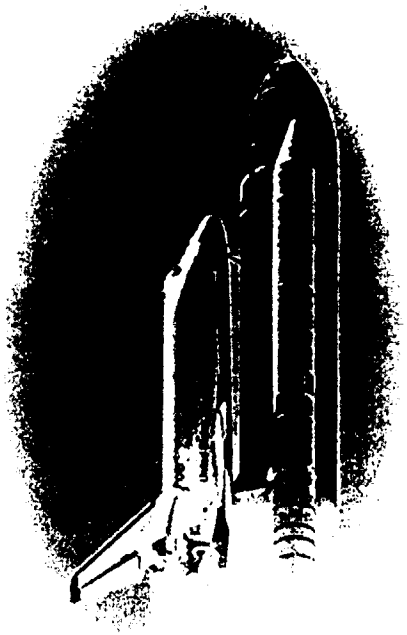
22P

Space Shuttle Projects Overview

To



Columbia Air Forces War College

Space Shuttle Projects Office
Jody Singer (256.544.0612)
August 25, 2000

Priorities

- ***Fly Safely***
- ***Meet the Manifest***
- ***Improve Mission Supportability***
- ***Improve the System***

Marshall Space Flight Center
Space Shuttle Projects Office

SPACE SHUTTLE PROJECTS OFFICE
Marshall Space Flight Center

August 2000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SSME Project


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RSRM Project


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Space Shuttle Propulsion Systems

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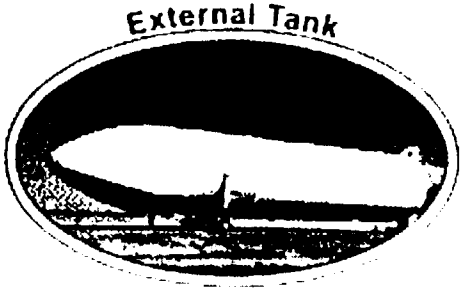
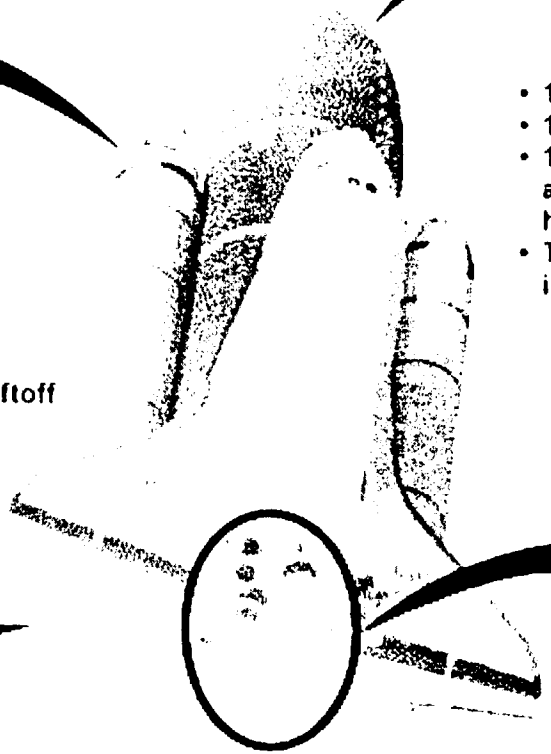
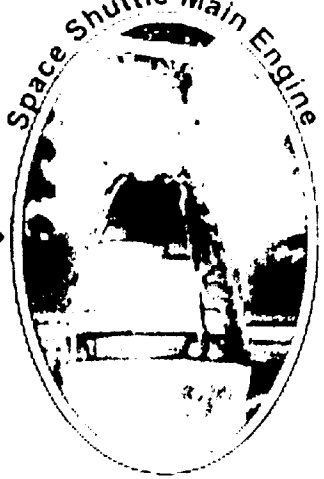
- Each is 149.1 feet high and 12.2 feet in diameter ($1/2$ football field long)
- Each produces 2,658,000 lbs of thrust at liftoff
- Largest solid rocket in the world
- Accelerate the vehicle to 3,000 mph at separation
- Booster and motor hardware recovered/ reused

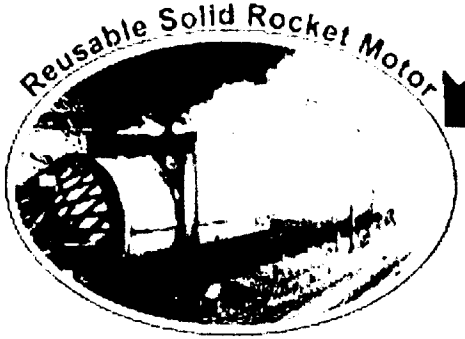


- 154 Feet long and 28.6 feet diameter
- 1,667,667 lbs at liftoff
- 140,000 gallons of liquid oxygen and 380,000 gallons of liquid hydrogen
- The only major expendable hardware in Shuttle system





- Each of 3 produces 375,000 lbs thrust at sea level
- They deliver 37 million hp (equivalent to 23 Hoover Dams)
- Reusable



Space Shuttle Program Major Sites

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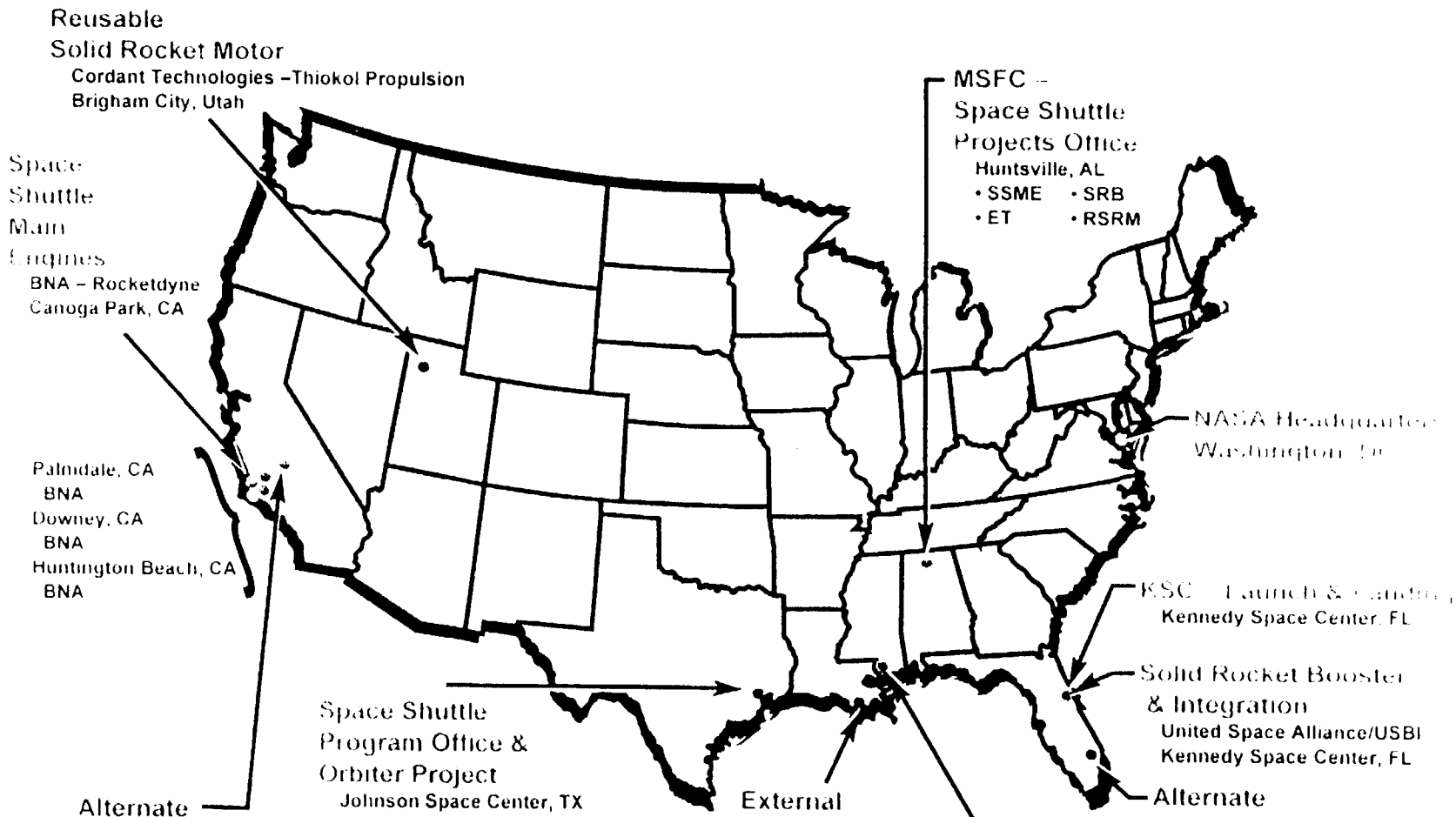

