Block II SSME Upgrade Project Overview

Joint Propulsion Conference 2000
Huntsville, Alabama
July 2000

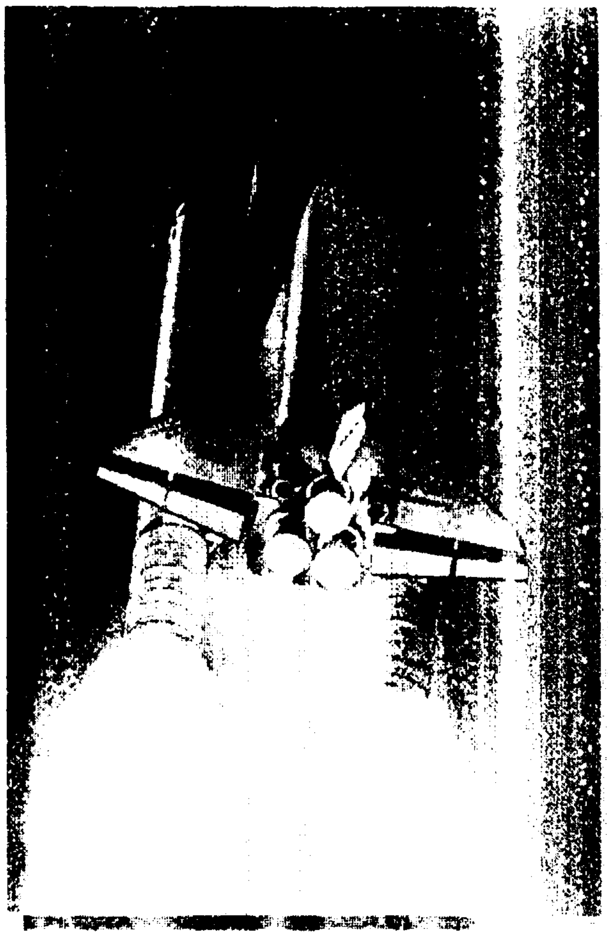
John Plowden

World's Only Operational, Reusable Lox/LH_2 Booster Engine

Space Shuttle Main Engine

- 98 shuttle missions
- 294 total engine flights
- 40 engines flown - highest reuse up to 19 times
- Over 2837 starts and 920,805 seconds logged
- 0.9994 demonstrated reliability

SSME Industry Firsts



- 1st booster designed for reusability
- 1st high performance engine
  - Energetic, non-toxic hydrogen fuel
  - >3x previous power densities
  - Near theoretical specific impulse
  - Efficient staged combustion cycle
- 1st with chamber pressure and mixture ratio close-loop control
- 1st with autonomous controller computer and health management

Block III SSME Project Overview
Discussion Topics

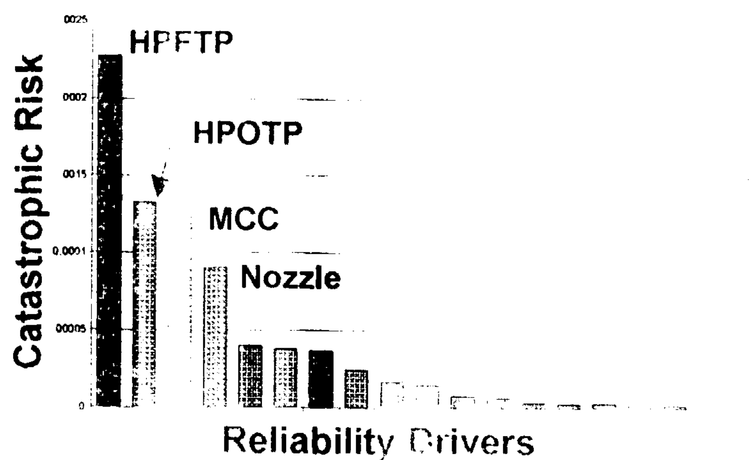
- Block III upgrade evolution
- Top-level goals
- Block III SSME design description
- Benefits
- Project schedule
- Summary

