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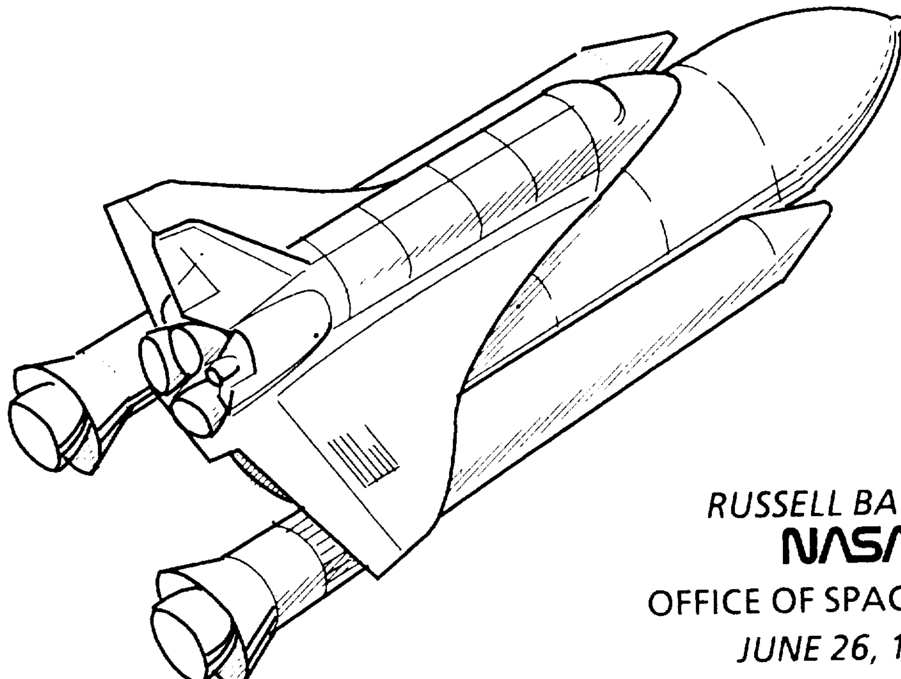
N91-28200