MSFC Shuttle Projects Work Force	
Civil Service	330
Contractor	6,916

NASA Office of Space Flight (OSF) Center Roles In Space Shuttle Program

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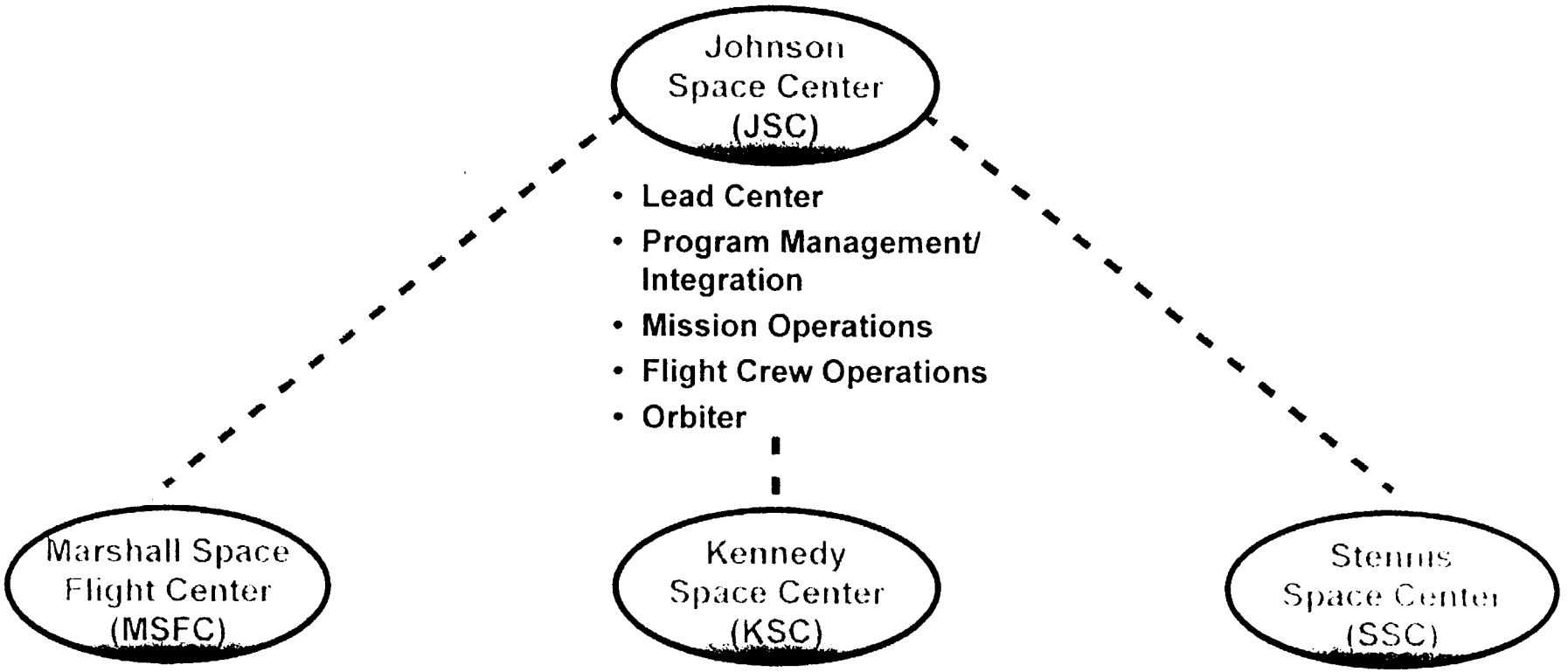

Space Shuttle Hardware Flow

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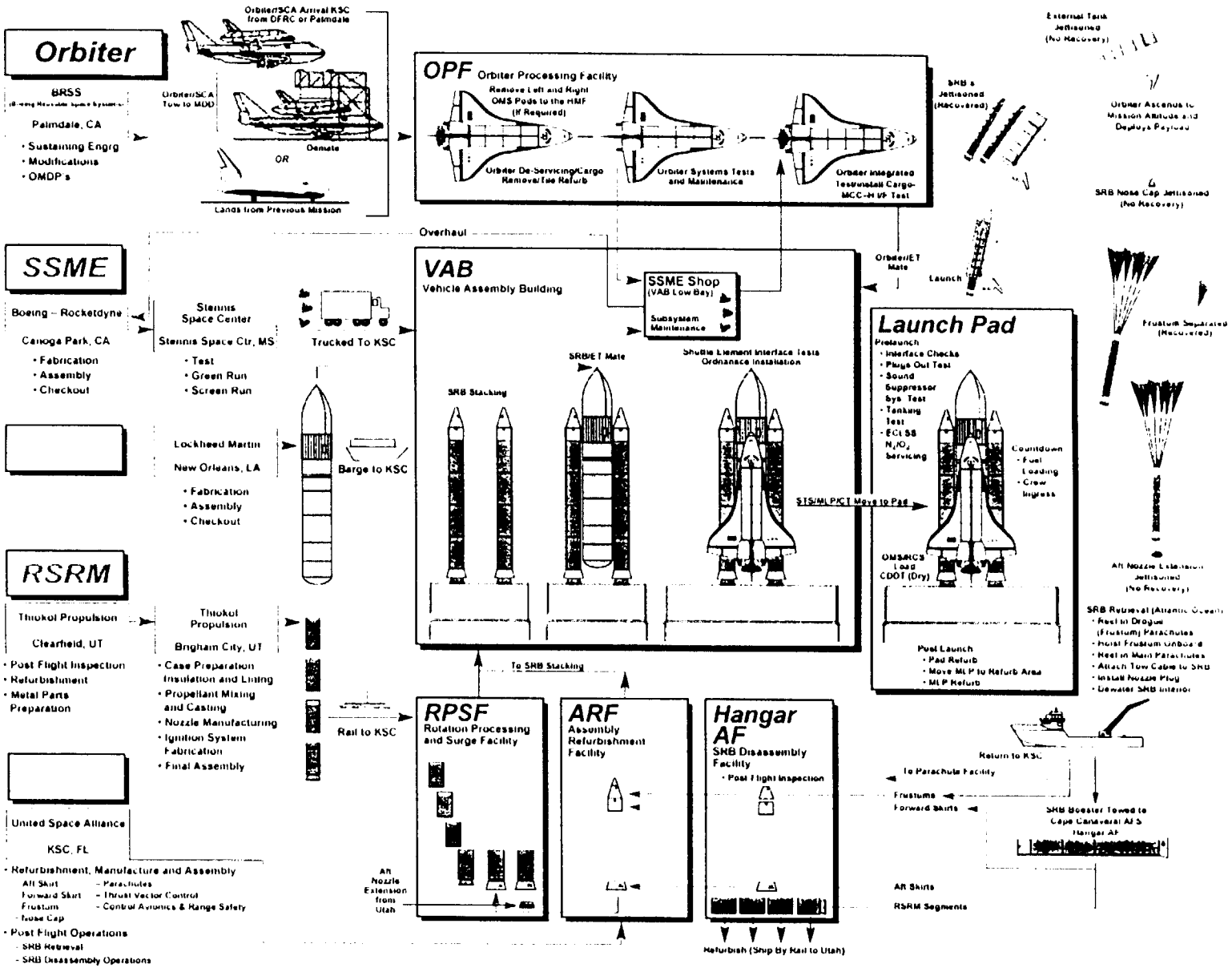

