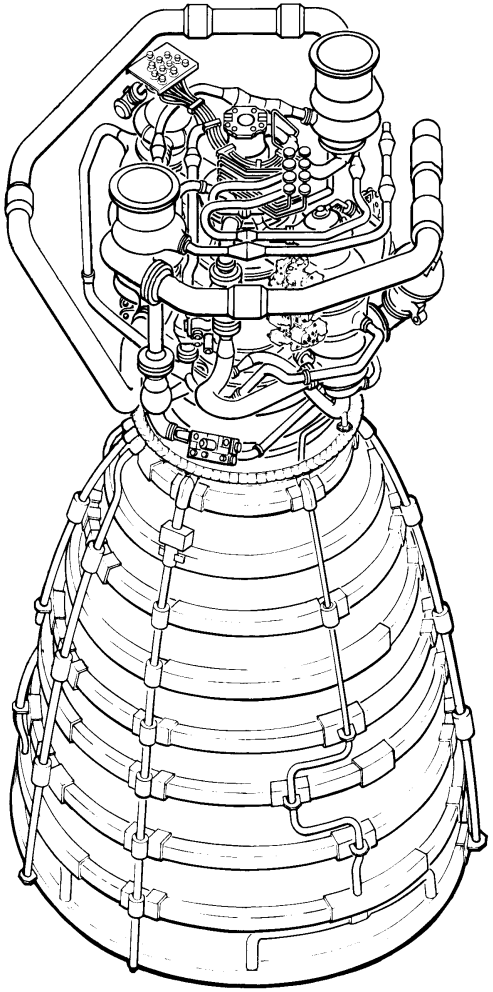

Atlantis STS-106

Space Shuttle Program

SSME Flight Readiness Review

August 29, 2000

Atlantis STS-106

Agenda

- **Major Components**
- **Engine Performance**
- **First Flight ECPs**
  - None
- **Material Review Reassessment**
- **Special Topics**
  - E0523 Premature Shutdown
  - G3 Seal Disbond
  - Antiflood Valve Contamination

Atlantis STS-106

SSME Major Components

Engine	ME-1 (2052) *Block IIA*	ME-2 (2044) *Block IIA*	ME-3 (2047) *Block IIA*
Last Hot-Fire	**STS-99**	**STS-99**	**STS-99**
Powerhead	6009	6010	6016
Main Injector	6007	4029	4027
MCC	6016	6007	6011
Nozzle	4025	2035	4027
Controller	F52	F59	F63
HPFTP	6016	4116	4214
LPFTP	4111	2232	2225
HPOTP/AT	8030	8014R1	8024
LPOTP	6004	2229	2230

No changes from last hot-fire.

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Predicted SSME Ignition Confirm Margins

Calculations use Block IIA Flight database sigmas

Parameter	ME-1 (2052)	ME-2 (2044)	ME-3 (2047)
HPFTP Minimum Speed	6.9	4.9	7.5
Min/Max Ignition Pc	4.4	3.1	4.2
Antiflood Valve Min Open	23.7	23.7	21.6
HPFTP Max Turbine Temp (1760 Limits)	5.2	4.1	4.5
HPOTP Max Turbine Temp (1460 Limits)	5.9	3.3	4.0
HPOTP Min Turbine Temp (720 Min @ 4.0 secs)	4.5	6.8	8.4
Preburner Max Purge Pressure (715/100 Limits)	20.9	25.4	21.4
POGO GOX Min/Max Pressure	3.9	4.2	3.5

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Predicted SSME Performance at 104.5% P.L.

At Engine Start + 200 seconds
(MR = 6.032, OPI = 69 psia, FPI = 28 psia)
Calculations use Block IIA 13 Engine database sigmas

Parameter	Block IIA 13 Engine Average	ME-1 (2052)		ME-2 (2044)		ME-3 (2047)	
		Predict	Sigma	Predict	Sigma	Predict	Sigma
HPFT Disch Temp A, Deg R	1597	1558	-0.9	1625	0.6	1611	0.3
HPFT Disch Temp B, Deg R	1604	1579	-0.6	1614	0.2	1594	-0.2
HPOT Disch Temp A, Deg R	**1214**	1161	-1.3	1313	**a [2.5]**	1226	0.3
HPOT Disch Temp B, Deg R	**1228**	1228	0.0	1322	**a [2.4]**	1248	0.5
HEX Interface Temp, Deg R	823	805	-0.8	859	1.5	844	0.9
HPFTP Speed, rpm	34293	33902	-1.5	34258	-0.1	34441	0.6
LPFTP Speed, rpm	15680	15697	0.1	15533	-0.5	15855	0.6
HPOTP/AT Speed, rpm	22323	22304	-0.1	22253	-0.5	22508	1.2
LPOTP Speed, rpm	5029	5043	0.4	5008	-0.6	5047	0.5
OPOV Position, %	**63.6**	63.4	-0.2	65.4	**a [2.3]**	62.6	-1.2
FPOV Position, %	76.5	76.6	0.2	76.4	-0.1	75.1	-1.9
PBP Disch Pressure, psia	6910	6897	-0.2	6936	0.3	6910	0.0
HPFTP Disch Pressure, psia	5666	5601	-1.5	5661	-0.1	5684	0.4
HPOTP Disch Pressure, psia	3804	3782	-0.7	3801	-0.1	3813	0.3
	HPFTP U/N	6016		4116		4214	
	LPFTP U/N	4111		2232		2225	
	HPOTP U/N	8030		8014R1		8024	
	LPOTP U/N	6004		2229		2230	

