ALTERNATE TURBOPUMP DEVELOPMENT PROGRAM

CRITICAL DESIGN REVIEW

August 2 - 6, 1993

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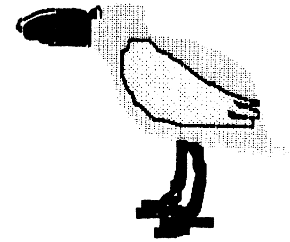
Program Overview

J. P. Mitchell

SSME/ATD CRITICAL DESIGN REVIEW

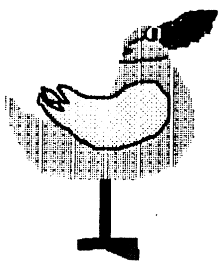
Agenda, Monday August 2, 1993

•	Opening	Loren Gross	8:30-8:45
•	Introduction/Program Overview	Pete Mitchell	8:45-9:15
•	HPOTP Design - Overview	John Price	9:15-10:00
•	HPOTP Performance	John Park	10:00-10:30
	Break		10:30-10:45
•	Internal Flow Management & Heat Transfer	Joe Sawyer	10:45-11:15
•	Structures (Fracture, Stress, Component Dynamics)	Rich Hammond	11:15-11:45
•	Rotordynamics	Dave Hudson	11:45-12:15
	Lunch		12:15-1:15
•	Integration	Dan Guisinger	1:15-1:45
•	Rocket Integration	Rocketdyne	1:45-2:15
•	CDR Format/Guidelines/Schedule	Lynn Gambill	2:15-2:30
•	Splinter Sessions		2:30-5:00

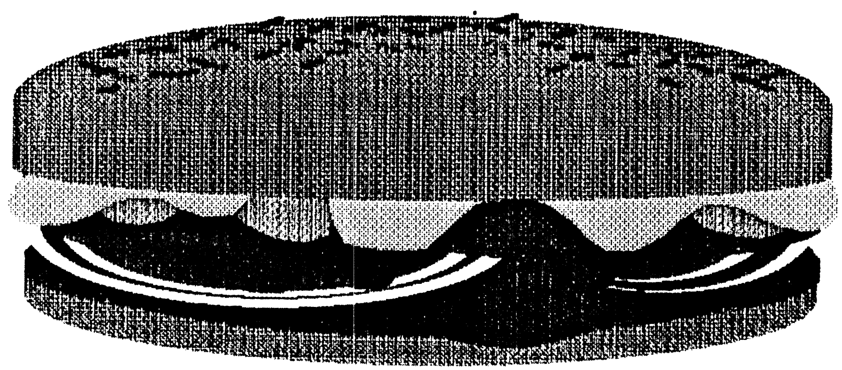



Wednesday Evening
Barbecue at the Beach!

Where: Carlin Park, Jupiter (see Lynn/Paula at the desk to sign up and get a map)




FOOD, FOLKS & FUN!



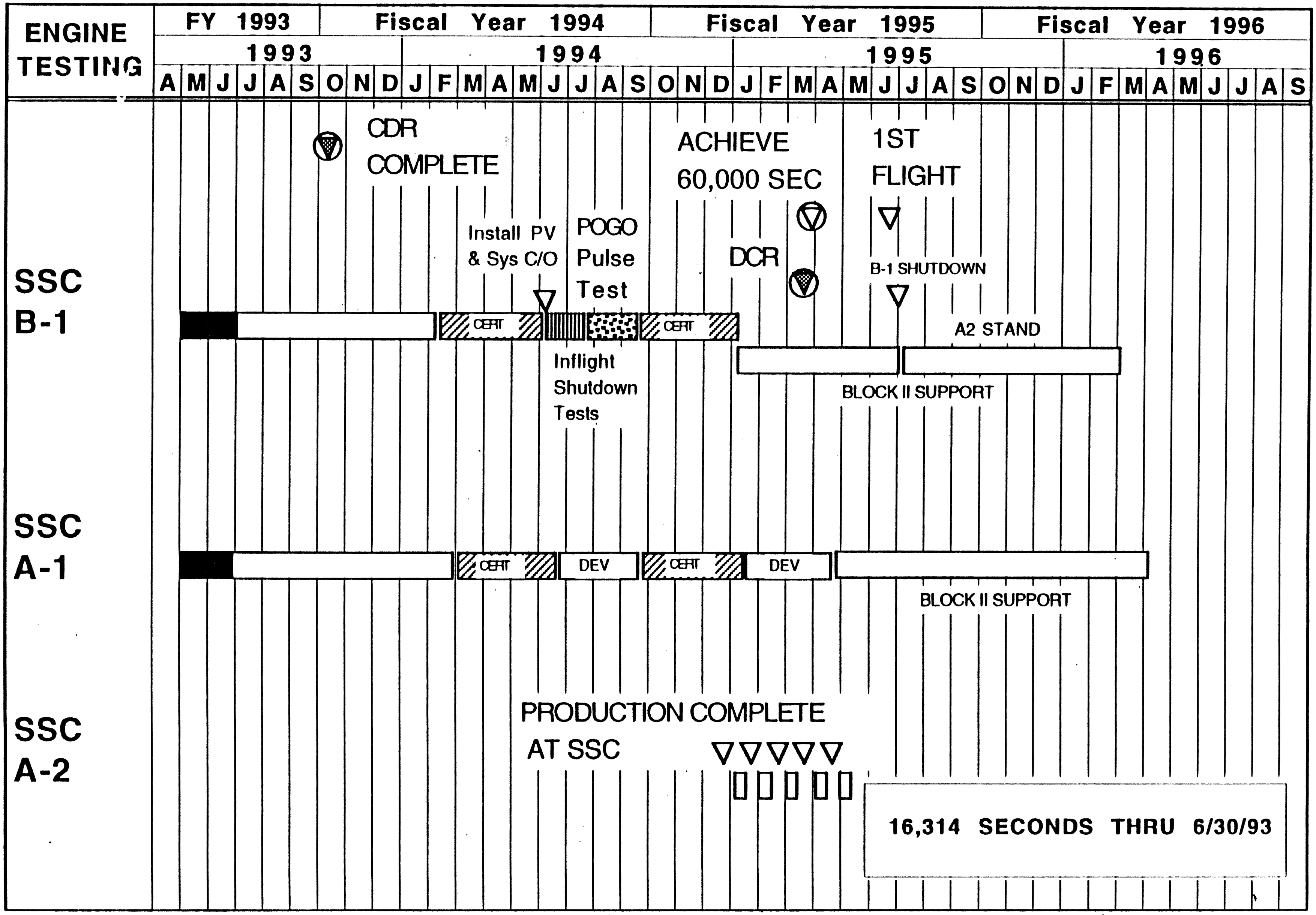
E-Area Tours

Tuesday, Wednesday & Thursday

Twice Daily

Sign up early (at the desk) for a seat!

ATD ENGINE LEVEL TEST - 06/30/93

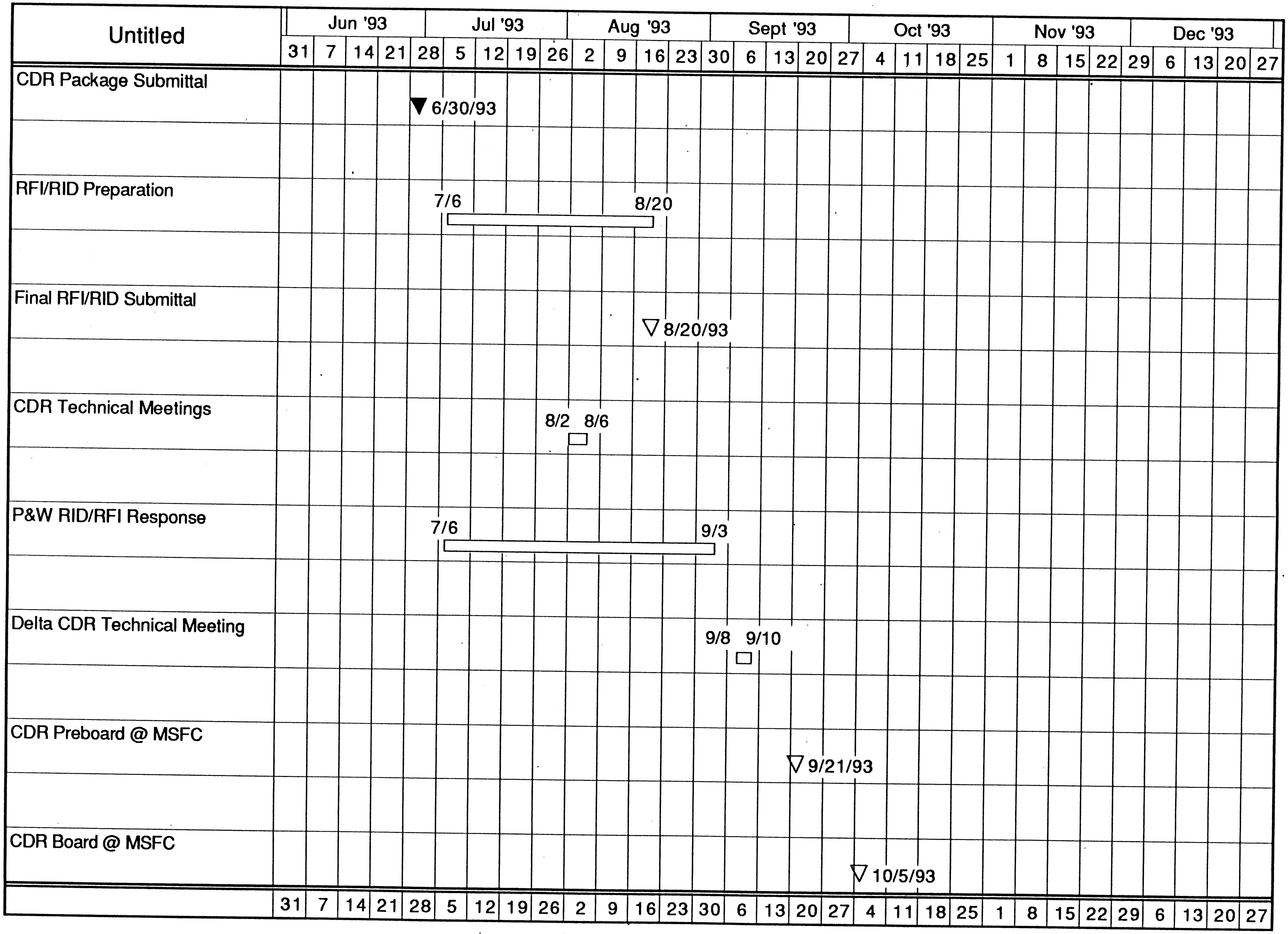


CERT: 9-1 10-1
9-2 11-1

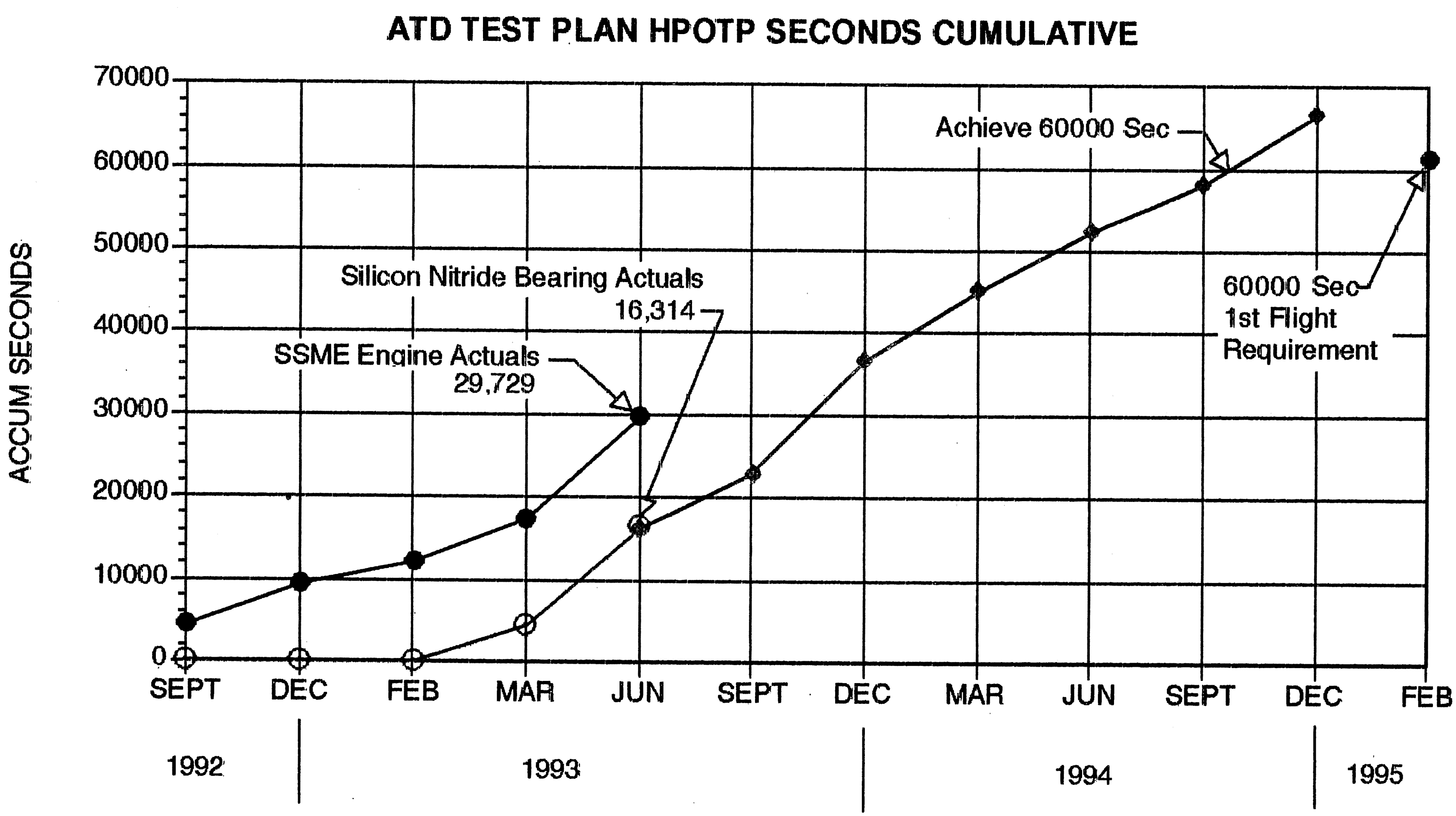
TESTING BASED ON 17,500 SEC A YEAR PER STAND

SSME ATD HPOTP CRITICAL DESIGN REVIEW

CDR Schedule

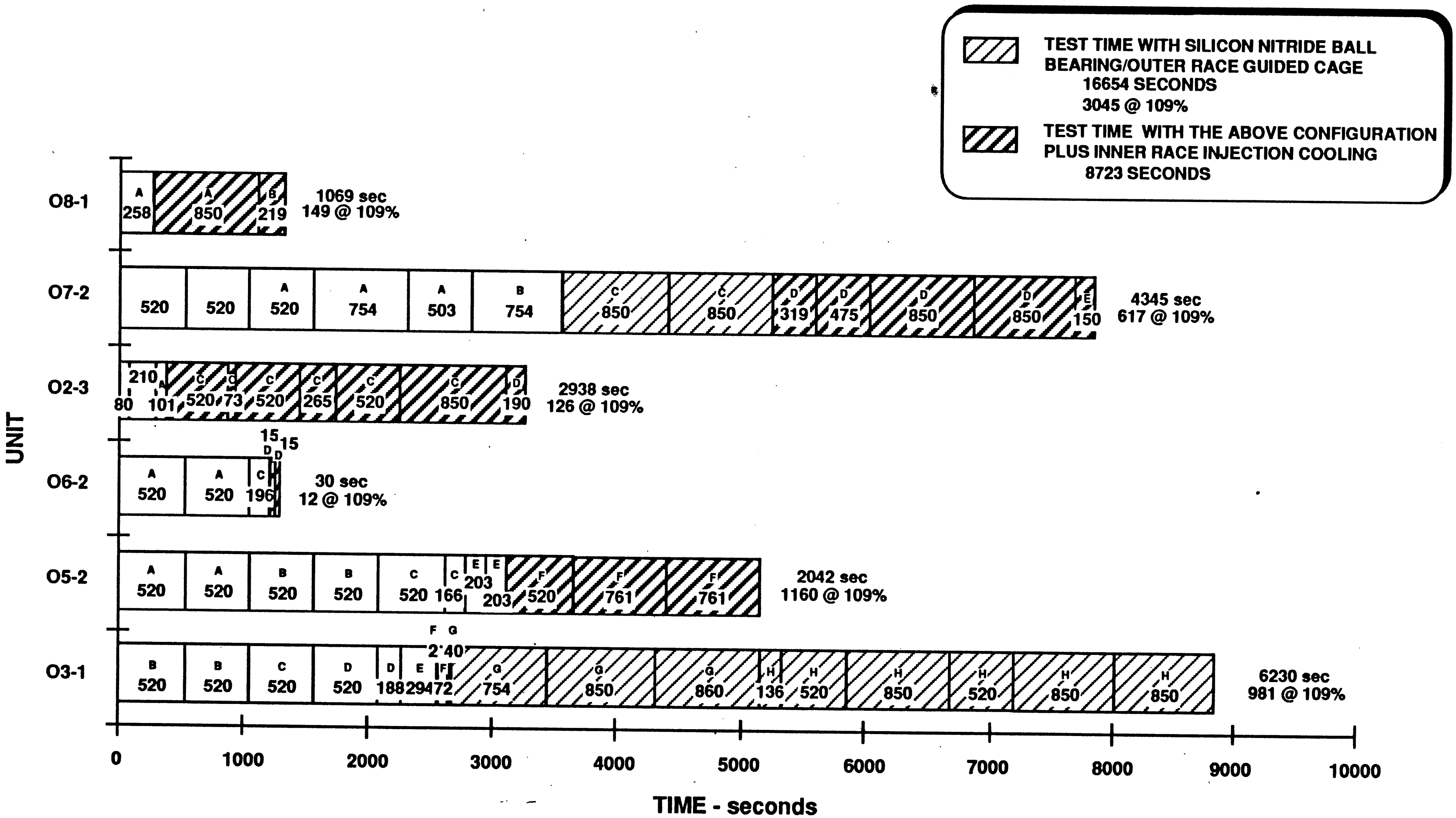


LG-CDR SCHED
KC-6/30/93


ATD TEST PLAN HPOTP SECONDS CUMULATIVE
ACCUM SECONDS
70000
60000
50000
40000
30000
20000
10000
0
SEPT
DEC
FEB
MAR
JUN
SEPT
DEC
MAR
JUN
SEPT
DEC
FEB
1992
1993
1994
1995
Silicon Nitride Bearing Actuals
16,314
SSME Engine Actuals
29,729
Achieve 60000 Sec
60000 Sec
1st Flight
Requirement

SSME ALTERNATE TURBOPUMP

UNIT TEST TIMES



CC/sm
7/13/93

TEST ACHIEVEMENTS

System Level Requirements Demonstrated At SSC

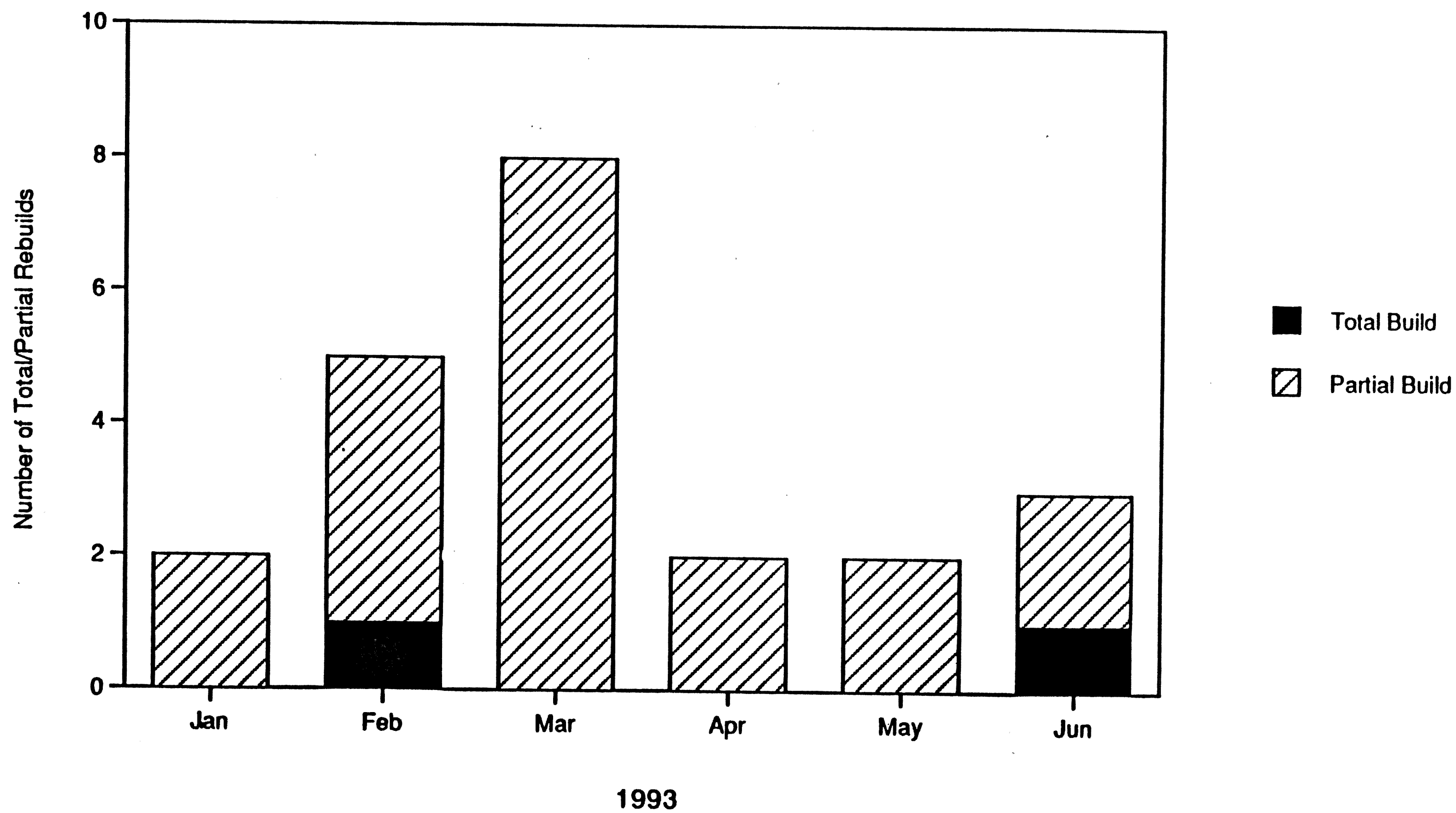
- 104% RPL and 20 NPSP
- 60% RPL without instability
- Min and max mixture ratio
- Engine control system electrical lockup
- IPS redlines proposed for flight
- Redline turbine discharge temperatures
- Extended duration tests up to 860 seconds
- Modified (Ph II+) start and shutdown
- 104% and 109% RPL abort mission profiles.

Also demonstrated cycle compatibility with Large Throat Main Combustion Chamber (LTMCC) in (2) firings at TTBE. Explored power levels to 109% RPL and spec minimum NPSP.

ASSEMBLY ACTIVITY

January - June, 1993 Agressive Turbopump Build Rate

Pratt & Whitney
SSME-ATD
Critical Design Review



PUMP END HARDWARE MODIFICATIONS FOR BEARING WEAR RESOLUTION

Rapid Turnaround Of Parts Achieved

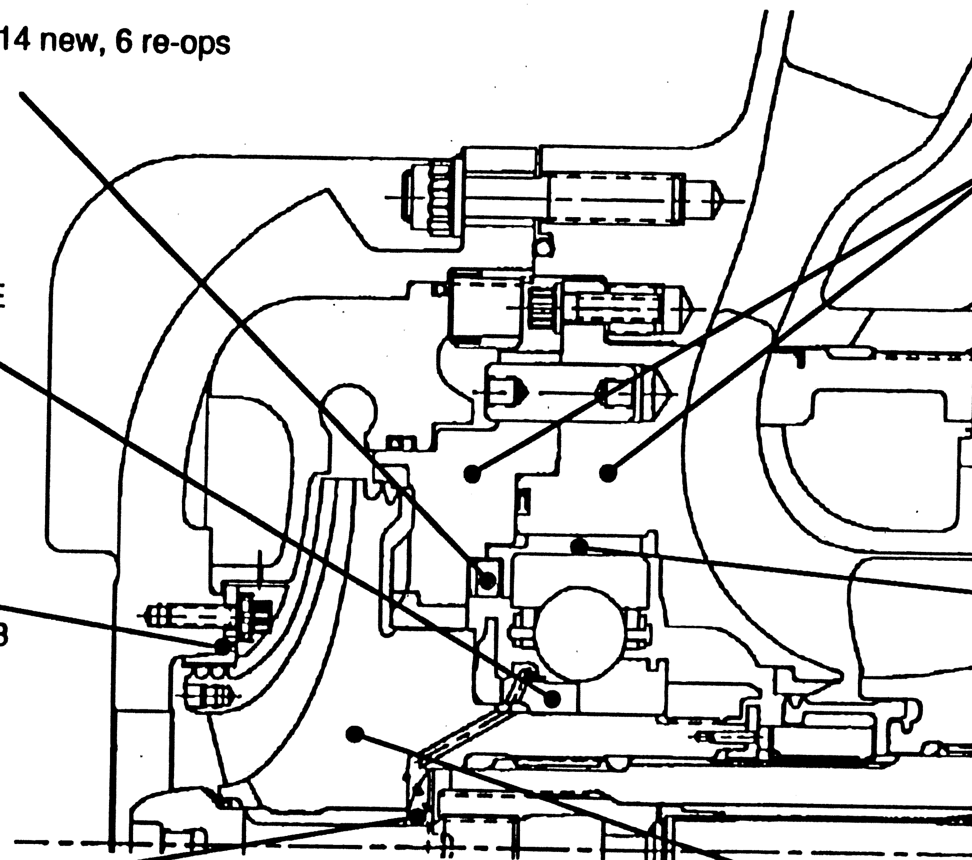
Pratt & Whitney
SSME-ATD
Critical Design Review

PRELOAD SPRING
- 20 parts provided for test - 14 new, 6 re-ops
- 3 week new part lead time
- 3 day rework leadtime

SHOWER HEAD INNER RACE
- 10 parts provided for test
- 7 day manufacture time

PREBURNER SEAL LAND
- 6 provided for test - 5 new, 3 re-ops
- 3 week new part lead time
- 4 day rework lead time

BORETUBE LOCK
- 7 parts tested with inner race cooling scheme
- 5 day mfg. time
- 2 configs. for use with inner race cooling



BEARING SUPPORT/DAMPER SUPPORT
- 19 sets provided for test - 8 new, 11 re-ops
- 10 day average lead time after req't identified.

BEARING SLEEVE
- 32 parts provided for test - 26 new, 6 re-ops
- 7 day new part leadtime (including coatings)
- 3 day re-op leadtime

PREBURNER IMPELLER
- 11 re-ops provided for test
- 7 day typical re-op time

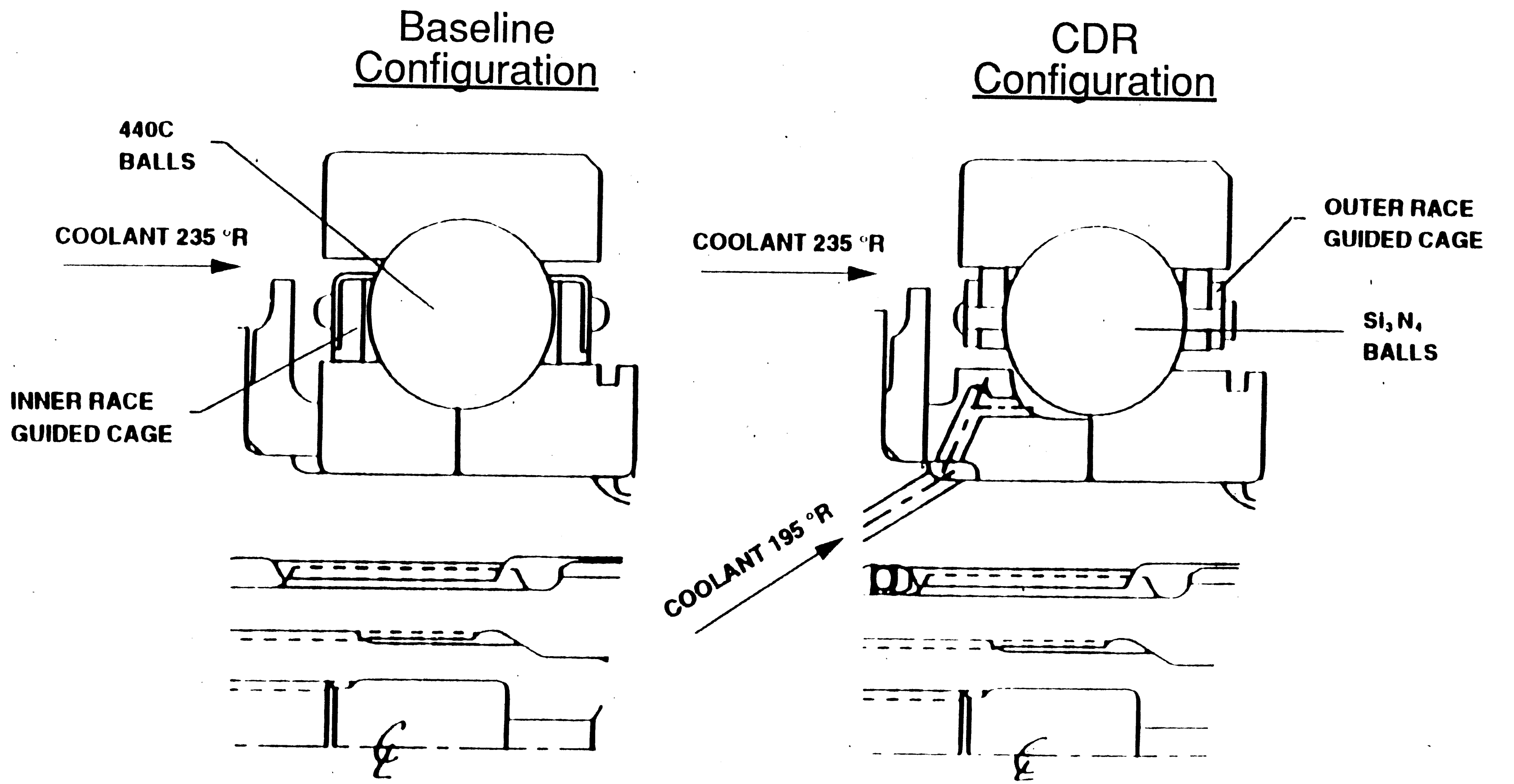
SSME-ATD/ATP HYBRID Si3N4 BEARING FLIGHT QUALIFICATION PLAN

Success Story/History - Ordered Ball Blanks, Ground, Assembled in HPOTP and Tested at SSC in Two (2) Months

- 12/23/92 - Initial international search for Silicon Nitride 13/16" dia. ball blanks.

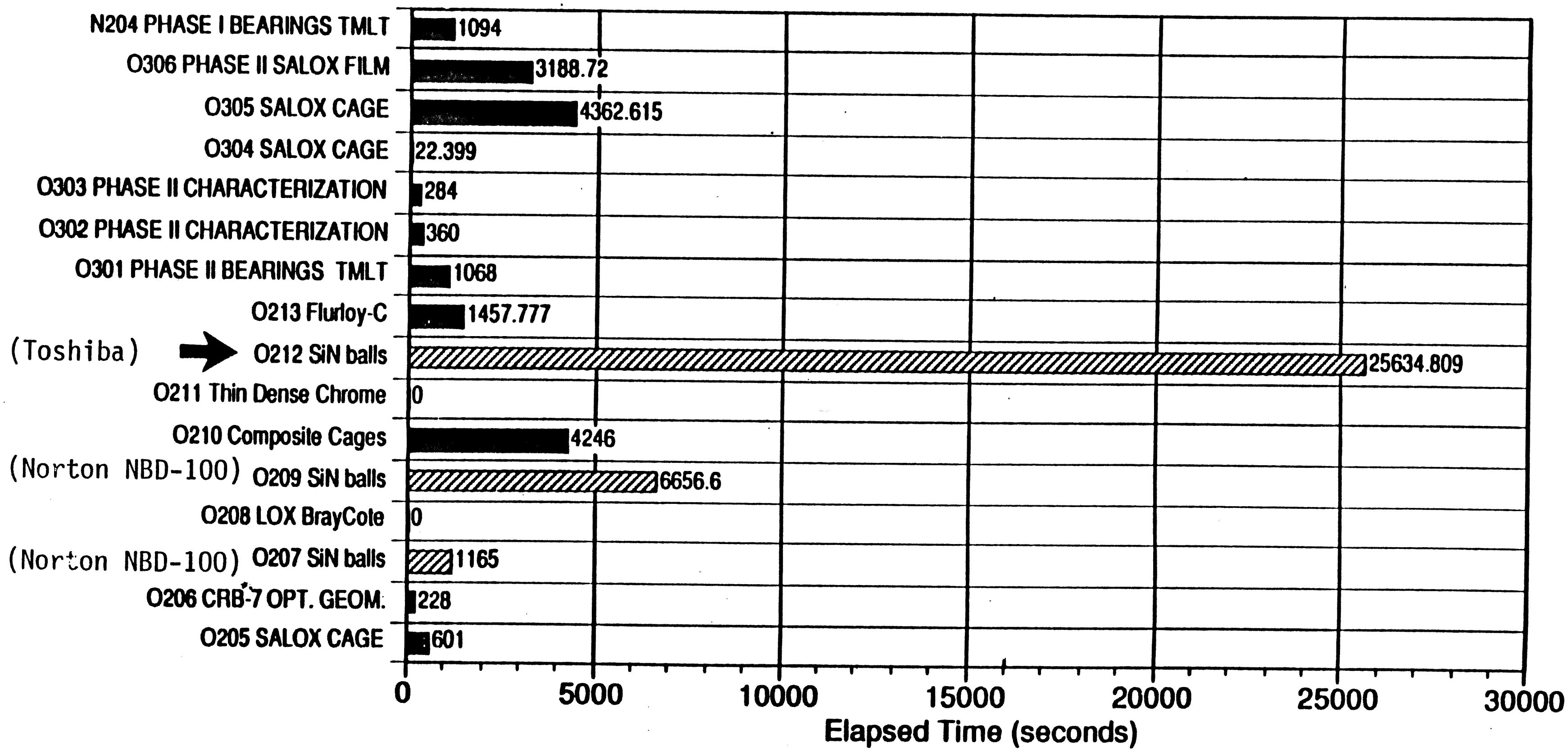
  US companies (Thomas Precision, MRC Brgs, Winsted Prec. Bals, Cerbec, Industrial Tectonics, Hoover Ball Brgs., ITI, Torrington).
- 01/06/93 - Located 270 13/16" dia. ball blanks at Toshiba in Japan. Ordered through Enceratic (US distributor).
- 01/26/93 - Ball blanks delivered; dual sourced the finish grinding to ITI and MRC.
- 02/06/93 - ITI completed grinding 20 balls; MRC completed grinding 151 balls on 2/18/93.
- 02/08/93 - Sonoscan finished NDT development.
- 02/26/93 - Sonoscan delivered first set of Silicon Nitride balls.
- 03/08/93 - First SSME-ATD engine level test at SSC using Hybrid Silicon Nitride PEBB - SUCCESS!

PUMP END BALL BEARING DESIGN ENHANCEMENTS



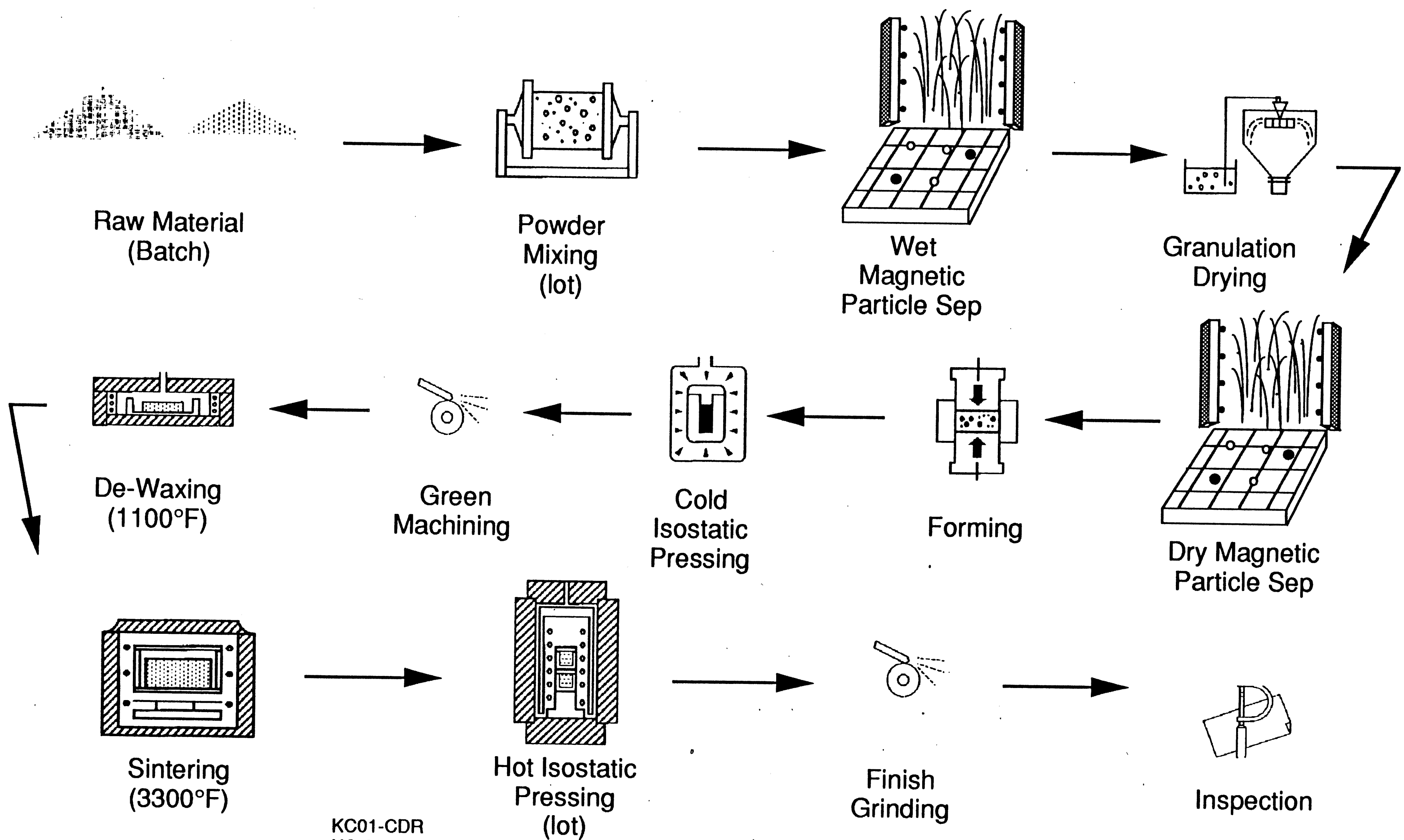
SSME-ATD HPOTP HYBRID CERAMIC BEARINGS

NASA LOX BSMT Test History (Tester Functional Capability Verification)



SSME-ATD/ATP SILICON NITRIDE PEBB

Fabrication Process

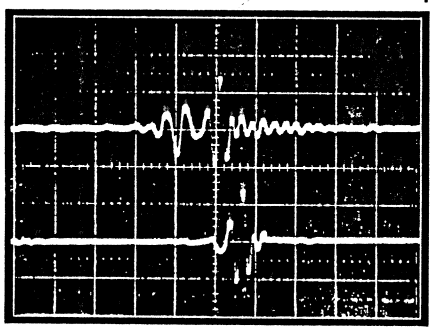


KC01-CDR
KC-6/15/93-##

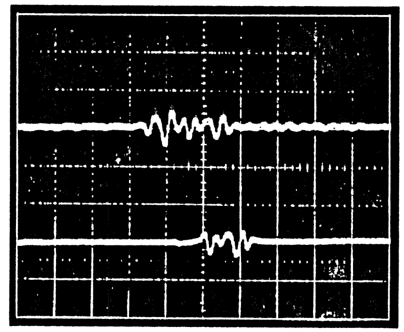
SSME-ATD HPOTP HYBRID CERAMIC BEARINGS

Acoustic Microscopy NDE Proves Flaw Detection Capability (Ultrasonic Inspection) of Si_3N_4 Ball Elements

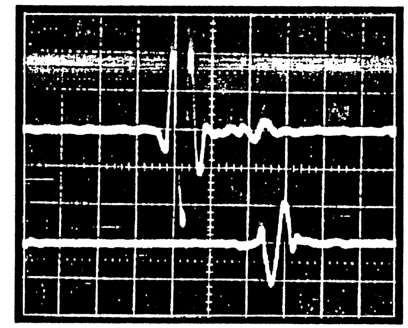
- Ball Masters Made With Known Flaws to Demonstrate NDT Flaw Detection Capability



Rayleigh Wave Normal (Surface)

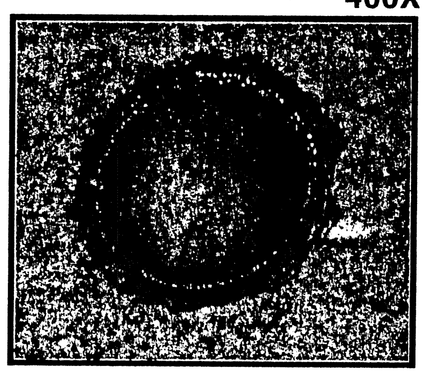


Rayleigh Wave Flaw Detection (Surface)

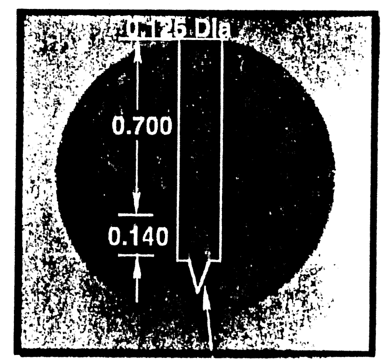


UT Pulse/Echo Signal (Sub-Surface)

400X



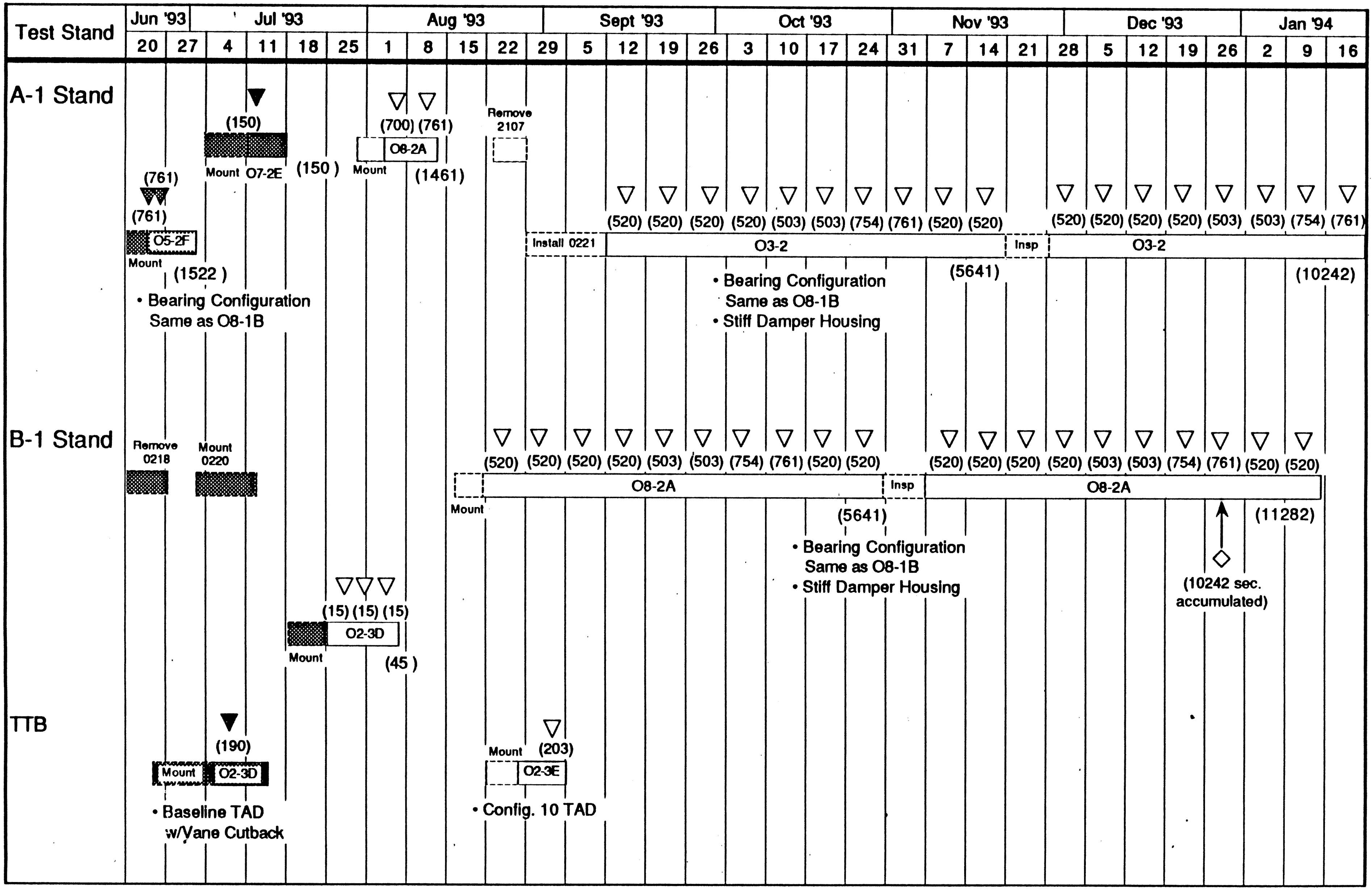
Laser Drilled Hole
0.0012" (depth) x 0.0030" (dia.)



Sub-Surface Flaw
0.035" (depth) x 0.002" (dia.)

37502

ATD-HPOTP TEST SCHEDULE



JLP0029-10B
7/28/93 HB

RECENT ATD VIBRATION PROBLEM

Problem Understood - Unit 8-2 Modified to Incorporate Fix

- Unit O7-2E at SSC experienced a vibration cutoff while operating at 109% RPL and venting inlet pressure.
- NASA vibration team reconvened to resolve cause of O7-2E event and sensitivity of ATD HPOTP synchronous vibration.
- Unit O8-2 removed from SSC prior to testing and returned to GESP.
- Unit O7-2E teardown inspection showed significant fretting between PEBB sleeve and housing. Deadband hangup had been identified as the potential cause of the vibration by the team.
- Hardware modification currently working to increase Unit O8-2 PEBB deadband to within operational ATD clearance experience.
- The NASA vibration resolution team concurs with the deadband clearance change. Further study of vibration sensitivity may include damper seal stiffness change.

ATD PROGRAM OVERVIEW

Altemate Turbopump Program - Important Dates

- Oxidizer turbopump Certification starts February, 1994
- Oxidizer turbopump Certification complete February, 1995
- <u>Oxidizer turbopump first flight</u> - June, 1995
- Fuel turbopump program limited restart - October, 1993
- Fuel turbopump Certification complete September, 1997
- <u>Fuel turbopump first flight</u> - October, 1997

ALTERNATE TURBOPUMP DEVELOPMENT PROGRAM

CRITICAL DESIGN REVIEW

HPOTP Design - Overview

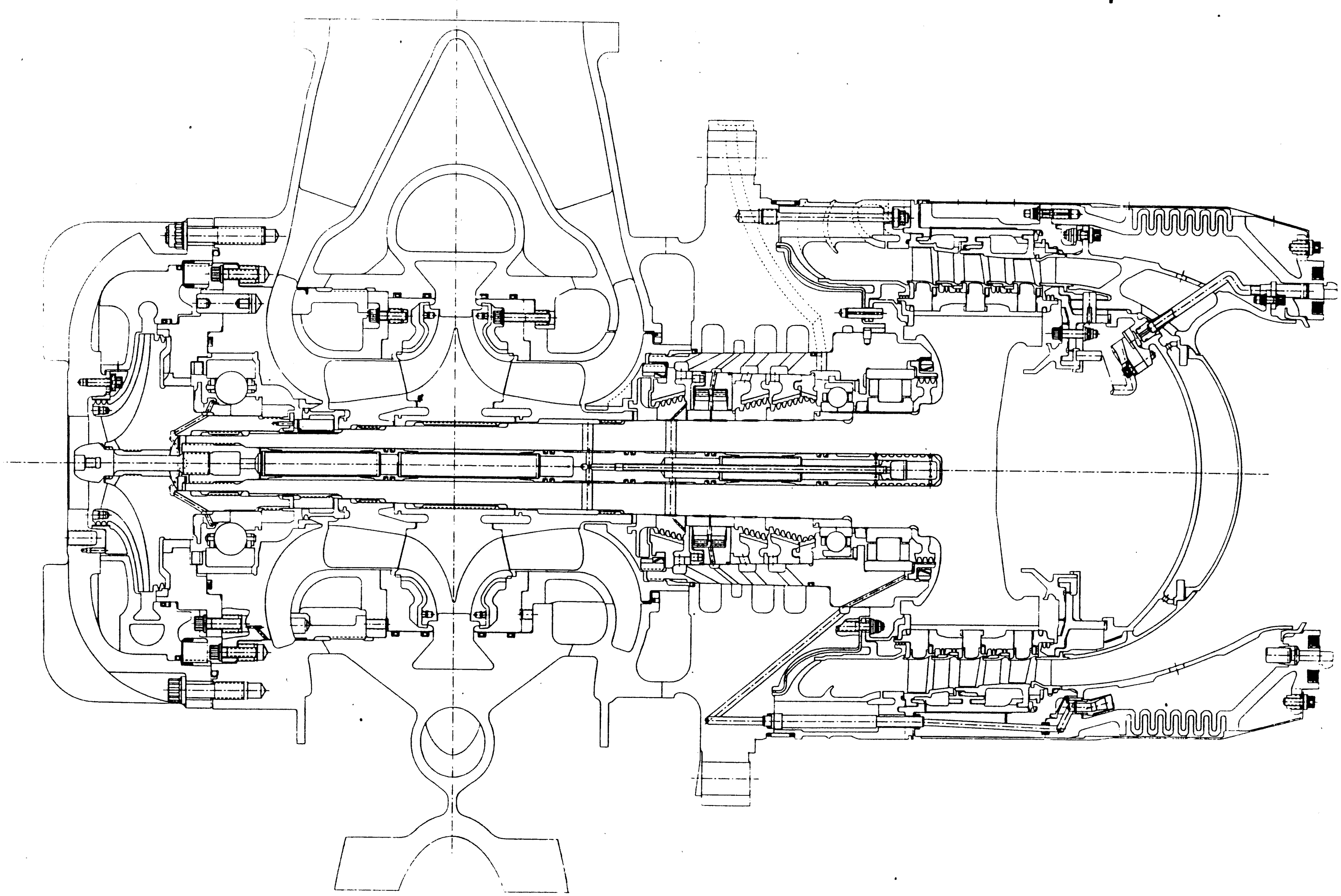
John L. Price
August 2, 1993

ALTERNATE TURBOPUMP FUNCTIONAL REQUIREMENTS

- Service life of 27,000 sec/55 missions/60 starts
- No maintenance except in-place health inspections
  - Borescope, torque checks
- Full life operation at 109% RPL (Full Power Level)
- Physical/functional interchangeability with current turbopumps
  - Mechanical interfaces maintained
  - No controller logic changes, adaptation constant changes only

HPOTP CRITICAL DESIGN REVIEW

Production Cross-Section (Rotated View)



ALTERNATE HPOTP DESIGN FEATURES

Robustness Introduced Through Basic Design Approach

	ATD HPOTP
• Minimize welds through fine grain investment castings	7 welds total
• Eliminate uninspectable welds	None
• Provide subcritical rotodynamic operation	25% critical speed margin
- Stiffen rotor system	Integral tiebolt/disk
- Minimize rotating elements	28
- Minimize bearings	2 ball & 1 roller (3)
• Provide significant suction (NPSP) margin	40%
• Reduce pump-induced radial load	650 lbs.
• Minimize LOX cooled bearings	1
• Eliminate coatings/closeouts required for HEE protection	None
• Eliminate turbine sheet metal	Thinwall, thermally compliant fine grain castings

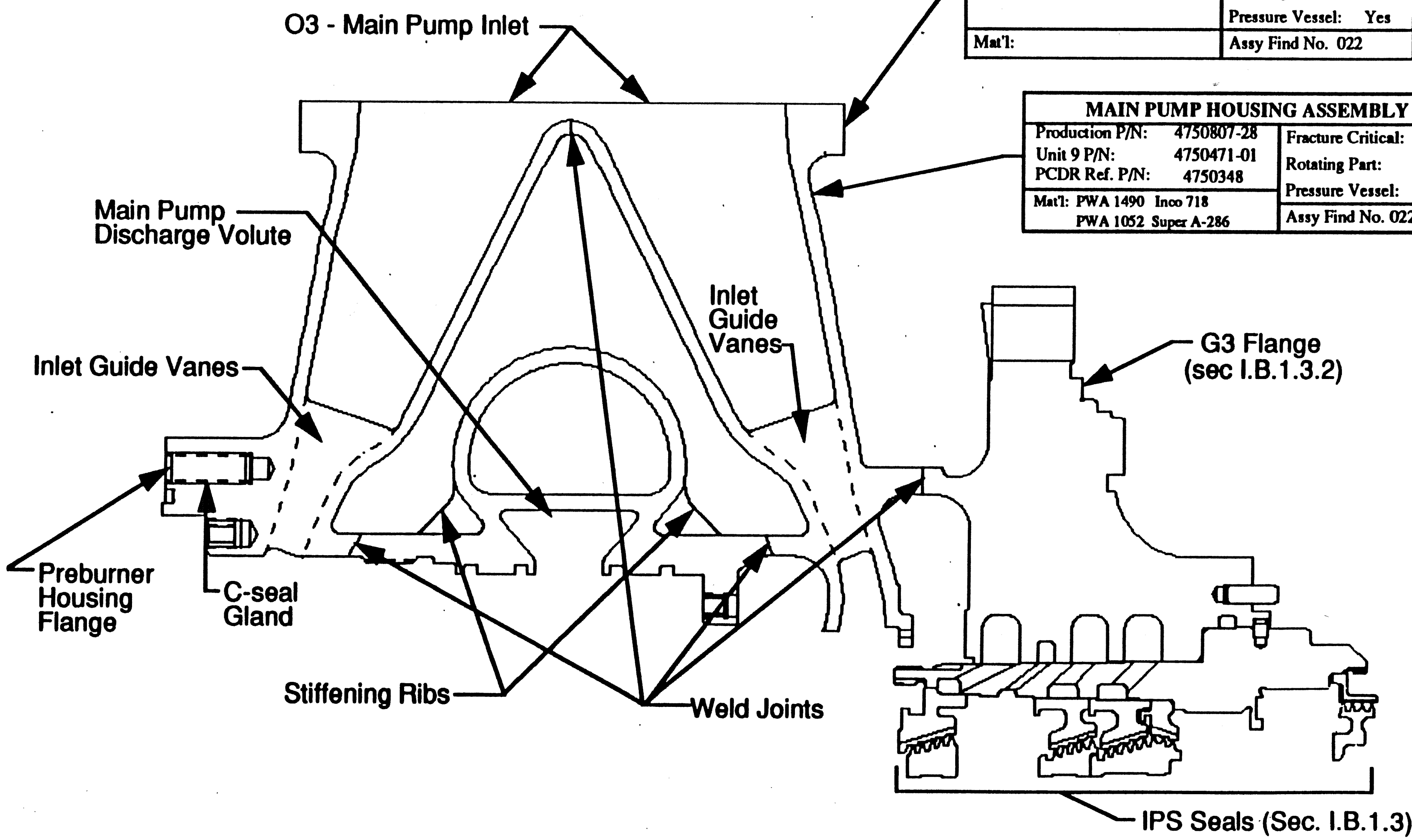
HPOTP MAIN STAGE PUMP DESIGN

Main Pump Housing

(I.B.1.2.1.1)

MAIN PUMP AND IPS HOUSING SET			
Production P/N:	4750807	Fracture Critical:	Yes
Unit 9 P/N:	4750471-01SK01	Rotating Part:	No
		Pressure Vessel:	Yes
Mat'l:		Assy Find No. 022	

MAIN PUMP HOUSING ASSEMBLY			
Production P/N:	4750807-28	Fracture Critical:	Yes
Unit 9 P/N:	4750471-01	Rotating Part:	No
PCDR Ref. P/N:	4750348	Pressure Vessel:	Yes
Mat'l: PWA 1490 Inco 718 PWA 1052 Super A-286		Assy Find No. 022-28	



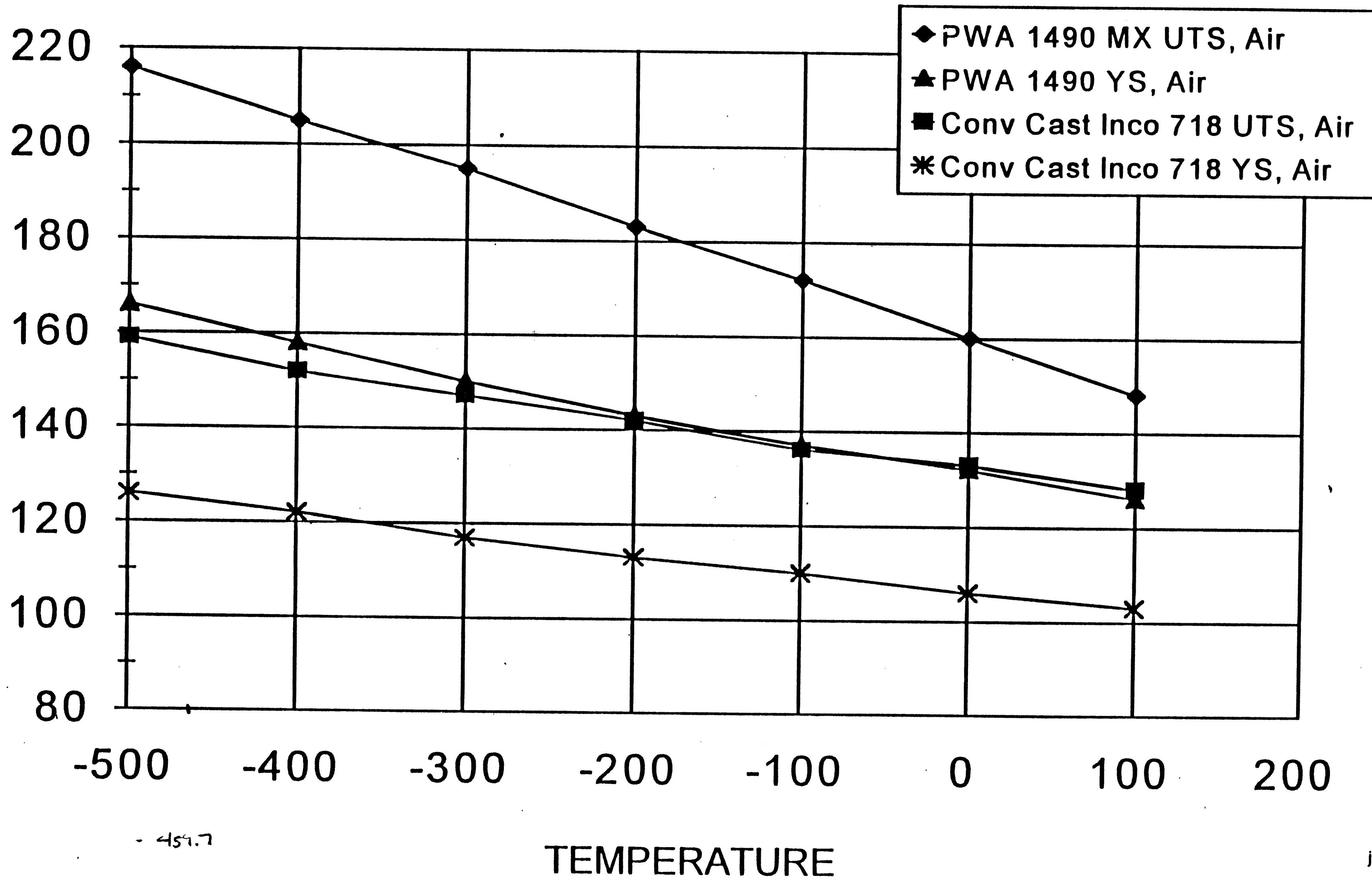
ATD HPOTP STRUCTURAL WELDS

Extensive Characterization and Validation Program Completed

- Four structural welds (seven total welds, three in external drain tubing)
- All structural welds are electron beam, fully automated
- Fully inspectable/root side access (two require borescope use)
- All x-ray and fluorescent penetrant inspected
- Inco 718/Inco 718 welds (3) HIP processed for further integrity
- Weld mechanical properties approach parent material capability

