PRESENTATION 4.4.8

SPACE SHUTTLE MAIN ENGINE

CERTIFICATION

FOR

MANNED SPACE FLIGHT

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PENN STATE PROP. SYMPOSIUM
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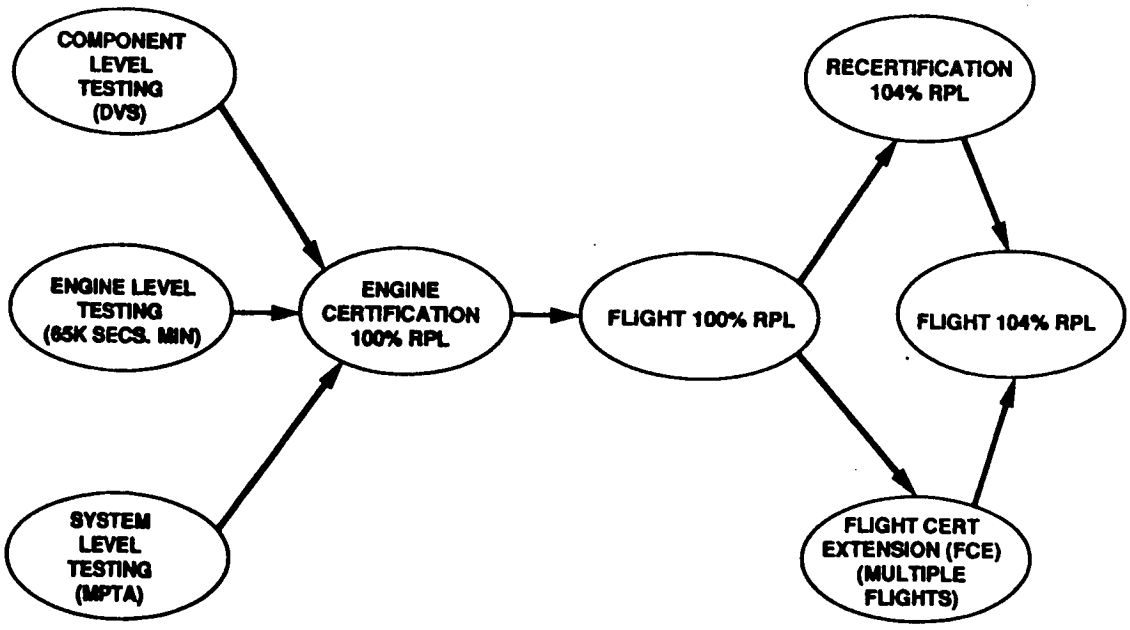
SSME IS FIRST REUSABLE LARGE LIQUID ROCKET ENGINE

• FULL POWER LEVEL (FPL) 109%	512,300 LBS
• RATED POWER LEVEL (RPL) 100%	470,000 LBS
• CHAMBER PRESSURE	3200 PSIA
• SPECIFIC IMPULSE AT ALTITUDE	435.5 SECONDS
• THROTTLE RANGE	65 TO 109%
• PROPELLANTS	OXYGEN/HYDROGEN
• WEIGHT	7000 LBS
• DESIGN LIFE	27,00 SECONDS 55 STARTS
• AT FULL POWER LEVEL	14,000 SECONDS

SSME CERTIFICATION PROCESS



SSME DEVELOPMENT/CERTIFICATION

- SSME REQUIREMENTS IDENTIFIED IN NASA APPROVED DOCUMENTS
- DESIGN VERIFICATION SPECIFICATIONS (DVS) USED TO DEFINE REQUIREMENTS AND METHOD OF VERIFICATION
- DETAILED AND COMPLETE PLANS PROVIDE FOR VERIFICATION OF EACH REQUIREMENT
  - LABORATORY TESTS, COMPONENT TESTS AND ENGINE TESTS
- TESTS PLANNED TO EXPOSE PROBLEMS EARLY
  - OFF LIMITS TESTING/MALFUNCTION TESTING/MARGIN TESTS
- ENGINE CERTIFICATION (CULMINATION OF DEVELOPMENT PROCESS)
  - TWO CERTIFICATION CYCLES ON EACH OF TWO ENGINES
  - CERTIFICATION CYCLE - 10 TESTS AND 5000 SECONDS

DESIGN VERIFICATION SPECIFICATIONS (DVS)

- ESSENTIALLY 25 LEVEL IV CEI'S CATEGORIZED BY MAJOR COMPONENT AND/OR SUBSYSTEM
- PROVIDES ALL DESIGN AND VERIFICATION REQUIREMENTS AT COMPONENT LEVEL
- PROVIDES TRACEABILITY TO THE CEI/ICD