Shuttle Flights To Date

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Marshall Space Flight Center

98 Total Flights
73 Since Return To Flight

As Of: 5/30/00

Legend

Flt. No.	STS-XX No.	Launch Date — Landing Date

After 51-L
Before 51-L (Flight -25)

Number Of Flights: 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30

Challenger OV-099

Flt. No.	STS-XX No.	Launch Date — Landing Date
25	51-L	1/28/86
22	61-A	10/30/85 – 11/06/85
19	51-F	7/29/85 – 8/06/85
17	51-B	4/29/85 – 5/06/85
13	41-G	10/05/84 – 10/13/84
11	41-C	4/06/84 – 4/13/84
10	41-B	2/03/84 – 2/11/84
8	8	8/30/83 – 9/05/83
7	7	6/18/83 – 6/24/83
6	6	4/04/83 – 4/09/83

Flt. No.	STS-XX No.	Launch Date — Landing Date
95	93	7/23/99 – 7/27/99
90	90	4/17/98 – 5/03/98
88	87	11/19/97 – 12/05/97
85	94	7/01/97 – 7/17/97
83	83	4/04/97 – 4/08/97
80	80	11/19/96 – 12/07/96
78	78	6/20/96 – 7/07/96
75	75	2/22/96 – 3/09/96
72	73	10/20/95 – 11/05/95
63	65	7/08/94 – 7/23/94
61	62	3/04/94 – 3/18/94
58	58	10/18/93 – 11/01/93
55	55	4/26/93 – 5/06/93
51	52	10/22/92 – 11/01/92
48	50	6/25/92 – 7/09/92
41	40	6/05/91 – 6/14/91
38	35	12/02/90 – 12/10/90
33	32	1/09/90 – 1/20/90
30	28	8/08/89 – 8/13/89
24	61-C	1/12/86 – 1/18/86
9	41-A	11/28/83 – 12/08/83
5	5	11/11/82 – 11/16/82
4	4	6/27/82 – 7/04/82
3	3	3/22/82 – 3/30/82
2	2	11/12/81 – 11/14/81
1	1	4/12/81 – 4/14/81

Discovery OV-103

Flt. No.	STS-XX No.	Launch Date — Landing Date
96	103	12/19/99 – 12/27/99
94	96	5/27/99 – 6/06/99
92	95	10/29/98 – 11/07/98
91	91	6/02/98 – 6/12/98
86	85	8/07/97 – 8/19/97
82	82	2/11/97 – 2/21/97
70	70	7/13/95 – 7/22/95
67	63	2/03/95 – 2/11/95
64	64	9/09/94 – 9/20/94
60	60	2/03/94 – 2/11/94
57	51	9/12/93 – 9/22/93
54	56	4/08/93 – 4/17/93
52	53	12/02/92 – 12/09/92
45	42	1/22/92 – 1/30/92
43	48	9/12/91 – 9/18/91
40	39	4/28/91 – 5/06/91
36	41	10/06/90 – 10/10/90
35	31	4/24/90 – 4/29/90
32	33	11/22/89 – 11/27/89
28	29	3/13/89 – 3/18/89
26	26	9/29/88 – 10/03/88
20	51-I	8/27/85 – 9/03/85
18	51-G	6/17/85 – 6/24/85
16	51-D	4/12/85 – 4/19/85
15	51-C	1/24/85 – 1/27/85
14	51-A	11/07/84 – 11/15/84
12	41-D	8/30/84 – 9/04/84

Atlantis OV-104

Flt. No.	STS-XX No.	Launch Date — Landing Date
98	101	5/19/00 – 5/29/00
87	86	9/25/97 – 10/06/97
84	84	5/15/97 – 5/24/97
81	81	1/12/97 – 1/22/97
79	79	9/16/96 – 9/26/96
76	76	3/22/96 – 3/31/96
73	74	11/12/95 – 11/20/95
69	71	6/27/95 – 7/07/95
66	66	11/03/94 – 11/14/94
49	46	7/31/92 – 8/08/92
46	45	3/24/92 – 4/02/92
44	44	11/24/91 – 12/02/91
42	43	8/02/91 – 8/11/91
39	37	4/05/91 – 4/11/91
37	38	11/15/90 – 11/20/90
34	36	2/28/90 – 3/04/90
31	34	10/18/89 – 10/23/89
29	30	5/04/89 – 5/08/89
27	27	12/02/88 – 12/06/88
23	61-B	11/26/85 – 12/03/85
21	51-J	10/03/85 – 10/07/85

Flt. No.	STS-XX No.	Launch Date — Landing Date
97	99	2/11/00 – 2/22/00
93	88	12/04/98 – 12/15/98
89	89	1/22/98 – 1/31/98
77	77	5/19/96 – 5/29/96
74	72	1/11/96 – 1/20/96
71	69	9/07/95 – 9/18/95
68	67	3/02/95 – 3/18/95
65	68	9/30/94 – 10/11/94
62	59	4/09/94 – 4/20/94
59	61	12/02/93 – 12/13/93
56	57	6/21/93 – 7/01/93
53	54	1/13/93 – 1/19/93
50	47	9/12/92 – 9/20/92
47	49	5/07/92 – 5/16/92

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MSFC Shuttle Projects Proposed Safety "Upgrades"

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Space Shuttle Main Engine

- Extra Large Throat Main Combustion Chamber
- Robust Nozzle
- Fuel Flowmeter
- Advanced Health Monitoring System

External Tank

- Friction Stir Welding
- Friction Plug Weld Repair
- Aluminum Domes and Thrust Panels
- Circumferential Welds
- Eliminate Cable Trays

