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A History of Solid Propulsion at the Marshall Space Flight Center

34th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit
July 13-15, 1998
Cleveland Convention Center
Cleveland, Ohio

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Marshall Space Flight Center

Propulsion Laboratory

A HISTORY OF SOLID PROPULSION AT THE MARSHALL SPACE FLIGHT CENTER JULY 15, 1998

LAUNCH VEHICLES

- SATURN VEHICLES
  - SATURN I, BLOCK I VEHICLE
    - H-1 ENG. SOLID PROPELLANT GAS GEN. (8)
    - S-1 STAGE RETRO (4)
  - SATURN I, BLOCK II VEHICLE
    - H-1 ENG. SOLID PROPELLANT GAS GEN. (8)
    - S-1 STAGE RETRO (4)
    - S-IV STAGE ULLAGE (4)
  - SATURN IB VEHICLE
    - H-1 ENG. SOLID PROPELLANT GAS GEN. (8)
    - S-1B STAGE RETRO (4)
    - S-IVB STAGE ULLAGE (3)
  - SATURN V VEHICLE
    - S-1C RETRO (8)
    - S-II ULLAGE (4)
    - S-II RETRO (4)
    - S-IVB ULLAGE (2)
- SPACE SHUTTLE
  - SOLID ROCKET MOTOR (SRM), THEN HIGH PERFORMANCE MOTOR (HPM), THEN REDESIGNED SRM (RSRM), THEN THEN REUSABLE SRM (RSRM) (2)
  - BOOSTER SEPARATION MOTOR (8)

ORBITAL TRANSFER VEHICLES

- INTERIM UPPER STAGE, THEN INERTIAL UPPER STG.
  - SRM-1
  - SRM-2
- PAYLOAD ASSIST MODULES
  - PAM D (DELTA CLASS PAYLOADS)
  - PAM A (ATLAS CLASS PAYLOADS)
  - PAM DII

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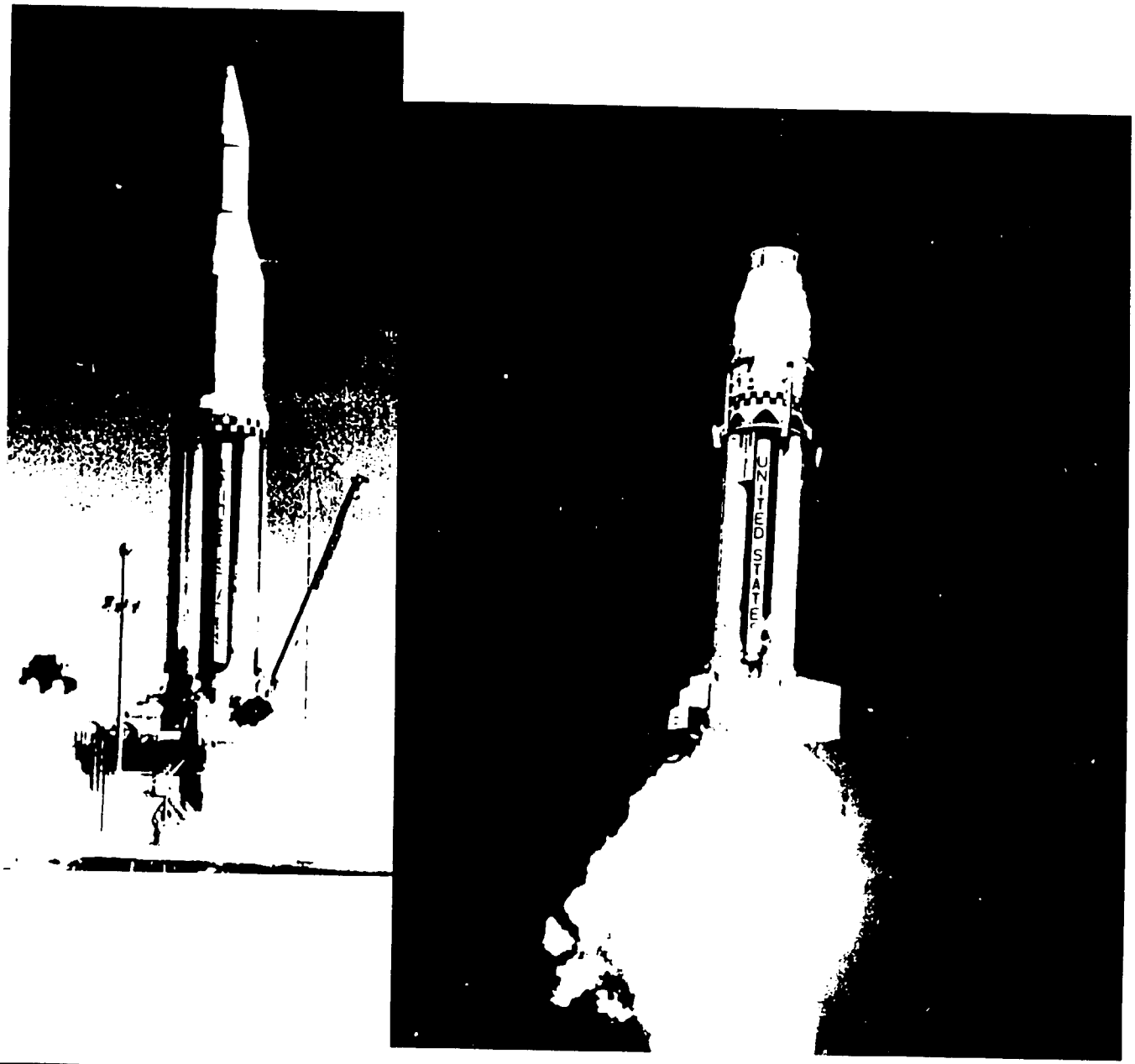

