As we discussed with Mr. Praktish, we will stand ready to respond to any questions that might arise on the attached responses and will work toward having all of the actions closed by June 16. We appreciated the opportunity to review our project elements status and activities with you and the Panel and will look forward to further discussions with you and the Panel members as we progress through the Shuttle program.

Robert E. Lindstrom
Manager, Shuttle Projects Office

10 Enclosures

Aerospace Safety Advisory Panel

FMEA/Critical Items List

Attached are copies of the Failure Mode Effects Analysis (FMEA/ Critical Items Lists (CIL) for the Space Shuttle Main Engine, External Tank, and Solid Rocket Booster. [Copies available in Panel office.] It should be noted that the FMEA/CIL enclosures are preliminary issues originally released at the Preliminary Design Review, except for the SSME which was updated November 1974, and as such, they have not yet been accepted by MSFC as a baseline list of critical hardware. The lists are being continuously updated as the design becomes more mature, and it is expected that they will be reduced significantly in the future. Also, MSFC has an effort in progress to evaluate these FMEA/CILs, and to assure that all critical failure modes are identified and minimized by elimination through design approaches or by redundancy. Final acceptance of the list will occur in conjunction with the baselining of the design at Critical Design Review.

Secondary Structural Items

Relative to the requirements that we are utilizing to assure that proper FMEA review is given to secondary structural items to account for items similar to the Skylab meteoroid shield, a number of actions should be recognized. As you are aware, special attention is given

Enclosure 1

to structures as well as other passive components such as wiring and tubing during the initial design and test phases. This attention consists of a stress analysis which is analogous to a single failure mode effects analysis to assure that the passive components will withstand all predicted stresses with a reasonable safety margin. For passive compon which are of a new design, the stress analysis is not considered adequate and environmental tests are initiated to verify the strength and reliability of such members. Of special interest are passive components in high pressure systems and the rupture failure mode for pressure vessels and flex hoses are considered in the failure mode effects analysis. Action has also been initiated to require FMEA evaluation of hardware items whose structural failure due to aerodynamic stresses could have a critical effect; e.g., fins/farings, shields, external insulation, external conduit and piping, exposed deployable/separable hardware, and access panels/doors. These hardware items will then be reviewed to assure that all aspects associated with their design and test program are given proper attention (structural/aerodynamic analysis, testing, material selection, bonding, attachment methods, sealing, and inspection techniques).

Aerospace Safety Advisory Panel

Hazard Analysis Status

As was noted in the response on the status of Failure Mode Effects Analysis (FMEA)/Critical Items Lists (CIL) activities on our projects, we are presently reviewing and analyzing the FMEAs / CILs released at the Preliminary Design Reviews on each of the MSFC Shuttle Projects. Our hazard analysis activity is proceeding in parallel with FMEA/CIL activity. Additionally, each of our elements are making inputs into the Element Interface Functional Analysis (EIFA) being developed by JSC for:

Space Shuttle Main Engine/Orbiter
Solid Rocket Booster/External Tank-Orbiter

All of these activities are focused on providing early visability of hazards to provide for minimizing hazards either through design approaches or redundancy prior to the element Critical Design Reviews. At this time, we are still in the process of establishing the milestones for completion of our analysis of the FMEA/CIL and the hazards list developed thus far by our element contractors. However, these documents are the subject of on-going technical and management reviews at Level III and Level II toward assuring that all failure modes, etc., are being covered.

Enclosure 2

Aerospace Safety Advisory Panel

<u>7075-T6</u>

<u>Action Item:</u> Provide Panel with relationship between the rejection of 7075-T6 material in the lunar module to the initially planned use of this material on the ET intertank.

7075-T6 forgings and plate were rejected for use on the lunar module because of susceptibility to stress corrosion cracking (SCC). The threshold tensile stress for onset of SCC is approximately 7000 psi for 7075-T6 stressed in the short transverse direction. This stress level can easily be exceeded in forgings and in plate material. It is nearly impossible to exceed the threshold stress in the short transverse direction in sheet material, hence the use of 7075-T6 sheet material is acceptable, provided it can be shown that the intended use meets the requirement of no short transverse tensile stresses exceeding 7000 psi.

The concern with the planned use of 7075-T6 by MMC had to do with notch sensitivity, and not SCC. The MMC usage involved 7075-T6 sheet largely, which will be exposed to liquid hydrogen temperatures. At LH_2 temperature the notch strength of 7075-T6 is inferior to both 2024-T7 and 7075-T73 hence the use of 7075-T6 sheet has been limited to temperatures no colder than -200°F. Any remaining 7075-T6 sheet uses at $>$ -200°F have been certified to have negligible short transverse tensile loading.