DOCUMENT	TITLE
DVS-SSME-101	SPACE SHUTTLE MAIN ENGINE
DVS-SSME-102	GIMBAL BEARING ASSEMBLY
DVS-SSME-106	POGO SUPPRESSION SYSTEM
DVS-SSME-201	CONTROLLER - VOLUME 1
DVS-SSME-201	CONTROLLER SOFTWARE - VOLUME 2
DVS-SSME-202	ELECTRICAL HARNESS ASSEMBLY
DVS-SSME-203	INSTRUMENTATION SYSTEM
DVS-SSME-204	FLOWMETERS FOR LH2 AND LO2 SERVICE
DVS-SSME-205	IGNITION SYSTEM
DVS-SSME-206	FASCOS CONTROLLER
DVS-SSME-303	THRUST CHAMBER ASSEMBLY
DVS-SSME-304	HOT GAS MANIFOLD
DVS-SSME-305	FUEL AND OXIDIZER PREBURNER ASSEMBLIES
DVS-SSME-401	LPOTP ASSEMBLY

DOCUMENT	TITLE
DVS-SSME-402	LPFTP ASSEMBLY
DVS-SSME-403	HPOTP ASSEMBLY
DVS-SSME-404	HPFTP ASSEMBLY
DVS-SSME-508	CHECK VALVES
DVS-SSME-510	PNEUMATIC CONTROL ASSEMBLY
DVS-SSME-511	FLEXIBLE AND HARD DUCTS AND LINE ASSEMBLIES
DVS-SSME-512	HYDRAULIC ACTUATION SYSTEM
DVS-SSME-513	HEAT EXCHANGER
DVS-SSME-514	STATIC SEALS
DVS-SSME-515	PROPELLANT VALVES
DVS-SSME-516	FUEL AND OXIDIZER BLEED VALVE ASSEMBLIES
DVS-SSME-517	POGO SUPPRESSION SYSTEM VALVE ASSEMBLIES

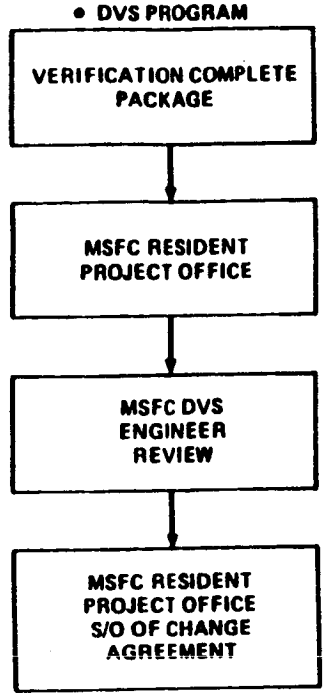
TOTAL LABORATORY DVS TEST SUMMARY
ALL COMPONENTS

THRUST CHAMBER	131	PNEUMATIC CONTROL ASSY	303
PREBURNERS	70	INSTRUMENTATION SYSTEM	70
CONTROLLER	192	CHECK VALVES	173
HIGH-PRESSURE FUEL T/P	365	HEAT EXCHANGER	22
HIGH-PRESSURE LOX T/P	830	STATIC SEALS	100
LOW-PRESSURE FUEL T/P	100	GINBAL BEARING	2
LOW-PRESSURE LOX T/P	96	DUCTS AND LINES	528
IGNITION SYSTEM	789	FLOWMETER	7
HYDRAULIC ACTUATION SYS	228	ENGINE SYSTEM	12
ELECTRICAL HARNESSES	85	POGO SYSTEM	125
HOT GAS MANIFOLD	40	POGO VALVES	276
PROPELLANT VALVES	38	FASCOS	16
BLEED VALVE	29	TOTAL	4627

COMPONENT HOT-FIRE TEST SUMMARY

TEST	NUMBER OF TESTS
SUBSCALE THRUST CHAMBER AND MAIN COMBUSTION CHAMBER AUGMENTED SPARK IGNITER	236
IGNITION SYSTEMS AND PREBURNERS	918
THRUST CHAMBERS	94
OXIDIZER TURBOPUMPS	70
FUEL TURBOPUMPS	100
TOTAL	1418

