

N91-28270

PRESENTATION 4.4.8

SPACE SHUTTLE MAIN ENGINE

CERTIFICATION

FOR

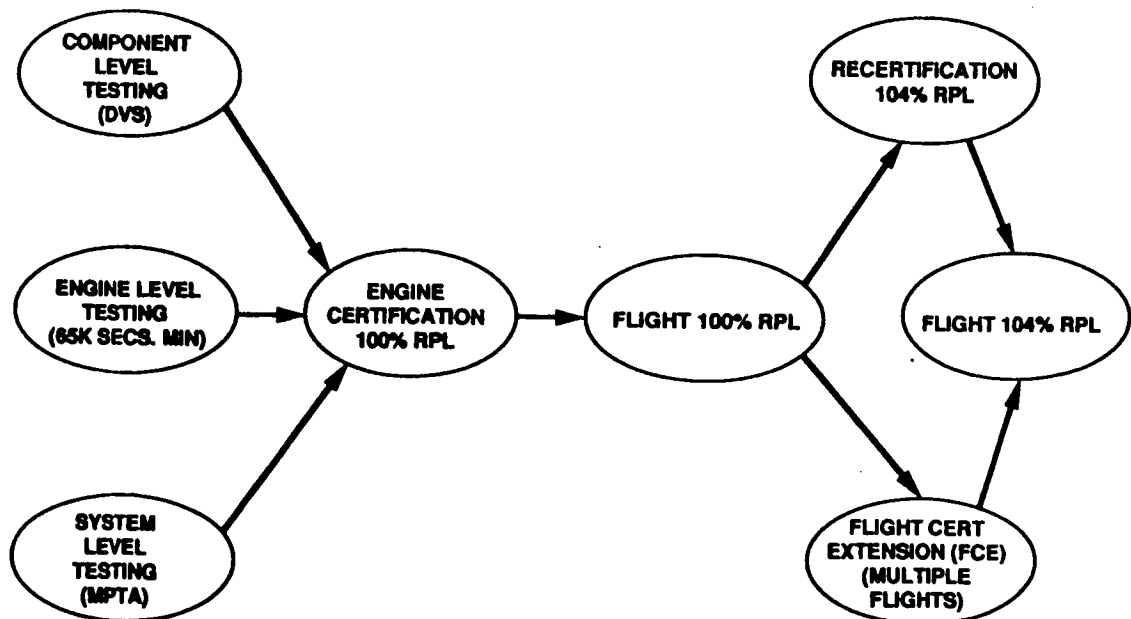
MANNED SPACE FLIGHT

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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

<u>DOCUMENT</u>	<u>TITLE</u>	<u>DOCUMENT</u>	<u>TITLE</u>
DVS-SSME-101	SPACE SHUTTLE MAIN ENGINE	DVS-SSME-402	LPFTP ASSEMBLY
DVS-SSME-102	GIMBAL BEARING ASSEMBLY	DVS-SSME-403	HPOTP ASSEMBLY
DVS-SSME-106	POGO SUPPRESSION SYSTEM	DVS-SSME-404	HPFTP ASSEMBLY
DVS-SSME-201	CONTROLLER - VOLUME 1	DVS-SSME-508	CHECK VALVES
DVS-SSME-201	CONTROLLER SOFTWARE - VOLUME 2	DVS-SSME-510	PNEUMATIC CONTROL ASSEMBLY
DVS-SSME-202	ELECTRICAL HARNESS ASSEMBLY	DVS-SSME-511	FLEXIBLE AND HARD DUCTS AND LINE ASSEMBLIES
DVS-SSME-203	INSTRUMENTATION SYSTEM	DVS-SSME-512	HYDRAULIC ACTUATION SYSTEM
DVS-SSME-204	FLOWMETERS FOR LH2 AND LO2 SERVICE	DVS-SSME-513	HEAT EXCHANGER
DVS-SSME-205	IGNITION SYSTEM	DVS-SSME-514	STATIC SEALS
DVS-SSME-206	FASCOS CONTROLLER	DVS-SSME-515	PROPELLANT VALVES
DVS-SSME-303	THRUST CHAMBER ASSEMBLY	DVS-SSME-516	FUEL AND OXIDIZER BLEED VALVE ASSEMBLIES
DVS-SSME-304	HOT GAS MANIFOLD	DVS-SSME-517	POGO SUPPRESSION SYSTEM VALVE ASSEMBLIES
DVS-SSME-305	FUEL AND OXIDIZER PREBURNER ASSEMBLIES		
DVS-SSME-401	LPOTP ASSEMBLY		