SPACE SHUTTLE PROPULSION SYSTEMS

SPACE TRANSPORTATION TECHNOLOGY SYMPOSIUM

PENNSYLVANIA STATE UNIVERSITY



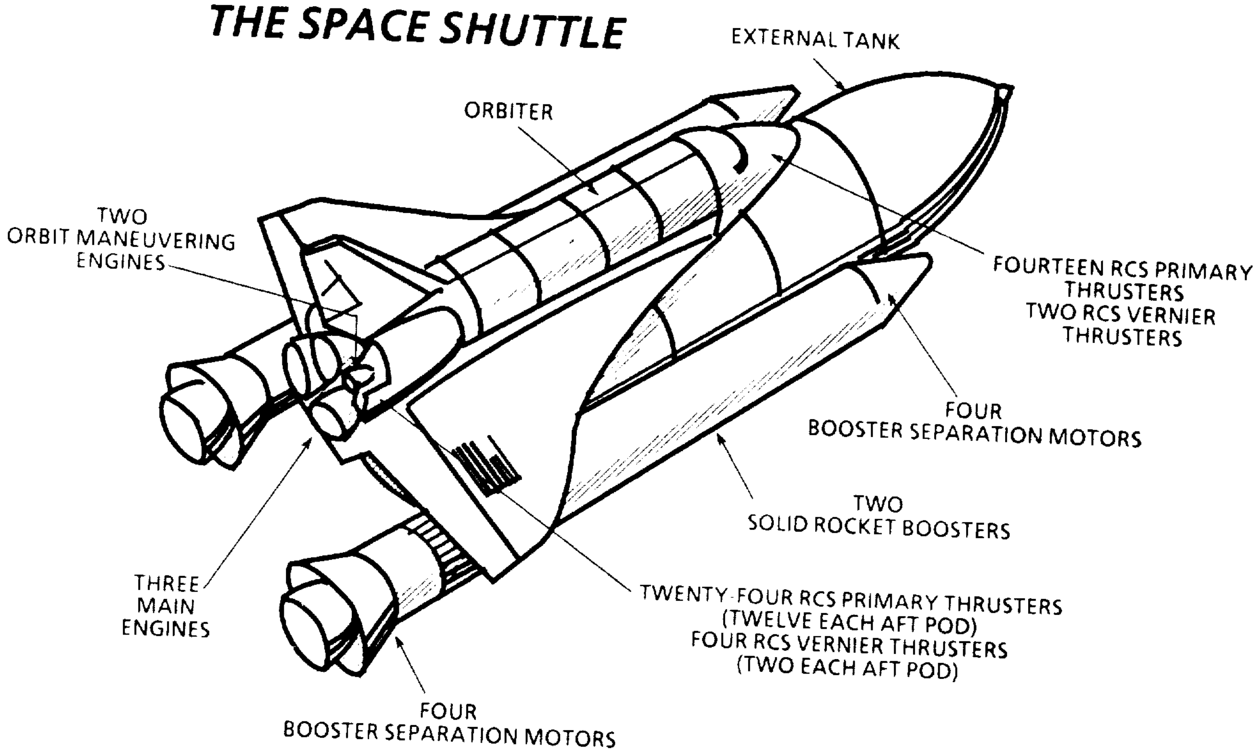
RUSSELL BARDOS

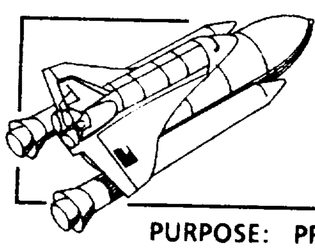
NASA

OFFICE OF SPACE FLIGHT

JUNE 26, 1990

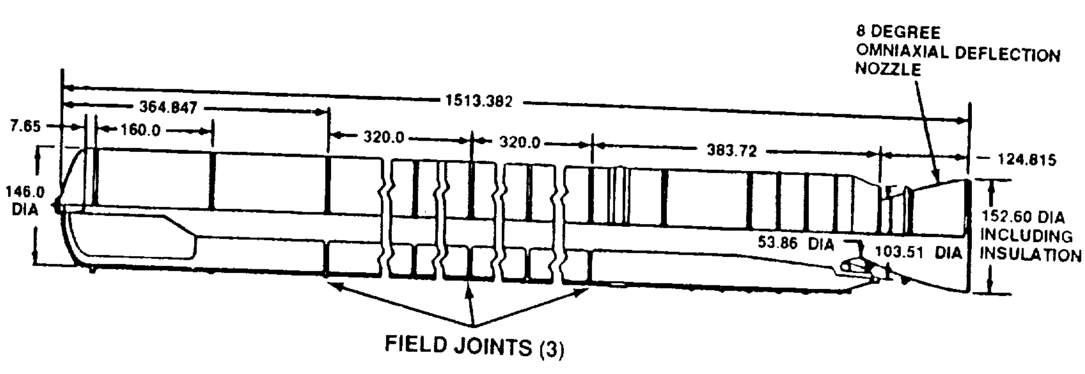
THE SPACE SHUTTLE

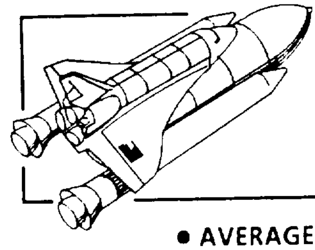




REDESIGNED SOLID ROCKET MOTOR
Four Segment Design

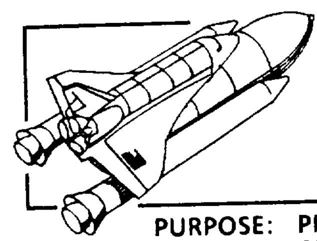
PURPOSE: PROVIDES PROPULSIVE THRUST FROM LIFTOFF THROUGH THE FIRST 123 SECONDS OF FLIGHT
SUPPLIER: THIOKOL CORP., WASATCH, UTAH