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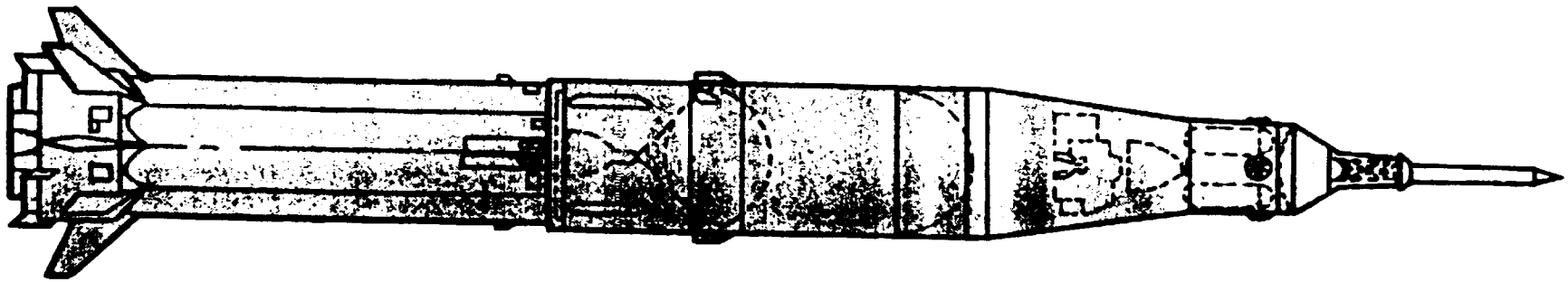