[ ] Exceeds database two sigma

a Low performing HPOTP/AT turbine

Atlantis STS-106

Predicted Redline Margins at 104.5% P.L.

Calculations use Block IIA Flight database sigmas

Parameter	Redline Limit	Margin Sigma		
		ME-1	ME-2	ME-3
HPFT Discharge Temp ChA, Deg R	1860 Max	6.6	5.2	5.5
HPFT Discharge Temp ChB, Deg R	1860 Max	6.7	5.9	6.5
HPOT Discharge Temp ChA, Deg R	1660 Max	8.1	5.4	6.9
HPOT Discharge Temp ChB, Deg R	1660 Max	8.0	6.3	7.7
HPOT Discharge Temp ChA, Deg R	720 Min	4.7	6.8	5.9
HPOT Discharge Temp ChB, Deg R	720 Min	5.3	7.4	5.8
HPOTP/AT IMSL Purge Pr, psia	159 Min	3.8	7.5	7.5
HPFTP Coolant Liner Pressure, psia	3392 Max	20.1	18.9	17.1
Low MCC Pc, psid				
Command-ChA Avg	200 Max	21.9	22.5	21.8
Command-ChB Avg	200 Max	30.2	29.8	30.9
FASCOS				
HPFTP (16 GRMS)	Not	6.3	6.4	6.5
HPOTP (11 GRMS)	Active	36.9	35.0	37.7

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Material Review Reassessment

	E2052		E2044		E2047	
	MRs	**PMRB ***	**MRs**	**PMRB ***	**MRs**	**PMRB ***
Powerhead	118	48	84	22	91	20
MCC	18	5	22	5	18	5
Nozzle	70	28	68	28	62	30
Controller	0	0	0	0	1	0
HPFTP	191	49	182	63	176	62
LPFTP	48	12	56	17	66	17
HPOTP/AT	160	25	226	43	155	28
LPOTP	34	4	34	9	40	12
Assembly Ops	141	33	101	26	127	35
Ducts/Interconnects	91	19	85	16	127	18
	871	**223**	**858**	**229**	**863**	**227**