RSRM DESIGN PARAMETERS

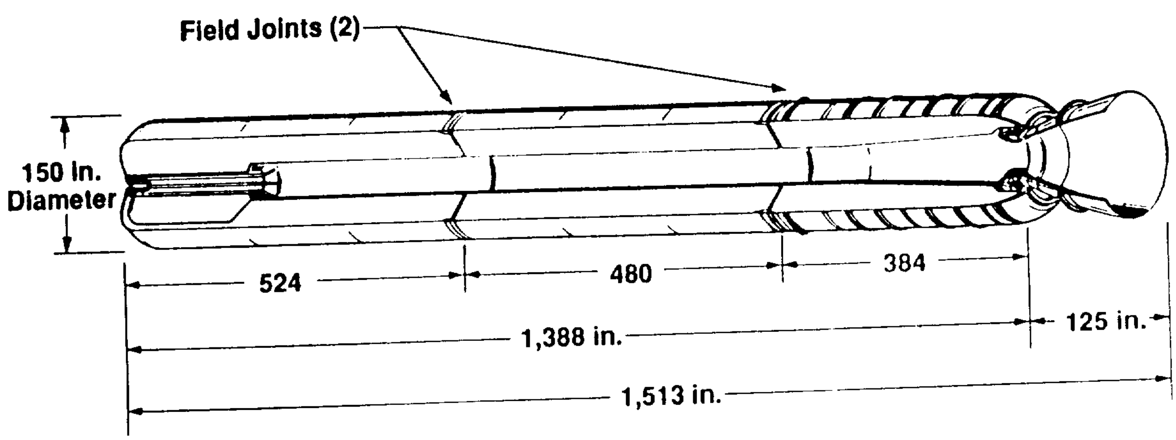
• AVERAGE VACUUM THRUST (WEB TIME)	2,590,000 LBS
• SPECIFIC IMPULSE (VACUUM)	267.9 SEC
• AREA RATIO (A_e/A_t)	7.72
• AVERAGE CHAMBER PRESSURE	625 PSIA
• ACTION TIME	123.4 SEC
• MOTOR WEIGHT	1,255,978 LBS
• PROPELLANT WEIGHT	1,107,169 LBS
• MASS FRACTION	0.882
• INERT WEIGHT:	
CASE	98,740 LBS
NOZZLE	23,965 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.