Block II SSME Upgrade Evolution

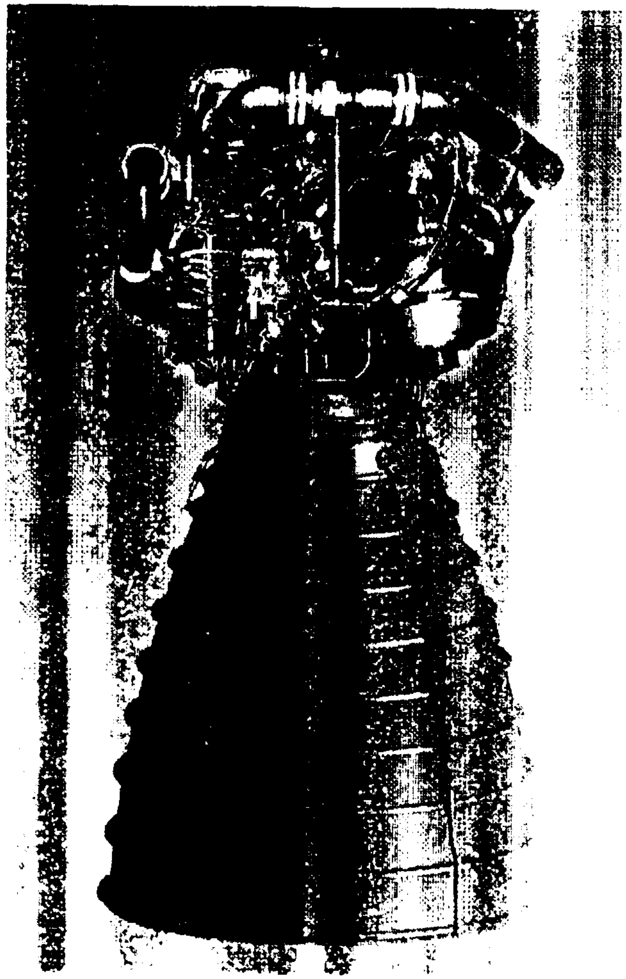
<u>NASA Space Shuttle Upgrades Request</u>
SSME candidates included safety, reliability, producibility and supportability improvements

<u>120% PL Engine</u>
Emphasis on improved thrust capability to improve abort scenarios. Nominal operation at 104.5%

<u>De-rated Engine</u>
Focus changed to improved safety at nominal power without cost/schedule risk associated with changes to high pressure pumps & powerhead. New Nozzle & MCC with larger throat to reduce turbopump environments.



Block III SSME
Top-Level NASA Goals



- Significantly improve Mission Safety
  - 3-engine ascent risk goal is < 1 in 3000
- Minimize impacts to Space Shuttle Mission
  - Maintain Isp, thrust and minimize weight increase
- Minimize impacts to the Space Shuttle Vehicle
  - No structural or mold line impacts
- Improve operability for KSC operations
  - Reduce engine maintenance requirements
- Minimize changes to engine operation
  - Stay within operating experience
- Fly by 2005

