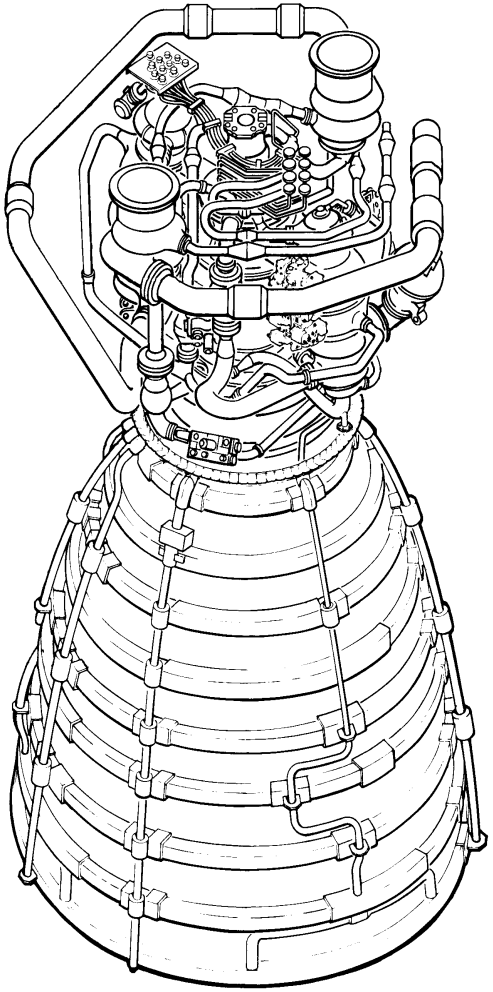

Columbia STS-109

Space Shuttle Program

SSME Flight Readiness Review

February 14, 2002

G. HOPSON
14 February 2002

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Agenda

- Major Components
- Engine Performance
- First Flight ECPs
- Special Topic
  - Main Injector LOX Post Tip Wear
- Material Review Reassessment

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SSME Major Components

Engine	ME-1 / 2056 *Block IIA*	ME-2 / 2053 *Block IIA*	ME-3 / 2047 *Block IIA*
Last Hot-Fire	**STS-104**	**STS-102**	**STS-104**
Powerhead	6012	6020	6016
Main Injector	2036	6020	4027
MCC	6004	6018	6011
Nozzle	2034	5006	4027
Controller	F38	F44	F63
HPFTP	6112	4214R1	6114
LPFTP	6106R1	5101	2225
HPOTP	8015R2	8031	8024
LPOTP	4108	2135	2230

No changes after last hot-fire.

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Predicted SSME Ignition Confirm Margins

Parameter	Margin Sigma		
	ME-1 (2056)	ME-2 (2053)	ME-3 (2047)
HPFTP Minimum Speed	5.2	5.7	7.8
Min/Max Ignition Pc	3.4	4.6	4.8
Antiflood Valve Min Open	27.0	25.8	24.7
HPFTP Max Turbine Temp	4.7	5.2	5.1
HPOTP Max Turbine Temp	3.1	3.4	**[2.8]**
HPOTP Min Turbine Temp	8.2	9.2	9.9
Preburner Max Purge Pressure	29.1	28.2	29.1
POGO GOX Min/Max Pressure	3.4	3.5	3.5

[ ] Less than 3 sigma margin. Margin is acceptable, 4.8 sigma using no pump changes database.

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Predicted SSME Performance at 104.5% P.L.

At Engine Start + 200 seconds

Parameter	ME-1 (2056) Sigma	ME-2 (2053) Sigma	ME-3 (2047) Sigma
HPFT Disch Temp A, Deg R	0.4	0.1	-0.3
HPFT Disch Temp B, Deg R	0.1	-0.3	0.3
HPOT Disch Temp A, Deg R	1.4	0.9	0.0
HPOT Disch Temp B, Deg R	2.0	1.5	1.0
HEX Interface Temp, Deg R	1.3	1.6	0.3
HPFTP Speed, rpm	1.3	0.2	0.1
LPFTP Speed, rpm	-0.3	-0.5	0.8
HPOTP Speed, rpm	-0.6	-0.3	0.4
LPOTP Speed, rpm	1.5	-1.4	0.1
OPOV Position, %	0.9	0.9	-1.0
FPOV Position, %	-0.6	0.7	-0.7
PBP Disch Pressure, psia	1.1	-1.5	-0.9
HPFTP Disch Pressure, psia	-1.2	0.5	0.1
HPOTP Disch Pressure, psia	1.5	**a** **[-2.3]**	-1.0
HPFTP U/N	6112	4214R1	6114
LPFTP U/N	6106R1	5101	2225
HPOTP U/N	8015R2	8031	8024
LPOTP U/N	4108	2135	2230