SSME-ATD STRUCTURAL CASTING REVIEW

Comparison of MX to Conventional Cast Inco 718

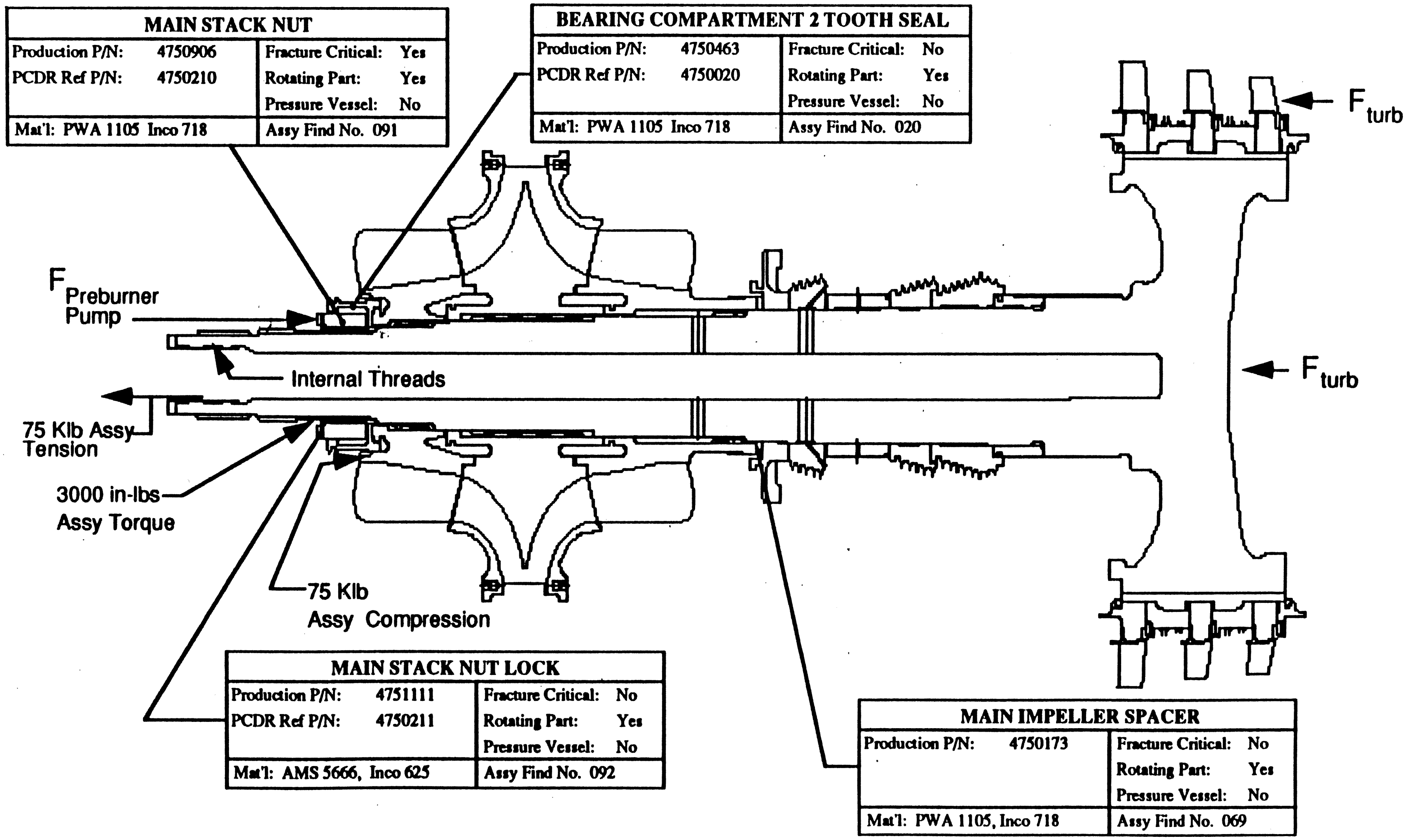


HPOTP MAIN STAGE PUMP DESIGN

Rotor Stack

(I.B.1.2.5.1)

Pratt & Whitney
SSME-ATD
Critical Design Review



ATD HPOTP BEARING CERTIFICATION CONFIGURATION

Material Selection

	Inner Ring	Outer Ring	Rolling Elements	Cage
Pump End Ball Bearing	440C**	440C	Si3N4 Balls	Salox/K-Monel shroud (ORG)
Roller Bearing	9310*	9310*	440C Rollers	Armalon (ORG)
Turbine End Ball Bearing	440C	440C	440C Balls	Salox/Alumn shroud (IRG)

* Plus corrosion protection coating of thin dense chrome and copper

** Loaded half of split IR

HPOTP ROTOR DYNAMICS

Critical Speed Analysis – Baseline
Structural Analysis Updates Since PCDR

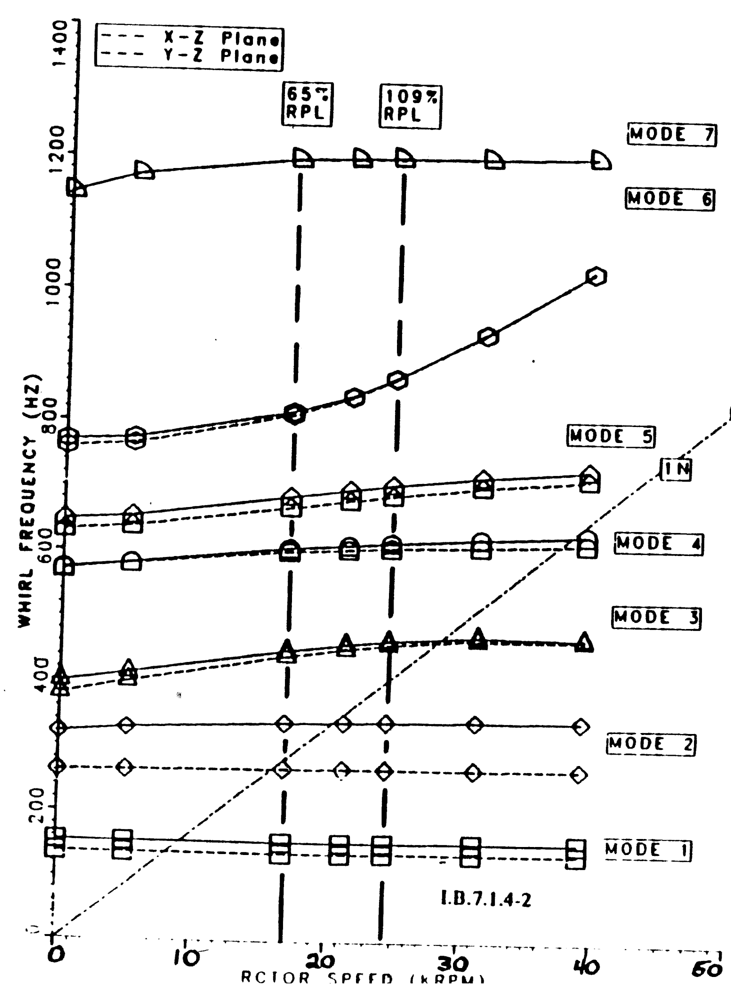
(I.B.7.1.4)

Subcritical operation predicted with high energy rotor bending modes well above 125% of maximum rotor speed.

MODE		CRITICAL SPEED	
NO.	DESCRIPTION	X–Z PLANE	Y–Z PLANE
1	Housing Bounce	9000 RPM (150 Hz)	8000 RPM (133 Hz)
2	Housing Pitch	20,000 RPM (335 Hz)	16,000 RPM (267 Hz)
3	Rotor Pump Bounce	28,500 RPM (475 Hz)	28,000 RPM (467 Hz)
4	Rotor Turbine Bounce	38,000 RPM (633 Hz)	37,000 RPM (615 Hz)
5	Housing 1st Bending	>40,000 RPM (665 Hz)	>40,000 RPM (753 Hz)
6	Rotor 1st Bending	>40,000 RPM (665 Hz)	>40,000 RPM (665 Hz)
7	Housing 2nd Bending	>40,000 RPM (665 Hz)	>40,000 RPM (665 Hz)

TABLE 6

HPOTP WHIRL FREQUENCY MAP

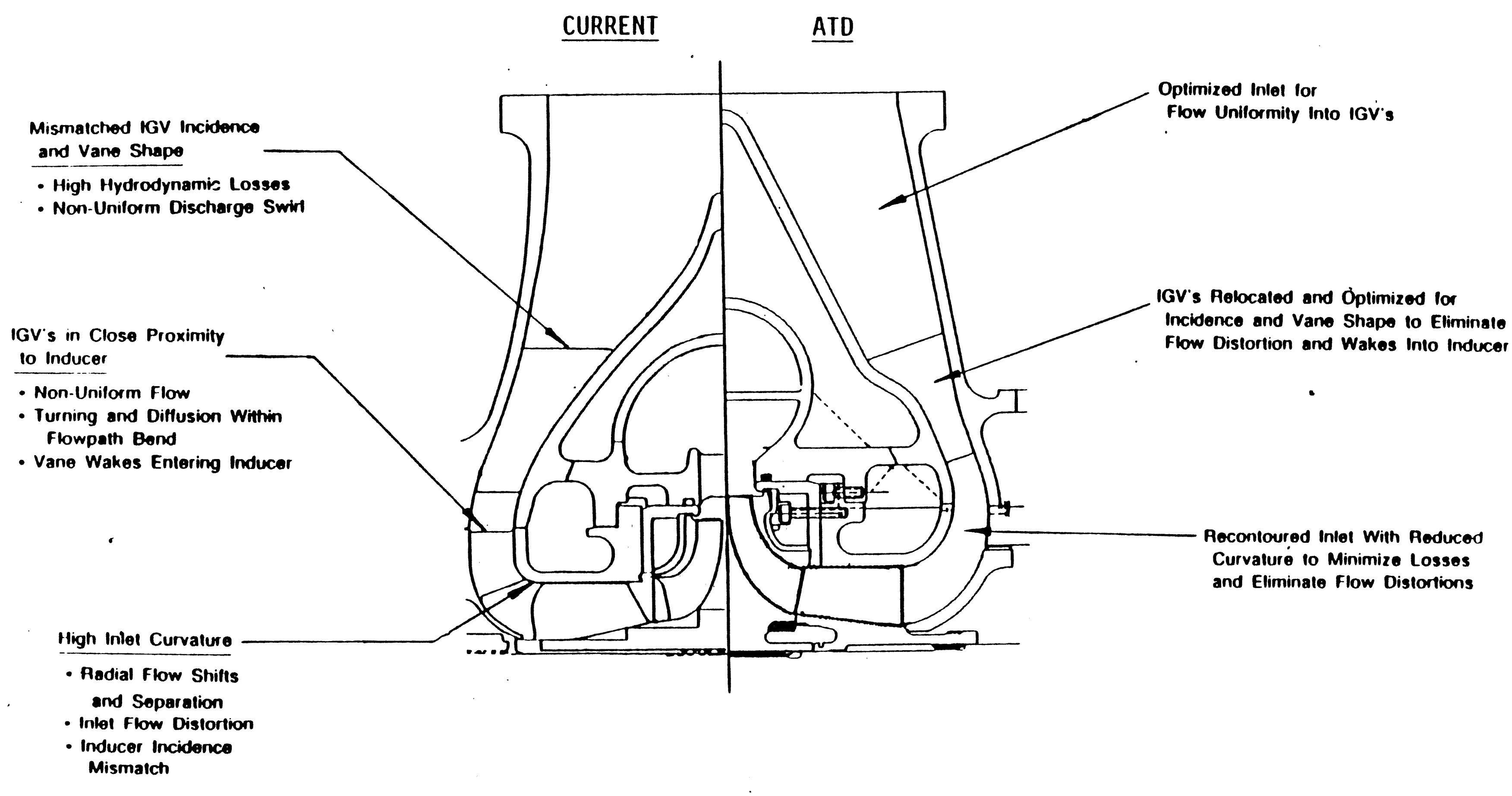


I.B.7.1.4-2

HPOTP INLET

Hydrodynamic Features Comparison

(I.B.2.1.2)



SSME ATD HPOTP

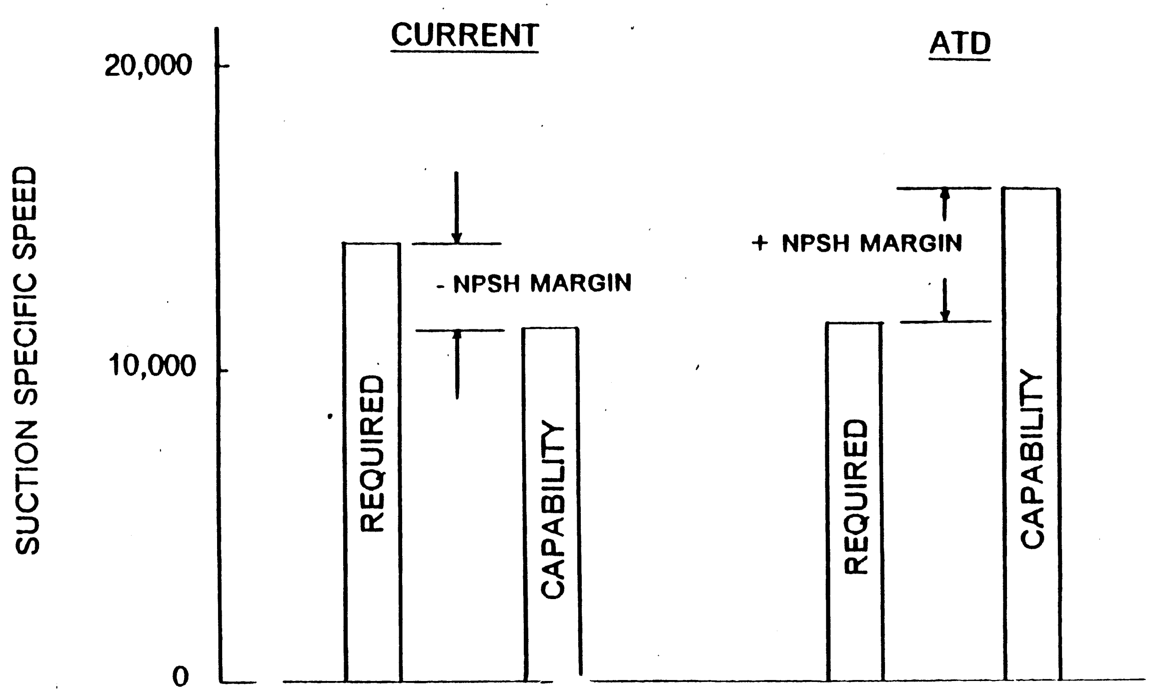
Suction Performance Improvement (109% RPL At SRB Cutoff)

(I.B.2.1.2)

At SRB (Solid Rocket Booster) cutoff where engine inlet pressures are low the HPOTP is most susceptible to cavitation. The current HPOTP has a negative NPSH (Net Positive Suction Head) Margin which indicates the pump is severely cavitating in this operating regime.

The ATD HPOTP suction performance was improved to provide a positive NPSH Margin and the elimination of cavitation head fall-off in this regime by 1) increasing the Suction Specific Speed Capability, and, 2) decreasing the Required Suction Specific Speed. The Nss Capability was increased by optimizing the inducer incidence and by improving the inlet velocity distortion. The required Nss was reduced by lowering the speed of the pump and by improving the design of the inlet to provide lower losses and less inlet pressure distortion.

(Reference VCR FR-19847-1)

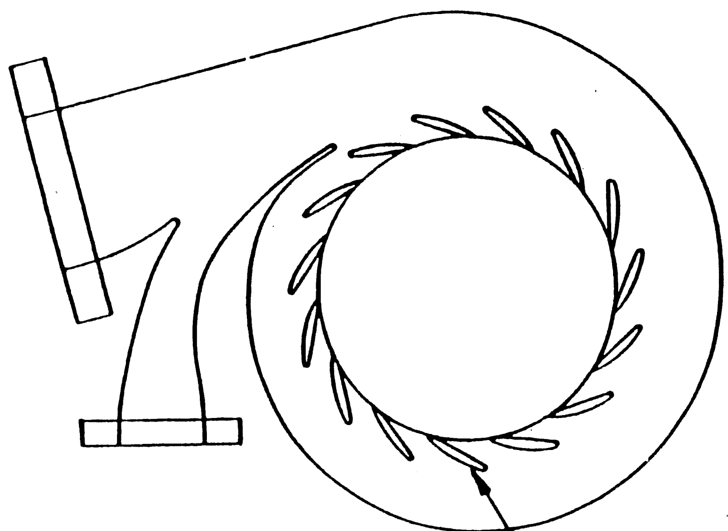


HPOTP DISCHARGE VOLUTE

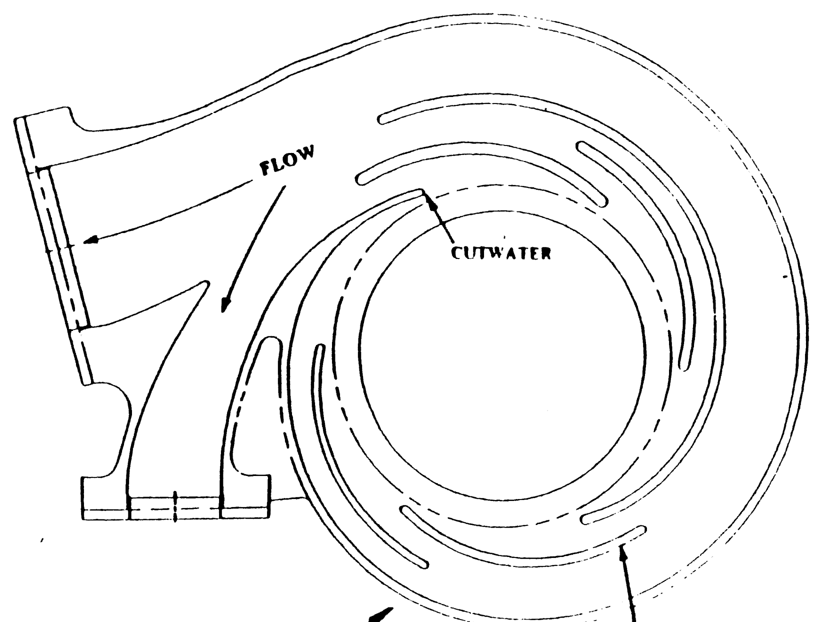
Hydrodynamic Features

(I.B.2.3.1.1.5)

CURRENT



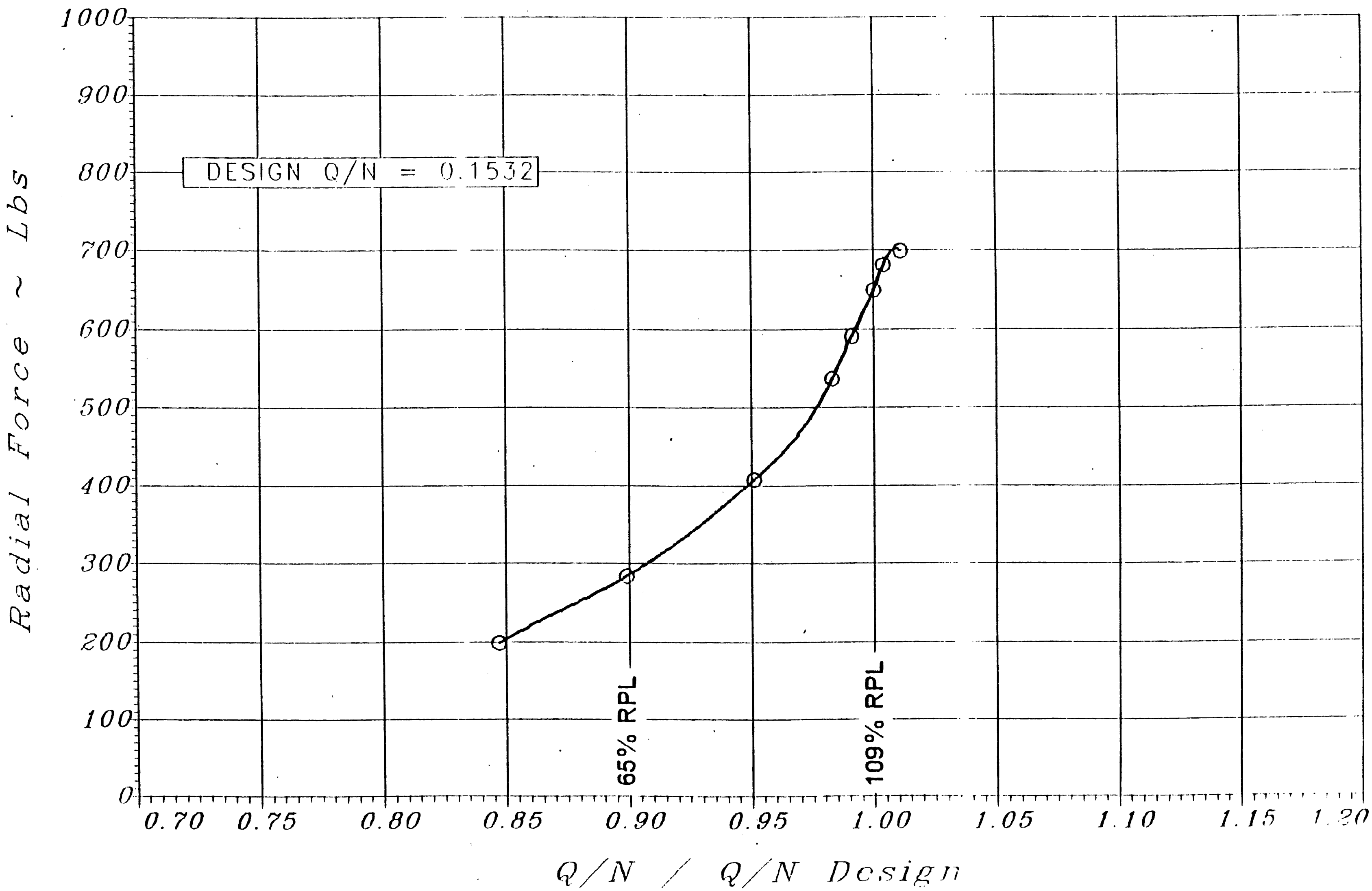
ATD



SSME ATD HPOTP

Radial Sideload Rig Data

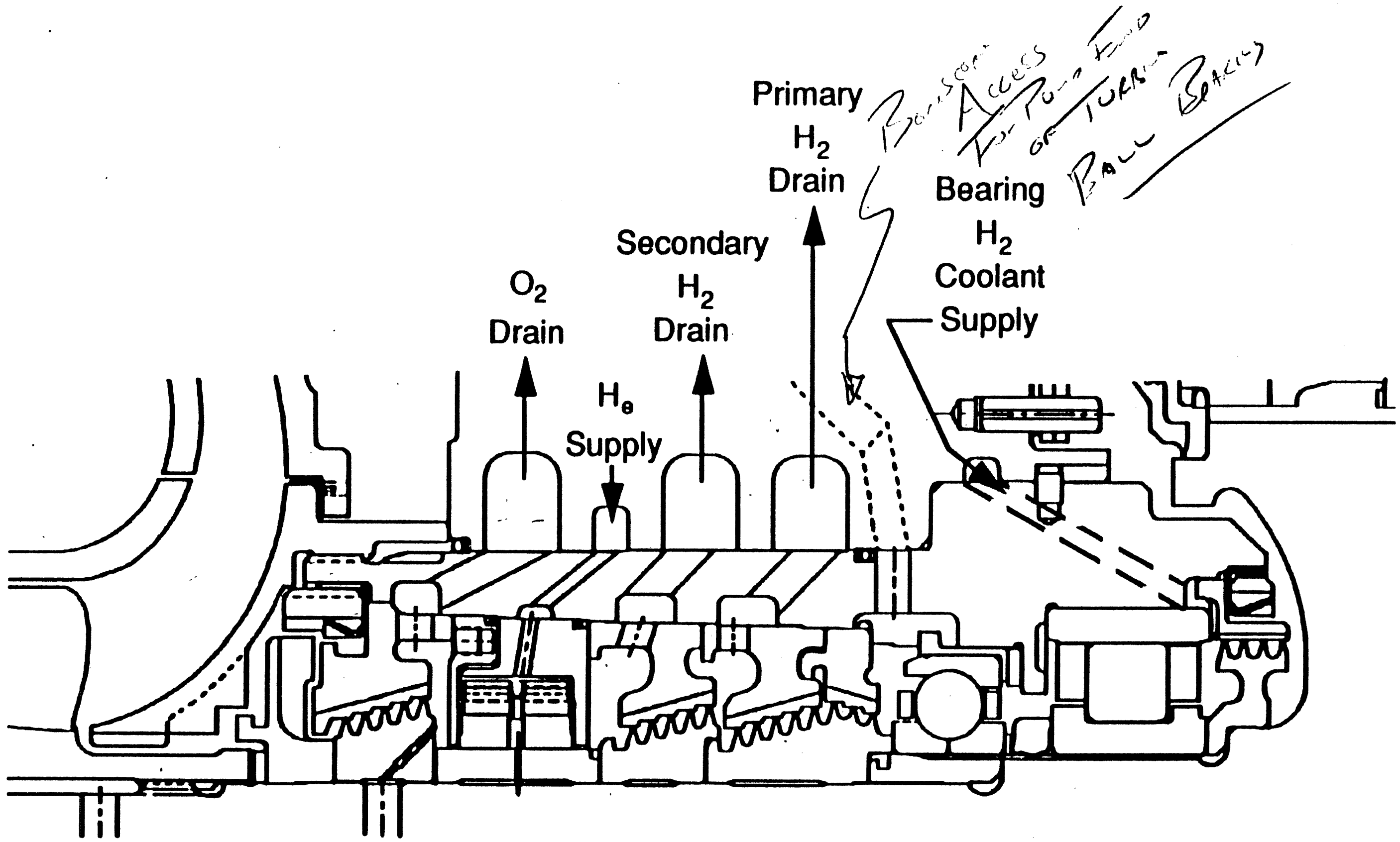
(I.B.2.3.1.1.5)



HPOTP INTERPROPELLANT SEAL DESIGN

Interpropellant Seal (IPS) - General Description

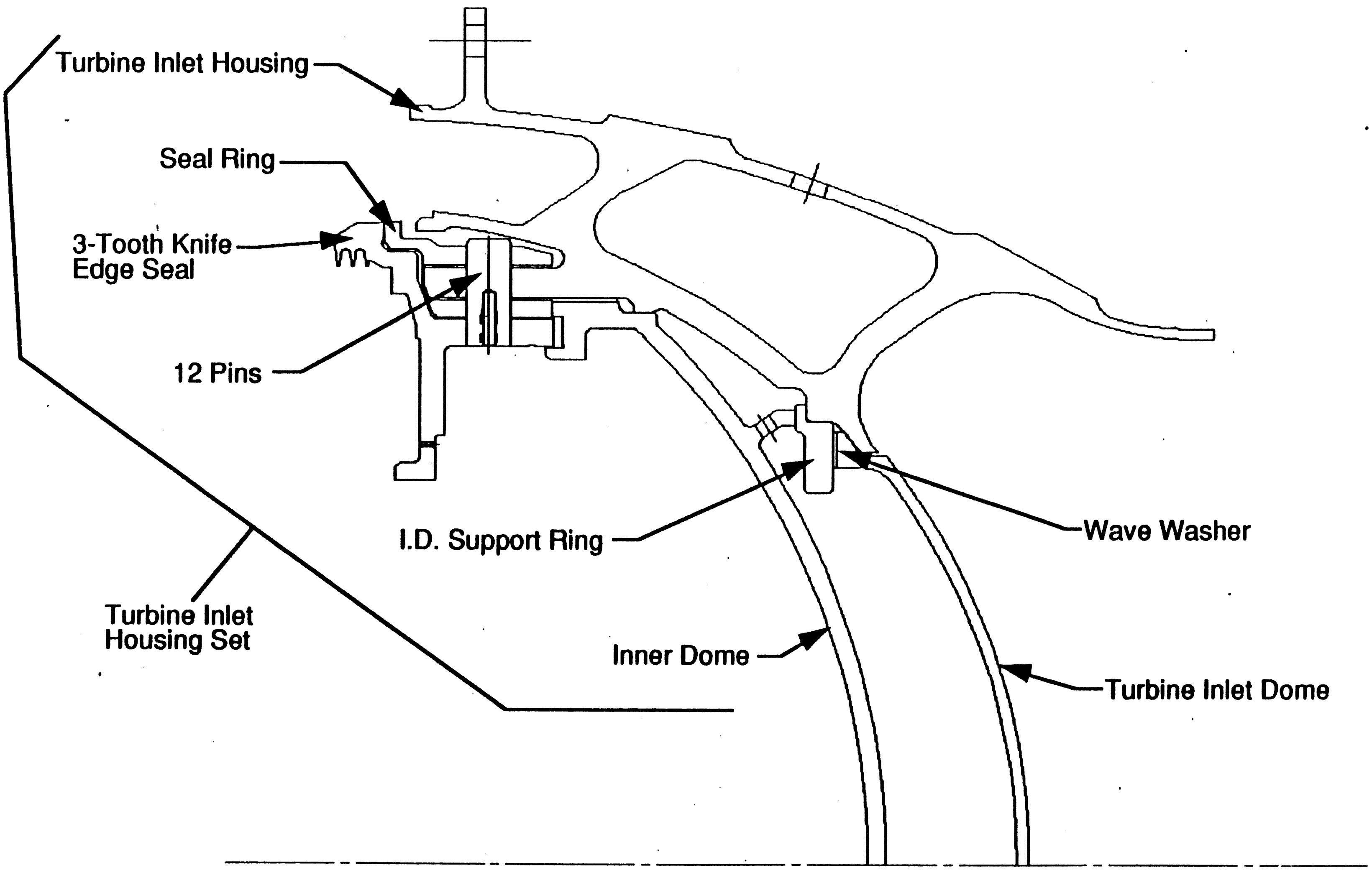
(I.B.1.3)



HPOTP TURBINE DESIGN

Turbine Inlet Housing Assembly - Mechanical Description

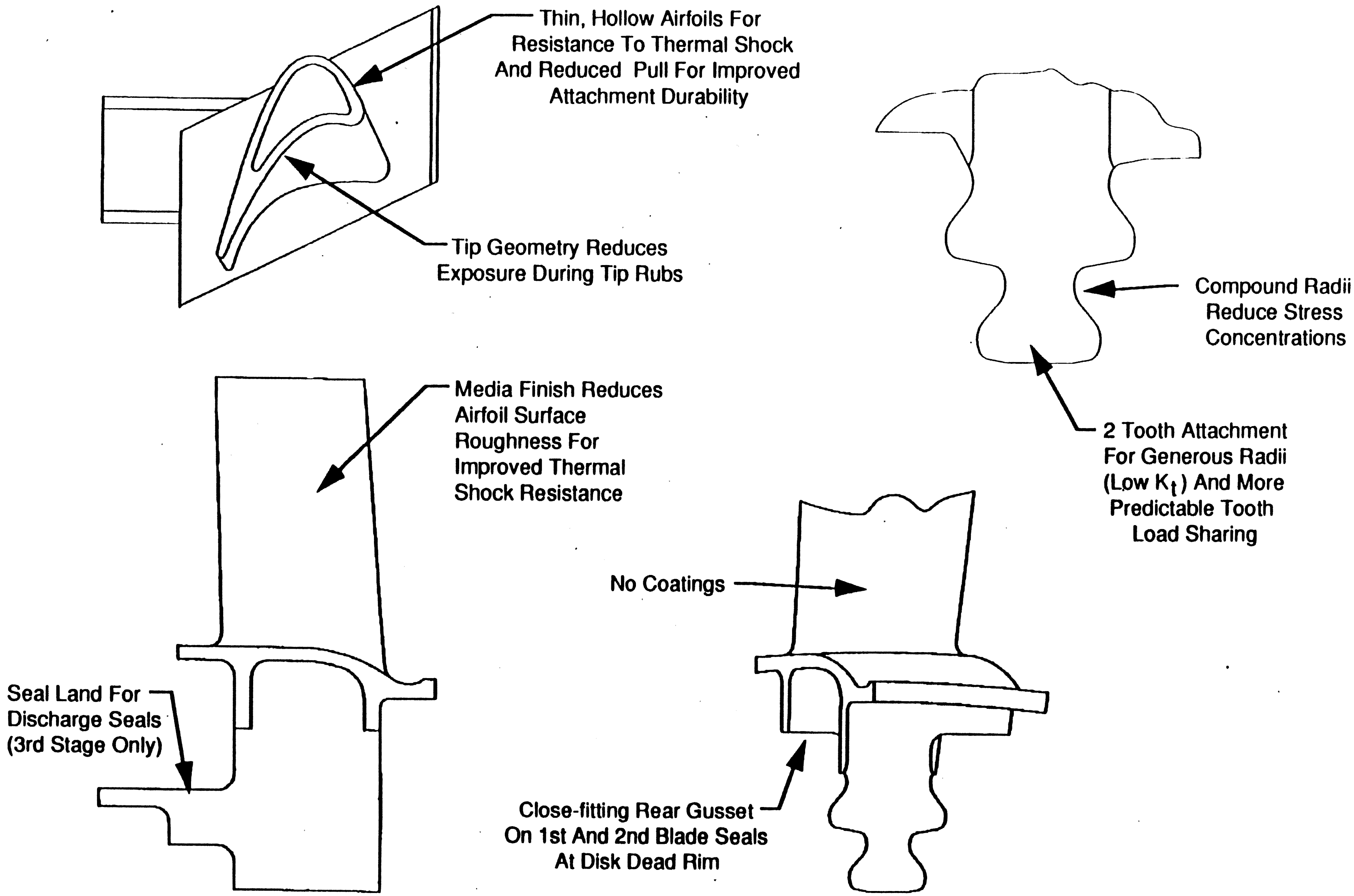
(I.B.1.4.2.1)



HPOTP TURBINE DESIGN

Blade Design Features

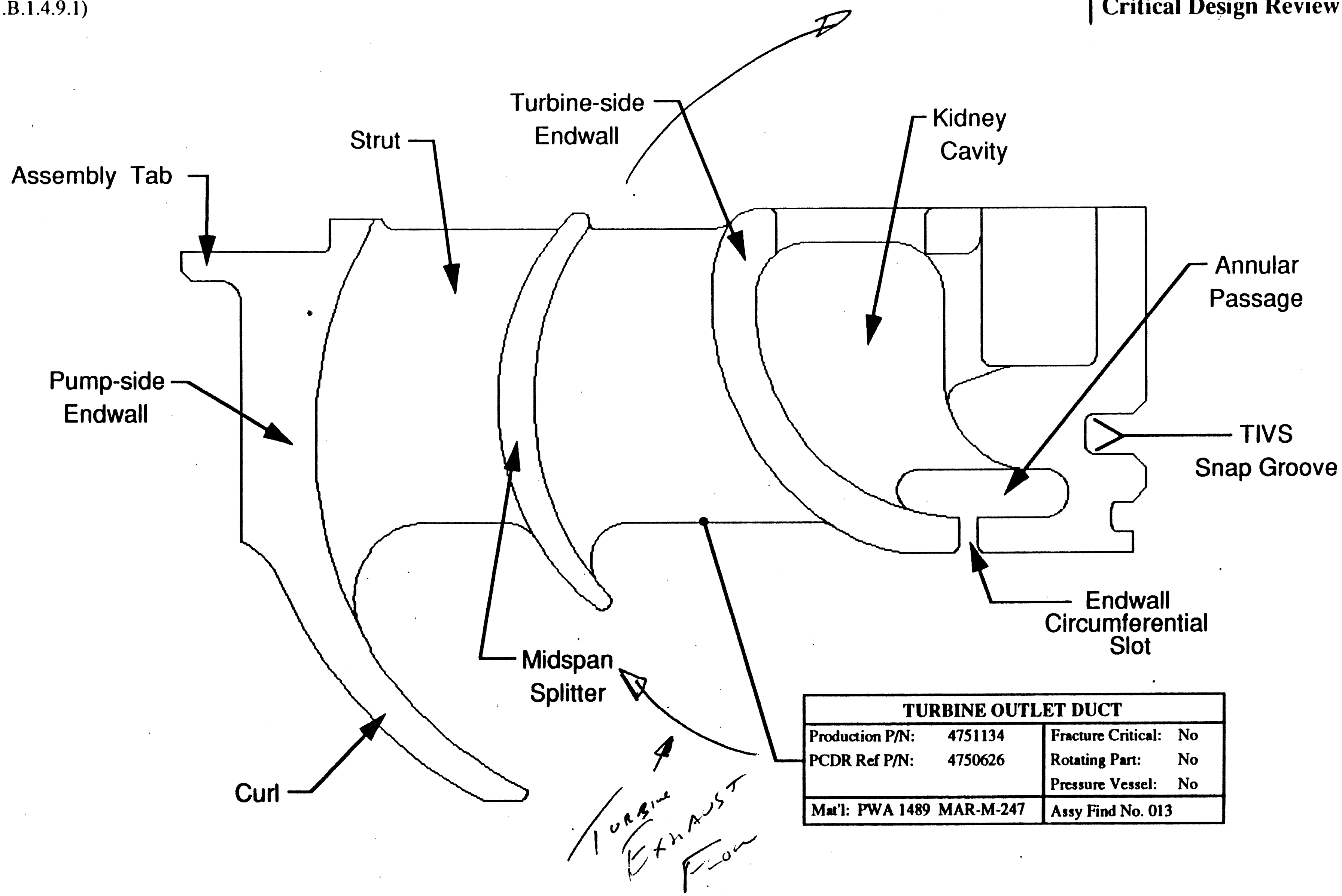
(I.B.1.4.5.1)



HPOTP TURBINE DESIGN

Turnaround Duct

(I.B.1.4.9.1)



TURBINE OUTLET DUCT			
Production P/N:	4751134	Fracture Critical:	No
PCDR Ref P/N:	4750626	Rotating Part:	No
		Pressure Vessel:	No
Mat'l: PWA 1489 MAR-M-247		Assy Find No. 013	

HPOTP DESIGN CRITERIA

Mission and Service Life Design Criteria

This table defines the mission and service life criteria for the ATD-HPOTP

FACTOR	CRITERIA
Service Life	28,5000 Seconds 60 Missions
Full Life Power Level (60 Missions)	109% Service Life Mission
Engine Out Power Level (Single Mission)	109% Redline (Abort) Mission
Fracture Life/LCF Life	60 x 4 = 240 Missions
Creep/Stress Rupture Life	32 hours at 109% Service Life Mission Plus 1 Mission at 109% Redline
HCF Life	10 E-8 Cycles

ATD SERVICE LIFE & DESIGN POINT

Requirements Evolution

1987

- Full service life at 109%
- 60 missions (55 missions + 5 ground cycles)
- Selected design point: 111% + 2σ . . . or 115% (whichever is limiting)

1991 (Contract Mod. 104)

- Full service life at 104%
- 30 missions
- Selected design point: 104% estimated maximums

1993 (Proposed)

- Full service life at 109%
- 60 missions (55 missions + 5 ground cycles)
- Selected design point: 109% estimated maximums

ATD SERVICE LIFE & DESIGN POINT

Power Balance Model Changes

- Estimated maximum variances from nominal have increased from 1987 to 1992.
- Turbine temperature variances have increased by ~ 70%
- Some pressure variances have increased as much as 37%
- Speed variance has increased by 44%

ESTIMATED MAXIMUM COMPARISONS

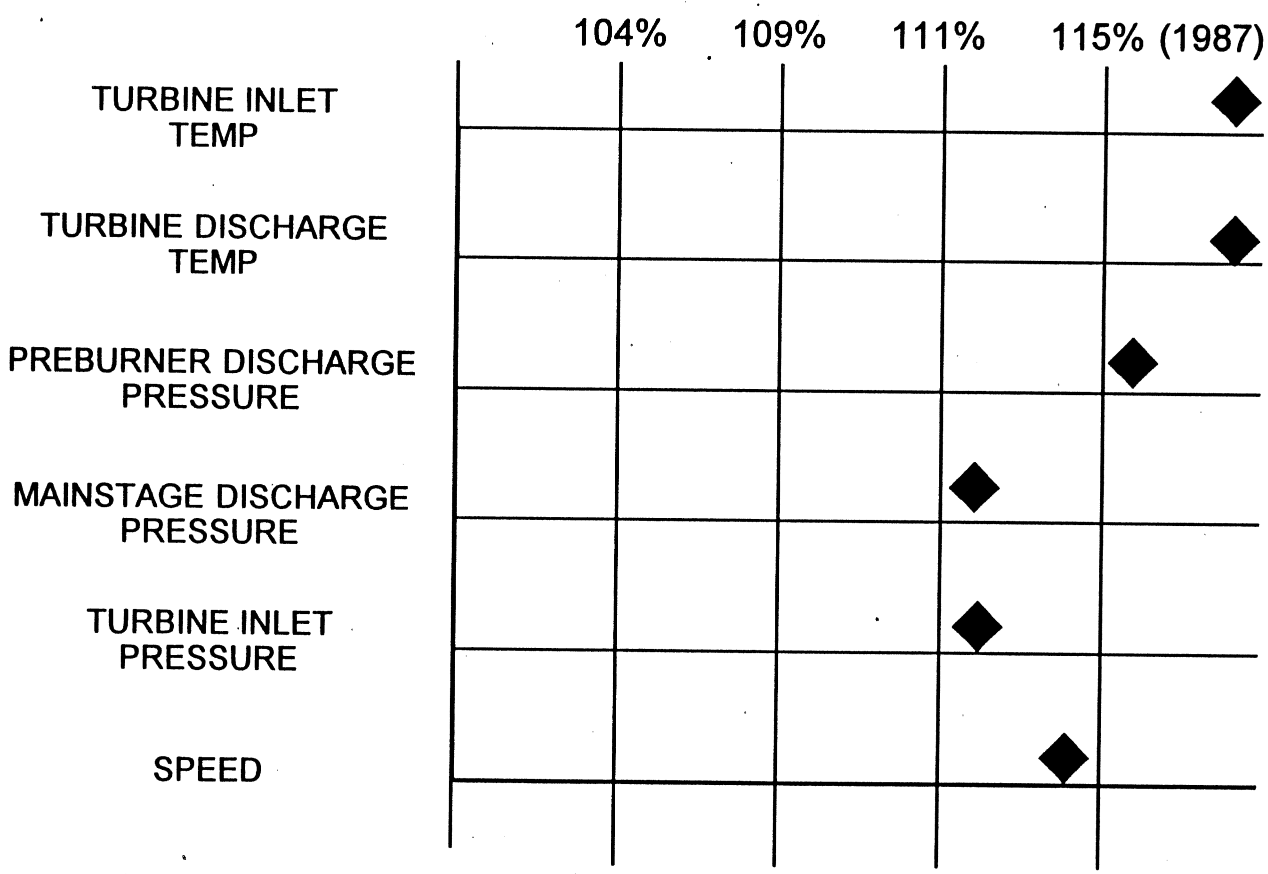
INTERFACE PARAMETERS	1987 ESTIMATED MAXIMUM PERCENTAGES ABOVE 109% NOM	1992 ESTIMATED MAXIMUM PERCENTAGES ABOVE 109% NOM	PERCENTAGE OF INCREASE FROM 1987 TO 1992
• TURBINE INLET TEMP.	9.72	16.86	+73
• TURBINE DISCH. TEMP	9.76	16.65	+71
• PREBURNER DISCH. PRESS.	3.12	4.06	+30
• MAINSTAGE DISCH. PRESS.	2.35	2.34	- <1
• TURBINE INLET PRESS.	2.67	3.66	+37
• TURBINE DISCH. PRESS.	1.49	1.65	+11
• SPEED	3.09	4.45	+44

MISSION CONDITIONS

INTERFACE PARAMETERS	104% NOMINAL	109% NOMINAL		111% NOMINAL	115% NOMINAL
• TURBINE INLET TEMP.	1504	1576		1604	1718
• TURBINE DISCHARGE TEMP.	1365	1427		1451	1524
• PREBURNER DISCH. PRESS.	7664	8072		8222	8354
• MAINSTAGE DISCH. PRESS.	4323	4587		4688	4872
• TURBINE INLET PRESSURE	5161	5491		5617	6064
• TURBINE DISCHARGE PRESS.	3422	3604		3673	3845
• SPEED	23,649	24,478		24,567	25,986

			104% SERVICE LIFE		109% SERVICE LIFE
• TURBINE INLET TEMP.			1769		1842
• TURBINE DISCHARGE TEMP.			1602		1664
• PREBURNER DISCH. PRESS.			7985		8400
• MAINSTAGE DISCH. PRESS.			4426		4695
• TURBINE INLET PRESS.			5356		5692
• TURBINE DISCHARGE PRESS.			3478		3663
• SPEED			24,735		25,567

109% ESTIMATED MAXIMUMS VS. NOMINAL CONDITIONS



HPOTP DESIGN CRITERIA

Mission and Service Life Design Criteria

This table provides the structural and performance assessment guidelines for the ATD-HPOTP.

104% NOM	109% NOM	109% Service Life	104/109% Abort
Optimize seal clearances and blade tip clearances Optimize all performance related parameters (efficiencies, etc) ↓ Even though optimization occurs at 104% NOM . . . this does not preclude safe operation from 65% to 109%	Check seal clearances and tip clearances to make sure that no anomalies exist	Use for all life analysis . . . the first 59 of the required 60 mission life criteria All required margins of safety apply to this condition LCF life analysis to be based on 60 service life missions Fracture life analysis to be based on 59 service life missions followed by one 109% redline mission	The turbopump must be capable of extended duration firing (754 sec at 104% RPL & 761 sec at 109% RPL) without debit to service life. All conditions of the service life mission apply except firing duration

* Even though a redline mission may occur at any time during the required 60 missions, the most stringent life criteria is to impose the redline mission on the last (60th) mission. During the redline mission, all useable life of the turbopump may be consumed. Even though the turbopump may be scrapped after the mission, the mission must be concluded safely.

ALTERNATE TURBOPUMP DEVELOPMENT PROGRAM

CRITICAL DESIGN REVIEW

HPOTP Performance

John Park
Propulsion Systems Analysis
August 2, 1993

MODEL SUBSTANTIATION – PBM/DTM

Math Models

(II.A.5.1.2)

The two primary math models used to analyze the alternate HPOTP's effects on the SSME operation are:

- **the Digital Transient Model (DTM)**
- **and the Power Balance Model (PBM).**

The PBM (version ATDPBM0693) and DTM (version ATDDTM1292) with the alternate HPOTP characterizations have been baselined in the alternate HPOTP Interface Control Document (ICD) and released to Rocketdyne and NASA.

MODEL SUBSTANTIATION – PBM

Alternate HPOTP Characterizations Corrected to Production

(II.A.5.1.2)

The Alternate HPOTP turbine discharge temperature raw data was converted to the production configuration using the following known differences:

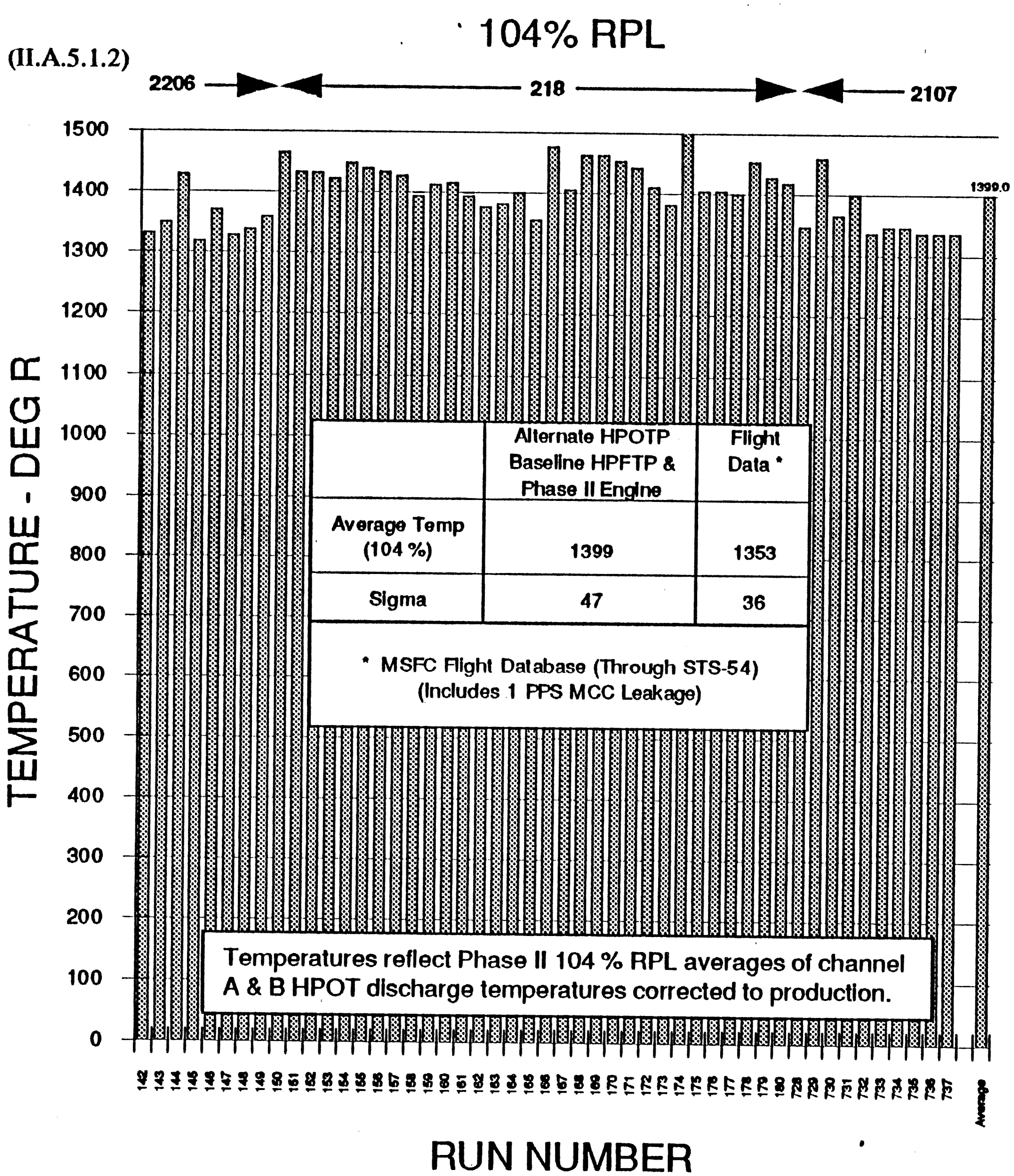
1. Turbine Tip Clearance Changes
2. Damper Flow Changes
3. Inducer Angle and Clearance Changes
4. Turbine Outer Vane Support Type
5. MCC Leakage Level
6. Mixture Ratio Changes
7. Fuel Pump Performance
8. Main Injector Resistance
9. LPOP Drive Orifice Changes

Nozzle Leaks were not used for this conversion to production temperature.

MODEL SUBSTANTIATION - PBM

Alternate HPOTP Characterizations Corrected to Production

(II.A.5.1.2)



Power Balance Model
Phase II Engine Configuration
(Corrected to Zero MCC Leakage)

HPOTP

Turbine Discharge Temperature (Phase II)			
RPL	Baseline Phase II	Alternate HPOTP Baseline HPFTP & Engine	Delta
100%	1303	1365	62
104%	1335	1381	46
109%	1424	1416	-8

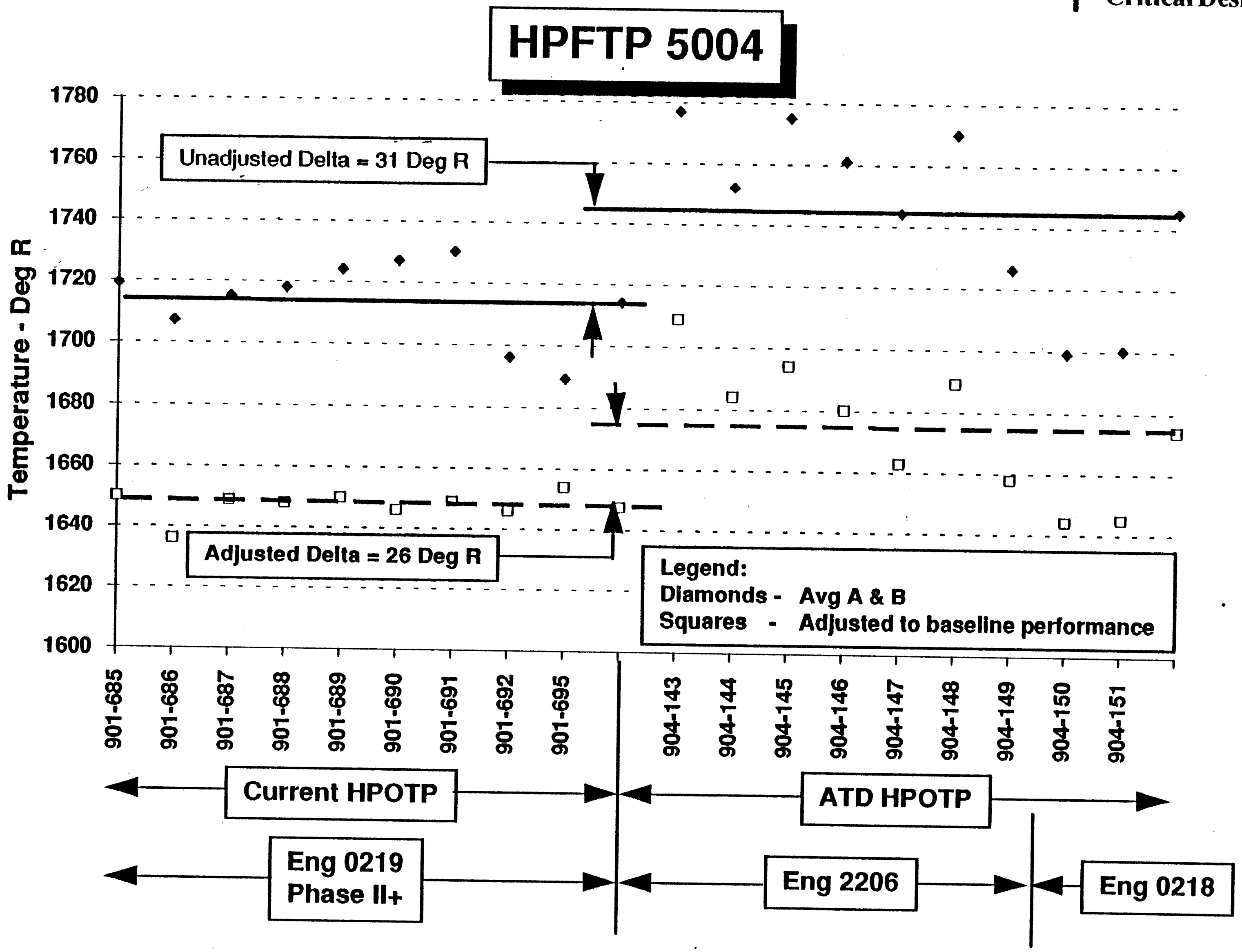
HPFTP

Turbine Discharge Temperature (Phase II)			
RPL	Baseline Phase II	Alternate HPOTP Baseline HPFTP & Engine	Delta
100%	1659	1685	26
104%	1694	1717	24
109%	1737	1773	35

MAINSTAGE OPERATIONAL CHARACTERISTICS

The Alternate HPOTP Yields 26 deg-R Higher Than Baseline HPFT Discharge Temperature At 100 % RPL

(II.A.5.1.2)

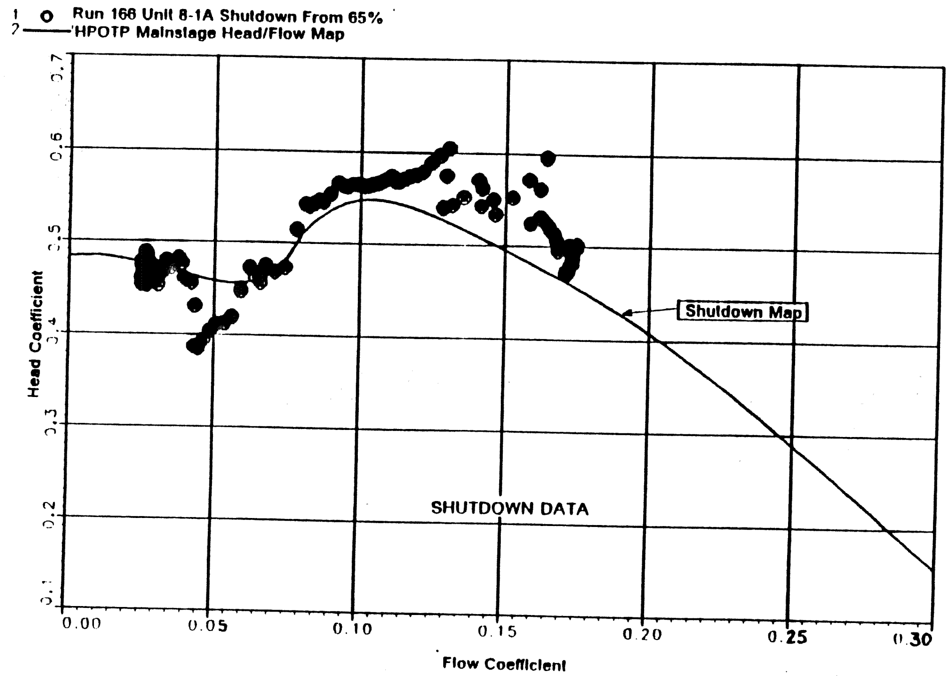


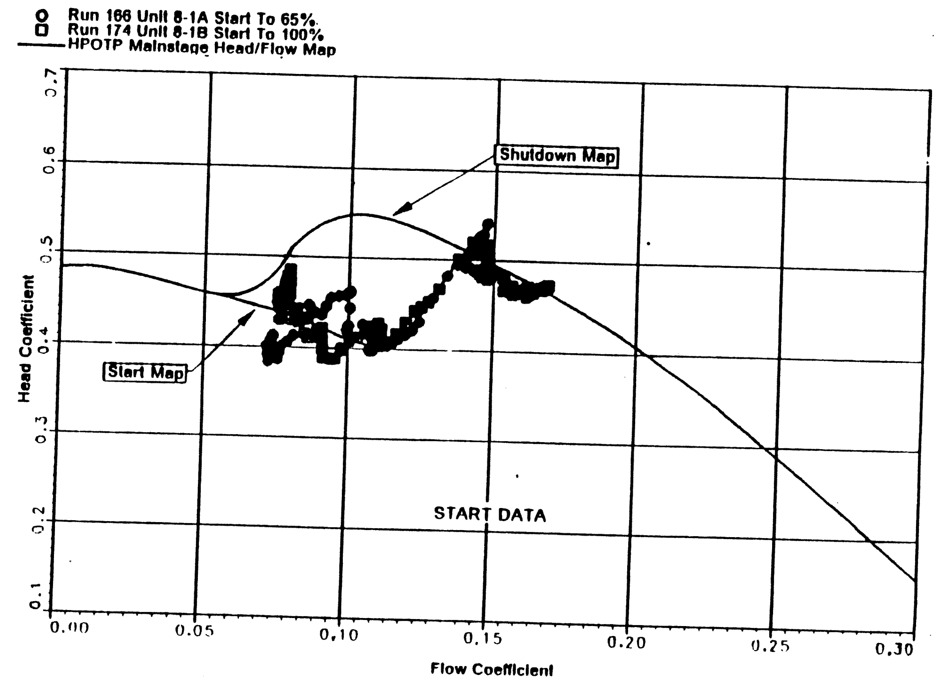
MODEL SUBSTANTIATION - DTM

Mainstage Pump Map Characterized By Actual Test Data From Unit 8-1

(II.A.5.1.2)

Pratt & Whitney
SSME-ATD
Critical Design Review





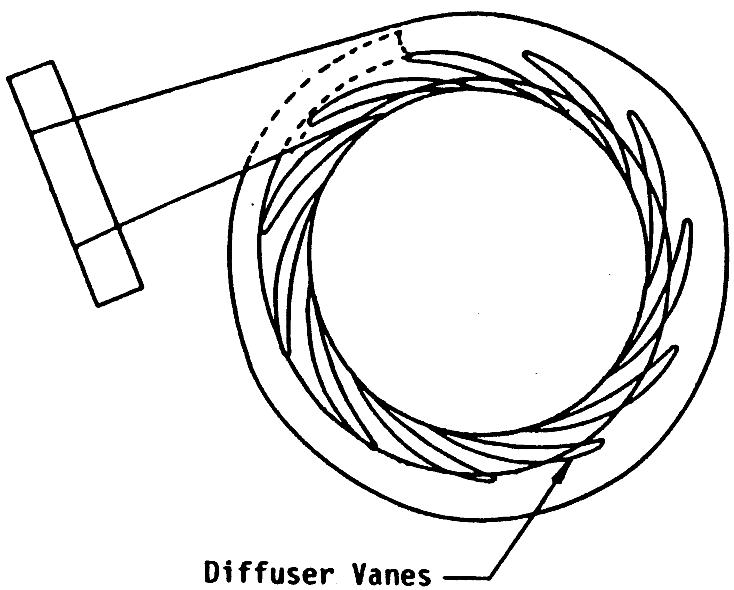
* Data shows hysteresis caused by flow separation at the exit guide vanes.