Reusable Solid Rocket Motor

- Nozzle Joint Enhancements
- Propellant Geometry
- Day-of-Launch Predictions
- Ignition System Redesign

Solid Rocket Booster

- Advanced Thrust Vector Control
- Advanced Avionics
- Attach/Holddown Hardware
- Next Generation Thermal Protection System

Space Shuttle Development Strategy

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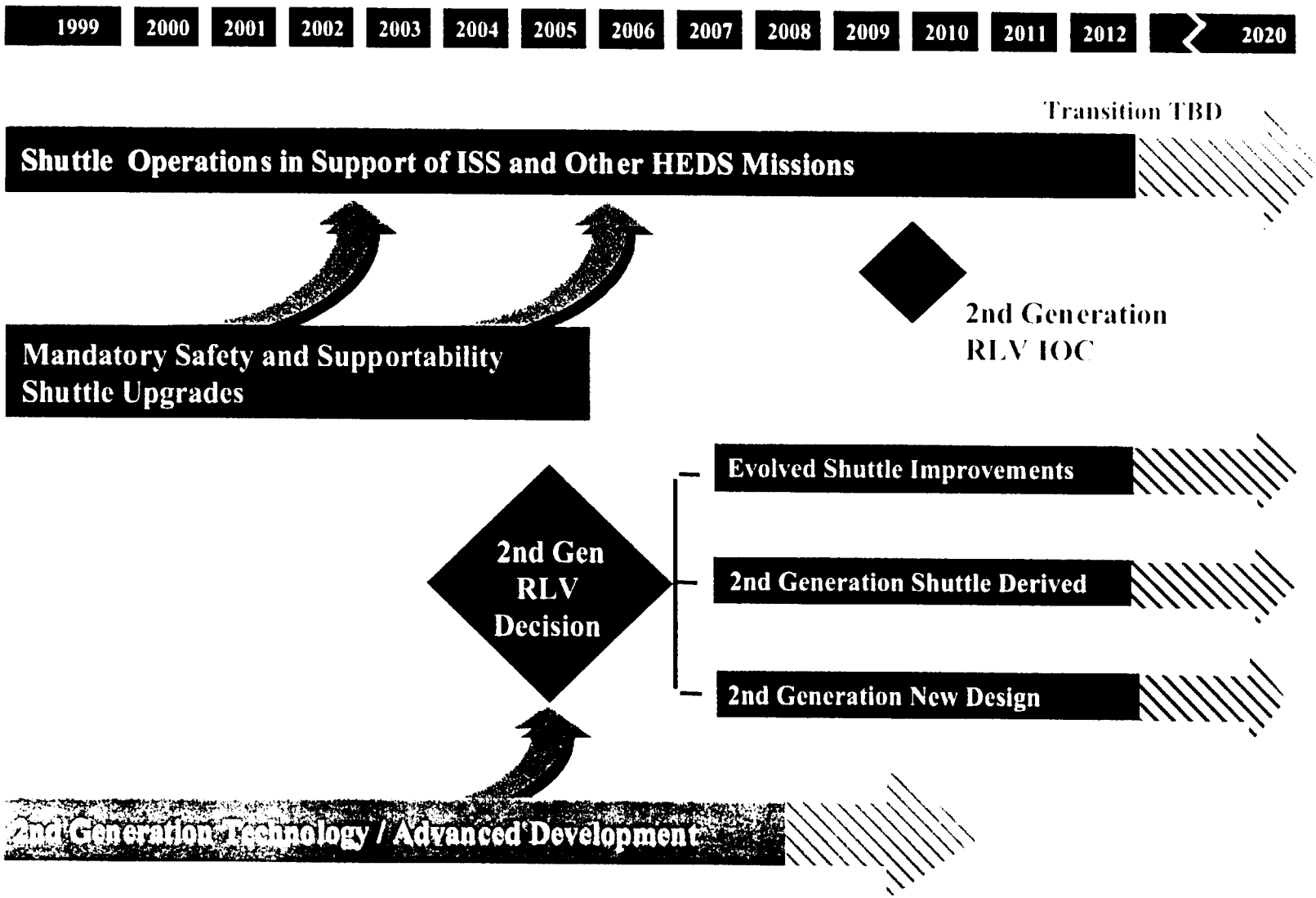
Marshall Space Flight Center



Space Shuttle Propulsion Elements Flight Support Technology/Expertise

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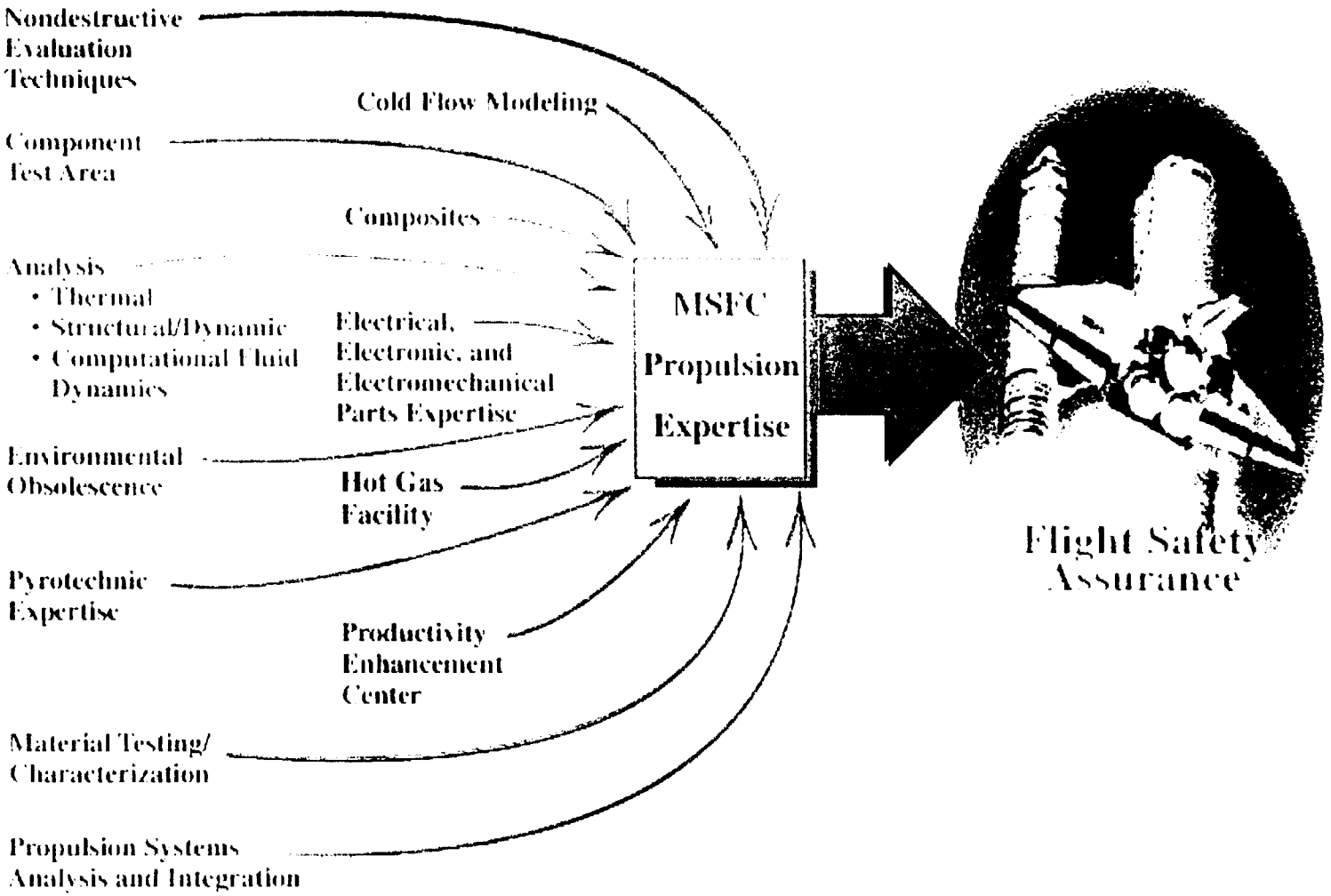
Marshall Space Flight Center

How MSFC Capabilities Support Safe Launch Decisions!