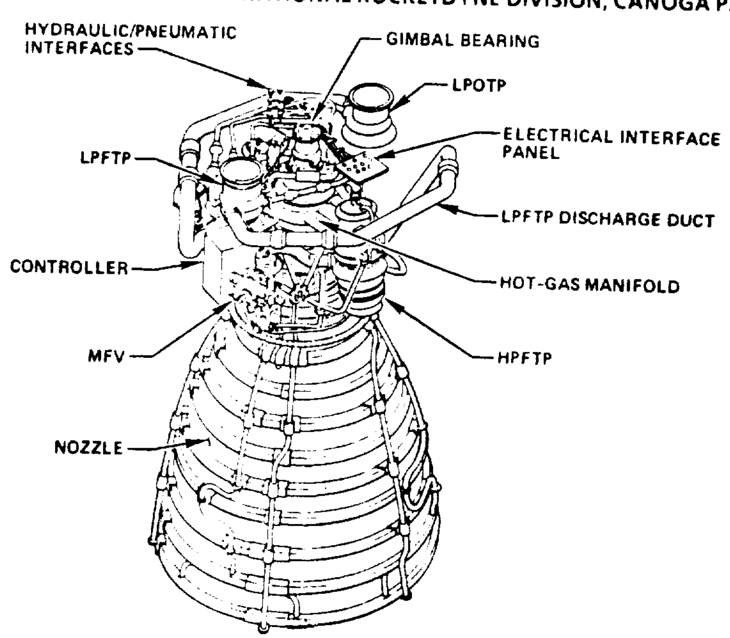


ASRM DESIGN PARAMETERS

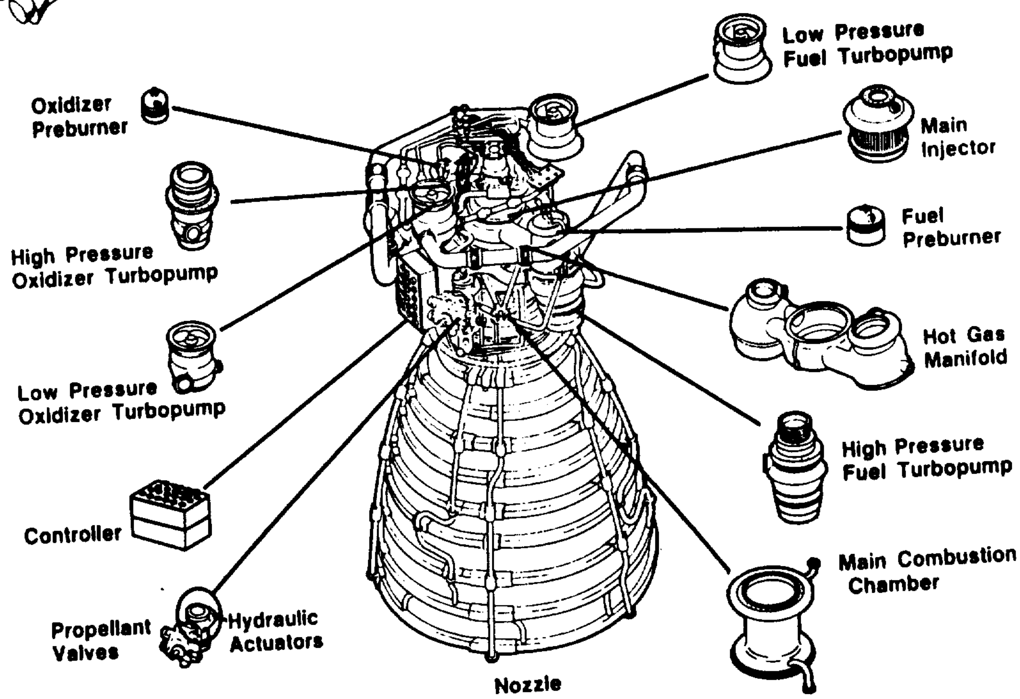
• AVERAGE VACUUM THRUST (WEB TIME)	624,031 LBS
• SPECIFIC IMPULSE (VACUUM)	70.3 SEC
• AREA RATIO (A_e/A_t)	7.54
• AVERAGE CHAMBER PRESSURE	633 PSIA
• ACTION TIME	134.1 SEC
• MOTOR WEIGHT	1,345,807 LBS
• PROPELLANT WEIGHT	1,205,807 LBS
• MASS FRACTION	8.96
• INERT WEIGHT:	
CASE	97,419 LBS
NOZZLE	18,947 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.