Total PMRB MRs = 679

Total MRs = 2592

***MRs that would meet today's Rocketdyne PMRB criteria

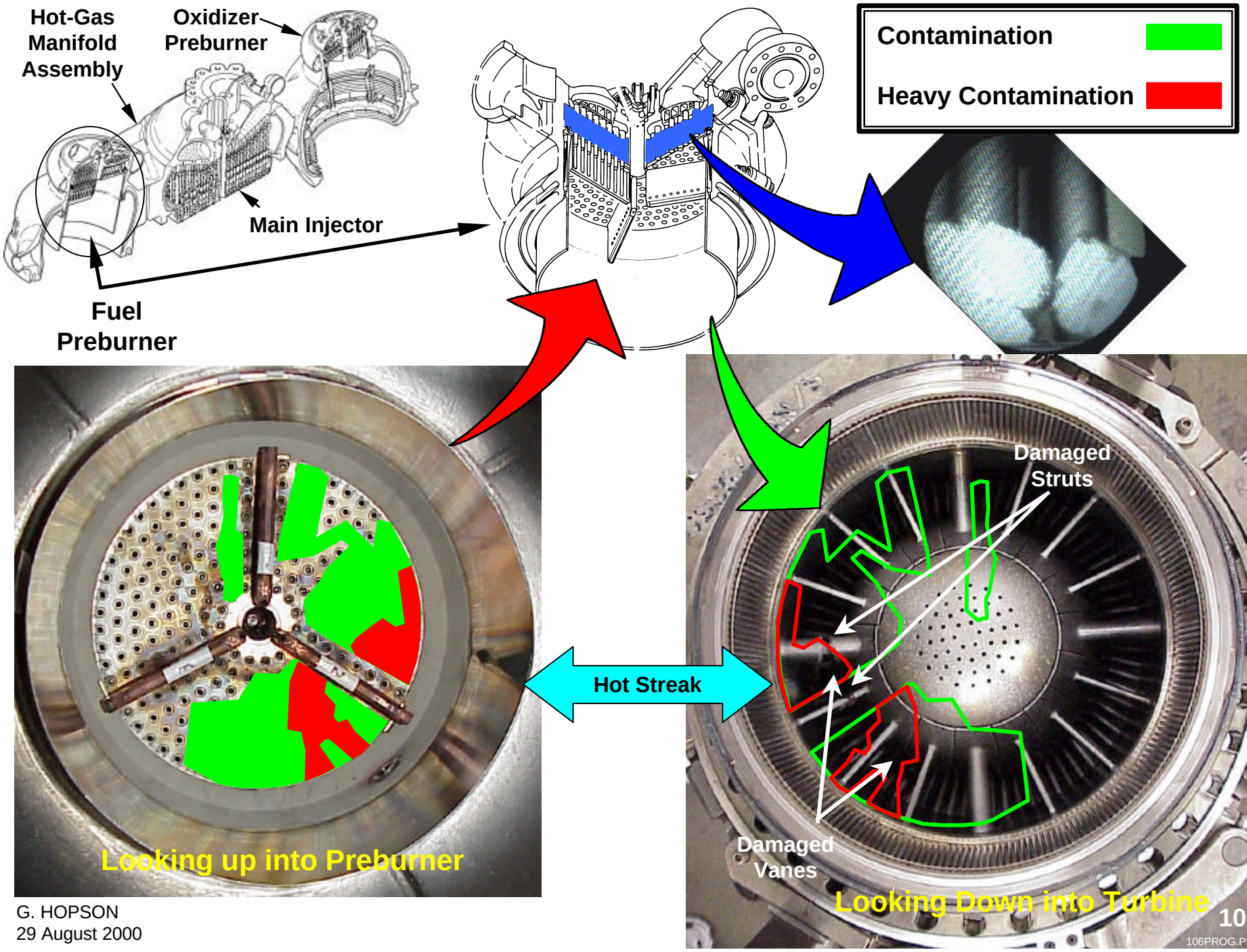
All dispositions reviewed and found acceptable for flight

Engine 0523 Premature Shutdown

- **Issue**
  - Engine 0523 prematurely shut down at SSC due to high turbine discharge temperatures
- **Background**
  - E0523 rebuilt at Canoga Park with Small Throat MCC for redline demonstration test of HPFTP/AT
  - Test 902-772 shut down 5.2 seconds after engine start (planned duration was 200 seconds)
    - Shutdown initiated by HPFT discharge temperatures exceeding 1860 R limit
    - Facility HPFTP/AT vibration redline also initiated shutdown command
  - Data and inspections indicated a hot streak initiated from Fuel Preburner
    - Burn-through damage observed on HPFTP/AT turbine inlet struts

Engine 0523 Premature Shutdown

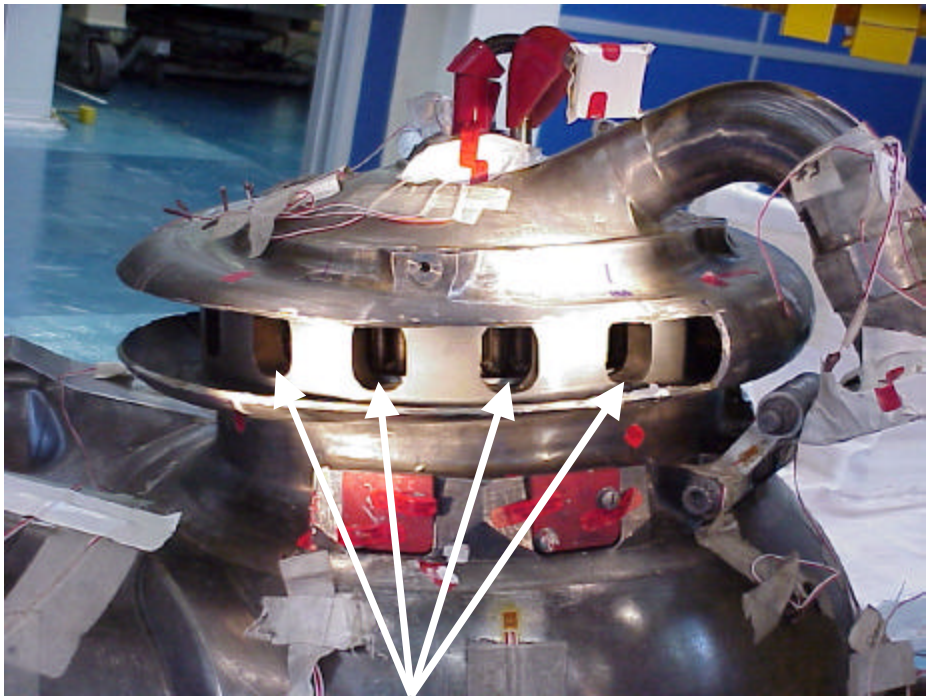
- **Investigation**
  - MSFC Investigation Team formed to determine cause of shutdown and damage
  - Post test inspections found numerous pieces of LOX tape in fuel preburner fuel manifold and blockage of fuel annulus of multiple elements
    - Resulted in LOX rich hot streak in excess of 2700 degrees R
  - Root-cause identified as contamination introduced during assembly and/or pretest processing
  - Investigation team recommendations being evaluated and corrective actions are being implemented
    - Borescope inspection of all joints prior to assembly has been initiated at all sites
    - Borescope inspection of all disturbed joints required during engine processing