[ ] Exceeds database two sigma
a Result of low LOX side resistance. Consistent with engine history.

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Predicted Redline Margins at 104.5% P.L.

Parameter	Margin Sigma		
	ME-1 (2056)	ME-2 (2053)	ME-3 (2047)
HPFT Discharge Temp ChA, Deg R	5.8	6.9	6.8
HPFT Discharge Temp ChB, Deg R	7.0	8.2	7.1
HPOT Discharge Temp ChA, Deg R	6.0	6.5	7.0
HPOT Discharge Temp ChB, Deg R	7.2	7.7	7.9
HPOT Discharge Temp ChA, Deg R	6.5	6.8	5.9
HPOT Discharge Temp ChB, Deg R	7.1	6.6	6.1
HPOTP IMSL Purge Pr, psia	7.3	3.7	6.2
HPFTP Coolant Liner Pressure, psia	14.3	15.0	17.0
Low MCC Pc, psid			
Command-ChA Avg	20.5	18.5	20.8
Command-ChB Avg	22.7	22.3	24.6
FASCOS			
HPFTP	14.6	15.1	14.3
HPOTP	34.6	30.9	34.6

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SSME First Flight ECPs

ECP#	Description	Engines
1395	**Joint O1.1 Seal Redesign**	All

LPOTP Torque Check Port Seal (O1.1)

ECP 1395

- **Issue**
  - Periodic rework required at joint interface to maintain proper sealing
- **Solution**
  - Replaced silver coated “K” design with Teflon Coated “Ω“ design
    - Decreased sensitivity to minor surface defects and groove depth variations
- **Certification Status -** Complete
  - Certified by analysis, lab testing, and hot-fire
  - Total hot-fire time: >31 tests, >13,000 seconds
  - VCR 0605 approved

