SPACE SHUTTLE PROPULSION SYSTEMS

SPACE TRANSPORTATION TECHNOLOGY SYMPOSIUM
PENNSYLVANIA STATE UNIVERSITY

RUSSELL BARDOS
NASA
OFFICE OF SPACE FLIGHT
JUNE 26, 1990
THE SPACE SHUTTLE

EXTERNAL TANK

ORBITER

TWO ORBIT MANEUVERING ENGINES

FOURTEEN RCS PRIMARY THRUSTERS
TWO RCS VERNIER THRUSTERS

FOUR BOOSTER SEPARATION MOTORS

TWO SOLID ROCKET BOOSTERS

TWENTY: FOUR RCS PRIMARY THRUSTERS
(TWELVE EACH AFT POD)
FOUR RCS VERNIER THRUSTERS
(TWO EACH AFT POD)

REDESIGNED SOLID ROCKET MOTOR
Four Segment Design

PURPOSE: PROVIDES PROPELLANT THRUST FROM LIFTOFF THROUGH THE FIRST 123 SECONDS OF FLIGHT
SUPPLIER: THIOKOL CORP., WASATCH, UTAH

9 DEGREE OMNIAXIAL DEFLECTION NOZZLE

FIELD JOINTS (3)
### RSRM DESIGN PARAMETERS

- **AVERAGE VACUUM THRUST (WEB TIME)**: 2,590,000 LBS
- **SPECIFIC IMPULSE (VACUUM)**: 267.9 SEC
- **AREA RATIO \( \frac{A_e}{A_t} \)**: 7.72
- **AVERAGE CHAMBER PRESSURE**: 625 PSIA
- **ACTION TIME**: 123.4 SEC
- **MOTOR WEIGHT**: 1,255,978 LBS
- **PROPELLANT WEIGHT**: 1,107,169 LBS
- **MASS FRACTION**: 0.882
- **INERT WEIGHT:**
  - **CASE**: 98,740 LBS
  - **NOZZLE**: 23,965 LBS
- **PROPELLANT TYPE**: PBAN
- **BURN RATE (@625 PSIA)**: 0.368 IN/SEC
- **THRUST VECTOR CONTROL**: FLEX BEARING
- **CASE MATERIAL**: D6AC STEEL
- **INSULATION MATERIAL**: ASBESTOS/NBR

### ADVANCED SOLID ROCKET MOTOR
Three Segment Design

**PURPOSE:** PROVIDES PROPULSIVE THRUST FROM LIFTOFF THROUGH THE FIRST 134 SECONDS OF FLIGHT

**SUPPLIER:** LOCKHEED MISSILES & SPACE COMPANY, SUNNYVALE, CA.
ASRM DESIGN PARAMETERS

- Average Vacuum Thrust (Web Time) 624,031 LBS
- Specific Impulse (Vacuum) 70.3 SEC
- Area Ratio ($A_e/A_t$) 7.54
- Average Chamber Pressure 633 PSIA
- Action Time 134.1 SEC
- Motor Weight 1,345,807 LBS
- Proellant Weight 1,205,807 LBS
- Mass Fraction 8.96
- Inert Weight:
  - Case 97,419 LBS
  - Nozzle 18,947 LBS
- Proellant Type HTPB
- Burn Rate (@625 PSIA) 0.345 IN/SEC
- Thrust Vector Control Flex Bearing
- Case Material 9 Ni-4 Co-0.3C
- Insulation Material KEVLAR-GLASS-EPDM

SPACE SHUTTLE MAIN ENGINE

Purpose: Provide Propulsive Thrust from Liftoff to Orbit
Supplier: ROCKWELL INTERNATIONAL ROCKETDYNE DIVISION, CANOGA PARK, CA.
SSME COMPONENTS

MAIN ENGINE PARAMETERS

- PROPELLANTS
- RATED POWER LEVEL (RPL) 100%
- FULL POWER LEVEL (FPL) 109%
- MINIMUM POWER LEVEL (MPL) 65%
- THROTTLE RANGE
- CHAMBER PRESSURE
- MIXTURE RATIO
- SPECIFIC IMPULSE
- FLOW RATES:
  - OXYGEN
  - HYDROGEN
- WEIGHT
- DESIGN LIFE
- FULL POWER LEVEL
- OVERALL HEIGHT
- NOZZLE DIAMETER @ EXIT