PREBURNER PUMP VOLUTE

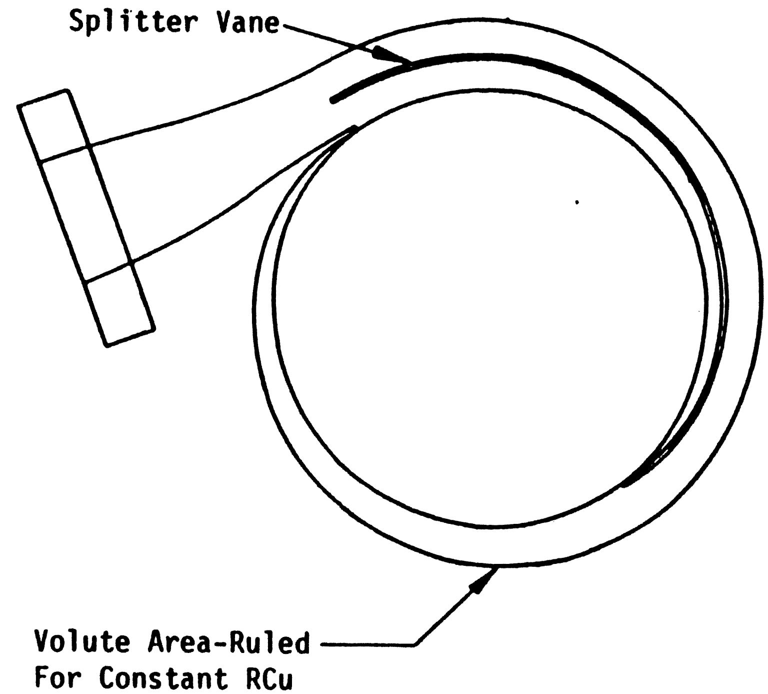
Hydrodynamic Features

(I.B.2.3.1.2.2)

CURRENT



ATD



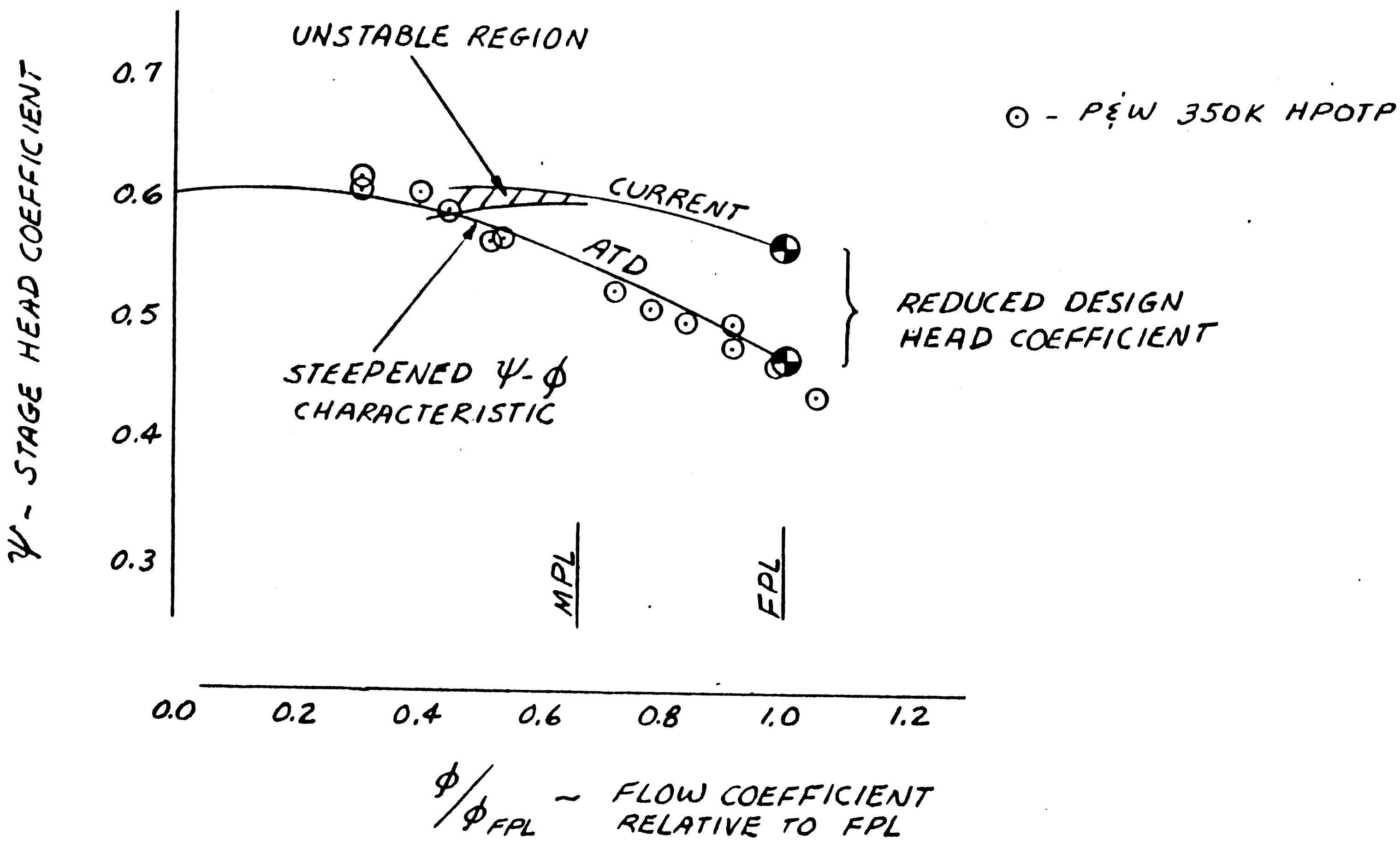
SSME ATD PREBURNER PUMP

Steepened Φ-Ψ Characteristic Provides Stable Operation

(I.B.2.1.2)

The major design concern of the preburner pump was to provide stall-free stable operation at low engine power levels. The design head coefficient of the ATD preburner pump was reduced to steepened the Phi-Psi characteristic curve and provide the stall-free stable operation desirable at low engine power levels.

(Reference VCR FR-19847-1)



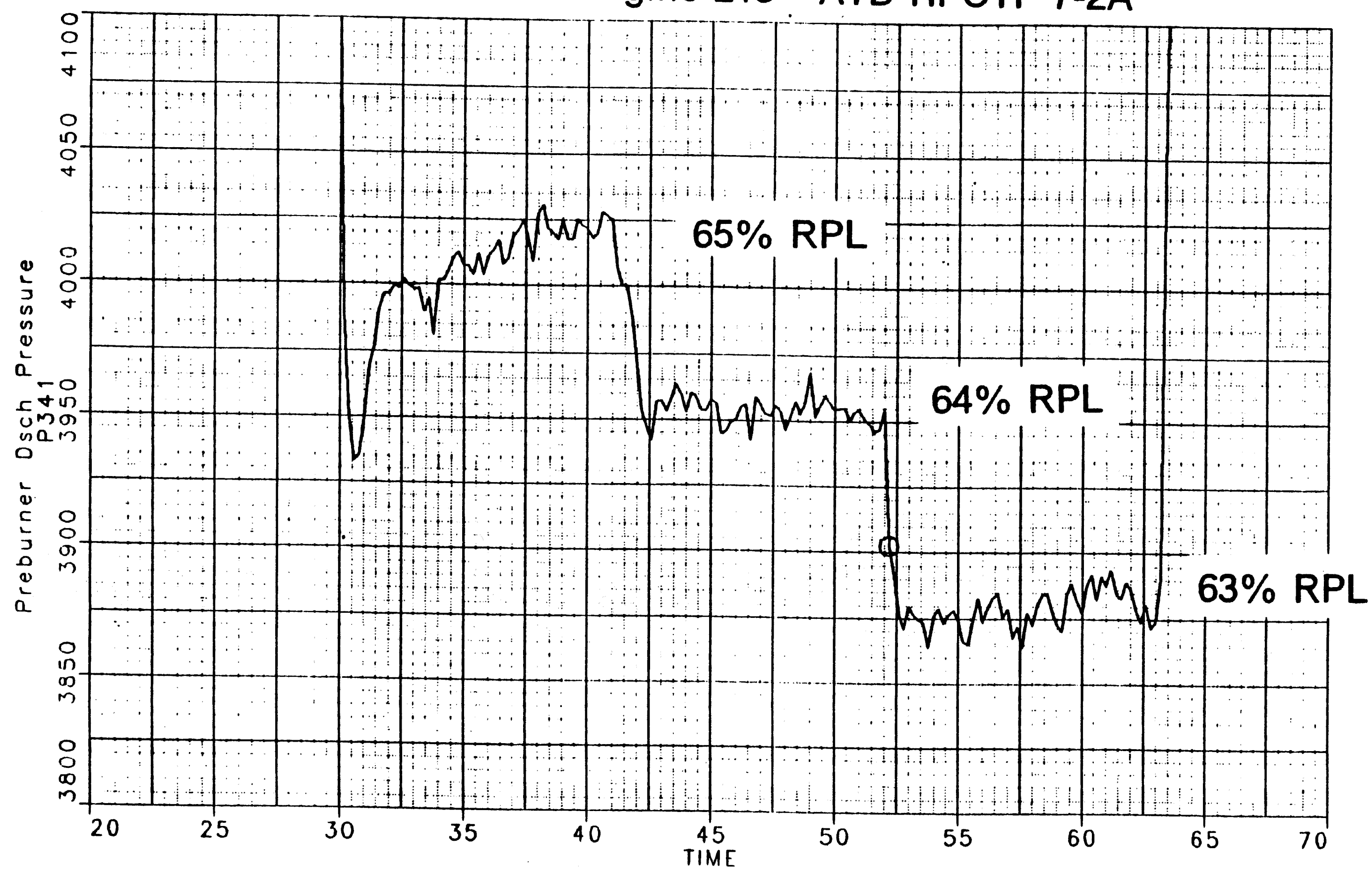
SSME ATD HPOTP PREBURNER STAGE

No Indications of Bi-Stable Pump Operation

(I.B.2.3.1.2.2)

One of the hydrodynamic objectives of the ATD HPOTP was to improve the preburner stage stability to achieve the required throttleability to min. power levels. Component testing at E-8 facility has demonstrated stable operation to as low as 52% of design flow coefficient. Engine testing at Stennis Space Center (SSC) has also demonstrated stable operation to min. power levels.

SSC Test 163 Engine 218 ATD HPOTP 7-2A

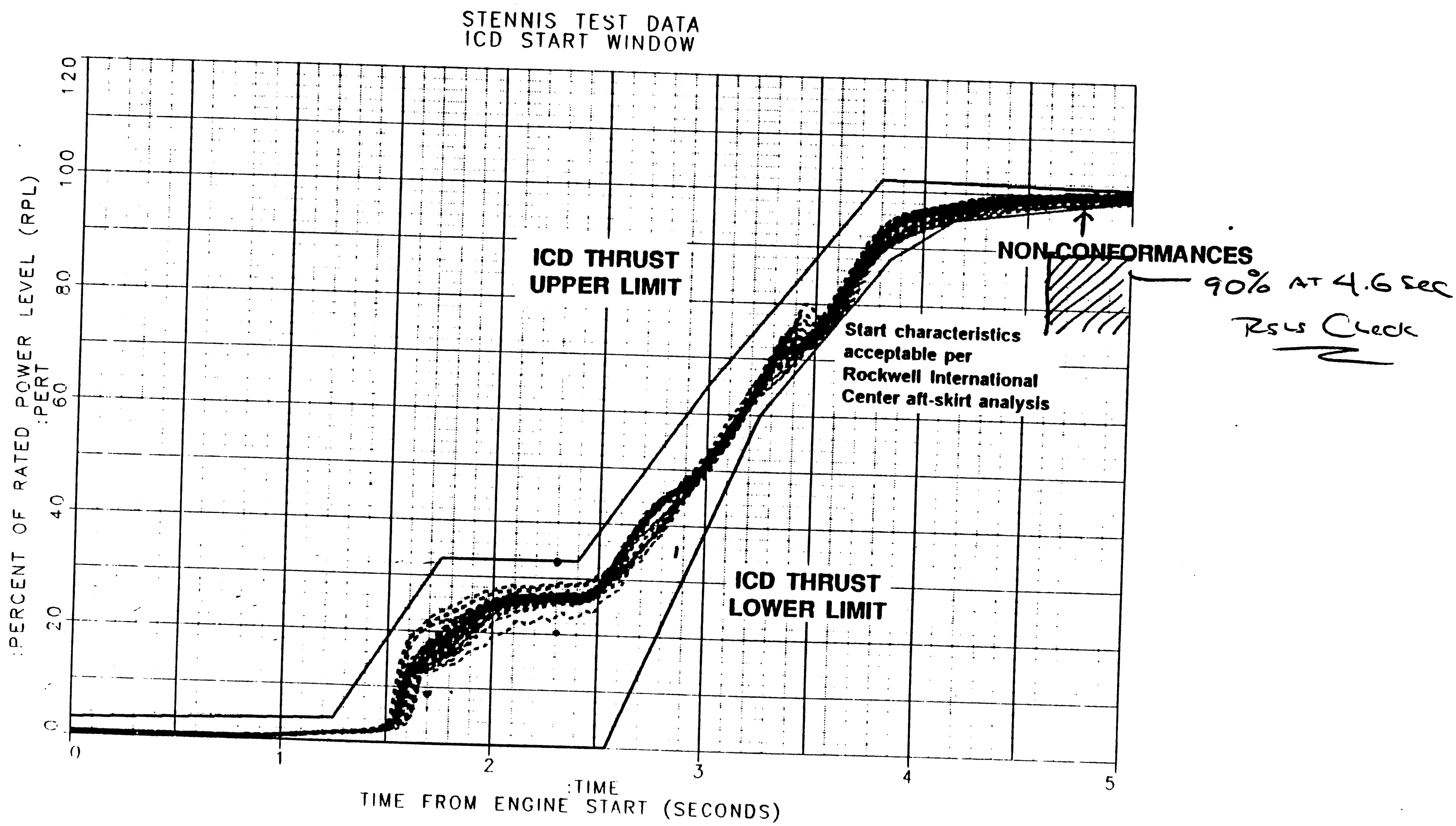


HPOTP TRANSIENT ANALYSIS

SSME With Alternate HPOTP Displays Acceptable Acceleration Characteristics

(II.A.5.3.1)

Start to RPL Stennis Test Data and ICD Limits:



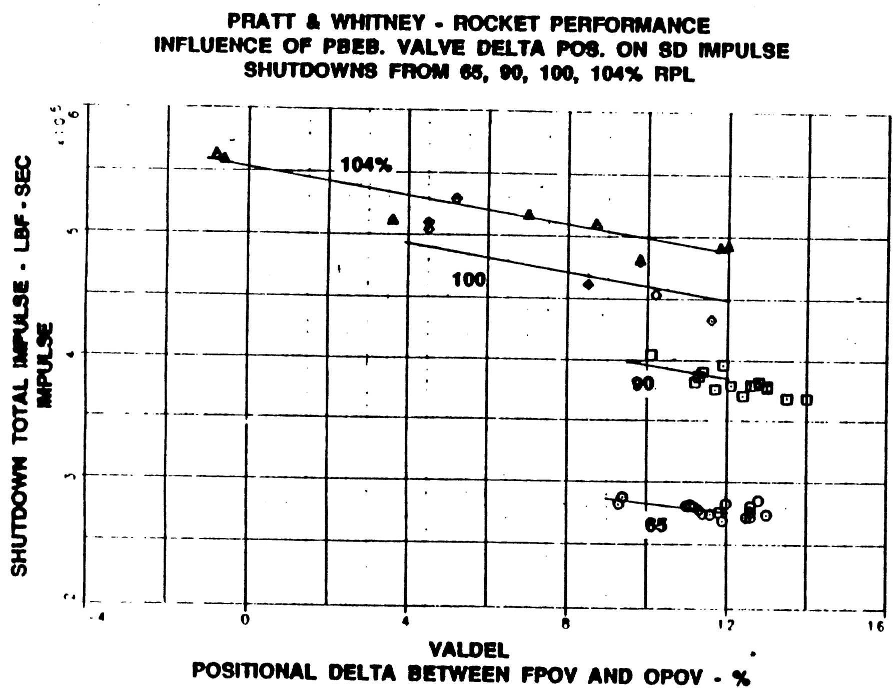
HPOTP TRANSIENT ANALYSIS

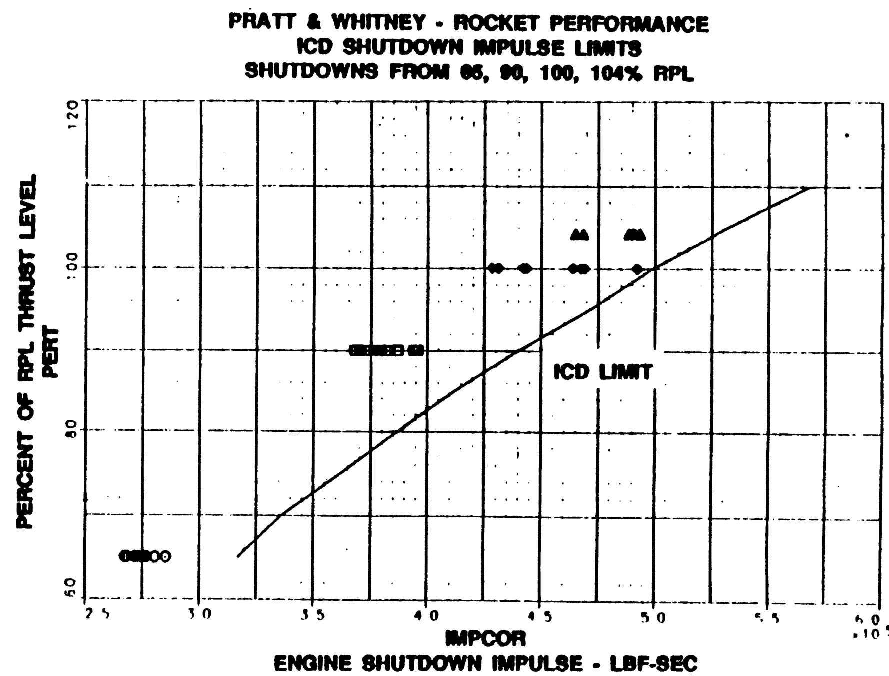
SSME With Alternate HPOTP Has Acceptable Shutdown Impulse

Pratt & Whitney
SSME-ATD
Critical Design Review

(II.A.5.3.1)

Shutdown Impulse Adjustment and Shutdown Impulse with ICD Limit



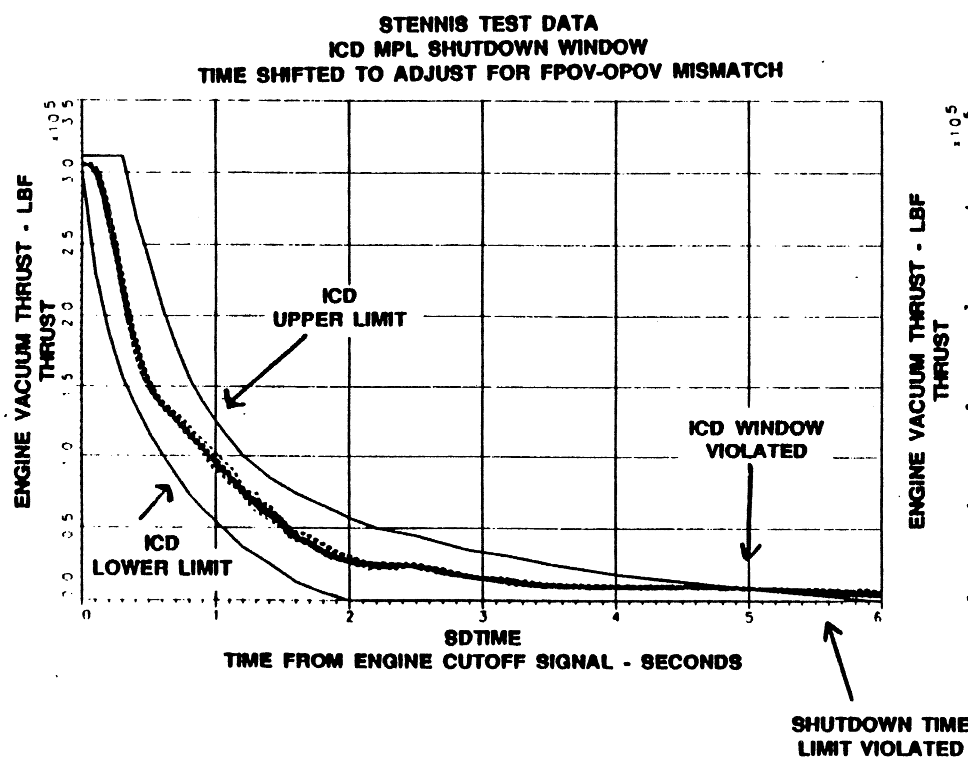


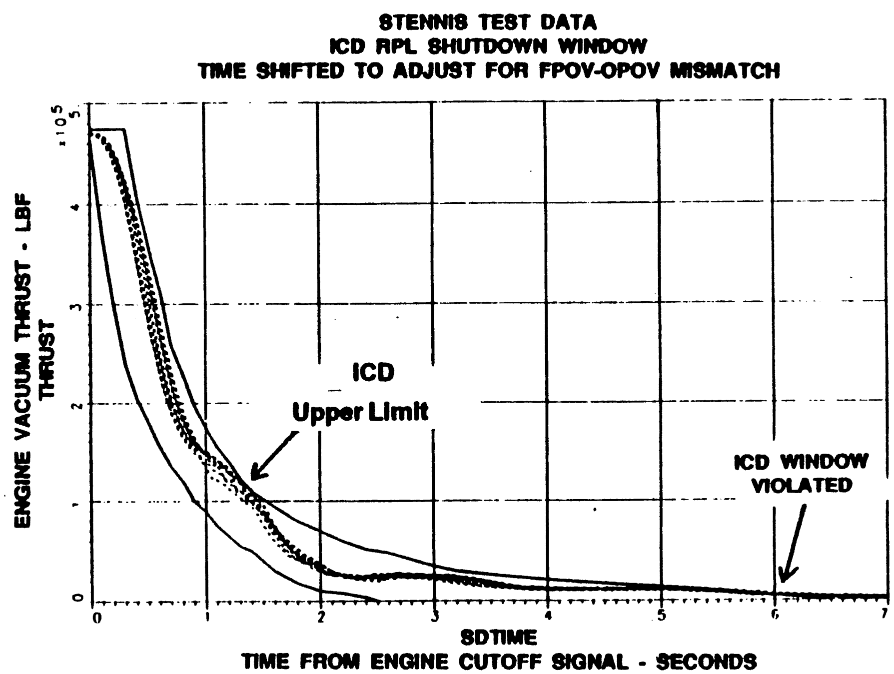
HPOTP TRANSIENT ANALYSIS

SSME With Alternate HPOTP Has Acceptable Shutdown Thrust Decay

(II.A.5.3.1)

Shutdown Thrust Decay and Shutdown Time From MPL and RPL:



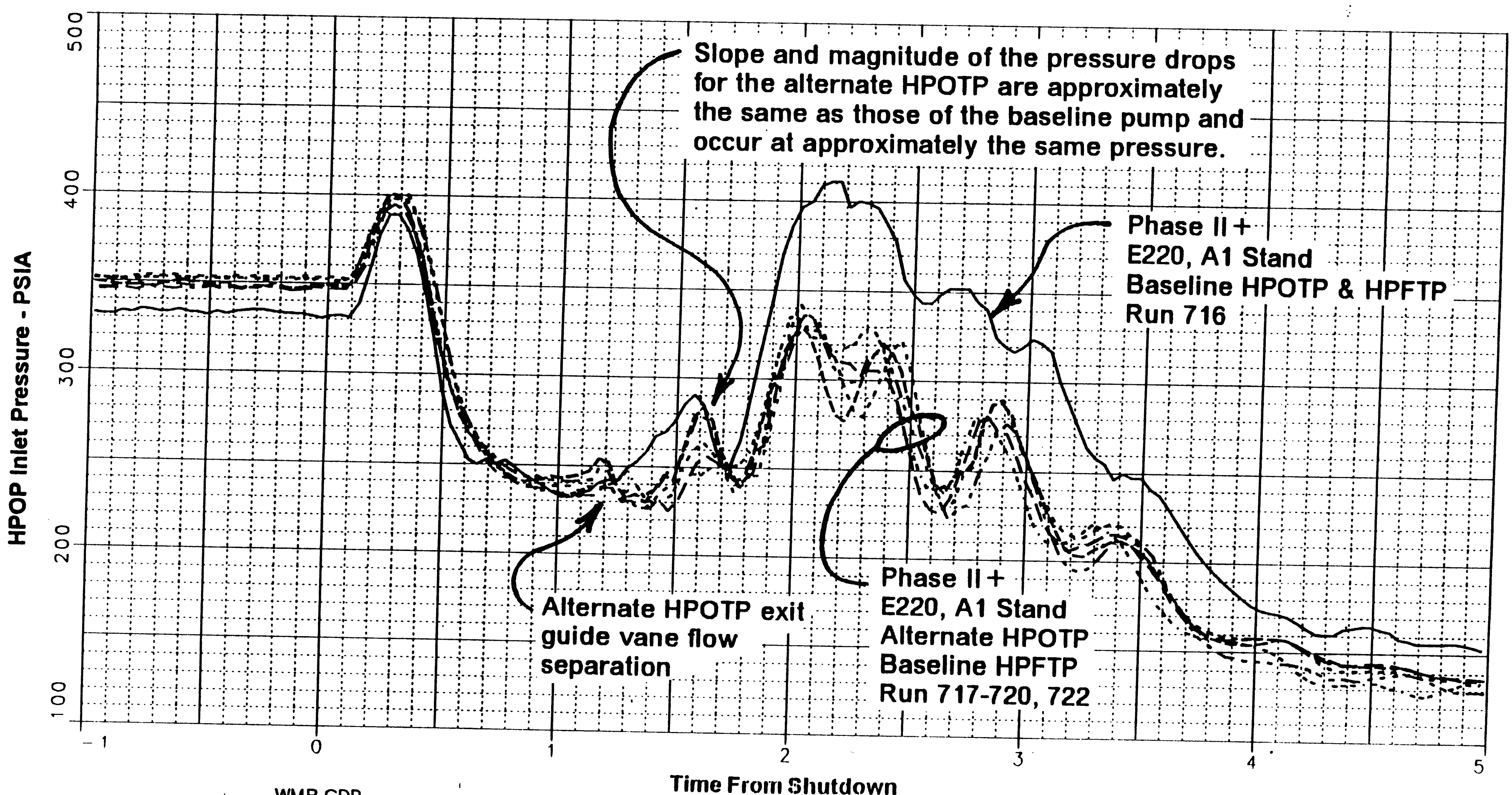


HPOTP TRANSIENT ANALYSIS

Alternate HPOTP Zero-G Shutdown Performance Acceptable With Testing Planned To Confirm Analysis

(II.A.5.3.2)

- The Small Differences Between The Shutdowns Using The Alternate HPOTP And The Baseline HPOTP Are Not Expected To Require Any Changes To The Shutdown Sequence.
- Tests Are Planned With An Alternate HPOTP On A Test Stand Modified To Simulate In-flight Shutdowns To Verify This Prediction.



MAIN STAGE PERFORMANCE

Engine Pulse Tests Planned To Confirm Altemate Power Head Gain

(II.A.5.4)

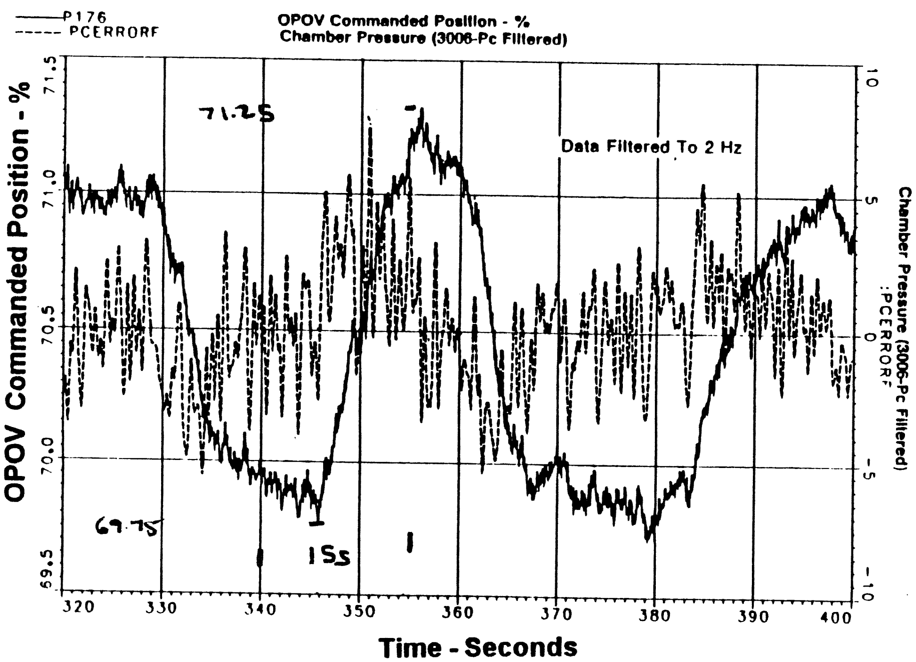
- Analytical predictions show alternate HPOP does not adversely affect POGO margins.
- Improved suction performance provides more margin than current pump at FPL..
- Engine pulse tests planned to verify analytical predictions.

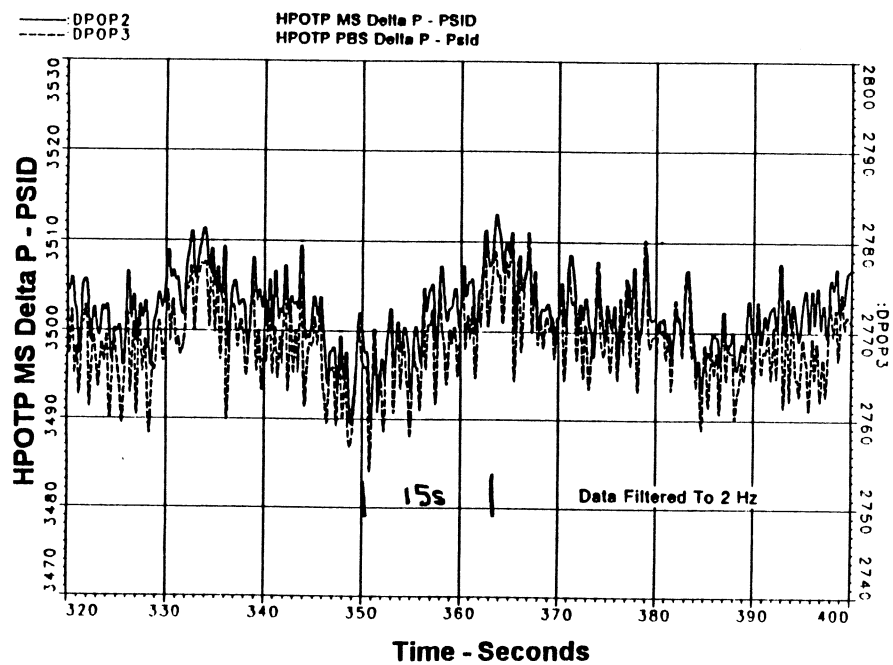
HPOTP TRANSIENT ANALYSIS

OPOV Oscillations Driven by Thermally Induced Turbine Anomaly

(II.A.5.3.3)

Steady State 100% - RD Fuel/PW LOX
Engine 218 - Run 150





- HPOTP MS & PB DP'S changing together w/similar magnitudes. Indicates change due to speed affect driven by turbine power.

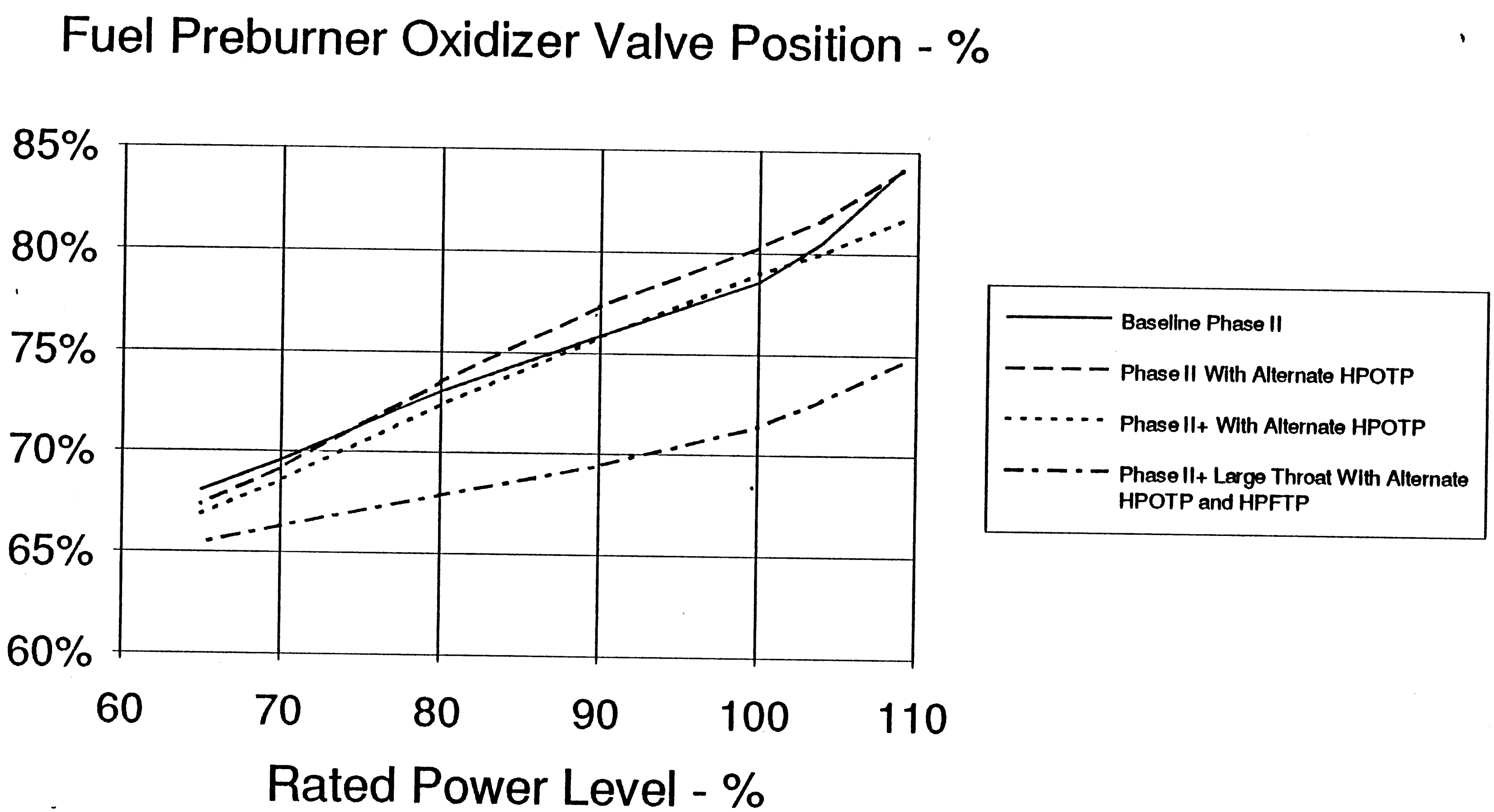
1.5% oscillations

½ Period = 15s
Period ≈ 30s

MAINSTAGE OPERATIONAL CHARACTERISTICS

The Alternate HPOTP Maintains SSME Baseline Valve Position Margin In All Engine/Turbopump Configurations

(II.A.5.4)

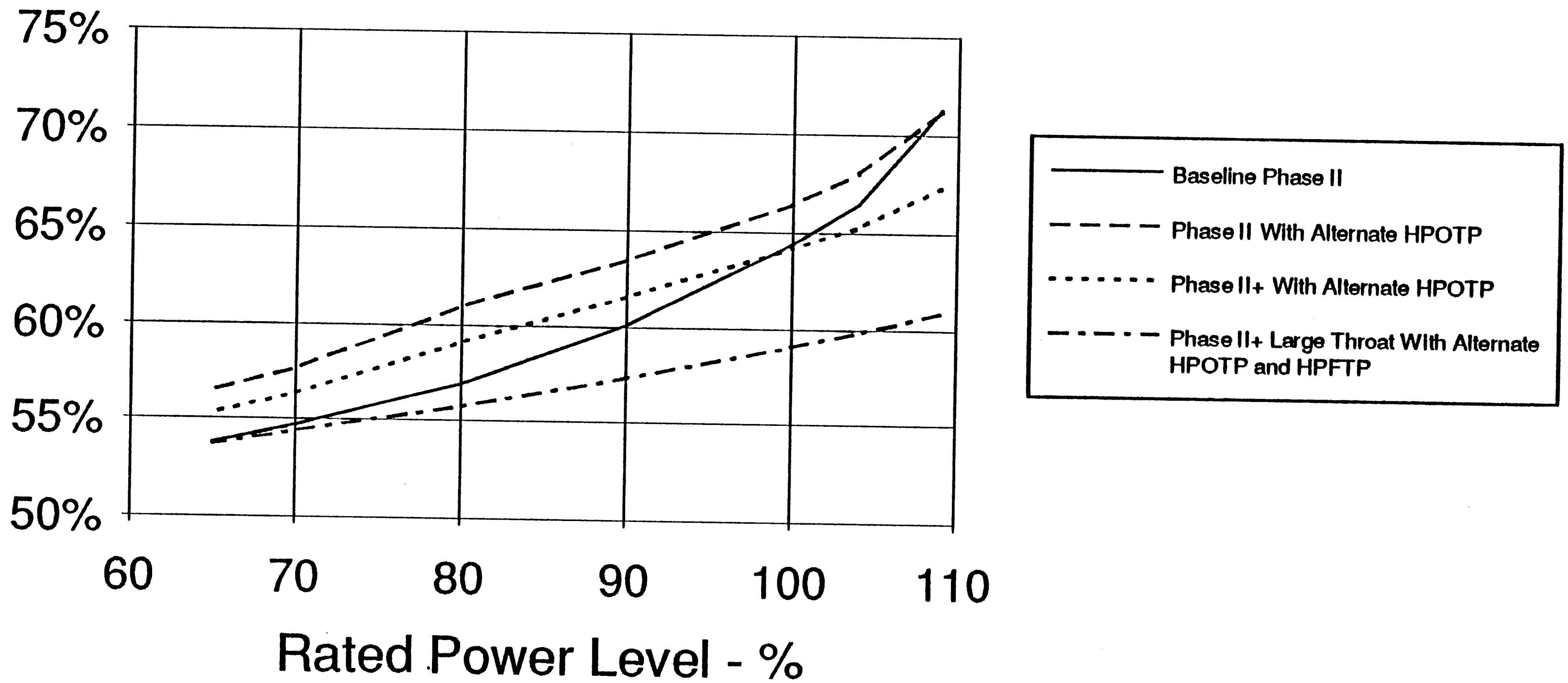


MAINSTAGE OPERATIONAL CHARACTERISTICS

The Alternate HPOTP Maintains SSME Baseline Valve Position Margin In All Engine/Turbopump Configurations

(II.A.5.4)

Oxidizer Preburner Oxidizer Valve Position - %



MAINSTAGE OPERATIONAL CHARACTERISTICS

Alternate HPOTP With 1.85 Inch Diameter Orifice Yields Baseline LPOTP Shaft Speed

(II.A.5.4)

	Test	Alternate HPOTP	LPOTP Speed
(A) Alternate HPOTP Experience With LPOTP 2312			
	904-151	3-1B	5350
	904-153	5-2A	5329
	904-156	2-3	5350
	904-157	5-2C	5330
	904-158	3-1D	5365
	904-159	3-1D	5352
	904-160	6-2A	5345
	904-161	3-1E	5349
	904-162	7-2	5339
	904-163	7-2A	5322
	904-164	7-2A	5347
	Average		5343
(B) Baseline HPOTP Experience With LPOTP 2312	Average		5250

Delta LPOTP Speed Due To Alternate HPOTP (Based On "A-B" From Table At Left)	93 RPM
Delta LPOTP Speed Due To Installation of 1.72 Inch Dia. Orifice (Based on Test 904-163 & 904-165 Data)	-184 RPM
Delta LPOTP Speed Due To Replacement Of 1.72 Inch Dia. Orifice With 1.85 Inch Dia. Orifice	92 RPM
Net Effect	1 RPM

Use of 1.85 Inch Diameter Orifice With Alternate HPOTP Yields Same LPOT Shaft Speed As Baseline HPOTP

MAINSTAGE OPERATIONAL CHARACTERISTICS

Specific Impulse Slightly Lower With Alternate HPOTP

(II.A.5.4)

104 % RPL (Nominal Inlet Conditions)					
Propellant Type	*Propellant Source*	*ISP Sensitivity (Secs/Pound)*	*Baseline HPOTP (PPS)*	*Alternate HPOTP (PPS)*	*Specific Impulse Delta (SECS)*
Oxidizer	Main Stage Oxidizer Inlet Flow	0.40	0.1400	0.2209	-0.03
Fuel	HPOT Hydrogen Coolant Flow	0.56	0.0000	0.4848	-0.27
System	HPOT Exhaust Flow	0.50	0.2200	0.0000	+0.11

Alternate HPOTP ISP Impact	-0.19 Seconds

INTRODUCTION

The Thrust Balance Design Meets Requirements for Operation in All SSME Environments

(I.B.6.1)

DESIGN GOALS:

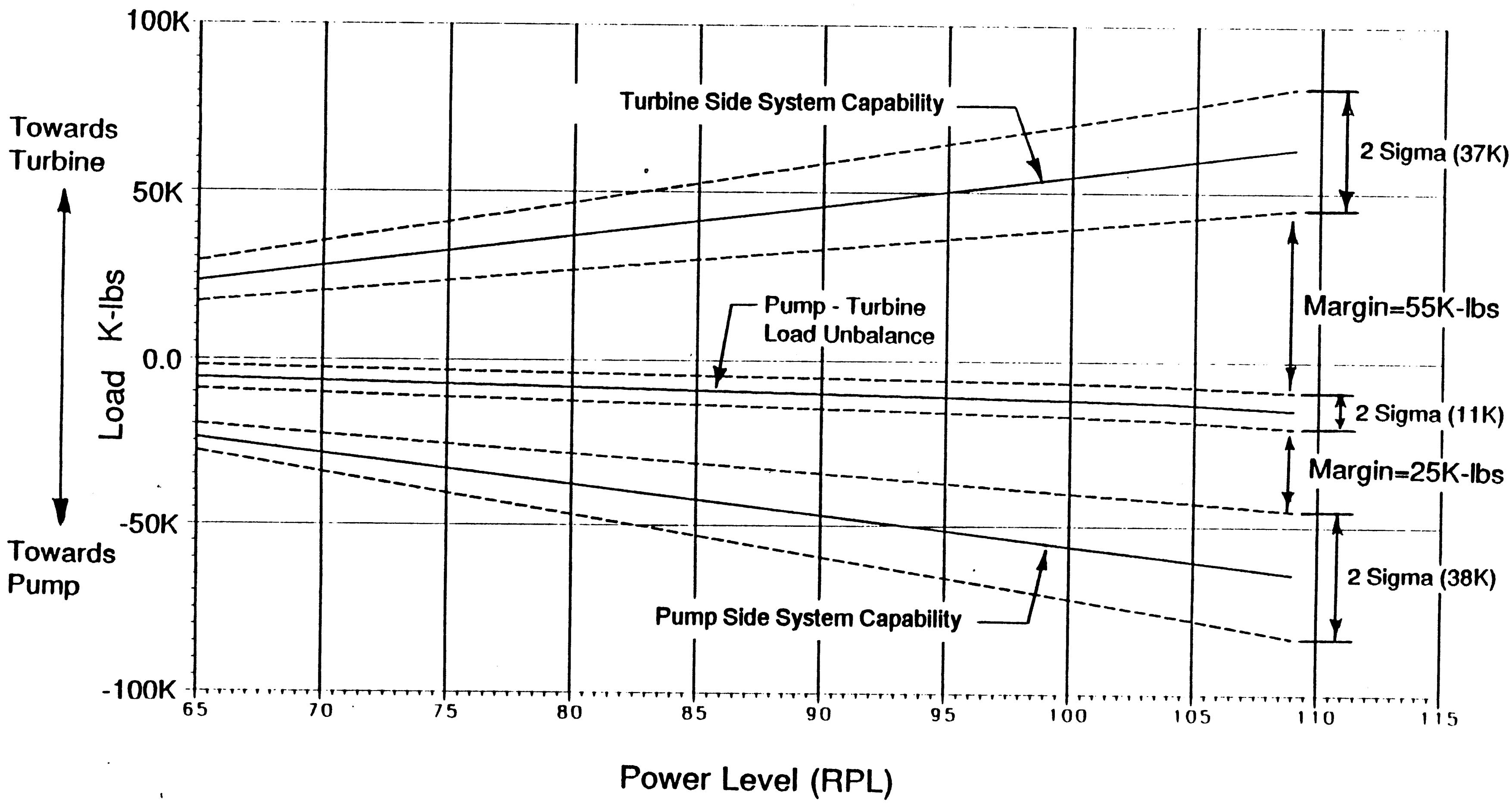
- Provide balanced rotor loads such that no bearing loads exist at mainstage except for the bearing spring preloads.
- Limit bearing loads during start and shutdown to within bearing capability, allowing margin for unit to unit variability and operational variations.

DESIGN IS SUBSTANTIATED BY 65 ENGINE TESTS ON 6 UNITS (36 DEVELOPMENT TURBOPUMP BUILDS).

STEADY STATE LOADS AND OPERATING MARGINS

Predicted Load Unbalance is Well Within Thrust Balance System Capability (Phase II Engine Shown)

(I.B.6.4)



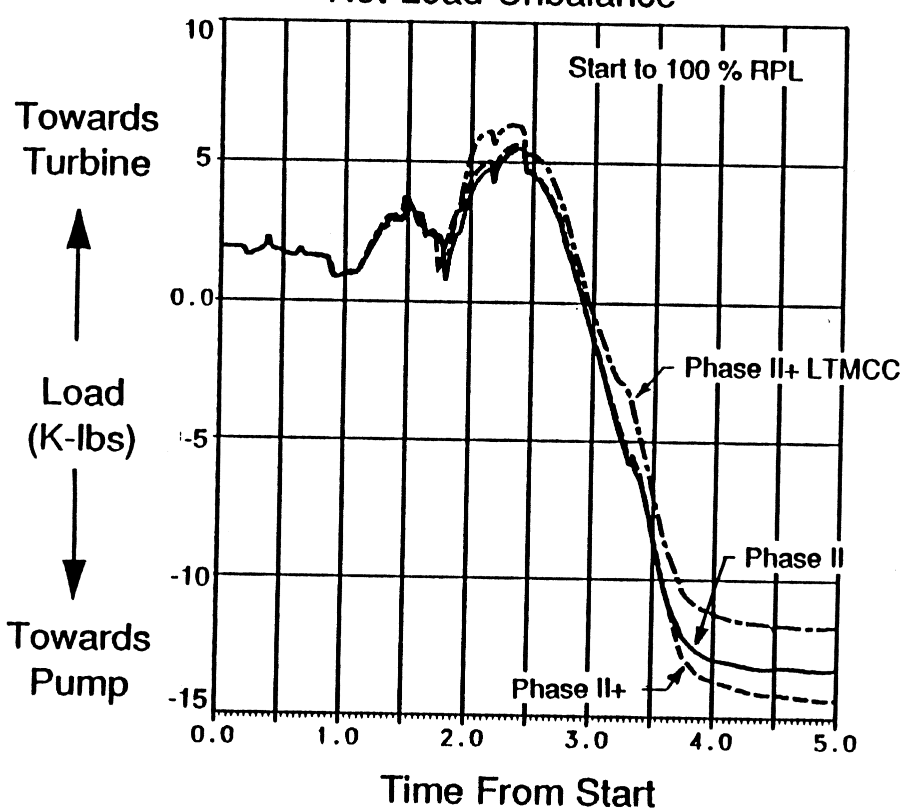
SSME CONFIGURATION COMPATIBILITY

Minimal Differences in Starting Loads On The TEBB Due To Configuration

Pratt & Whitney
SSM-ATD
Critical Design Review

(I.B.6.6)

Net Load Unbalance



Start to 100%:

Peak Turbine End Ball Bearing Load	Nominal	2 Sigma
Phase II	<1500	<1500
Phase II +	<1500	<1500
Phase II + LTMCC	<1500	<1500

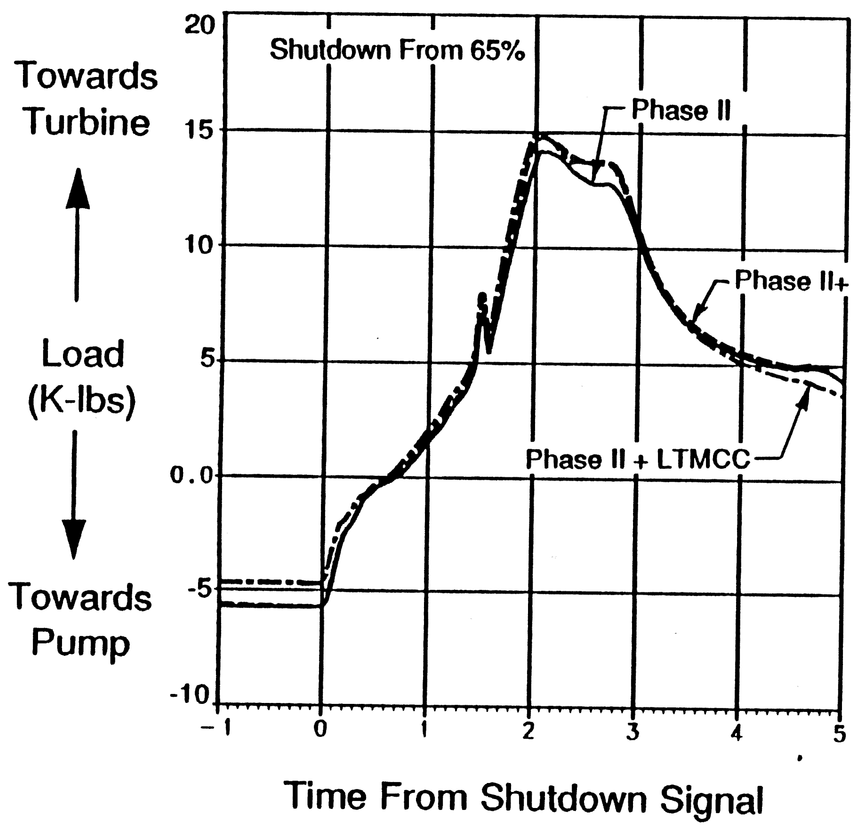
(Note: Load in lbs)

Turbine End Ball Bearing Axial Load Capability exceeds 10,000 lbs

SSME CONFIGURATION COMPATIBILITY

Minimal Differences in Shutdown TEBB Loads Due To Configuration

(I.B.6.6)



Shutdown From 65%:

Peak Turbine End Ball Bearing Load	Nominal	2 Sigma
Phase II	<1500	2500
Phase II +	<1500	2700
Phase II + LTMCC	<1500	2800

(Note: Load in lbs)

Turbine End Ball Bearing Axial Load Capability exceeds 10,000 lbs

SUMMARY

The Alternate Turbopump Thrust Balance System Meets all Requirements

(I.B.6.9)

- The thrust balance system meets design goals: no axial bearing loads above preloads at mainstage; and moderate bearing loads, well within bearing capability, during start and shutdown.
- The axial load system design has been substantiated by numerous engine tests and E-8 turbopump rig tests.
- The thrust piston has capability to meet load balancing requirements with substantial margin.
- Sufficient steady state thrust balance margin exists with maximum system statistical variability.
- Sufficient ball bearing axial load margin exists during start and shutdown from any power level.
- The turbopump rotor is axially stable.