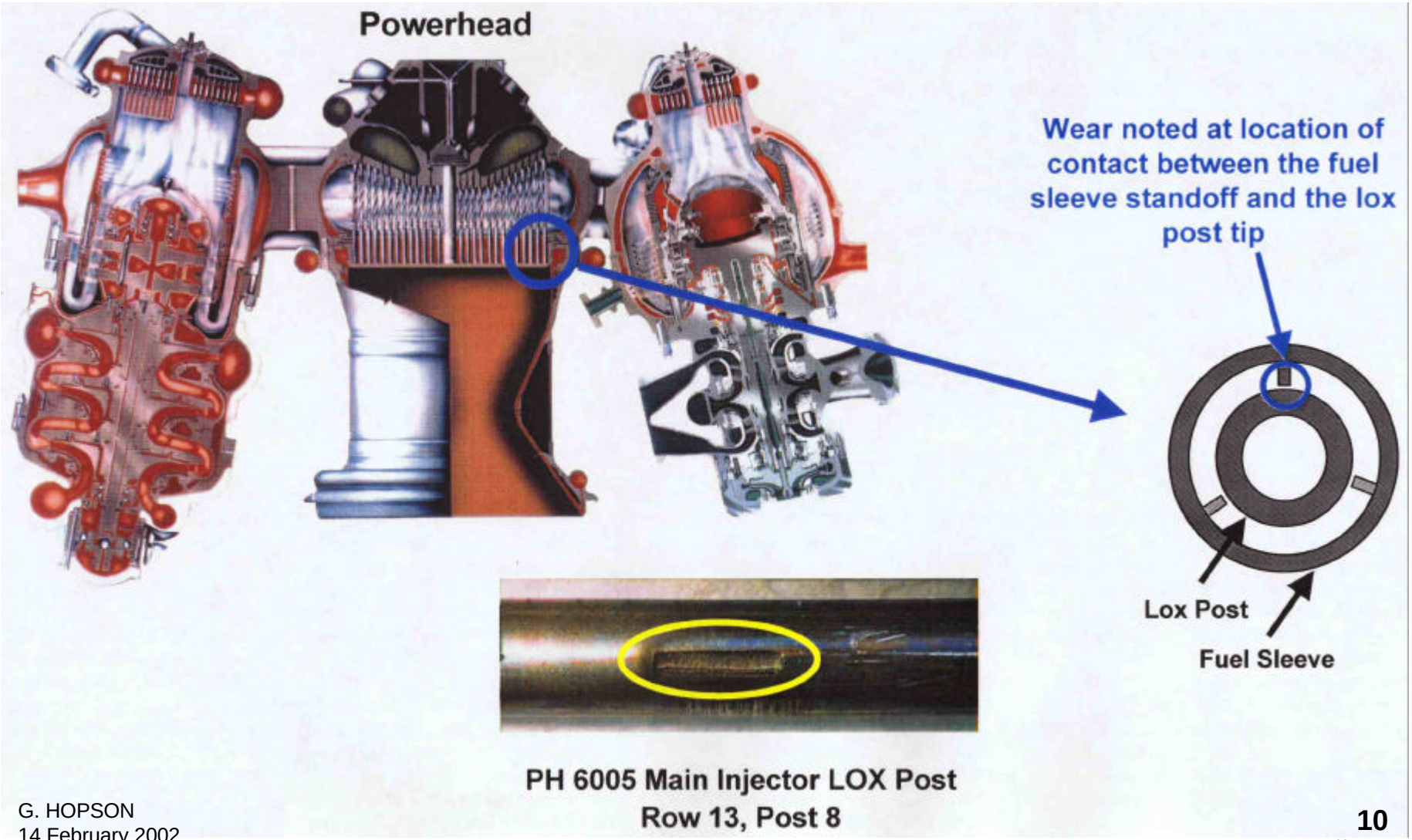
Main Injector LOX Posts

Tip Wear

- **Issue**
  - Wear found on Main Injector LOX post outer diameter surface
- **Background**
  - E0521 / Powerhead 6005 disassembled as part of routine, periodic high-time hardware evaluation
    - 110 starts / 58,607 seconds
  - Wear marks found in line with fuel sleeve stand-offs
    - Similar conditions found on 3 other high time powerheads
    - Average wear depth: 8% of wall thickness
  - Minor wear depth in inner 12 rows (< 15% of thickness)
  - Larger wear depths in outer row 13 (< 40% of thickness)
    - Isolated occurrences of wear up to 60% and 85% of wall thickness
  - Some posts contain multiple wear patterns
    - Fuel sleeves reclocked during injector rebuild