OXYGEN/HYDROGEN

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<th>Parameter</th>
<th>Value</th>
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<td>Rated Power Level</td>
<td>470,000 LBS</td>
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<td>Minimum Power Level</td>
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<td>Throttle Range</td>
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<td>Chamber Pressure</td>
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<td>Oxygen Flow Rate</td>
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<td>Hydrogen Flow Rate</td>
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<td>Design Life</td>
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<tr>
<td>Full Power Level</td>
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<tr>
<td>Overall Height</td>
<td>14 FEET</td>
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<tr>
<td>Nozzle Diameter</td>
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SRB BOOSTER SEPARATION MOTOR

PURPOSE: PROVIDES PROPULSIVE THRUST TO SEPARATE SRBS FROM THE ORBITER AND EXTERNAL TANK
SUPPLIER: UNITED TECHNOLOGIES, CHEMICAL SYSTEMS DIV., SAN JOSE, CA.

BSM DESIGN PARAMETERS

- AVERAGE VACUUM THRUST: 20,050 LBS
- AREA RATIO: 5.8
- AVERAGE CHAMBER PRESSURE: 2221 PSIA
- ACTION TIME: 0.805 SEC
- TOTAL IMPULSE: 15,000 LB - SEC
- MOTOR WEIGHT: 167 LBS
- PROPELLANT TYPE: HTPB
- CASE MATERIAL: 7075 AL
PURPOSE: PROVIDES PROPULSIVE THRUST FOR ORBIT INSERTION, ORBIT CIRCULARIZATION, ORBIT TRANSFER, RENDEZVOUS, DEORBIT, AND LAUNCH ABORT

SUPPLIER: AEROJET PROPULSION DIVISION; SACRAMENTO, CA.

OMS ENGINE DESIGN PARAMETERS

- PROPELLANTS
  MMH/N₂O₄

- THRUST (VACUUM)
  6,000 LBS

- NOMINAL SPECIFIC IMPULSE
  313.2 SEC

- CHAMBER PRESSURE
  125 PSIA

- MIXTURE RATIO
  1.65

- EXPANSION RATIO
  55:1

- FLOW RATES
  FUEL
  11.93 LB/SEC
  OXIDIZER
  7.23 LB/SEC

- DRY WEIGHT
  297 LBS

- LIFE
  100 MISSIONS
  1000 STARTS
  15 HOURS CUM. FIRING

- GIMBAL CAPABILITY
  PITCH
  ± 6 DEG
  YAW
  ± 7 DEG
RCS PRIMARY AND VERNIER THRUSTERS

PURPOSE: PROVIDE PROPULSIVE THRUST FOR ORBIT STABILIZATION AND ORIENTATION MANEUVERS

SUPPLIER: THE MARQUARDT COMPANY, VAN NUYS, CA.

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RCS PRIMARY & VERNIER THRUSTER PARAMETERS

- PROPELLANTS
  - PRIMARY: MMH/N₂O₄
  - VERNIER: MMH/N₂O₄

- NOMINAL VACUUM THRUST
  - PRIMARY: 870 LBS
  - VERNIER: 24 LBS

- CHAMBER PRESSURE
  - PRIMARY: 152 PSIA
  - VERNIER: 110 PSIA

- MIXTURE RATIO
  - PRIMARY: 1.6
  - VERNIER: 1.65

- SPECIFIC IMPULSE
  - PRIMARY: 280 SEC (22:1 AREA RATIO)
  - VERNIER: 265 SEC

- INLET PRESSURE
  - PRIMARY: 238 PSIA
  - VERNIER: 246 PSIA

- RATIO (Aₑ/Aₐ)
  - PRIMARY: 22:1 TO 30:1
  - VERNIER: 20.7:1

- LIFE
  - MISSIONS
    - PRIMARY: 100
    - VERNIER: CHAMBER LIMITED
  - CYCLES
    - PRIMARY: 20,000
    - VERNIER: 330,000
  - TOTAL FIRING DURATION
    - PRIMARY: 12,800 SEC
    - VERNIER: 125,000 SEC

- WEIGHT
  - PRIMARY: 16 LBS
  - VERNIER: 9.4 LBS

- CONSTRUCTION
  - PRIMARY: COLUMBIUM/TITANIUM
  - VERNIER: COLUMBIUM/TITANIUM
ORBITER OMS & REACTION CONTROL SYSTEM

38 Primary Thrusters (14 Forward, 12 per Aft Pod)
Thrust Level = 870 Pounds Vacuum
8 Vernier Thrusters (2 Forward, 4 Aft)
Thrust Level = 24 Pounds Vacuum