VERIFICATION COMPLETE APPROVAL FLOW
VERIFICATION COMPLETE PACKAGE



- ENGINE LEVEL TESTING
  - PROGRAM REQUIREMENT OF 65,000 SECONDS TO DEMONSTRATE FLIGHT WORTHINESS
  - 619 STARTS/79,235 SECONDS ACCUMULATED PRIOR TO STS-1
- SYSTEM LEVEL TESTING (MPTA)
  - SYSTEMS LEVEL TESTING TO VERIFY MPS COMPATIBILITY AND PERFORMANCE
  - TEST ARTICLE CONSISTED OF 3 SSME'S, ET, ORBITER SIMULATOR, ETC.
  - TEST PROGRAM INCLUDED STRUCTURAL RESONANT SURVEYS, PROPELLANT LOADING TESTS, AND 12 HOT FIRINGS
  - 54 STARTS / 11,326 SECONDS ACCUMULATED PRIOR TO STS-1

- FLIGHT CERTIFICATION PROGRAM
  - CERTIFICATION DEMONSTRATION TEST PROGRAM
  - TWO CERT CYCLES ON EACH OF TWO FLIGHT CONFIGURATION ENGINES
  - EACH CERT CYCLE CONSISTED OF 10 STARTS/5000 SECONDS
  - INCLUDED OVERSTRESS TESTING AND ABORT SIMULATION
  - SSME CERTIFIED FOR 100% RPL OPERATION
  - 109% RPL ABORT CAPABILITY DEMONSTRATED
  - 51 STARTS/19,858 CERT SECONDS ACCUMULATED PRIOR TO STS-1
- TOTAL HOT-FIRE TEST EXPERIENCE PRIOR TO STS-1:

  >110,000 SECONDS
  >720 STARTS
- STS-1 THROUGH STS-5 FLOWN AT 100% RPL

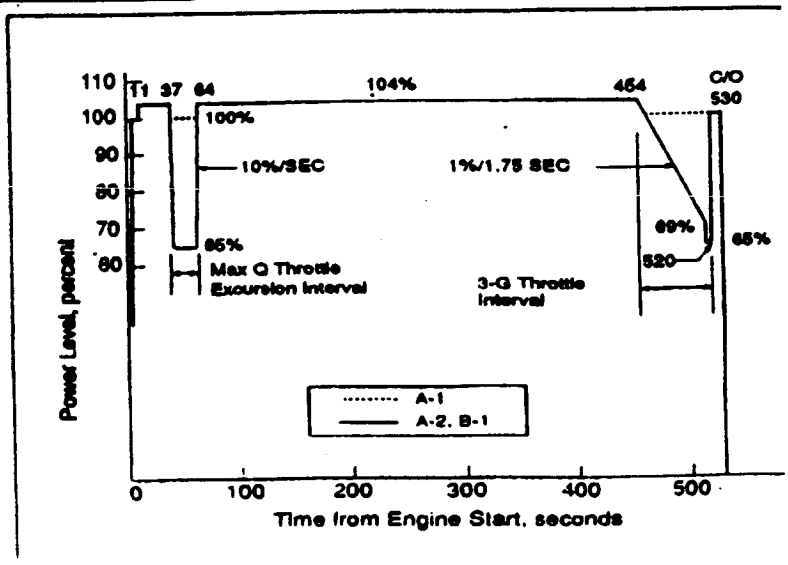
CERTIFICATION EXPERIENCE PRIOR TO STS-6 104% POWER LEVEL

- RE-CERTIFICATION (104% RPL)
  - FOUR CERT CYCLES COMPLETED (52 STARTS/20,710 SECONDS)
  - ENGINE CERTIFIED FOR 104% RPL OPERATION
- ENGINE DEVELOPMENT TESTING
  - 812 STARTS/117,514 SECONDS CUMULATIVE TOTAL PRIOR TO STS-6
- STS-6 AND SUBS WERE FLOWN AT 100% OR 104% RPL