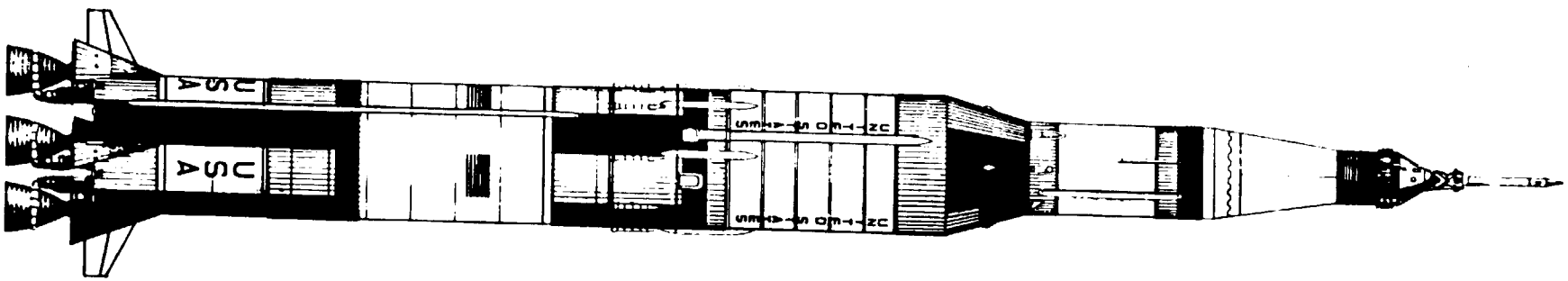

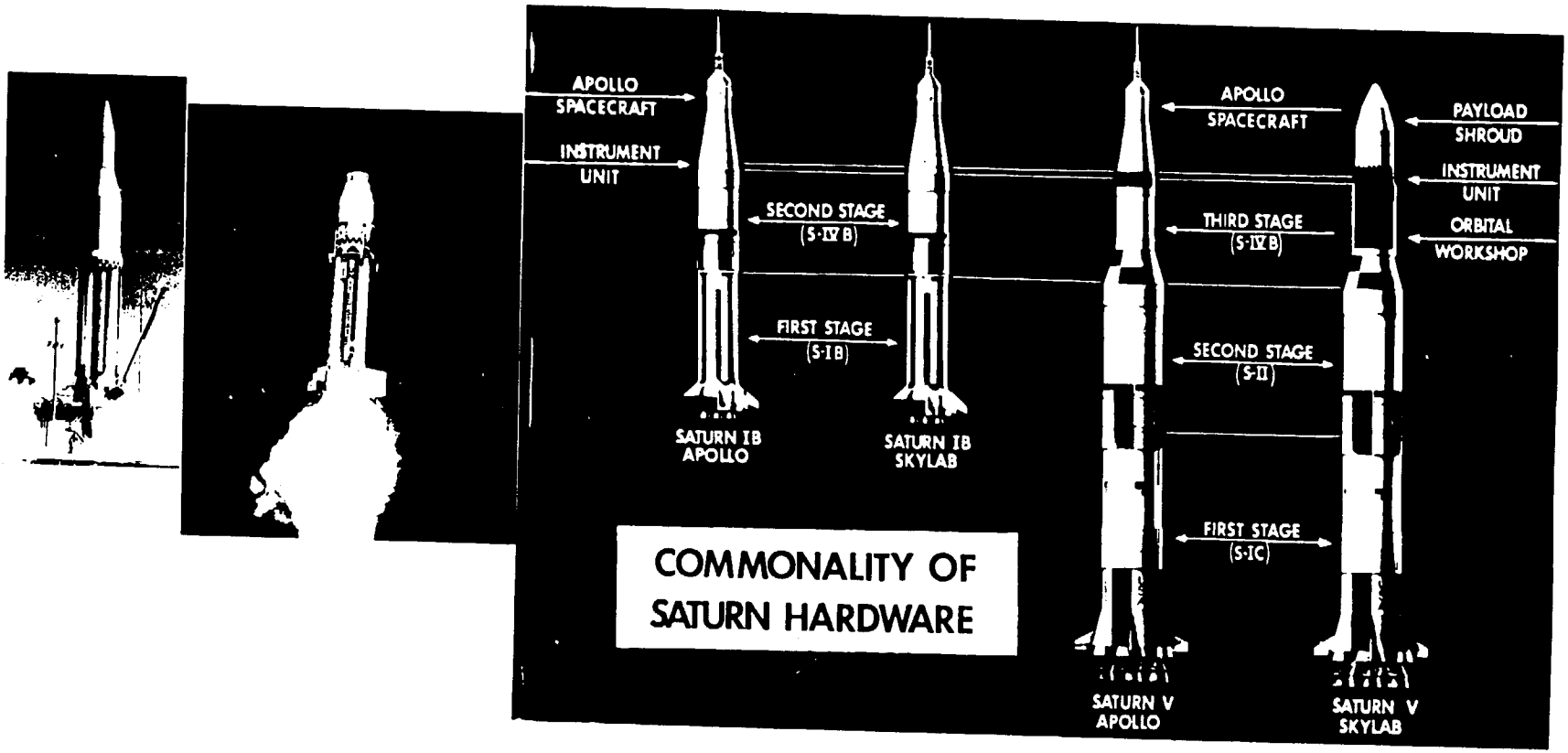
APOLLO SPACECRAFT
INSTRUMENT UNIT
SECOND STAGE (S-IV B)
FIRST STAGE (S-I B)
SATURN IB APOLLO
SATURN IB SKYLAB
COMMONALITY OF SATURN HARDWARE
APOLLO SPACECRAFT
PAYLOAD SHROUD
INSTRUMENT UNIT
THIRD STAGE (S-IV B)
ORBITAL WORKSHOP
SECOND STAGE (S-II)
FIRST STAGE (S-IC)
SATURN V APOLLO
SATURN V SKYLAB