☆ Testing ☆ Analysis ☆ Assembly Simulations



Space Shuttle Program

SPACE SHUTTLE PROJECTS OFFICE
Marshall Space Flight Center

- 98 Successful Missions (June 2000)
- National Asset
  - Only reusable human-rated space vehicle
  - Capable of payload delivery and retrieval
  - Serves as a scientific and technology space platform
  - Supports other program (e.g., *International Space Station (ISS)*)
- Shuttle Capability:
  - Maximum Liftoff Weight: 4.5 million pounds
  - Payload Capability: 47,000 pounds
  - Payload Return to Earth Capability: 32,000 pounds
- Accomplishments:
  - Reduced Shuttle operating cost
  - Flown over 406 million miles
  - Deployed over 607 payloads / 10,400 tons of payload
  - Retrieved over 22 tons of payload
  - Deployed over 57 satellites
  - 571 crew members flown with 12 countries represented

MSFC
Space Shuttle Propulsion Elements

SPACE SHUTTLE
PROJECTS OFFICE
Marshall Space Flight Center

- MSFC assigned Shuttle propulsion elements are a major part of the Shuttle Program

- MSFC propulsion expertise, both in engineering and facilities/equipment capabilities, is critical to maintaining the Space Shuttle transportation system's highest priority – *FLIGHT SAFETY*

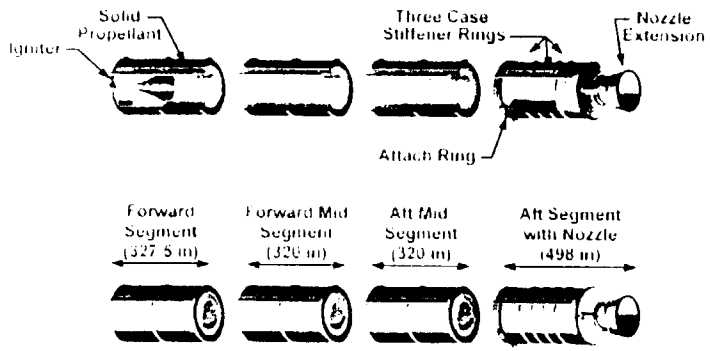
- Shuttle propulsion elements continue to evaluate and implement upgrades to make the hardware safer, more reliable, easier to manufacture and with increased mission/schedule flexibility

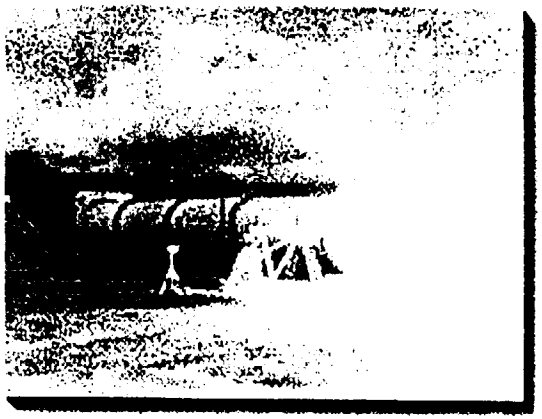
- Shuttle propulsion elements have demonstrated significantly measurable improvement over Program's history in:
  - Safety
  - Reliability
  - Workforce and cost efficiency

- Shuttle system is a proven workhorse that will continue to support the nation's Human Space Flight endeavor into the foreseeable future

Backup

Reusable Solid Rocket Motor (RSRM)





Manufactured by:

Alcoa Industrial Components

Thiokol Propulsion

Promontory, UT

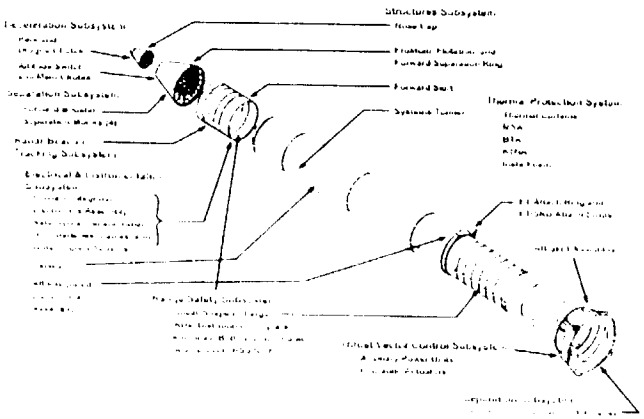
Technical Data

Rocket Type:	• Solid Propellant, controllable nozzle • Manufactured in four segments, stacked at KSC in the Vertical Assembly Building (VAB) • Reusable
Thrust:	2,658,000 lbs (sea level) 3,300,000 lbs (vacuum)
Chamber Pressure:	920 psia (at ignition)
Combustion Gas Temp:	6,000 °F
Burn Time:	123.4 Seconds
Weight:	1,255,997 lbs each
Dimensions:	• 126 Feet in length (without forward skirt and nose cap booster hardware attached) • 12.2 Feet in diameter
Transportation:	Segments delivered and returned Utah to KSC via rail car

Interesting Facts

- RSRM's produce 80% of thrust for each Shuttle launch.
- Largest operational solid rocket motor in the world.
- Only human-rated solid rocket motor.
- *Each* RSRM equivalent output during flight is 16,400,000 hp or about 51,300 Corvettes.
- RSRM's produce more thrust than thirty-two 747 jets at takeoff power.
- If you could harness the heat of two RSRM's during their two minutes of burn time you would have 2,200,000 kilowatt hours of power, enough to power 87,000 homes for a full day.
- RSRM combustion gas temperature is approaching 6,000 °F, approximately two-thirds the temperature at the sun's surface. At this temperature steel does not melt, it boils.

Solid Rocket Booster (SRB)



Manufactured/ Assembled by:

United Space Alliance (USA) / USBI Co.

