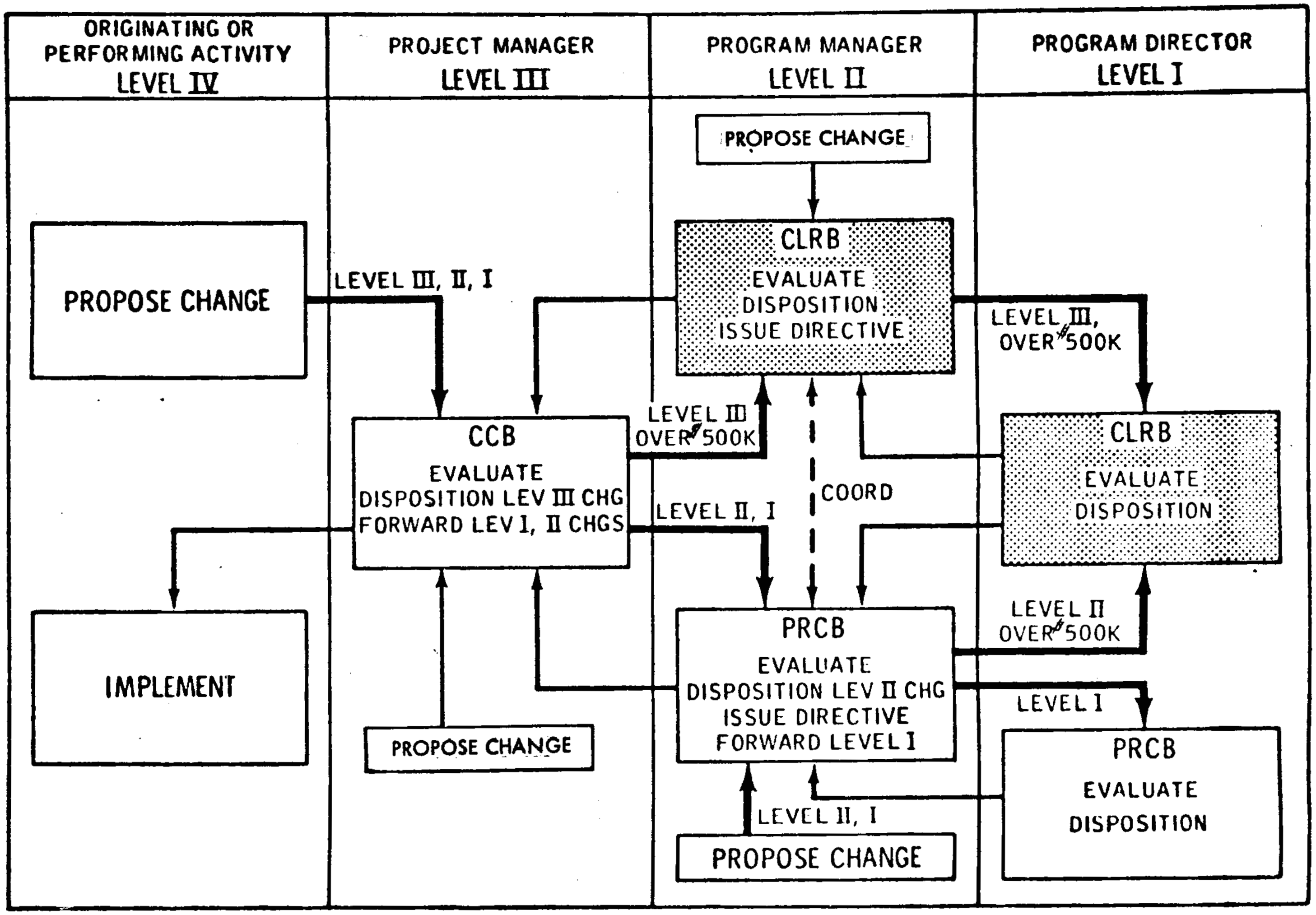
SPACE SHUTTLE CONFIGURATION MANAGEMENT
CHANGE CONTROL FLOW

FIGURE IX-3



X. ORBITAL FLIGHT TEST PROGRAM

A. Introduction

The orbital flight test program is the last phase in the verification process. It demonstrates the total vehicle capabilities under operational environments. Many aspects of the 102, e.g., aerosurface and hydraulic system development, are also a part of the 101 story and in that respect are covered under Orbiter 101 for the ALT. The Panel is also monitoring those subsystems on Orbiter 102 which would not be proven on the Orbiter 101/ALT flights as well as the major new elements, i.e., Main Engine, External Tank and Solid Rocket Booster.

Later reports will deal more directly with the Orbiter for the first OFT. The purpose of this section is to describe the objectives and the major issues to be investigated through the OFT program so that the following Sections X and XI covering the SSME, ET and SRB are put in the proper context.

B. OFT Objectives

The program objectives are to verify (1) the performance of each of the subsystems across the board, (2) the integrity of the integrated or total vehicle, (3) the operations and checkout procedures, (4) Compatibility of the vehicle with the ground system, (5) the orbiter-to-payload interface, (6) payload handling including deployment and retrieval, and (7) specific capabilities and orbital/sortie maneuvers.

For each phase of the OFT mission there are a number of "issues" that are to be investigated to meet the OFT program objectives. There are ten phases noted by the program and at least 55 issues within those phases, e.g.,

Phase-Liftoff and boost issues - propellant slosh dynamics
thermal load, external tank
POGO (Stability and Control)

While the Panel does not have the resources to track each issue, the Panel does monitor the handling of the most significant ones. Volume XI "Shuttle Orbital Flight Test Requirements" of the Master Verification Plan series of documents establishes the OFT requirements which must be verified or demonstrated during the Space Shuttle Development Flights.

Because of discussions concerning the appropriate use of the concepts "demonstration" and "verification" in terms of certifying the system, the following definitions are given as found in the "Master Verification Plan-Definitions:"

"Flight Demonstration refers to the verification of the performance of the flight vehicles under a predetermined mix of flight conditions."

"Verification is the process of planning and implementing a program that determines that the Shuttle System meets all design, performance, and safety requirements. The verification process includes certification, development testing, acceptance testing, flight demonstration, pre-flight checkout, and analysis necessary to support the total verification process."

Thus, demonstration is only one facet of the verification process.

C. Risk Assessment

The Panel also monitors the handling of the major safety concerns. The latest issue of the "Major Safety Concerns," JSC 09990 is of significance here because it underlines the risks and/or concerns associated with the OFT and ALT test program. These were considered by the Panel in planning the direction the Panel task teams should take in reviewing the SSME, ET, SRB and other unique aspects of the Orbiter and launch/recovery facilities.

For example, the Panel tracks the programs handling of open safety concerns such as the use of the SRB nozzle extension separation ordnance during the first OFT and the ET thermal insulation flammability.

The Panel also monitors the system for abort and contingency planning. The Panel's interests were defined in the Panel's 1976 Annual Report (Vol. I, Page 17-19).

D. Additional Data of Interest

There are numerous factors that must be evaluated and trade-off assessments made for each flight. For example, the ascent segment of the mission required such evaluation of the vehicle loads, thermal stresses, operational techniques, separation techniques, communications coverage, abort plans, range safety, error sources and so on. Flight planning for on-orbit segments include such evaluations of attitude limitation, crew activities requirements, flight test requirements, consumables management and so on. During the de-orbit, entry and landing stages of the mission the same is true of such things as evaluation of energy management, communications, actual systems performance versus predicted and so on.

It is expected that the flights will begin with a crew size of two because of the number of ejection seats (two). The Orbiter, as designed, can actually be flown by one crewman, so that having two or more adds to the safety of operations. The last two OFT flights will have four crewmen onboard if prior flights indicate that this is a prudent move.

The time between Shuttle OFT launches is approximately 2 to 2 1/2 months with a greater time expected between OFT #1 and #2 and a lesser time between OFT #5 and #6 due to the "learning curve" as experienced on all previous programs.

Current planning shows the following broad information, which can vary with maturity of the program.

OFT-1	Launch and entry performance under the very best of conditions to optimize for a safe mission.
OFT-2	On-orbit systems tests. Increased launch and entry loads.
OFT-3	Remote Manipulator System operation/verification. More detailed thermal testing and again somewhat increased launch loads to further explore the safe capability of the system.
OFT-4	Further thermal testing, operating payload deployment, and again somewhat high entry loading.
OFT-5	Work towards proper payloads approach and capture in orbit. Working with increased size crews, and further overall testing to furthedr define results from previous missions.
OFT-6	Final tests prior to going operational with heavy payloads, off-nominal tests on all systems as applicable, and EVA.

All of these will exercise the KSC Launch and Landing Systems.

E. Orbital Flight Test Design Certification Review (OFT-DCR)

This review is a major program milestone whose purpose is to review and certify that the design meets the OFT requirements as verified by test or analysis, and should have substantiating data that validates that those requirements were actually met. The present date for this review is set for May 1978, but may vary depending upon the degree of completeness of the test programs.

XI. SPACE SHUTTLE MAIN ENGINE

A. Introduction

The SSME Critical Design Review was completed at the end of September 1976 capping a review cycle that commenced in April. The status of the program at that time could be summarized as follows. The potential of the design has been demonstrated and it is an acceptable risk to proceed with the flight engine fabrication. A number of major problems persist and redesigns have been defined where necessary. Flight engine 2004 design has been released. A delta-CDR is scheduled for February 1977 owing to the number of major items to be resolved, e.g., the subsynchronous whirl and turbine cooling problems, the full-scale brazed nozzle. Thus, by the end of February 1977 the following key objectives should be accomplished:

1. Operation of the Space Shuttle Main Engine at Rated Power level (RPL) for long durations, e.g., 60 seconds at RPL as a minimum.

2. Development of the procedures and demonstration of them for use in "start-to-RPL" testing with the 77.5:1 flight-type nozzle.

3. Operation under altitude simulation conditions.

4. Testing of the SSME Heat Exchanger with oxidizer and resolution of the propellant conditioning problems.

The material that follows provides further detail on the results of the CDR and testing program and the status of problems and their resolution.

B. Observations

1. Significant Items From the SSME CDR.

The engine design was critiqued by the following teams: the Engine System Team, the Mechanical and Fluid Systems, Controller Team and the SSME Controls team. The CDR Board, chaired by the SSME Project Manager from MSFC, reviewed the results of these team reviews and concluded that the CDR had been conducted in considerable depth and the results presented with candor. The disposition of all significant RID's was reviewed in detail and approved. The SSME Project accepted the following action assignments in addition to the RID actions:

a. Provide appropriate JSC insight into the Design Verification Specification rebaseline for system related issues.

b. Increase the visibility for MPTA (Main Propulsion Test Article) configuration differences from flight engine requirements.

c. Provide an appropriate review of the closeout actions taken on significant RID's.