Propellants: Nitrogen Tetroxide Oxidizer
Monomethyl Hydrazine Fuel
Nominal Forward RCS Full Load
1,477 Pounds Nitrogen Tetroxide
928 Pounds Monomethyl Hydrazine
Nominal Aft RCS Full Load for Each Pod
1,477 Pounds Nitrogen Tetroxide
825 Pounds Monomethyl Hydrazine

Left Aft OMS/RCS Pod
(Right Aft OMS/RCS Pod Contains Identical Components)

NOTE: Shaded areas part of orbital maneuvering system
SPACE SHUTTLE PROPULSION ISSUES

RSRM
- IGNITER SEAL ANOMALIES
- CASE STIFFENER SEGMENT ATTRITION
- IMPROVED O-RING MATERIAL
- ASBESTOS-FREE INSULATION
- FORWARD SEGMENT GRAIN REDESIGN

SRB
- AFT SKIRT FACTOR OF SAFETY
- OBSOLESCENCE OF ELECTRONIC COMPONENTS
- RECOVERY SYSTEM MARGINS
- DEBRIS CONTAINMENT SYSTEM

SSME
- HIGH PRESSURE TURBOPUMP BEARINGS
- HEAT EXCHANGER
- CONTROLLER OBSOLESCENCE
- UNINSPECTABLE WELDS

RCS THRUSTERS
- COMBUSTION INSTABILITY
- CONTAMINATION

PROPELION SYSTEM
IMPROVEMENTS IN WORK

RSRM
- IGNITER-TO-CASE JOINT REDESIGN

SRB
- ENHANCED MULTIPLEXER/DEMULTIPLEXER
- DEBRIS CONTAINMENT SYSTEM FRANGIBLE LINK
- MAIN PARACHUTE RIPSTOP
- HDP/AFT SKIRT BIAS

SSME
- PHASE II + POWERHEAD
- HPOTP/HPFTP LIFE IMPROVEMENTS
- ALTERNATE TURBOPUMP DEVELOPMENT
- BLOCK II CONTROLLER
- SINGLE COIL HEAT EXCHANGER

ORBITER
- IMPROVED AUXILIARY POWER UNIT
- IMPROVED AUXILIARY POWER UNIT CONTROLLER
- IMPROVED MULTIPLEXER/DEMULTIPLEXER

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ASA PROGRAM
DEFINITION

OBJECTIVE: EXTEND THE LIFE OF THE SPACE SHUTTLE PROGRAM TO THE YEAR 2020

BENEFITS: PLANS FOR OBSOLESCENCE, IMPLEMENTS CURRENT TECHNOLOGY
INCREASES SAFETY MARGINS
INCREASES MISSION SUCCESS PROBABILITY
MAINTAINS A HIGH LEVEL OF TECHNICAL EXCELLENCE
IMPROVES VEHICLE TURNAROUND AND OPERATIONS COSTS
DEVELOPS AND QUALIFIES ALTERNATE SOURCES

ASA PROGRAM
SELECTION METHODOLOGY

PROBLEM AREAS IDENTIFIED
CANDIDATES SUBMITTED
VIAABLE CANDIDATES CATEGORIZED
FEASIBILITY STUDIES BEGUN ON SOME CANDIDATES
CANDIDATES BEING PRIORITIZED
# ASA Program Priorities

## Program Priorities Established

**Primary:** Assurance of system supportability and safety margin improvement

**Secondary:** Improvements in system reliability, economy and performance

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# ASA Program Candidates

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<td>EPD&amp;C Subsystem Redesign</td>
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<tr>
<td>Control System Redesign</td>
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<td>Integrated Communications</td>
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<td>Aft Skirt Redesign</td>
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<td>Redesigned Stiffener Ring</td>
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<td>Composite Structures</td>
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<td>Orb/SSME</td>
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ASA PROGRAM

CATEGORIES

A. HIGHEST PRIORITY
   NEAR TERM SUPPORTABILITY ISSUES
   SAFETY MARGIN INCREASES

B. HIGH PRIORITY-SYSTEMS IMPROVEMENTS WITH IMPLEMENTATION OPPORTUNITIES

C. OTHER IMPROVEMENTS WITH INDEFINITE SCHEDULE DRIVERS

D. IMPROVEMENTS WITH NO SCHEDULE DRIVER AND/OR HIGH PROGRAM RISK

ASA PROGRAM

PROPULSION PROGRAM CANDIDATES

SRB CONTROL SYSTEM REDESIGN
SSME ADVANCED FABRICATION
AFT SKIRT REDESIGN
INTEGRATED OMS/RCS
ASA PROGRAM
SRB CONTROL SYSTEM REDSIGN