HPOTP PERFORMANCE

SUMMARY

The production alternate HPOTP will meet all SSME performance compatibility requirements:

- **for all engine/turbopump configurations**
- **at all required power levels**
- **for all transient conditions**

ALTERNATE TURBOPUMP DEVELOPMENT PROGRAM

CRITICAL DESIGN REVIEW

Internal Flow Management
and
Heat Transfer

Joe Sawyer
August 2, 1993

INTERNAL FLOW MANAGEMENT & HEAT TRANSFER

Major Design Goals

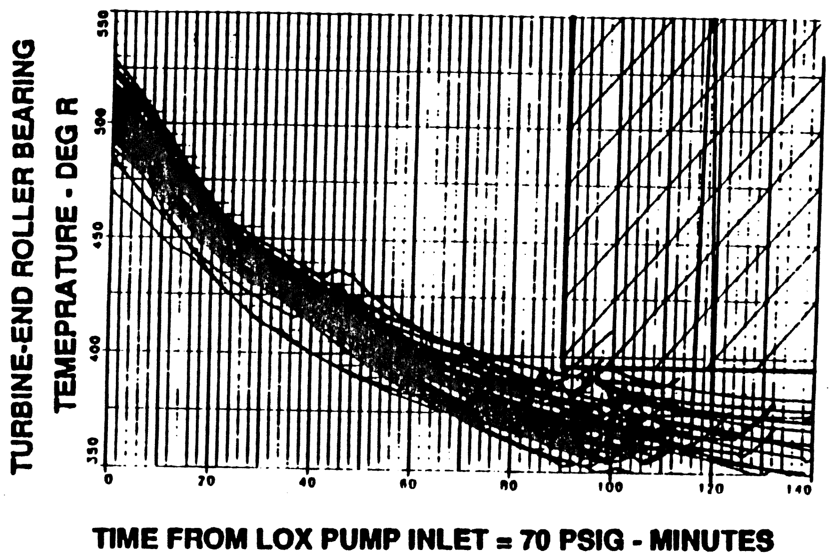
- Provide thermal conditioning of the LOX pump with a main pump LOX bleed flowrate of 5.3 lbm/sec within 90 minutes and prevent liquid air generation (ICD CP-11371A paragraphs 4.1 and 6.5)
- Maintain overboard drain flows through IPS housing drains within ICD requirements (ICD CP-11371A paragraph 5.4)
- Operate with a maximum of 2.5 pps of turbine and bearing coolant supplied from the hot gas manifold at a minimum pressure of 5969 psia and a maximum temperature of 280 degrees Rankine for 109% RPL conditions (ICD CP-11371A paragraph 5.1.1)
- Minimize leakage past internal and external static or dynamic seals (CEI CP-11369A paragraph 3.8.9.1)
- Control nonmainstream flows and critical hardware metal temperatures to ensure meeting life requirements (CEI CP-11369A paragraph 3.7.1)

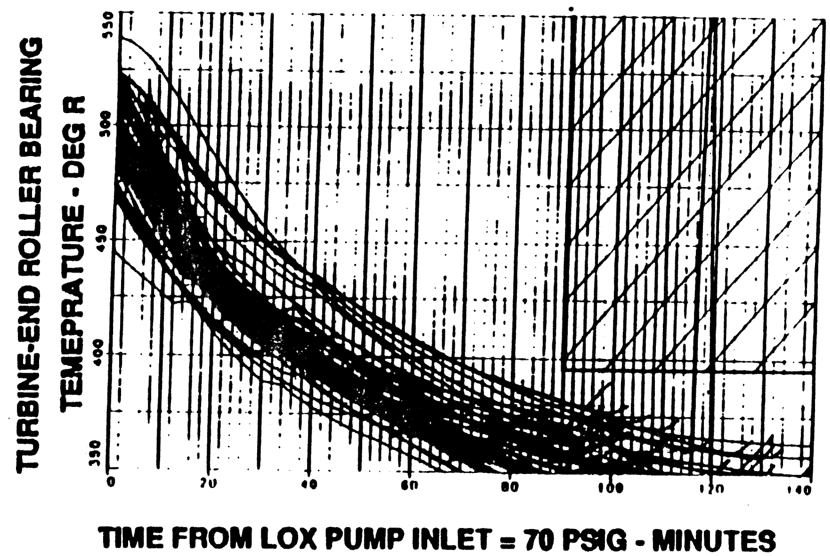
INTERNAL FLOW MANAGEMENT & HEAT TRANSFER

Stennis Tests Show Thermal Conditioning Requirements Met

Pratt & Whitney
SSME-ATD
Critical Design Review

SSC Turbine End Roller Bearing Outer Race Cooldown





INTERNAL FLOW MANAGEMENT & HEAT TRANSFER

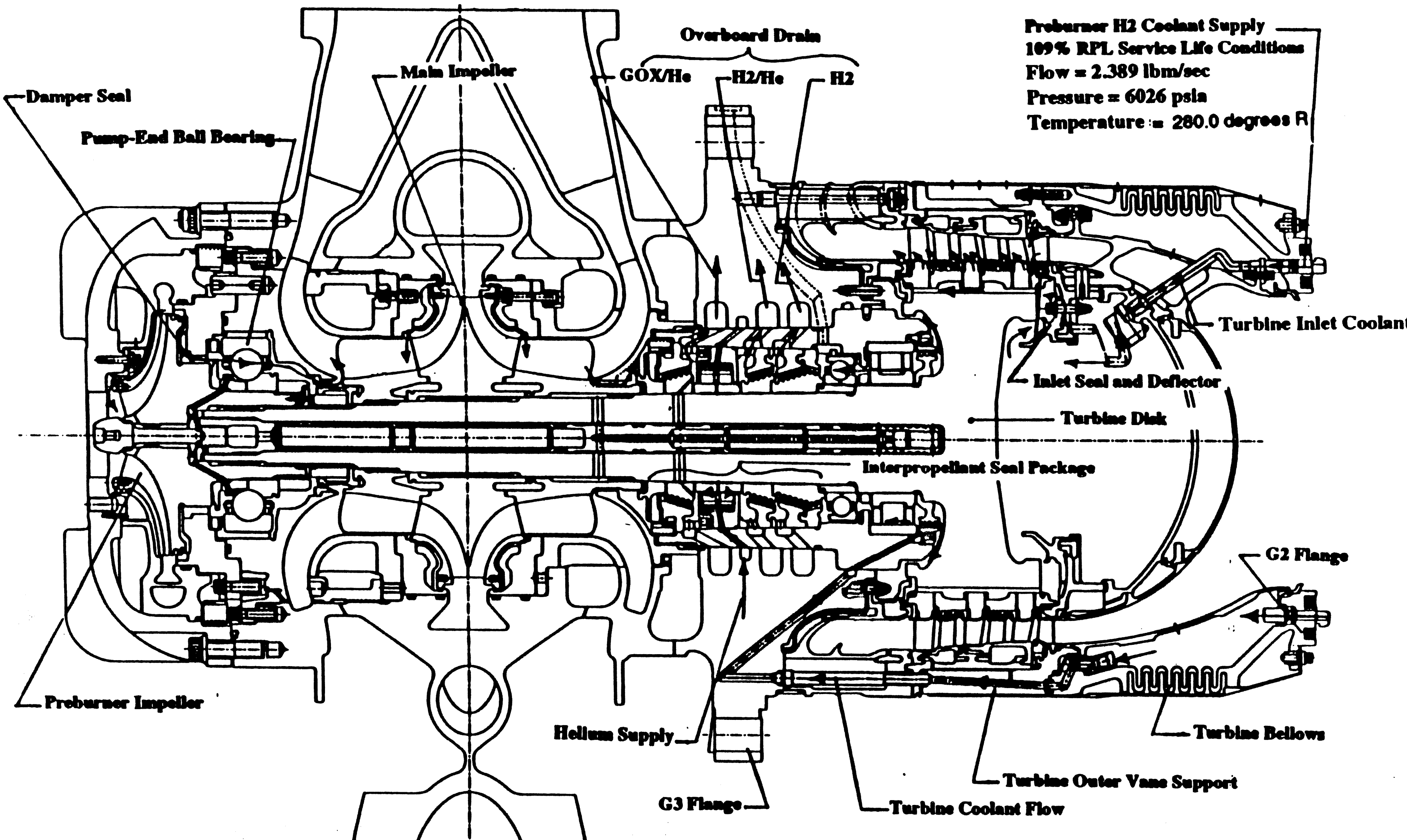
ICD Overboard Flow Limits Vs Actual Flows

	ICD REQUIREMENTS (SCIM)	109% SERVICE LIFE (SCIM)
Primary Turbine Drain Launch	GH2 = 12,204,000	CDR= GH2 = 10,632,042.
Secondary Turbine Drain Pre-launch	GHe = 230,000.	CDR= GHe = 224,700
Secondary Turbine Drain Launch	GH2 = 1,100,000	CDR = GH2 = 971,346.
Secondary Turbine Drain Launch	GHe = 230,000.	CDR = GHe = 208,600.
HPOTP Oxidizer drain Pre-Launch	LOX = 1,000,00	CDR = O2 = 692,323.
HPOTP Oxidizer drain Pre-Launch	GHe = 230,000	CDR = GHe = 214,150.
HPOTP Oxidizer drain Launch	GOX = 250,000	CDR = O2 = 307,508.
HPOTP Oxidizer drain Launch	GHe = 230,000	CDR = GHe = 230,250.

INTERNAL FLOW MANAGEMENT & HEAT TRANSFER

Turbine And Bearing Coolant Meet 2.5 PPS Requirement

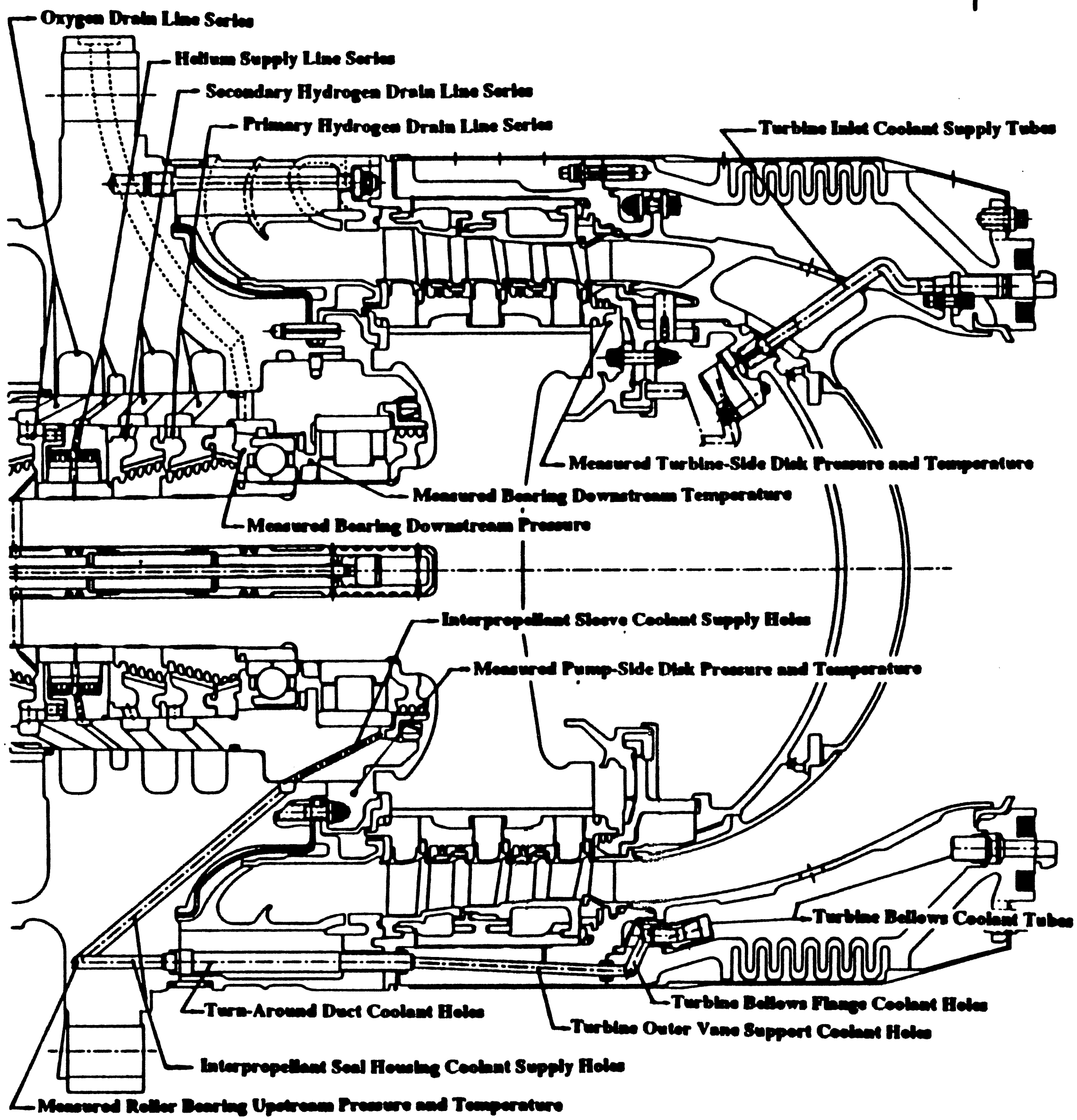
Pratt & Whitney
SSME-ATD
Critical Design Review



INTERNAL FLOW MANAGEMENT & HEAT TRANSFER

Turbine Flow Model Calibration Based On Rig/Engine Tests

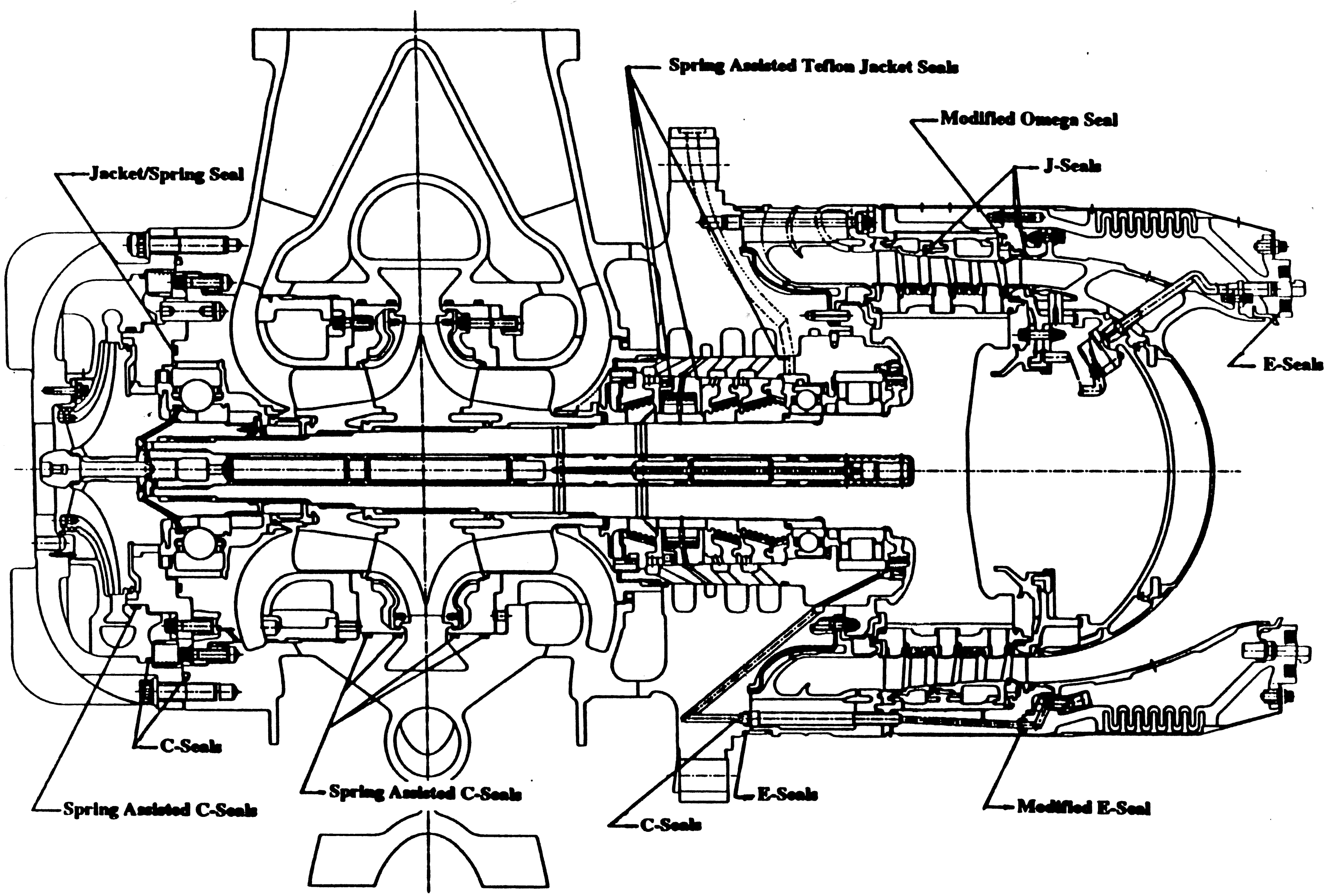
Pratt & Whitney
SSME-ATD
Critical Design Review



INTERNAL FLOW MANAGEMENT & HEAT TRANSFER

Static Sealing Features - Minimize Leakage

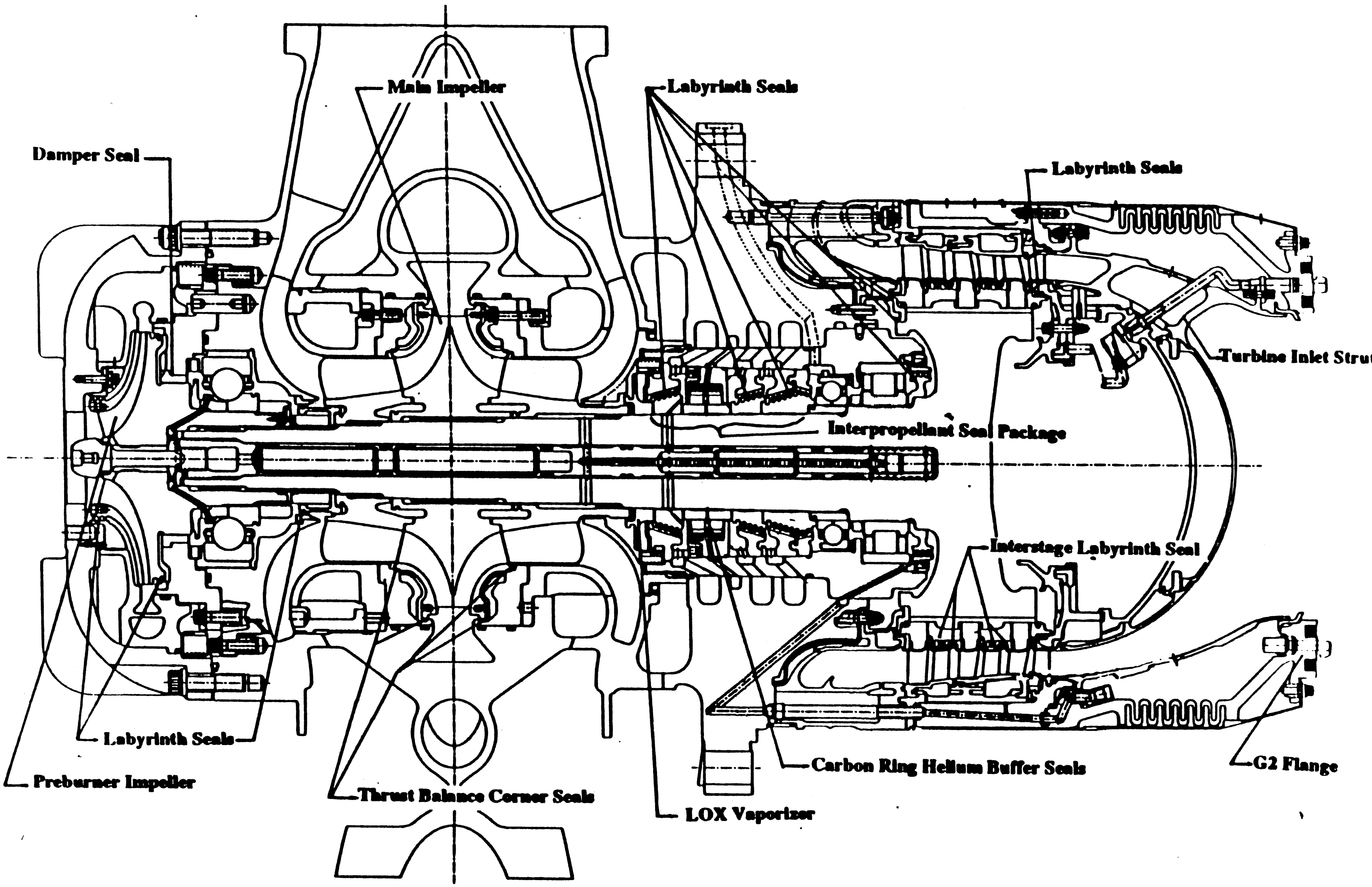
Pratt & Whitney
SSME-ATD
Critical Design Review



INTERNAL FLOW MANAGEMENT & HEAT TRANSFER

Rotating Sealing Features - Minimize Leakage

Pratt & Whitney
SSME-ATD
Critical Design Review



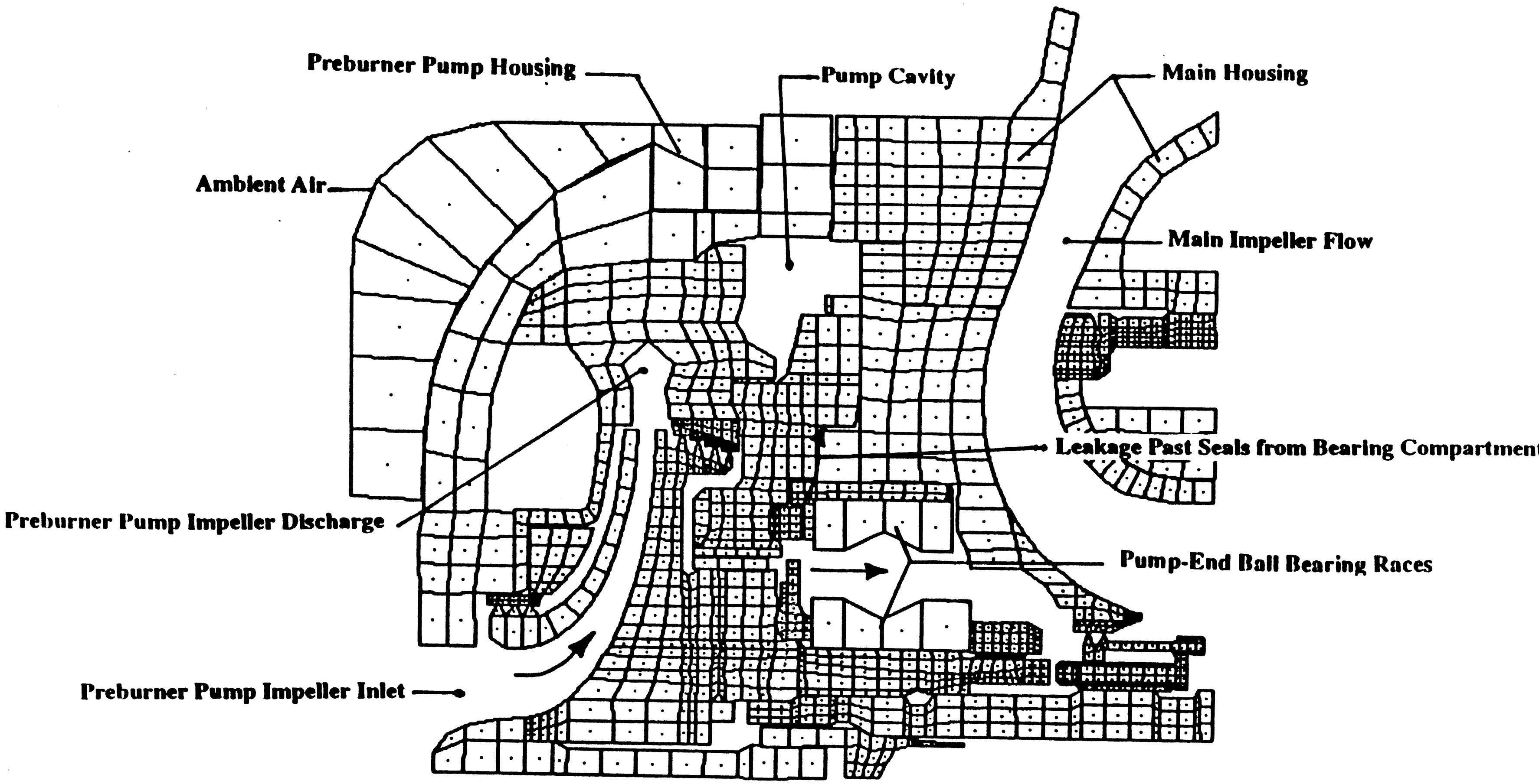
INTERNAL FLOW MANAGEMENT & HEAT TRANSFER

Summary Of Thermal Models

- 2D Preburner Housing Model
- 2D Rotor Model
  (Local 3D Features)
- 2D Global Turbine Static Structure Model
- 3D Models of Critical Hot Section Parts

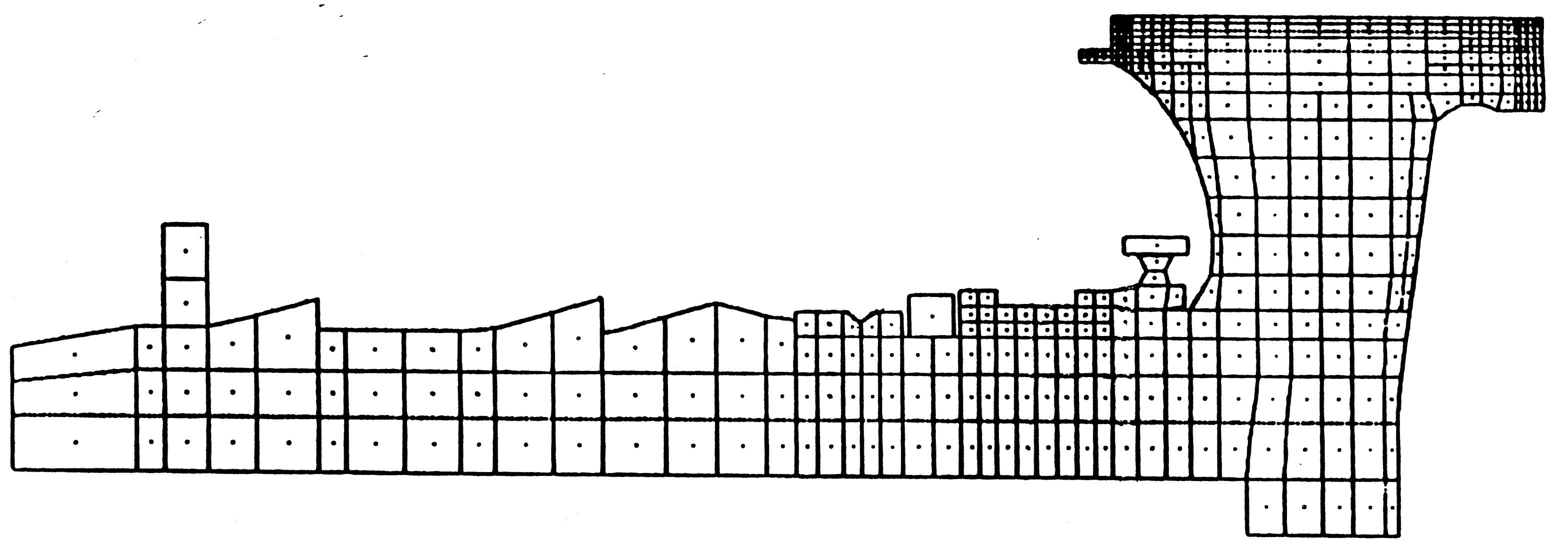
INTERNAL FLOW MANAGEMENT & HEAT TRANSFER

2D Preburner Pump Housing Thermal Model



INTERNAL FLOW MANAGEMENT & HEAT TRANSFER

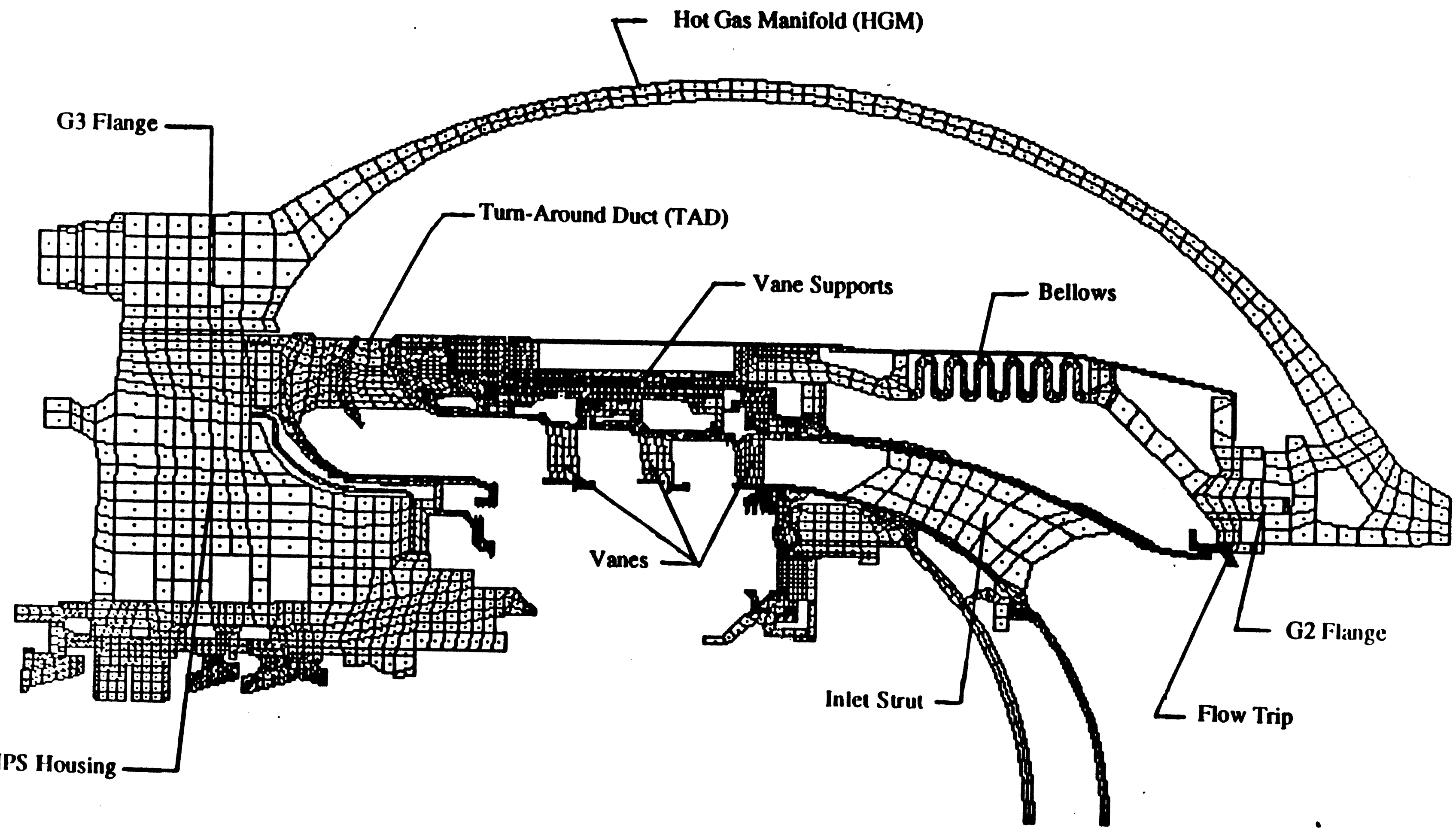
2D Rotor Thermal Model



INTERNAL FLOW MANAGEMENT & HEAT TRANSFER

2D Global Static Thermal Model Overview

Pratt & Whitney
SSME-ATD
Critical Design Review

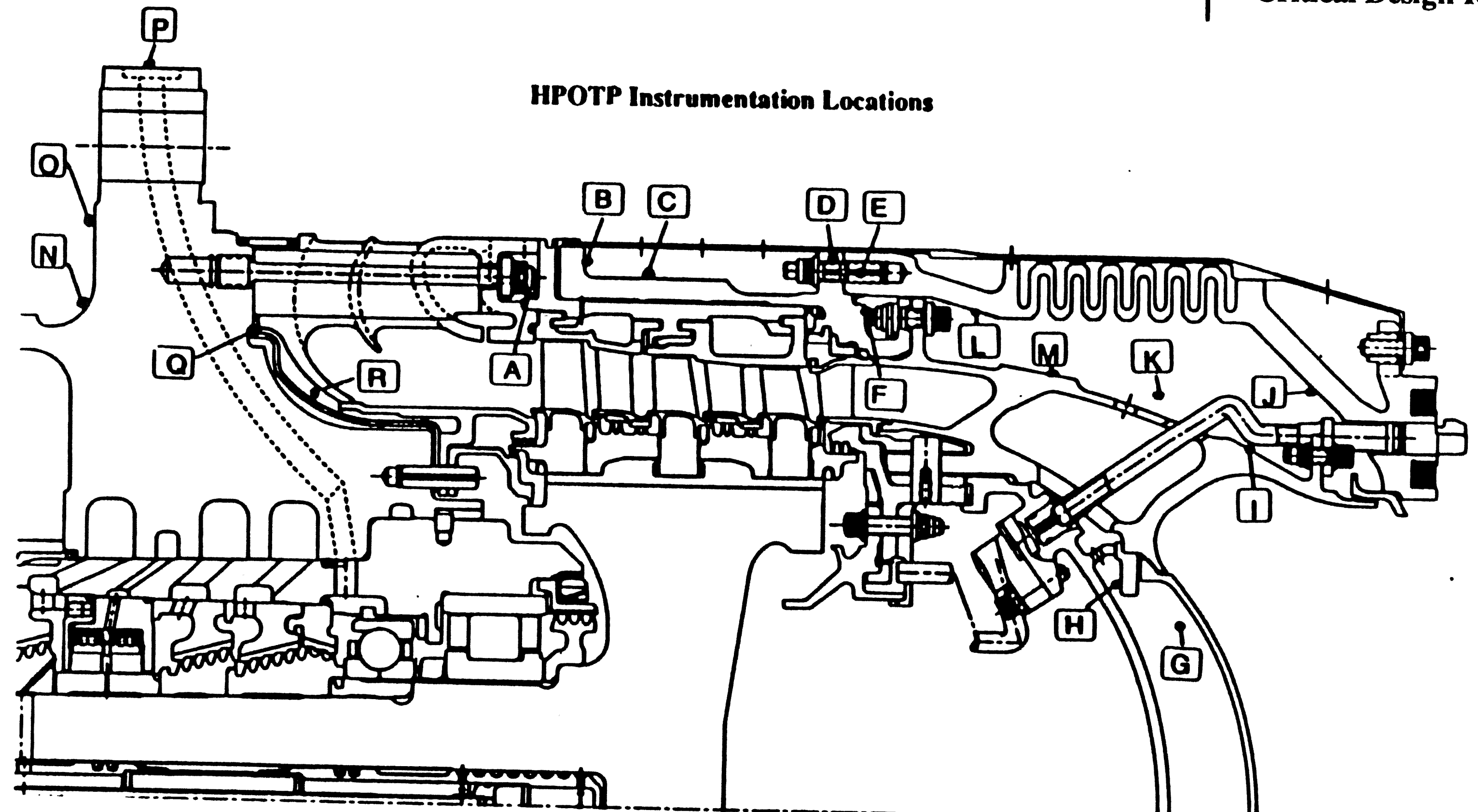


INTERNAL FLOW MANAGEMENT & HEAT TRANSFER

2D Global Static Thermal Model Calibration - Engine Data

Pratt & Whitney
SSME-ATD
Critical Design Review

HPOTP Instrumentation Locations



A = TMOTAD01 (PID 6384)
B = TMOTHP01 (PID 6381)
TMOTHP02 (PID 6382)
C = TMOTHW01 (PID 6383)
D = TMOTHFLG (PID 6390)
E = TMOBLFLG (PID 6389)
F = TMOTHT01 (PID 6380)
G = TFOTURI1 (PID 6360)

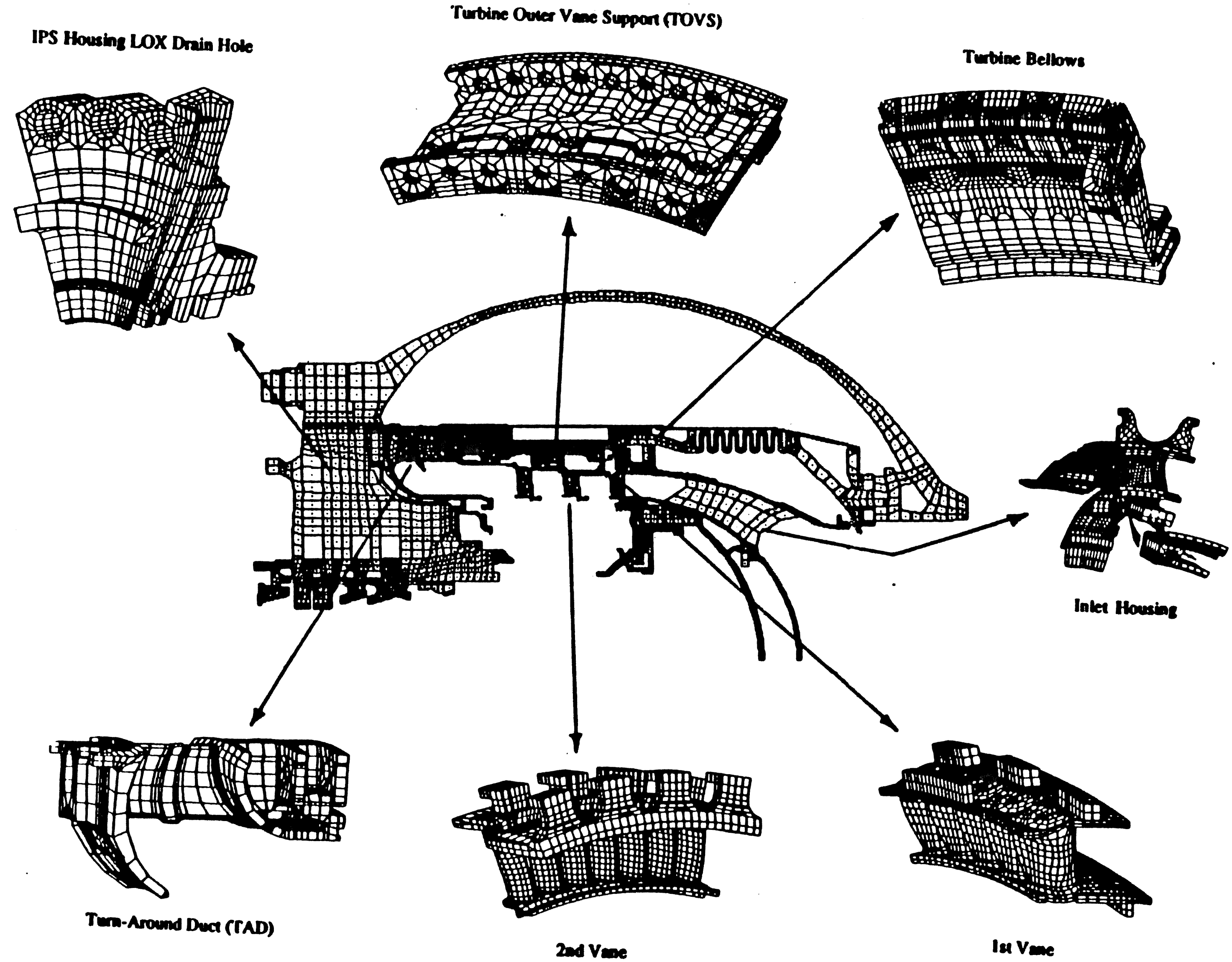
H = TMOLDRNG (PID 6361)
I = TMOTUR01 (PID 6368)
J = TMOBEL02 (PID 6388)
K = TFOBELA1 (PID 6294)
L = TMOBEL01 (PID 6387)
M = TMOTUR02 (PID 6358)
N = TMOG312A (PID 6400)
TMOG323A (PID 6402)

O = TMOG312B (PID 6401)
TMOG323B (PID 6403)
P = TMOG312C (PID 6445)
Q = TFOTMHA1 (PID 6435)
TFOTMHA2 (PID 6436)
TFOTMHA3 (PID 6437)
R = TFOTHSA1 (PID 6441)
TFOTHSA2 (PID 6442)

INTERNAL FLOW MANAGEMENT & HEAT TRANSFER

2D Global Thermal Model Relationship To 3D Models

Pratt & Whitney
SSME-ATD
Critical Design Review



ALTERNATE TURBOPUMP DEVELOPMENT PROGRAM

CRITICAL DESIGN REVIEW

Structures

Rich Hammond
August 2, 1993

ATD HPOTP STRUCTURAL ANALYSIS OVERVIEW

Topics

- Design Criteria
- Mission Usage
- Methodology and Analysis Tools
  - Component Static Analysis
  - Component Dynamic Analysis
  - Component Fracture Analysis

ATD HPOTP STRUCTURAL ANALYSIS OVERVIEW

Structural Design Criteria

Yield Factor of Safety		$\geq$ 1.1 (Under combined loads)
Ultimate Factor of Safety		$\geq$ 1.4 (Under combined loads)
Proof Factor	(Under pressure loads)	1.2 x Material Correction Factor; (never less than 1.05)
Ultimate Factor	(Under pressure loads)	1.5 x Material Correction Factor
LCF/Fracture Life		$\geq$ (60 x 4) = 240 missions
HCF Life		$\geq$ 10E8 cycles (infinite life)
Service Life		60 109% service life missions (28,500 sec)
Engine Out Single Mission		109% redline (abort) mission
Creep/Stress Rupture		32 hours @ 109% service life + 1 mission @ 109% redline

ATD HPOTP STRUCTURAL ANALYSIS OVERVIEW

Mission and Service Life Definition and Usage

- Different missions are used for different Design/Structures tasks:
- 104% nominal - optimize seal and blade tip clearances, performance related parameters. (Also demonstrate safe operation from 65% to 109%.)
- 109% nominal - check clearances for anomalies
- 109% service life - used for all life analysis and margins of safety.
- 104/109% Abort - turbopump components must be capable of extended duration firing (754 sec @ 104% and 761 sec @ 109%) without debit to life. All conditions of the service life mission apply except firing duration.
- 109% Redline (abort) -used as the 60th mission of the 60 mission life criteria

ATD HPOTP STRUCTURAL ANALYSIS OVERVIEW

Stress Analysis Tools

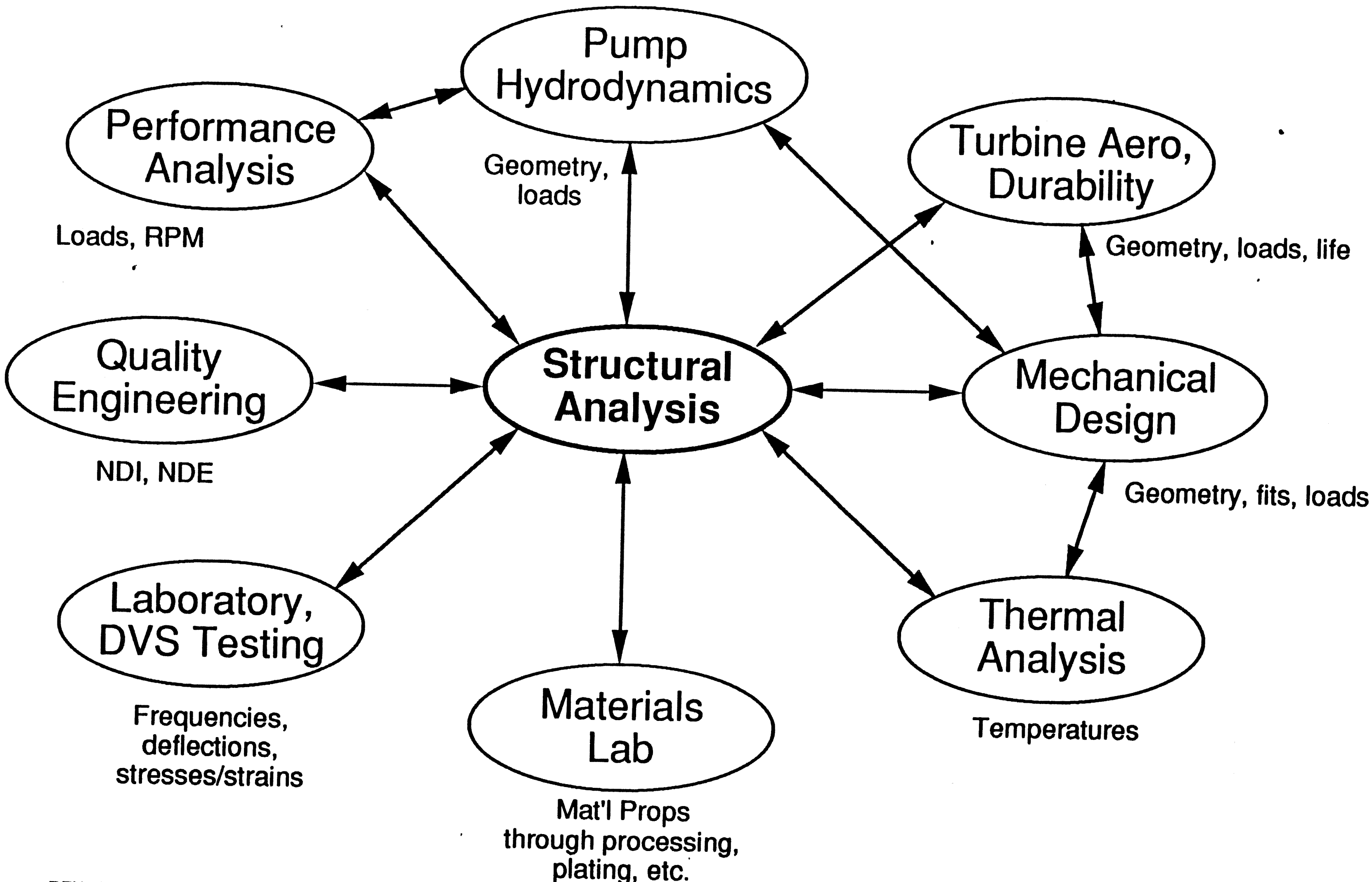
- Finite Element Codes - 2D, 3D, BOR for global and local stresses
  - NASTRAN - static stress, normal modes, forced response
  - P&W General Shell Deck
  - ANSYS
  - MARC - non-linear stress
- Boundary Integral Solution Codes - 2D, 3D, BOR for stress concentrations
  - PWBEST
  - RASNA - higher order elements
- Lifing Codes
  - P&W U553 - LCF Design System
  - BIGIF
  - SURCK
  - FLAGRO

  (BIGIF, SURCK, FLAGRO } F/M LIfe Prediction)

ATD HPOTP STRUCTURAL ANALYSIS OVERVIEW

Structural Analysis is Part of an Iterative Design Process

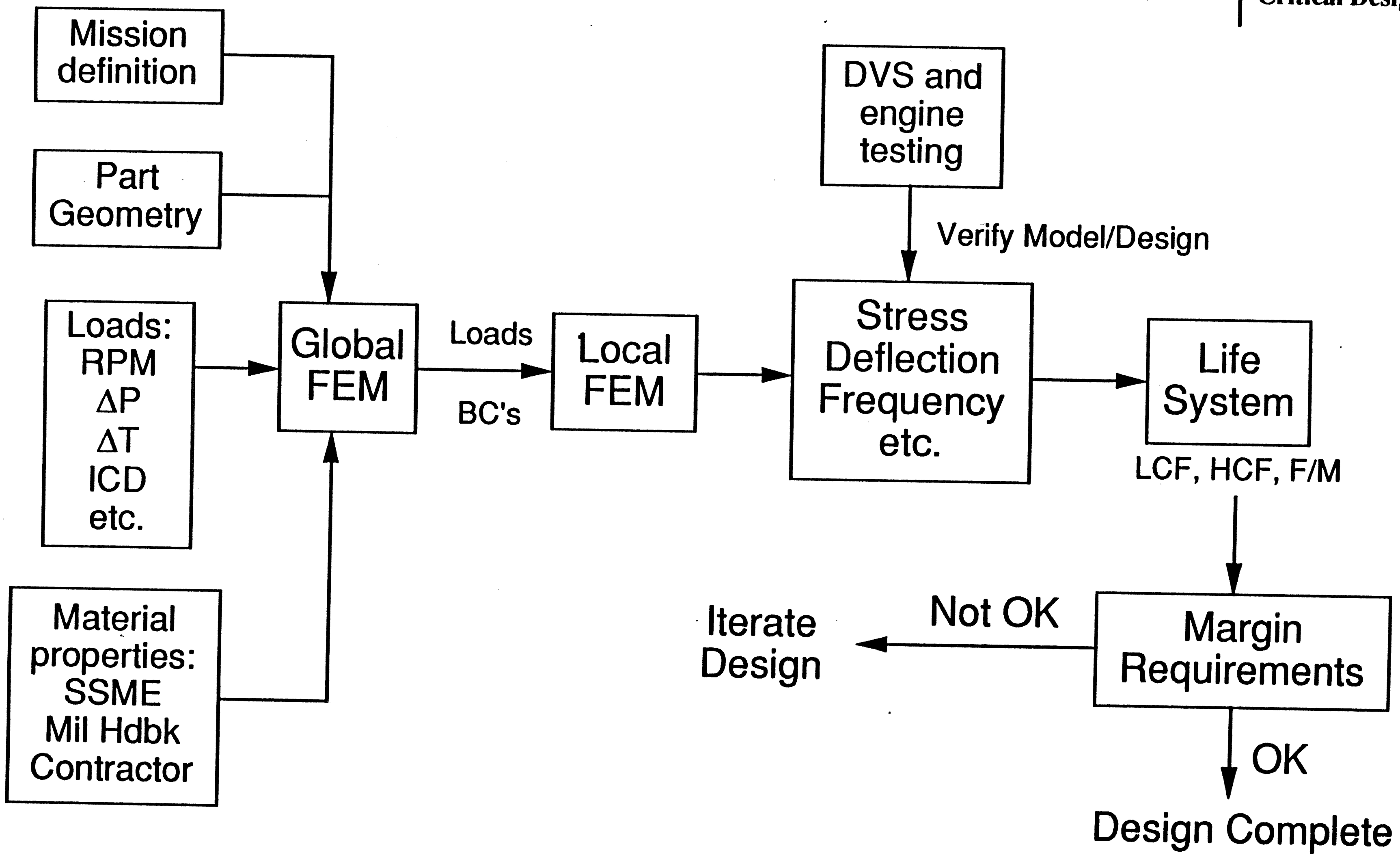
Pratt & Whitney
SSME-ATD
Critical Design Review



RFH04.1-CDR - OVERVIEW
8/02/93

ATD HPOTP STRUCTURAL ANALYSIS OVERVIEW

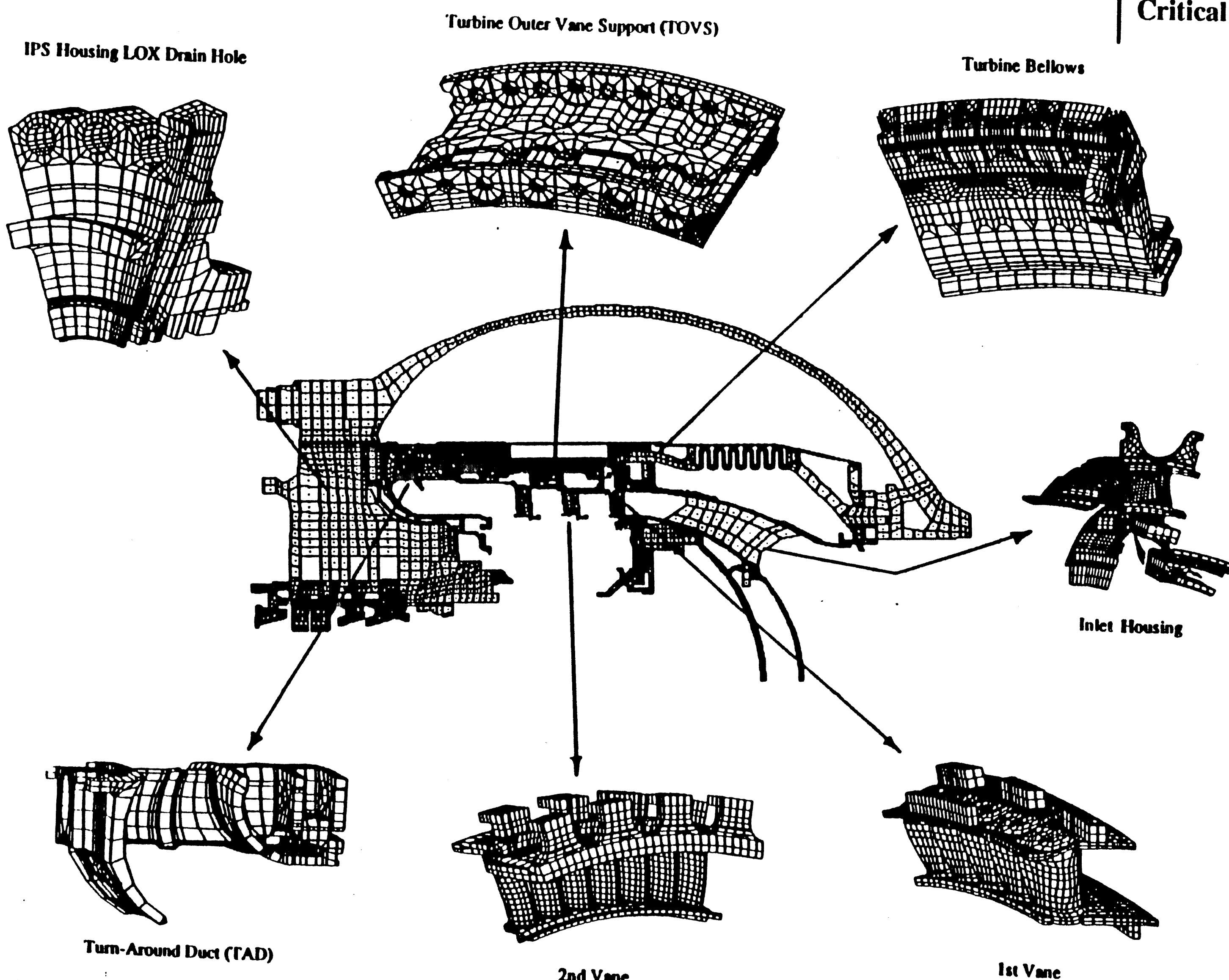
Typical Structural Analysis Procedure



ATD HPOTP STRUCTURAL ANALYSIS OVERVIEW

2D Global Structural Model Relationship to Local 3D Models

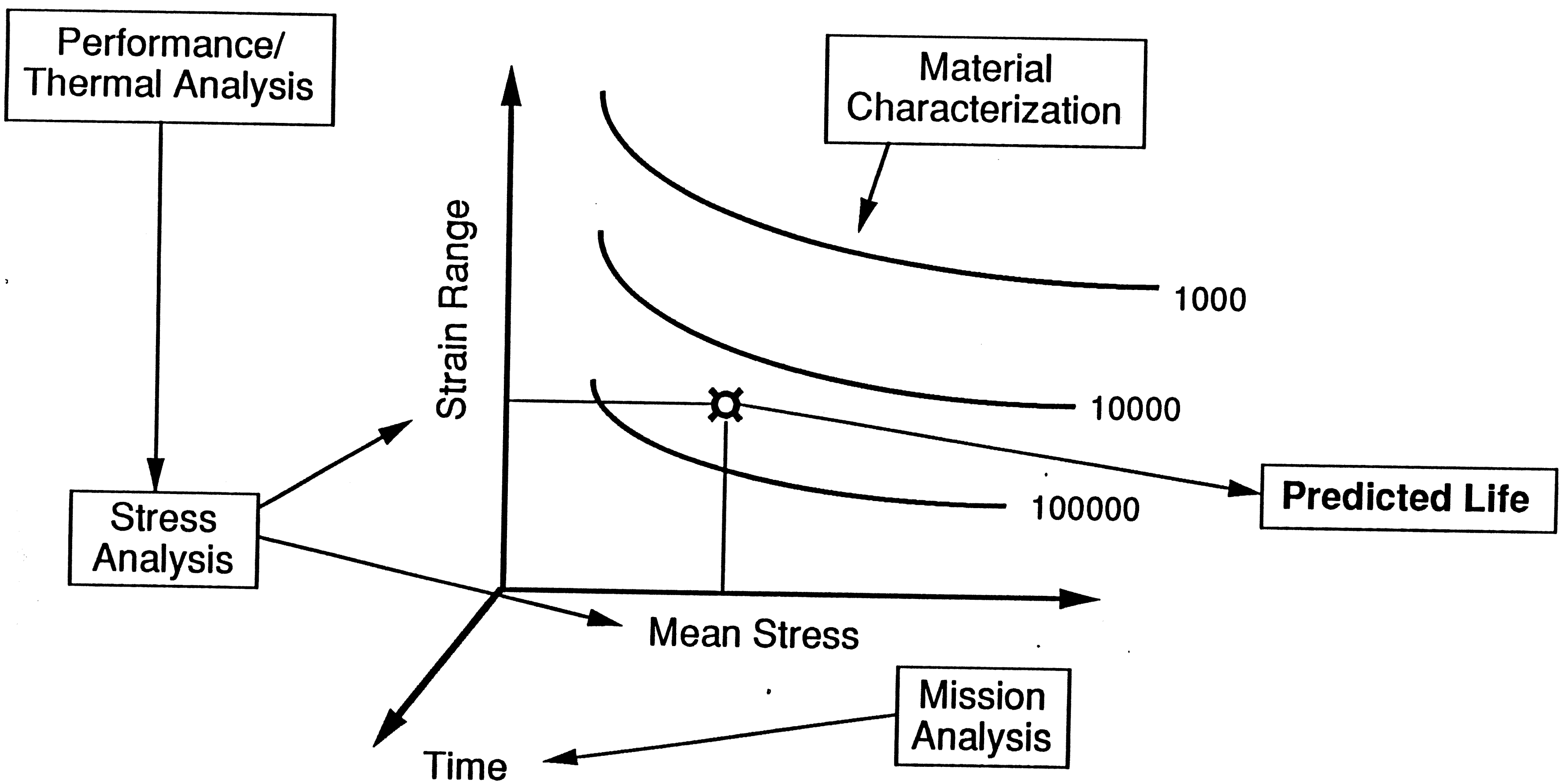
Pratt & Whitney
SSME-ATD
Critical Design Review



ATD HPOTP STRUCTURAL ANALYSIS OVERVIEW

LCF Design System

- LCF design system integrates input from five areas to predict B.1 life to a 1/32 inch crack



ATD HPOTP STRUCTURAL ANALYSIS OVERVIEW

LCF Design System Features

- Elastic stress range calculation
- Mean stress based on plastic stress/strain curves
- Temperature effects included
- Miner's Rule used for sub-cycle damage
- Debits applied for manufacturing processes and environment (surface finish, hydrogen, etc.)

ATD HPOTP STRUCTURAL ANALYSIS OVERVIEW

LCF Design System Calibration

- System is calibrated to reflect a 1 in 1000 (B.1) probability of developing a 1/32 inch crack in the part population for the defined mission usage.

- Calibration factors include:
  - Specimen/component testing and correlation of analytical parameters
  - Temperature variation
  - Environmental effects
  - Cumulative damage

- Statistical analysis techniques used (Weibull, etc.)

- High strain LCF data generation for selected ATD materials in process.

ATD HPOTP STRUCTURAL ANALYSIS OVERVIEW

HCF Design Criteria

- Based on Spec CP11369A, MSFC Hdbk 505A, DVS Spec DVS-29.
- Design Goal $\geq$ 10E8 cycles life (infinite life)
- $\geq$ 10% frequency margin for pump operating speed range
- Design away from potential excitation sources:
  - Blades: No. of upstream and downstream vanes
    Differences of vane counts
    Rotor response and 2nd to 4th harmonics
  - Flowpath static hardware: No. of upstream and downstream blades
    Rotor response and 2nd harmonic
  - Non-flowpath static hardware: Rotor response
- Design with awareness of fundamental modes:
  - Blades, struts, vanes: 1st bending, 1st torsion
  - Static hardware: 0 to 12 nodal diameter modes

ATD HPOTP STRUCTURAL ANALYSIS OVERVIEW

HCF Analysis Methodology

- Frequency/modeshape/dynamic stress predicted by:
  - Empirical/experienced based methods
  - Nastran
  - P&W General Shell Deck

- Dynamic stress predicted for critical components
  - 21 HPOTP components analyzed to date
  - 0.5% damping assumed
  - Applied ICD environment
  - Models include all appropriate parameters (centrifugal effects, ΔT, ΔP, material properties, etc.)