The CDR RID's are shown in Table XI-I. There are 45 RID's from the Engine Systems Team, 35 from the Mechanical and Fluid systems, 9 from the Electromechanical Controls group, and 16 from the Controller group. The RID's considered significant are noted in the Table XI-I by an asterisk next to the RID number. The current status of RID action assignments and closeout are shown in Table XI-II.

As for the Main Engine Controller, the baseline unit was originally the P-4 Engine Controller. However, because of numerous changes based on tests/analyses over the past six months the P-6 controller was considered as the baseline item to be critiqued at this review. This baseline has the following modifications over the P-4 design: the heater set point, POGO related changes, software simplification dealing with the use of dual sensors, power supply changes, uses of dual coils in the electrical system, an asynchronous demodulator, elimination of memory parity errors, variation in the use of the foam used to reduce problems resulting from vibration, elimination of many electrical jumpers and "cuts," changes to history memory, temperature sensor range changes, power supply buss bar connection, Digital Computer Unit no-go timer, etc. The effect of such changes will be determined through a combination test and analysis program. Such qualification requires close attention to be assured that the baseline (P-6) as now accepted is in fact acceptable.

Other major items reviewed, discussed and noted at the CDR include the following:

a. SSME management made a special point of the fact that every individual on the program has the responsibility to make sure nothing falls-through-the-crack by paying attention to everything they do and being aware of the program activities in general.

b. The "long pole in the tent" or major critical objective to be met is the attainment of the specified performance from the turbomachinery.

c. The engines used in the Main Propulsion Tests at NSTL will probably not have all the modifications which apply to flight engines, and the contractor and MSFC will do all they can to keep these differences to a minimum.

d. The biggest uncertainty in defining the achieved Specific Impulse will be the combustion efficiency, C*. Test results to date indicate that this should be no problem.

e. Temperature and pressure stability conditions at the propellant inlet have been demonstrated in test.

f. The POGO suppression system accumulator no longer utilizes the teflon balls to cover the liquid/gas oxygen interface. Instead a baffle arrangement has been designed to retain the stability of the liquid/gas interface. See Figures XI-1 and XI-2.

g. The improvements that have been made to uprate the engine thrust include the reduction of LPFTP discharge duct pressure loss and increasing the turbomachinery head and efficiency by decreasing the inducer tip clearance and modifying the inducer trim on the LPOTP as well as by under-filing impeller vanes on the HPOTP, by reducing LPFTP clearances and improving seals and under-filing impeller vanes on the HPFTP.

h. Hazard analyses have been completed on the engine heat exchanger for such possibilities as coil leakage, spark igniter "fail-on" and the failure of the limit control for stability and vibration. The FMEA for POGO has been updated and shows six single failure points, for which appropriate solutions have been identified. In addition the traceability system for materials and components has been computerized and is in operation.

i. Changes are being made in the manufacturing process for the flight nozzle to alleviate buckling which resulted during previous brazing operations. Part of this problem resulted from tubes with uneven wall thicknesses.

2. SSME Project Status

The status of the project as presented here is, of course, like a snapshot in that it shows the engine project as of the date of writing. Progress is continually being made in all areas of the project and this assessment requires updating as tests and analyses are accomplished.

a. NSTL Test Activity

There are two test stands in use: Stand A-1 in which engine 0003 is installed and Stand A-2 in which engine 0002 is installed. 87 tests had been conducted on A-1 and 38 tests on A-2 by the end of the first week of December 1976. Engine 0003 has been run at a sustained thrust level of 75% of RPL. Engine 0002 was operated for the first time for 3.7 seconds on December 3rd in the A-2 altitude simulation (diffuser) facility with the 77.5:1 flight nozzle. In all of the current engine firings several different versions of the high pressure fuel turbo pump are used. These pumps carry modifications which have proved sufficient to cope with the subsynchronous whirl problems and bearing cooling.

The various Engine Controller Units are being used as follows:

BT-1, Engine 0003 on NSTL Stand A-1

PP-1, Software Support at Honeywell
PP-2, Upgraded at Honeywell and now at MSFC Simulation Lab
PP-3, Engine 0002 in NSTL Stand A-2

P-4, Acceptance testing continues

P-5, Completed initial integration testing and acceptance tests continue

b. Engine 0004 Status

There was a weld failure in the main injector during the powerhead proof test. The crack occurred during the second cycle of a five cycle test and extends around the injector portion of the power head. The pressures were about 7700 psi in upper chamber and 5400 psi in lower chamber with ambient external pressure. The electron beam weld that failed was in the lower chamber. The powerhead weld has been repaired and has successfully passed the five cycle test. Further, certain lessons learned regarding such welds and their characteristics should be helpful in supporting not only the SSME welding program but perhaps those of other Shuttle elements. For example, the "nailhead" portion of the weld must not carry high loads (stress/strain).

c. Turbomachinery

The high pressure fuel turbopump (HPFTP) "whirl" problems and bearing cooling problems have been under attack for some time now. The causes of the whirl problem have been identified, solutions determined, stability thresholds predicted, and safe operation demonstrated up to 36,800 rpm. It was concluded that complete redesign was not required. Basic fixes have included increased stiffness, elimination of deadband, decreased "drivers" and added damping. The term "drivers" relates to internal hysteresis, the Alford Effect, interstage seals, non-linearities, deadband. It was determined that the turbine aerodynamic forces were not the principal-type driver. Various combinations of these modifications have been incorporated in the three HPFTP's and have had slightly different degrees of success. Two additional turbopumps are being assembled with additional instrumentation and modification to the inboard bearings. These will be tested in the near future and should do even better than the three mentioned above. Deadband is the "play" in a system, or the available motion through which the shaft can move without effective response from adjacent parts. Further testing is in progress on NSTL engines and at in-house laboratories. It is hoped that this problem will be adequately resolved by February 1977 so that the program can meet the schedule for a 60-second Rated Power Level (RPL) firing.

The turbine cooling for the HPFTP has been the subject of much attention at the same time that subsynchronous whirl has been of concern. There have been turbine end bearing failures and hardware cracks resulting from insufficient cooling capacity. The following actions have been taken:

(1) Turbine cooling is to be enhanced by improvements in the high pressure coolant supply, tip seal, and piston ring.

(2) Fuel coolant directed to the turbine end bearing (pre-start flow).

(3) Baffle incorporated in the 2nd stage turbine wheel hub to reduce the pressure loss in the coolant vortex. Tests have confirmed that vortex was the primary cause of turbine end overheating.

(4) The bearing test program will cover the existing bearings, an improved cage bearing and the use of a roller bearing. A better understanding of the cooling circuit can be gained from Figure XI-3.

(5) Procurement of a 45 mm heavy-duty type bearing as a backup unit.

The performance or efficiency of the turbomachinery has, in some cases, been below that required by the design specifications. Depending on the turbopump the efficiency ran between 10% and 15% low and the head between 5% and 15% low.

The low pressure oxygen turbopump (LPOTP) has shown dramatic improvement when the inducer vane and the tip clearances were changed, e.g., vane height increased and tighter clearances. Tests will continue on these modifications and include those involved in POGO suppression. The high pressure oxygen turbopump (HPOTP), although low in head (6%) and low in efficiency (10%) based on COCA-1 tests, appears to be sufficient to meet current engine performance requirements. None the less further actions are being taken with the hope that with increased head, reduced speed improved suction performance can be achieved through underfiling the impeller. The low pressure fuel turbopump (LPFTP) low head problem is being worked through modification of the inducer trim and improvements in the volute design. The high pressure fuel turbopump (HPFTP) besides the "whirl" problem has experienced a 6.5% low head condition at RPL. A number of changes are being made to bring the head and efficiency up to a higher level. It should be emphasized that such performance problems are a normal part of the development cycle for large high performance engines and were experienced on the Saturn F-1 and J-2 engines.

d. Combustion Devices

The Thrust Chamber Assembly has been undergoing a series of "bomb" tests to develop the stability rating. The fourteen detonations were successfully completed and recovery from all disturbances was within 5 milliseconds. The bomb and bomb locations within the main injector of the thrust assembly are shown in Figure XI-4; the thrust chamber pressures based on such tests are shown in Figure XI-5.

The other major item in this subsystem is the 77.5:1 flight nozzle. There have been fabrication problems over the past months because of the cooling tubes, new thermal design loads and the brazing process. Most of this has now been cleared up and testing of the reworked nozzle is now underway. Nozzle testing at COCA-4B stand at Santa Susana has been successful in terms of characterizing the nozzle heat load, pressure drop and performance as well as the nozzle side loads and transient behavior during ignition and transition to higher and higher power levels. Some of the significant results of this testing are:

(1) The heat load turned out to be about 65% of the calculated value.

(2) The pressure drop was 297 psi versus a calculated 316 psi.

(3) The I_{sp} value was 455.3 seconds. (Calculated)

(4) The side load was about 65% of the design value.

The redesign of the nozzle jacket to cope with latest heat loads provided by the JSC and Rockwell International/Space Division for the flight environment will cost an additional 140 pounds per engine. This redesign is shown schematically in Figure XI-6 and XI-7. The nozzle tube rupture during proof test appeared to be caused by weak spots in the wall thicknesses. The problem was traced back to the tube manufacturer's tube drawing machine, which produced reverse taper in the tubes. Tubes for the three R&D and two MPTA nozzles to be used in development tests will be selected from those currently available. Tubes will be inspected and those which yield a safety factor of 1.4 or higher are to be used. Only the new tapered tubes having a minimum safety factor of 1.5 will be used on the flight nozzles.

e. Controller

The controller hardware and software are beginning to jell. Controller maturity would indicate that the option of a backup unit may never be needed. The BT-1 unit has more than 1200 hours of trouble free service, the PP-3 mounted on engine 0002 has 560 hours, and the PP-2 at the NASA simulator laboratory in MSFC has more than 620 hours. The P-4 controller has been delivered to support the 0004 engine test program, and controller P-5 has been delivered to support the 2001 engine test program, which is the MPTA unit. The other MPTA units designated F-1 and F-2 are presently scheduled for delivery in March and April of 1977. The development verification tests for the improved power supply unit have been successfully completed. The unit included those configuration changes addressed to the P-6 controller, e.g., EMI fixes, power transient mods, vibration fixes, producibility improvements. Another configuration update is being made to the PP-2 controller to bring it up to the P-4 configuration for use in the MSFC sim lab.