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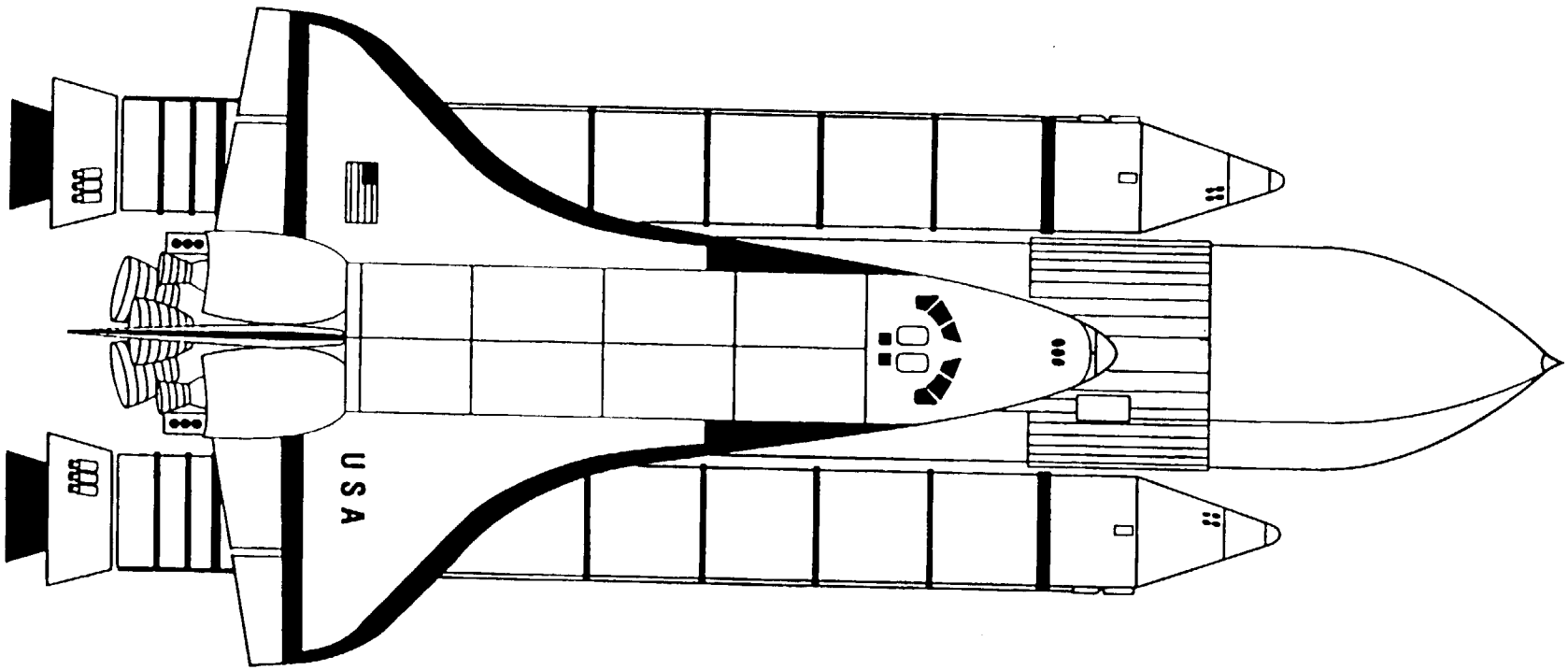