DESCRIPTION:
- REPLACE OBSOLETE ELECTRONIC CONTROL SYSTEMS (FORWARD & AFT IEA'S) WITH SINGLE INTEGRATED MICROPROCESSOR SYSTEM
- ADD SOLID PROPELLANT APU GAS GENERATOR TO REPLACE HYDRAZINE SYSTEM
- ADD NEW LASER INITIATED ORDNANCE TO REPLACE CURRENT SYSTEM

BENEFITS:
- SMART INTEGRATED ELECTRONICS ASSEMBLIES (IEA) AND RANGE SAFETY DISTRIBUTER (RSD) CONTROLLERS AND LASER ORDNANCE CONTROLS ELIMINATES COMPONENTS, FAILURE MODES AND REDUCES COSTS
- EXTERNALLY PROGRAMMABLE MICROPROCESSOR SYSTEM
- HIGHER LAUNCH PROBABILITY FROM REDUCED WING LOADS DUE TO ELIMINATION OF AFT IEA PROTRUBERANCE
- FIBER OPTIC DATA BUSES FOR BETTER COMMUNICATIONS
- ELIMINATE ORDNANCE SYSTEM EMI CONCERNS WITH FIBER OPTIC LINES
- ELIMINATE HYDRAZINE CONCERNS

ASA PROGRAM
SRB AFT SKIRT REDESIGN

DESCRIPTION:
- NEW AFT SKIRT, DESIGN TO:
  - INCREASE STRUCTURAL FACTOR OF SAFETY (1.28 TO 1.4)
  - ENHANCE HOLDDOWN MECHANISM
  - ADD INTEGRAL STIFFENER RINGS TO MINIMIZE WATER IMPACT DAMAGE

BENEFITS:
- SAFETY MARGIN ENHANCEMENT
- ELIMINATE STUD HANGUP AND LAUNCH LOADS
- REDUCTION IN WATER IMPACT DAMAGE
DESCRIPTION:

MAJOR REDESIGNS EMPLOYING ADVANCED FABRICATION AND CASTING TECHNIQUES TO RESOLVE MAJOR ISSUES:
- FINE GRAINED INVESTMENT CASTINGS
- VACUUM PLASMA SPRAY FOR MAIN COMBUSTION CHAMBER

BENEFITS:

IMPROVE THE INSPECTABILITY OF CRITICAL WELDS
ELIMINATE 3000 UNINSPECTABLE WELDS
REDUCE FABRICATION COSTS OF MAJOR COMPONENTS
INCREASE DESIGN PERFORMANCE MARGIN

DESCRIPTION:

REDESIGN SEPARATE OMS/RCS SYSTEMS INTO ONE INTEGRATED SYSTEM
ELIMINATE RCS TANKS/PRESSURIZATION SYSTEM
ALLOW OMS TANK PLUS ENTRY SUMP USE FOR BOTH OMS AND RCS PROPELLANT
IMPROVE ABORT DUMP CAPABILITY
ALLOW LANDING WITH INCREASED RESIDUAL PROPELLANT
INCREASE CHECKOUT/MAINTENANCE CAPABILITY WITH POD ON ORBITER

BENEFITS

IMPROVE SAFETY MARGIN
REDUCE COST
SIMPLIFIED MISSION PLANNING
350 LB DRY WEIGHT REDUCTION
RETAIN CONTRACTOR/SUBCONTRACTOR DESIGN/PRODUCTION SKILLS
THE SHUTTLE LIFE CYCLE CAN BE EXTENDED FROM 20 TO 40 YEARS
SIGNIFICANT BUDGET SAVINGS CAN BE REALIZED OVER A NEW SHUTTLE II
SUBSYSTEM MANDATORY UPGRADES FOR OBsolescence, SAFETY MARGIN,
AND PERFORMANCE IS REQUIRED TO EXTEND THE SHUTTLE LIFE
UPGRADE PROGRAMS WILL HAVE A DEDICATED MANAGEMENT SYSTEM
UPGRADES WILL BE TIMED FOR EFFICIENT IMPLEMENTATION
UPPER STAGES/PROPULSION