Kennedy Space Center, FL

Technical Data

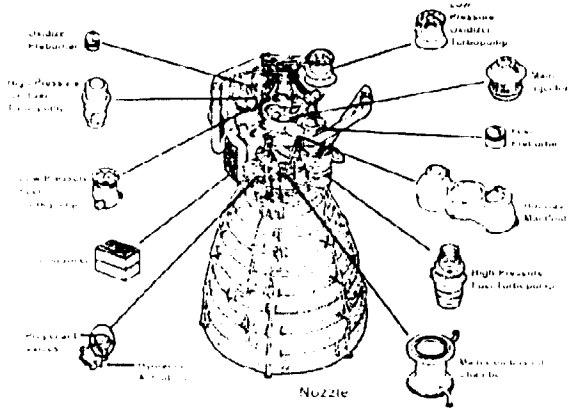
Booster Component/Functions:

- Forward skirt, forward assembly frustum, and nose cap assemblies house parachute recovery system and supporting electronics for separation, deceleration, and recovery
  - Forward skirt contains attach fitting for transfer of SRB thrust loads to ET
- Aft Assembly
  - Aft skirt provides attachment to mobile launch pad holddown posts
  - Houses thrust vector control system which provides flight control of the RSRM nozzles
    - Each aft skirt houses two auxiliary power units (APU's), two hydrazine fuel systems, two hydraulic power units (HPU's), two precision actuators and associated tubing/hoses
- SRB/ET attach ring strut assembly reacts ET and orbiter loads into the SRB allowing expansion and contraction
- Systems tunnel extends from forward skirt to aft skirt on outside of each SRB. It contains electrical cables and the linear shaped charge of the range safety system.
- Booster Separation Motors (BSM's) are located four each on forward skirt and aft skirt to separate boosters from the ET at L+ 125 seconds

Interesting Facts

- SRB is the *only* solid rocket system ever to be qualified for Human Space Flight.
- SRB is the *only* solid rocket in the world which is launched, recovered, refurbished, and reused time after time.
- Assembled boosters are 149.1 feet high, about 2 feet shorter than the Statue of Liberty, yet they weigh three times as much (~ 700 tons, each).
- Boosters separate at altitude of 140,000 feet and continue their trajectory to their apogee of 220,000 feet; an additional altitude climb of approximately 15 miles after burnout and separation (inertial energy).
- Impact velocity at splashdown with full parachute deployment is 60 mph.
- An SRB is over three times heavier than the next heaviest object ever lowered to the surface of the planet by parachute.

Space Shuttle Main Engine (SSME)



Manufactured by:

Boeing North American
Rocketdyne Propulsion & Power
Canoga Park, CA

Technical Data

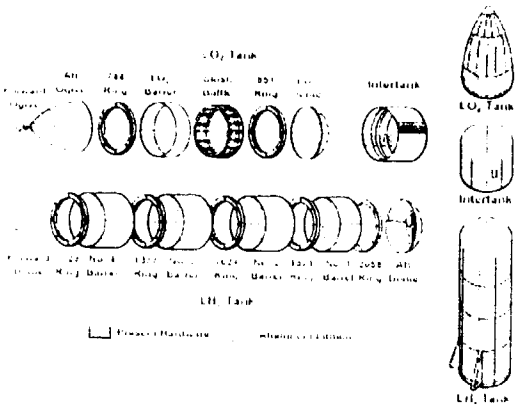
(Block I Configuration @104%)

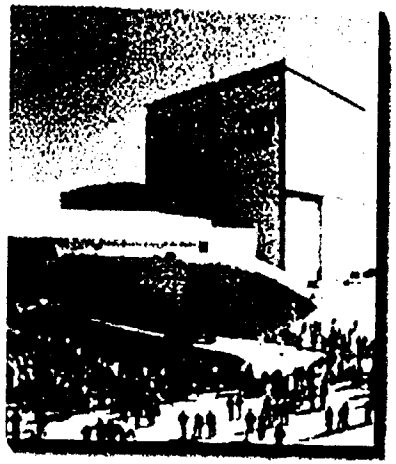
Engine Type:	Staged Combustion Cycle, Reusable
Propellants:	Liquid Hydrogen, Liquid Oxygen
Throttle Range:	67% to 109%
Ignition to Main Engine Cutoff:	Approximately 8.5 Minutes
Pressures:	H_2 Pump Discharge 6,240 psia O_2 Pump Discharge 7,290 psia Chamber Pressure 3,140 psia
Thrust:	395,700 lbs each (sea level) 490,000 lbs each (vacuum)
Power:	High Pressure Turbopumps H_2: 64,800 hp O_2: 24,400 hp
Weight:	7,380 lbs
Dimensions:	168 inches long 96 inches wide

Interesting Facts

- Combined output of 37 million hp; energy equivalent of 23 Hoover Dams.
- Combined pumping capability of all turbopumps could drain an average family-sized swimming pool in 25 seconds.
- High Pressure Fuel Turbopump (HPFTP) weighs no more than a standard V–8 engine, yet it develops 200 times more hp, as much as 28 diesel locomotives.
- HPFTP Shaft rotation = 37,000 rpm; a V–8 engine at 60 mph is around 3,000 rpm (1.8 million perfect revolutions/flight)
- One Space Shuttle Main Engine could power two and a half 747 airliners.

External Tank (ET)





Manufactured by:

Lockheed Martin Space Systems Company (LMSSC)

Michoud Assembly Facility (GOCO Facility)

New Orleans, LA

Technical Data

External Tank Components/ Functions:

- Liquid oxygen tank
- Liquid hydrogen tank
- Intertank

Structural backbone of the assembled vehicle:

- Expendable structure which delivers propellants to main engines
- Welded structure of aluminum and aluminum-lithium alloy
  - Manufactured in varied configuration; weight requirements

Tank Capacities: Liquid hydrogen 380,000 gallons
Liquid oxygen 140,000 gallons

Weight: 1,667,667 lbs (at liftoff)

Dimensions: 152.8 Feet in length
27.5 Feet in diameter

Interesting Facts

- Only major Shuttle component expended on each launch (separation L+8:42).
- Contains 36,000 inches of weld (> $^1/_2$ mile).
- Michoud Assembly Facility houses ET fabrication operations under one roof, 43 acres.
- Must meet *extreme* performance requirements for:
  - Structural; orbiter, boosters, external tank with propellants total weight of approximately 4,484,000 lbs (2,242 tons)
  - Thermal; contains cryogenic temperature propellants
    - Liquid hydrogen –423 °F
    - Liquid oxygen –300 °F
  - Aerodynamics; withstands dynamic effect of pressure and temperature associated with 17,500 mph velocity