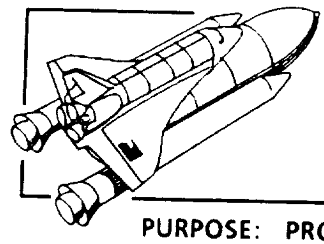


SSME COMPONENTS



MAIN ENGINE PARAMETERS

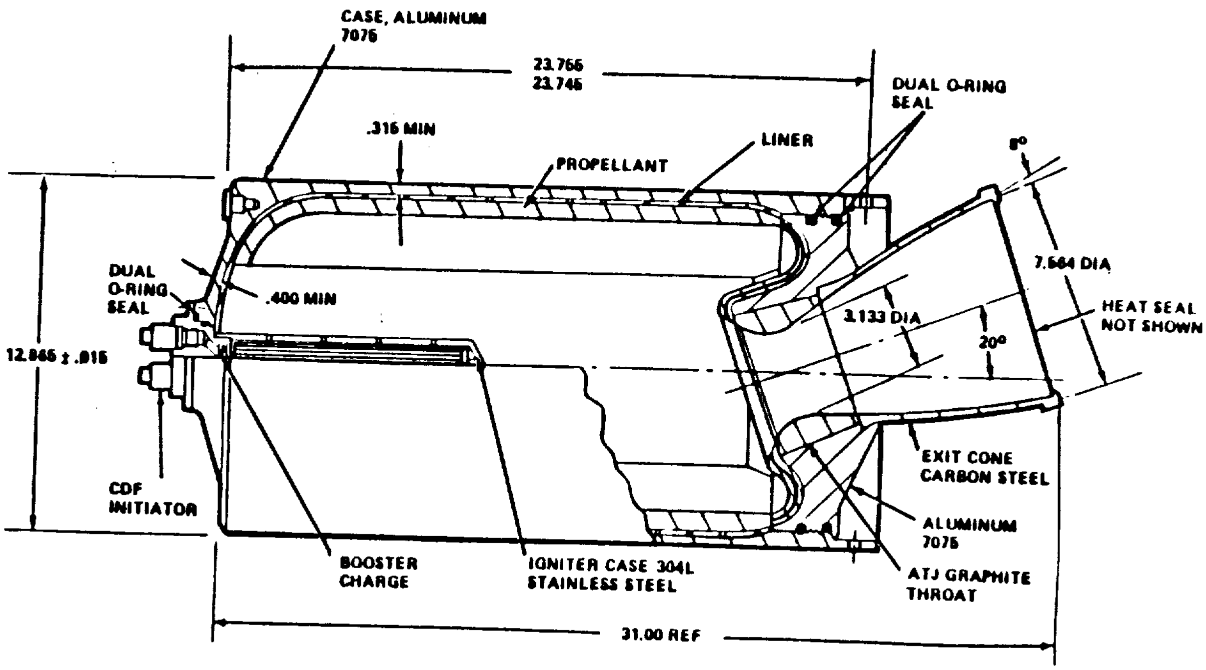
• PROPELLANTS	OXYGEN/HYDROGEN
• RATED POWER LEVEL (RPL) 100%	470,000 LBS
• FULL POWER LEVEL (FPL) 109%	512,300 LBS
• MINIMUM POWER LEVEL (MPL) 65%	305,500 LBS
• THROTTLE RANGE	65% TO 109% (1% Increments)
• CHAMBER PRESSURE	3200 PSIA
• MIXTURE RATIO	6.03 : 1
• SPECIFIC IMPULSE	453.5 SEC
• FLOW RATES:	
OXYGEN	973 LB/SEC
HYDROGEN	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

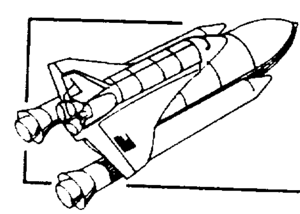


SRB BOOSTER SEPARATION MOTOR

PURPOSE: PROVIDES PROPULSIVE THRUST TO SEPARATE SRBs FROM THE ORBITER AND EXTERNAL TANK

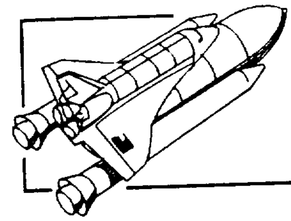
SUPPLIER: UNITED TECHNOLOGIES, CHEMICAL SYSTEMS DIV., SAN JOSE, CA.



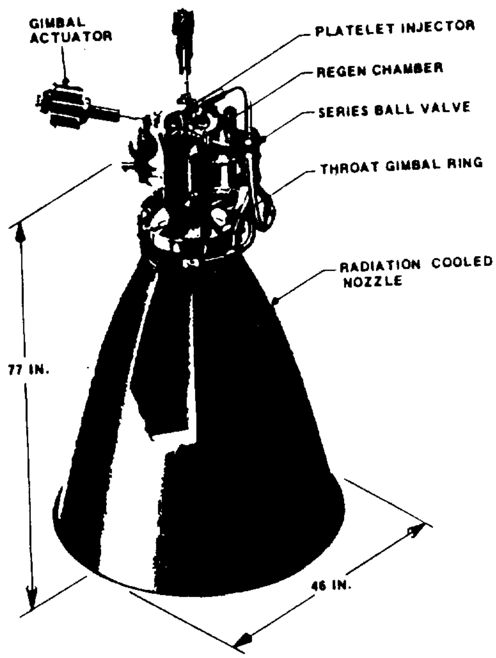


BSM DESIGN PARAMETERS

• 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

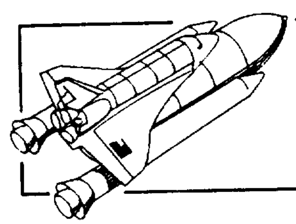


OMS ENGINE



PURPOSE: PROVIDES PROPULSIVE THRUST FOR ORBIT INSERTION, ORBIT CIRCULARIZATION, ORBIT TRANSFER, RENDEZVOUS, DEORBIT, AND LAUNCH ABORT

SUPPLIER: AEROJET PROPULSION DIVISION; SACRAMENTO, CA.