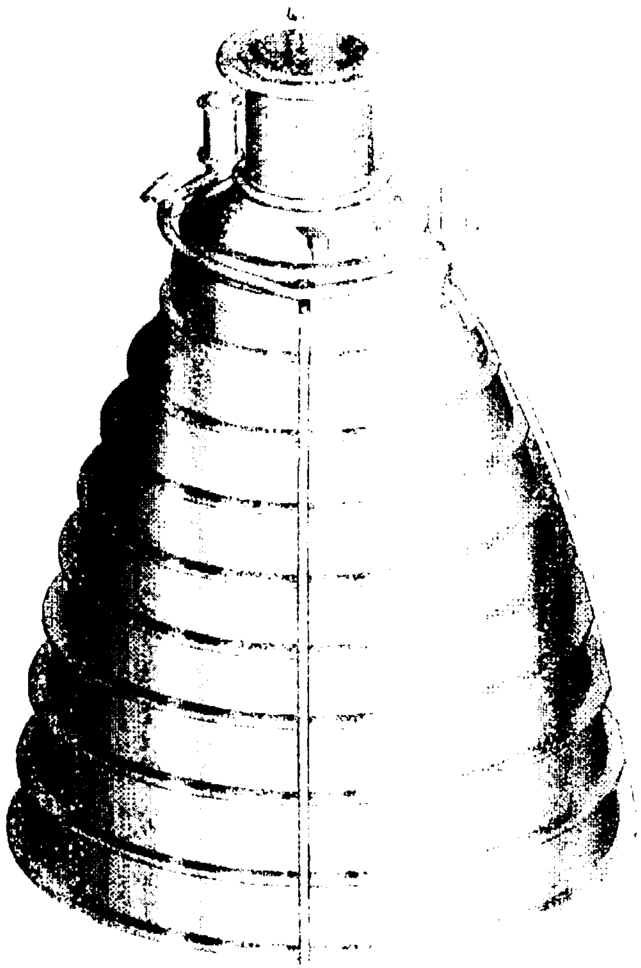
SSME Block III
Engine Configuration

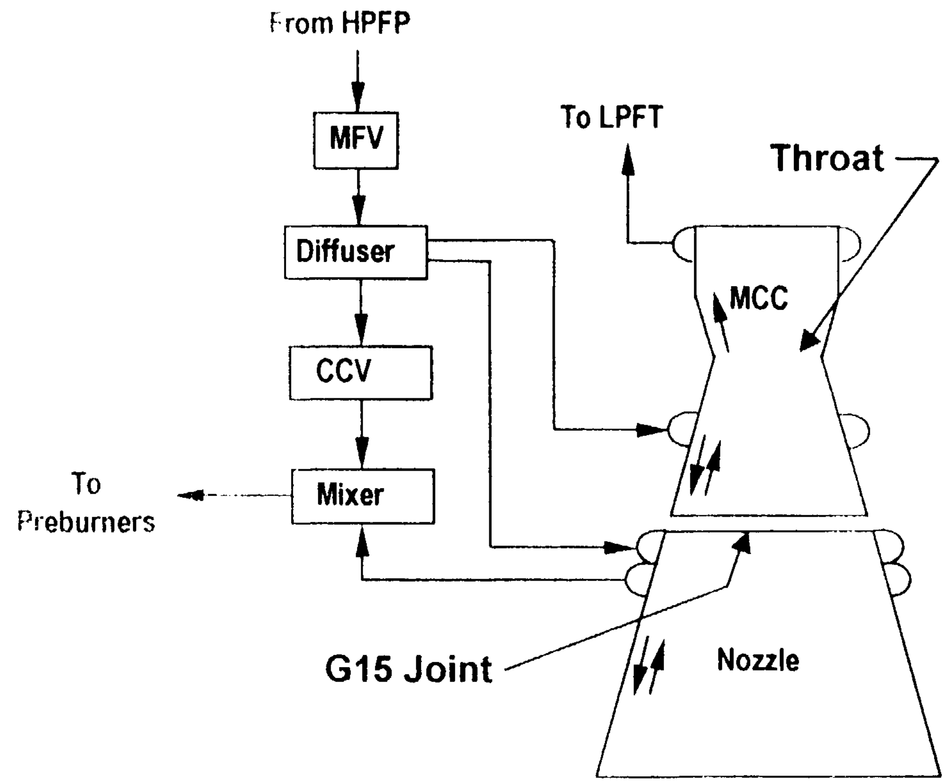
- New Main Combustion Chamber and Nozzle
- Maintains most SSME Block II components
  - Powerhead
  - High and low pressures turbopumps
  - Valves and actuators
  - Controller and sensors
  - Ducts & lines except for those interfacing with the MCC and nozzle
- Includes other upgrades and producibility improvements
  - Advance Health Management System
  - New fuel flow meter

SSME Block III
Description of Major Changes

- New larger throat main combustion chamber (XLTMCC)
  - Hot-isostatic pressure (HIP) braze process used instead of the electrodeposited construction
- New nozzle
  - Goal is 2-pass (down & up) cooling scheme to eliminate feedlines at aft end
  - Channel-wall and tube nozzles evaluated
- MCC/Nozzle assembly
  - Contour optimized for performance
  - MCC/Nozzle interface (G15) lowered to simplify nozzle construction for higher reliability
  - New G-15 seal package