Because the P-6 controller is now the flight-type baseline controller and it has some twenty-one changes from prior P-4 controller which was the baseline, it received a Preliminary Design Review (PDR). It will also be reviewed again through a special Critical Design Review at the appropriate stage of testing.

Some of the changes for P-6 are:

(1) New heater set point

(2) Changes related to POGO

(3) Software simplification changes dealing with the use of dual sensors.

(4) Power supply changes (mentioned above).

(5) Use of dual coils in the electrical system.

(6) New asynchronous demodulator.

(7) Deletion of cuts and jumpers.

Software appears to be moving along at a compatible pace with the engine test program and the MPTA andSAIL operations. The software utilization plan which ties engines, controllers and the development program tests to software development schedule is shown in Figure XI-8. A Flight requirements baseline review has been completed and this baseline is under Class I configuration management as a Rocketdyne responsibility with NASA Technical concurrence.

f. Additional Items of Interest

There had been indications that Incoloy 903 which is used in portions of the SSME will have significantly reduced life capability when subjected to hydrogen flow in a form of hydrogen rich steam at 1400° F, Tests conducted by Rocketdyne indicate the same thing. Additional tests are being conducted to gather more data on the physical properties involved and more specific data on life cycle values. The components where Incoloy 903 is used include:

(1)	Hot Gas Manifold Liner	Max. Temp.	1200 to 1400 F.
(2)	HPOTP Turbine Housing		1275
(3)	HPOTP Turbine Inlet Strut		1150
(4)	HPOTP Inner Stage Seal		1000
(5)	HPOTP Exhaust Strut		1000
(6)	HPFTP Bearing Support Seal		875

(7)	HPFTP Turbine Support	700
(8)	HPFTP Bellows	600

The problem is Low Cycle Fatigue reducing the life expectancy, which is related to environmental and hold-time effects. High Cycle Fatigue is related to the processing and surface effects. Resolution of this concern at elevated running temperatures is expected by the end of January 1977.

Major SSME milestones as seen at this time are shown in Figure XI-9.

C. Information Update

The number of tests conducted on the SSME are quite large since this period and for some months to come, will be devoted to development tests at NSTL on two test stands, and at the Santa Susana sites. The resolution of the turbomachinery whirl and cooling problems require tests to be conducted as often as possible to determine state-of-the-resolution. For instance, at NSTL Stand A-1 four and even five tests a week have been made. Perhaps the major area of concern is the ability of the analysts to reduce the test data and to thoroughly digest and understand what it means before going into the next set of tests. One thing that mitigates this problem is the small steps or incremental method of attacking the problem and this permits smaller pieces of data to be handled at any one time. Tests to date indicate problems are yielding to the engineering attack. The engine 0003 in stand A-1 has been operated at 100% of rated thrust for more than 10 seconds and it has been operated at this level more than two times.

Engine 0004 assembly is proceeding with very few problems and the major remaining work is the installation of harnesses and some fluid lines. This engine is being assembled with dummy fuel pumps which will be changed at the time the engine is received at NSTL.. Full power level operation of this engine is expected to take place in March 1977 with conversion to the MPTA configuration in the following month.

Engine Controller Unit PP-2 has been delivered to MSFC after retrofit and is in process of being integrated into the MSFC Simulation Laboratory. The laboratory has been running simulated engine firings as if it were engine 0003. The Flight-I software is being developed and appears to be on schedule.

A close watch is made on the RID's resulting from the CDR, and as they are closed notification is made to all interested parties. The first status report dated January 11, 1977 showed that seven RID's had been closed (S-21, S-29, S-32, M-1, M-2, M-4, M-10).

RID SUMMARY

TABLE XI-I

Date OCT

SSME Critical Design Review

Sheet 1 of 8

ID o.	Subject	Cate-gory	Actionee	Due Date	Notes
-1*	Flanges, External Leakage Detection	D	J. Eaton	11/1/76	Prepare closeout sheet
-2	Pneumatic Assembly, Operational Temperature Range	DR	J. Eaton	11/1/76	Forward to Main Propulsion Panel
S-3*	Helium System, Operational Pressure	A-3	J. Eaton	11/1/76	Coordinate helium system requirements
S-4	Fuel System, Liquid Air Formation	DR	J. Thomson	1/1/77	Incorporate with DVS baseline
S-5*	HEX, Hazards	A-3	O. Morris(JSC) & RKD	1/1/77	RKD support Level II's integration efforts
-6	System, Propellant Feed System	DR	J. Thomson	1/1/77	Incorporate with DVS baseline
-7	Hydraulic System, On Orbit, etc., Thermal Conditioning	DR	J. Thomson	1/1/77	Incorporate with DVS baseline
-8	Hydraulic System, Hydraulic Lockup Verification	DR	J. Thomson	1/1/77	Incorporate with DVS baseline
-9	System, Shutdown Sequence	A-1	RKD	1/1/77	Initiate PIRN defining sequence
-10	System, Injector Dome Purge at Cutoff	A-1	RKD	1/1/77	Define purge requirement
S-11	System, Pneumatic Shutdown	A-1	RKD	5/1/77	Demonstrate capability
S-12	System, Fuel Insulation	A-1	RKD	4/1/77	Demonstrate design adequacy
S-13	System, Operation Subsequent to Hydra/ Controller Failure	A-1	RKD	12/1/76	RD to define plan
-14	System, Envelope Verification	A-1	J. Thomson & RKD	1/1/77	Verify envelope against MSFC template
S-15*	System, Start Sequence Development	A-1	RKD	12/1/76	RD to define plan
S-16	Ducting, Interconnects Gimbal Testing	A-1	RKD	12/1/76	RD to define plan

SSME Critical Design Review

Sheet 2 of 8

RID No.	Subject	Category	Actionee	Due Date	Notes
S-17	System, Specific Impulse	A-1	RKD	12/1/76	Validate capability
S-18	System, Alignment	A-1	RKD	2/1/77	Validate capability
S-19*	System, Fracture Mechanics Analysis	A-1	RKD	12/1/76	RD to define plan
S-20*	System, Fracture Critical Components (58)	A-1	RKD	12/1/76	RD to define plan
S-21	System, Validation of Casting and Suppliers	A-1	RKD	11/1/76	Submit closeout sheet
S-22	AF Valve/HEX Coil Failure	D	R. Weesner	11/1/76	Submit closeout sheet
S-23	AF Valve Checkout	D	R. Weesner	11/1/76	Submit closeout sheet
S-24*	Bleed Valve Failure Mode	A-1	J. Thomson	11/15/76	Clarify FMECA ground rules
S-25	FMEA, Open Actions on Criticality 1 and 2 Items	A-1	RKD	1/1/77	Submit closeout sheet
S-26	Ducting, Bellows Liner Cracking	A-1	RKD	1/1/77	Define 2004 duct design
S-27	Thrust Chamber, Oscillations	D	J. Smith	11/1/76	Submit closeout sheet
S-28	System, Bleed Flow Post Shutdown or Abort	A-4	O. Morris (JSC)	12/1/76	Define Level II requirement
S-29*	System, Drying Purge	A-4	RKD	12/1/76	Define requirement
S-30	System, Overhaul	D	J. Eaton	11/1/76	Submit closeout sheet
S-31*	System, Water Entry into Engine	A-3	RKD	1/1/77	Define moisture removal technique
S-32	GSE, Thrust Chamber Nozzle Sling	A-1	RKD	11/1/76	Define requirement
S-33	GSE, Engine Handler Locking	A-1	RKD	12/1/76	Revise documentation
S-34	Ducting, Interconnect Design vs Current Engine Balance	A-1	RKD	4/1/77	Release design

RID SUMMARY

Date OCT [illegible]

SSME Critical Design Review

Sheet 3 of 8

ID N.	Subject	Category	Actionee	Due Date	Notes
S-35	Pogo, Screen Attachment	A-1	RKD	2/1/77	Release design
S-36	System, Transient Model Verification	A-1	RKD	12/1/76	Verify model
S-37	Ducting, LPFTP Discharge Duct Gas Trap	A-1	RKD	2/1/77	Submit analyses
S-38	GSE, Closure Material Incompatible with LOX	A-1	RKD	12/1/76	Submit Material Usage Agreement (MLIA)
S-39 *	Analysis of Lines, Ducts, Brackets, Gimbal	A-1	RKD	12/1/76	RD to define plan
S-40	Ducting, Flex Joint Test Gimbal Angel	DR	J., Thomson	1/1/77	Incorporate with DVS baseline
S-41	GSE, Design not Complete on GSE	A-1	RKD	1/1/77	Release design
S-42 *	System, Burst Diaphragm Leakage, - Engine Compartment	A-1	RKD	12/1/76	Submit recommendations
S-43	System, Residual Hazard Rationale	A-1	RKD	12/1/76	Submit required analyses
S-44	System, Open Safety Items	A-1	RKD	12/1/76	Submit required analyses
S-45 *	System, Incoloy 903 Fatigue Properties	A-1	RKD	1/1/77	RD to define plan

RID SUMMARY

Date OCT 5 1976

SSME Critical Design Review

Sheet 4 of 8

	Subject	Category	Actionee	Due Date	Notes
1	Main Combustion Chamber Stability Demonstration	A-1	RKD	11/1/76	Submit test results
2	Contamination Blockage of Main Injector Feul Passages	A-1	RKD	11/1/76	Submit closeout sheet
3*	Flt Nozzle Capability Demonstration	A-3	RKD	1/1/77	Submit study results
4	Flt Nozzle Thermal Protection	D	J. Smith	11/1/76	Submit closeout sheet
5*	Heat Exch Capability Demonstration	A-1	RKD	6/1/77	Submit test results
6	Preburner Resistance Discontinuity	A-1	RKD	2/1/77	Submit test results
7	Preburner Stability Demonstration	A-1	RKD	3/1/77	Submit test results
8	HGM Operational Capability	A-1	RKD	3/1/77	Submit test results
9	ASI Injection and Spark Plug Erosion	A-1	RKD	12/1/76	Submit test results
10	Overhaul Cost	D	C. Pinson	11/1/76	Submit closeout sheet
11*	LPOP Veh Duct Internal Bellows Restraints	A-2	RKD	5/1/77	Submit test results
12*	LPOP Flange Non-uniform Loading	A-3	RKD-SD	2/1/77	Submit interface assessment
13*	LPOP Performance Deficiencies	A-1	RKD	1/1/77	Define design solution
14*	HPOTP Lox Starvation Capability	A-4	J. Eaton	11/1/76	Initiate Level II change request
15*	HPOTP Performance Deficiencies	A-1	RKD	2/1/77	Pursue parallel efforts through decision point
16	HPOTP FPL Operation	A-1	RKD	4/1/77	Submit test results
17	HPOTP Turbine Nozzle Life	A-1	RKD	7/1/77	Submit life assessment
18	HPFTP Axial Thrust Balance	A-1	RKD	1/1/77	Define design solution