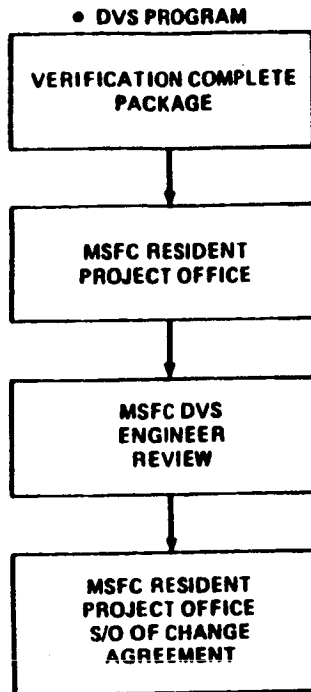
TOTAL LABORATORY DVS TEST SUMMARY ALL COMPONENTS

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 HARNESSSES	85	POGO SYSTEM	125
HOT GAS MANIFOLD	40	POGO VALVES	276
PROPELLANT VALVES	38	FASCOS	<u>16</u>
BLEED VALVE	29	TOTAL	4627

COMPONENT HOT-FIRE TEST SUMMARY

<u>TEST</u>	<u>NUMBER OF TESTS</u>
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	<u>1418</u>

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**

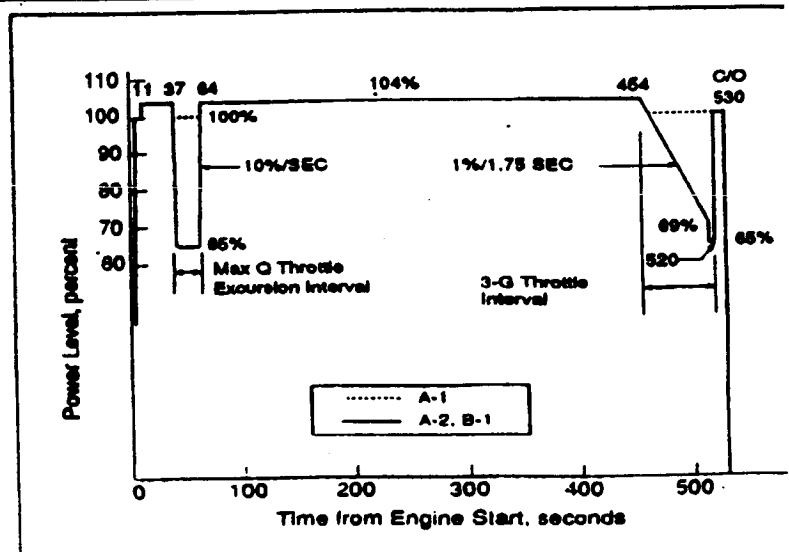
**CERTIFICATION EXPERIENCE PRIOR TO STS-6
104% POWER LEVEL**

- **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

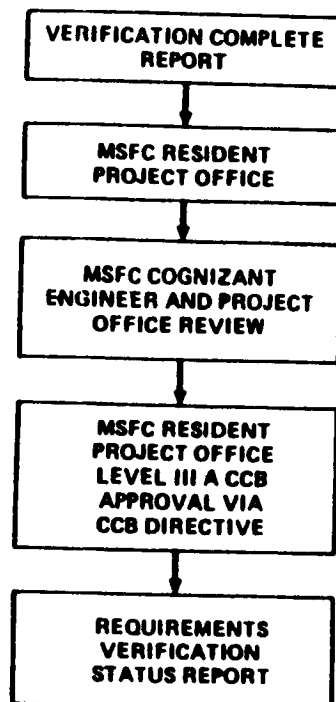
Test	Thrust Profile	Objective	Mainstage Duration, sec				
			Total	109%	104%	100%	Other
1	1	104% Nominal Mission	520		416		104
2	1	104% Nominal Mission	520		416		104
3	1	104% Nominal Mission	520		416		104
4	2	109% Nominal Mission	503	381			122
5	2	109% Nominal Mission	503	381			122
6	1	104% Nominal Mission	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**