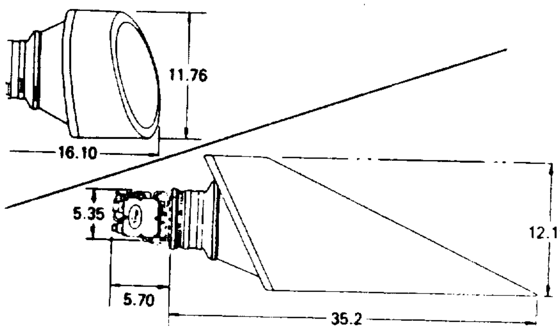
OMS ENGINE DESIGN PARAMETERS

• PROPELLANTS	MMH/N_2O_4
• 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

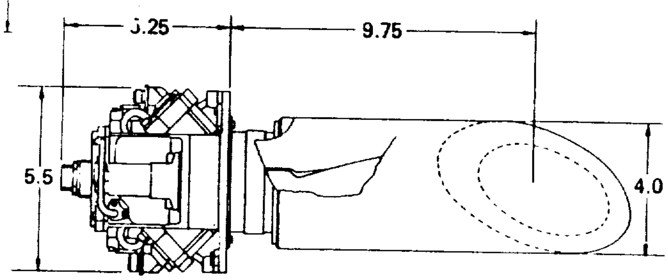
PURPOSE: PROVIDE PROPULSIVE THRUST FOR ORBIT STABILIZATION AND ORIENTATION MANEUVERS

SUPPLIER: THE MARQUARDT COMPANY, VAN NUYS, CA.