RID SUMMARY

SSME Critical Design Review

Date OCT [illegible]

Sheet 5 of 8

D	Subject	Cate-gory	Actionee	Due Date	Notes
19	HPFTP Turbine Nozzle Life	A-1	RKD	7/1/77	Submit life assessment
20	HPFTP Performance Deficiencies	A-1	RKD	1/1/77	Define design solution
21	HPFTP Subsyncronous Whirl	A-1	RKD	1/1/77	Define design solution
22	HPFTP Bearing Design	A-1	RKD	4/1/77	Submit test results
23	HPFTP FPL Operation	A-1	RKD	4/1/77	Submit test results
24	HPFTP Turbine Housing Coolant Liner	A-1	RKD	1/1/77	Define design solution
25	HPFTP Turbine Rotor Blade Life	W			No action required
26	HPFTP & HPOTP Fracture Mechanics Flaw Detection	A-1	RKD	12/1/76	RD to define plan
* 27	LPFTP Non-uniform Interface Loading	A-3	RKD	2/1/77	Submit interface assessment
* 28	LPFTP Performance Deficiencies	A-1	RKD	9/1/77	Submit test results
* 29	LPFTP Vehicle Duct Internal Bellows Restraints	A-2	RKD	7/1/77	Submit test results
30	HPFTP Turbine Purge for Water	A-4	RKD	1/1/77	Define purge requirement
31	TCA Functional Characteristics	A-1	RKD	1/1/77	Clarify balance requirements
32	MCC Service Life	A-1	RKD	1/1/77	Submit life analysis
33	Preburner Erosion	A-1	RKD	2/1/77	Submit test results
34	Preburner Delta P	A-1	RKD	2/1/77	Submit test results
35	HPFTP Turbine Tip Seal Erosion	A-1	RKD	1/1/77	Submit test results

RID SUMMARY

Date 10/5/76

SSME Critical Design Review

Sheet 6 of 8

D	Subject	Category	Actionee	Due Date	Notes
-001	Controller DVS Testing	A-1	RKD	5/1/77	Submit thermal cycle test results
-002	Vibration Testing	A-1	RKD	11/1/76	Define requirement consistent with CH004
-003	Intermittent Failure Resolution	A-1	RKD	2/1/77	Define plan
-004	Change Implementation	A-1	R. Morris/ RKD	11/1/76	Define design baseline
-005	Foam-Pack Testing	A-1	RKD	11/1/76	Define requirement consistent with CH004
* -006	MIB DVS Testing	A-1	RKD	5/1/77	Submit test results
-007	PVB Specifications	A-1	RKD	11/1/77	Submit specification
008	Convection Cooling	A-1	RKD	1/1/78	Submit study result
009	Solder Joint Configurations	A-1	RKD	12/1/76	Revise controller documentation
* -001	Operational Program Technical Reviews	A-1	RKD	12/1/76	Submit schedule
-002	Development, Management and Configuration Plans for Software	A-1	RKD	12/1/76	Submit Development Plan
* -003	Configuration Control of Software	A-1	RKD	11/1/76	Revise configuration Management Plan
-004	Software Test Requirements	A-1	RKD	11/1/76	Define specific plan
* -001	Fail Operational/Fail Safe	A-3	RKD	1/1/77	Submit study results
-002	Single Point Failures	DR	RKD	11/1/77	Define design baseline
-003	Controller Checkout Requirements Definition for MPTA	DR	W. Seiser	11/1/77	Submit closeout form

RID SUMMARY

SSME Critical Design Review

Date OCT 5 [illegible]

Sheet 7 of 8

	Subject	Category	Actionee	Due Date	Notes
-1*	Hydraulic Actuator, Servoswitch & Servovalve Replacement	DR	R. Weesner	11/1/76	Submit closeout sheet
-2*	Hydraulic System, Mission Duty Cycle Simulation	DR	J. Thomson	1/1/77	Incorporate with DVS baseline
-3	Hydraulic System, Hydraulic Actuator Hold Mode	D	R. Weesner	11/1/76	Submit closeout sheet
-4	Hydraulic Actuator, Position Control and RVDT Interaction	A-1	RKD	12/1/76	Define design solution
-5	Hydraulic Actuator, RVDT Linearity	D	R. Weesner	11/1/76	Submit closeout sheet
-6	Remote Mounted Flight Pressure Sensor	A-1	RKD	1/1/77	Submit VCP
-7	Hot Gas Temperature Sensor Design Change	A-1	RKD	1/1/77	Define design solution
-8	Hot Gas Temperature Sensor Response Requirement	A-1	RKD	11/1/76	Submit study results
-9	Spark Igniter Environment	A-1	RKD	12/1/76	Submit test results

. Encl. Sheet 8 of 8

SSME - CDR Space Shuttle September 27, 1976	REVIEW ITEM DISPOSITION CLOSEOUT		RID No. As appropriate
INITIATOR: RID Initiator's Name	ORGANIZATION: RID Initiator's Organization	SYSTEM: SSME	TEAM NAME: CDR Team
	TITLE: RID I.D. No. and Title		

RID Closeout Instructions

1. Complete heading of RID Closeout Form.
2. Define action taken; i.e.,

Category	Action
A-1	Actionee identify released formal engineering, quality, test, etc., documentation which implements the requested action.
A-2	Actionee identify ECP submitted or contract change authorized to implement the requested action.
A-3	Actionee identify report resulting from requested study or investigation and recommend appropriate action.
A-4	Actionee identify the Level I or II requirement change or deviation request submitted to change system.
D	Actionee document rationale for disapproval.
DR	Actionee document consideration of recommendation. (Note: CDR Board requested these actions be documented, therefore, a Closeout Form is required)

3. Actionee should sign and date Closeout Form and forward to MSFC, SA52, Attention: Mr. Scott Boothman.
4. Contractor signature, for actions not assigned to Rocketdyne, will be obtained by the MSFC SSME Project Office as required.
5. SSME Project Manager's signature completes all necessary RID action.
6. Copy of completed RID Closeout Form will be forwarded to RID Initiator.

Rocketdyne	NASA SIGNATURE James R. Thompson, Jr. SSME Project Manager

[illegible] Apr 76

TABLE XI-II

SSME RID STATUS

RID No.	STATUS
S-21	"System, Validation of Casting and Suppliers" - First article inspection has been performed on all castings procured for Period "A". Period "B" castings will continue to be processed through full Material Review Board for acceptance. CLOSED.
S-29	"Drying Purge" - Requirements for SSME post operational flight and post ferry flight drying purges at all landing locations were provided. CLOSED.
S-32	"GSE-Thrust Chamber Nozzle Sling" - Rocketdyne will provide a sling for single engine use and the Orbiter contractor will ass an adapter to their horizontal installer for on-the-vehicle thrust chamber handling. CLOSED.
M-1	"Combustion Chamber Stability Verification" - Bomb stability rating were completed and a summary of the test results examined. All stability bomb detonation disturbances to the main chamber were damped with 4 milliseconds. CLOSED.
M-2	"Contamination Blockage of Main Injector Fuel Passages" - A change has been made to incorporate screens on the main element feed passages to eliminate contamination of the main combustion chamber baffle sleeves and attached elements. CLOSED.
M-4	"Flight Nozzle Thermal Protection System" - An ECP has been submitted and is in work.
M-10	"Overhaul Costs" - This RID has been eliminated as the deletion of such costs requirements from the CEI specification has been accomplished.
E-1	"Servoswitch and Servovalve Replacement"was assessed and favored the retention of the released design concept. RID not approved.
E-3	"Hydraulic Actuator Hold Mode Operation" capability is to be demonstrated as a part of and ECP and testing. RID not approved.
E-4	"Postion Control and Hydraulic actuator position sensor (RVDT) interaction" modification will eleiminate the effects of channel cross-coupling. CLOSED.
E-5	"RVDT Linearity and Control Precision" has been established through an engineering change using appropriate insulation to make the unit operative in the required thermal environment. RID not approved.

TABLE XI-II Continued

E-7	"Hot Gas Temperature Sensor Design Change" was authorized through an engineering change to decrease response time. CLOSED.
E-8	Recommended a model study to define the hot gas temperature sensor response time required to provide the required degree of engine safety. A study was conducted and the response of 0.3 seconds is sufficient to meet the requirement. CLOSED.
S-22	"Antiflood Valve Failure" position indicator as a part of the start logic or engine shutdown. Recommended action is being taken via an engineering change. RID not approved.
S-23	"Antiflood Valve Checkout" is being covered by a design modification under an engineering change. RID not approved.
CS-001	"Operational Program Technical Reviews" schedules for the requirements baseline and design baseline for both Flight 1 and Flight 2 software have been established and published. CLOSED.
CS-002	"Developmet, Management and Configuration Plans for Software" was released in November 1976. CLOSED.
CX-003	"Controller Checkout Requirements Definition For MPTA". The MPTA Program has not requested or provided budgeting for Command and Data Simulator or Controller Checkout Console equipment to permit checkout of the Controller. Therefore, additional procedures beyond those developed for the Orbiter checkout have not been developed. CLOSED.
CS-004	"Software Test Requirements" documentation has been established and a schedule set up for implementation. CLOSED.