- Conservative allowables are used
  - -3σ lower bound minimum material properties
  - HCF endurance limit @ 10E8 cycles
  - Minimum $K_t = 1.5$

- Verify hardware design and analysis with Design Verification Tests (DVS)

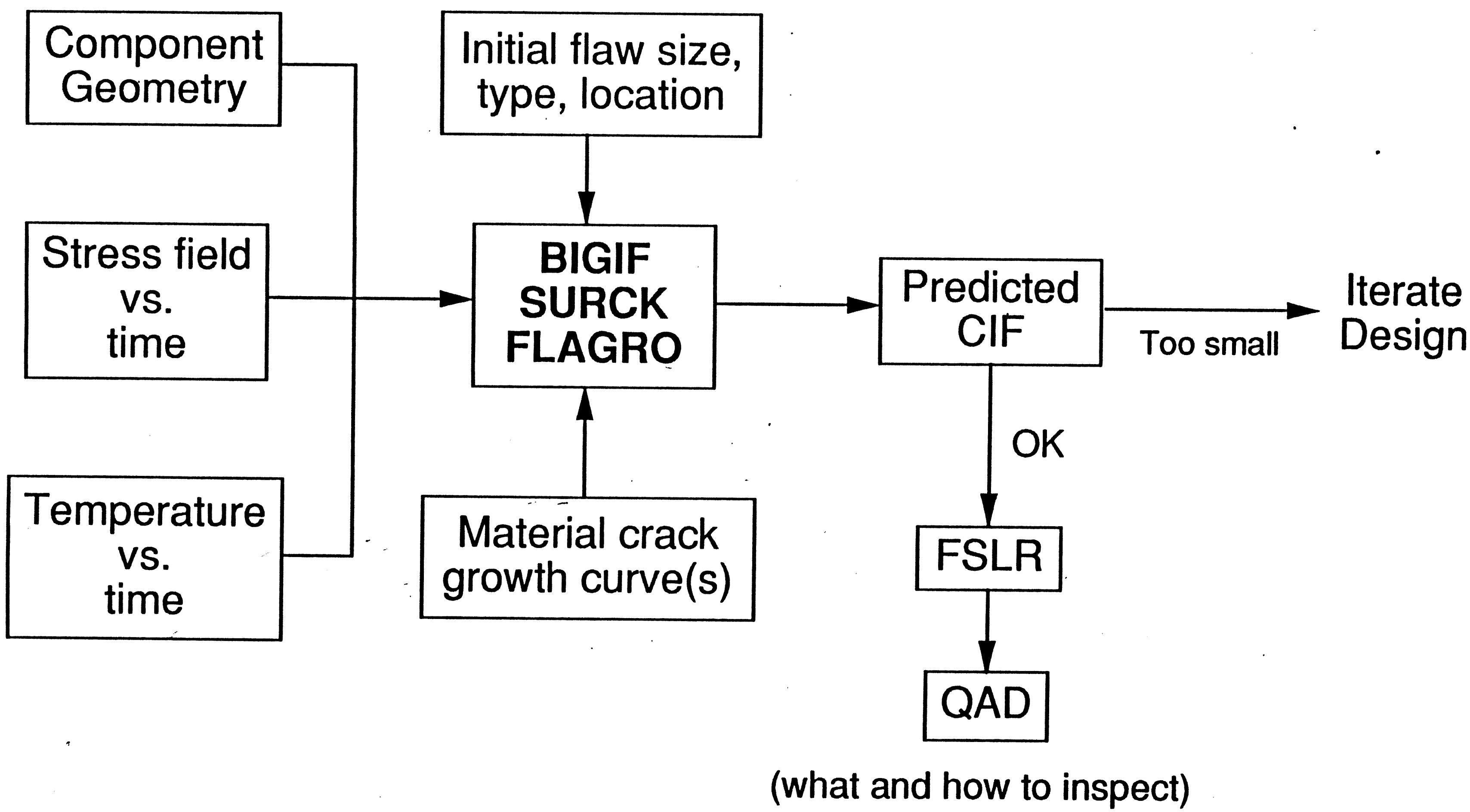
ATD HPOTP STRUCTURAL ANALYSIS OVERVIEW

ATD Fracture Control Plan Goals and Objectives

- Identify fracture sensitive components
- Categorize fracture sensitive components as contained/restrained, fail-safe, pressure vessel, or safe-life.
- Provide the system to implement fracture control on ATD components to ensure their structural integrity throughout the mission service life of the turbopumps.
- Define the critical initial flaw (CIF) and NDE and proof test procedures to establish that safe-life components will not fail in 4x the service life

ATD HPOTP STRUCTURAL ANALYSIS OVERVIEW

Fracture Mechanics Analysis Procedure



ATD HPOTP STRUCTURAL ANALYSIS OVERVIEW

F/M Design System Features

- System is based on linear fracture mechanics theory
- System is calibrated by comparison of measured crack growth data from specimen and component tests to predicted material crack growth behavior
  - Mean actual/predicted life and scatter defined
  - Growth models include effects due to R-ratio, temperature, frequency, and environment
- Automated flight point selection
- Automated stress field preprocessor
- Cycle-by-cycle access to interpolative da/dn model library
- Automated post-processor for combining mission damage
- Automated LCF/HCF ΔKth impact on remaining life

ALTERNATE TURBOPUMP DEVELOPMENT PROGRAM

CRITICAL DESIGN REVIEW

Rotordynamics

Dave Hudson
August 2, 1993

HPOTP ROTOR DYNAMICS

Goals

- Provide a stable turbopump rotor system with low level vibration
- All rotor modes > 120% max rotor speed for subcritical operation
- Onset speed of instability (OSI) > max rotor speed

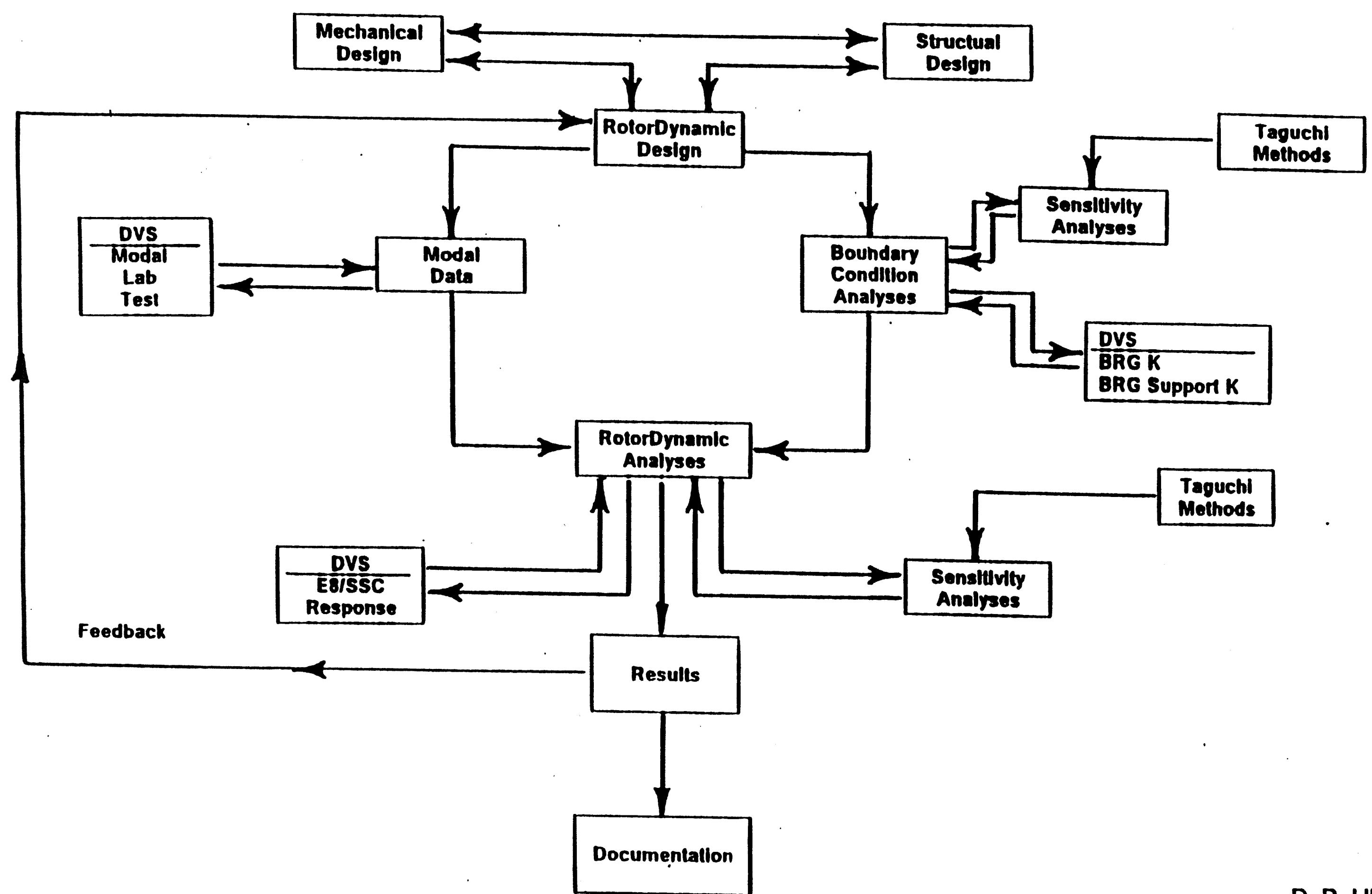
D. B. HUDSON/m.c.

HPOTP ROTOR DYNAMICS

Methods

Pratt & Whitney
SSME-ATD Critical
Design Review

Rotordynamic Design



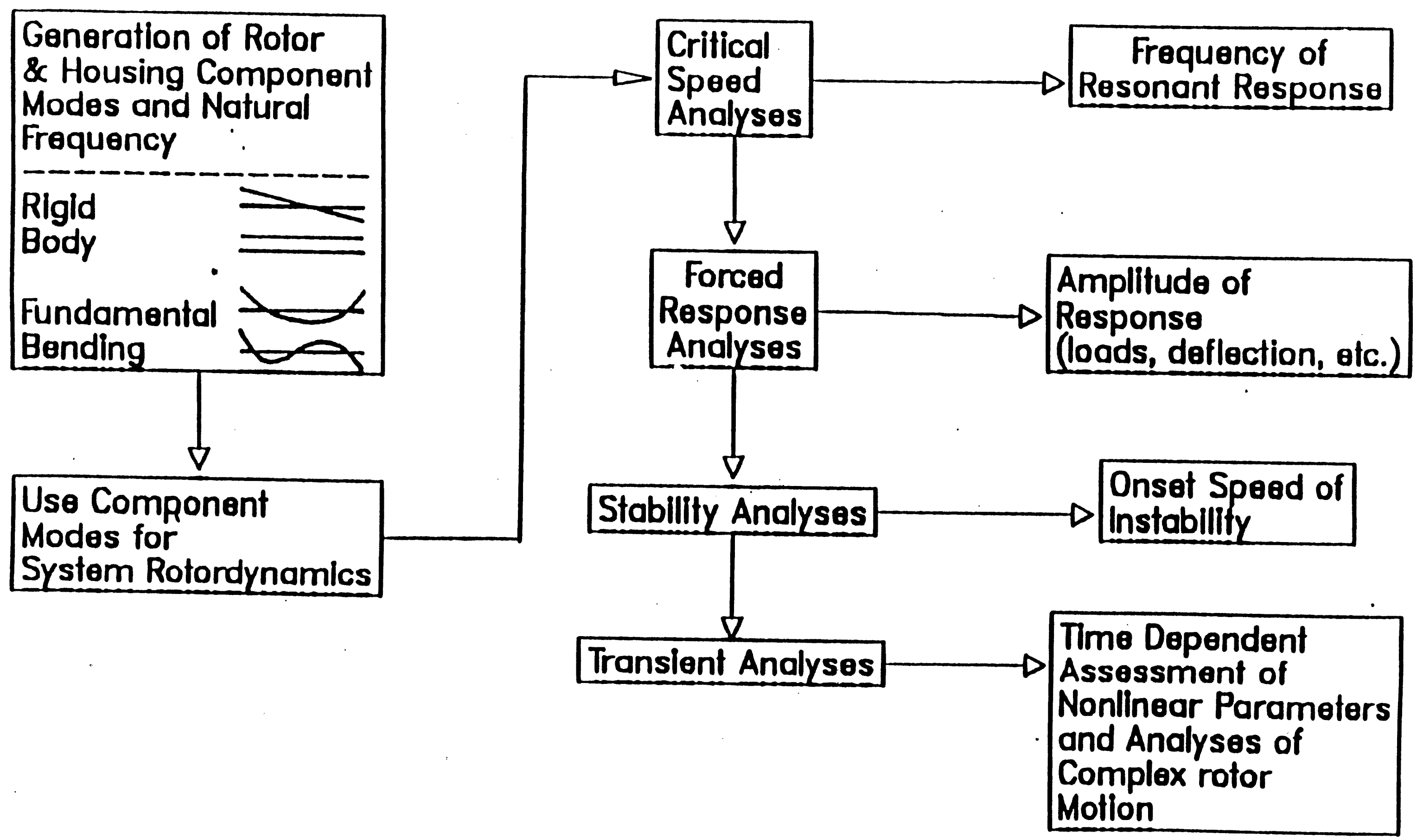
D. B. HUDSON/m.c.

8-2-93

HPOTP ROTOR DYNAMICS

Methods

Rotordynamic Analyses



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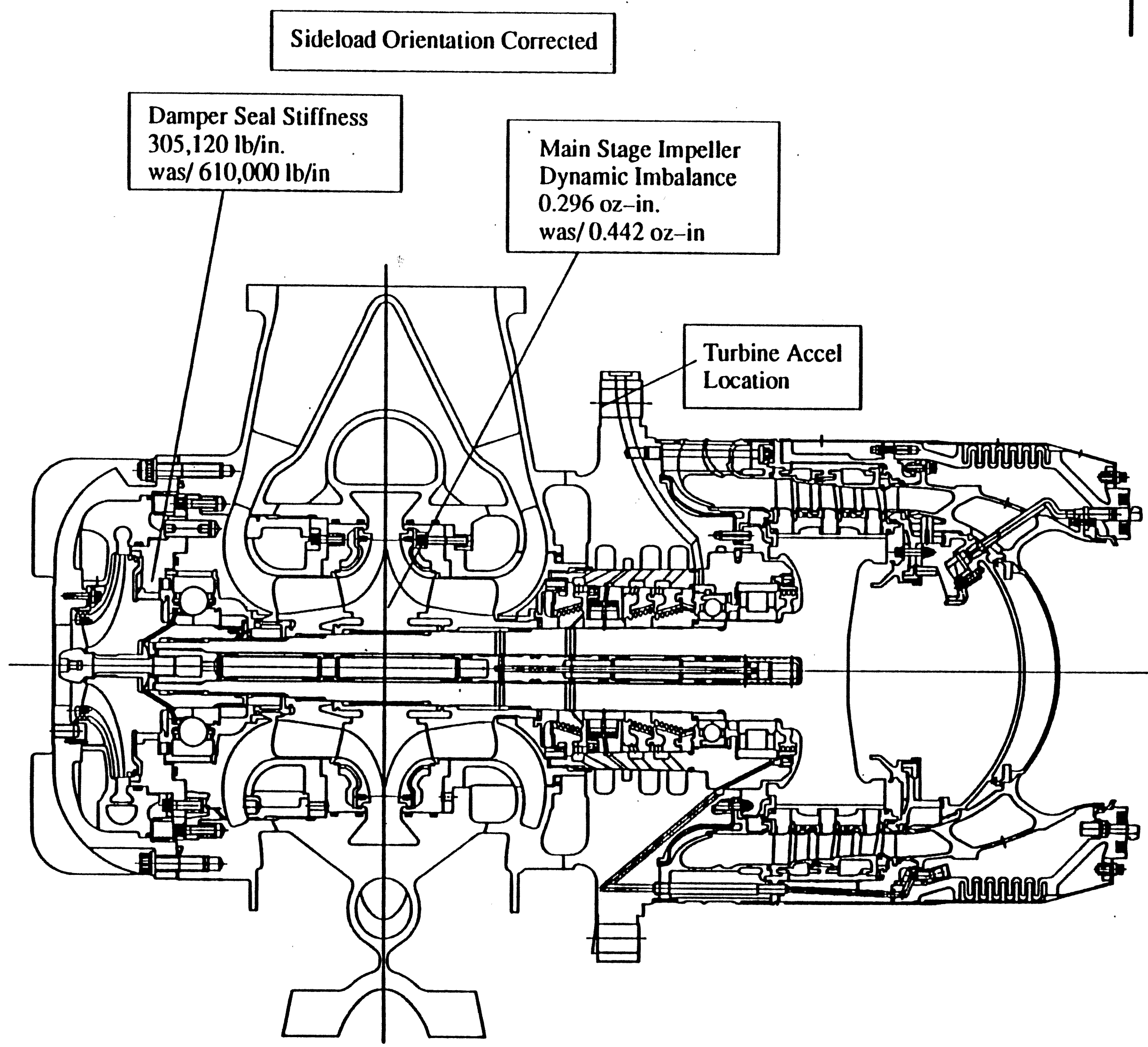
HPOTP ROTOR DYNAMICS

Rotor Dynamic Changes From FR-20730-27



HPOTP ROTOR DYNAMICS

Vibration Team Resolutions

- Review of current rotordynamic model correlation to high vibration experienced on Unit 7-2E may impact the following parameters used in the CDR package:
  - PEBB deadband
  - Main stage hydrodynamic forces
  - Damper seal coefficients

D. B. HUDSON/m.c.
8-2-93

HPOTP ROTOR DYNAMICS

Damper Seal Performance Updates

Damper seal dynamic coefficient calculations have been updated to include current operating clearances, delta pressures and dimensions. Calculations are made vs speed for use in all the rotordynamic analyses.

Major parameter changes include increased delta pressures from approximately 1800 (PCDR) to 2750 psi (Production) at 109% RPL. The pressure change is a result of redesigned back-face PBI labyrinth seal, PEBB coolant circuit and down-stream 2-tooth labyrinth clearances.

The damper seal performance has varied greatly during development testing with the high synchronous and PEBB wear corrective actions, including replacement of the damper seal with a 5-tooth labyrinth seal. Variations in the Production damper seal performance are included for minimal and maximum conditions.

D. B. HUDSON/m.c.

8-2-93

HPOTP ROTOR DYNAMICS

Ball Bearing Radial Stiffness

Analytical methods of ball bearing radial stiffness have been substantiated with the HPFTP ball bearing rig and documented in FR-20730-18. This rig used a smaller ATD bearing design (0.611" ball) in the slave bearing position. Critical speed analysis, rotor modal analysis for model calibration, and A.B. Jones load-deflection bearing analysis were used to empirically verify the radial stiffness predictions. This model was then applied to the HPOTP PEBB design.

Updates to bearing springrates include redesigned axial preload, ranging from 900 to 1300 lbs for full range of rotor axial position. This results in stiffness values from 0.67E6 to 0.72E6 lb/in.

Note: For rotordynamic sensitivity analyses, a larger range of radial stiffness was used, 0.5E6 to 1.0E6 lb/in. Larger critical speed margins are anticipated for actual stiffness values.

HPOTP ROTOR DYNAMICS

Dynamic Boundary Conditions

Several updates have been made to the dynamic coefficient boundary conditions. All input and output data are fully documented in FR-20730-27. All calculations are provided vs speed including parametric analyses of the boundary conditions for the influential inputs. The outline and selection of parametric methods were the result of NASA/MSFC consultations. Range of input variation is intended to represent design tolerances and operations tolerances where applicable.

An introduction to the updates include ...

- New Parameters
  1) Preburner Impeller 2-Tooth Labyrinth Seal
  2) Interpropellant Gox Labyrinth Seal
  3) Interpropellant Primary H2 Labyrinth Seal
  4) Interpropellant Secondary H2 Labyrinth Seal

- Revised Parameters
  1) Turbine Aeromechanical
  2) Pump Hydromechanical
  3) Damper Seal
  4) Turbine Interstage labyrinth Seals
  5) Static Sideloads
  6) Bearing Deadbands

These results are fully documented in FR-20730-27.

HPOTP ROTOR DYNAMICS

Critical Speed Results

Natural frequencies were calculated using the rotor model design of Unit 4-1 (i.e. calibrated rotor of Unit 1-1 with Preburner Impeller "nut" spacer) and updated dynamic coefficients documented in FR-20730-27.

The Frequency Map (natural frequency vs speed) is calculated with speed dependent boundary conditions. Critical Speeds are defined at the intersection of the forward whirl frequency and 1N rotor spin speed. The Critical Speeds results represent the lateral housing and rotor resonances in the X-Z and Y-Z planes as a result of the housing mount asymmetry.

These results, as well as pump orientation, mode shapes, and backward whirl frequencies are documented in FR-20730-27.

HPOTP ROTOR DYNAMICS

Stability Results

Stability Analyses were made using the rotor model design of Unit 4-1 (i.e. calibrated rotor of Unit 1-1 with Preburner Impeller "nut" spacer) and updated dynamic coefficients documented in FR-20730-27.

The Log-Dec Map is calculated with speed dependent boundary conditions. The first seven system modes were observed to have Onset Speed of Instability greater than the maximum search speed of 39,000 RPM.

These results are documented in FR-20730-27.

D. B. HUDSON/m.c.
8-2-93

HPOTP ROTOR DYNAMICS

Forced Response Results

Forced Response Analyses were made using the rotor model design of Unit 4-1 (i.e. calibrated rotor of Unit 1-1 with Preburner Impeller "nut" spacer) and updated dynamic coefficients documented in FR-20730-27. The linear and non-linear analyses were calculated with speed dependent boundary conditions. Non-linear analyses included ball and roller bearing deadbands and static side loads.

These results are documented in FR-20730-27.

D. B. HUDSON/m.c.

8-2-93

HPOTP ROTOR DYNAMICS

Sensitivity Studies

Sensitivity Studies were Completed for the Following:

- Critical speed
  - Pump end ball bearing (PEBB) springrate
  - Turbine end roller bearing (TERB) springrate
- Stability
  - Boundary condition sensitivity (i.e. min/max input parameters)
- Forced response
  - Boundary condition sensitivity (i.e. min/max input parameters)

ALTERNATE TURBOPUMP DEVELOPMENT PROGRAM

CRITICAL DESIGN REVIEW

August 2 - 6, 1993

Integration

Dan Guisinger
(407) 796-4223

INTEGRATION

Agenda

- Mass Characteristics
- Flight Redlines
- Overboard Leakages
- Purge Requirements
- DVS-34 Requirements
- Inspections & Checks

INTEGRATION

Mass Characteristics

- Predicted Alternate HPOTP flight configuration weight is as follows:

	ICD Dry (lbs)	Measured 08-1/2 (Pre Cert)
Alternate HPOTP	741	715
Baseline HPOTP	580	580
Difference	161	135

- Changes in HPOTP C.G. and Moments of Inertia accompany the weight change as specified in ICD CP11371B, Section 2.0.
- Rocketdyne assessment of impact on engine interface loads and adjacent component loads is in work. ECD: TBD
- Mass characteristics changes must be assessed by Level II.

INTEGRATION

Flight Redlines

Pratt & Whitney
SSME-ATD
Critical Design Review

- Redline changes are isolated to the Alternate HPOTP IPS Package.
- Recommended Alternate HPOTP Flight IMSL redline changes are as follows:

Parameter	Shutdown Condition	Activate/ Deactivate	Limit ATP	Limit Baseline
Helium IMSL Purge Pressure	Over Pressure	0.0/C/O	153 psia min	170 psia min
	Under Pressure	0.0/C/O	210 psia max	625 psia max
HPOP Oxidizer Seal	Over Pressure	0.0/4.0	29 psia max	N/A
Drain Pressure		4.0/0.0 c/o	20 psia max	N/A
HPOP Secondary Seal	Over Pressure	0.0/C/O	N/A	100 psia max

Maybe Delete ATP Pressure Just Monitor As A Maintenance Parameter

Already Been Deleted/Reassigned to OXID PR LINE

- Quantity of IMSL redlines is unchanged from baseline HPOTP.
- Alternate HPOTP design changes have been made to eliminate the secondary seal cavity probe from the bill-of-material.

INTEGRATION

Flight Redlines

- Rocketdyne assessing impact to engine system to delete Secondary Seal Drain Cavity Pressure redline and add Oxidizer Seal Drain redline.
- IMSL flight redlines submitted to Level III CCB via PIRN PW0029 on 6/7/93. Approval pending CCB review.
- IMSL flight redlines must also be assessed by Level II.

INTEGRATION

Overboard Leakage

Pratt & Whitney
SSME-ATD
Critical Design Review

- Predicted Alternate HPOTP flight configuration seal drain leakage rates:

Leakage Source	Leakage Exit Location	Operation Phase	Flow Media	(1)ICD (SCIM)	(2)ICD (SCIM)	(3)Alternate HPOTP (SCIM)
Primary Turbine Seal Drain	Drain Line at Nozzle Exit	Prelaunch	GHe	0	N/C	N/C
			GN2	0	N/C	N/C
		Launch	GH2	4,700,000	12,204,000	10,632,700
		Re-Entry	GHe	0	N/C	N/C
Secondary Turbine Seal Drain	Drain Line at Nozzle Exit	Prelaunch	GHe	230,000	N/C	224,700
		Launch	GH2	1,100,000	N/C	971,346
			GHe	230,000	N/C	208,600
		Re-Entry	GHe	1,400	N/C	N/C
HPOTP Oxidizer Seal Drain	Drain Line at Nozzle Exit	Prelaunch	GOX	1,000,000	N/C	692,323
			GHe	230,000	N/C	214,150
		Launch	GOX	250,000	N/C	307,508
			GHe	230,000	N/C	230,250
		Re-Entry	GHe	15,000	N/C	N/C

(1) Maximum leakage rate during the life of the baseline HPOTP under normal operating conditions, Level II ICD 13M15000.

(2) Maximum leakage rate with maximum blue print seal clearance at 109% RPL service life as given in Level III ICD CP11371B.

(3) Predicted maximum leakage rate with maximum blueprint seal clearance at 109% RPL service life.

CDR04-4 pl

INTEGRATION

Overboard Leakage

- Effects of overboard seal drain leakage on engine Isp is addressed by P&W and Rocketdyne, 0.2 second decrease

- Effects of oxidizer seal leakage during prelaunch on lox drainback is TBD
  - Safety hazard does not appear to be an issue since leakage is predicted to be less than ICD
  - Rocketdyne to provide baseline HPOTP leakages for comparison

- Overboard leakage must be assessed by Level II.

INTEGRATION

Purge Requirements

- Alternate HPOTP requires a bearing drying purge be applied post shutdown (FRF and Launch Abort) and post flight.
- Purge is applied simultaneously with IPS drain purges to preclude IPS moisture from entering turbine end bearing compartment.
- Purge timeline is consistant with baseline HPFTP ICD requirements.
- No change in purge supply pressure or temperature from that currently delivered to the baseline HPFTP.
- Purge port access is at Joint N16 which is located outside the heatshield similar to Joint N13 used for the baseline HPFTP.
- Bearing Drying Purge Line, 9R039138-1 (used during development test at SSC) connects Joint N15, which is located under the heatshield with Joint N18 on the HPOTP G3 flange.
- Bearing Drying Purge Line is exposed to 5010 psia GH_2 @ 290 degrees R and at a no flow condition during HPOTP mainstage operation (111% RPL).
- Dryness verification to be demonstrated on pre cert/cert units to preclude need to check at Joint G3.3 on flight units.
- Purge requirements must be assessed by Level II.

INTEGRATION

Purge Requirements

Post Shutdown Purge Requirements (FRF, Launch Abort, Flight)

Purge Description	Pressure (psia)		Temperature (R)		Flow (scfm)	Purge Timeline (Time from Engine C/O or After Landing)
	Design Nominal	Interface Variation	Design Nominal	Interface Variation	Design Nominal	
<u>Nitrogen</u> HPOT Bearing Drying (Alternate HPOTP)	600	± 50	590	+35 -55	241±50	← 24 hr.max → ; |← 8 hr.min →|
HPFTP Bearing Drying (Baseline HPFTP)	600	± 50	590	+35 -30	80±10	← 24 hr.max → ; |← 8 hr.min →|
HPOT Primary Seal Drain	40	± 5	590	+35 -55	50±20	(1)
HPOT Sec Seal Drain	40	± 5	590	+35 -55	50±20	(2)

(1) Purge until HPOT Primary Seal Drain effluent is within 5 degrees F of supply gas dew point.

(2) Purge until HPOT Secondary Seal Drain effluent is within 5 degrees F of supply gas dew point.

INTEGRATION

Major DVS-34 Requirements Requiring Hot Fire Verification

- POGO Pulse Testing: 6/94 or earlier
- Inflight/Zero-G Shutdown: 6/94 or earlier
- Hot Lox Testing: 9/93
- ICD min NPSP @ power levels < RPL: (TBD)
  - Stand capability 13.0 NPSP
  - 7.8 NPSP at 100% RPL and 6.0 NPSP at 65% RPL required
- Helium Ingestion Testing: 10/93
- Prelaunch Service Free Duration: 10/93
- Thrust Oscillations: 11/93
- Interface Loading/Vibrating Environment: 11/93
- Gimbal Capability Testing: 10/93

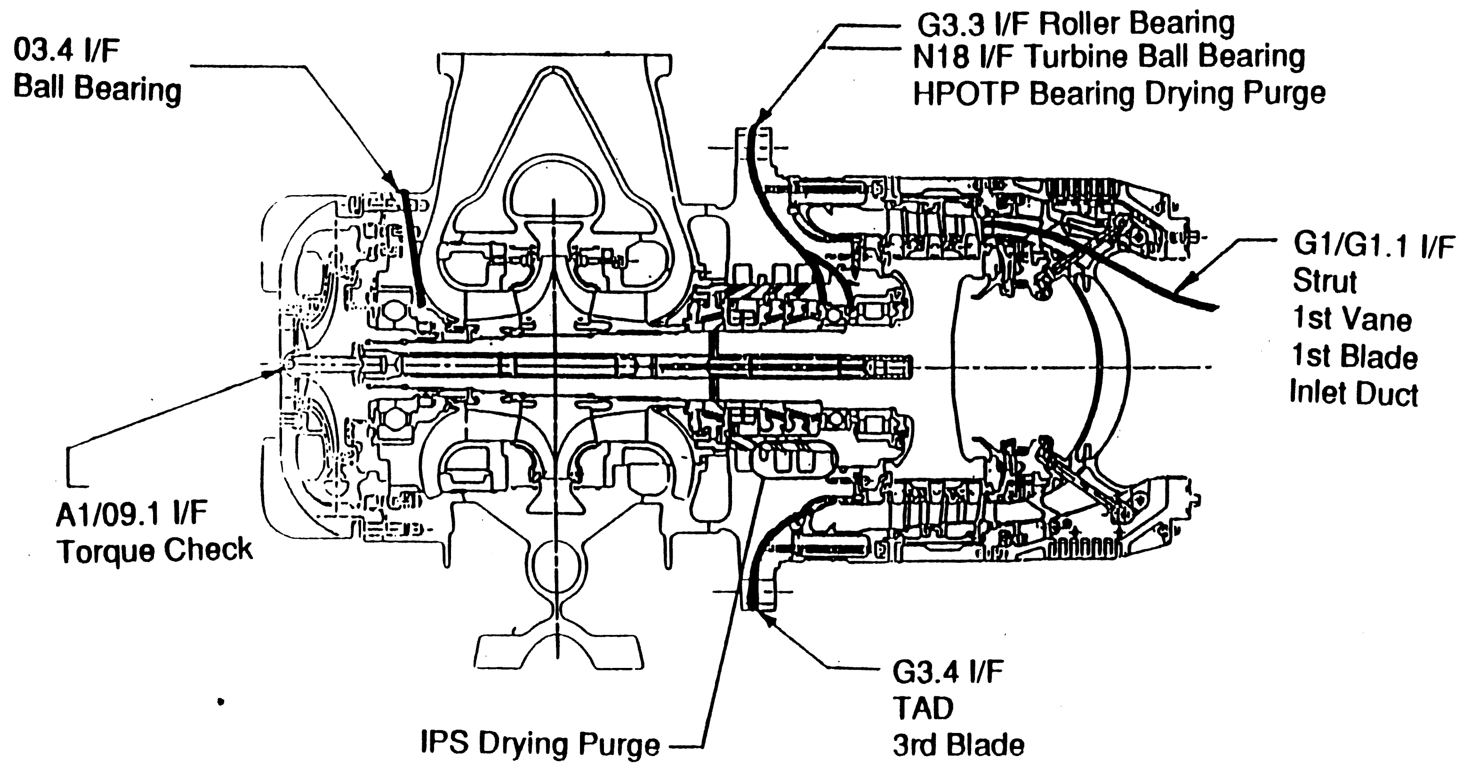
Current plan identifies one HPOTP sample per requirement to satisfy DVS-34 Requirements

HPOTP Interface Inspections and Checks (Post Test/Flight)

I/F	Name	Inspection/Checks Completed
G1/G1.1	Instrumentation Port	Turbine inlet housing including struts, 1st vanes, L.E. & pressure side of 1st blades
G3.4	Turbine Borescope Access	Turbine discharge including TAD, T.E. and suction side of 3rd blades, inner gas path seal
G3.3	Roller Bearing Borescope Access	Roller bearing (pump side) roller elements, races, cage
N18	Turbine End Ball Bearing Purge & Borescope Access	Turbine end ball bearing (pump side) balls, cage, outer race, forward half inner race. Roller & ball bearing drying & dew point test (Development Units Only)
O3.4	Ball Bearing Borescope Access	Pump end ball bearing (inlet side) balls, cage, outer race, & aft half inner race
Nozzle Exit	HPOTP Primary and Secondary Turbine Seal Drains	IPS drying
A1/09.1	Torque Access Port	Rotor breakaway & rotating torque. Also used to rotate pump for bearing & turbine blade inspection. Shaft axial travel checks is not required

INTEGRATION

HPOTP Interface Inspections and Checks



ALTERNATE TURBOPUMP DEVELOPMENT PROGRAM

CRITICAL DESIGN REVIEW

CDR Format/Guidelines/Schedule

Lynn Gambill
August 2, 1993

ATD HPOTP CRITICAL DESIGN REVIEW

Objectives

- Review ATD HPOTP
  - Baseline Design Configuration
  - System Compatibility
  - Maintainability
  - Producibility
  - Safety
  - Reliability
- Authorize Release of Baseline Design for Certification Testing

ATD HPOTP CRITICAL DESIGN REVIEW

CDR Format

- Presentations (Monday a.m., Friday a.m.)

- Splinter Session Meetings
  - Team Coordinator (P&W)
    (Lead Splinter Sessions, Follow Agenda)
  - Team Facilitator (NASA)
    (Action Items, Status)
  - Meetings held in Hardware Display Room and Presentation Center

- Coordinator and Facilitator Responsible for Presentations on Friday a.m.
  - Summary of Topic
  - Summary of Action Items
  - Dispositions of Action Items

ATD HPOTP CRITICAL DESIGN REVIEW

CDR Splinter Sessions

- Objective - Discuss, Resolve, Disposition Topics

TEAM #	TOPIC	COORDINATOR
1	Internal Flow Management	Joe Sawyer
2	Integration	Dan Guisinger
3	Structures	Rich Hammond
4	Component Dynamics	Stuart Montgomery
5	Rotordynamics	Dave Hudson
6	SRM & QA	Fred Vettori
7	IPS	Dan Guisinger
8	Performance	John Park
9	Materials	Chris Rhemer
10	Stackup/Assembly Procedures	Mike Quinlan

SSME/ATD CRITICAL DESIGN REVIEW

Agenda, August 3 - 6, 1993

Tuesday, 8/3/93		
Splinter Sessions		8:30-5:00
Wednesday, 8/4/93		
Team Update	Team Coordinator	8:30
Splinter Sessions		10:30
Thursday, 8/5/93		
Splinter Sessions		8:30-5:00
Friday, 8/6/93		
Team Reports	Team Coordinator	8:30
CDR Closure		12:30

NOTE: Wednesday, all Splinter Sessions end at 4:00pm - Barbecue begins at 5:00pm!

Block I SSME Integration Meeting
Block I Engine Definition/Description

PRATT & WHITNEY
ALTERNATE TURBOPUMP

ATD HPOTP

D.E. Guisinger

April 19, 1994

Alternate High Pressure Oxidizer Turbopump

Mass Characteristics (Flight)

- Per ATD HPOTP ICD

≈161 lbs > Roc Pump

	Dry	Wet
• Weight (lbs)	741	792
• Center of Gravity (inches)		
$X^{(1)}$	-3.12	-3.42
$Y^{(2)}$	0.03	0.03
$Z^{(2)}$	0.08	0.08

(1) X measurement taken from G3 flange with -X in direction toward pump end

(2) Y & Z measurements taken from pump centerline

	Dry	Wet
• Moments of Inertia (lb-sq.in) (about C.G.)		
Ix roll	16607	18021
Iy pitch	54547	56684
Iz yaw	54238	56374

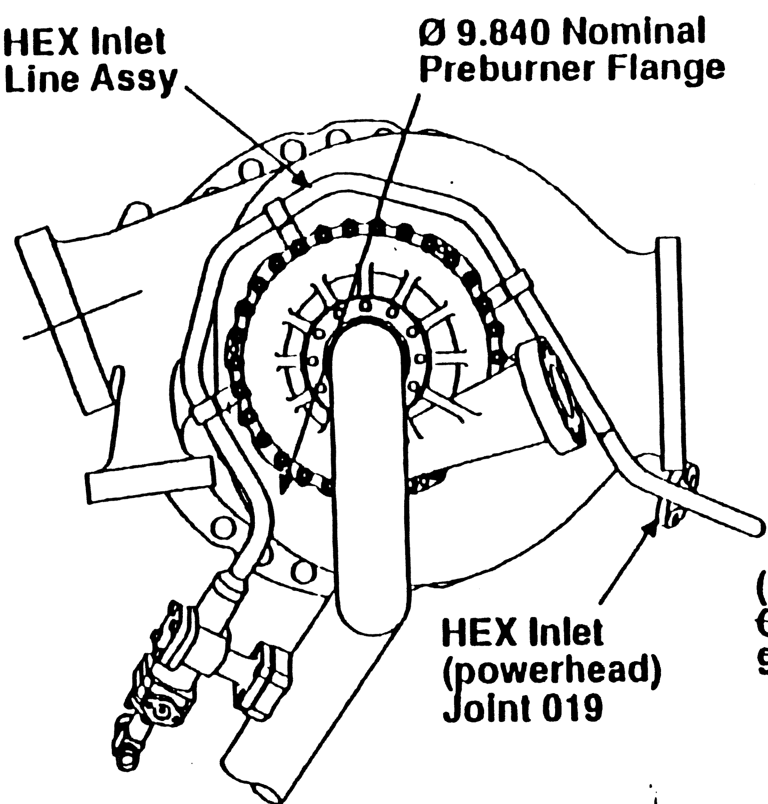
Alternate High Pressure Oxidizer Turbopump

Installation/Removal Requirements

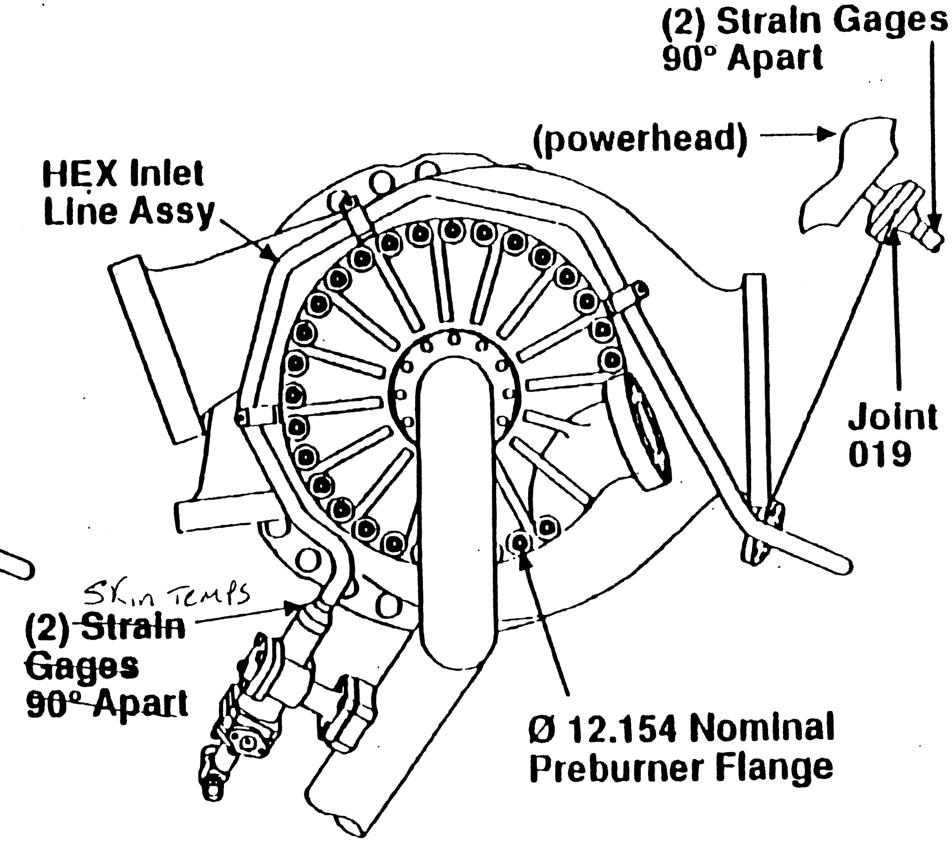
- Installation/Removal requirements same as baseline HPOTP except:
  - E Seals have replaced Omega Seals at G2
  - Primary Drain Manifold P/N 4751043-01 is removed from HPOTP prior to either operation (G3 Flange Stretch Procedure/Wrench Clearance)
  - Requires modified RG000202 HPOTP handler for either operation
  - HPOTP PWA15458 Manifold Covers and PWA15475 Drain Interface Covers are installed for all installation/removal operations (Replaces existing Rocketdyne RK covers/closures)
  - Requires new Heat Exchanger Supply Line (RS007083-TBD)
  - Requires new Turbine Bearing Drying Purge Line (R0039138-TBD)
  - Requires 1.85 in orifice plate sandwiched at Joint 05
  - Requires PWA15474 Rotator for rotor torque checks during installation
  - Requires ATD04986 Balance Cavity Adapters at Joints 03.1/03.2 (Green run only)

Alternate High Pressure Oxidizer Turbopump

Installation/Removal Requirements



Rocketdyne Config

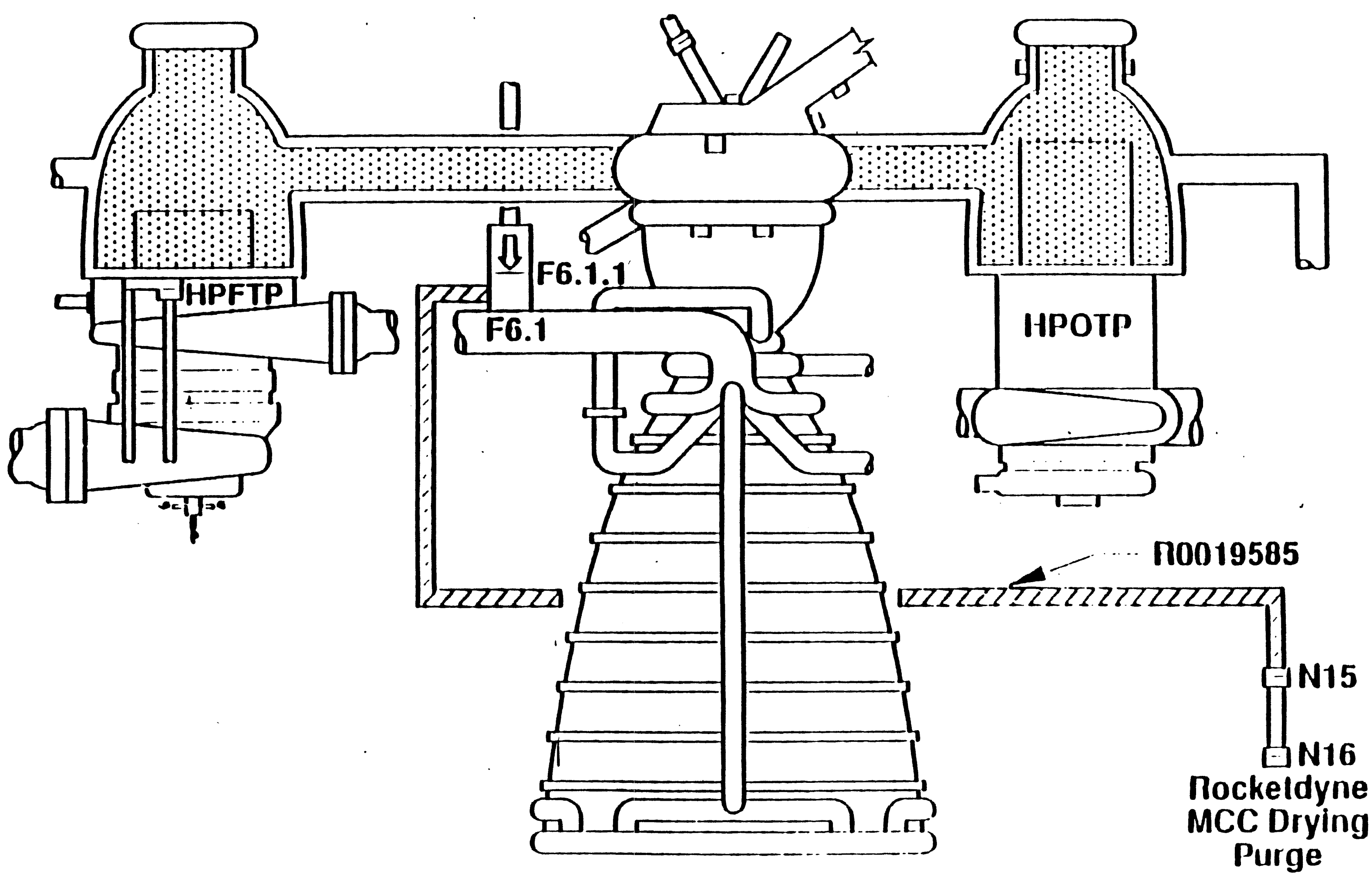


ATD Config

deg/pl/4/15/94.15

Alternate High Pressure Oxidizer Turbopump

Installation/Removal Requirements



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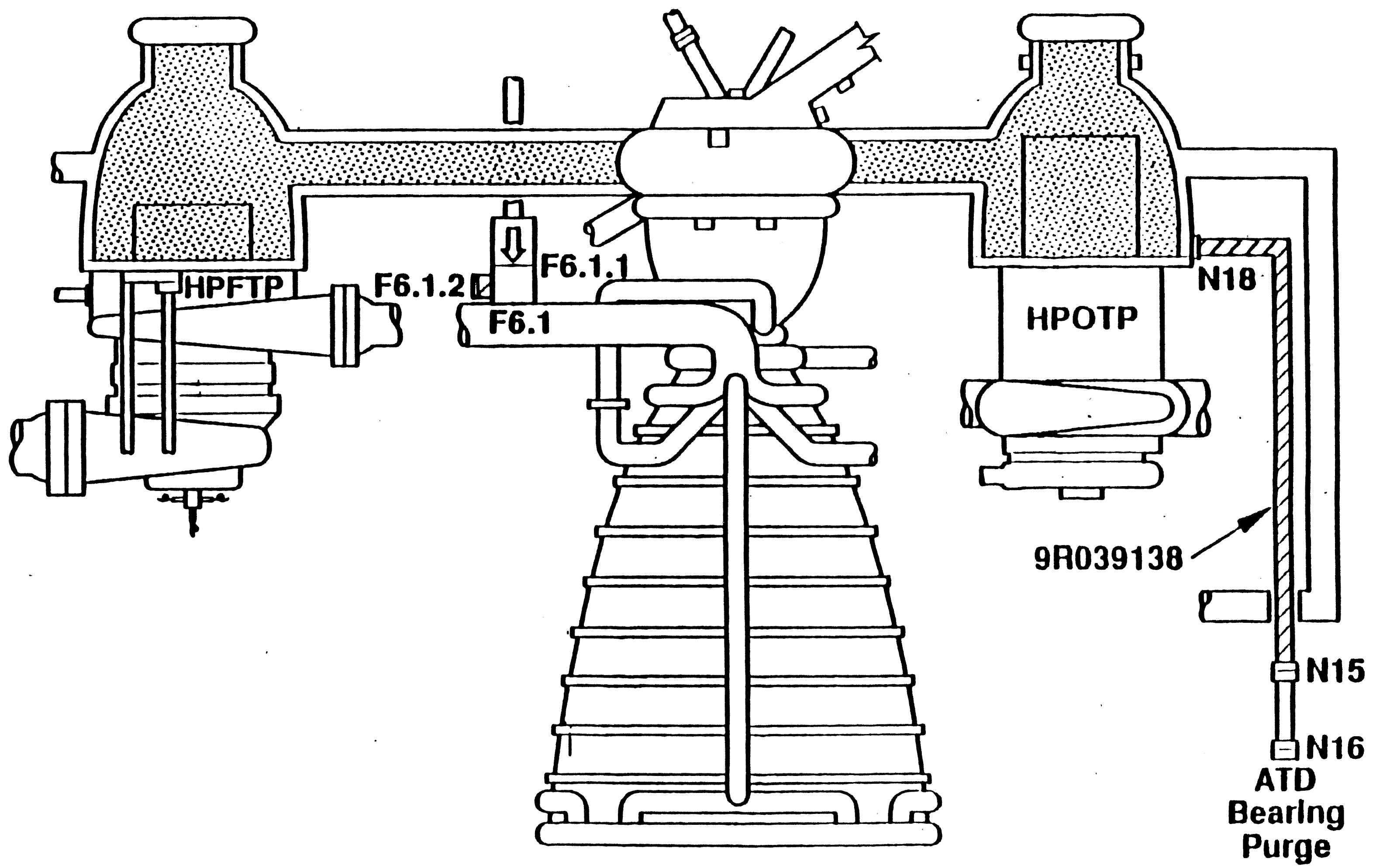
Alternate High Pressure Oxidizer Turbopump

Installation/Removal Requirements



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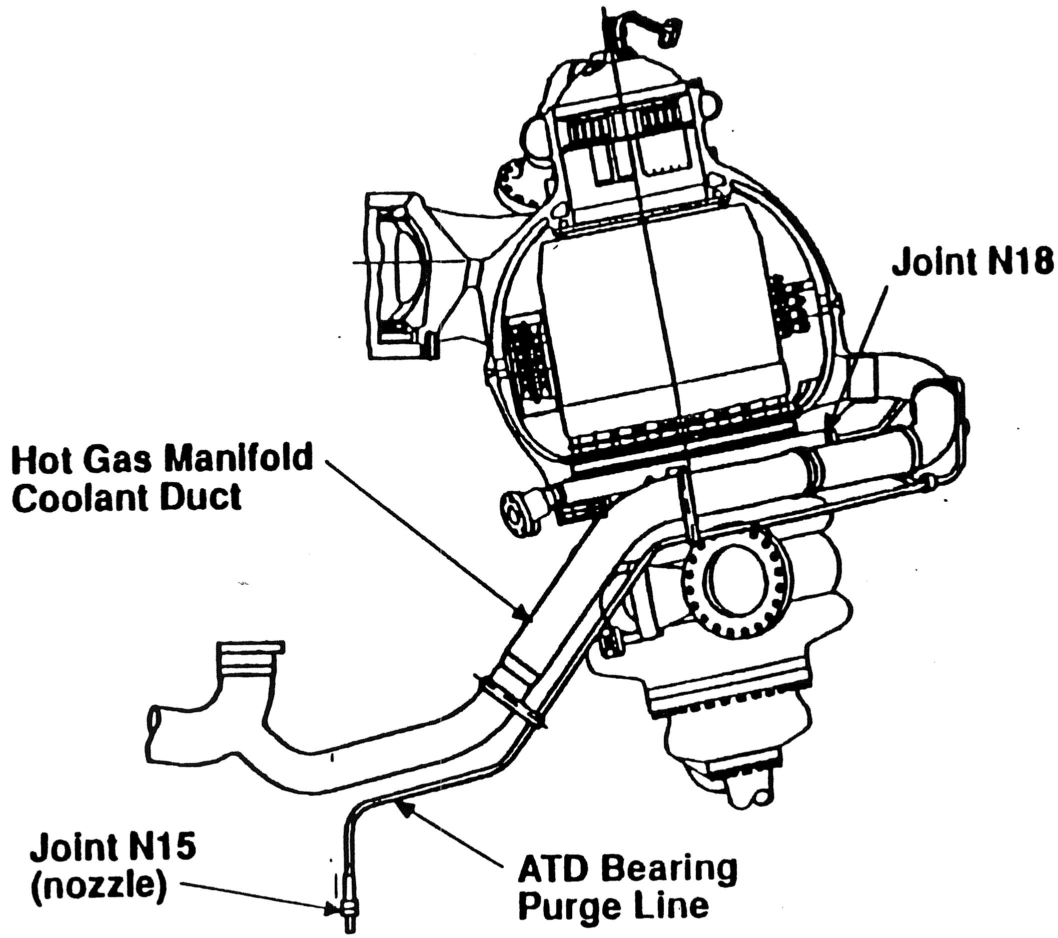
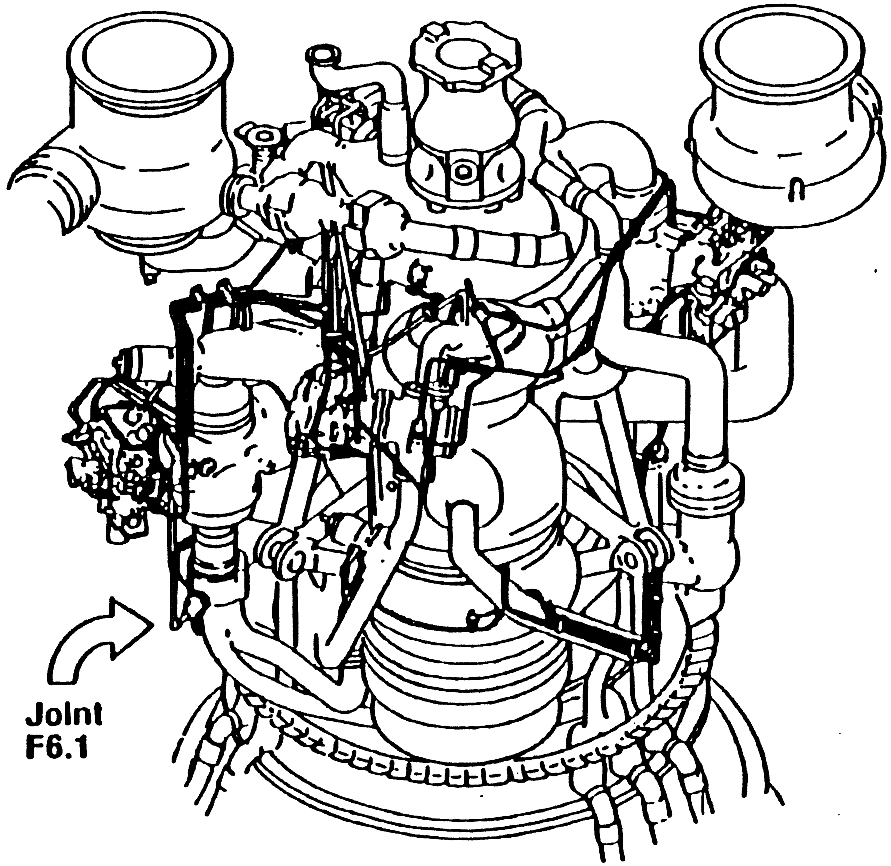
Alternate High Pressure Oxidizer Turbopump

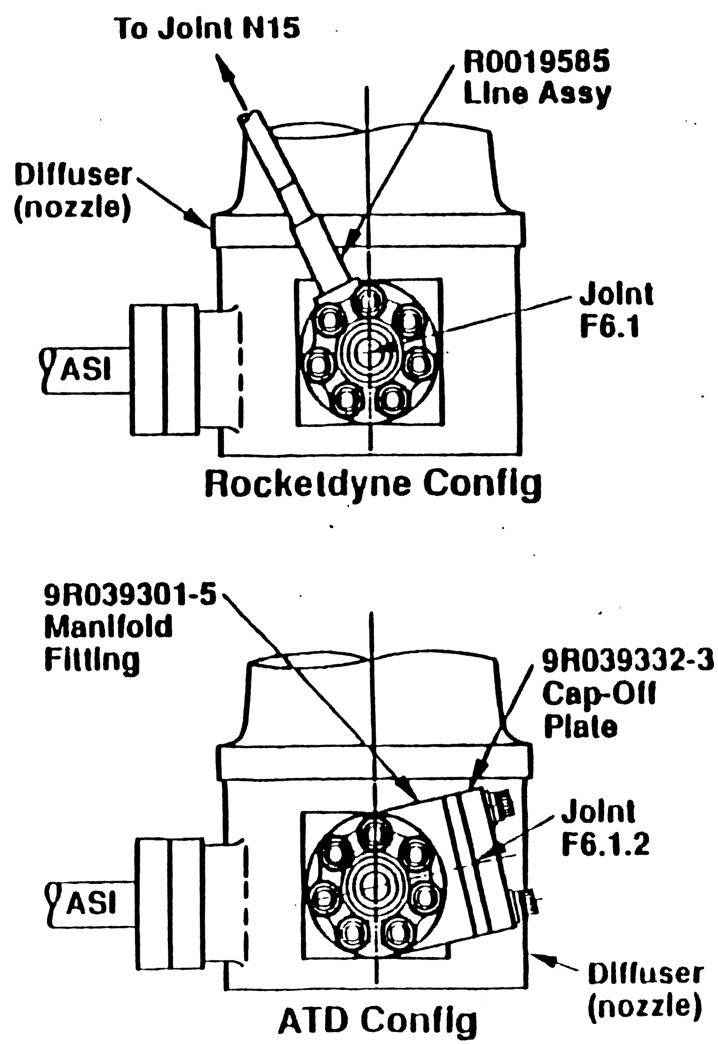
Installation/Removal Requirements



Alternate High Pressure Oxidizer Turbopump

Installation/Removal Requirements





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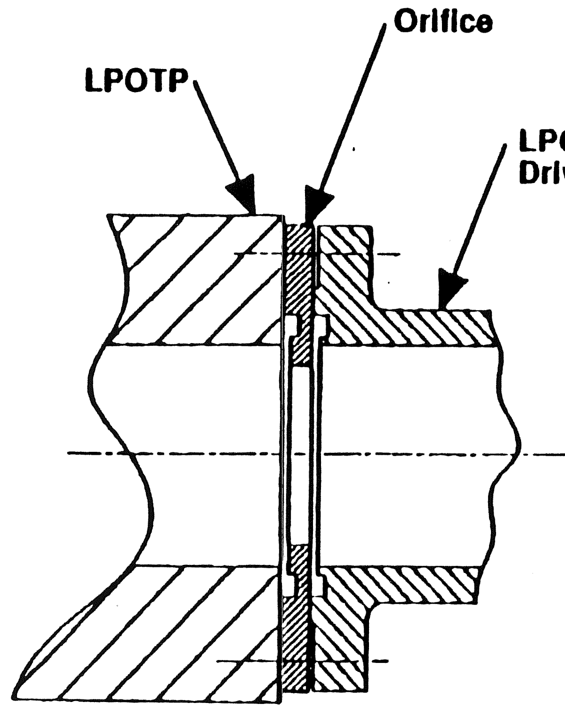
Alternate High Pressure Oxidizer Turbopump

Installation/Removal Requirements



Current Test Configuration
Sandwich Orifice Design

Alternate High Pressure Oxidizer Turbopump

Post Test/Mission Inspection Requirements

Inspection	Requirement
• Turbine Inlet, 1st Vanes Dome, Struts	R
• 1st and 3rd Blades	#
• Turnaround Duct	R
• Bearings (TERB,TEBB,PEBB)	#
• Inducers	#
• Main Impeller	#
• Rotor Torque	X
• Tiebolt Lock (If Torque>100 in-lbs)	X
• Bellows Heatshield	#
• External Visual	X
Key: R = Inspect when Turbopump Removed from Engine # = Inspection not Required Except for Cause X = Post Firing Inspection Required	

Removed every 5000 seconds ?