10-TEST CERTIFICATION CYCLE/TYPICAL PROFILE

Table 1A. Certification Test Requirements
Sample No. 1

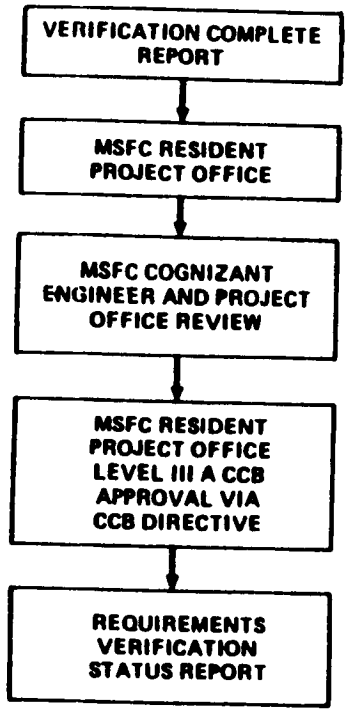
Test	Thrust Profile	Objective	Mainstage Duration, sec				
			Total	109%	104%	100%	Other
1	1	104% Nominal Mission	520		416		104
2	1	104% Nominal Mission	520		416		104
3	1	104% Nominal Mission	520		416		104
4	2	109% Nominal Mission	503	381			122
5	2	109% Nominal Mission	503	381			122
6	1	104% Nominal Mission	520		416		104
7	4B	104% Abort - AOA	623		581		42
8	3A	109% Abort - RTLS	761	518		194	49
9	1	104% Nominal Mission	520		416		104
10	1	104% Nominal Mission	520		416		104
		Minimum Cum	5510	1280	3077	194	959



CERTIFICATION EXPERIENCE POST-51L (RETURN TO FLIGHT)

- 39 CHANGES CERTIFIED AND INCORPORATED PRIOR TO STS-26R
  - CUMULATIVE TESTING DURING PERIOD - 234 STARTS/89,384 SECONDS
- PRIMARILY CHANGES TO IMPROVE LIFE OF PUMPS AT FPL
  - REDUCED FUEL TURBINE TEMPERATURE
  - IMPROVED TURBINE BLADES
  - IMPROVE DYNAMIC STABILITY OF HPOTP
  - INCREASED HPOTP BEARING LIFE
- TWO 5000-SECOND CERTIFICATIONS REQUIRED FOR MODIFICATIONS

VERIFICATION COMPLETE APPROVAL FLOW
VERIFICATION COMPLETE REPORT



CERTIFICATION REQUIREMENTS (CONT'D)

- FLIGHT CERTIFICATION EXTENSION (FCE) RSS-8503-2E
  - VERIFY SSME CAPABILITY FOR EXTENDED LIFE
  - MAINTAIN A FACTOR OF TWO ON STARTS/DURATION ON TWO SAMPLES WITH A LEAD TIME OF TWO YEARS OVER FLIGHT PROGRAM (2X2X2 RULE)
- FLEET LEADER CRITERIA (RF005-009)
  - CERTIFIED HARDWARE IS RESTRICTED FOR FLIGHT USE TO 50% OF THE FLEET LEADER EXPOSURE
  - LOWER LIFE LIMITS (RESULTING FROM PART FAILURE, ANALYSIS OR EMPIRICAL DATA) CAN BE IMPOSED BY DEVIATION APPROVAL REQUESTS (DAR)

IN RETROSPECT...

- STRUCTURED COMPONENT DEVELOPMENT YIELDED HIGH RETURN ON INVESTMENT - SHOULD HAVE BEEN EXPANDED
- EXTENSIVE GROUND TEST PROGRAM WHICH BRACKETED FLIGHT OPERATIONS ASSURED SAFE FLIGHTS
- SYSTEM LEVEL TEST PROVIDED NECESSARY VALIDATION OF ELEMENT INTERACTIONS
- SOPHISTICATED HIGH POWER/DENSITY RATIO DESIGNS COMPROMISE RELIABILITY, MANUFACTURING AND COST. ROBUST DESIGNS RECOMMENDED
- HARDWARE UNDERSUPPORT FOR FAB., ASSEMBLY AND TEST REQUIRES COMPROMISE AND CONCESSION IN EVERY ASPECT OF THE PROGRAM AND SHOULD BE VIGOROUSLY AVOIDED
- MATERIAL CHARACTERIZATION, WELD ASSESSMENT AND STRUCTURAL AUDIT SHOULD BE EARLY IN THE PROGRAM AND VERY THOROUGH
- PROGRAM COULD HAVE GREATLY BENEFITED FROM TODAY'S CFD TECHNOLOGY - ALSO CAD/CAM, TQM
- AVIONICS SIMULATION LAB FOR SOFTWARE VALIDATION PROVED TO BE MAJOR PROGRAM ASSET
- MAINTAINABILITY AND CONDITION MONITORING FEATURES WERE EXCELLENT AND SHOULD HAVE BEEN MORE EXTENSIVE
- EFFORT TO MINIMIZE CRITICALITY 1 FAILURES SHOULD HAVE BEEN MORE INTENSIVE IN THE INITIAL DESIGN PHASE
- COMPUTER CONTROLLED ENGINE OFFERS GREAT FLEXIBILITY AND WAS A DEFINITE PLUS