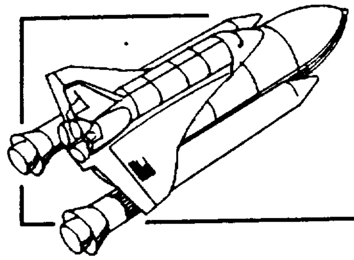
PRIMARY

VERNIER

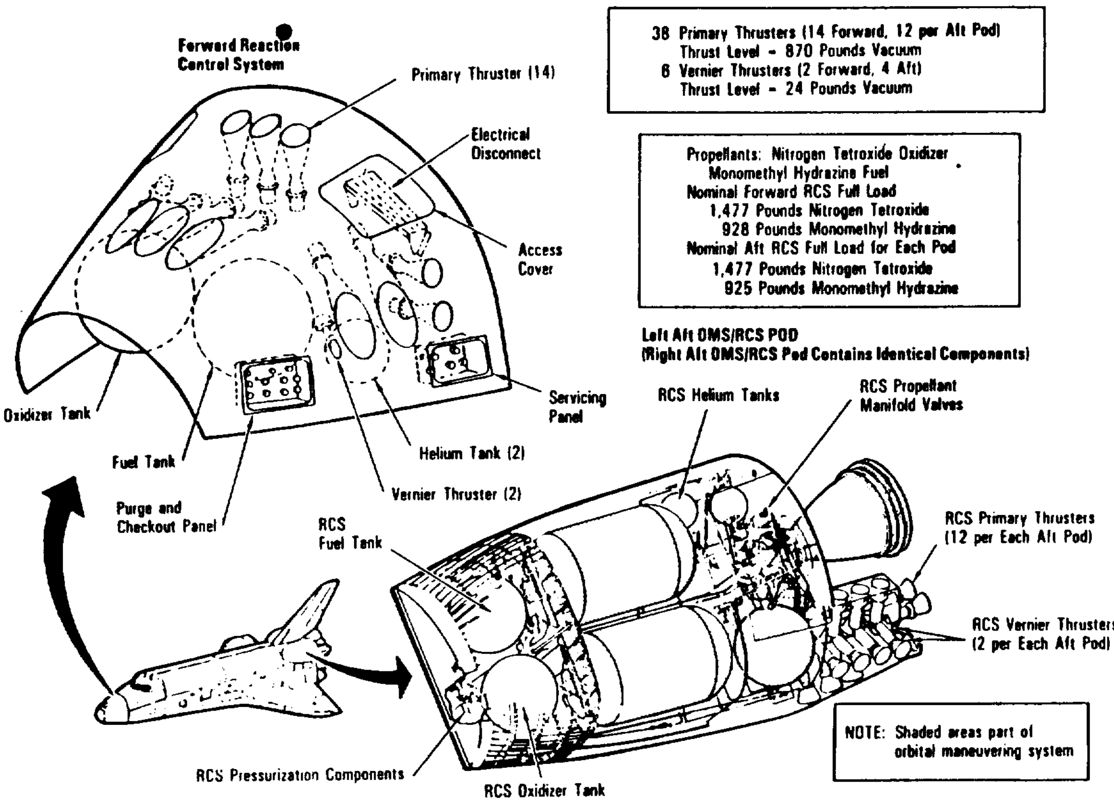


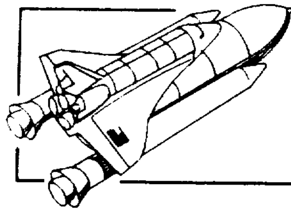
RCS PRIMARY & VERNIER THRUSTER PARAMETERS

	PRIMARY	*VERNIER*
• PROPELLANTS	MMH/N_2O_4	MMH/N_2O_4
• NOMINAL VACUUM THRUST	870 LBS	24 LBS
• CHAMBER PRESSURE	152 PSIA	110 PSIA
• MIXTURE RATIO	1.6	1.65
• SPECIFIC IMPULSE	280 SEC (22:1 AREA RATIO)	265 SEC
• INLET PRESSURE	238 PSIA	246 PSIA
• RATIO (A_e/A_t)	22:1 TO 30:1	20.7:1
• LIFE		
MISSIONS	100	CHAMBER LIMITED
CYCLES	20,000	330,000
TOTAL FIRING DURATION	12,800 SEC	125,000
• WEIGHT	16 LBS	9.4 LBS
• CONSTRUCTION	COLUMBIUM/TITANIUM	COLUMBIUM/TITANIUM



ORBITER OMS & REACTION CONTROL SYSTEM





SPACE SHUTTLE PROPULSION ISSUES

RSRM

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

SSME

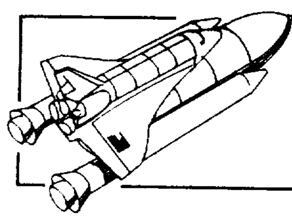
- HIGH PRESSURE TURBOPUMP BEARINGS
- HEAT EXCHANGER
- CONTROLLER OBSOLESCENCE
- UNINSPECTABLE WELDS

SRB

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

RCS THRUSTERS

- COMBUSTION INSTABILITY
- CONTAMINATION



PROPULSION SYSTEM
IMPROVEMENTS IN WORK

RSRM

- IGNITER-TO-CASE JOINT REDESIGN

SRB

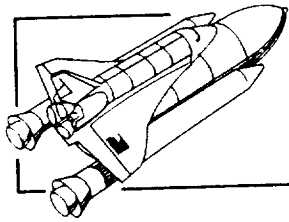
- ENHANCED MULTIPLEXER/DEMULTIPLEXER
- DEBRIS CONTAINMENT SYSTEM FRANGIBLE LINK
- MAIN PARACHUTE RIPSTOP
- HDP/AFT SKIRT BIAS