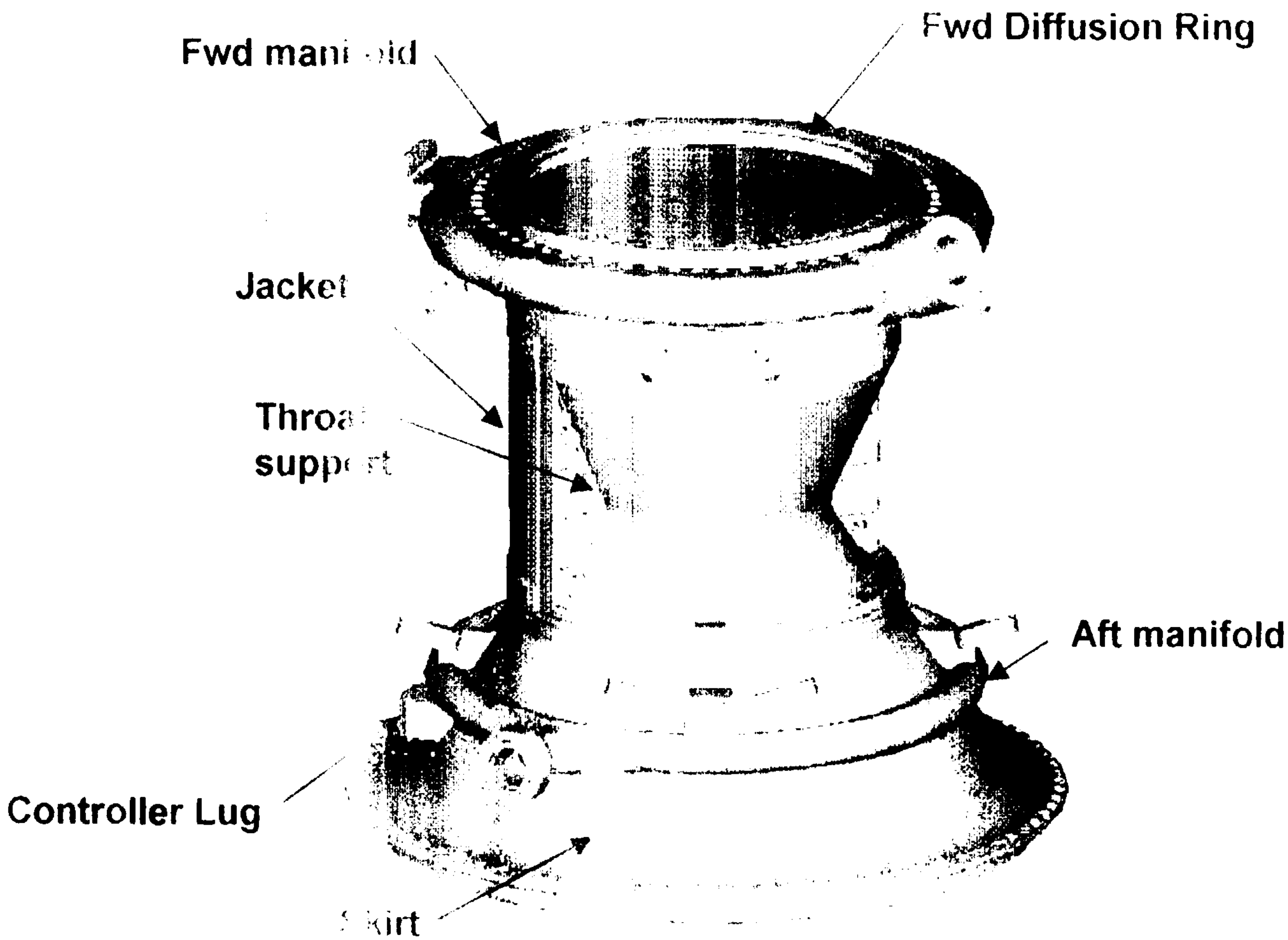
Block III SSME
Design Concept





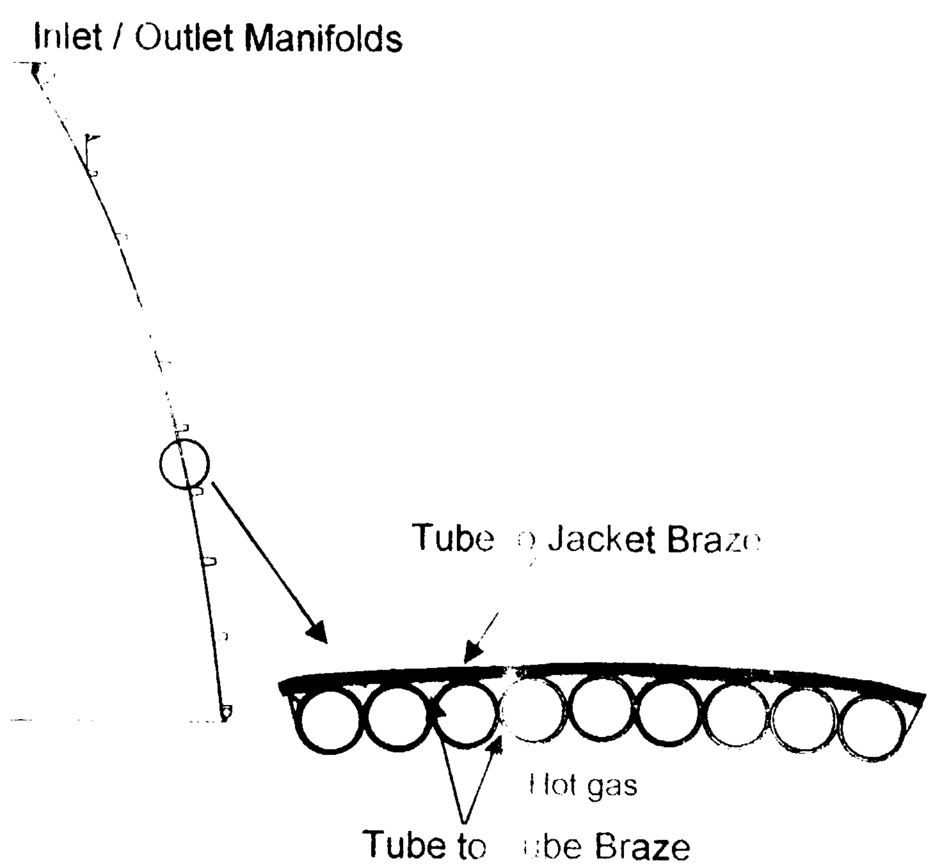
Block III SSME

Main Combustion Chamber Design Concept

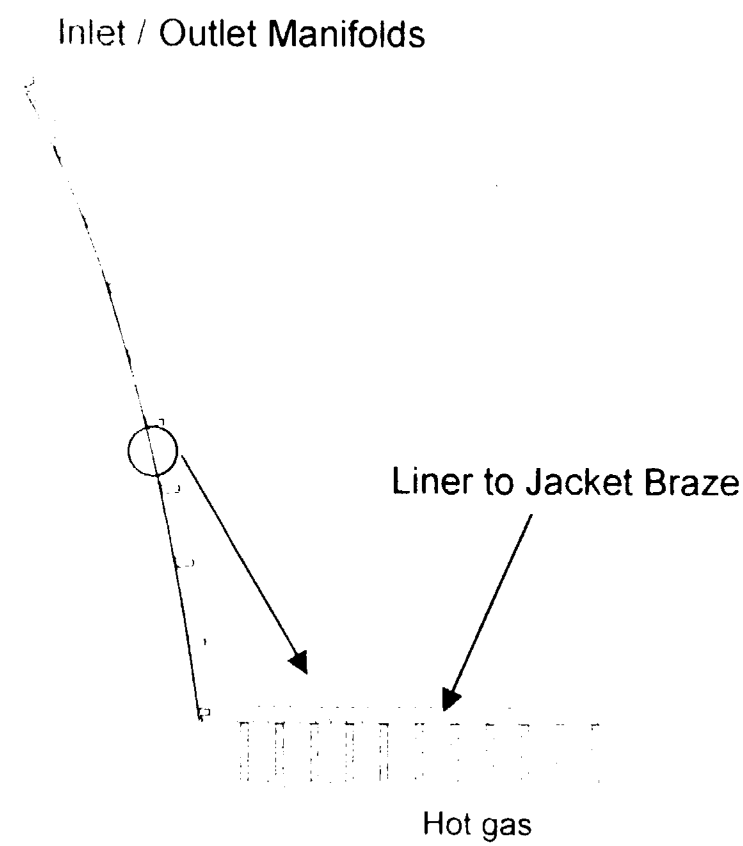


SSME Nozzle
Construction Comparison

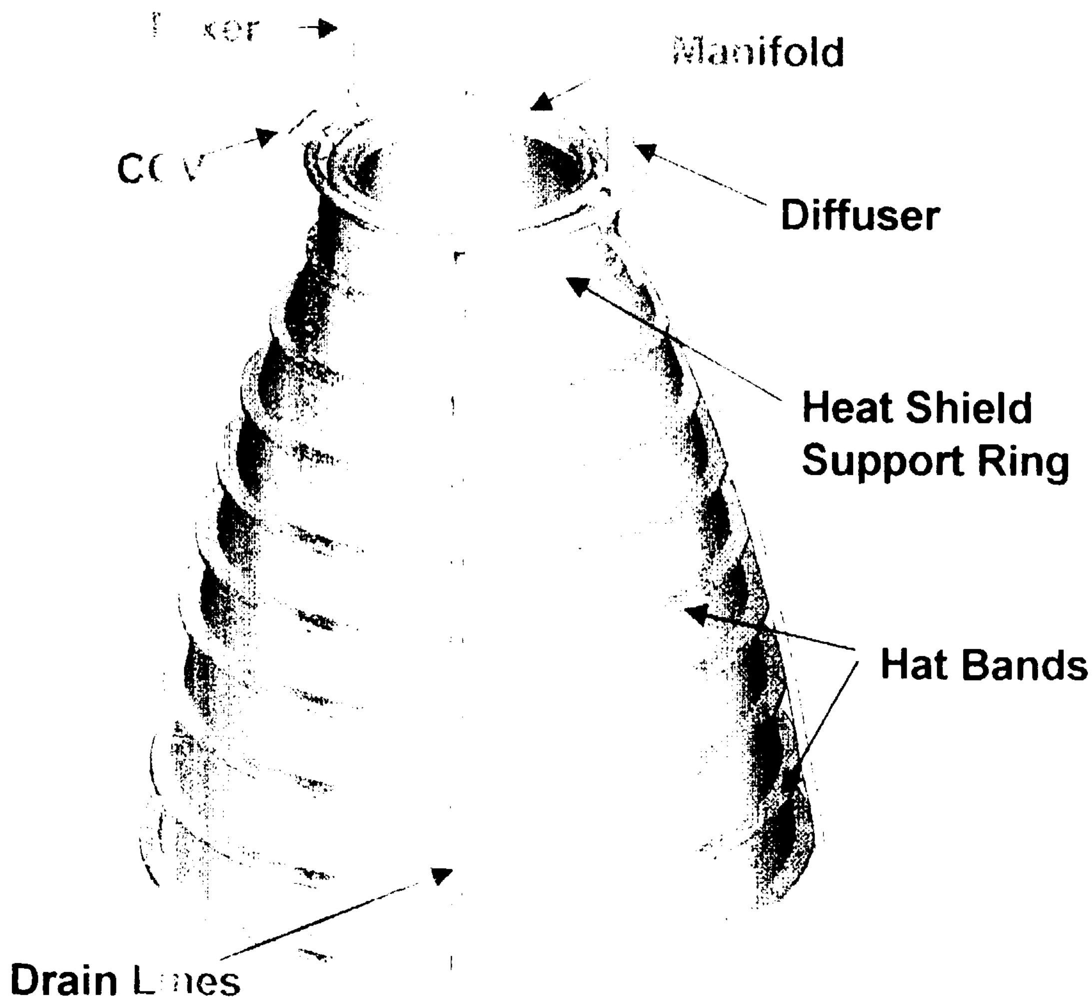