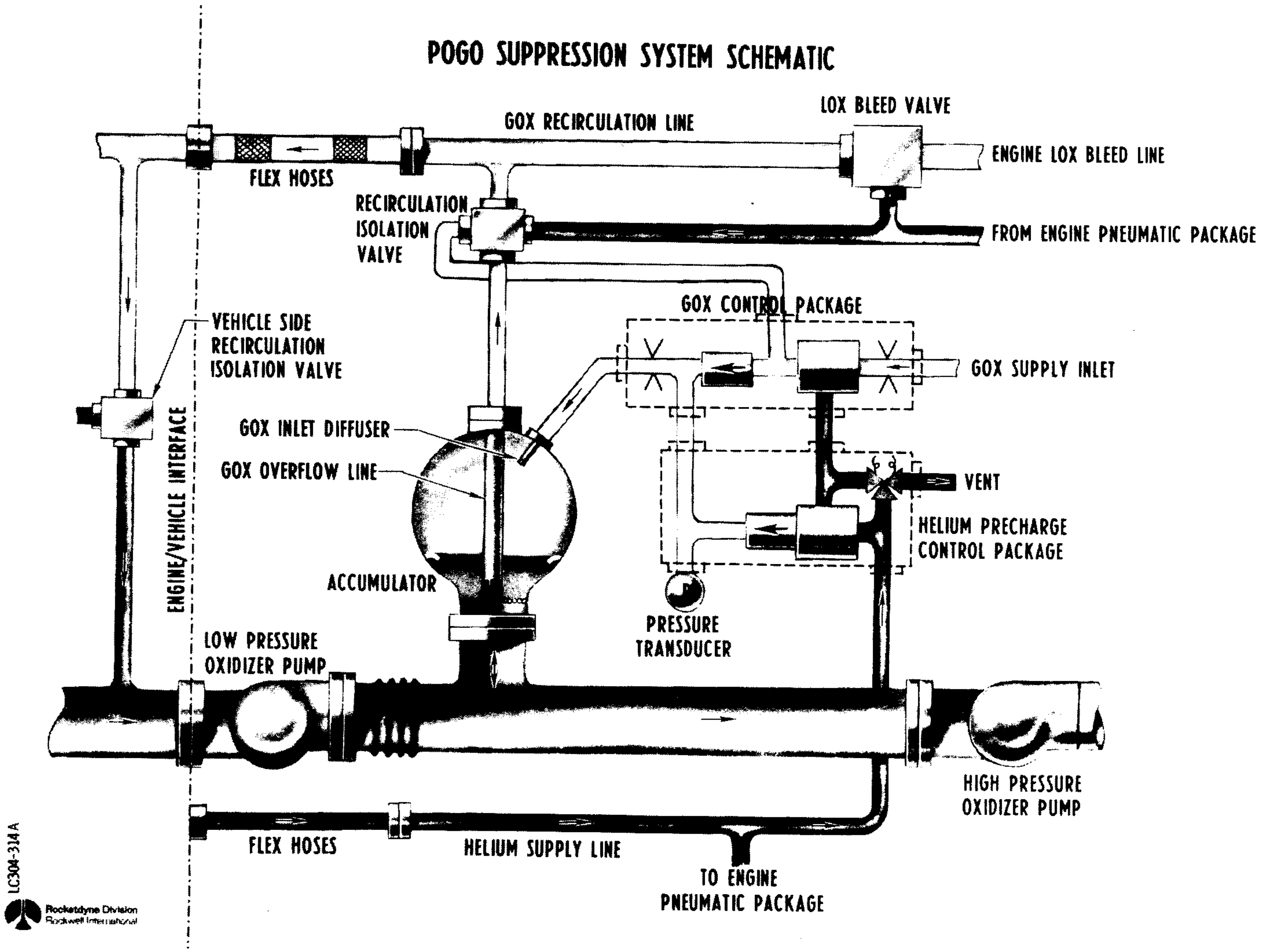
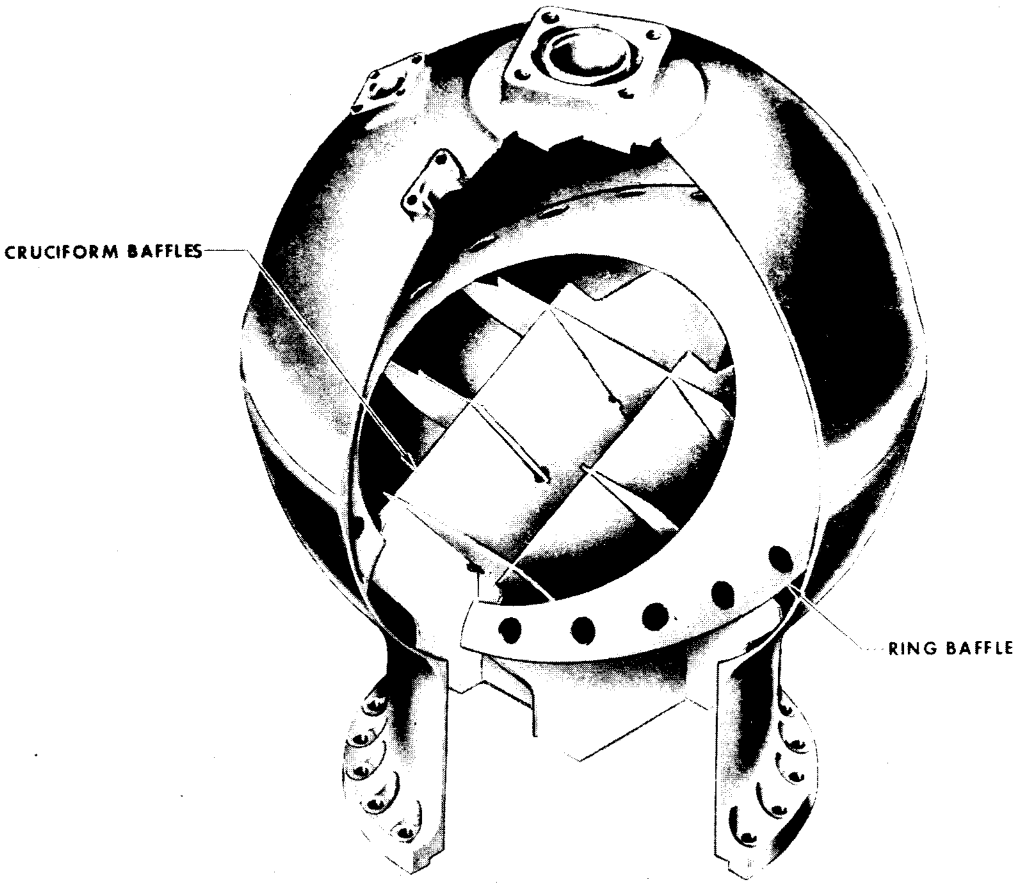

POGO SUPPRESSION SYSTEM SCHEMATIC
GOX RECIRCULATION LINE
LOX BLEED VALVE
ENGINE LOX BLEED LINE
FLEX HOSES
RECIRCULATION ISOLATION VALVE
FROM ENGINE PNEUMATIC PACKAGE
GOX CONTROL PACKAGE
VEHICLE SIDE RECIRCULATION ISOLATION VALVE
GOX SUPPLY INLET
GOX INLET DIFFUSER
GOX OVERFLOW LINE
VENT
ENGINE/VEHICLE INTERFACE
HELIUM PRECHARGE CONTROL PACKAGE
ACCUMULATOR
PRESSURE TRANSDUCER
LOW PRESSURE OXIDIZER PUMP
HIGH PRESSURE OXIDIZER PUMP
LC304-314A
FLEX HOSES
HELIUM SUPPLY LINE
TO ENGINE PNEUMATIC PACKAGE
Rocketdyne Division
Rockwell International

FIGURE XI-1

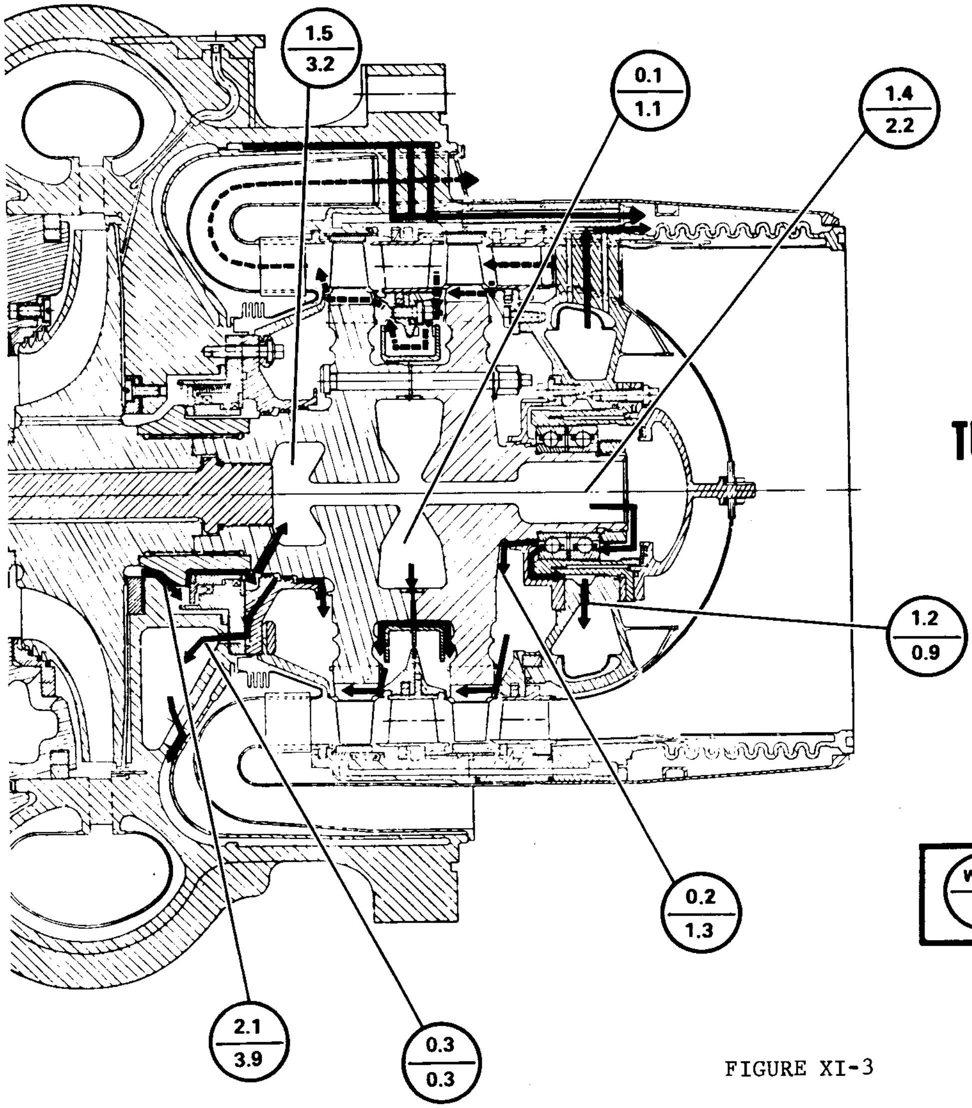
ACCUMULATOR ASSEMBLY



LC305-308A

Rockwell
International
Rockeldyne Division

FIGURE XI-2



HPFTP
TURBINE COOLANT CIRCUIT
MPL

WAS / IS	COOLANT FLOW (LB/SEC) (AT 30,400 RPM)