Reusable Solid Rocket Motor

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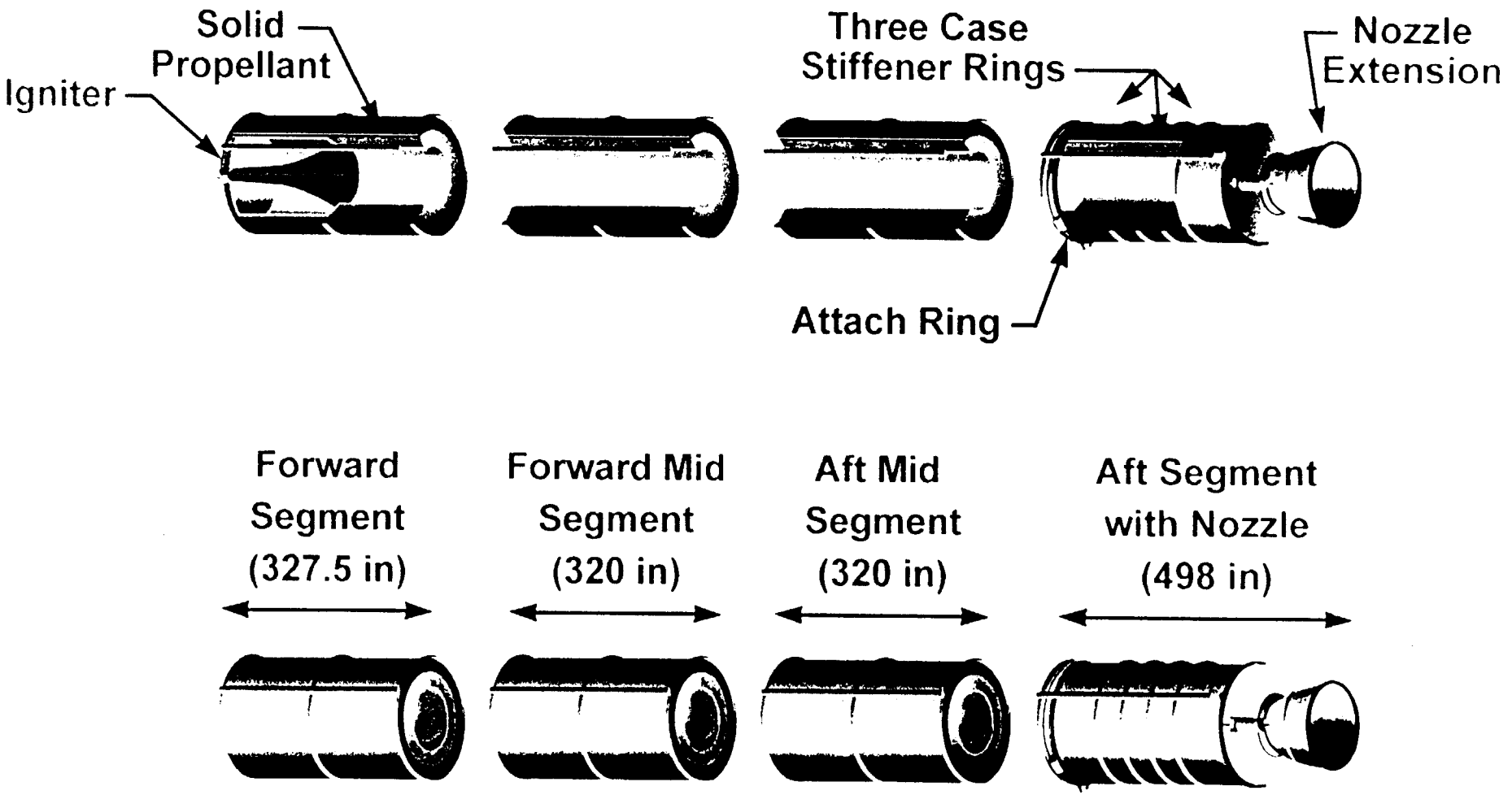

Solid Rocket Booster

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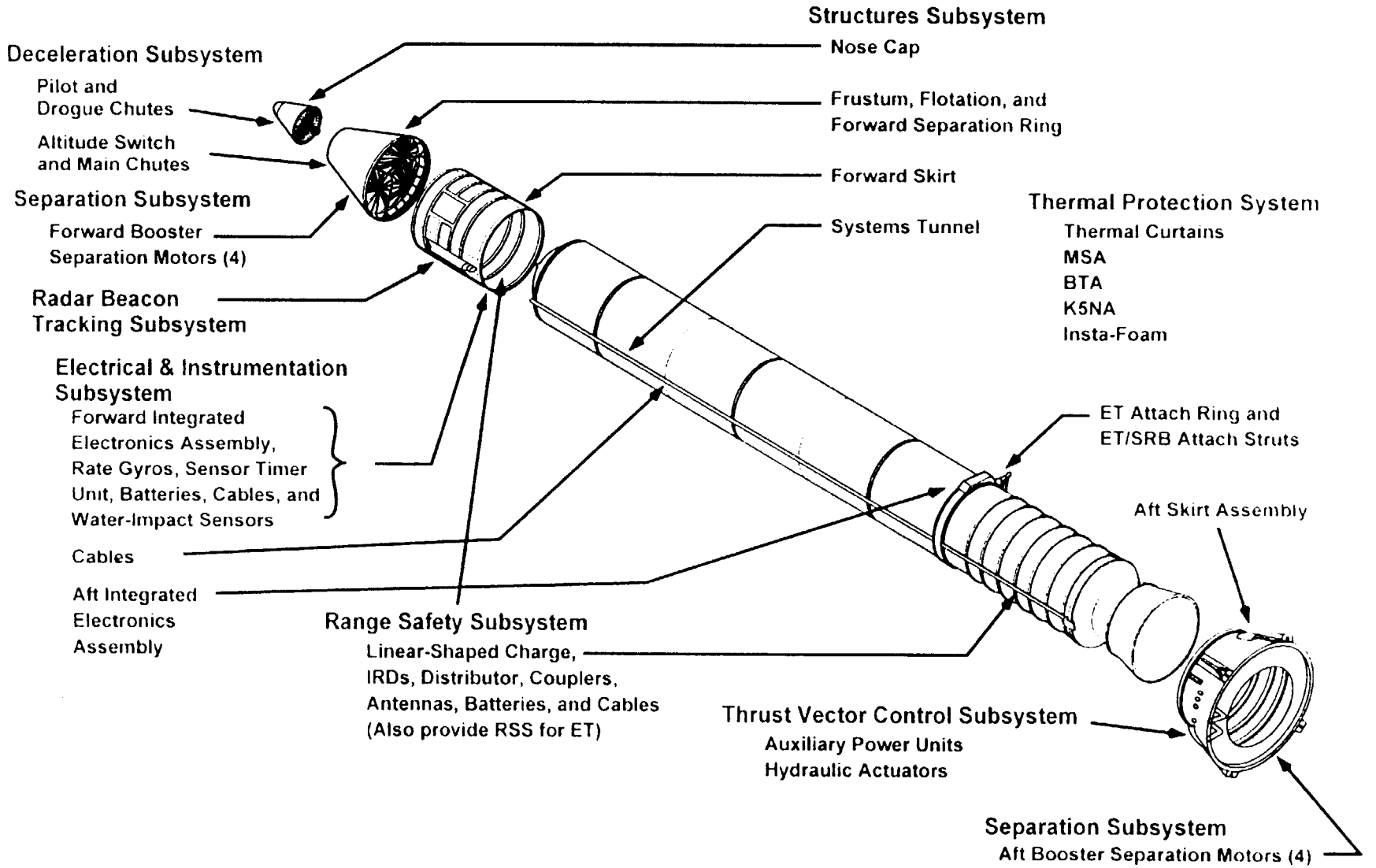

