THE SPACE SHUTTLE

EXTERNAL TANK

ORBITER

TWO ORBIT MANEUVERING ENGINES

FOURTEEN RCS PRIMARY THRUSTERS
TWO RCS VERNIER THRUSTERS

FOUR BOOSTER SEPARATION MOTORS

FOUR MAIN ENGINES

TWO SOLID ROCKET BOOSTERS

THIRTY-FIVE RCS PRIMARY THRUSTERS
(TWENTY-EIGHT EACH AFT POD)
FOUR RCS VERNIER THRUSTERS
(TWO EACH AFT POD)

REDESIGNED SOLID ROCKET MOTOR
Four Segment Design

PURPOSE: PROVIDES PROPULSIVE 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 ($A_e/A_t$): 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 (Ae/At): 7.54
- Average Chamber Pressure: 633 PSIA
- Action Time: 134.1 SEC
- Motor Weight: 1,345,807 LBS
- Propellant Weight: 1,205,807 LBS
- Mass Fraction: 8.96
- Inert Weight:
  - Case: 97,419 LBS
  - Nozzle: 18,947 LBS
- Propellant 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**
  - OXYGEN/HYDROGEN
  - OXYGEN 470,000 LBS
  - HYDROGEN 512,300 LBS
  - 305,500 LBS

- **RATED POWER LEVEL (RPL) 100%**
  - 3200 PSIA

- **FULL POWER LEVEL (FPL) 109%**
  - 65% TO 109% (1% Increments)
  - 3200 PSIA

- **MINIMUM POWER LEVEL (MPL) 65%**
  - 65% TO 109% (1% Increments)

- **THROTTLE RANGE**
  - 6.03 : 1

- **CHAMBER PRESSURE**
  - 453.5 SEC

- **MIXTURE RATIO**
  - 453.5 SEC

- **SPECIFIC IMPULSE**
  - 973 LB/SEC
  - 161 LB/SEC

- **FLOW RATES: OXYGEN/HYDROGEN**
  - 973 LB/SEC
  - 161 LB/SEC

- **WEIGHT**
  - 7,000 LBS

- **DESIGN LIFE**
  - 27,000 SEC
  - 55 STARTS

- **FULL POWER LEVEL**
  - 14,000 SEC

- **OVERALL HEIGHT**
  - 14 FEET

- **NOZZLE DIAMETER @ EXIT**
  - 7.5 FEET
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

PROPELLANT: 1ZU8
INITIATOR: 31,00 REF

CASE, ALUMINUM 7075
DUAL O-RING SEAL
.316 MIN
23,766
22,746
.400 MIN
12.845 ± .015
DUAL O-RING SEAL
CIF INITIATOR
BOOSTER CHARGE
IGNITER CASE 304L STAINLESS STEEL
21.00 REF
EXIT CONE CARBON STEEL
ALUMINUM 7075
AT6 GRAPHITE THROAT
200
2.132 DIA
7.664 DIA
HEAT SEAL NOT SHOWN

200
OMS ENGINE

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.

RCS PRIMARY & VERNIER THRUSTER PARAMETERS

- PROPELLANTS
- NOMINAL VACUUM THRUST
- CHAMBER PRESSURE
- MIXTURE RATIO
- SPECIFIC IMPULSE
- INLET PRESSURE
- RATIO (Ae/Ai)
- LIFE
  - MISSIONS
  - CYCLES
  - TOTAL FIRING DURATION
- WEIGHT
- CONSTRUCTION

**PRIMARY**
- PROPELLANTS: MMH/N₂O₄
- NOMINAL VACUUM THRUST: 870 LBS
- CHAMBER PRESSURE: 152 PSIA
- MIXTURE RATIO: 1.6
- SPECIFIC IMPULSE: 280 SEC (22:1 AREA RATIO)
- INLET PRESSURE: 238 PSIA
- RATIO (Ae/Ai): 22:1 TO 30:1
- LIFE
  - MISSIONS: 100
  - CYCLES: 20,000
  - TOTAL FIRING DURATION: 12,800 SEC
- WEIGHT: 16 LBS
- CONSTRUCTION: COLUMBIUM/TITANIUM

**VERNIER**
- PROPELLANTS: MMH/N₂O₄
- NOMINAL VACUUM THRUST: 24 LBS
- CHAMBER PRESSURE: 110 PSIA
- MIXTURE RATIO: 1.65
- SPECIFIC IMPULSE: 265 SEC
- INLET PRESSURE: 246 PSIA
- RATIO (Ae/Ai): 20.7:1
- LIFE
  - MISSIONS: CHAMBER LIMITED
  - CYCLES: 330,000
  - TOTAL FIRING DURATION: 125,000 SEC
- WEIGHT: 9.4 LBS
- CONSTRUCTION: COLUMBIUM/TITANIUM
ORBITER OMS & REACTION
CONTROL SYSTEM

38 Primary Thrusters (14 Forward, 12 per Aft Pod)
Thrust Level = 970 Pounds Vacuum
8 Vernier Thrusters (2 Forward, 4 Aft)
Thrust Level = 24 Pounds Vacuum

Propellants: Nitrogen Tetraoxide Oxidizer
Monomethyl Hydrazine Fuel
Nominal Forward RCS Full Load
1,477 Pounds Nitrogen Tetraoxide
1928 Pounds Monomethyl Hydrazine
Nominal Aft RCS Full Load for Each Pod
1,477 Pounds Nitrogen Tetraoxide
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

PROPULSION 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
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
VIABLE 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

ASA PROGRAM
CANDIDATES

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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
ASA PROGRAM
SSME ADVANCED FABRICATION

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

ASA PROGRAM
INTEGRATED OMS/RCS

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