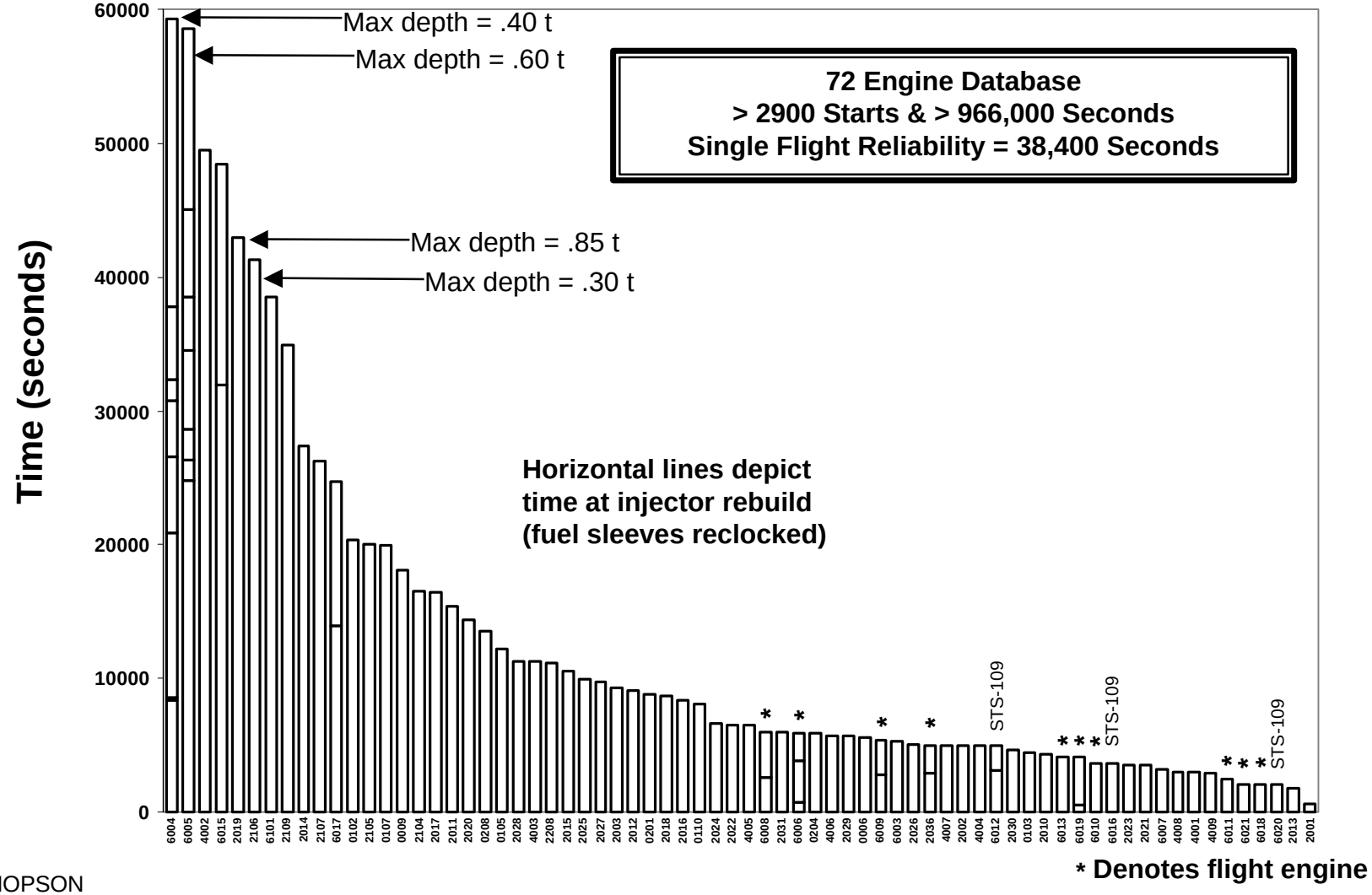
Main Injector LOX Posts

Tip Wear



Main Injector LOX Posts

Tip Wear



* Denotes flight engine

Main Injector LOX Posts

Tip Wear

- **Investigation**
  - Wear is time dependent phenomenon
    - Highly variable with multiple contributing factors
      - Injector element configuration, post position, geometry and fit-up
      - Engine-to-engine, test-to-test, post-to-post localized operating environment variations
  - Standard preflight visual inspections verify injector integrity
    - Wear through of post would result in noticeable overheating and erosion of the faceplate

Main Injector LOX Posts

Tip Wear

- **Flight Rationale**
  - Extensive successful operating history with no anomalies
    - > 2900 starts and > 966,000 seconds
    - Single Flight Reliability: 38,400 seconds
  - Flight engines maintain large margins against worst case condition and exposures to date
    - STS-109 Powerhead History
      - E2047: 7 starts / 3588 seconds
      - E2056: 10 starts / 4906 seconds
      - E2053: 4 starts / 2053 seconds
  - Standard preflight inspections verify injector integrity
    - STS-109 injectors inspected - no discrepancies

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Material Review and Problem Report Reassessment

- **All Material Reviews and Problem Reports Reassessed**
  - Encompasses entire part / component histories
    - Fabrication
    - Assembly
    - Test
    - Flight
    - Recycle
  - Verified proper dispositions in light of current program sensitivities, knowledge and experience

- **All dispositions evaluated and judged acceptable for flight**

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SSME Certification of Flight Readiness

- **Flight Readiness Review CoFR Exception**
  - None

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SSME Readiness Statement

- **The Columbia Main Engines are in a ready condition for STS-109**

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