FIGURE XI-3

MAIN INJECTOR BOMB LOCATIONS

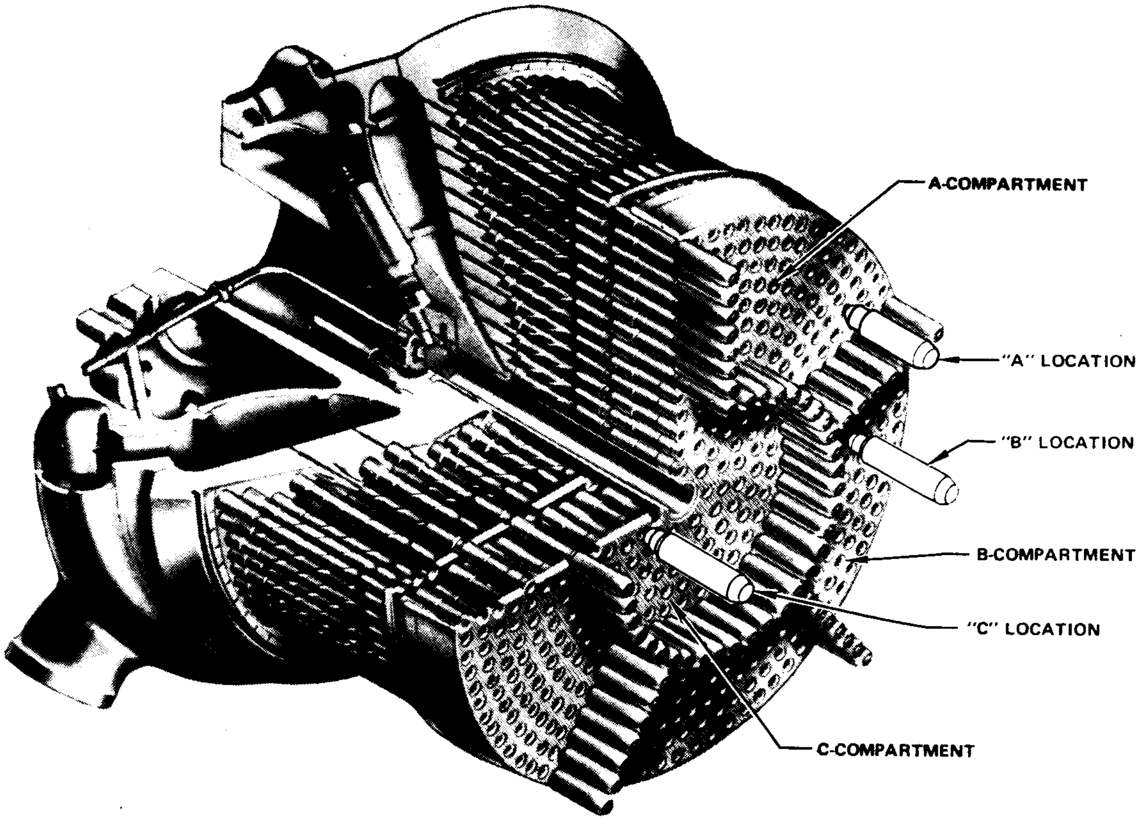
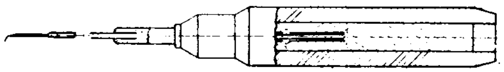
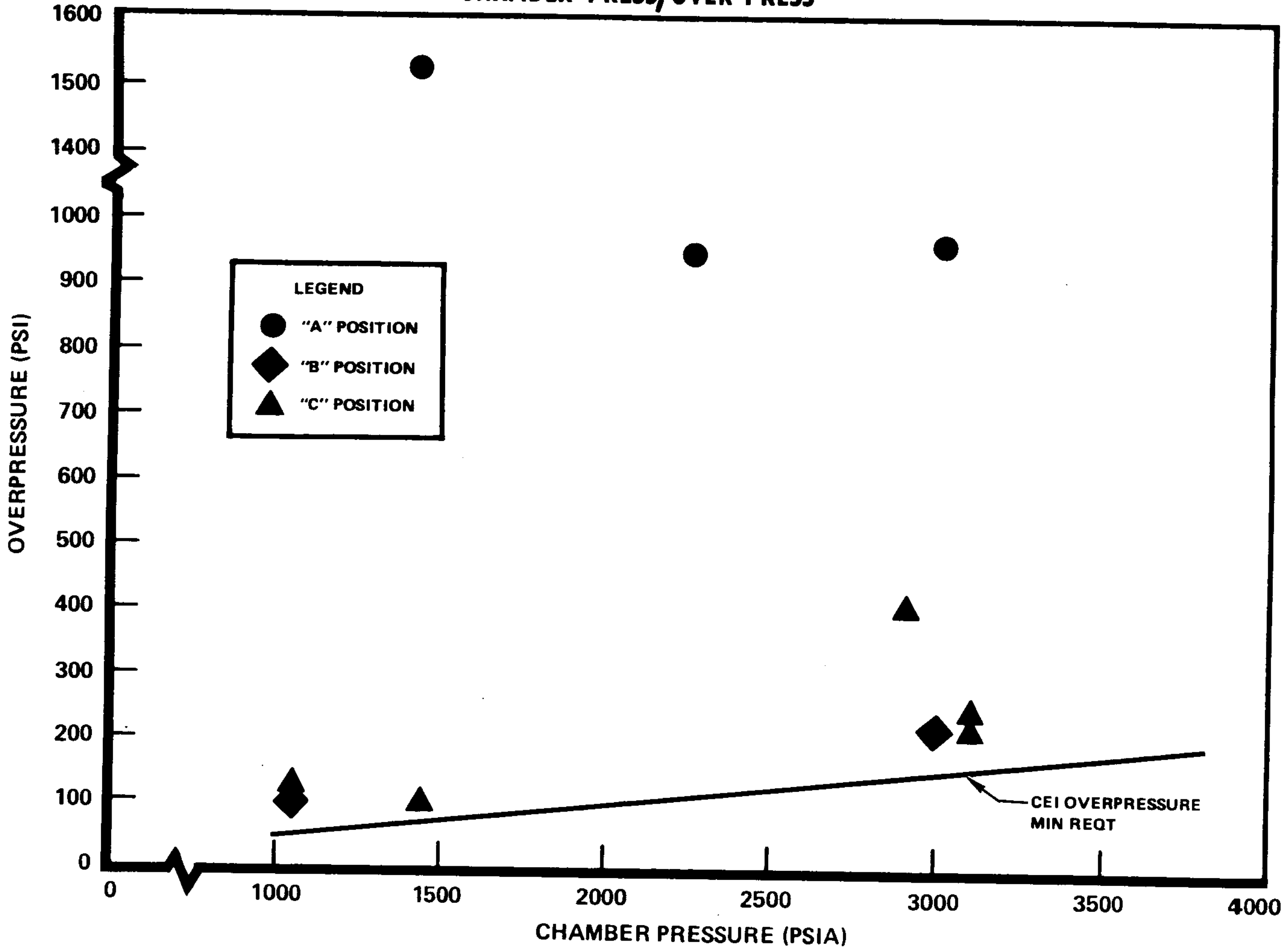