Tube Wall Noz



Channel Wall Nozzle



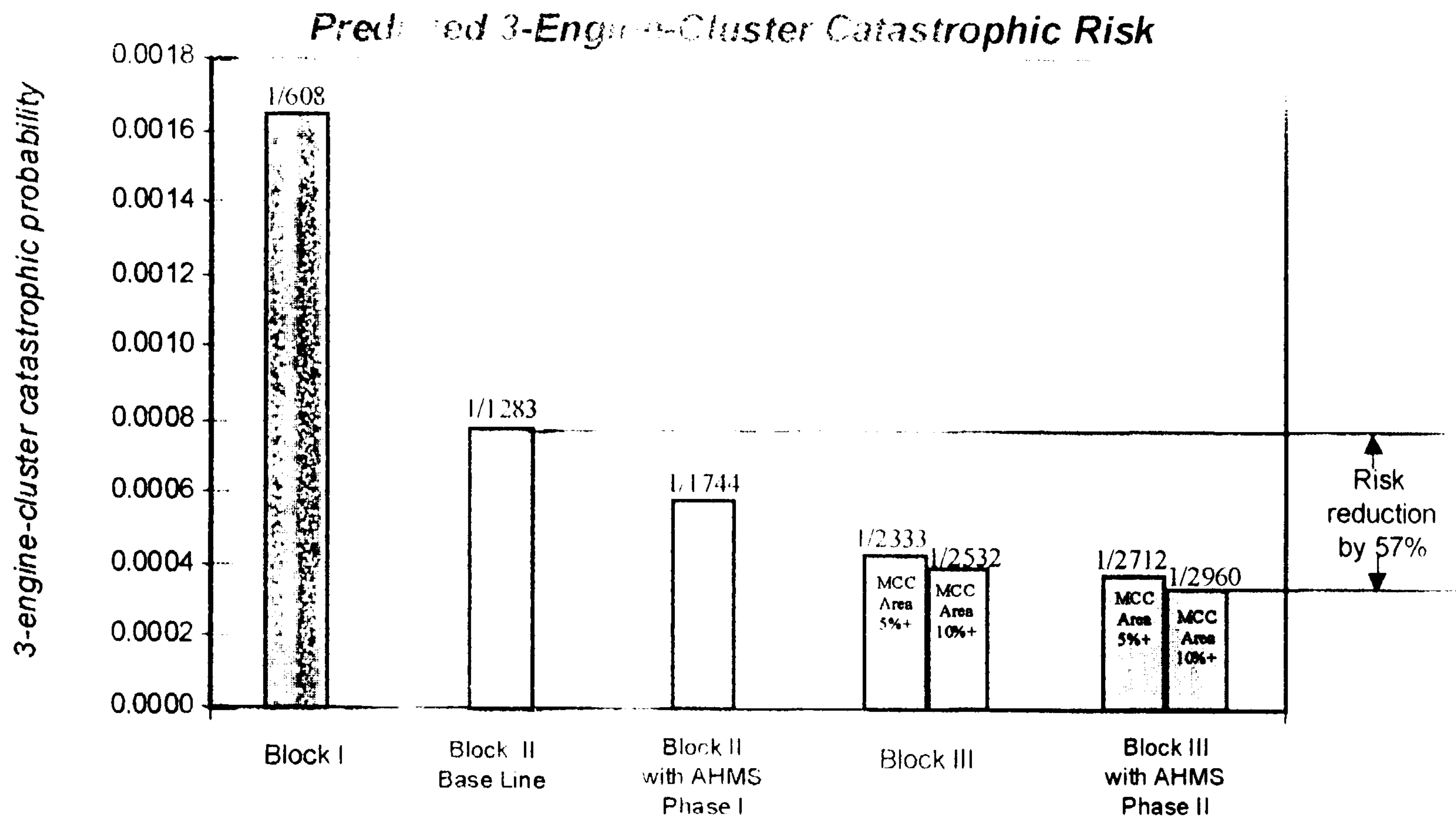
Block III SSME
Nozzle Design Concept



Benefits of Block III SSME

- Reliability of most components increased
  - Larger throat MCC reduces engine operating environments (temperatures, pressures, & pump speeds) for given engine thrust
- MCC and Nozzle reliability doubled with new robust designs and manufacturing processes
  - Failure modes eliminated with new designs
  - Probability of failure decreased with robust manufacturing processes
- Provides engine environment for increased thrust capability for contingency aborts