Alternate High Pressure Oxidizer Turbopump

Post Test/Mission Checks

- Checks
  - Rotor Torque checks are required
  - IPS Leak checks are not required
    - Primary, Secondary and Oxidizer Seal flow checks eliminated for Alternate HPOTP
  - IPS drying and dryness verification are not required
    - Hydrogen and helium flow out Primary/Secondary Turbine Seal Drains
    - Drying has been deferred on the past 17 tests at SSC with pre-cert HPOTPs
    - Dryness verification has verified IPS to be <27ppm spec requirement

      Turbine Primary Drain avg = 3.2 ppm

      Turbine Secondary Drain avg= 3.7 ppm
  - Eight hour HPOTP bearing drying is required, however, dryness verification (dew point check) has been eliminated

Alternate High Pressure Oxidizer Turbopump

Bearing Drying Requirement

- Post test/mission drying purge required for ATD HPOTP turbine ball and roller bearing components
- Drying to be initiated within 48 hours following landing, FRF or on-pad abort
- Eight (8) hour minimum drying required
- Purge introduced at Engine Joint N16 (outside heat shield)
  - New purge line, R0039138-TBD, required which connects to Joint N15 (engine) and Joint N18 (HPOTP)
  - Configuration change required at Joint F6.1
- GN_2 purge gas requirements
  - Temperature @ 590 + 35/-55 deg R
  - Pressure @ 600 $\pm$ 50 psia
  - Flow @ 241 $\pm$ 50 scfm
- Post drying dryness verification not required

Alternate High Pressure Oxidizer Turbopump

Redlines/LCCs (Flight)

Turbopump Redline Limits

Parameter	Shutdown Condition	Activate/ Deactivate	Limit
HPOT Turbine Discharge Temperature	Over Temperature	2.3/5.78 5.8/C/O	1560 R Max 1760 R Max
	Under Temperature	3.8/C/O	720 R Max
FASCOS	Excessive Vibration	5.0/C/O	11 Grms
HPOP IMSL Purge Pressure	Under Pressure	0.0/C/O C/O+	155 psia Min 155 psia Min

Launch Commit Criteria

HPOP IMSL Purge		PSN4 ± 2 min to E/S PSN2 to PSN4 ± 2 min	162 psia Min TBD* (100 psia min current LCC)

* *Analysis in work to determine if change to existing LCC required. ECD: 5/1/94*

Note: No PSN4 LCC currently envisioned for roller brg thermal conditioning. Analysis in work. ECD: 6/1/94

Alternate High Pressure Oxidizer Turbopump

Internal Seal Drain Leakage

Leakage Source	Leakage Exit Location	Operation Phase	Flow Media	Predicted ATD HPOTP (SCIM)	13M15000 (SCIM)
Primary Turbine	Drain Line at	Prelaunch	GHe	N/C	0
Seal Drain	Nozzle Exit		GN2	N/C	0
		Launch	GH2	10,632,700	4,700,000
		Re-Entry	GHe	N/C	0
Secondary Turbine	Drain Line at	Prelaunch	GHe	224,700	230,000
Seal Drain	Nozzle Exit	Launch	GH2	971,346	1,100,000
			GHe	208,600	230,000
		Re-Entry	GHe	N/C	1,400
HPOTP Oxidizer	Drain Line at	Prelaunch *	GOX	692,323	1,000,000
Seal Drain	Nozzle Exit		GHe	214,150	230,000
		Launch	GOX	307,508	250,000
			GHe	230,250	230,000
		Re-Entry	GHe	N/C	15,000

Roc Admits actual ≥ 1,200,000

** Oxygen overboard leakage during pre launch has not been quantified, CDR predictions listed. HPOTP Unit 6-4 test data indicates pressures to be high side of current pump experience. Effect of leakage on pad safety and/or lox drainback is TBD.*

Alternate High Pressure Oxidizer Turbopump

GSE (P&W provided)

- PWA15473 HPOTP Inspection Equipment Kit consisting of:
  - MAT3100PW 3mm flexible borescope – for 1st stage blade inspections
  - MA06VPW flexible vacuum borescope
  - PWA15474 HPOTP rotator

Note: Plan is to incorporate Kit into existing RG000020 Inspection Kit

- HPOTP Protective Devices consisting of:
  - PWA15470 N18 Borescope Access Cover
  - PWA15450 PB Inlet Protective Cover - Joint 010 Adapter
  - PWA15458 HPOTP Drain Manifold Covers
  - PWA15475 Drain Interface Protective Covers

Note: Plan is to incorporate devices into new RK395-00184 ATD HPOTP Protective Devices Kit

Block I SSME Integration Meeting
Block I Engine Integration Plan

ATD HPOTP

D.E. Guisinger

April 19, 1994

dog/pl/4/15/94.10

ATD HPOTP CERT: OPEN ACTION STATUS

Program Area: Integration

ITEM/REQUIRED ACTION	REQUIRED CLOSURE	PLANNED CLOSURE	STATUS
FR-22885-1 "HPOTP Acceptance Plan" (Green Run Spec) **- Provide Prel. Acceptance Criteria**	6/15/94 - CERT 9/15/94 - FLIGHT RL00461	4/29/94	**I/W - HPOTP Acceptance Criteria (limits will be based on pre-cert units test data)**
FR-22886-1 "HPOTP Hot Fire Cert Plan" **- Agreement on Cert reqmt's needed**	6/15/94	4/29/94	**I/W - Revised Plan presented to and approved by NASA with comments. Rocketdyne action to development Block I plan and provide for CERT.**
CP11371B "HPOTP ICD" **- Issue Rev C w/ approved PIRNs, RIDs**	6/15/94 - CERT 9/15/94 - FLIGHT 13M15000	5/16/94	**I/W**
CP11369B "HPOTP CEI" **- Issue Rev B w/ approved ECPs, RIDs, and Mods**	6/1/94 - CERT 9/15/94 - FLIGHT CP320R0003B	5/16/94	**I/W**

ATD HPOTP CERT: OPEN ACTION STATUS

Program Area: Integration

ITEM/REQUIRED ACTION	REQUIRED CLOSURE	PLANNED CLOSURE	STATUS
PWA - SP36182 "HPOTP Inspection Criteria" **- Provide accept/reject limits**	6/15/94 - CERT 9/15/94 - FLIGHT RF0001-053	5/16/94	**Post test inspection accept/reject limits being established. Format same as RKDN/KSC Specs/Maintenance Manual**
PWA-SP36183 "HPOTP Standard Field Repairs" **- Provide in-field standard repairs**	6/15/94 - CERT 9/15/94 - FLIGHT RSS8559, Vol 4	5/16/94	**I/W - standards to be similar to current practice at SSC and KSC**
ECP 93WA110 "HPOTP Flight Redlines and LCCs" **- Provide Flight IPS redlines and LCCs**	6/15/94 - CERT 8/5/94 - FLIGHT 13M15000 NSTS06327	5/6/94	**Currently rerunning matrix of redline protection vs. seal distress modes. ECD: 4/22/94. Plan to issue ECP 93WA110R2 summarizing results, redlines, LCCs for flight**
ECP 93WA118 "HPOTP Inspection Equipment" **- ECP is at MSFC for approval, plan to board on 4/18/94.**	6/15/94 - CERT 7/15/94 - FLIGHT RG000020	TBD	**ECP identifies P&W inspection equipment (ie borescope, rotators, etc.) to be qualified on Unit 9. Waiting MSFC Level III CCB approval**

DEG/pl-4/7/94

ATD HPOTP CERT: OPEN ACTION STATUS

Program Area: Integration

ITEM/REQUIRED ACTION	REQUIRED CLOSURE	PLANNED CLOSURE	STATUS
ECP 93WC005 - "HPOTP Drain Protective Covers" **-ECP approved by MSFC on 4/11/94**	6/15/94 - CERT TBD - Flight RK395-00184	TBD	**ECP provides drain interface and manifold protective covers which are to be qualified on HPOTP Unit 9 RKDN action to incorporate in RK Kit**
NSTS 07700, Vol X **- (4) deviations to P&W procedures identified and submitted, via Level IICR to MSFC for approval. MSFC plans to present to Level II: TBD**	6/15/94 - CERT TBD - Flight	TBD	**4 Level II CRs submitted 3/11/92** **• Selection of Materials & Processes (per SE-R-0006 vs. MIL-STD-506)** **•Identification of non-flight hardware (Class II vs. EI)** **• Fracture Critical Parts Analysis (per RSS-8589 vs. FR-19793)** **• Selection of Specifications and Standards (per MIL-STD-143B vs. MIL-STD-970)**
Plans/Agreements **JOA** **SSC OP** **- Update to reflect MR process, inspection responsibilities, etc.**	6/1/94 - CERT	5/16/94	**Negotiations in process between P&W, MSFC & RKDN to define MR process, identify responsibilities, etc.**

ATD HPOTP CERT: OPEN ACTION STATUS

Program Area: Integration

ITEM/REQUIRED ACTION	REQUIRED CLOSURE	PLANNED CLOSURE	STATUS
RL00050-04 "Hot Fire Spec" **-Update FEC 8391 for CERT**	6/15/94 - CERT 9/15/94 - Flight	5/6/94	**I/W - FEC and Spec are being marked to update reqmt's for CERT. FEC planned for CERT; Class I ECP required to revise spec (RKDN)**
RL00663 "SSME Post Hot Fire Drying Procedure" **- Update FEC 8387 for CERT**	6/15/94 - CERT 9/15/94 - Flight	5/6/94	**I/W - Same as above**
RF0004-131 "HPOTP Install/Removal Procedure" **- Update FEC 8390 for CERT**	6/1/94 - CERT 7/15/94 - Flight	5/6/94	**I/W - Same as above**
RF0004-126 "HPOTP Internal Inspection Spec" **- Update FEC 8397 for CERT**	6/15/94 - CERT TBD - Flight	5/16/94	**IW - FEC and Spec are being marked to update requirements for CERT. FEC is planned for CERT; Class I ECP required to revise Spec (RKDN)**

ATD HPOTP CERT: OPEN ACTION STATUS

Program Area: Integration

ITEM/REQUIRED ACTION	REQUIRED CLOSURE	PLANNED CLOSURE	STATUS
RF0001-053 "SSME Inspection Criteria"	6/15/94 - CERT	5/16/94	I/W - FEC and Spec are being marked to update reqmt's for CERT. FEC planned for CERT; Class I ECP required to revise spec (RKDN)
-Update FEC 8398 to incorporate PWA-SP36182 limits.	9/15/94 - Flight		
RK395-00182 or RK395-00184 "Protective Devices Kit"	6/1/94 - CERT	5/6/94	I/W - Same as above
- Update FEC 8395 for CERT	TBD - Flight		

- PWA15470 Borescope Access Cover- on order, 5/2/94
- PWA15450 PB Inlet Protective Closure - available
- PWA15458 HPOTP Drain Manifold Covers - on order, 5/20/94
- PWA15475 Drain Interface Protective Cover - available
- PWA15473 HPOTP Inspection Equipment - on order, 5/15/94
  - MAT 3100PW Kit -3mm Borescope - available
  - MA06VPW Kit - Flexible Vacuum Borescope - available
  - PWA15474 Rotator- on order, 5/15/94

ATD HPOTP CERT: OPEN ACTION STATUS

Program Area: Integration

ITEM/REQUIRED ACTION	REQUIRED CLOSURE	PLANNED CLOSURE	STATUS
FR-21279 "Maintenance Plan" **-Update post CDR - Incorporate RID actions**	90 days after CDR 10/1/94 - Flight RSS-8559-2-1	8/1/94	**I/W - document is on schedule for release**
FR-21977 "Maintenance Requirements Plan" **-Update post CDR - Incorporate RID actions**	90 days after CDR 10/16/94 - Flight OMRSD	3/11/94	**Preliminary document issued at (MSFC request) to MSFC and KSC so that OMRSD revisions can be started. Final document to be issued on 8/1/94**
FR-22154 "Hazard Analysis Plan" **-Release production level hazard analysis**	7/15/94 Flight dates coordinated w/MSFC Level III SSRP. SIP reqm't - TBD	7/15/94	**I/W - Delivered prel. fault tree 7/93; Prel. draft doc. 12/93. Final doc. due 7/94 with updates on 12/94 and 3/95. SSRP status briefing scheduled @ MSFC on 4/19/94**
FR-22159-1 "FMEA/CIL" **-Formatting, incorporate design changes**	4/29/94 SIP Reqm't - TBD	4/29/94	**I/W - Document is being reformatted per MSFC direction. Incorporate CDR RID actions and Delta CDR design changes**

BLOCK 1 ENGINE CONFIGURATION DOCUMENTATION INTEGRATION (ATP)

- OBJECTIVE:
  - INSURE THAT ALL ATP RELATED DOCUMENTATION IS IN PROPER ORDER TO SUPPORT BLOCK 1
- APPROACH:
  - IDENTIFY BLOCK 1/ATP RELATED DOCUMENTS
  - REVIEW DOCUMENTS FOR NEEDED CHANGES
  - DEFINE SCOPE OF EFFORT & TIME FRAME TO ACCOMPLISH CHANGES
  - COLLECT INPUT FROM ALL FACILITIES/FUNCTIONS - ELEVATE TO SCHEDULES
  - IDENTIFY CONFLICTS IN NEED/COMPLETE DATES
  - NEGOTIATE COMPROMISE OR WORK AROUND
  - REVIEW SCHEDULES FOR COMPLETENESS

BLOCK 1 ENGINE CONFIGURATION DOCUMENTATION INTEGRATION (ATP)

- STATUS
  - INPUT RECEIVED FROM NASA, RD, KSC, & P&W
  - RD - DOCUMENTS CONTINUE TO BE IDENTIFIED
  - KSC - CLOSE TO 100% OF NEEDS COMMUNICATED
  - NASA - NEEDS AND TIME FRAMES NEED DEFINITION
  - P&W - INFORMATION AVAILABLE TO BE ELEVATED TO SCHEDULES
  - SSC, JSC
- PLANS:
  - CONTINUE TO COLLECT INFORMATION, ELEVATE TO SCHEDULES, REVIEW SCHEDULES FOR CONFLICTS AND COMPLETENESS

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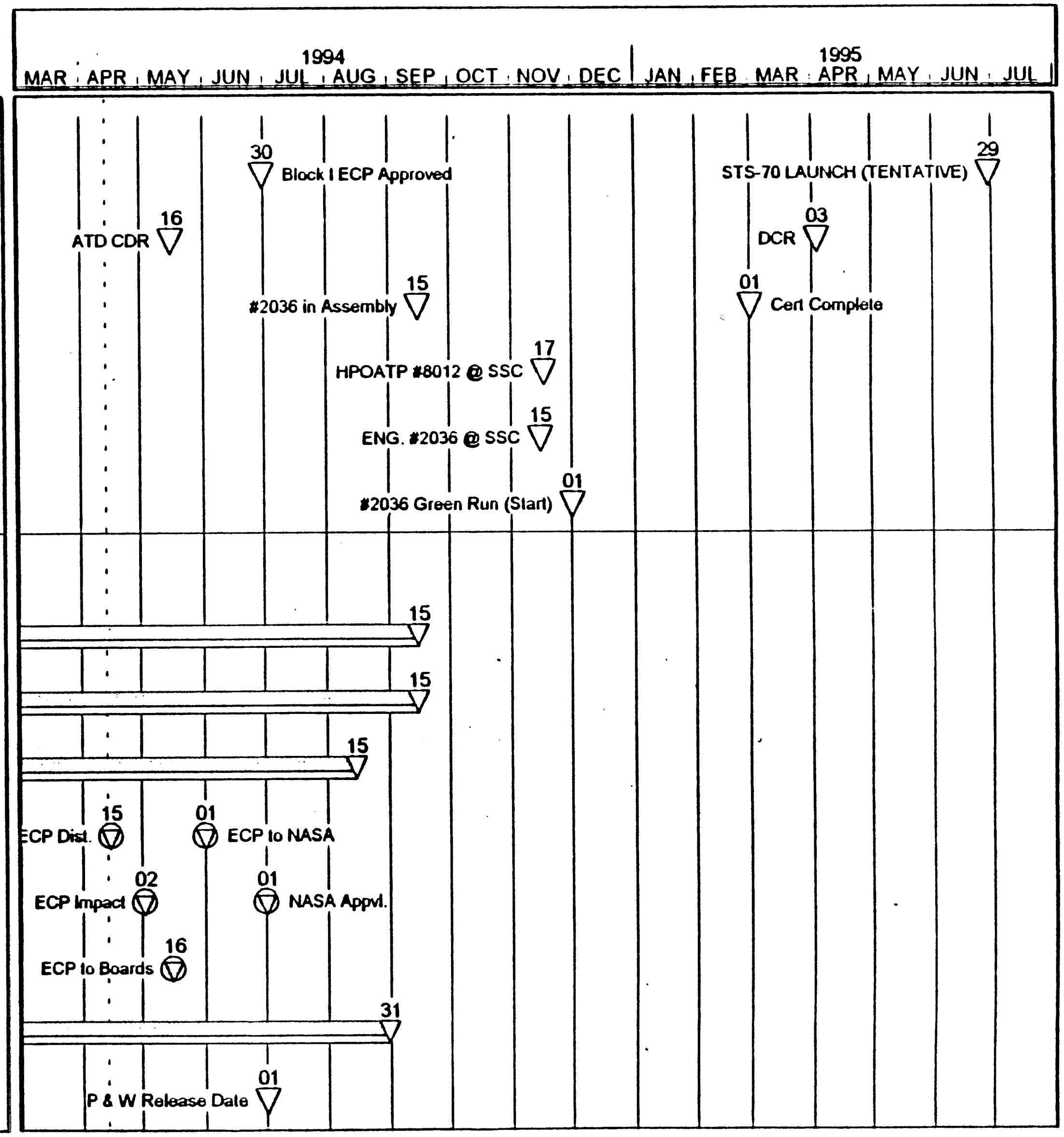
STATUS DATE: 14APR94

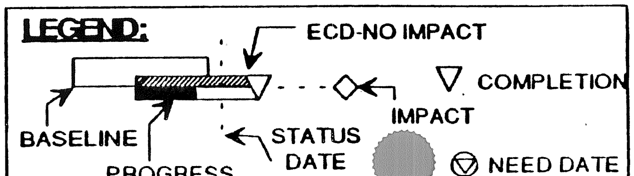
BLOCK I ENGINES

ATD DOCUMENTATION

PRELIMINARY DATA ONLY

Doc #	Description	Responsibility
	Block I ECP Approved	
	ATD CDR	
	#2036 in Assembly	
	HPOATP #8012 @ SSC	
	ENG. #2036 @ SSC	
	#2036 Green Run (Start)	
	SPECIFICATION DEVELOPMENT	
CP320R0003	CEI Specification	Bennett/Lincoln
13M15000	ICD Specification	Bennett/Lincoln
ECP - Block I	Engine Installation Dwg. Release	Eldib/Larson/Seitz
	ECP Dist.	
	ECP Impact	
	ECP to Boards	
FR19634-7	P & W Quality Program Plan	Surynt/Hritz/Garcia
	P & W Release Date	





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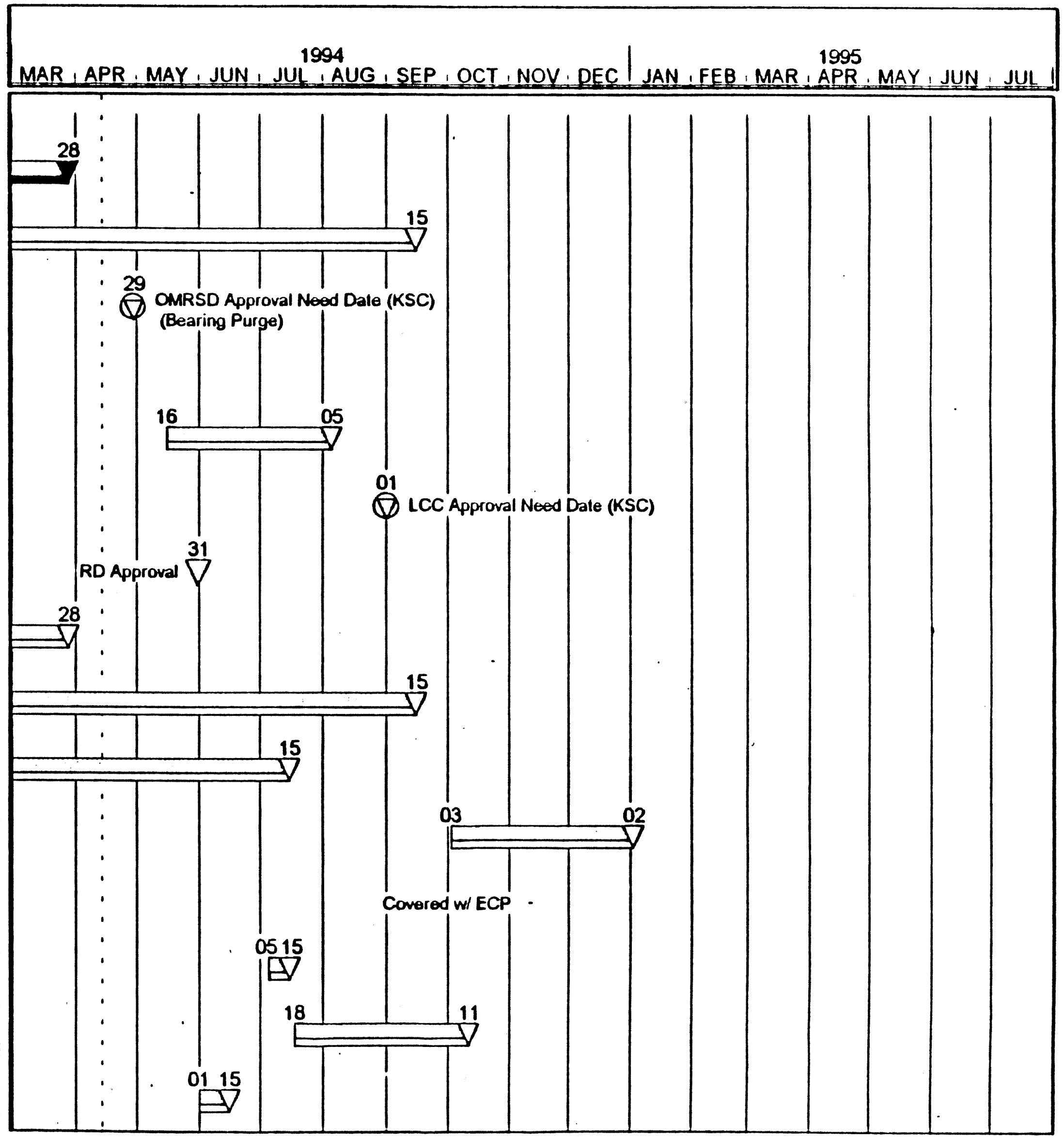
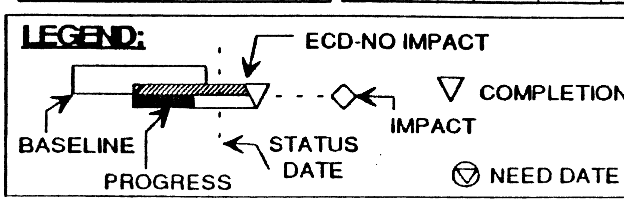
PRELIMINARY DATA ONLY

Doc #	Description	Responsibility
NSTS08117	COFR	Hausman/Crane
NSTS08171	OMRSD	Fernandez/Crane/Whitne
	OMRSD Approval Need Date (KSC)\ (Bearing Pu	
NSTS08327	System Integration Plan	Kotila/Crane
NSTS16007	LCC	Kan/Crane
	LCC Approval Need Date (KSC)	
ECP93WA110R	P & W Redline ECP	Guisinger
PCIN42070A	Level II CR	Bennett/Lincoln/MSFC
RG001124-1	LOBE Wrench	Lewis/Carroll
RG001167	Transducer Adapter Assembly	Lewis/Carroll
R-9983	SSME Maintenance Plan Vol's I,II,III, & IV	Caldwell
R0019351	Loose Equip. List	Wong
R037863	Orifice Plate	Wong
R037863	Planning & Fab.	Wong
R039301	MCC Drying Adapter	Wong





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BLOCK I ENGINES

ATD DOCUMENTATION

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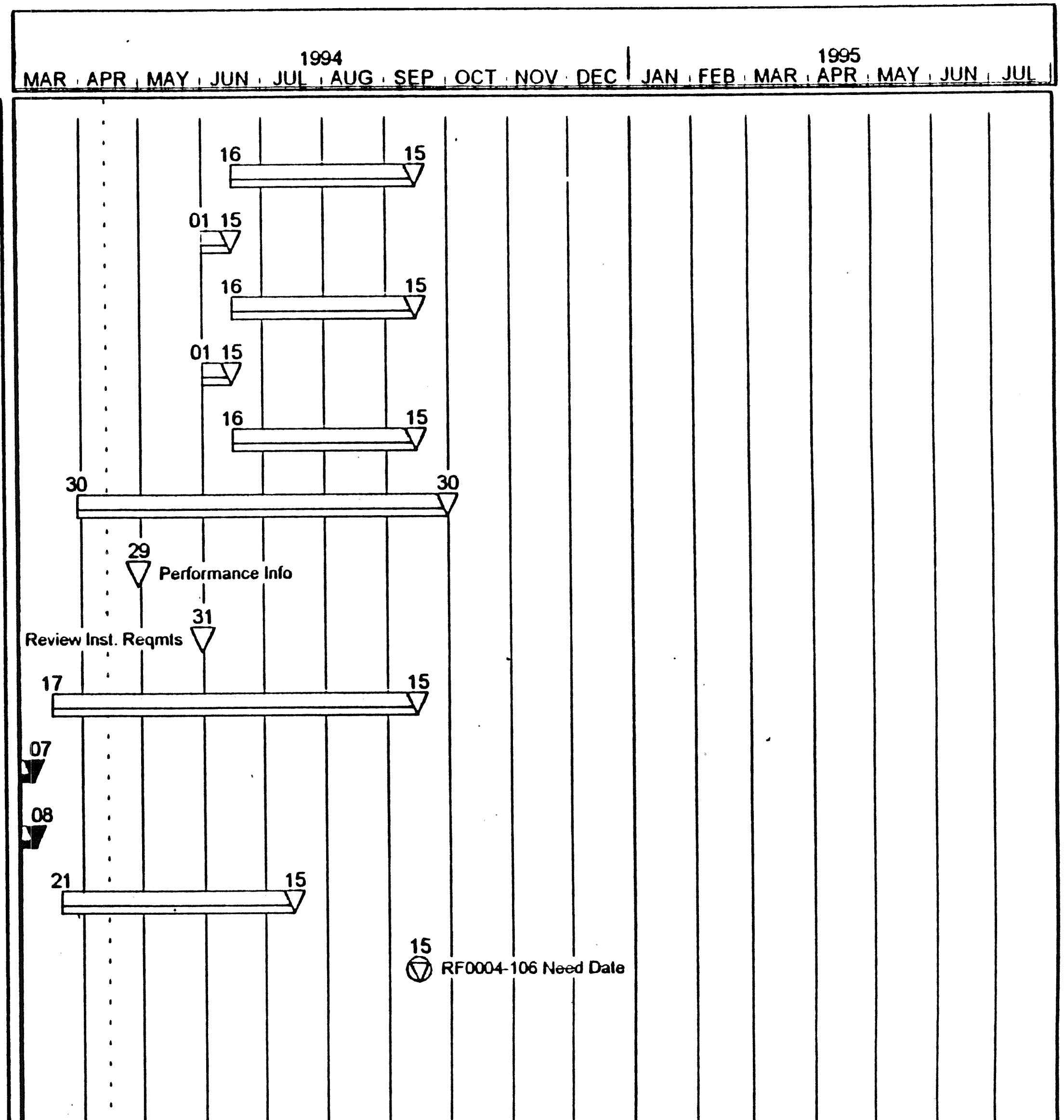
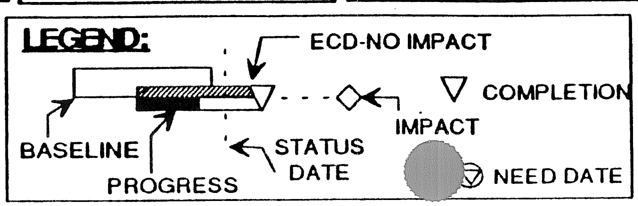
STATUS DATE: 14APR94

PRELIMINARY DATA ONLY

Doc #	Description	Responsibility
R039301	Planning & Fab.	Wong
R039332	Adapter Cap	Wong
R039332	Planning & Fab.	Wong
R039138	ATD Bearing Purge Line	Wong
R039138	Planning & Fab.	Wong
RA0201-050	Accept. Test Instr. Reqmts	Heim
	Performance Info	
	Review Inst. Reqmts	
RF0001-053	SSME Inspect. Criteria	Bennett/Plourde
RF0001-080	HPOTP Turbine Shield	Roschak
RF0004-019	Tracking Spec.	Pennock
RF0004-106	Remove/Install HPOTP-Assembled Eng.	Lewis
	RF0004-106 Need Date	
RF0004-125	Retrieval Equip. Prep.	German
RF0004-126	Retrieval of Foreign Objects	German





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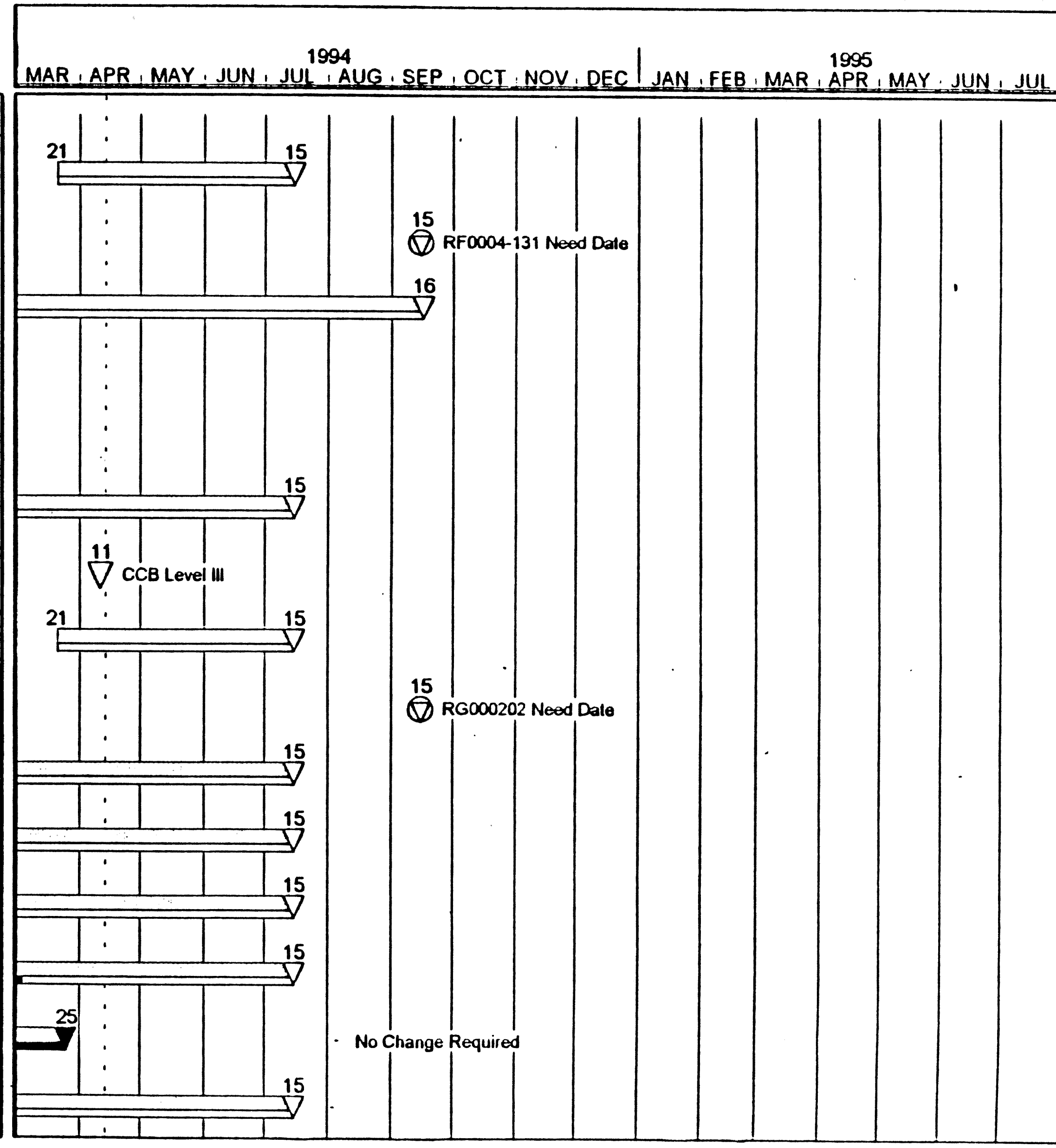
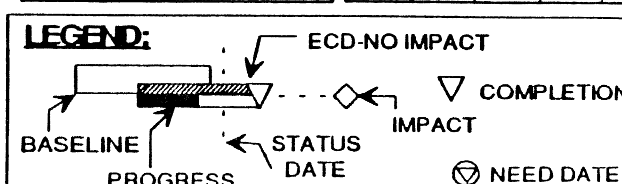
BLOCK I ENGINES

ATD DOCUMENTATION

PRELIMINARY DATA ONLY

Doc #	Description	Responsibility
RF0004-131	Remove/Install HPOTP-from Engine	Lewis
	RF0004-131 Need Date	
RF0005-009	SSME Component Fleet Leader Reqmts	Bennett/Skopp
RG000009	Handler Sling	Lewis/Carroll
RG000017	Tool Set	Lewis/Carroll
RG000020	Internal Inspection Set - ECP93WA118 (P&W)	Lewis/Carroll
	CCB Level III	
RG000202	HPOTP Handler	Lewis/Carroll
	RG000202 Need Date	
RG001541	Extensometer Pump Set	Lewis/Carroll
RG001542	Extensometer Set	Lewis/Carroll
RG001668	MCC Drying Adapter	Lewis/Carroll
RK395-00150	Protective Devices	Yobs/Keller
RK395-00162	Protective Devices	Yobs/Keller
RK395-00184	Protective Devices (ECPWC005)	Yobs/Keller





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BLOCK I ENGINES

ATD DOCUMENTATION

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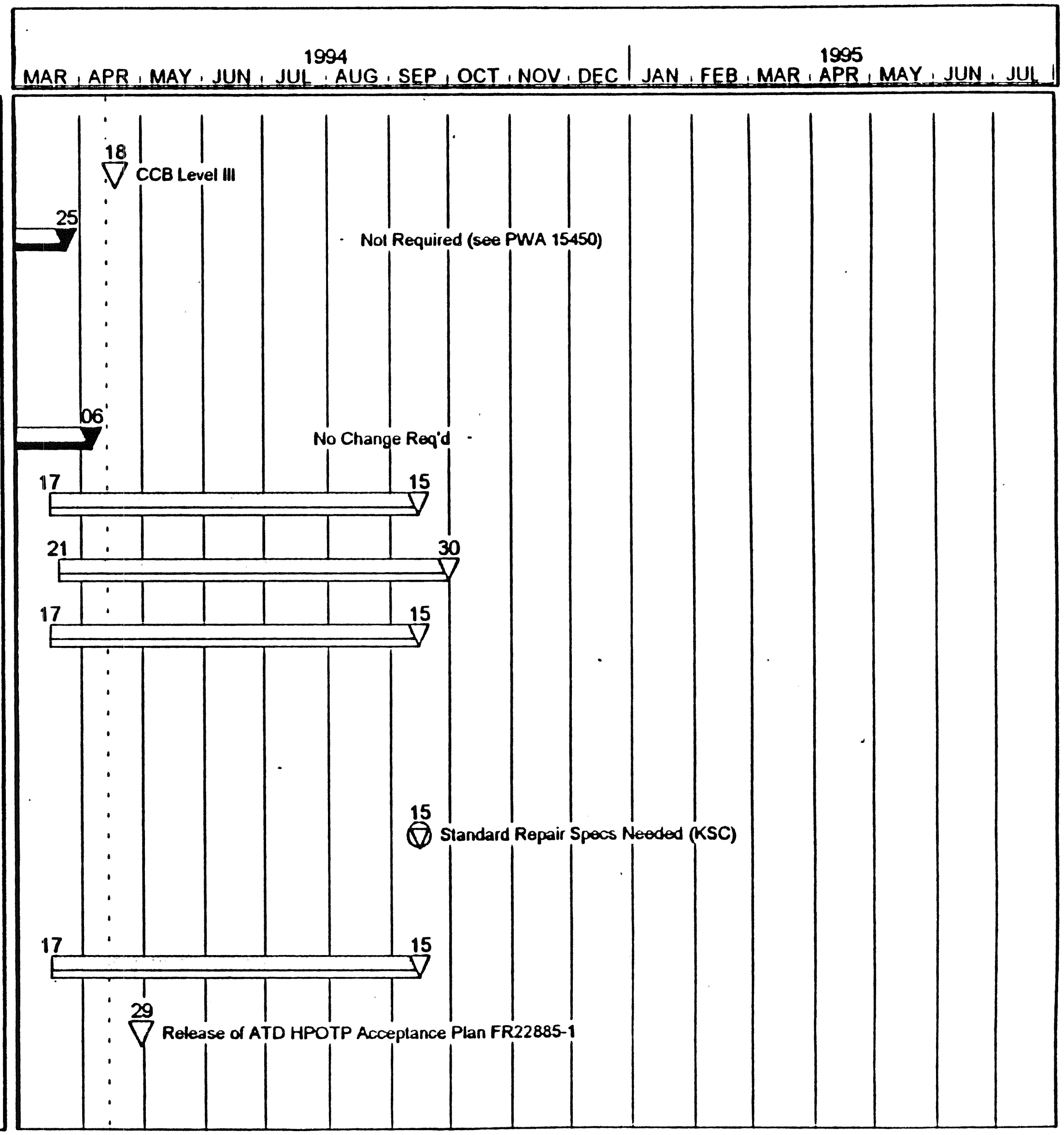
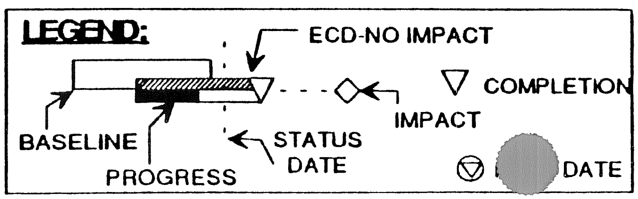
STATUS DATE: 14APR94

PRELIMINARY DATA ONLY

Doc #	Description	Responsibility
	CCB Level III	
RK395-44118	Closures/Adapters	German
RL00039	Elect. Harness-Mock up & Install	Hill
RL00042	SSME Process Grouping Spec.	Bennett
RL00047	Handling, Shipment & Storage	Yobs/Keller
RL00050-04	Accept. Test, Calib. & Adjust.	Bennett/Plourde
RL00051-03	Accept. Test Data Processing & Reduction	Daumann
RL00056-06, 07	Final Inspect & Accept Procedure-Test Stand	Bennett/Plourde
RL00059	Overhaul/Recycle/Repair Reqmts	Wong/Iam
	Standard Repair Specs	Cuadros/McKeon
	Standard Repair Specs Needed (KSC)	
RL00144	Doc's for Design & Construct of Component	Dean
RL00461	Component level Hot Fire Testing Proced.	Bennett/Plourde
	Release of ATD HPOTP Acceptance Plan FR228	
RL00470	T-Pump Assy. HPOTP Service/Overhaul	Williams/Dean





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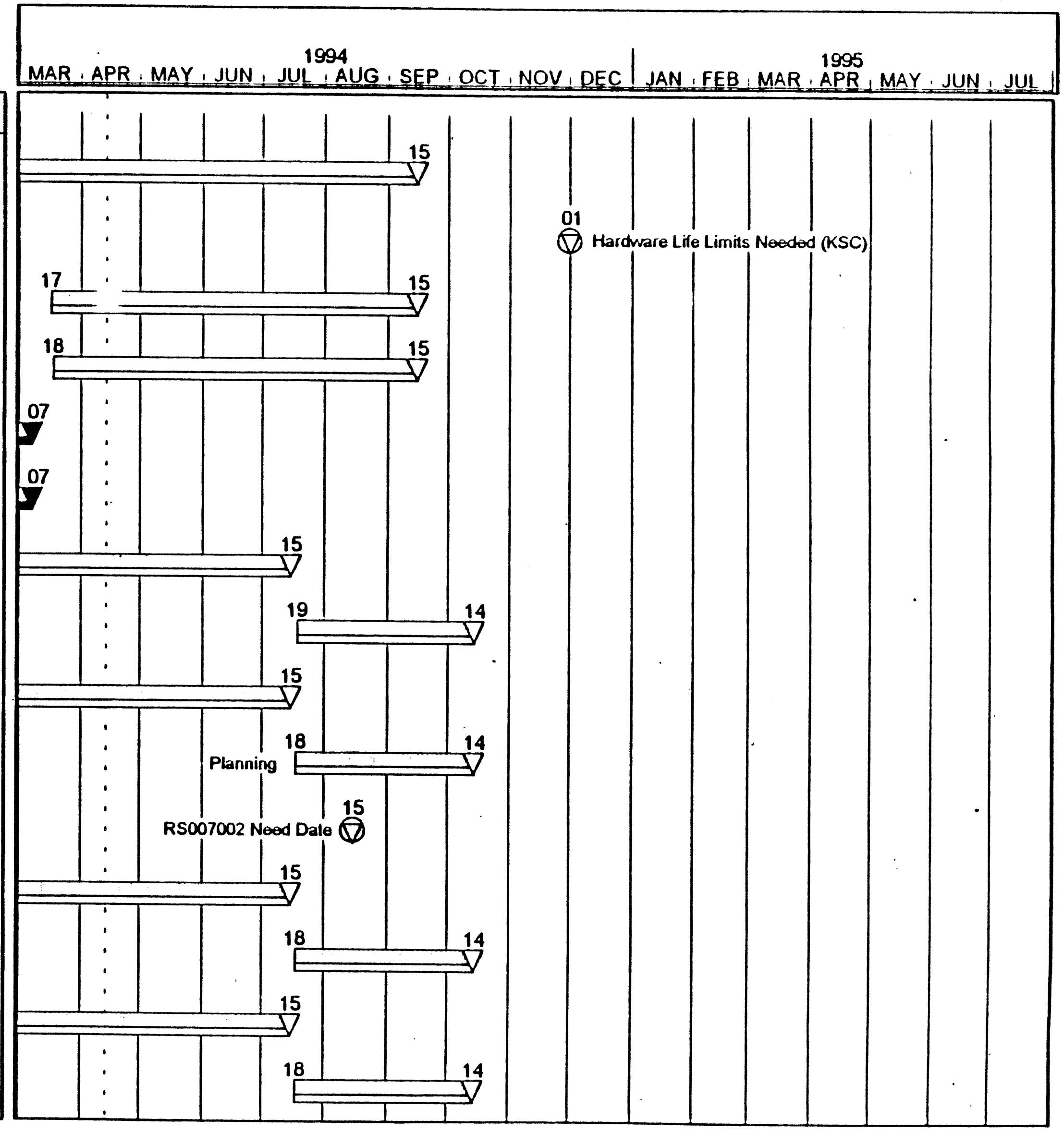
BLOCK I ENGINES

ATD DOCUMENTATION

PRINT DATE: 15APR94 14:49
STATUS DATE: 14APR94

PRELIMINARY DATA ONLY

Doc #	Description	Responsibility
RL00532	Component Allowable Life & Tracking Reqmts	Bennett/Skopp
	Hardware Life Limits Needed (KSC)	
RL00663	Post Hot Fire Drying Proced.	Bennett/Plourde
RL0071L	Encapsulation Leak Check	Bennett
RL00703	HPOTP Turbine Housing Sheet Metal Inspect.	Roschak
RL01034	HPOTP Micro Shaft Travel	Roschak
RS007001	Engine Assembly - Release	Wong
RS007001	Planning	King
RS007002	Turbopump Installation	Wong
RS007002	Planning	King
	RS007002 Need Date	
RS007003	Propellant Feed System	Wong
RS007003	Planning	King
RS007004	HEX Supply Line Installation Dwg.	Wong
RS007004	Planning	King



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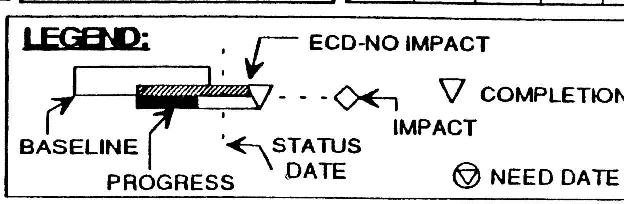

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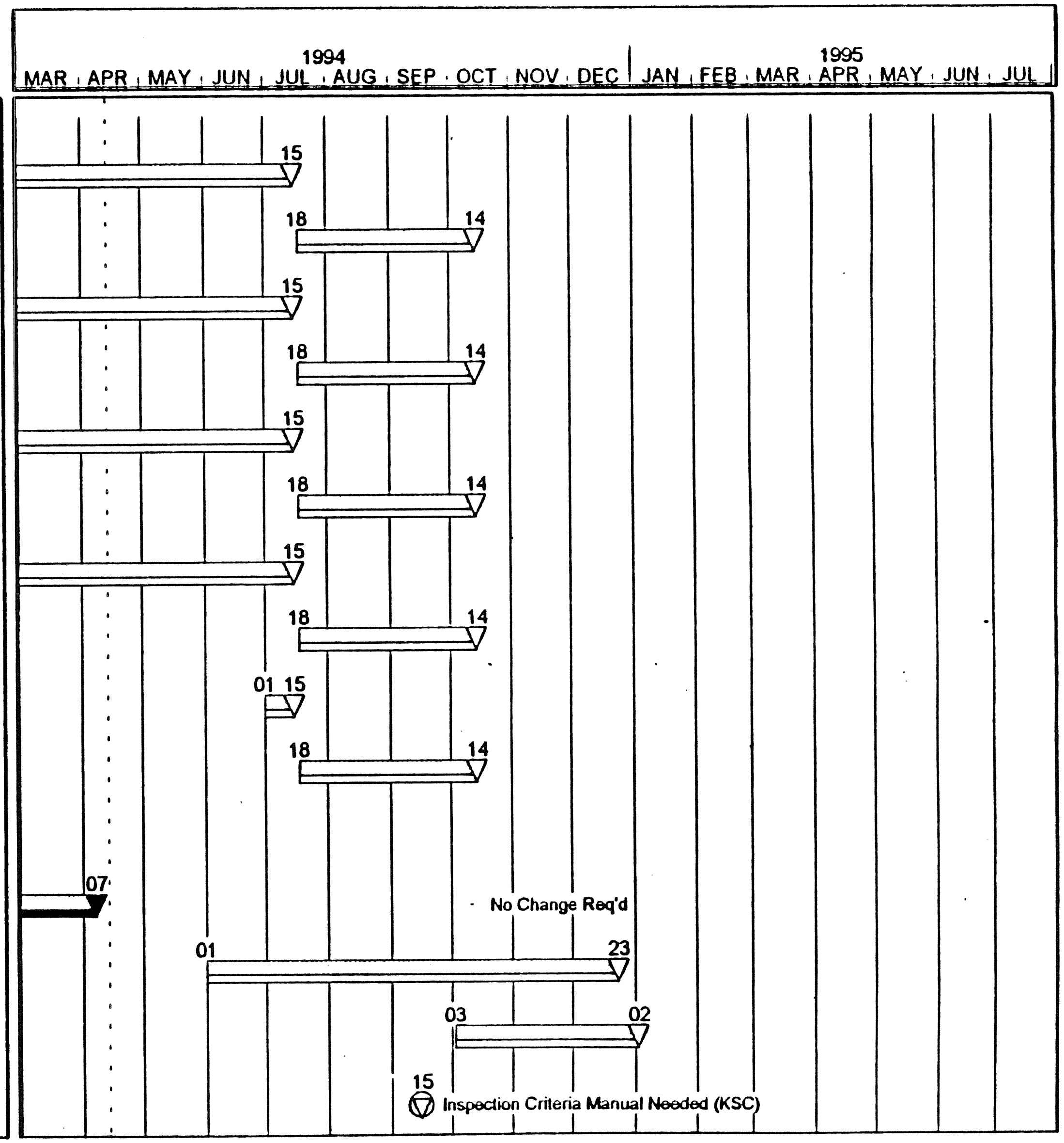
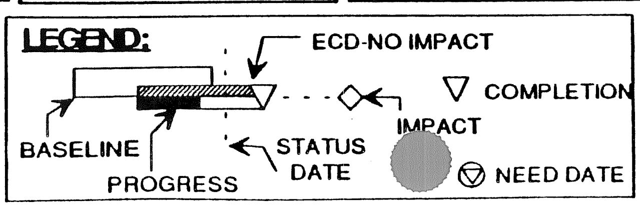
BLOCK I ENGINES

ATD DOCUMENTATION

PRELIMINARY DATA ONLY

Doc #	Description	Responsibility
RS007005	Bearing Purge Line Install. Dwg.	Wong
RS007005	Planning	King
RS007006	Drain System	Wong
RS007006	Planning	King
RS007007 &007R	Electrical System	Wong
RS007007 & 007007R	Planning	King
RS007009	Test Instrumentation Dwg.	Wong
RS007009	Planning	King
RS007083	ATD Heat Exchanger Line	Lee (Avionics)
RS007083	Planning	Rehn (Avionics)
RS007285	Line Assembly	Wong
RS007701	Turbopump Assembly	Wong
RSS-8503-3	SSME CM Plan (Invoke ATD ICD)	Tafoya
RSS-8559-2-1	Intermed. Level Maintenance (Shop Man	Lewis/Caldwell
	Inspection Criteria Manual Needed (KSC)	





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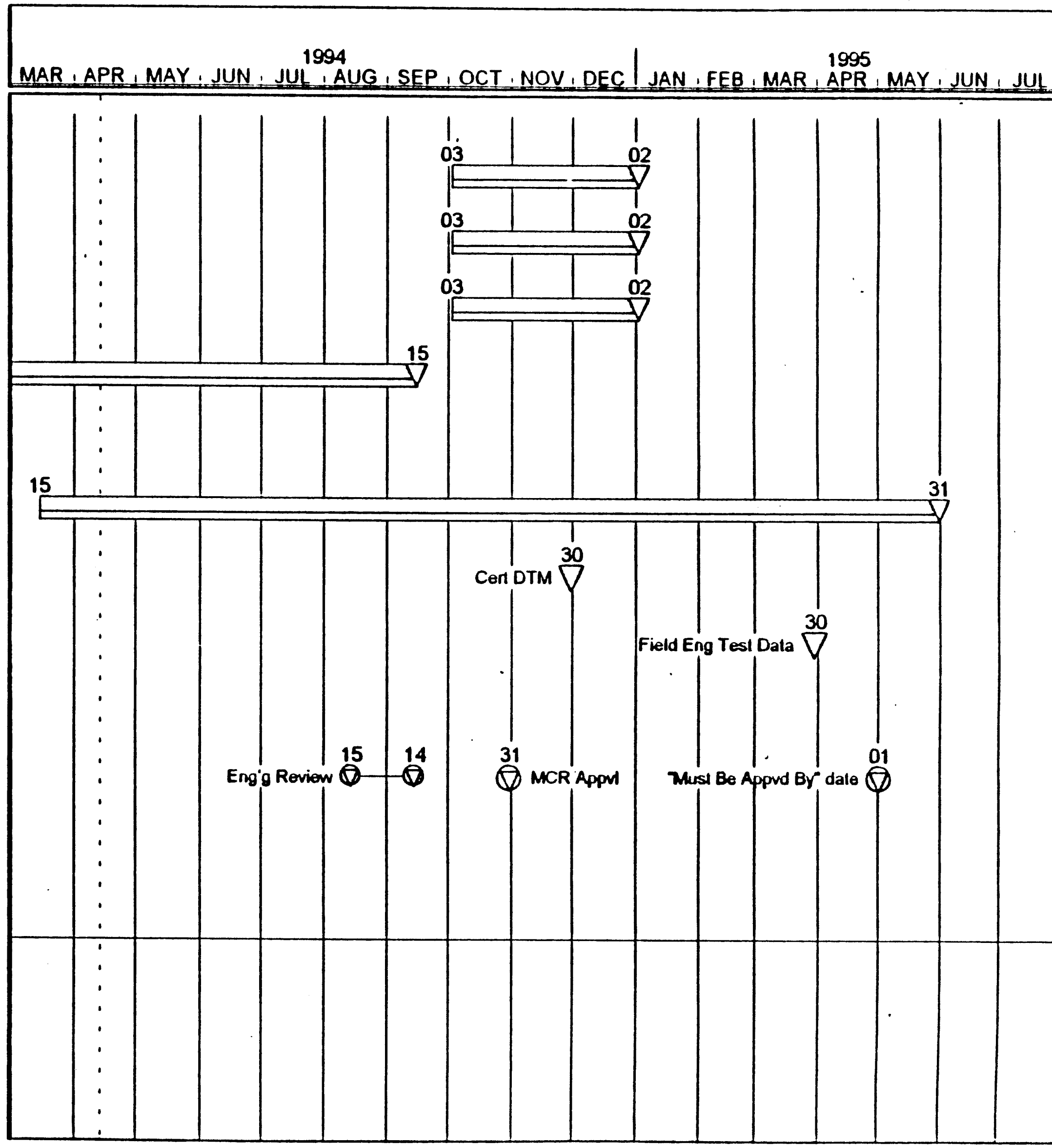
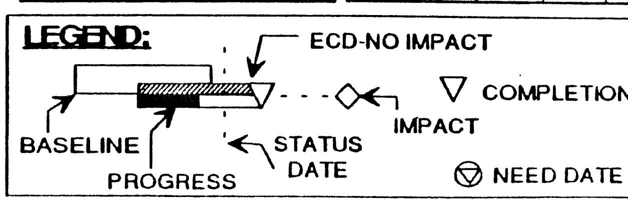
PRELIMINARY DATA ONLY

Doc #	Description	Responsibility
RSS-8559-1-1-7	Inspect. Criteria-Launch/Landing	Lewis/Caldwell
RSS-8559-1-3-x	Ground Support Equipment	Lewis/Caldwell
RSS-8559-2-1 Vol III	Illustrated Parts Breakdown	Lewis/Caldwell
RSS-8561	Structural Loads Criteria	Bennett/Skopp
	Component Accept. Review	Crane/Spencer
	Digital Transient Model	Daumann
	Cert DTM	
	Field Eng Test Data	
	ES&P	Varner/Garcia
	Block I FMEA/CIL	Spencer
RSS8503-7	RD Quality Plan	Garcia/Graf
	FRR	Breeden/Crane/Plourde
	Interface Dwgs	Eldib/Wong
RS007015	LPOTP Discharge	Eng.
RS007035	LPOT Drive	Eng.