Enclosure 3

Aerospace Safety Advisory Panel

Teflon Wire Usage in LOX/GOX Environment

The ET Project selection of Teflon (FEP) insulated wire was based on extensive Saturn experience and testing in identical environments. These environments differed drastically from the high pressure two phase system used on Apollo.

Our test experience on the Saturn Program with this wire insulation may be summarized as follows:

a. No ignitiions could be induced in LOX environments in any case tested.

b. Ignitions could be induced in GOX (55-75 psi) environments only with 800% electrical overloads. In cases where ignition was initiated, the wire and insulation self-extinguished at the wall of the test chamber and drip burn products were quenched by the LOX in the test chamber.

c. Using flight hardware connectors, connector pins failed before the wire could be overloaded to a point where ignition could occur.

The current ET design uses 22 gage Teflon (FEP) insulated wire for the liquid level and loading sensors in the LOX tanks. This wire capability is:

a. Fusion current - 60 amps

b. Recommended design capability - 15 amps

c. Normal ET usage - 0.09 amps

d. Maximum ET current (limited by sensor fusing) - 1.5 amps

Therefore, it is MSFC's conclusion that the flammability testing experience during the Saturn Program and specific tests required by NHB 8060. 1A will verify the acceptability of the current design. The most critical test of this specification is electrical overload on actual harnesses at worst case temperatures and pressures.

Enclosure 4

This test will be performed when actual production harnesses are available, which will not occur for some time.

MSFC recommends that this action be closed based on our compliance with NHB 8060.1A. Should the harness overload test fail, then corrective action will be implemented.

Aerospace Safety Advisory Panel

Material Management System

The question as posed in the May 23 correspondence asked for the specific management system being utilized that assures that stress corrosion problems are under control. Our briefing to the Panel on April 7 addressed our utilization of a materials specification and the requirement for submission of Materials Usage Agreements to a Materials Applications and Evaluation Board (MAEB) when a deviation from the specification was being considered for implementation. The MAEB is chaired by the Director, Materials & Processes Laboratory.

Regarding the visability that is conveyed across the program elements on any approved deviations from the materials specification information is being provided through two methods at the present time; The requirement for MATCO Forms (Material Tracking and Control) is being implemented on Shuttle Projects for transmittal to JSC/RI/SD and daily exchanges of information are taking place between materials and processes personnel throughout the NASA organizations. Additionally, JSC will be placed on the distribution for the Material Usage Agreements processed on MSFC Shuttle Projects. Visability across the program elements and NASA Centers is further enhanced by the release of SAF-ALERTS and ALERTS on material or material process problems experienced during the development, testing, and production of hardware.

Enclosure 5

Aerospace Safety Advisory Panel

Lightning - External Tank

Action:

Provide closeout documentation on the ET lightning protection implementation.

Discussion:

a. Two meetings of the Lightning Team were held on April 21, 1975, and May 20, 1975, to assess ET progress.

b. The assessment is now being directed to defining swept stroke lightning model which is representative of the conditions ET can expect during ascent. This approach is based on:

(1) ET will be protected on the launch pad by the KSC Facility Protection System.

(2) The Shuttle Vehicle will not be launched through a thunderstorm, rain, or hail because of structural or Orbiter TPS conditions.

(3) ET involvement with lightning because of these constraints will be at some minimum altitude and vehicle velocity.

(4) Vehicle velocity at the minimum altitude is a factor in assessing the tank burn through potential which is the prime concern in ET lightning protection.

c. JSC and consultants will develop swept stroke lightning model on or about June 18, 1975. Another team meeting will be established thereafter to discuss verification aspects.

For contingency purposes, MMC will continue the investigation of suitable metallic paints for diverter strips and will perform tests to determine burn through limits of the ET tank walls.

Conclusion:

ET lightning protection design is currently predicated upon use of the GO_2 pressurization line and a lightning rod for swept stroke lightning dispersion. It is anticipated that the current design will meet the

Enclosure 6

intent of the Level II lightning specification when that specification is corrected to recognize swept stroke design criteria. Verification of design performance will be accomplished through analyses and emperical data.

Aerospace Safety Advisory Panel

Potential Ice Damage to Orbiter TPS

MSFC does not have a test program to specifically define/establish the effect of condensation forming on flight type interface structure and subsequently running down the tank and freezing, which may result in damage to the Orbiter TPS. However, as a part to the ice/frost test, using a 10-foot tank at EAFB, water, fog, and mist will be applied to the tank sidewall including simulated interface structure under anticipated worst environmental conditions. Results of this testing (quantitative ice/frost characteristics) will be provided to the System Integration Contractor for defining the Orbiter TPS tolerances for ice/frost debris.