FIGURE XI-4



25 GRAIN BOMB



THRUST CHAMBER ASSEMBLY STABILITY TESTS

COCA-4B

CHAMBER PRESS/OVER PRESS

FIGURE XI-5

77.5:1 NOZZLE JACKET REDESIGN
PIRN 0034 THERMAL ENVIROMENT

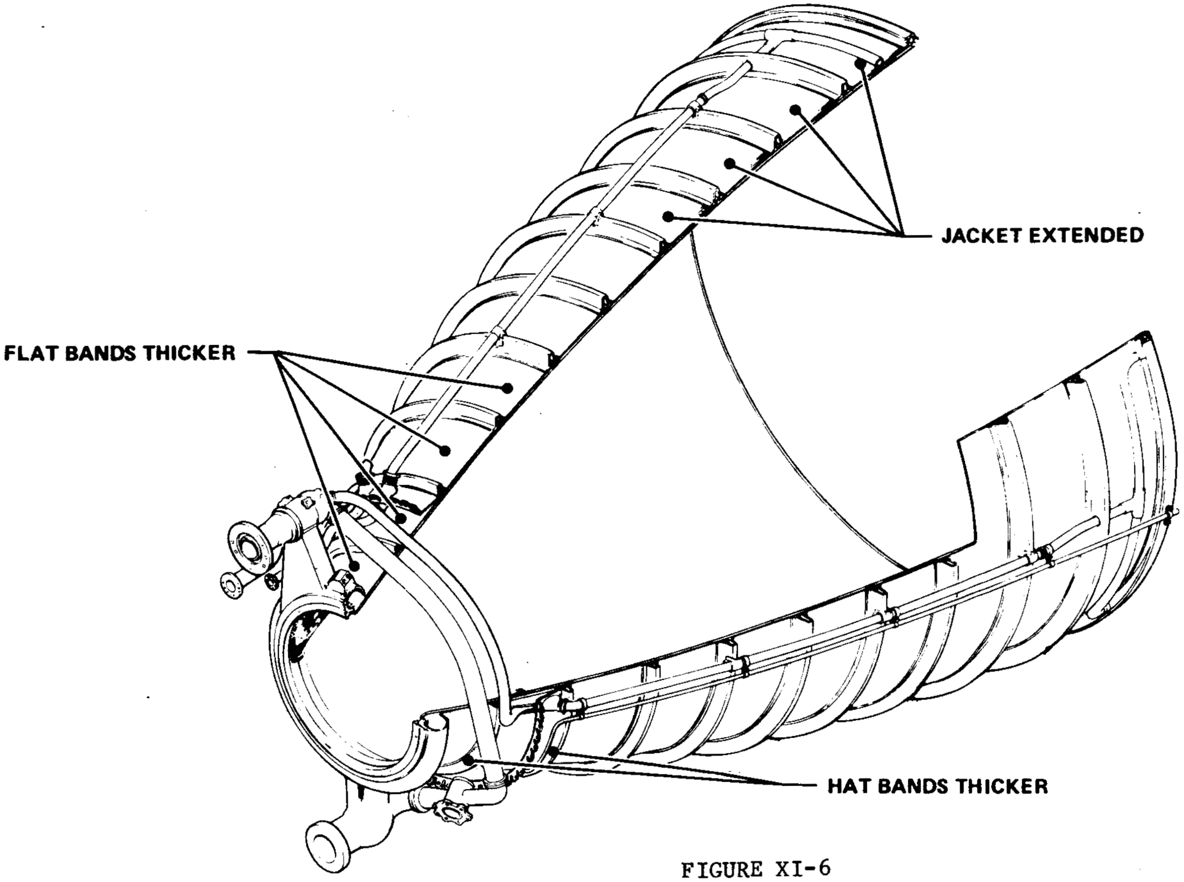


FIGURE XI-6

FLIGHT THERMAL INSULATION

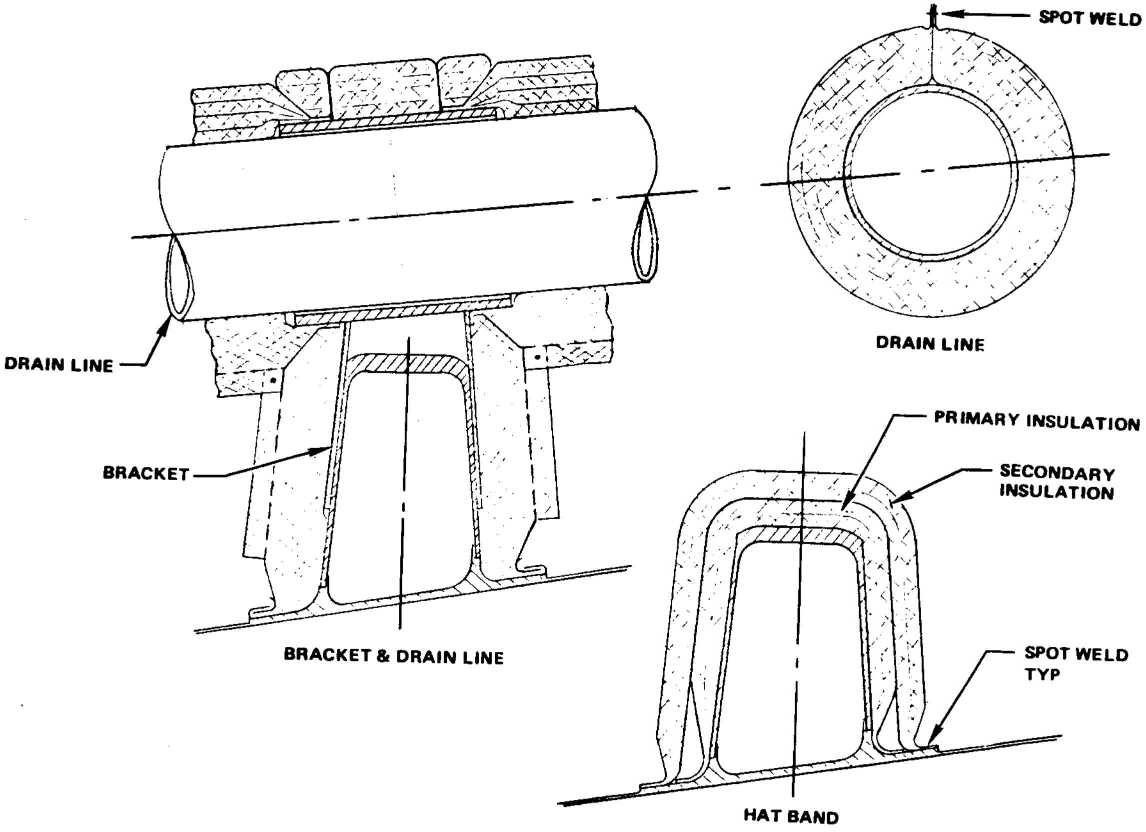


FIGURE XI-7

ENGINE/CONTROLLER/SOFTWARE UTILIZATION PLAN 1 NOVEMBER 1976

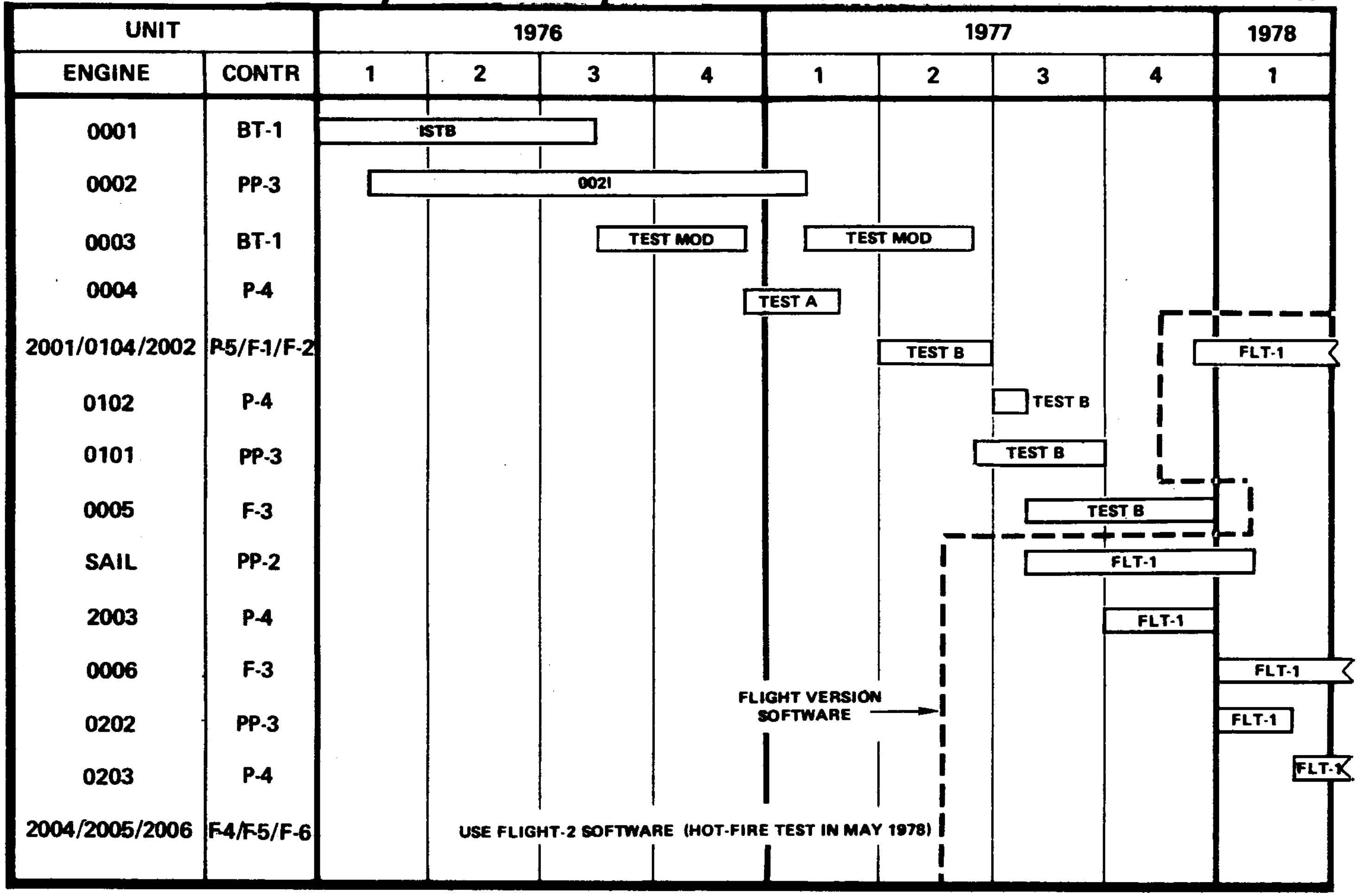


FIGURE XI-8

SSME MAJOR MILESTONES

10-28-76

MILESTONE	1976			1977									
	O	N	D	J	F	M	A	M	J	J	A	S	O
FLIGHT NOZZLE TEST	▽												
ENGINE OPERATION AT RPL		▽											
ENGINE 0004 COMPL			▽										
TURBOPUMPS TO FPL			▽										
LOX HEX TEST			▽										
ENGINE ALTITUDE TEST				▽									
ALL UP THROTTLING TEST				▽									
ENGINE GIMBAL TEST				▽									
START ENGINE RPL					▽								
ENGINE OPERATION AT FPL					▽								
SPECIFIC IMPULSE DEMO						▽							
POGO SYSTEM TEST (CTL-5)								▽					
ENGINE DURATION - 1 HOUR									▽				
MPTA DELIVERY (3)										▽			
ENVELOPE/ELECTRICAL SIMULATORS DELIVERY											▽		

FIGURE XI-9

XII. EXTERNAL TANK AND SOLID ROCKET BOOSTER

A. Introduction

These two elements of the Shuttle system are used only during full operational launch, e.g., they are the major elements, along with the SSME, that propell the system into orbit. In each of these programs the current effort is on the fabrication of hardware to be used in major test programs starting in mid-1977. Production of flight hardware has also been started in certain areas.

A reasonably detailed hazard and risk analysis has been completed for both of these elements and is being updated and expanded as required. In addition hazard analyses have been completed for NSTL facilities and test operations involving the External Tank, the Main Propulsion Test and other associated activities.

B. External Tank

External tank hazard analysis are performed in accordance with the requirements defined in NASA NHB 5300.4 (ID-1) and the procedures in Martin's MMC-ET-RA03. The results of this work is contained in the External Tank Catalog of Hazards. The first part of the catalogue is structured to provide quick reference to each hazard analysis by number, latest revision, date of issue, and hazard description. It also reports the actions taken to eliminate or reduce the risks as well as the further actions planned. In those cases where a significant risk still exists after all appropriate measures have been taken to reduce and control the hazard are categorized as residual hazards. These are identified and explained in Part II of the catalog.

The number of hazards by subsystem at the time this is written looks like this:

Structural and Thermal Protection Subsystem	22 items
Propulsion and Mechanical	31 items
Electrical	13 items
Ground Support Equipment	3 times

There are seven (7) residual hazards noted by the ET program:

1. The ultimate load testing of the Structural Test Article LH_2 Tank and the 10 ft. diameter test tank with liquid hydrogen in them can cause a catastrophic fire if there is a leak for any reason and an ignition source of any type. This testing is to take place at MSFC and the means of containing and controlling this problem are still being worked out.

2. There are a number of so-called "single point failure" fasteners which could lead to the loss of the Shuttle vehicle. Nineteen (19) such fasteners have been identified and these are being handled independently of all other fasteners and will receive 100% proof test and mandatory inspections.