Space Shuttle Main Engine

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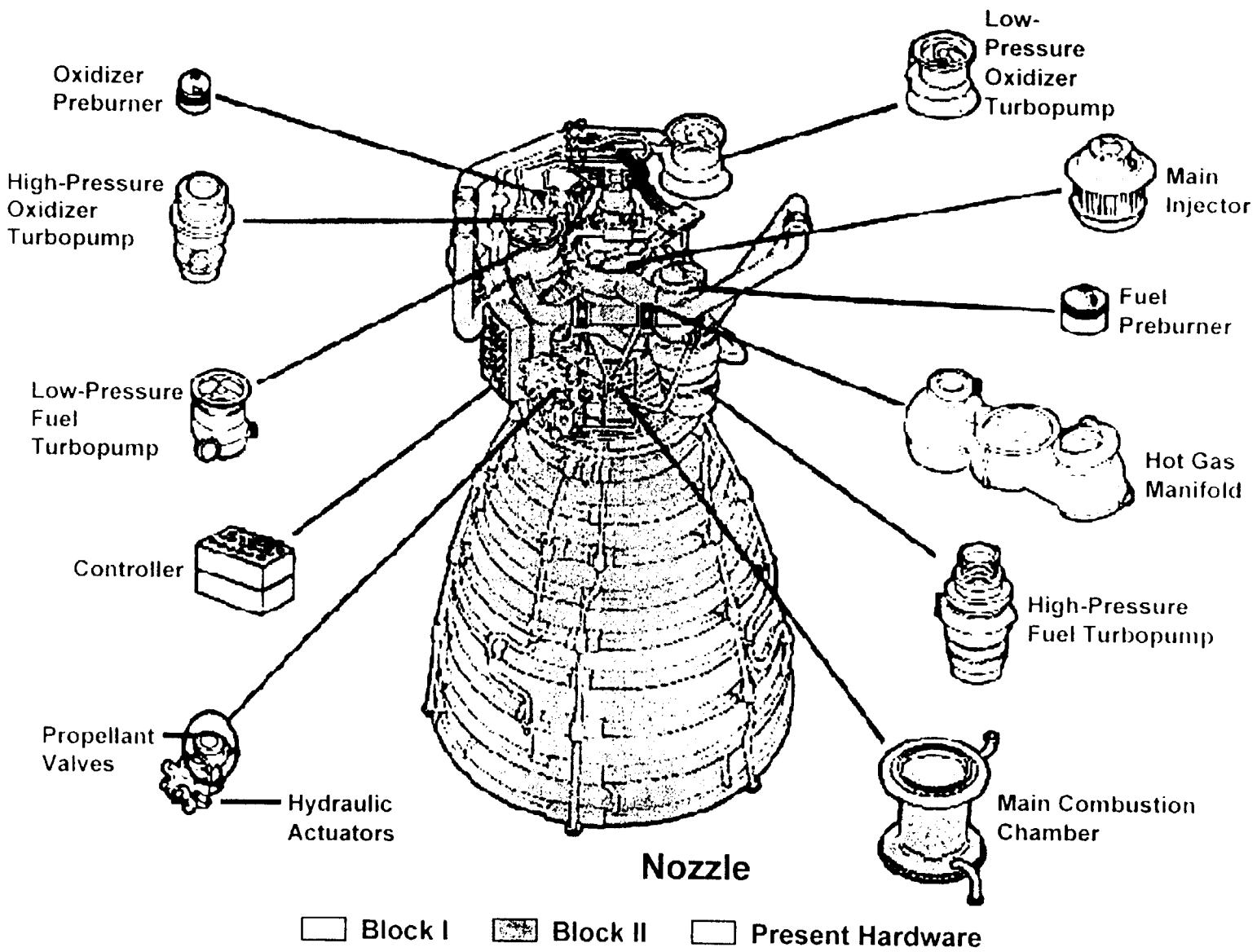

External Tank

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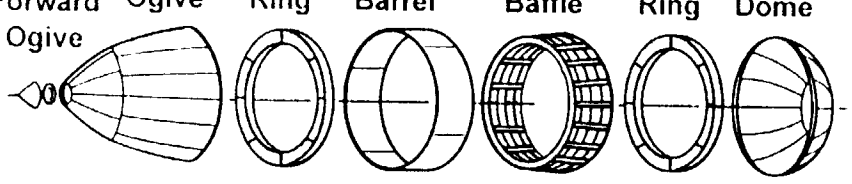
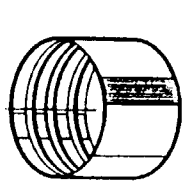
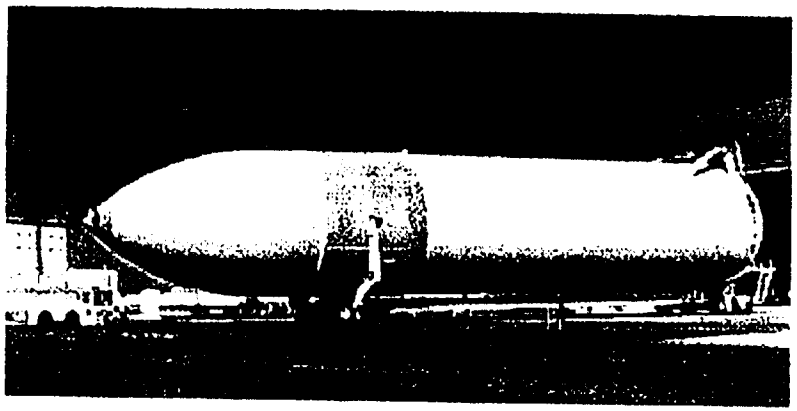
LO_2 Tank

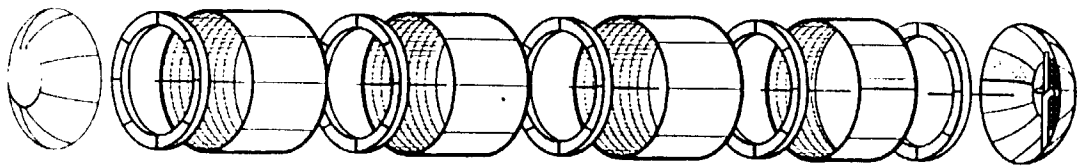
Forward Ogive | Aft Ogive | 744 Ring | LO_2 Barrel | Slosh Baffle | 851 Ring | LO_2 Dome



Intertank

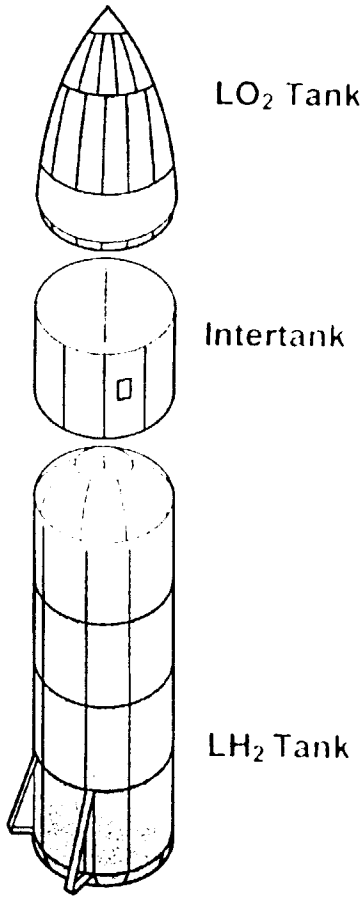






Forward Dome | 1129 Ring | No. 4 Barrel | 1377 Ring | No. 3 Barrel | 1624 Ring | No. 2 Barrel | 1871 Ring | No. 1 Barrel | 2058 Ring | Aft Dome

LH_2 Tank



Present Hardware Aluminum Lithium