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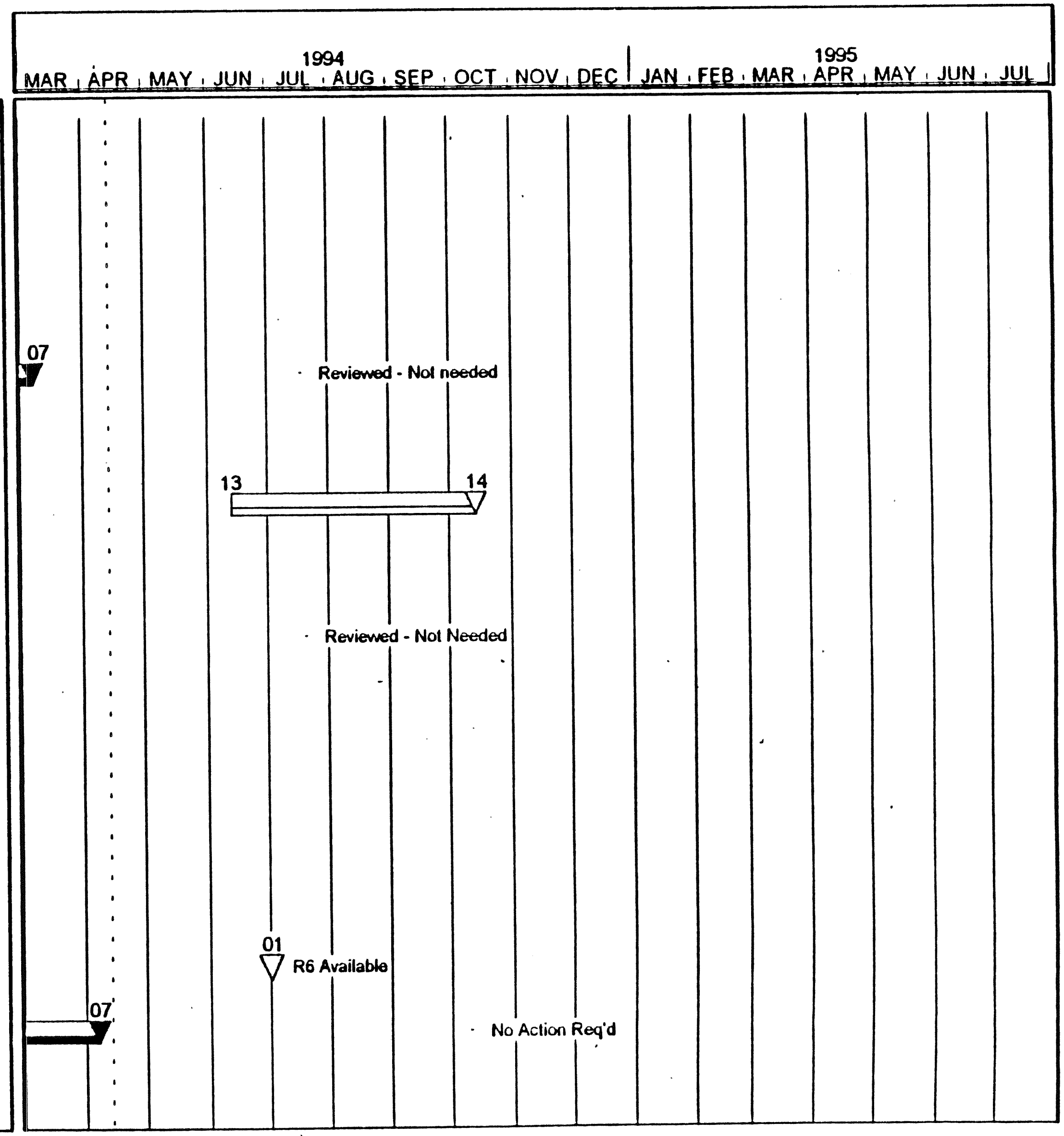
BLOCK I ENGINES

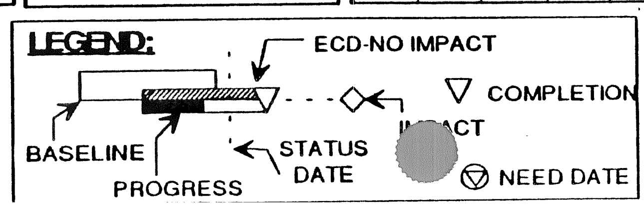
ATD DOCUMENTATION

PRINT DATE: 15APR94 14:51
STATUS DATE: 14APR94

PRELIMINARY DATA ONLY

Doc #	Description	Responsibility
RS007021	HPOTP Discharge	Eng.
RS007029	PB Pump Inlet	Eng.
RS007032	PB Pump Discharge	Eng.
	Joint Operating Agreement	ATD Group
	KSC Operating Plan	Twisdale
	Power Balance Model	Daumann
	RAR's	Bennett/Seitz/Hausman
	SSC Operating Plan	ATD Group
	SSC Engineering Inst.	Smith/Cobb
	KSC OMI	Chilton/Plourde Fernandez
	M. R. Process (Flight)	Johnson
RF0004-004	UCR Process (Flight)	Garcia
	Dynamic Environment	Strauss
RSS8559-4	Config. I. D. & Status Report	Caldwell
RSS8610	CDR Package (Engine & GSE)	Johnson





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BLOCK I ENGINES

ATD DOCUMENTATION

PRELIMINARY DATA ONLY

Doc #	Description	Responsibility	Schedule (1994: MAR APR MAY JUN JUL AUG SEP OCT NOV DEC; 1995: JAN FEB MAR APR MAY JUN JUL)
RSS8670	Operational and Flight Support Pgm	Feight	06; No Action Req'd
RSS8559-3-1&-2	Ground Support Equip LRU Intermed. Maint. Da	Caldwell	07; No Action Req'd
RSS8983	SSME Maintenance Plan	Feight	
RSS8665	SSME Supply Support Plan	Feight	
RSS8539	Reliability Requirement Spec.	O'Kelley	
RSS8540	Parts List & Approval Status	Brown	
RSS8568	Internal Design Review - Minutes	Johnson	
RF0005-007	Material & Process Spec List	Dean/Johnson	
RSS8587	Safety Analysis Report	Bietzel	
RSS8503-9	GSE List & Description	Caldwell	05; No Action Req'd
RSS8560	Component Stress Analysis Report	O'Connor	
RSS8561	Struct. Loads Report	O'Connor	
RSS8562	Design Criteria Report	O'Connor	
RSS8617	Material Control Plan	Fransden	
RSS8656	SSME Flight Report	Seitz	

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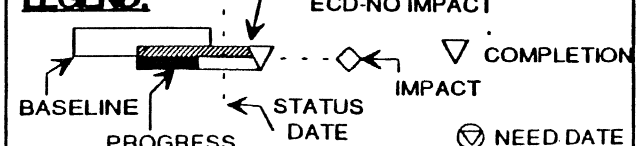

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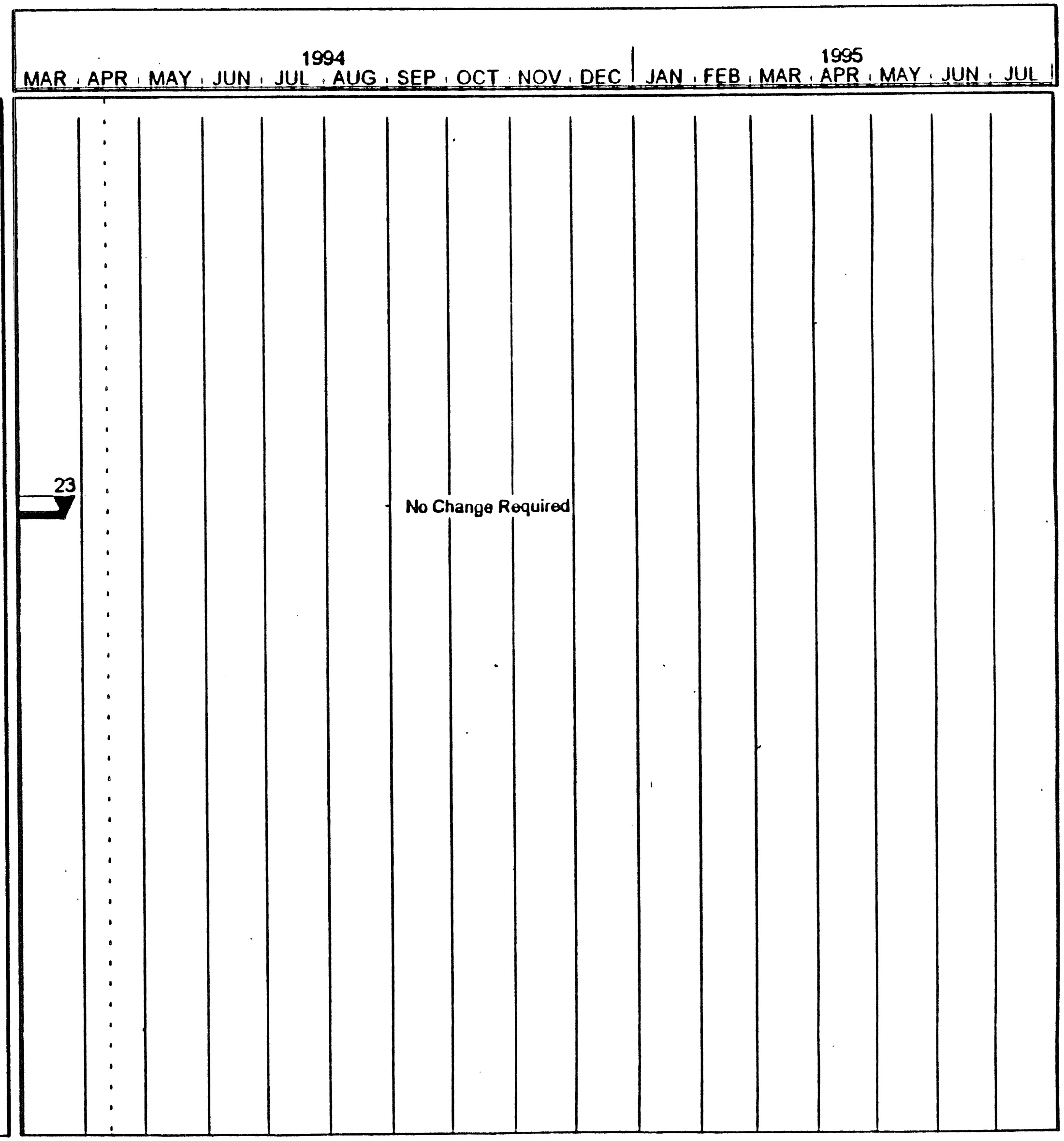
BLOCK I ENGINES

ATD DOCUMENTATION

PRINT DATE: 15APR94 14:52
STATUS DATE: 14APR94

PRELIMINARY DATA ONLY

Doc #	Description	Responsibility
RSS8660	SSME Verification Requirements Spec.	Ebert
RSS8694	SSME Hardware Life Management Plan	Ebert
RSS8680	Design Verification Spec. (Phase II+)	Blewett
RSS8672	Phase II & II+ Flight Cert. Extension Service	Ebert
RSS8842	100%-104% RPL Flight Cert Hot Fire Demo Plan	Ebert
RSS8600	Material Characterization Plan	Meisels/Abesamis
RES/RC7001	Vib. in Workmanship Testing	J. Klea
RES/RC7002	Vib. in Workmanship Testing	E. Acosta
RES/RC7004	Vib. in Workmanship Testing	E. Acosta
RES/RC7005	Vib. in Workmanship Testing	E. Acosta
RES/RC7007	Vib. in Workmanship Testing	J. Klea
RES/RC1008		B. McWade
	Impact To Component "Qual" (DVS)	
CM-001-8	DR - Configuration Identification Lists	Geiger/McFarlen/Seitz
CM-001-9	DR Configuration Status Reports	Geiger/McFarlen/Seitz



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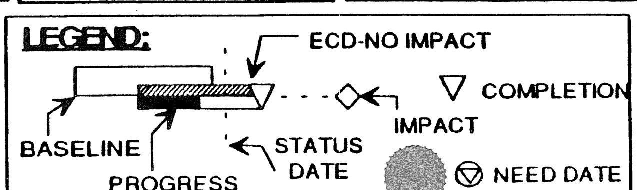

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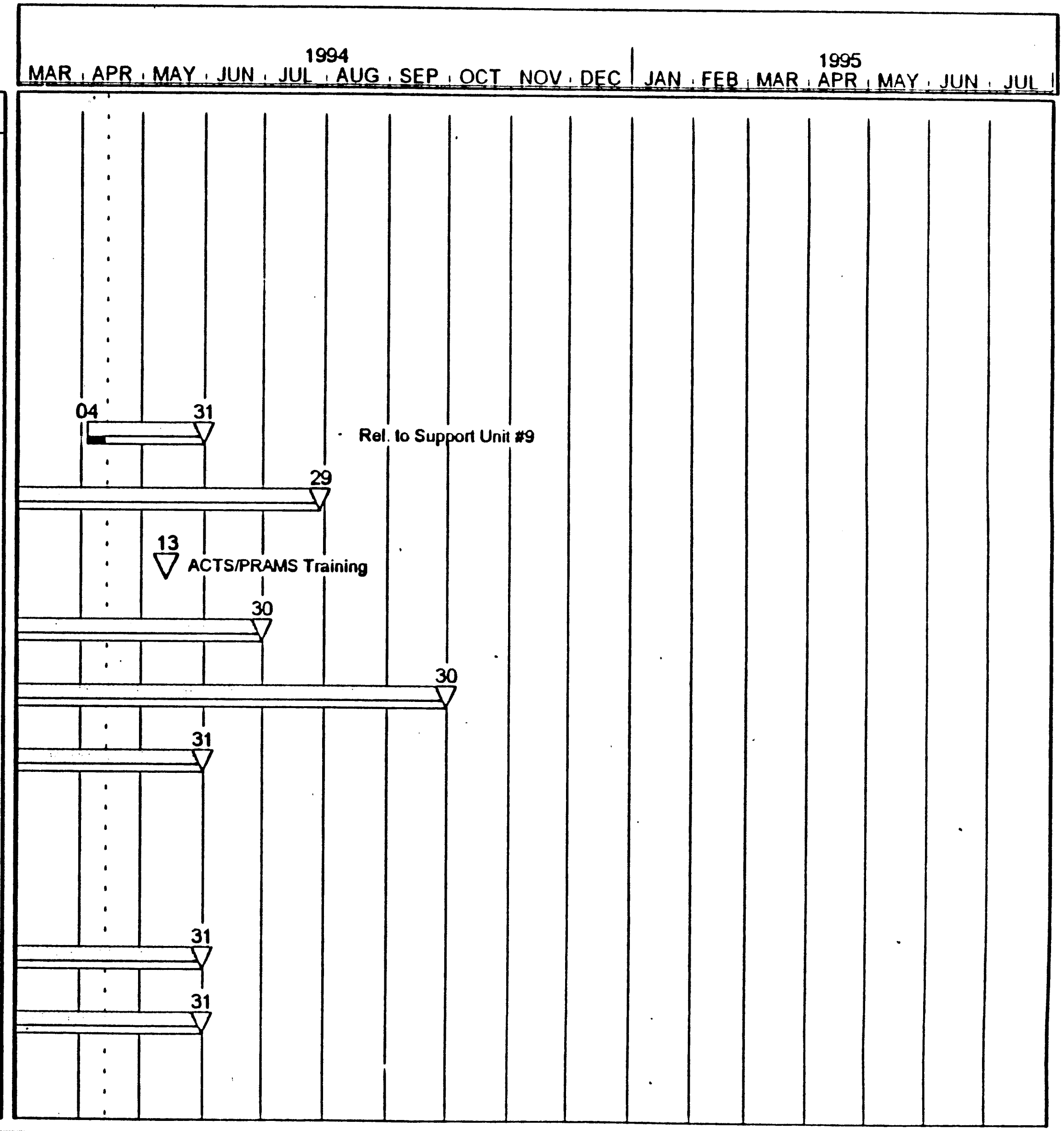
BLOCK I ENGINES

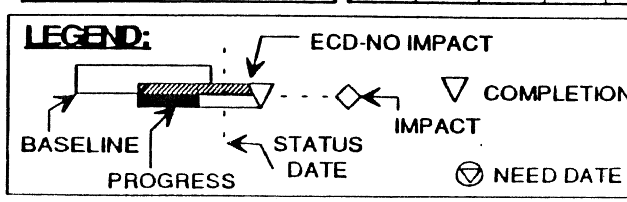
ATD DOCUMENTATION

PRINT DATE: 15APR94 14:52
STATUS DATE: 14APR94

PRELIMINARY DATA ONLY

Doc #	Description	Responsibility
RA-146-4	DR - Acceptance Data Package	Geiger/McFarlen/Seitz
SE-236-24	DR - COFR	Geiger/McFarlen/Seitz
SE-236-31	DR - Cert Letter for Pumps after Green Run	Geiger/McFarlen/Seitz
SE-236-41	Limited Life Components Report	Geiger/McFarlen/Seitz
	Block I Cert Plan	McAllister
	ACTS	Sam/Rivetti
	ACTS/PRAMS Training	
	PRAMS	Sam/Bennett
	ADM	Sam
QAI RI-16.1-XIV	MR Process	Johnson
QAI RI-16.1-XX (ES&P 5007)	Hardware Tracking Process	Geiger/McFarlen/Seitz
QAI RI-16.1-XXIII	Pedigree Process	Geiger/McFarlen/Seitz
ES&P 4080.1 (incl. appendix G)	Change Control Process	Varner/Johnson
ES&P 5006.1	DAR, NFL Process	Varner/Johnson
QAI RI-16.1-XIII	Acceptance Testing	Geiger/Seitz





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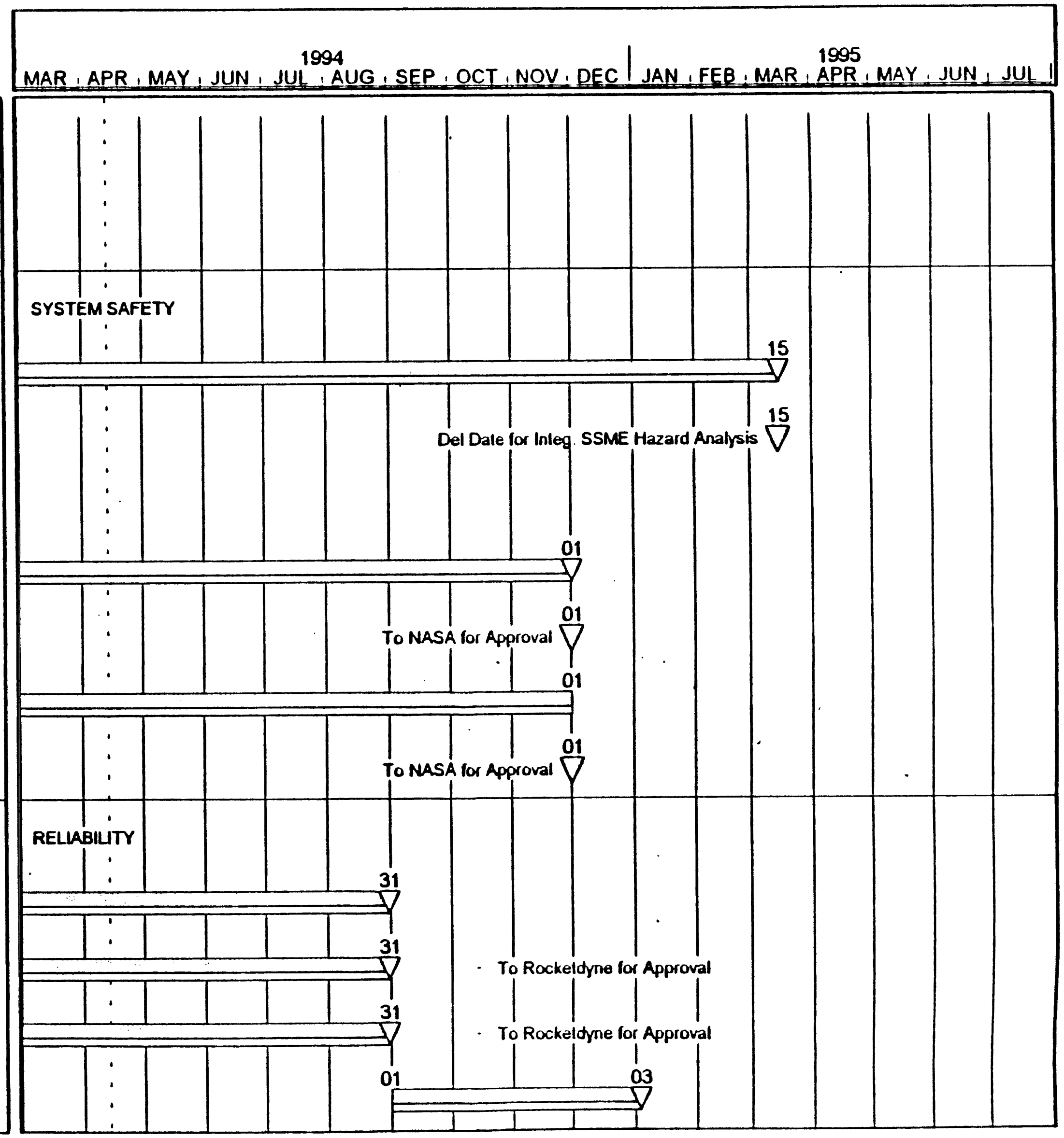
PRELIMINARY DATA ONLY

Doc #	Description	Responsibility
QAI RI-16.1-XV	Shipment & Storage Controls	Geiger
QAI RI-16.1-X	MOR Records	Graf
	SYSTEM SAFETY	
	ATP Hazards Analysis	Walker/Beitzel
	Del Date for Integ. SSME Hazard Analysis	
	Contract Data Reqmt - Data Transmission	Short/Garcia
RSS8503-8	System Safety Program Plan	Beitzel/Garcia
	To NASA for Approval	
RSS8545	SSME Hazards Analysis	Beitzel/Garcia
	To NASA for Approval	
	RELIABILITY	
RSS8503-6	SSME Reliability Program Plan	O'Kelley/Garcia
FR-22158	Alt Turbopump FMEA	Walker/Garcia
FR-22159	Alt Turbopump CIL	Walker/Garcia
RSS8553-11 Vol IV	SSME FMEA (LOX Turbopumps)	McElhaney/Garcia



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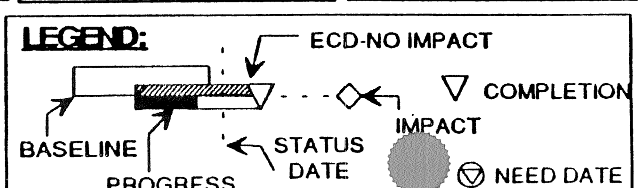

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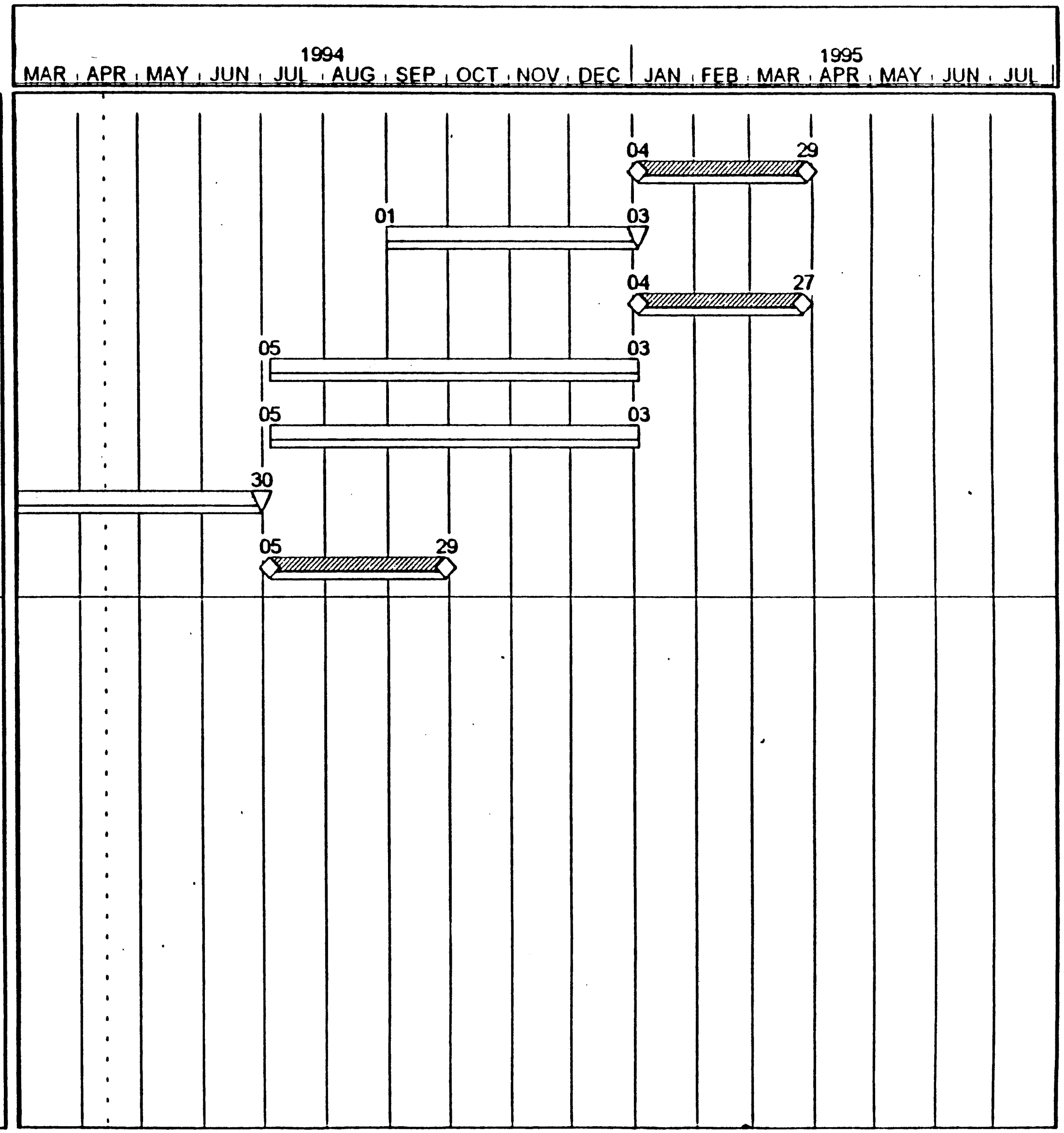
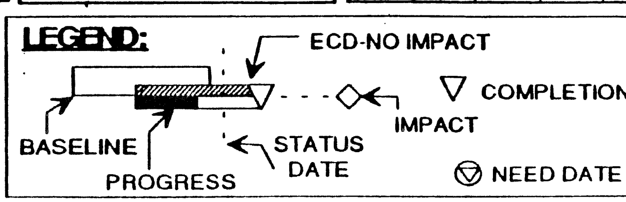
PRELIMINARY DATA ONLY

Doc #	Description	Responsibility
	NASA Approval Cycle	
RSS8740-11 Vol IV	SSME CIL (LOX Turbopumps)	McElhaney/Garcia
	NASA Approval Cycle	
RSS8553-11 Vol ?	SSME FMEA (Lines & Ducts)	McElhaney/Garcia
RSS8740-11Vol ?	SSME CIL (Lines & Ducts)	McElhaney/Garcia
RF0004-004	SSME Problem Reporting (VCR)	O'Kelley/Garcia
	NASA Approval Cycle	
	PROCUREMENT	





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Rockwell International
Rocketdyne Division

McKeon

SPACE SHUTTLE

4/16/94

SSME BLOCK I

INTEGRATION PLAN

BLOCK 1 ENGINE INTEGRATION PLAN

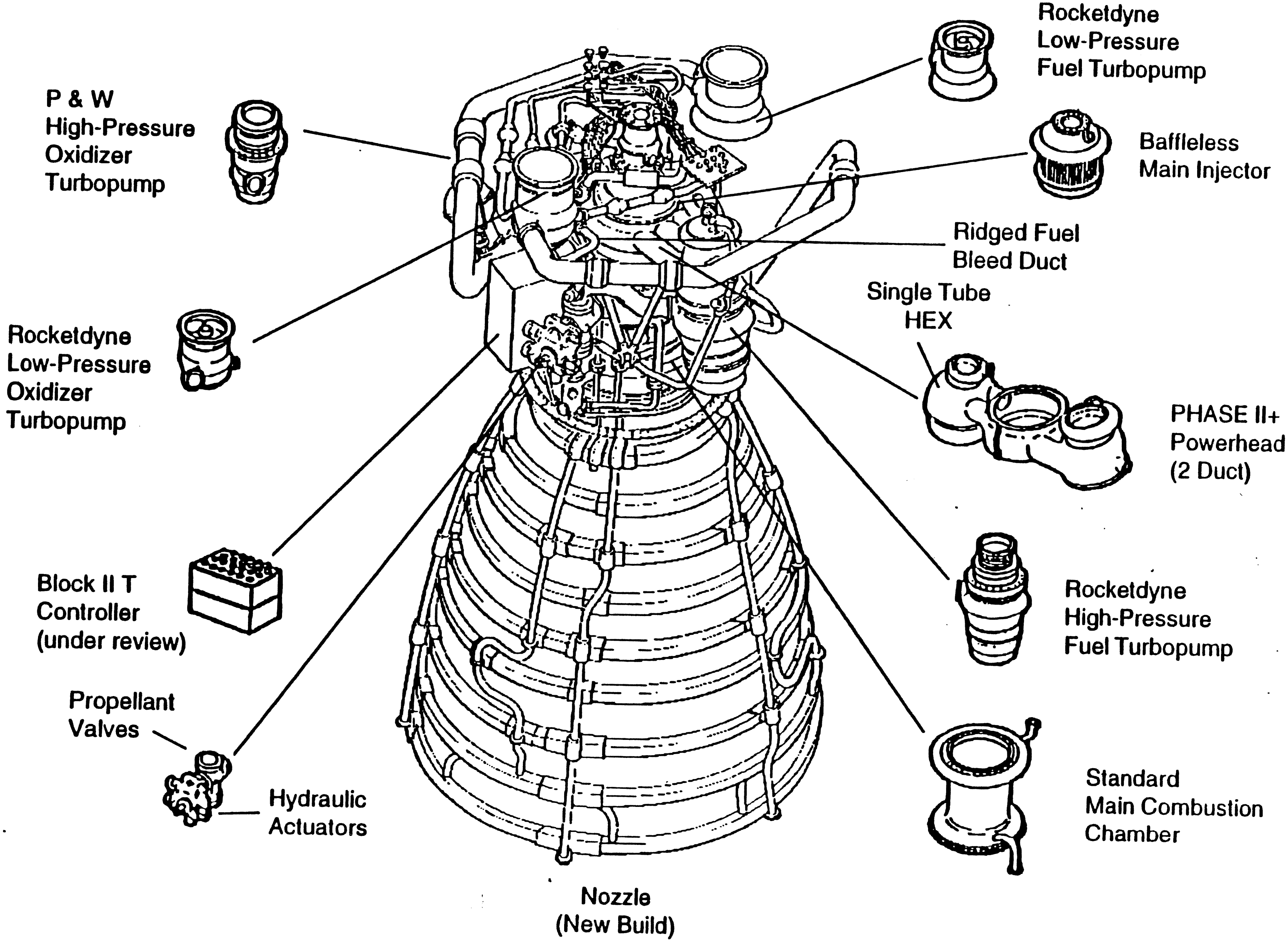
4/18/94

- **PURPOSE**
  - INTEGRATE BLOCK I ENGINE , (PHASE II+ POWERHEAD , SINGLE TUBE HEX , AND ATP LOX TURBOPUMP) REQUIREMENTS INTO FLIGHT PROGRAM
- **BACKGROUND**
  - EFFORTS INITIATED TO DEFINE FLIGHT REQUIREMENTS THAT WILL BE IMPACTED WITH THE INCORPORATION OF BLOCK I ENGINES
  - INTEGRATION SCHEDULES ESTABLISHED TO MEET STS-70 FLIGHT PLAN
  - FLIGHT HARDWARE REQUIREMENTS ARE ASSEMBLED INTO A BLOCK 1 ENGINE DEFINITION ENGINEERING CHANGE PROPOSAL (ECP)
    - THE ECP GROUPS REQUIREMENTS FROM APPROVED ECP's FOR THE PHASE II+ POWERHEAD, SINGLE TUBE HEX , AND RIGID FUEL BLEED DUCT
    - PRE-CRITICAL DESIGN REVIEW / ATP CERTIFICATION INPUT HAVE BEEN USED TO DEFINE ATP REQUIREMENTS
- **ACTIONS**
  - REVIEW BLOCK 1 ENGINE ECP DEFINITION
  - REVIEW SCHEDULE TO SUPPORT BLOCK I MILESTONES
  - REVIEW INTEGRATION ISSUES

SSME BLOCK 1 ENGINE

- **PLAN**
  - INCORPORATE UPGRADED BLOCK I ENGINE INTO FLEET FOR STS-70 FIRST FLIGHT (29 JUNE 1995)
- **BLOCK I ENGINE DEFINITION**
  - UPGRADED SSME PROVIDES IMPROVED UNIT LIFE WITH REDUCED MAINTENANCE WHILE INCORPORATING PERFORMANCE ENHANCEMENTS AND INCREASED SAFETY
    - ELIMINATION OF CRITICAL 1 WELDS, CHECKOUT INSPECTIONS AND LIFE LIMITS
    - PERFORMANCE IMPROVEMENTS AND INCREASED OPERATING MARGINS
  - ENGINE LEVEL DEFINITION REQUIREMENTS WILL BE DEFINED IN ROCKETDYNE ECP TBD TO INTEGRATE BLOCK-I ENGINES INTO FLEET
    - CEI WEIGHT, CERTIFICATION, ICD VARIATIONS, ENGINE LEVEL ACCEPTANCE AND INSPECTION SPECIFICATIONS, FMEA/CIL ...ETC.

BLOCK I SSME COMPONENTS



SSME BLOCK 1 ENGINE DEFINITION MAJOR COMPONENTS IMPROVEMENTS

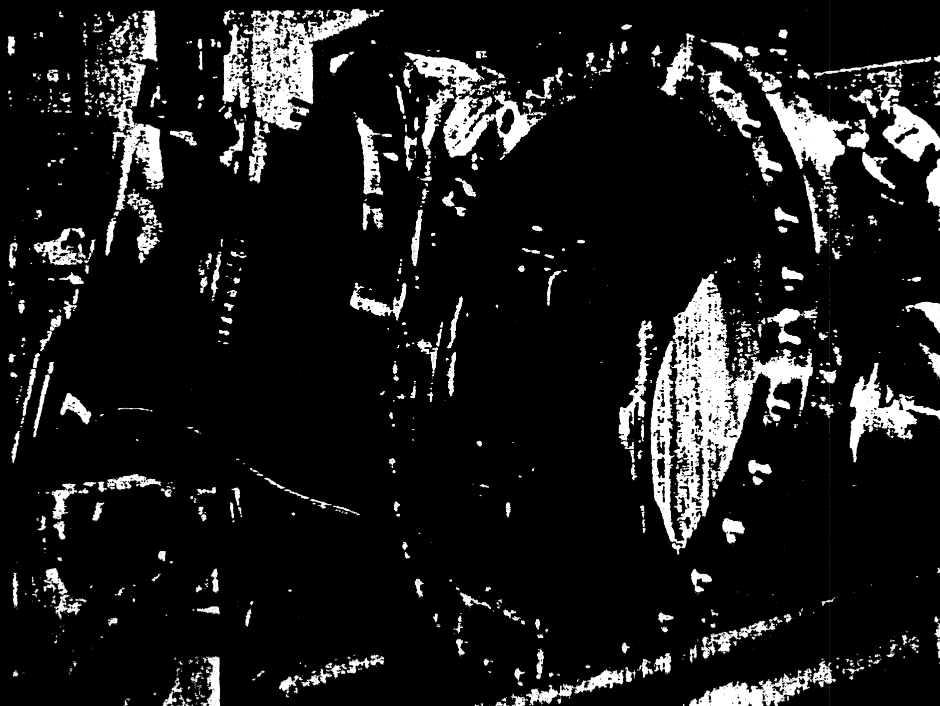
4/15/94

- PHASE II+ POWERHEAD (ECP 1177)
  - TWO-DUCT HOT GAS MANIFOLD
  - BAFFLELESS MAIN INJECTOR WITH LOX POST BIASING
  - ENLARGED PRIMARY FACEPLATE BOUNDARY COOLANT HOLES
  - CCV RESCHEDULED AND ENGINE START MODIFICATION
- SINGLE TUBE EXCHANGER (ECP 1150)
  - ELIMINATION OF CRITICAL WELDS
  - STHEX OUTLET ORIFICE SYSTEM
- ATP LOX TURBOPUMP (ECP TBD)
  - IMPROVED LIFE AND MAINTENANCE REQUIREMENTS
- RIGID FUEL BLEED DUCT (ECP 1200)
  - INCONEL 625 MATERIAL CHANGE
  - IMPROVED FABRICATION TECHNIQUES

SSME BLOCK 1 ENGINE
HARDWARE CHANGES

- **PHASE II+ POWERHEAD - ECP 1177**
  - 18 ADDITIONAL CHANGES TO SYSTEM HARDWARE DUE TO POWERHEAD ENVELOPE CHANGE
- **SINGLE TUBE OXIDIZER HEAT EXCHANGER - ECP 1150**
- **ATP LOX TURBOPUMP - ECP TBD**
  - 6 ADDITIONAL CHANGES TO SYSTEM HARDWARE TO SUPPORT PUMP INSTALLATION
- **RIGID FUEL BLEED DUCT-ECP 1200**
- **ASSOCIATED GROUND SUPPORT EQUIPMENT**
  - ROCKETDYNE AND P&W FURNISHED

Phase II+ Powerhead Two-Duct Hot Gas Manifold



- 4 units
- 143 starts/63,658 sec

- Increased margin
  - Reduces flow velocity & fluctuating pressure (75% at main injector)
  - Reduced turbine transverse ΔP (60% at HPFTP turbine exit)
- Reduced maintenance
  - No preburner support pins
- Improved producibility
  - 74 welds eliminated (24%)
  - Six, 903 overlays eliminated
  - Part count reduced by 52
- Increased I_{sp} – +0.76 sec
- Mcc life extended – reduced blanching

Rockwell
Rocketdyne

SC90c-12-250
(4/15/94)

PHASE II+ POWERHEAD

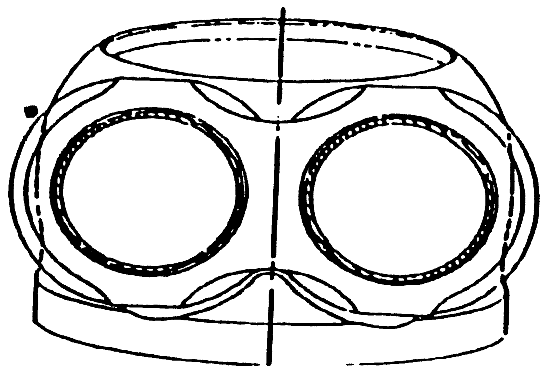
- **KEY OBJECTIVES**
  - REDUCE HPFT & HOT GAS MANIFOLD TRANSVERSE DELTA-P
  - REDUCE HOT GAS FLOW RESISTANCE
  - IMPROVE FLOW DISTRIBUTION THROUGH FUEL SIDE TRANSFER TUBES
  - REDUCE MAIN INJECTOR OXIDIZER POST-HIGH-VELOCITY HOT GAS IMPINGEMENT
  - REDUCE DYNAMIC STRESS IN PREBURNER INJECTOR ELEMENTS
  - INCREASE OPERATING MARGIN AT 109% RATED POWER LEVEL
  - REDUCE MAINTENANCE
  - IMPROVED PRODUCIBILITY

PHASE II+ POWERHEAD

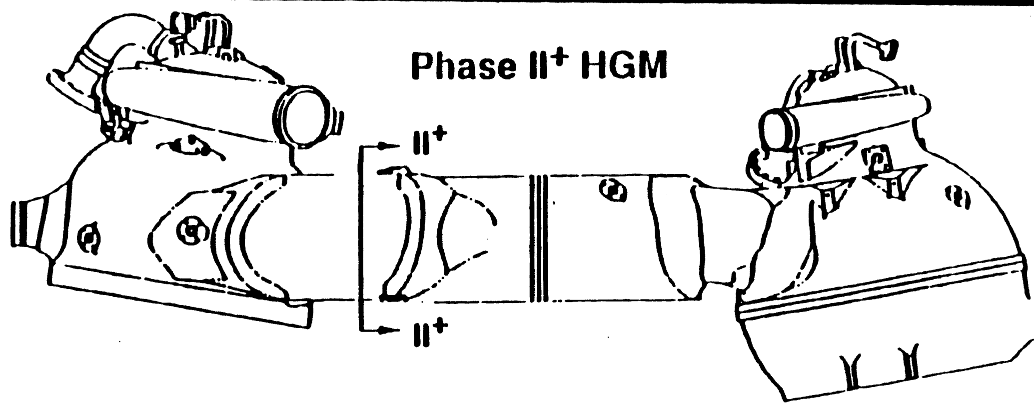
- **DESIGN IMPROVEMENTS**
  - INCREASED HOT GAS FLOW AREA
  - IMPROVED CONTOUR FOR HOT GAS FLOW
  - ELIMINATED CENTER FUEL TRANSFER DUCT
  - IMPROVED MAIN INJECTOR FLOW SHIELD DESIGN
  - SHORTENED PREBURNER INJECTOR ELEMENTS
  - IMPROVED MARGIN ON COOLANT DUCTS & LOX INLET MANIFOLD

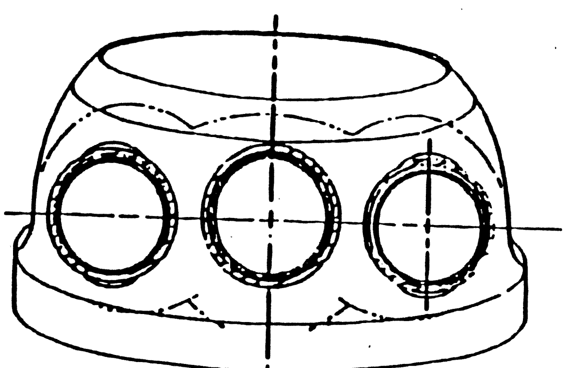
PHASE II+ POWERHEAD
HGM COMPARISON

7/22/92



Sec II⁺ - II⁺





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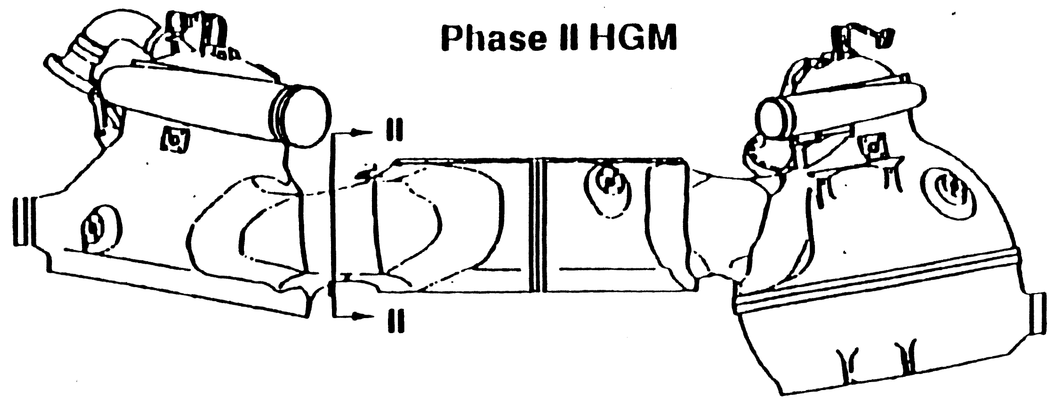


C92-825

PHASE II+ POWERHEAD
MARGIN IMPROVEMENT SUMMARY

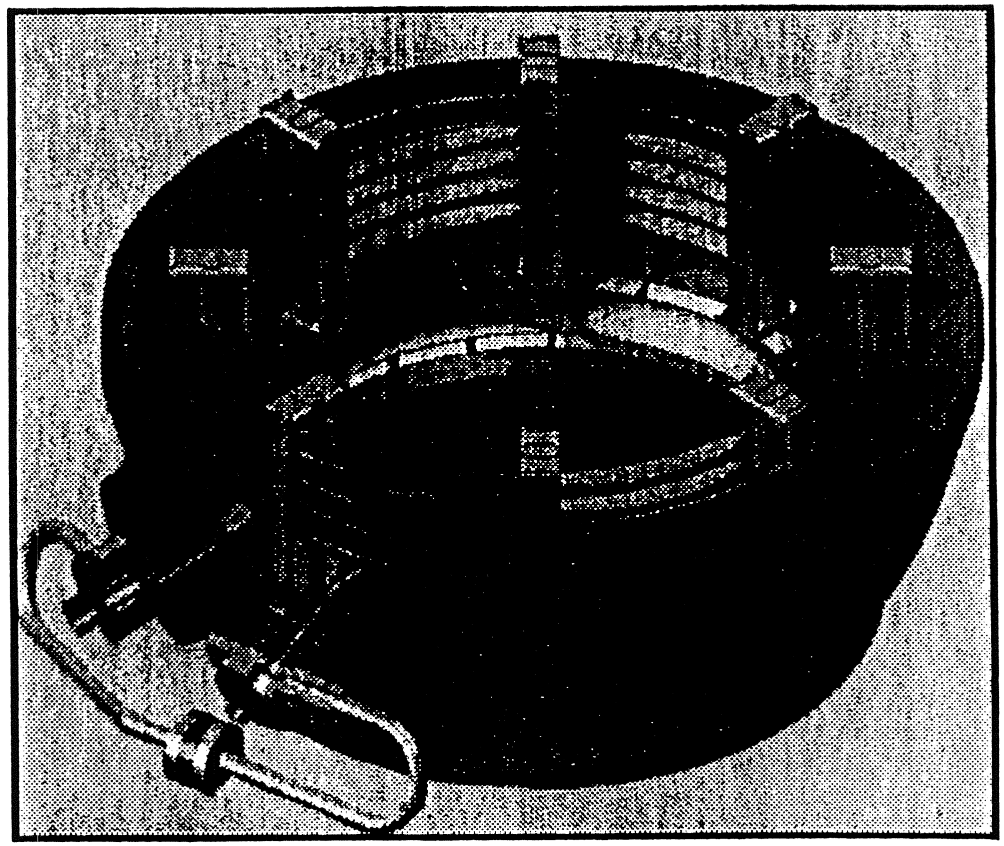
- **PHASE II+ POWERHEAD MARGIN IMPROVEMENTS**
  - IMPROVED FLOW UNIFORMITY
    - REDUCED TRANSVERSE DELTA PRESSURE FOR HIGH-PRESSURE PUMP TURBINE BLADES
    - DECREASED TURBULENCE LEVELS & PRESSURE LOSSES
    - ELIMINATES CENTER TRANSFER TUBE LINER CRACKING EXPERIENCED ON PHASE II
    - REDUCED FLOW LOADS ON MAIN INJECTOR LOX POSTS
  - PROVIDES ADDED MARGIN FOR MCC HOT WALL BLANCHING/CRACKING
    - INCREASED MARGIN FOR COOLANT TO HOT GAS PRESSURE TO PREVENT HOT GAS INGESTION
    - ENLARGED BOUNDARY LAYER COOLANT HOLES PROVIDES ADDED COOLING FOR MCC HOT WALL

PHASE II+ POWERHEAD
MARGIN IMPROVEMENT SUMMARY

- **PHASE II+ POWERHEAD MARGIN IMPROVEMENTS (CONT)**
    - REDUCED CAUSES FOR CRITICALITY 1 FAILURE OF PREBURNER INJECTORS THROUGH ELEMENT REDESIGN
    - FATIGUE LIFE OF PREBURNER INJECTOR LOX POSTS IMPROVED THROUGH ELEMENT REDESIGN
    - FATIGUE LIFE OF POWERHEAD DUCTS INCREASED BY ADDED WALL THICKNESS AT WELD JOINTS
    - IMPROVED FATIGUE LIFE AT MAIN INJECTOR LOX INLET TEE & ELBOW WITH USE OF FORGING
    - BAFFLELESS MAIN INJECTOR IMPROVES THRUST & MCC MARGIN
    - 74 HOT GAS MANIFOLD LINER WELDS ELIMINATED

SINGLE TUBE HEAT EXCHANGER

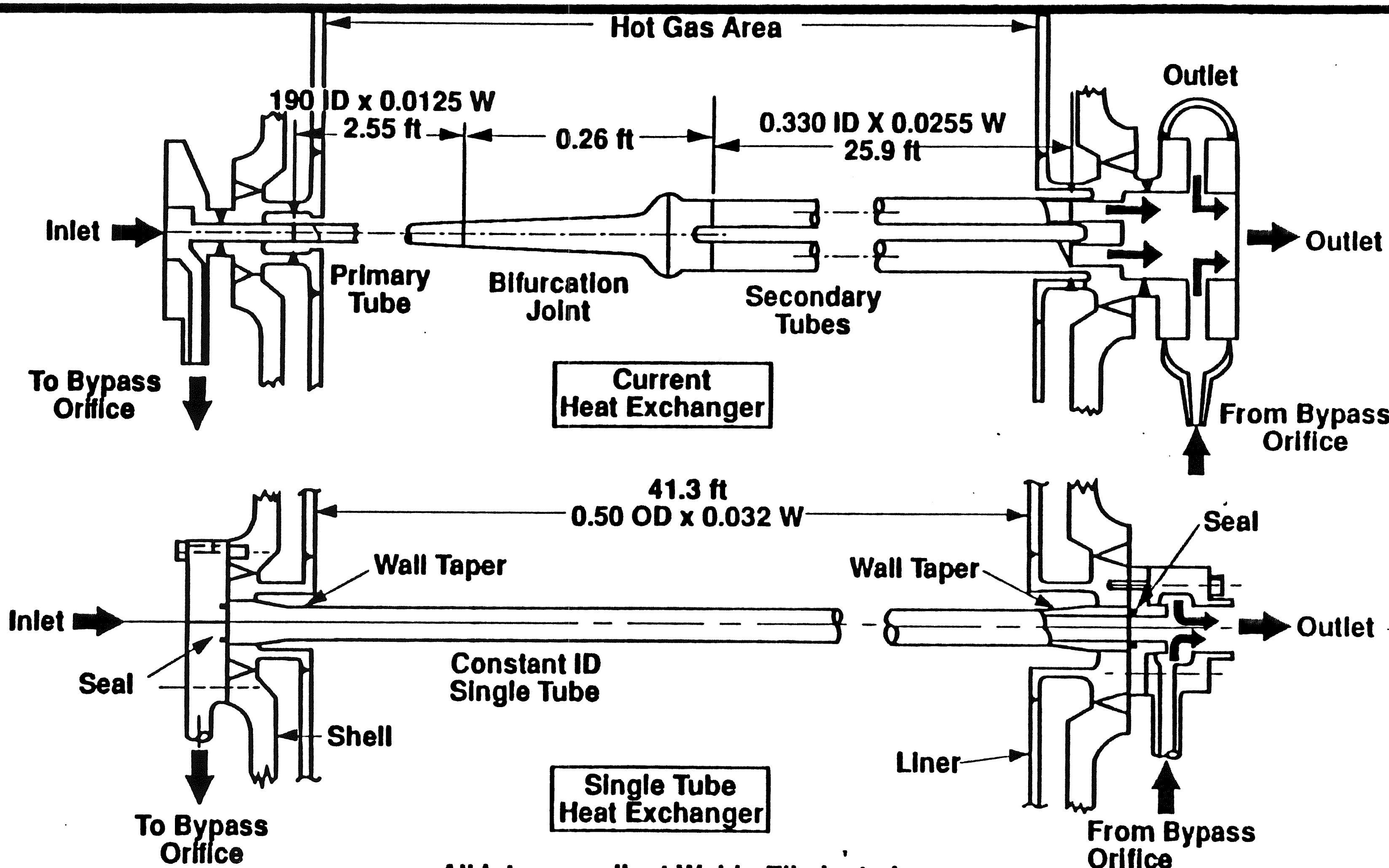
- HEX COIL FRACTURE MARGIN
  - ELIMINATES INTERPROPELLANT WELDS
  - THICK TUBE WALL INCREASES MARGIN FOR TUBE WEAR & DAMAGE 0.032 WAS 0.0125
  - ELIMINATES/IMPROVES INLET/OUTLET WELDS
- REDUCES MAINTENANCE/POST FLIGHT INSPECTIONS



SINGLE TUBE HEAT EXHCHANGER
DESIGN FEATURES

- **TUBE - CONSTANT DIAMETER SINGLE TUBE WITH THICK ENDS**
  - ELIMINATES ALL 7 INTERPROPELLANT WELD JOINTS (SIGNIFICANT FMEA FAILURE CAUSE)
    - ELIMINATES CRITICAL PROCESSING & INSPECTION REQUIREMENTS RELATED TO WELDS
  - THICKER TUBE WALL
    - INCREASED MARGIN FOR TUBE WEAR & IMPACT RESISTANCE
    - COIL THERMAL EXPANSION LOOP & SIMPLIFIED ASSEMBLY SEQUENCE
      - REDUCED POTENTIAL FOR TUBE/BRACKET INTERFACE WEAR DURING OPERATION
  - IMPROVED STRUCTURAL MARGINS

Single Tube Heat Exchanger
STHEX Compared to Current Bifurcated HEX



All Interpropellant Welds Eliminated

SINGLE TUBE HEAT EXCHANGER
DESIGN FEATURES

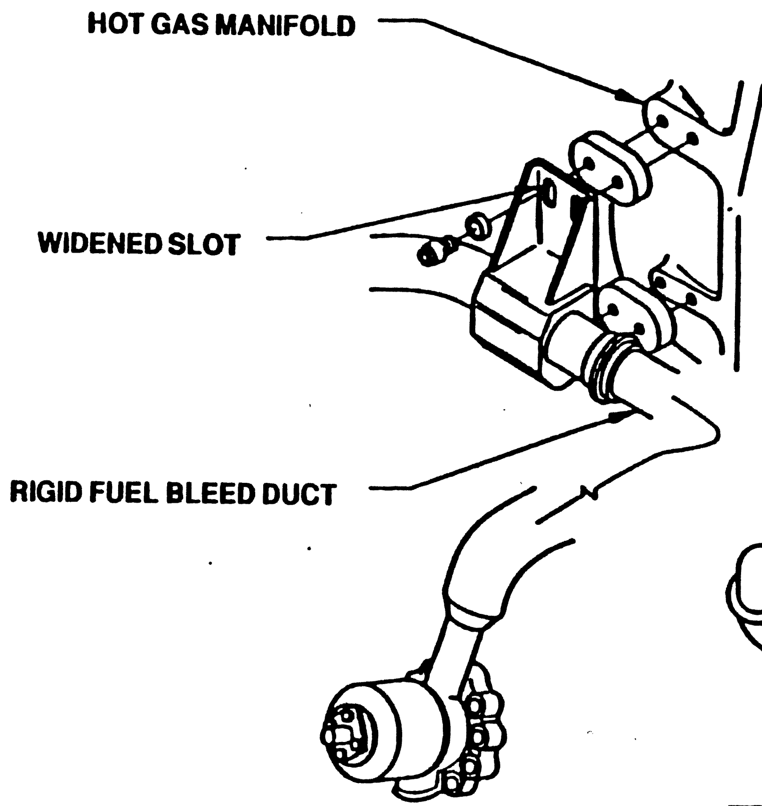
- **TOTAL OF 30 WELD JOINTS ELIMINATED FROM STHEX ASSEMBLY**
  - 7 INTERPROPELLANT COIL WELDS
  - 15 BYPASS ASSEMBLY WELDS & 4 OUTLET DUCT WELDS
  - 2 FITTING-TO-SLEEVE WELDS PLUS 2 SLEEVE OVERLAYS
- **REDESIGNED WELD JOINTS TO OBTAIN 100% INSPECTABILITY**
  - VERIFIED CRITICAL INITIAL FLAW SIZES COULD BE DETECTED BY INSPECTION TECHNIQUES

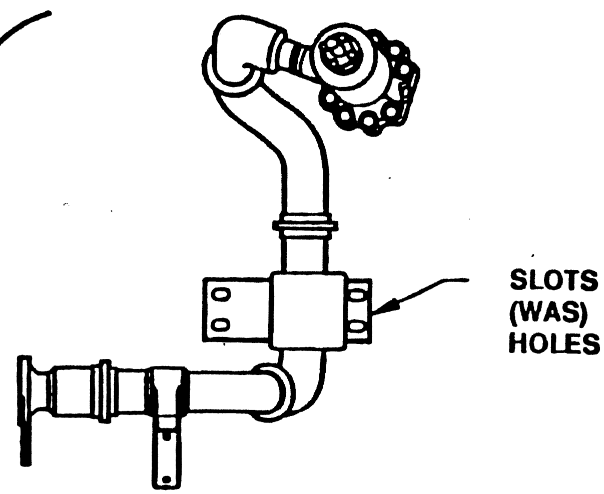
SSME BLOCK 1 ENGINE
ATP LOX TURBOPUMP - ECP TBD

- **DESIGN REQUIREMENTS**
  - SERVICE LIFE OF 27,000 SEC / 55 MISSIONS / 60 STARTS
  - NO MAINTENANCE EXCEPT IN PLACE HEALTH INSPECTION
    - BORESCOPE / TORQUE CHECKS
  - FULL LIFE OPERATION AT 109% RPL (FULL POWER LEVEL)
  - CURRENT ENGINE MECHANICAL INTERFACE MAINTAINED

RIGID FUEL BLEED DUCT
ECP 1200

HOT GAS MANIFOLD TO RIGID BLEED DUCT INTERFACE





BRACKET CHANGE

SSME BLOCK 1 ENGINE

RIGID FUEL BLEED DUCT - ECP 1200

- **PHASE II+ POWERHEAD REQUIRED MODIFICATION TO FUEL BLEED DUCT RS007168**
  - POWERHEAD ENVELOPE CHANGE AT SUPPORT BRACKET LOCATION
- **IMPROVEMENTS INCORPORATED INTO REDESIGN**
  - MATERIAL CHANGE FROM 21-6-9 CRES TO INCONEL 625
    - IMPROVED RESISTANCE TO CORROSION
    - ELIMINATES NEED FOR CORROSION INHIBITOR PAINT
  - MODIFIED SUPPORT BRACKET DESIGN
    - ELIMINATED 2 CLASS II WELDS
    - ELIMINATED 3 OF 5 BENDS
    - SLOTTED BRACKET MOUNTING HOLES
      - ELIMINATES INSTALLATION INTERFERENCE PROBLEMS

SSME BLOCK 1 ENGINE
ROCKETDYNE DELIVERABLE FLIGHT GSE

- PHASE II+ POWERHEAD - AUTHORIZED BY ECP 1177
  - REQUIREMENTS
    - HPFTP HANDLERS - 8 UNITS
      - MODIFICATION REQUIRED DUE TO LARGER PHASE II+ POWERHEAD PREBURNER ENVELOPE
    - PURGE ADAPTER SET - 10 UNITS
      - BOLT HOLE PATTERN CHANGE FOR PHASE II+ POWERHEAD
- PLAN
  - RETROFIT KIT DELIVERIES TO KSC - ECD JAN 1995

SSME BLOCK 1 ENGINE
ROCKETDYNE DELIVERABLE FLIGHT GSE

- **ATP LOX TURBOPUMP - BLOCK 1 ECP TBD**
  - REQUIREMENTS
    - HPOTP HANDLERS 7 UNITS Modify KSC Hardware - Can be used for Both HPOTPs
    - LOBE WRENCH SETS - 7 UNITS
    - TRANSDUCER ADAPTER SETS - 14 UNITS
    - MCC DRYING ADAPTER SETS - 10 UNITS
- **PLAN**
  - AUTHORIZE FABRICATION PRIOR TO ECP APPROVAL
    - LETTER OF AUTHORIZATION TRANSMITTED TO MSFC
  - DRAWINGS COMPLETE - ORDER HARDWARE ECP 30 APRIL 1994
  - RETROFIT KIT DELIVERS TO KSC - ECD JAN 1995

SSME BLOCK 1 ENGINE
ADDITIONAL CHANGES

- CRYOGENIC TEMP BULBS WITH IMPROVED PROCESSING (ECP 1241)
    - ELIMINATE BRAZE FLUX CONTAMINATION
- PIND TEST OF PRESSURE SENSORS
- 6 DESIGN CHANGES TO INCORPORATE ATD HPOTP
    - BEARING PURGE LINE / HEX AFV LINE / MCC DRYING ADAPTER / ADAPTER CAP-OFF PLATE / STRAIN GAGE HARNESS CAP / JOINT 05 ORIFICE
- 18 DESIGN CHANGES DUE TO PHASE 2+ POWERHEAD
    - RESULTS OF HGM ENVELOPE CHANGES AND BOLT PATTERN CHANGE

BLOCK 1 ENGINE HARDWARE IMPACT

ITEM	PART NO.	DESCRIPTION	REASON
1	R007083-XXX	HES SUPPLY LINE ASSY	RE-ROUTED LINE - ATD HPOTP PREBURNER PUMP HAS LARGER DIAMETER
2	R039138-XXX	BEARING PURGE LINE ASSY	NEW CONFIGURATION - ATD HPOTP REQUIRED PURGING ITS TURBINE END BEARING
3	R039301-5	MCC DRYING ADAPTER	NEW CONFIGURATION - MAINTAIN DRYING OF FUEL SYSTEM DOWNSTREAM OF MFV
4	R039332-3	ADAPTER CAP-OFF PLATE	NEW CONFIGURATION - CAP OFF R039301-5
5	R037863	JOINT 05 ORIFICE PLATE	NEW CONFIGURATION - REDUCE LPOTP SPEED INCREASE AS A RESULT OF ATD HPOTP
6	R0018027-3	FUEL PURGE LINE SUPPORT BRKT	FPB ENVELOPE DESIGN CHANGE
7	R039345	FUEL SUPPLY ASI BRKT	HGM ENVELOPE DESIGN CHANGE
8	R0018053-1	FUEL SUPPLY ASI BRKT	HGM ENVELOPE DESIGN CHANGE
9	RE127-20111-1065	SADDLE CLAMP	SINGLE COIL OUTLET HAS SMALLER DIA & HIGHER TEMP
10	R0017623-5	HGM RETAINER	RETAINER BOLT PATTERN CHANGE
11	R0017624-5	MCC RETAINER	RETAINER BOLT PATTERN CHANGE
12	R0011044-041	G4 PLUG	BOLT PATTERN CHANGE
13	R0017433-3	G4 CAP	RELOCATED JOINT
14	R0018041-1	LPF DRIVE DUCT ARTICULATING	REROUTE - PH ENVELOPE CHANGE
15	R0018051-1	FPBO ASI LINE	REROUTE - PH ENVELOPE CHANGE
16	R0018042-1	FPBF ASI LINE	REROUTE - PH ENVELOPE CHANGE
17	RS007135-151	FPB PURGE LINE	REROUTE - PH ENVELOPE CHANGE

BLOCK 1 ENGINE HARDWARE IMPACT

ITEM	PART NO.	DESCRIPTION	REASON
18	R0018031-11	G4.1 OFFSET MOUNT	BOLT PATTERN CHANGE
19	R0018043-1	FUEL BLEED DUCT	BRACKET CHANGE DUE TO POWERHEAD
20	R0017434-3	G4.2 PLUG	NEW JOINT
21	R0019432-003	G4.1.1 SPACER	PROVIDE CLEARANCE
22	RE127-2012-1014	CLAMP - OXID PRESSURANT TO RECIRC VALVE LINE	SINGLE COIL OUTLET HAS SMALLER DIAMETER & HIGHER TEMPERATURE
23	R039366-3288	JOINT 020.2 ORIFICE	SINGLE COIL OUTLET PRESSURE IS HIGHER - REDUCE FOR TANK PRESSURIZATION
24		HPOTP STRAIN GAGE HARNESS CAP	STRAIN GAGE BEARING MEASUREMENT NOT REQUIRED FOR ATD HPOTP