G. HOPSON
29 August 2000

Engine 0523 - Contamination

Fuel Preburner Manifold

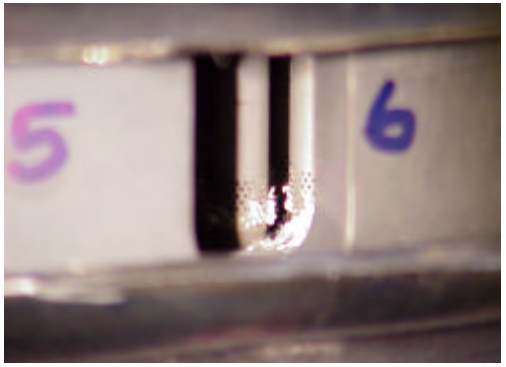


Tape Contamination Observed Through FPB Transfer Windows

FPB Window 4

Tape Contamination

Oxidizer Preburner Manifold



Lesser Amounts of Tape Contamination

STS-106 SSME Assessment

Rationale for Flight

- **All Flight Engines and Major LRUs are acceptance tested at SSC and inspected prior to delivery to KSC**
  - STS-106 Engines last flew on STS-99 (No anomalies)
- **Acceptance Rationale provided for all disturbed joints during processing of STS-106 engines**
  - Engineering and Quality review of STS-106 engine processing Work Authorization Documents (WAD) identified no discrepant conditions
    - All barrier installation and removal steps properly documented
  - Rocketdyne Action Request (RAR) 1418 issued to inspect engines for contamination prior to installation to OV-104 (no contamination found)
    - Borescope inspections through instrumentation ports
    - Oxidizer side not inspected if not disturbed (E2052 disturbed)
      - E2052 Joint O2 acceptable without inspection per exception
    - STS-106 Engines FPB Fuel Manifold verified clear of contamination

STS-106 SSME Assessment

Rationale for Flight

- **Engine 2052 Exception rationale provided for Joint O2, LPOTP discharge duct to LPOTP**
  - No lapping of Joint during engine shop processing
  - Temporary closure used and vertical orientation makes it difficult for FOD introduction
  - Temporary closure would not allow seal or bolt installation
  - Joints are easily inspected and verified during assembly
  - Joint passed successful bubble soap leak check and encapsulation test
- **STS-106 Engines acceptable for Launch**

STS-106 SSME Assessment

Acceptance Rationale for Disturbed Joints

Category	Rationale
A	Borescope Inspected
B	Area borescope inspected after removal of internal barrier
C	Engine checkouts verifies no blockage
D	Large area flange easily inspected, no potential for hidden contaminants, verified by multiple personnel
E	Drying port, Pump torque access port, small diameter cover plate installed immediately post operation
F	Not able to install if barrier is present

STS-106 SSME Assessment

Acceptance Rationale for Disturbed Joints

Joint #	Description	2052	2044	2047	Contamination Barrier	Acceptance Rationale	RAR Inspections	Exception
	Fuel System							
F2.2	LPFTP Discharge Pressure	X	X	X		A	X	
F2.3	LPFTP Discharge Temperature	X	X	X		A	X	
F4	HPFTP Discharge	X	X	X		A	X	
F3.1	HPFTP Speed Transducer	X	X	X		F		
F3	HPFTP Pump Inlet	X	X	X		A	X	
F20	HPFTP Balance Cavity Pressure Port	X	X	X		F		
F5	MFV Inlet		X			A	X	
F3.2/F3.3	HPFTP Thrust Bearing	X	X	X		E,F		
F1	LPFTP Inlet	X	X	X	X	B		
	HPFTP Turbine Discharge	X	X	X	X	B		
	HPFTP Turbine Inlet	X			X	A,B	X	
	HPFTP Volute	X	X	X	X	B		
	GOX System							
O23/O24	Oxid Tank Supply to GCV	X	X	X		C		
O19	Heat Exchanger Inlet	X	X	X		C		