3. Fracture critical welds increase the potential for tank rupture during proof pressure and load tests. Methods are being developed to maintain continuous leak detection to permit test shutdown. In addition provisions are being made to contain explosive decompression if it does occur.

4. Allowable leaks at LH_2 flanges may cause mechanical damage to the thermal insulation increasing the fire potential due to air

liquifaction. Damage to the thermal protection subsystem can lead to structural overheating and possible loss of the external tank dome. Testing to determine the extent of this type problem will not be performed, but seals will receive 100% inspection and so will the flange surfaces prior to seal installation. These then will be completely leak checked. Another added protective process has been to use soft surface coating which seal surface imperfections can impact and minimize seal leakage.

5. External Tank propellants are loaded and off-loaded through the Orbiter. In the event of a leak in the tank, or leak, fire, etc. in the Orbiter, the lack of an independent External Tank propellant drain requires off-loading through the possible hazard zone. This must be kept in mind during KSC operations analyses and requires a thorough integrated ET/Orbiter risk assessment.

6. The reactivity of Titanium with Oxygen. Liquid air formation could occur at those points near LH_2 lines where insulation is not sufficient to preclude it. There appears to be Titanium fittings near such points. This hazard is considered closed based on the direction given to design to preclude air liquifaction and the remote probability of LO_2 leaks with sufficient impact possibilities to cause ignition. Such spark ignition would require a double failure, i.e., an LOX leak accompanied by an electrical failure.

7. Lightning discharge, either natural or triggered by the vehicle, would provide a powerful ignition source for flammable materials on the ET. This is considered manageable because of the protection

provided by the ground facilities and the existence of an inflight protection system. The inflight system is designed to withstand the effects of a direct strike followed by a restrike during flight. Thus the penetration of an electrical charge into the compartments of the ET are remote.

The Intertank Structural Test Article status is such that its delivery to MSFC is now targeted for March 15, 1977, on schedule. The LOX simulator and the Liquid Hydrogen simulator to be used along with the STA intertank appear to be supporting the STA schedule. Figure XII-I shows these components.

The External Tank Main Propulsion Test Article (MPTA) has had some difficulties in fabrication over the past months. The welding problems for this assembly (Figures XII-2,-3) have delayed the fabrication process by 1 1/2 months. A major problem is obtaining a "round" tank at the welds as well as weld strength with proper safety factors. It appears that the tanks are out-of-round after welding and are then forced into shape creating an undetermined locked-in stress in the weld. More specifically, the status is:

a. LH_2 Tank

The aft dome and aft barrel have been rewelded with heat repairs required to complete the job. The weld inspection which followed identified minor mismatch of the two welded assemblies. This condition, after due study and evaluation has been accepted for use in the MPTA test program. The remaining barrel sections have been successfully welded.

b. LOX Tank

The LOX dome body and frame installation was completed with the machining of the dome chord, which is the interface with the mating flange of the intertank. The assembly of the slosh baffles were completed. The aft ogive assembly has been welded and inspected and hear repairs were required. The forward ogive assembly heat repairs have been made and accepted and this component of the LOX tank is in process of being welded to the aft ogive.

A number of actions are being taken to complete the MPTA tank sections and have the entire external tank available in time to support the MPTA test schedule by such means as selected Sunday work. There will be a continued in-depth review of the operations at each major tool prior to first usage to assure proper results and minimize physical interferences.

The External Tank weight at this time is somewhat over the control weight. Inert Control Weight (Level III) is about 73,300 pounds while the Inert weight (88% calculated, 12% estimated) is about 73,900 pounds. If you add to this the new weight from changes (about 500 pounds) and the normal expected weight growth over the next year there is a weight problem to be resolved.

There are many differences between the flight tanks and the MPTA test tanks. Most of these are to support the special test program requirements such as ground safety requirements. Examples of these differences are:

1. In the vent/relief system an auxiliary common vent mani-

fold has been added on the LOX tank for MPTA along with an auxiliary valve and line in the Liquid Hydrogen tank.

2. Additional Intertank access door panels have been added to the MPTA.

3. An auxiliary propulsion drain has been added in the MPTA manhole covers on both tanks.

4. The tumble system is not on the MPTA unit.

5. There is to be special instrumentation on MPTA.

A major area of concern on the TPS from an operational standpoint is the insulation material properties when heated or subjected to LOX and water environments. The differences between the MPTA and the flight types:

TPS Location	MPTA-Material	ET-1, Material
LOX Tank	BX 250	CPR 488
Intertank	BX 250	CPR 488
LH_2 Tank	CPR 488	CPR 488
Ablator Components	21 square feet of BX 250	1630 square feet of CPR 488

The choice of a material to provide external insulation on the tank has been a complex and difficult one because of the demanding thermal requirements as well as the requirements for producibility. This evaluative process continues and thus the types of insulation noted above for the MPTA and the ET-1 (flight) units may change in the future. At the time this is written:

1. BX-250 is now being tested for material characterization.

2. CPR 488 was selected over the CPR 421 material for use on the LOX tak for ET-1 because of its better toxic outgassing properties.

3. The development of light weight ice protection designs for many local protuberances on the External Tank continue to be a major design concern. The original approach left some areas susceptible to icing. Some of the ice prevention and reduction techniques under consideration are shown in Figures XII-4 and -5.

4. The development of alternate insulated wire designs for use in the LOX tank ullage zone is continuing. This wiring is expected to be subjected to an environment of temperatures up to 500°F and pressures up to 44 psia. A number of alterations have been investigated and a decision on this area should be forthcoming within a short time.

C. Solid Rocket Booster (SRB)

NASA has selected the United Space Boosters, Inc. (USBI) of Sunnyvale, California, a subsidiary of United Technology Corporation, as the assembly contractor for the Space Shuttle Solid Rocket Booster. The scope of work covers all the necessary activities at MSFC and KSC. This is the last major contract on the SRB, and thus takes MSFC out of the direct role of SRB integrator and assembler which has been their role up to now. However, MSFC still retains some integration responsibilities through the DDT&E flights. Basically, though, they will now manage the SRB elements as they have been doing on the SSME and ET portions of the program.

The following observations are based on Panel fact-finding and the SRB Critical Design Review conducted December 8, 1976 at MSFC. The SRB CDR was well organized and the work leading up to the CDR Board meeting appeared to be quite thorough. The total number of Review Item Discrepancy's (RID's) received were 799 of which 614 were approved for action of some type.

A number of items such as these were to be completed in early 1977:

1. A study to evaluate the acoustic emission and x-ray fluorescent techniques is planned during the DDT&E phase to determine the propellant burn rates of the SRM.

2. Transducers have been one of the most replaced components on past NASA programs and the requirment for redundant and must be inspected and leak checked where possible.

3. There appears to be a thermal environment problem with the SRM nozzle outer boot in terms of protecting the flexible seal and the flexible seal to fixed housing joint. Studies of this are being accomplished by NASA and the contractor.

4. Plans should be baselined shortly for integrated testing of the SRM flexible bearing and the SRB Thrust Vector Control system at Thiokol as well as for the development firing of SRM's.

Based on the Task Team visit,the Wasatch Division of Thiokol Corporation appears to be staffed by experience, motivated and creative personnel at all levels. This also is the case for the NASA Resident Office located on-site. It was noted that the contractor has given the SRM project "individual status," something accorded to major programs at Thiokol.

To date over 250,000,000 pounds of the propellant used in the SRM has been produced for Minuteman Missile motors and others. The changes in the formulation are in the quantity of iron oxide used to control the burning rate. Minuteman used no iron oxide and the Poseidon uses 0.4%, while the Shuttle SRM uses 0.07%. The higher the percentage of iron oxides the higher the burning rate in terms of pounds per minute. The propellant is not adversely affected by its storage or aging. Thiokol had some 40,000 pounds held in storage for over 13 years and it met all specifications when used. There is, then, an extensive experience base as well as fully characterized materials and processes.

Batch mixing is used to produce the propellant since the so-called "continuous mixing process" has never worked out. Six hundred gallon batches (7000 pounds) are mixed at a time in each of three mixers so that there can be continuous pouring of the SRM segments. This is the equivalent of truely continuous casting.

The antioxidant currently used in the SRM polymer is PBNA supplied by Goodrich Chemical Company. Unfortunately they have ceased production so the following alternatives are being investigated. Modify the manufacturing process at Goodrich and the American Synthetic Rubber Company so that they would resume production; find and qualify a new source; or find and qualify a new antioxidant. Thiokol has prepared a plan to qualify an alternate material to replace PBNA by June 1977.

There is sufficient polymer for DM-1 and 2 already on hand and the polymer for DM-3 is on hand but not yet processed by American Synthetic Rubber. The SRM is expected to operate as required from the point of view of thrust capability. The calculated and specified time-thrust curves are shown in Figure XII-6.

The work of the SRB Fracture Control Board continues to assure that attention is focused on minimizing any detrimental effects of stress corrosion and material fractures from material imperfections. Some of the interesting material developed through this board include:

1. Fracture Control Plans for the case, nozzle and ignition system are in the process of review for publication.

2. The SRB Thrust Vector Control Hydraulic Reservoir contains approximately 35 gallons of fluid at 3,000 psi on the high side and approximately 60 psi on the low side. The factors of safety are 1.5 on proof and 2.5 on burst for both operating pressures. The reservoir is being supplied by Arkwin, who also supplies the Orbiter reservoir. The first development unit was completed in November 1976. All pressure vessels are under "fracture control." The remaining question is whether there is a fracture control plan and a requirement for supporting analysis and test?

3. Problems exist with the making of thick butt welds which has triggered an examination of this area and the methods to be used to eliminate unacceptable weldments.

D. Information Update

1. Solid Rocket Booster

As with any rapidly moving program the status of accomplishments and concerns also changes. The material contained here provides more specifics on items already discussed as well as items not previously covered.

Key milestones to look forward to in this SRB Project include the following:

a. The first development firing test of an SRM is scheduled for the June 1977 period,

b. The so-called "Allup" Electrical & Instrumentation Verification Test" (EIVT) is scheduled for sometime in the March 1977 period,

c. An important sub-system delivery Integrated Electronics Assembly (IEA) is scheduled for March which will be a part of the EIVT,

d. Prototype parachutes for the recovery sub-system scheduled for April, and

e. The next months should see a great deal of activity in qualification testing of components for this project.

An examination of the project, e.g., the Critical Design Review and Quarterly Reviews indicate that the Solid Rocket Booster is progressing very well and that the concerns and problems are being resolved in an orderly and comprehensive manner. Special efforts are being made in the following areas which are considered as some-