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 OBSOLESENCE, IMPLEMENTS CURRENT TECHNOLOGY

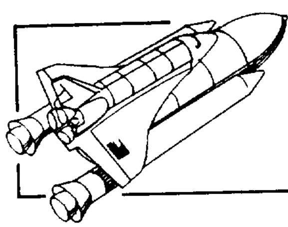
INCREASES SAFETY MARGINS

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

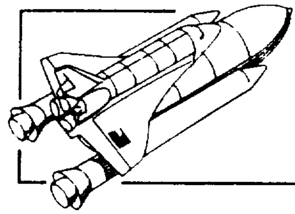
PROBLEM AREAS IDENTIFIED

CANDIDATES SUBMITTED

VIABLE CANDIDATES CATEGORIZED

FEASIBILITY STUDIES BEGUN ON SOME CANDIDATES

CANDIDATES BEING PRIORITIZED

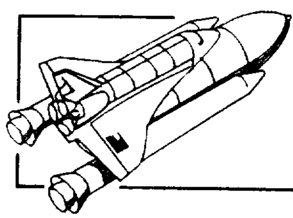


ASA PROGRAM
PRIORITIES

PROGRAM PRIORITIES ESTABLISHED

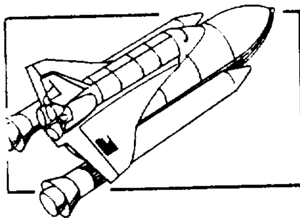
PRIMARY: ASSURANCE OF SYSTEM SUPPORTABILITY AND SAFETY MARGIN IMPROVEMENT

SECONDARY: IMPROVEMENTS IN SYSTEM RELIABILITY, ECONOMY AND PERFORMANCE



ASA PROGRAM
CANDIDATES

TITLE	PROJECT
COCKPIT DISPLAYS AND CONTROLS	ORBITER
EPD&C SUBSYSTEM REDESIGN	ORBITER
CONTROL SYSTEM REDESIGN	SRB
INTEGRATED COMMUNICATIONS	ORBITER
AFT SKIRT REDESIGN	SRB
INTEGRATED OMS/RCS	ORBITER
REDESIGNED STIFFENER RING	RSRM
IGNITER JOINT IMPROVEMENT	RSRM
INTEGRATED NAVIGATION SYSTEM	ORBITER
PROCESS CHEMICALS	SSME
LONG-LIFE FUEL CELLS	ORBITER
COMPOSITE STRUCTURES	SRB
POWERHEAD UPGRADE	SSME
ENHANCED CONTROLLER	SSME
LIGHTWEIGHT STRUCTURES	ORIBTER
INTEGRATED THERMAL CONTROL	ORBITER
FWD SEGMENT MANDREL REDESIGN	RSRM
ALUMINUM LITHIUM ALLOYS	ET
ELECTROMECHANICAL ACTUATORS	ORB/SSME



ASA PROGRAM
CATEGORIES

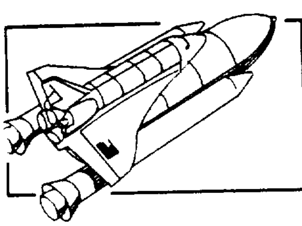
A. HIGHEST PRIORITY

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



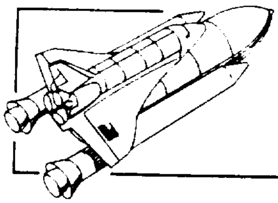
ASA PROGRAM
PROPULSION PROGRAM CANDIDATES

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 INTEGRADED 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

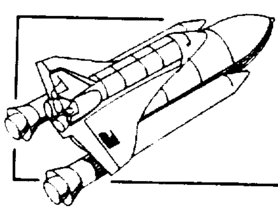
EXTERNALLY PROGRAMMABLE MICROPROCESSOR SYSTEM

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:

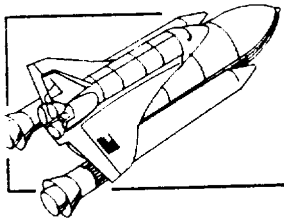
- INCREASE STRUCTURAL FACTOR OF SAFETY (1.28 TO 1.4)
- ENHANCE HOLDDOWN MECHANISM
- ADD INTEGRAL STIFFENER RINGS TO MINIMIZE WATER IMPACT DAMAGE

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

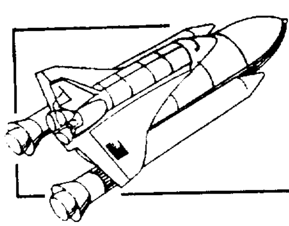
BENEFITS:

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

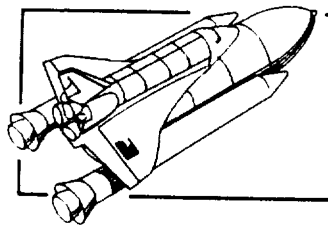
IMPROVE SAFETY MARGIN

REDUCE COST

SIMPLIFIED MISSION PLANNING

350 LB DRY WEIGHT REDUCTION

RETAIN CONTRACTOR/SUBCONTRACTOR DESIGN/PRODUCTION SKILLS



ASA PROGRAM

SUMMARY

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