Block III SSME Significantly Reduces Catastrophic Failure Risks

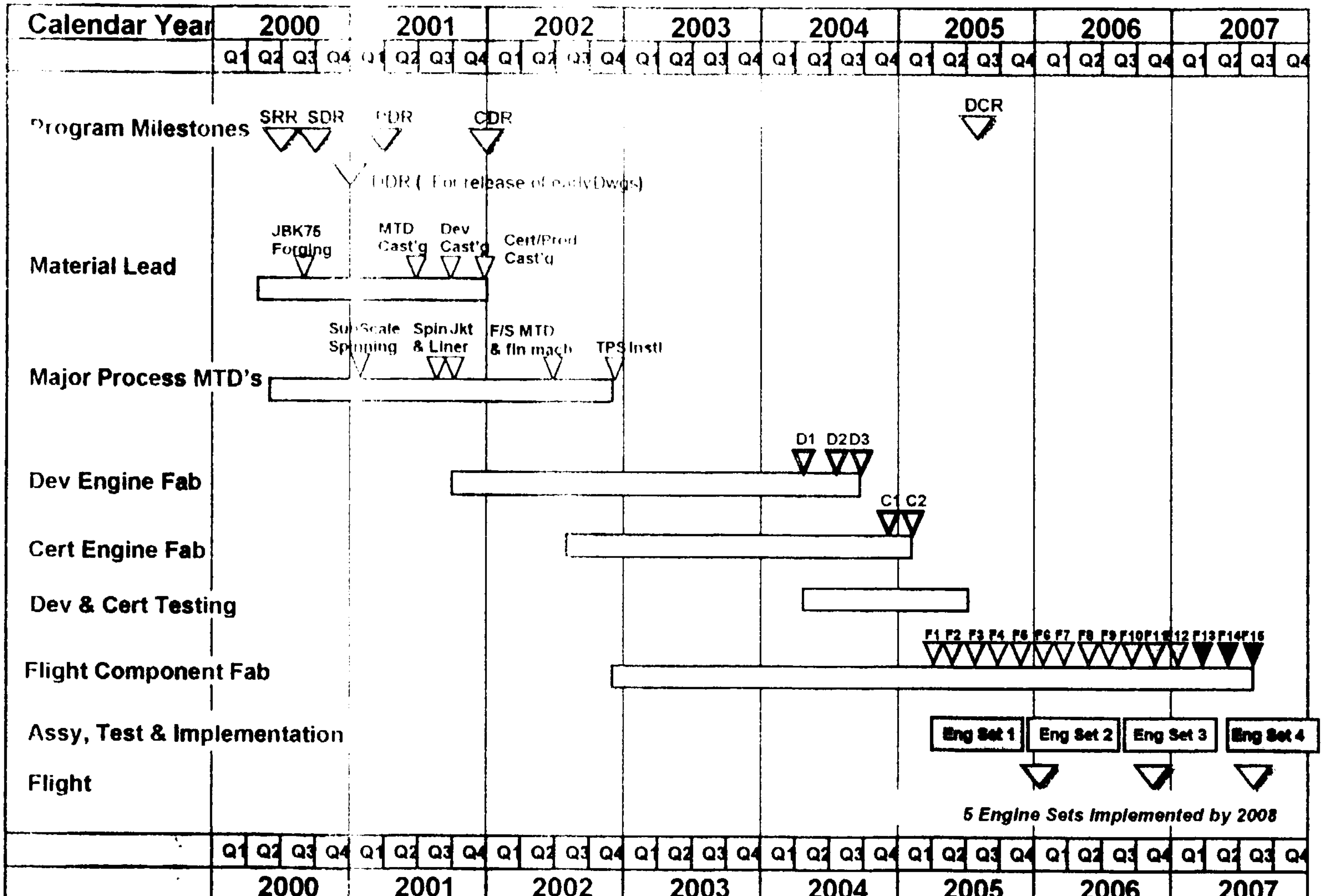


Block III reliability assessment supports NASA's objective to significantly improve Shuttle reliability through upgrade activity