Enclosure 7

Aerospace Safety Advisory Panel

Allowable SSME Heat Exchanger Oxidizer Coil Leakage Rate

During the presentation on this subject the Safety Panel questioned the allowable heat exchanger oxidizer coil leakage rate of 1 X 10^{-6}cc helium/second. It was stated that the present technology in leak detection permits measurement of leakage at considerably lower rates. The Panel position was correctly stated since leakage rates in the range of 1 X 10^{-10}cc helium/second are detectable with mass spectrometers and halogen leak detectors. However, the SSME allowable heat exchanger coil leakage was not established based on measurement capabilities in a controlled laboratory but rather the feasibility of measurement in a field operational environment with a specified turnaround time. The minimum expected leakage with welded joints was also considered. Our present plan is to allow leakage of 1 X 10^{-6}cc helium/second during component tests and 1 X 10^{-3}cc helium/second during the field operational leak test inspection. The adequacy of this approach will be verified during the engine development (DVS) test program and the allowable heat exchanger leakage will be reassessed against our latest test results.

Enclosure 8

AEROSPACE SAFETY ADVISORY PANEL

LIGHTNING - SPACE SHUTTLE MAIN ENGINE

Action:

Provide closeout documentation on the SSME lightning protection.

Discussion:

a. Rocketdyne assessment of JSC 07636(Space Shuttle Lightning Protection Criceria Document, dated September 11, 1973) was completed and provided to MSFC on April 23, 1975.

b. MSFC is in process of evaluating the Rocketdyne assessment to determine the degree of change, if any, that MSFC will recommend be made to the SSME design. The MSFC assessment is based on the following:

(1) On-Pad Protection: The SSME, as well as the entire Space Shuttle Vehicle, will be protected on the launch pad by the KSC Facility Protection System.

(2) Ascent Protection - Direct Strike: The SSME is in cones of protection of the Orbiter stabilizer and SRB's on ascent; hence, a direct strike (200 KA current) to the SSME on ascent and the resulting direct effects (blast, burn, etc.) are ruled out. Tests by MDAC for JSC have confirmed this SSME protective situation. (Reference McDonnell - Douglas Corporation Report MDCA3155, "Final Report, Simulated Lightning Test, Shuttle 0.03 Scale Model", October 25, 1974). In addition, the heat shield is expected to divert the direct stroke around engine compartment. Thus, only the nozzle could be liable to direct effects damage.

(3) Reentry Protection - Direct Strike: A direct strike to the SSME on reentry (200 KA current) may be possible, but similar MDAC tests are necessary to determine if the SSME may also be in a cone of protection, ruling out this situation. Such a strike, however, would not affect the mission since the SSME is inoperative on reentry. Only minor damage, if any, would be sustained by the SSME to the nozzle since the heat shield would divert the current from the nozzle around the engine compartment.

(4) Protection - Indirect Effect: Indirect effects (induced voltages and currents caused by electromagnetic fields) are based upon field strengths provided by JSC. A change to add shielding to most SSME electrical harnesses will provide complete SSME protection from indirect effects based upon JSC provided data. Engine shutdown due to indirect effects would thus be prevented on ascent.

Enclosure 9

(5) Current SSME Capability: Current SSME design is adequate if launch restrictions due to weather are imposed, and if the defined maximum strike current and induced field levels are too conservative.

(6) Swept Stroke: The SSME is subject to swept stroke lightning on ascent and reentry, but tests by Lightning Transients Research Corp. (LTRI Report No. 563) indicate no damage to nozzle if 100 KA current stroke is swept along by 90 mph air flow. JSC and consultants plan to develop swept stroke lightning model in June on which further assessment can be made.

(7) The SSME is protected by a shroud during ferry flights.

c. MSFC recommendation will be made to JSC (Shuttle Program Manager) by June 20, 1975, upon completion of the MSFC evaluation.

Conclusion:

Current SSME design appears to afford adequate protection if appropriate launch and reentry constraints are imposed. Added shielding to harnesses ($1M) will protect from engine shutdown on ascent provided a direct strike to SSME is ruled out as a possibility. Full implementation of protection against direct strike during ascent is not considered warranted based on test data.

Aerospace Safety Advisory Panel

Utilization of Teflon Balls in POGO Suppressor Unit

The analyses supporting the subject utilization (acting as a membrane on the liquid surface) were covered with Dr. Mrazek in a separate briefing. The initial POGO suppressor design effort did consider a flexible membrane in lieu of Teflon balls. The RI/SD concept, located upstream of the low pressure oxidizer pump, used a flexible membrane. Rocketdyne's suppressor is located downstream of the pump and is exposed to higher pressure differentials. A flexible membrane was considered but the pressures and increased compliance to the system led to utilization of the Teflon balls.

Concern for the difficulty in developing the hollow Teflon balls was discussed and the possibility that the balls may have to be stainless steel with Teflon coatings was covered. The emphasis will remain on the use of Teflon due to its recognized LOX/GOX compatibility properties.

Enclosure 10