STS-106 SSME Assessment

Acceptance Rationale for Disturbed Joints

Joint #	Description	2052	2044	2047	Contamination Barrier	Acceptance Rationale	RAR Inspections	Exception
	Hot Gas System							
N11.2	HPFTP Liner Cavity Pressure Sensor	X	X	X		C,E		
F6.1.2	FPB PC Port Cover Plate	X	X	X		E		
G8.7/G8.7.1	2 ea MCC PC Sensor to Mount & Mount to MCC Port	X	X	X		A,C		
G8.8/G8.8.1								
G4	FPB PC Port Cover Plate	X	X	X		A,E	X	
G1/G1.1	OPB PC Port Covers Plates	X	X	X		A	X	
N13	HPFTP Bearing Purge Port	X	X	X		E		
N16	HPOTP Bearing Purge Port	X	X	X		E		
F9.1	LPFTP Torque Access Port	X	X	X		E		
F6.10/F6.11	Nozzle Aft Manifold Port	X	X	X		A,E		
F12.1	Preburner Fuel Supply instrumention port Cover Plate	X	X	X		A	X	
G3.1/G3.2	HPOTP & HPFTP Turbine Discharge	X	X	X		A		
G5.1/G5.2	Temperature Sensors					A		
G6	HPFTP to Hot Gas Manifold	X	X	X		D		
G3	HPOTP/AT to Hot Gas Manifold	X				D		
G13	MCC Igniter	X				C		
N18	Bearing Purge Line to HPOTP/AT	X	X	X		A		
O8.3	MCC Lox Dome Temp to MCC	X	X	X		A		
D1/D25/PTD1A	HPOTP Primary Turbine Seal Drain	X				C		
PTD1B		X				C		
D2/D26	HPOTP Turbine Secondary Turbine Seal Drain	X				C		

STS-106 SSME Assessment

Acceptance Rationale for Disturbed Joints

Joint #	Description	2052	2044	2047	Contamination Barrier	Acceptance Rationale	RAR Inspections	Exception
	Oxidizer System							
O18.1	AFV Test Port	X	X	X		F		
O1.1	LPOTP Speed Transducer	X	X	X	2047	E,F		
O9.1/O10	HPOTP Torque Access Port & Preburner Oxidizer Pump	X	X	X		A,E		
	Inlet							
O3.4	HPOTP/AT Inspection Port	X	X	X		A		
O2.2	LPOTP Discharge Pressure Sensor	X				A,C	X	
O30	Oxidizer Bleed Line to Recirculation Line Joint	X	X	X		F		
O2.3	LPOTP Discharge Duct Port (Flight Plate)	X				A	X	
O3	LPOTP Discharge Duct to HPOTP	X				A	X	
O4	HPOTP to LPOTP Turbine Drive Duct	X			2052	A	X	
O2	LPOTP Duct to LPOTP	X						X
O6	HPOTP Discharge Joint	X			2052	A	X	
O6.1	HPOTP Discharge Transducer	X				A	X	
O7	High Pressure Oxidizer Duct to MOV Prior Joint	X				A	X	
O9	High Pressure Oxidizer Duct to Oxidizer Supply	X				A	X	
	Duct Joint							
O11	HPOTP to OPB Supply Duct Joint	X				A	X	
O12	OPB Oxidizer Supply Duct to OPOV Joint	X				A	X	
O11.1/O11.1.2	OPB Oxidizer Supply Duct Temp Tranducer/Pr sensor Jt.	X				A,C	2052	
O22	Preburner Oxidizer Supply to OPOV/FPOV	X				A	X	
O29/O31	Joint Adapter to RIV	X				C		
D3/D27	Oxidizer Seal Dran from HPOTP	X				C		