Block III SSME Performance Impacts

- Performance impact is minimal
  - Specific Impulse (Isp) is 0.5 to 1.5 second lower because of decrease in nozzle expansion ratio
  - Optimum contour, smooth-wall nozzle, and increase in exit diameter are trade factors to minimize potential loss
- Weight may increase up to 400 pounds per engine
  - HIP braze of XLTMCC uses lower strength stainless steel alloy to match thermal expansion of copper liner
  - Both nozzle options are using lower strength material for the cast manifolds, but tube nozzle is 130 pounds lighter than channel-wall nozzle

Block III SSME
Baseline Program Schedule



BOEING

2086 ppt 7/11/00

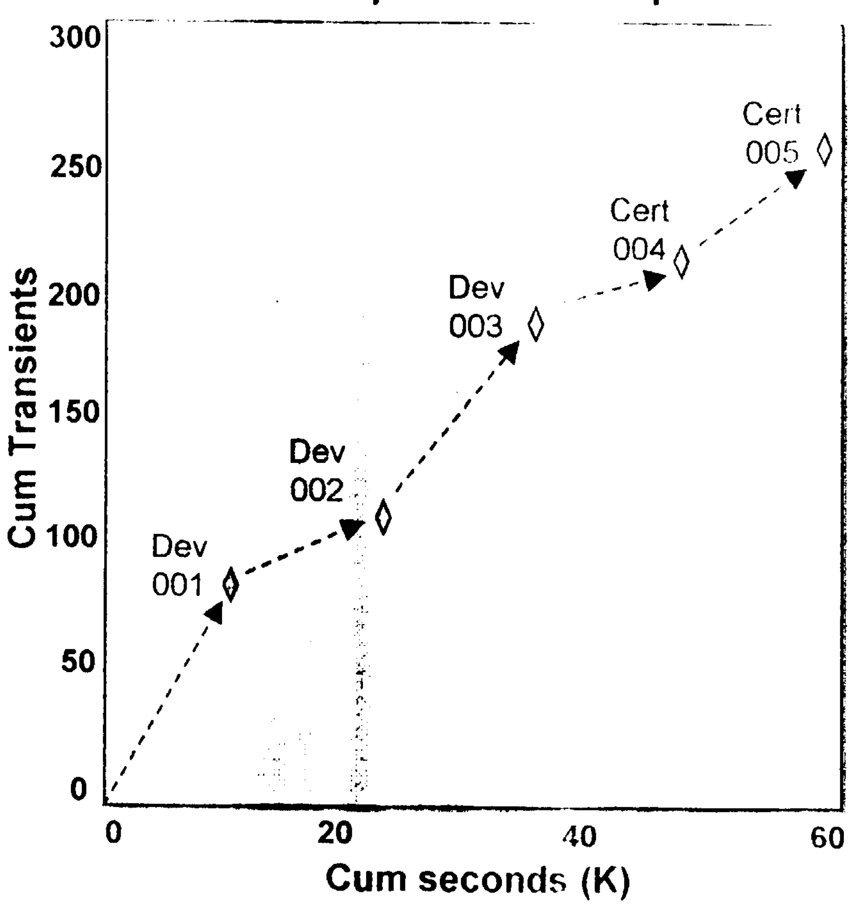
Extensive Test Program Planned

Addresses Technical & Schedule Needs

- Maximize earliest confirmation of Block III robustness
  - Primary validation of life and operability with sea-level operation
  - Secondary validation of performance
  - Interaction with engine systems
- Minimize test schedule
  - Goal is to provide earliest possible fleet implementation
  - Full SSC crews & parallel stand testing

Block III SSME Test Matrix

Development Envelope



Blk III Unit #	A1 Starts	A2 Starts	Total Starts	Nozzle Trans	Total Seconds
001 Dev	40		40	80	10,000
002 Dev		30	30	30	12,000
003 Dev	40		40	80	16,000
004 Cert		22	22	22	11,000
005 Cert	22		22	44	11,000
Totals			154	256	60,000

Block III is Viable Upgrade

Targets Achievable

- Safety goal achievable
  - Ascent risk reduced by 30%
- Insignificant changes to vehicle system
  - Orifice modification for tank repressurization -- similar to Block I to Block II conversion
  - Operational software updates
- No risk to engine operation
  - Unblocking LPFTP nozzle is similar to Block II change
  - Parameters within existing experience
- Major maintenance items addressed with new joint G15 seal design and robust nozzle

Block III is Viable Upgrade

Risks Acceptable & Manageable

- Technical risk is low
  - Change is within experience Reliability improvements anchored to previous Block changes
- Have plan to achieve 2005 first flight
  - Parallel development paths for risk mitigation

NASA-MSFC and Boeing-Rocketdyne have the experienced team to make Block III SSME happen