SSME BLOCK 1 ENGINE
CHANGES UNDER EVALUATION

- **REVIEW OF ALL ECP's TO DETERMINE EFFECTIVITY - IN WORK**
  - INCORPORATION INTO E2037 AND SUBS NEED TO BE EVALUATED
    - EXTENDED LIFE HARNESSES, ETC
- **RELIABILITY INITIATIVES**
  - HOT GAS THERMOCOUPLE/ CONTROLLER / HARNESS / SOFTWARE
  - HYDRAULIC ACTUATOR SPOOL REDESIGN
  - CONTINUOUS MFV PURGE
  - FLOW FLOW/SPEED SENSOR REDESIGN - ECP 1250 APPROVED
- **PNEUMATIC VENT MODIFICATION - ECP 1247**
  - ECP APPROVAL PENDING

BLOCK I PERFORMANCE COMPARISION TO PHASE II
104% PL, 6.011 MR

PARAMETER	UNITS	2 DUCT HOT GAS MANIFOLD	BAFFLE-LESS MAIN INJECTOR	ADD'L ENLARGED BLC HOLES	SINGLE TUBE HEAT EXCHANGER	ATD HPOTP	BLOCK I TOTAL (3 ENGS)
WEIGHT (3 ENGINES)	LBS	+513	<- -	<- -	<- -	+483	+996
SPECIFIC IMPULSE	SECS		+1.0	-0.24		-0.16*	+0.6
THRUST	LBS					+170	+170
PAYLOAD (3 ENGINES)	LBS	-513	+1200	-300		-653	-266

* TURBINE SEAL OVERBOARD FLOWS - TOTAL PRESSURE PROBES INSTALLED IN DRAIN LINES TO DETERMINE ACTUAL ISP LOSS

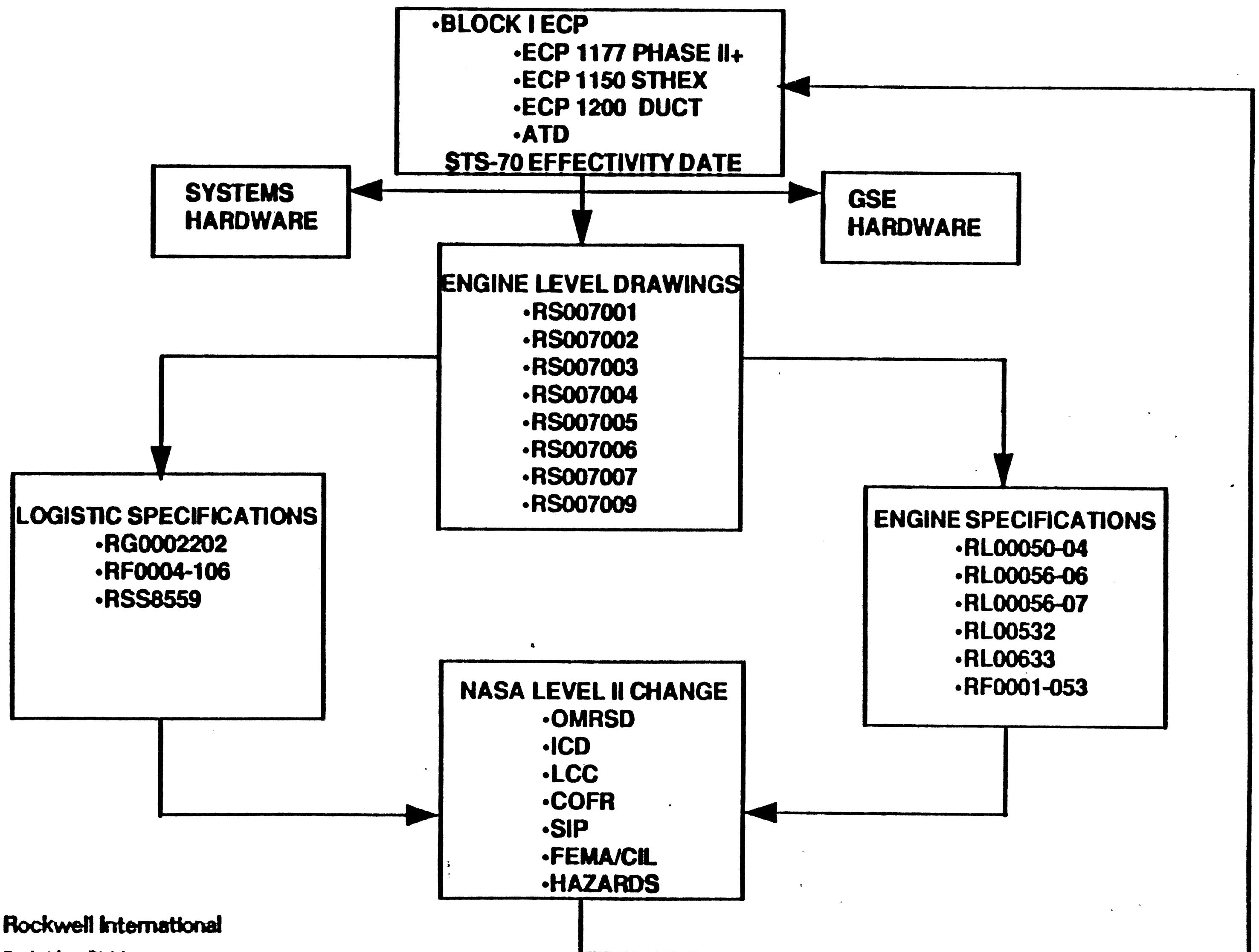
SSME BLOCK 1 INTEGRATION PLAN

4/16/94

- **LEVEL II INTEGRATION REQUIREMENTS ESTABLISHED BY SPACE SHUTTLE SYSTEM INTEGRATION PLAN (SIP)**
  - ORIGINAL ATD SIP RELEASED APRIL 8, 1993
  - REVISION REQUIRED TO IMPLEMENT BLOCK 1 ENGINE FOR STS-70
    - CURRENT ECD - 15 MAY 1994
  - ENGINE DATA REQUIREMENTS ESTABLISHED BY NSTS 08209 CRITICAL MATH MODEL
    - REQUIRED DATA TO BE ESTABLISHED BY AFSIG(ASCENT FLIGHT SYSTEM INTEGRATION GROUP) - ECD 15 MAY 1994
- **ENGINE LEVEL DEFINITION REQUIREMENTS WILL BE DEFINED IN ROCKETDYNE ECP TBD TO INTEGRATE BLOCK 1 ENGINE INTO FLEET**
  - ROCKETDYNE MAJOR COMPONENTS FLIGHT REQUIREMENTS APPROVED BY MSFC THROUGH ECP's 1177, 1150 AND 1200
  - NEED FORMALIZED ATD FLIGHT REQUIREMENTS FOR INCORPORATION INTO ROCKETDYNE ECP

BLOCK 1 ENGINE INTEGRATION PLAN

4/15/94



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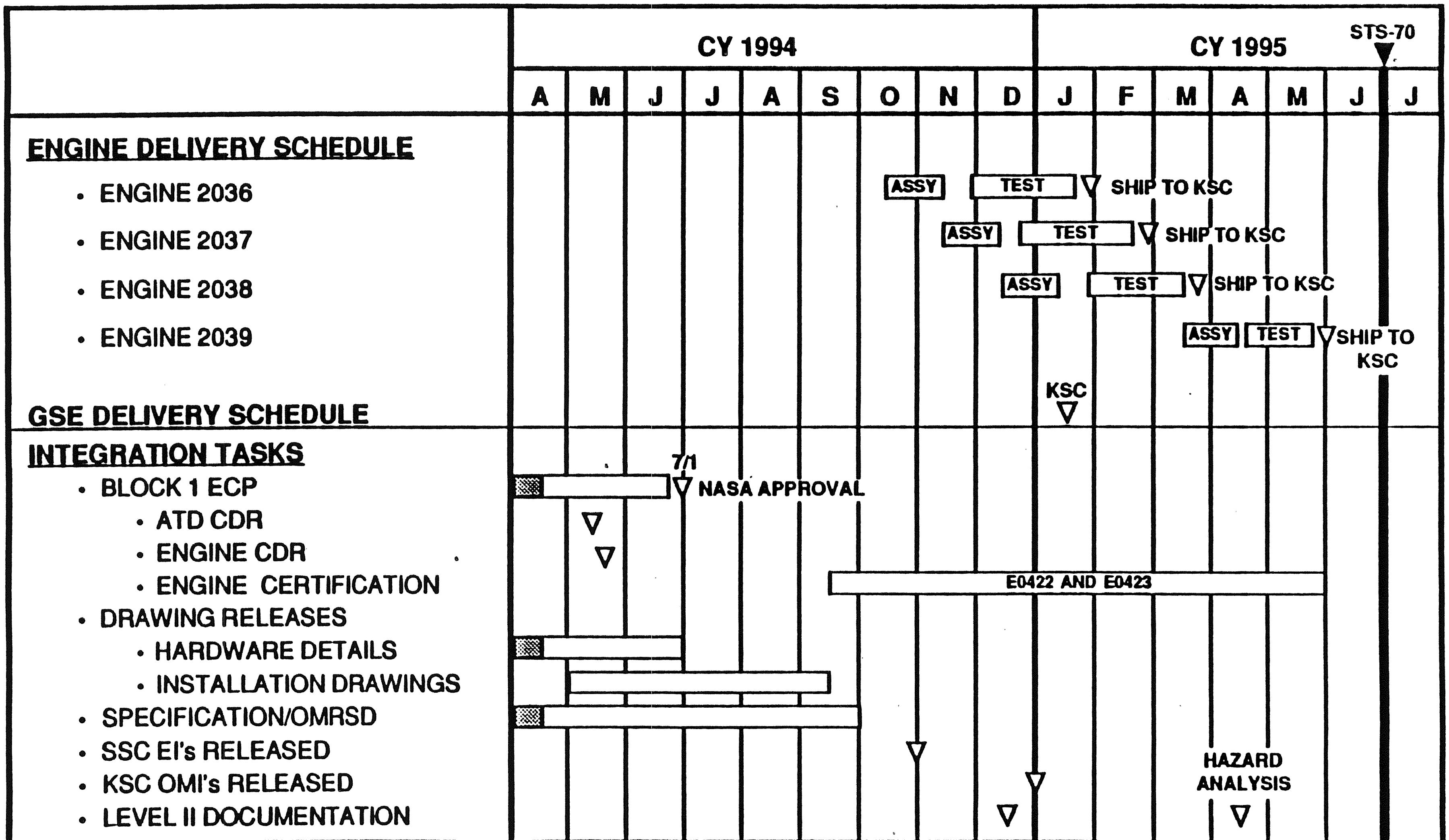
SSME BLOCK 1 INTEGRATION PLAN
PROGRAM SCHEDULE

4/16/94



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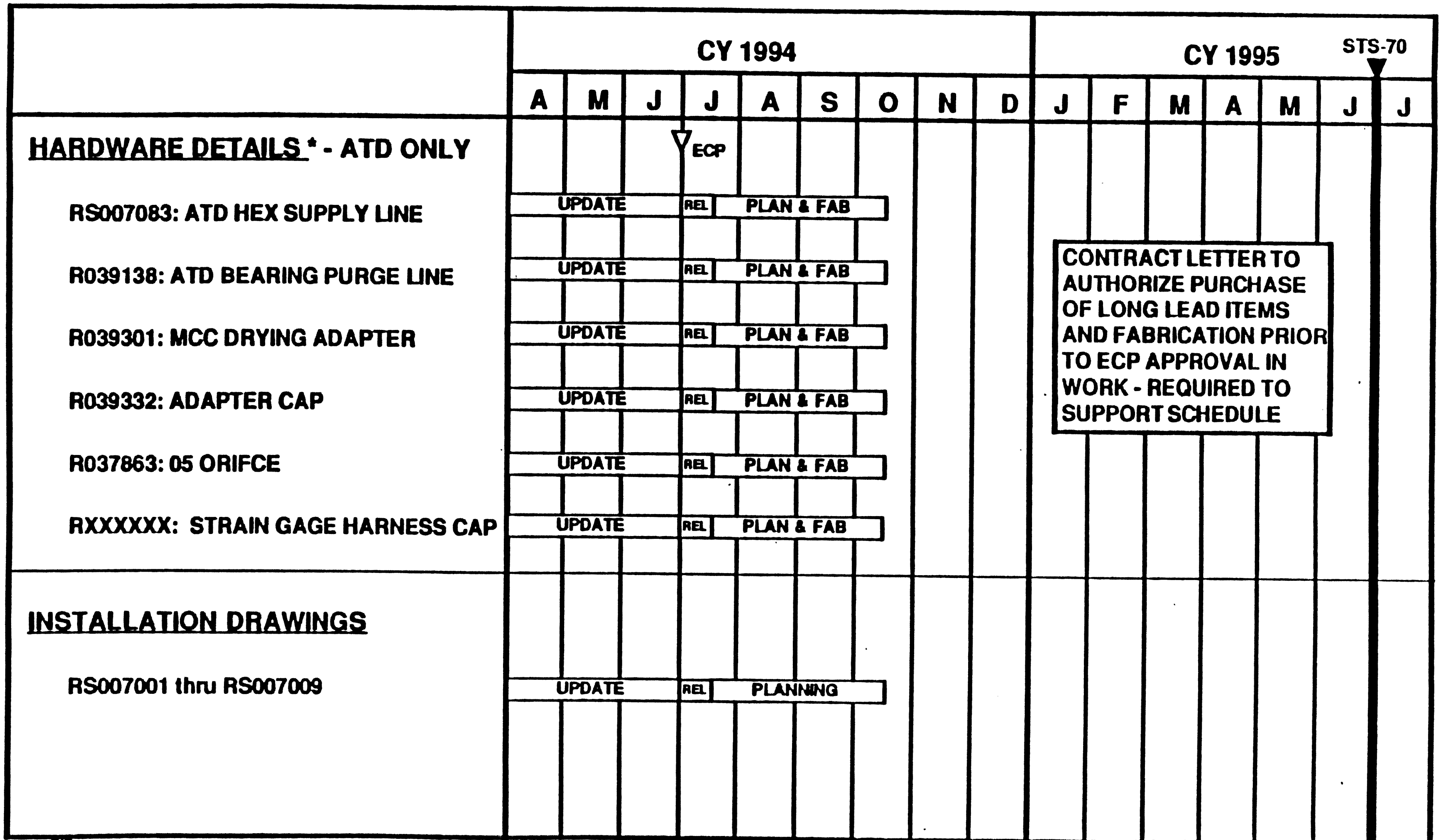
Rocketdyne Division

X: \VALERIE\ BLK-1.PPT

SSME BLOCK 1 INTEGRATION PLAN
DRAWING RELEASE SCHEDULE

4/16/94



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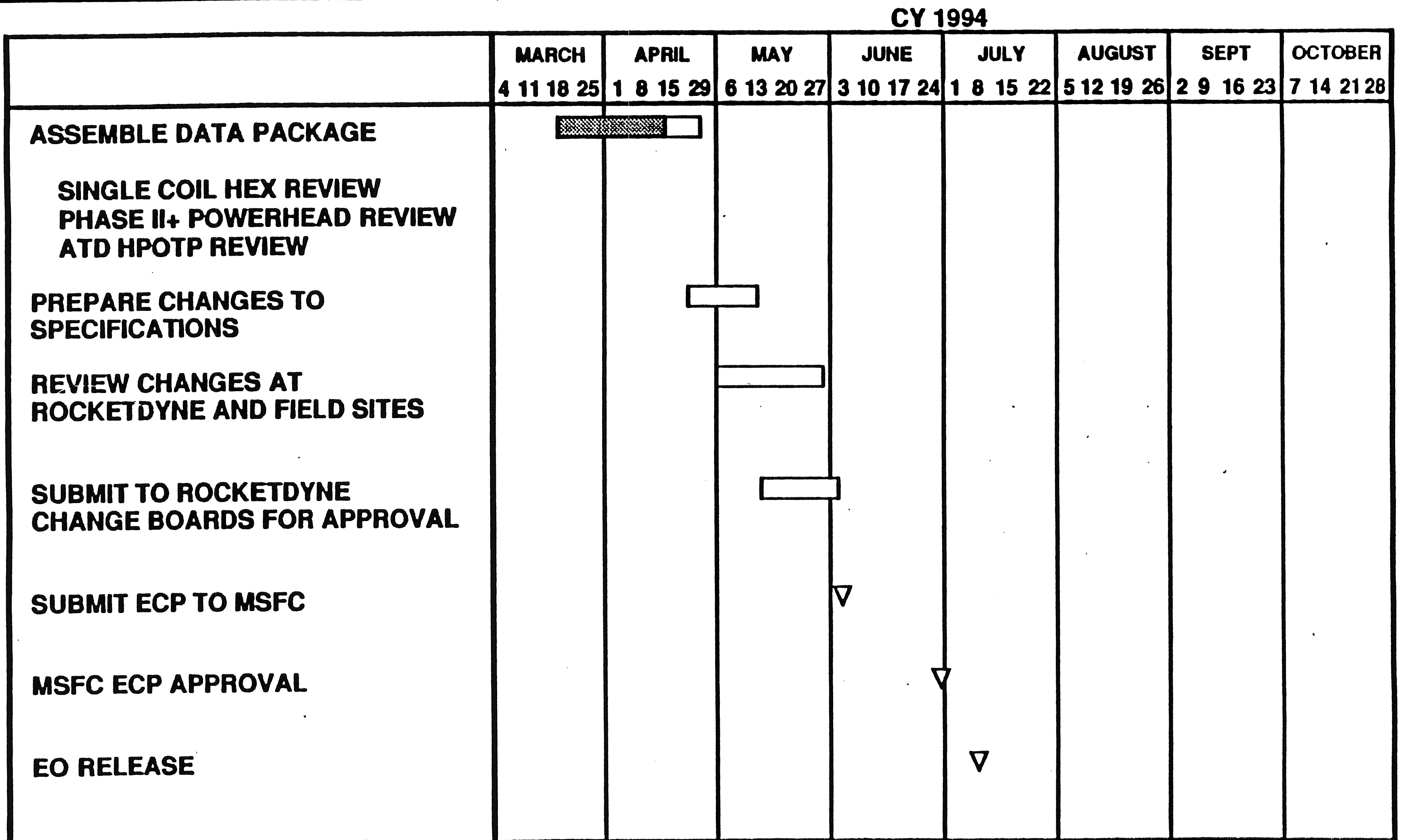
X: \VALERIE\ BLK-1.PPT

* ALL HARDWARE DETAILS TO SUPPORT ECP 1177, 1150 AND 1200 HAVE BEEN RELEASED AND FABRICATION IN PROCESS (18 ITEMS)

SSME BLOCK 1 INTEGRATION PLAN
SPECIFICATION SCHEDULE

4/16/94



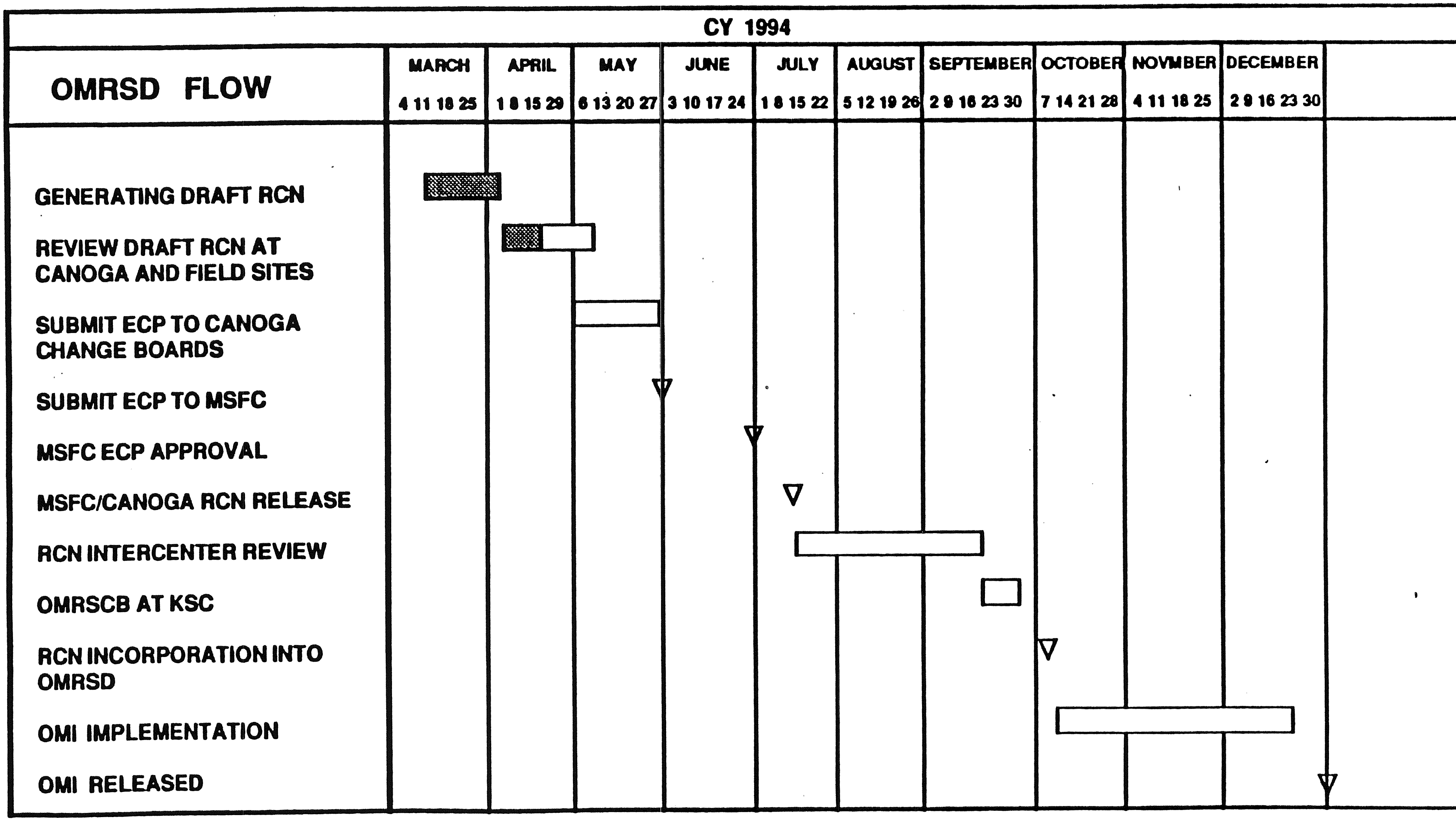
SSME BLOCK 1 INTEGRATION PLAN
SPECIFICATION CHANGES

4/15/94

SPECIFICATION NO	DESCRIPTION - TITLE	CHANGES REQUIRED	ITEMS TO REVIEW
RL00050-04 (HOT-FIRE)	SSME ACCEPTANCE TEST, CALIBRATION & ADJUSTMENT	ADD ATD & PHASE II+ POWERHEAD INSPECTIONS	EXISTING FEC/IDCR AND TEAM INPUTS
RL00056-06 RL00056-07 (2ND E&M)	SSME FINAL INSPECTION & ACCEPTANCE CHECKOUT (-06 OUT OF STAND, -07 IN STAND)	ADD ATD & PHASE II+ POWERHEAD INSPECTIONS	EXISTING FEC/IDCR AND TEAM INPUTS
RL00461 (GREEN RUN)	SSME COMPONENT LEVEL HOT FIRE TESTING	NEW SPECIFICATION FOR ATD	ATD TEAM INPUT DESIGN REVIEW CRITERIA
RL00532	SSME COMPONENT ALLOWABLE LIFE & HARDWARE TRACKING	ADD ATD & PHASE II+ POWERHEAD LRU	DEFINE LRU'S AND FLIGHT CONFIGURATION
RL00712	POWERHEAD, SSME, ENCAPSULATION LEAK CHECK	ADD ATD & PHASE II+ POWERHEAD REQUIREMENTS	EXISTING FEC/IDCR AND TEAM INPUTS
RL00663	SSME POST HOT FIRE DRYING PROCEDURE	ADD ATD DRYING REQUIREMENTS	EXISTING FEC/IRDC AND TEAM INPUTS
RF0001-053	SSME INSPECTION CRITERIA	ADD ATD & PHASE II+ POWERHEAD INSPECTIONS	EXISTING FEC/IRDC AND TEAM INPUTS
RF0005-009	SSME COMPONENT FLEETLEADER REQUIREMENTS	ADD ATD & PHASE II+ POWERHEAD LRU	DEFINE LRU'S AND FLIGHT CONFIGURATION
RSS 8561	STRUCTURAL LOADS CRITERIA	ADD ATD & PHASE II+ POWERHEAD CRITERIA	TEAM INPUTS
NSTS 08171 (OMRSD)	KSC MAINTENANCE AND INSPECTION REQUIREMENTS	ADD ATD & PHASE II+ POWERHEAD INSPECTIONS	EXISTING FEC/IDCR AND TEAM INPUTS
13M15000 (ICD) CP320R0003 (CEI)	SSME/VEHICLE ICD & CONTRACT END ITEM SPECIFICATION	WEIGHT & PERFORMANCE CHANGES FOR ATD AND PHASE II+	ATD TEAM INPUT DESIGN REVIEW CRITERIA

SSME BLOCK 1 INTEGRATION PLAN
RCN (OMRSD) SCHEDULE

4/16/94



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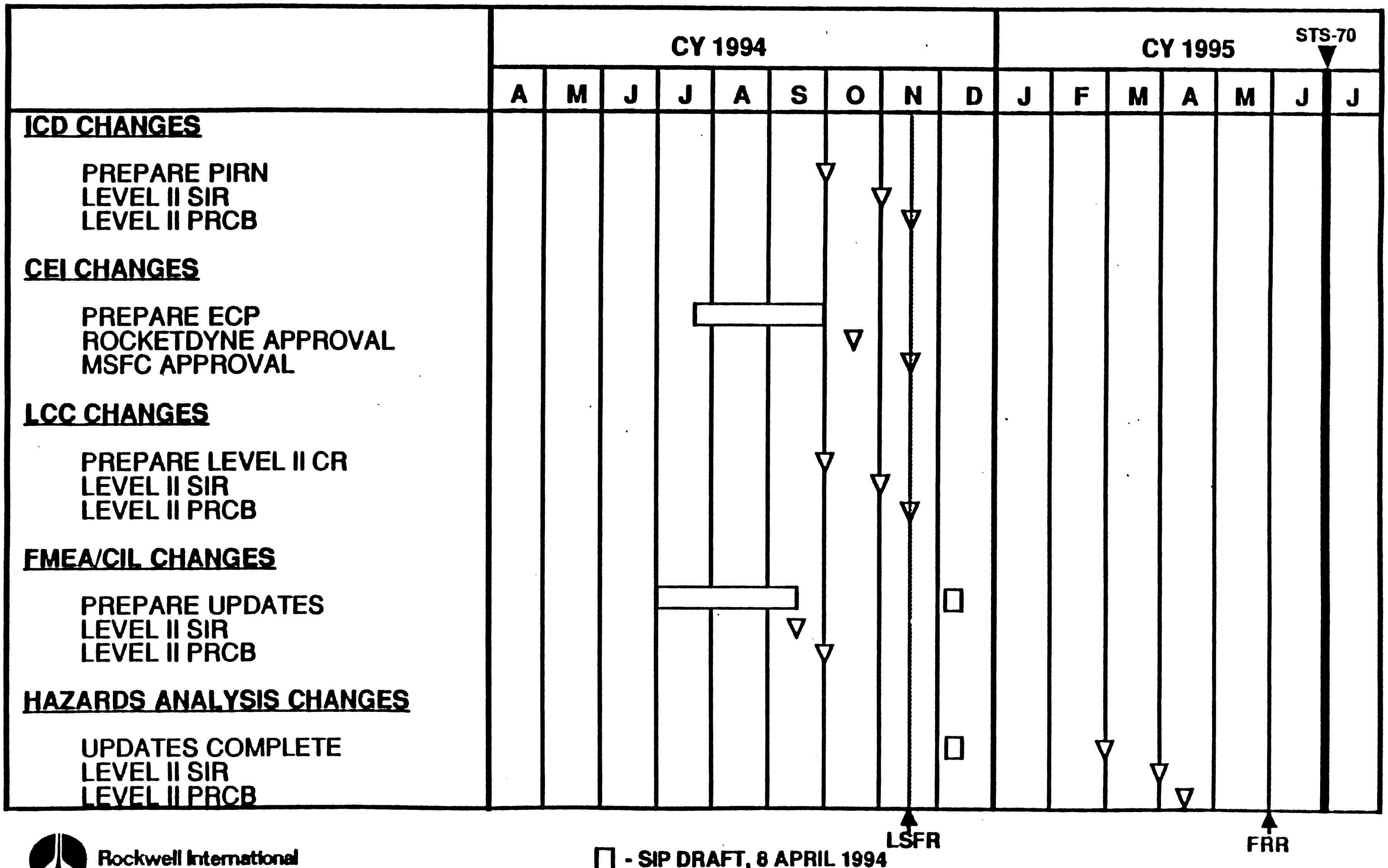
* OMI RELEASED 30 DAY PRIOR TO HARDWARE DELIVERY TO KSC

SSME BLOCK 1 INTEGRATION PLAN
LEVEL II DOCUMENTATION SCHEDULE

4/16/94



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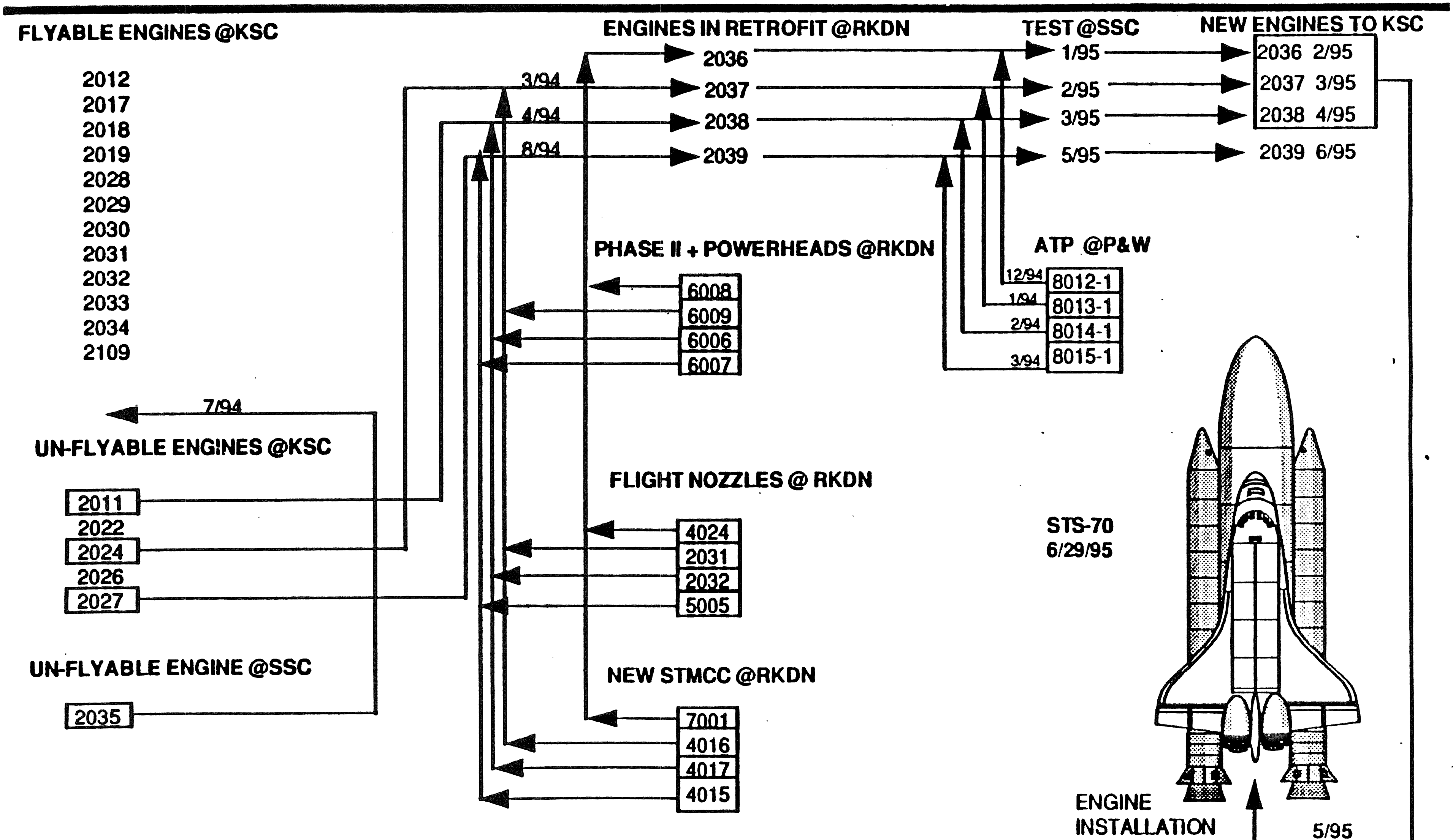
SSME BLOCK 1 ENGINE
FIRST FLIGHT DEFINITION

4/15/94



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SPACE SHUTTLE

SSME BLOCK 1 ENGINE INTEGRATION ISSUES

4/16/94

- **NO ECP TO DEFINE P&W ATD FLIGHT CONFIGURATION**
  - REQUIRED FOLLOWING ATD CDR TO FORMALIZE IMPACTS TO LEVEL II REQUIREMENTS
    - WEIGHT
    - PERFORMANCE
    - OPERATIONS & MAINTENANCE
    - REDLINES & LCC
    - FMEA/CIL AND HAZARD IMPACT
  - COMPLETES DOCUMENTATION TRAIL FOR BLOCK 1 ENGINE

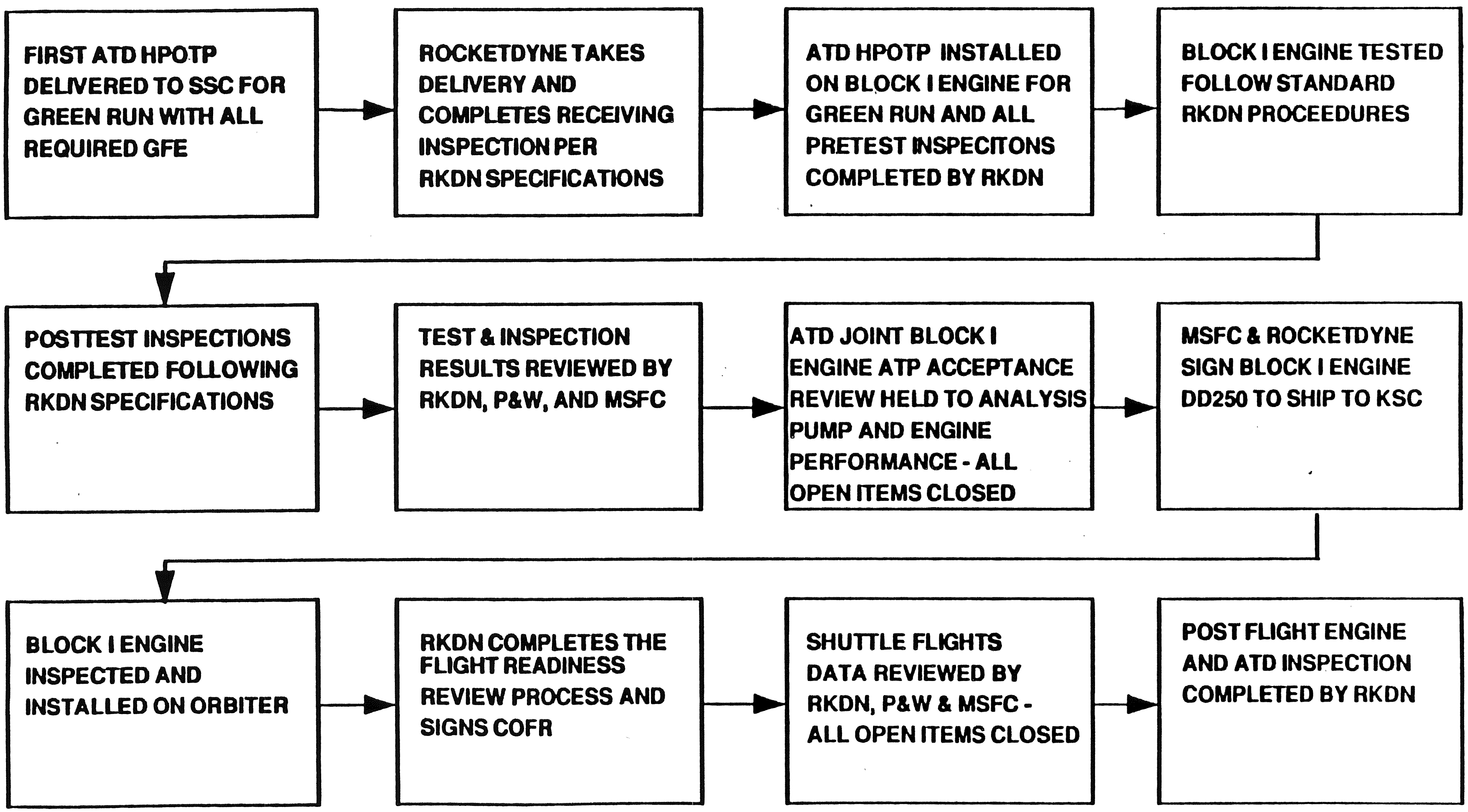
- **NEED DEFINITION OF RESPONSIBILITIES FOR ATD INSPECTIONS AND STANDARD REPAIRS**
  - DOES ROCKETDYNE OR P&W DO THE WORK — ROC will perform all inspections/processing
  - WHO PROVIDES THE WARRANTY — Otto does not see a need for P+W at KSC unless requested at

- **ATD POST LANDING DRYING REQUIREMENTS & KSC GSE MODIFICATIONS**
  - KSC NEEDS REQUIREMENTS BY 29 APRIL TO HAVE LOCKHEED REVIEW GSE IMPACTS

- **DEFINITION OF ATD ACCEPTANCE AND POST FLIGHT INSPECTIONS REQUIRED**
  - ALL CRIT 1 FAILURES IDENTIFIED ON FMEA/CIL MUST BE INSPECTED IF ACCESSIBLE
  - NEED FORMAL DEFINITION TO FINALIZE ORMSD CHANGES

BLOCK I ENGINE INTEGRATED FLOW

4/16/94



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SYSTEM INTEGRATION PLAN (SIP)

Presenter
C. KOTILA / F. BENNETT
Date
4/19/94

- DEFINES COMMITMENT ON ROLES & RESPONSIBILITIES ASSOCIATED WITH INCORPORATION/IMPLEMENTATION OF A CHANGE INTO THE SSP

- INFORMATION/DATA PRODUCTS NEEDED FROM OTHER ELEMENTS/ORGANIZATIONS

- CONTAINS SCHEDULE COMMITMENTS FOR SPECIFIC TASKS/ACTIVITIES NEEDED TO ASSURE SYSTEM CHANGE INTEGRATION

SPACE SHUTTLE

SYSTEM INTEGRATION PLAN

SPACE SHUTTLE MAIN ENGINE

BLOCK I CONFIGURATION

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FOREWORD

Efficient management of the Space Shuttle Program (SSP) dictates that effective control of program activities be established. Requirements, directives, procedures, interface agreements, and information regarding system capabilities are to be documented, baselined, and subsequently controlled by SSP management.

Program requirements controlled by the Program Manager, Space Shuttle, are documented in, attached to, or referenced from Volume I through XVIII of NSTS 07700.

This System Integration Plan (SIP) is the agreement on the responsibilities and tasks which directly relate to the integration activities associated with the incorporation of the Space Shuttle Main Engine (SSME) with the Block I Configuration (BLK I) into the Space Shuttle Program. Baselining of this document constitutes the technical agreement on the part of affected parties as to those tasks that require accomplishment in order to assure proper system change integration. In addition, this document contains the schedule commitments associated with the specific tasks/activities.

All elements of the (SSP) must adhere to these baselined requirements. When it is considered, by the Space Shuttle project/program element manager to be in the best interest of the (SSP) to change, waive or deviate from these requirements, an (SSP) Change Request (CR) shall be submitted to the Level II Program Requirements Control Board (PRCB) Secretary. The CR must include a complete description of the change, waiver or deviation, and the rational to justify its consideration. All such requests will be processed in accordance with NSTS 07700, Volume IV, and dispositioned by the Program Manager, Space Shuttle on a Space Shuttle PRCB Directive (PRCBD).

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Brewster H. Shaw, Jr.
Program Manager, Space Shuttle

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TABLE OF CONTENTS

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1.0 INTRODUCTION

This system integration plan (SIP) provides the management roles and responsibilities as well as the definition of the interfaces and schedule requirements to accomplish the integration of Space Shuttle main engines (SSME's) equipped with Block I Configuration (BLK I) into the Space Shuttle program.

2.0 APPLICABLE DOCUMENTS

The following documents of the date and issue shown form a part of this document to the extent specified herein. "(Current Issue)" is shown in place of a specific date and issue when the document is under Level II PRCB control. The current status of documents with "(Current Issue)" may be determined from NSTS 08102, Level II Document Description and Status Report.

2.1 SYSTEM LEVEL SPECIFICATIONS

NSTS 07700 VOLUME X, SPACE SHUTTLE FLIGHT AND GROUND SPECIFICATION Reference paragraph 4.1, 5.0, 7.1, 7.2

NSTS 07700-10-MVP-01, SHUTTLE MASTER VERIFICATION PLAN Reference paragraph 7.1

NSTS 07700-10-MVP-02, COMBINED ELEMENT MASTER VERIFICATION PLAN Reference paragraph 7.2

NSTS 07700-10-MVP-06, SPACE SHUTTLE MAIN ENGINE MASTER VERIFICATION PLAN

NSTS 08130, POGO PREVENTION PLAN Reference paragraph 4.2.1

NSTS 08171, OPERATIONS AND MAINTENANCE REQUIREMENTS AND SPECIFICATIONS FOR SPACE SHUTTLE PROGRAM, FILE II, VOLUME 1 AND FILE III, VOLUME 41

NSTS 08209, SHUTTLE SYSTEMS DESIGN CRITERIA

ICD 13M15000, SPACE SHUTTLE ORBITER VEHICLE/MAIN ENGINE INTERFACE CONTROL DOCUMENT Reference paragraph 5.0

ICD 2-0A002, SHUTTLE SYSTEMS/LAUNCH PAD AND MLP INTERFACE CONTROL DOCUMENT

NSTS 16007, SHUTTLE LAUNCH COMMIT CRITERIA AND BACKGROUND REVISION D

NSTS 85-0169-1,2,3, and 4 STRUCTURAL DESIGN LOADS DATA BOOK

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NSTS 07700, INFORMATION REQUIREMENTS, VOLUME V

NSTS 22206, INSTRUCTIONS FOR PREPARATION OF FAILURE MODE AND EFFECTS ANALYSIS (FMEA) AND CRITICAL ITEMS LIST (CIL)

NSTS 22254, METHODOLOGY FOR CONDUCT OF NSTS HAZARDS ANALYSIS

2.2 OTHER SPECIFICATIONS

ROCKETDYNE, RSS-8553-11, SSME FAILURE MODE AND EFFECTS ANALYSIS
ROCKETDYNE, RSS-8740-11, CRITICAL ITEMS LIST

ROCKETDYNE, RSS-8545-20, SSME INTEGRATED HAZARDS ANALYSIS

JSC-08934, SHUTTLE OPERATIONAL DATA BOOK

JSC-12820, STS OPERATIONAL FLIGHT RULES PCN-4

CREW PROCEDURES - AS APPLICABLE

MSFC LETTER, EP01 (88-316), TRANSMITTAL OF SSME THRUST BUILDUP MODELS FOR STS-26R/FRF PLUS STS-37 AND SUBSEQUENT FLIGHTS

3.0 DESCRIPTION

The Block I Configuration (BLK I) for the SSME incorporates a two duct manifold in the fuel side of the engine powerhead, a single tube heat exchanger in the oxygen side of the engine powerhead, an oxygen Alternate Turbopump (AT), removal of injector baffles in the main burner, and enlargement of the boundary layer coolant holes (EBLCH) in the main injector. These changes are related to safety enhancements except for the removal of injector baffles and EBLCH. The baffles were removed for I_{sp} gain to offset some of the weight increase. The EBLCH was necessitated to prevent erosion of the main combustion chamber (MCC). First flight of the BLK I/SSME's with is scheduled June 1995 (STS-70).

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3.1 IMPACTS

The BLK I/SSME's are being developed to replace the current SSME configuration. As such, the BLK I configuration shall operate within the existing engine parameters and insurance that it complies with these parameters will require system characterization, analysis, and verification. Based upon the current BLK I design, impacts may be experienced for:

1. Performance
   net weight increase
   net Isp increase
   net thrust increase
   reduced payload lift capability

2. Loads/dynamics
   POGO stability
   engine startup & shutdown thrust profiles

3. Guidance, navigation, and control
   slight C. G. shift aft

4. Shock, vibration, acceleration, and acoustics (additional or different)

5. Main propulsion system (additional or different)

6. Integrated hazards (additional or different)

7. Redlines (additional or different)

8. Failure modes (additional or different)

9. Ground support equipment (GSE)

10. Operations and maintenance requirements specifications (OMRS).

4.0 RESPONSIBILITIES

The responsibility for assuring the definition, control, implementation, and accomplishment of the activities identified in this document is vested with the organizations as established in the subsequent subsections. These organizations shall support the integration activities and the schedule completion dates of the items contained in section 9. Overall responsibility for the preparation and maintenance of this SIP is authorized in accordance with NSTS 07700, Volume IV and vested with the Space Shuttle System Integration Organization.

4.1 DEVELOPMENT PROJECT

The SSME Project Office has management responsibility for the development, production, and integration of the BLK I/SSME's into the Shuttle. The BLK I/SSME's are to operate within the current Orbiter and SSME interface control documents (ICD's), NSTS 07700, Volume X, and Shuttle Systems Design Criteria NSTS 80209. Variances that affect the SSP SSME/Orbiter operating environment would require changes to these documents and the SSME Project Office is responsible for initiating and coordinating these changes.

The SSME Project Office shall be responsible for the preparation and submittal of changes for the SSME failure modes and effects analysis and critical items list updates (FMEA/CIL, element hazards, launch commit criteria (LCC), Shuttle Operational Data Book (SODB), and Operational Maintenance Requirements and Specifications Document (OMRSD). The SSME Project Office shall also review the updated integrated hazards provided by Space Shuttle System Integration.

The SSME Project Office is responsible for design requirements changes for GSE to support the BLK I SSME's. This includes GSE that is the responsibility of MSFC as well as GSE that is the responsibility of KSC. Also this office shall provide modification kits or new GSE to KSC for GSE that is MSFC responsibility.

The SSME Project Office is responsible for providing project verification status as specified in NSTS 07700, Volume X and for furnishing the products required for combined element verification as stated in paragraph 7.2 of this SIP.

This office is responsible for initiating the change process and providing the Space Shuttle System Integration Office and JSC/Mission Operations Directorate with the APPROPRIATE data pertaining to additional flight redlines or changes to current flight redline parameters

4.2 SPACE SHUTTLE PROGRAM OFFICE

4.2.1 System Integration Office.

Space Shuttle System Integration is responsible for the integration analyses and assessments of the SSME's equipped with the BLK I into the Shuttle flight and ground systems. This office shall provide a systems recommendation for use of the SSME/BKL I in a mixed cluster on the Orbiter. This Office is responsible for evaluating SSP requirements changes; processing necessary loads environment updates; conducting the Systems Integration Review (SIR) and coordinating PRCB presentations for redline changes and LCC changes, and approving the OMRSD changes. The integrated hazards analysis and the combined element verification process are the responsibility of this office.

Space Shuttle System Integration is responsible for analyses or assessments for performance including mass properties and operating characteristics; loads/dynamics; guidance, navigation, and control; shock, vibration, acceleration, and acoustics; and the main propulsion system (MPS). This office is responsible for updating the existing math models from test results of thrust buildup and decay profile differences and HPOTP pressure transfer functions for integrated POGO stability assessments. This office shall update NSTS 08130, POGO Prevention Plan, for the BLK I requirements. The Shuttle Systems Integration office shall provide letter with a detailed description of data required to complete the above analysis to the SSME Project Office. Detailed delivery schedules of this data shall be directed in writing by the groups and panels reporting to the (SIR).

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4.2.2 Orbiter and GFE Projects Office.
This office concurs with OMRSD and ICD changes and participates in the assessments and GSE change process.

4.2.3 Safety, Reliability, and Quality Assurance Office.
This office shall be responsible for review, assessment, and coordination of all SR&QA documentation updates required of all Space Shuttle Program elements by NSTS 07700, Volume V, Appendix C. This office shall also be responsible for assuring that SR&QA program requirements as specified in NSTS 07700, Volume X, are adequately met. This includes, but is not limited to, assessing design changes, supporting hardware certifications, evaluating updated procedures (flight rules, crew procedures, LCCs, OMRSD, etc.), SSME FMEA/CILs, SSME hazards , and integrated hazards changes to verify program risks are adequately controlled.

4.3 OTHER AFFECTED PROJECTS/ORGANIZATIONS

4.3.1 KSC
KSC is responsible for supporting launch operations changes, postflight operations changes, and launch site GSE changes. The preparation of technical operating procedure (TOP), operations and maintenance instruction (OMI), and test preparation sheet (TPS) changes is a KSC responsibility.

KSC is responsible for design changes to the Thomson rail and KSC provides either the new rail or the modification kits for the existing rail based upon design requirements provided by the SSME Project Office.

4.3.2 JSC/Mission Operation Directorate
JSC/Mission Operation Directorate shall make mission planning and mission control center changes. Mission Operations is responsible for changing flight rules and updating systems briefings, handbooks, drawings, and standard console procedures. This office is responsible for changes to the Shuttle mission simulator and crew procedures and training necessary for the SSME's with the BLK I.

4.3.3 JSC/Engineering Directorate
JSC/Engineering Directorate participates in the definition of POGO pulsing and test requirements and supports all technical analyses requirements through the appropriate panel.

5.0 SHUTTLE/ENGINE SYSTEMS INTERFACES

The SSME's with the BLK I must comply with the shuttle/engine system requirements of the latest version of the ICD 13M15000 and NSTS 07700, Volume X. Requests for deviations to these documents are to be submitted against the ICD 13M15000 and NSTS 07700, Volume X where the SSME's with the BLK I do not meet shuttle/engine systems requirements.

6.0 SYSTEMS ANALYSES

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This section contains a description of the required systems analyses and identifies the responsible parties for performing the analyses. This information is cross-referenced to the specific schedule entry.

6.1 PERFORMANCE
The SSME Project Office shall provide performance data to characterize the BLK I/SSME's. Space Shuttle System Integration shall conduct a systems performance assessment for all phases of SSME operation including nominal, dispersed, and abort conditions .

6.2 LOADS/DYNAMICS
The POGO system, start sequencing, thrust buildup, thrust decay, additional mass, and ignition overpressure are possible SSME variances. Systems impacts due to these variances shall be verified by Space Shuttle System Integration. The SSME Project Office provided engine thrust profiles (reference MSFC letter EP-01 (88-316)) will allow calculations of Space Shuttle vehicle and mobile launch platform loads and solid rocket booster ignition timing requirements which are to be assessed against Shuttle systems environments.

6.3 AERODYNAMICS - not applicable.

6.4 AEROHEATING/THERMAL - not applicable

6.5 AVIONICS - not applicable

6.6 SOFTWARE - not applicable

6.7 GUIDANCE, NAVIGATION, AND CONTROL
The Space Shuttle System Integration Office shall conduct a systems analysis of the additional mass for the BLK I/SSME's to assure proper gimballing and thrust vector control operation. The SSME Project Office shall provide engine mass properties, pump spin rate and inertia in support of this analysis.

6.8 SHOCK, VIBRATION, ACCELERATION, AND ACOUSTICS
Shock, vibration, acceleration and acoustics require an analysis for any environmental change to assure compliance with the applicable Shuttle systems defined in MF 0004-014, Environmental Requirements and Test Criteria for the Orbiter Vehicle, and SD 74-SH-0082, Space Shuttle System Acoustics and Shock Data Book. The SSME Project Office shall identify changes from current environments for operating the BLK I/SSME's and Space Shuttle System Integration conducts the assessment for the Shuttle environments.

6.9 MAIN PROPULSION SYSTEM
Fluid systems performance parameters for nominal, dispersed, and failure conditions during all phases of SSME operation shall be assessed against the ICD to assure proper integrated main propulsion system operations and compliance with systems requirements. The SSME Project Office is responsible for characterizing the fluid systems performance parameters, in

the update of the ICD, and the Space Shuttle System Integration Office is responsible for the systems analysis.

6.10 INTEGRATED HAZARDS

The Space Shuttle System Integration Office provides an integrated hazards analysis for the BLK I equipped SSME and the Shuttle system. The SSME Project Office shall participate in the review of the integrated hazard analysis.

7.0 VERIFICATION

7.1 PROJECT ELEMENT VERIFICATION

Project element verification activities shall be identified in the project's updated master verification plan as approved by project element management. The verification activity must exhibit traceability to each applicable NSTS 07700, Volume X requirement as specified in MVP-01.

7.2 COMBINED ELEMENT VERIFICATION

Combined element verification shall be managed by Space Shuttle System Integration. System Integration shall update MVP-02 to define plans and products for verification of combined element requirements as specified in NSTS 07700, Volume X, Table 4.1.

8.0 IMPLEMENTATION INTO THE SPACE SHUTTLE PROGRAM

8.1 IMPLEMENTATION

The BLK I are to be implemented into the SSME fleet as new flight engines. Prior to fleet implementation, the performance of the SSME's equipped with the BLK I shall be established and the integration efforts are to be completed. The Launch Site Flow Review (LSFR) for the appropriate vehicle is the formal board for accepting the Orbiter configuration.

9.0 SCHEDULE

The attached schedule identifies product delivery dates, test dates, verification milestones, and other program milestones. This schedule provides the plan for the integration of the SSME's with the BLK I into the Space Shuttle program. Detailed milestones are compliance objectives which enable subsequent activities to effectively and efficiently occur.

Proposed changes to the attached schedule shall be reviewed for technical requirements and schedule impacts by the responsible organization and submitted for concurrence and baselining through the appropriate Space Shuttle program change control process (e.g. SIR and PRCB).

DRAFT

APPENDIX

ACRONYMS

BLK I Block I configuration
CIL Critical Items List
CR Change Request
DA Mission Operations Directorate
ECP Engineering Change Proposal
FMEA Failure Modes and Effects Analysis
GPC General Purpose Computer
GSE Ground Support Equipment
HPFTP High Pressure Fuel Turbopump
HPOTP High Pressure Oxidizer Turbopump
ICD Interface Control Document
KSC Kennedy Space Center
LCC Launch Commit Criteria
LRU Line Replacement Unit
LSRF Launch Site Flow Review
MSFC Marshall Space Flight Center
NA Safety, Reliability, and Quality Assurance Office
NSTS National Space Transportation System
OMI Operations and Maintenance Instruction
OMRS Operations Maintenance Requirements Specification
OMRSD Operational Maintenance Requirements and Specifications Document
PCIN Program Change Identification Number
PIRN Preliminary Interface Revision Notice
PRCB Program Requirements Control Board
RCN Requirements Change Notice
SIP System Integration Plan
SIR Systems Integration Review
SODB Shuttle Operational Data Book
SR&QA Safety, Reliability, and Quality Assurance
SSME Space Shuttle Main Engine
TOP Technical Operation Procedure
TPS Test Preparation Sheet
VA Orbiter and GFE Projects Office
WA System Integration

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SSP SYSTEMINTEGRATION - DRAFT

SSME / BLOCK I CONFIGURATION - 1st FLT JUNE 95

Description		1994 1995
	1	
REFERENCE MILESTONES	2	
	3	
ATD CDR COMPLETE	4	16MAY
SYSTEM - POGO TESTING	5	20MAY
SYSTEM - ZERO-G TESTING	6	09SEP
LAUNCH SITE REQUIREMENTS REVIEW	7	04NOV
BLK I DCR	8	14APR
FIRST FLIGHT	9	30JUN
SSME PROJECT	10	
	11	
LOADS MATH MODEL UPDATES	12	01AUG
GN&C DATA	13	01AUG
ASCENT PERFORMANCE DATA	14	01AUG
VERIFICATION DATA	15	01AUG
DATA BOOK UPDATES (CR TBD)	16	01AUG
GSE DESIGN EFFORT (ECP TBD)	17	01AUG
THOMSON RAIL DESIGN REQUIRMENTS	18	01AUG
LCC CHANGES (CR TBD)	19	01SEP
SODB CHANGES (BY LETTER)	20	09SEP
ICD (PIRN TBD)	21	15SEP
	22	

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SSME / BLOCK I CONFIGURATION - 1st FLT JUNE 95

Description		1994 1995
SSME PROJECT - CONTINUATION	23	
	24	
OMRSD CHANGES (RCN TBD)	25	15SEP
NSTS 07700 VOL X (CR TBD)	26	30SEP
FLIGHT REDLINE CHANGES (CR TBD)	27	01DEC
ELEMENT FMEA/CIL CHANGES (PCIN TBD)	28	01FEB
ELEMENT HAZARD CHANGES (PCIN TBD)	29	01FEB
INT HAZ ANALY SUPPORT/REVIEW	30	01FEB
MODIFY /NEW GSE	31	31MAR
	32	
SYSTEM INTEGRATION	33	
	34	
RECOMEMDATION FOR MIX CLUSTER	35	24MAY
SYS INTEG ASSESS DATA REQ (LETTER)	36	31MAY
NSTS 07700 VOL X - APPROVE CR	37	01NOV
LOADS/DYNAMICS FINAL ASSESSMENT	38	01NOV
PERFORMANCE ASSESSMENT	39	01NOV
GN&C ASSESSMENT	40	01NOV
SHOCK VIB, ACELL & ACOU ASSESSMENT	41	01NOV
MAIN PROPULSION ASSESSMENT	42	01NOV
LCC CHANGES - CR APPROVAL (SIR)	43	01NOV
OMRSD CHANGES - SIR (RCN APPROVAL)	44	01NOV

SSP SYSTEMINTEGRATION - DRAFT
SSME / BLOCK I CONFIGURATION - 1st FLT JUNE 95

Description		1994 – 1995 (J F M A M J J A S O N D J F M A M J J A S O N D)
SYSTEM INTEGRATION - CONTINUATION	45	
	46	
ICD - APPROVE PIRN	47	01NOV △
COMBINED ELEMENT VERIFICATION	48	01NOV △
INTEGR HAZ ANALY APPROVAL - SIR	49	13JAN △
FLT REDLINE CHANGES APPROVAL - SIR	50	01FEB △
LOADS ENVIRONMENT UPDATES (CR TBD)	51	01MAR △
UPDATE ORBITER DYM LOADS MATH MODEL	52	01MAR △
SR&QA	53	
	54	
REVIEW ELEMENT FMEA/CIL	55	15FEB △
REVIEW ELEMENT HAZARDSL	56	15FEB △
INTEGRATED HAZARDS REVIEW	57	15FEB △
KSC	58	
	59	
THOMSON RAIL DESIGN Rockwell is Paid by & KSC to change Design	60	07OCT △
TOP/OMI/TPS CHANGES	61	01MAR △
THOMSON RAIL MODIFICATIONS	62	01JUN △
JSC/MOD	63	
	64	
OPERATIONS CHANGES	65	01DEC △