STS-106 SSME Assessment

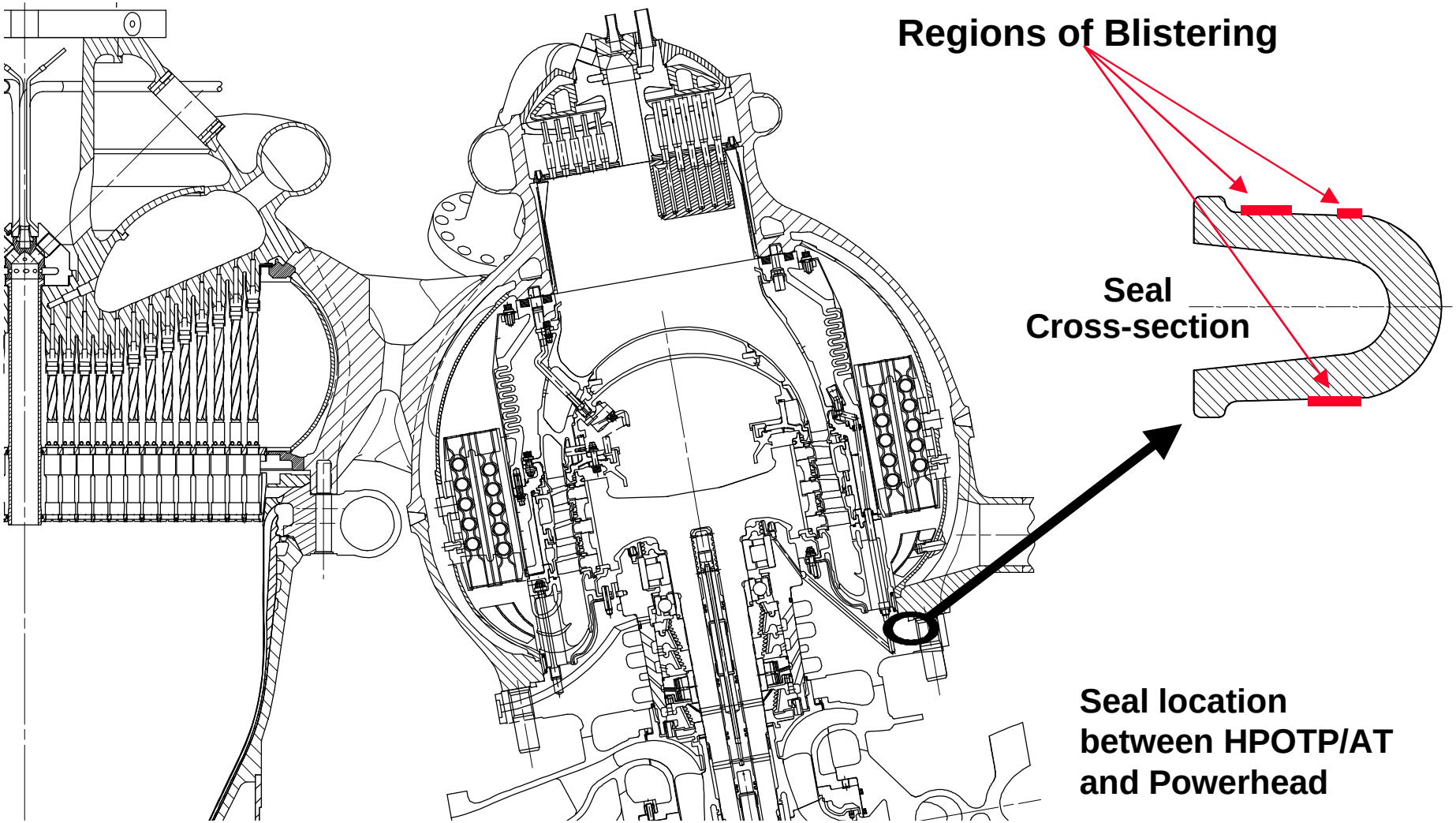
Acceptance Rationale for Disturbed Joints

Joint #	Description	2052	2044	2047	Contamination Barrier	Acceptance Rationale	RAR Inspections	Exception
	Pneumatic System							
N6/N7	HPV Warmant/Main Injector Purge Check Valve	X				C		
P23	GCV Control Line	X				A	X	
P25	Recirculation Isolation Control Line	X				C		
P35	POGO Helium Precharge Control Line	X				C		
	Pneumatic Control Assembly Joints			X		C		
P2				X		C		
P3/P3.1				X		C		
P4				X		C		
P5/5.1				X		C		
P9/P24				X		C		
P12				X		C		
P28				X		C		
N2.3				X		C		
N2.4				X		C		
P10				X		C		
P2.1				X		C		
P2.2				X		C		
P2.3				X		C		
P2.4				X		C		
P2.5				X		C		

SSME Joint G3 Blistered Seal

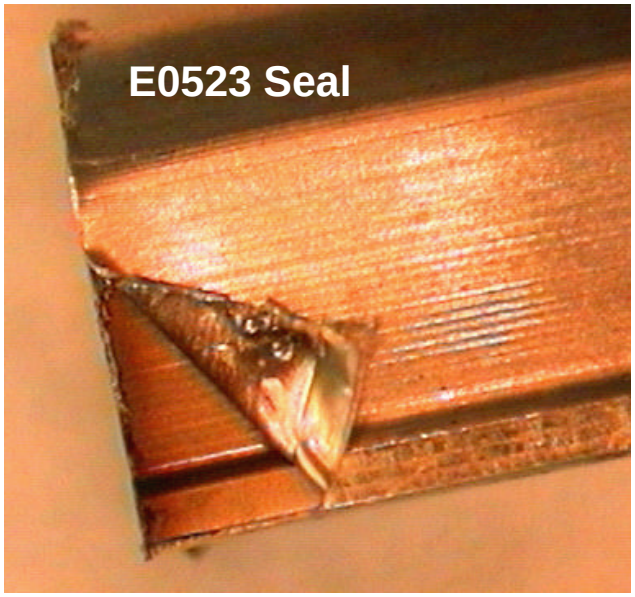
- **Issue**
  - Blisters noted on silver plating of two “increased compression” G3 seals after removal from engine
- **Background**
  - G3 seal is an “omega type” seal between the Powerhead and HPOTP/AT and prevents hot gas leakage into the aft compartment
  - S/N 8833535 from Engine 0526
    - 22 starts / 12,333 seconds on HPOTP/AT Unit 8110
  - S/N 8832020 from Engine 0523 (test 902-772 premature shutdown)
    - 5.2 seconds on HPOTP/AT Unit 8308
  - Initial post hot fire visual inspections noted blistering of silver plating
    - Further examination revealed lack of plating bond in additional areas
  - Two configuration G3 seals used in program
    - Fleet currently being retrofitted with “increased compression” seals

SSME Joint G3 Blistered Seal



SSME Joint G3 Blistered Seal

- **Investigation**
  - Blistered seals purchased on 2 different orders
    - One from Hydrodyne (E0526) and one from Langley (E0523)
    - Both plated by Metal Surfaces Inc. approximately 1 year apart
    - Post plating adhesion bake test was verified by the supplier
  - Sealing surface inspection completed
    - No indications of leak paths
    - No evidence of hot gas leakage past seal
  - Microscopic examination of the seal plating performed
    - Lack of bond between plating layers



SSME Joint G3 Blistered Seal

- **Investigation**
  - Only 2 blistered seals out of 175 seals
    - Re-inspection consisted of visual and adhesion “tape test”
      - Entire Canoga stock of flight seals (162 total)
      - 13 “used” seals
  - Randomly selected 20 prior configuration seals (Phase II/Block I)
    - Tape tests performed on 5 seals - no blistering or plating defects found
  - All new “increased compression” configuration seals in the flight fleet from one supplier lot
    - Blistered seals from two different plating lots, not currently in the flight fleet

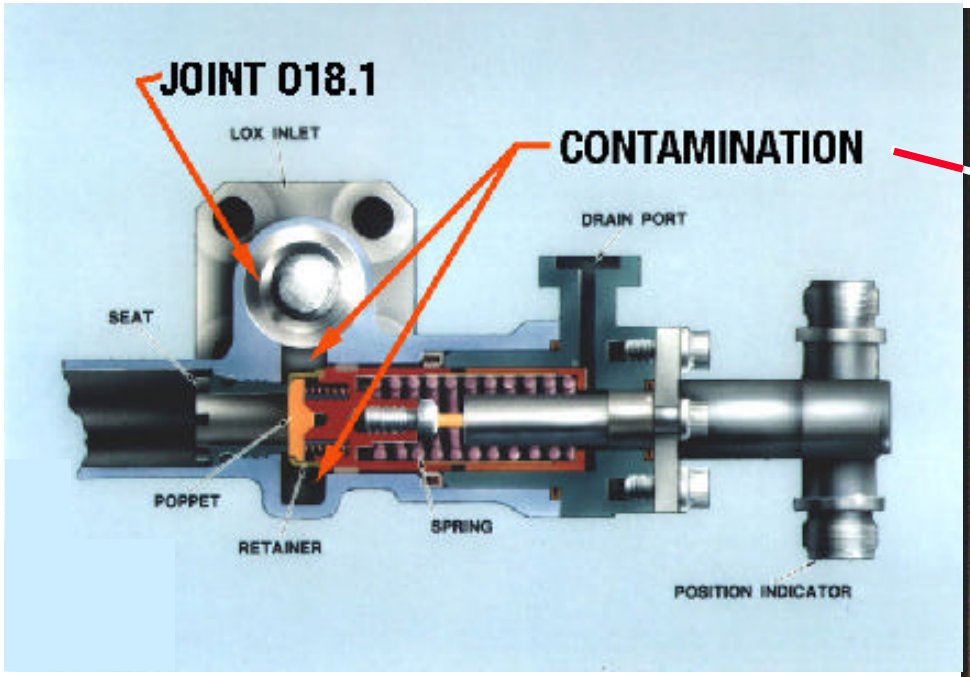
SSME Joint G3 Blistered Seal

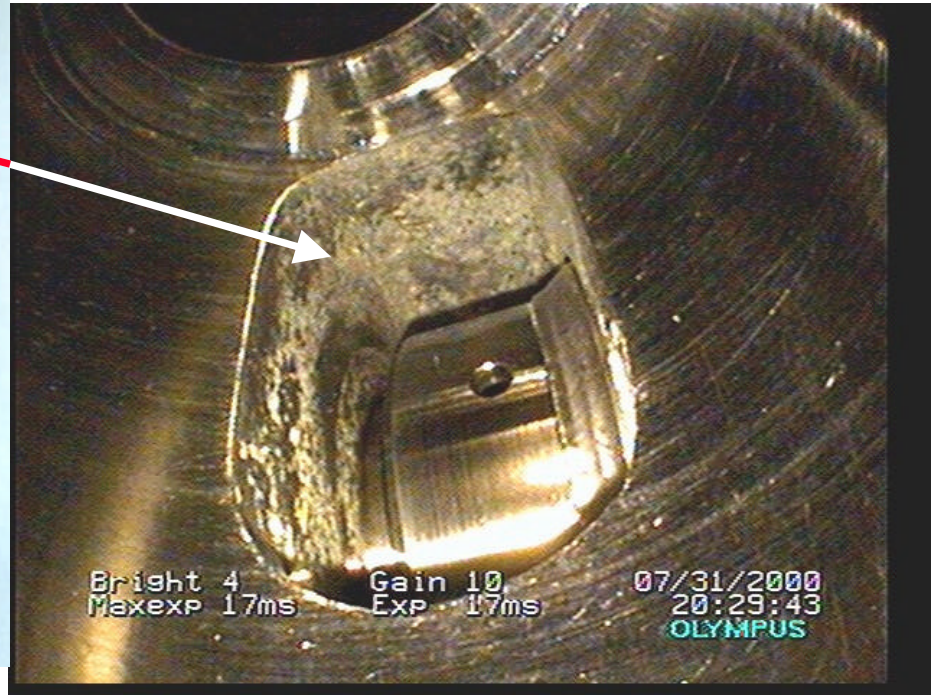
- **Rationale for Flight**
  - Joint G3 is leak tested prior to hot fire test/flight
    - Seal visually inspected for damage immediately prior to installation
    - Soap check after initial installation
    - Helium Encapsulation leak check prior to each flight
  - Seals inspected from same plating lot as flight seals show no blisters after use
  - Low probability of occurrence
    - Blisters found on 2 out of 175 re-inspected seals
  - Seal performance has not been affected
    - E0523 seal showed worst case plating, no evidence of leakage
  - No history of problem with prior configuration seals

Anti Flood Valve Contamination

- **Issue**
  - Contamination found within Anti Flood Valves (AFV)
- **Background**
  - Post flight inspection of AFV on Engine 2054 identified heavy contamination in poppet cavity
  - Engine 2054 AFV and two spare AFVs returned to Canoga for inspection, disassembly, and analysis
  - Contamination confined to poppet cavity in housing
    - Physically characterized as hard, well adhered scale
    - Contaminant constituents determined to be silicon, minor calcium and oxygen
      - Composition similar to silicated alkaline based cleaners

Anti Flood Valve Contamination





Anti Flood Valve Contamination

- **Background**
  - Material composition and location suggests contaminant introduced during AFV housing fabrication and cleaning process
    - Lab examination supports scenario of liquid being present in poppet cavity during heat treat operation
  - Fleet wide inspection of valves completed (25 valves)
    - Contamination limited to valve housings manufactured by Globe Dynamics (6 of 6 contaminated)
    - Remaining 19 valves (encompassing 4 different suppliers) found acceptable
  - Additional GOX system inspections completed
    - Two minor discrepancies (“white spots”) noted in LOX tank pressurization ducts on E2049 and E2054
      - Particles of insignificant size and mass to cause concern (< 20µ)

Anti Flood Valve Contamination

- **Rationale for Flight**
  - All AFVs on STS-106 inspected and verified free of contamination
  - Contamination concern limited to AFVs processed by Globe Dynamics
    - No Globe Dynamics valves on STS-106
  - All Globe Dynamics fabricated housings being removed from flight service

Atlantis STS-106

SSME Certification of Flight Readiness

- **Flight Readiness Review CoFR Exception**
  - NONE

Atlantis STS-106

SSME Readiness Statement

- **The Atlantis Main Engines are in a ready condition for STS-106**

signed by G. Hopson

G.D. Hopson
Manager
SSME Project

signed by J. Plowden

J. B. Plowden
Vice President and Program Manager
Space Shuttle Main Engine