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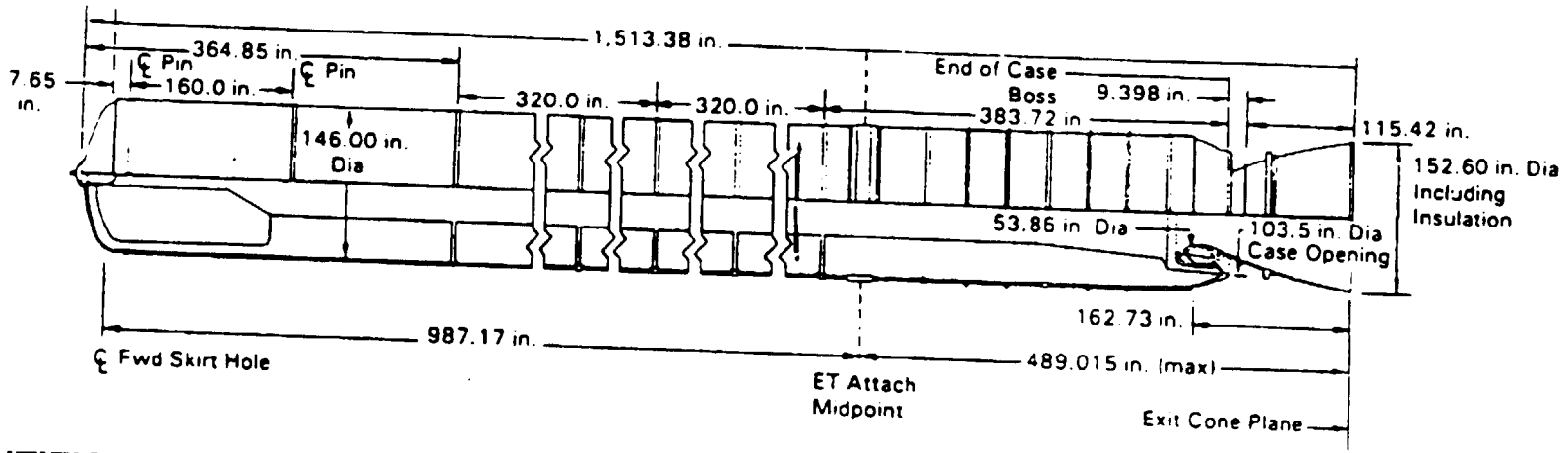
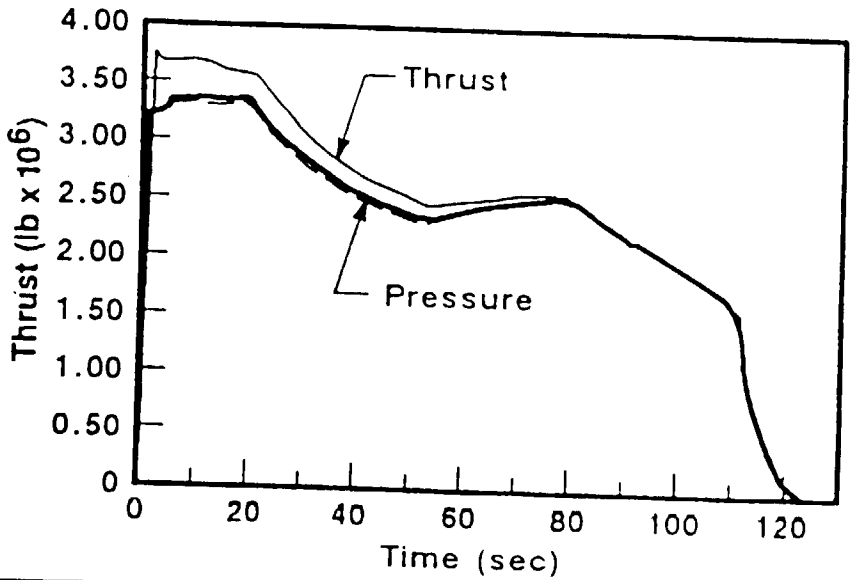
JULY 15, 1998



IDENTIFICATION

NAME	REUSABLE SRM
MFR	THIOKOL
USE	SPACE SHUTTLE BOOSTER
	MOTORS/VEHICLE 2



PERFORMANCE, NOMINAL, VACUUM

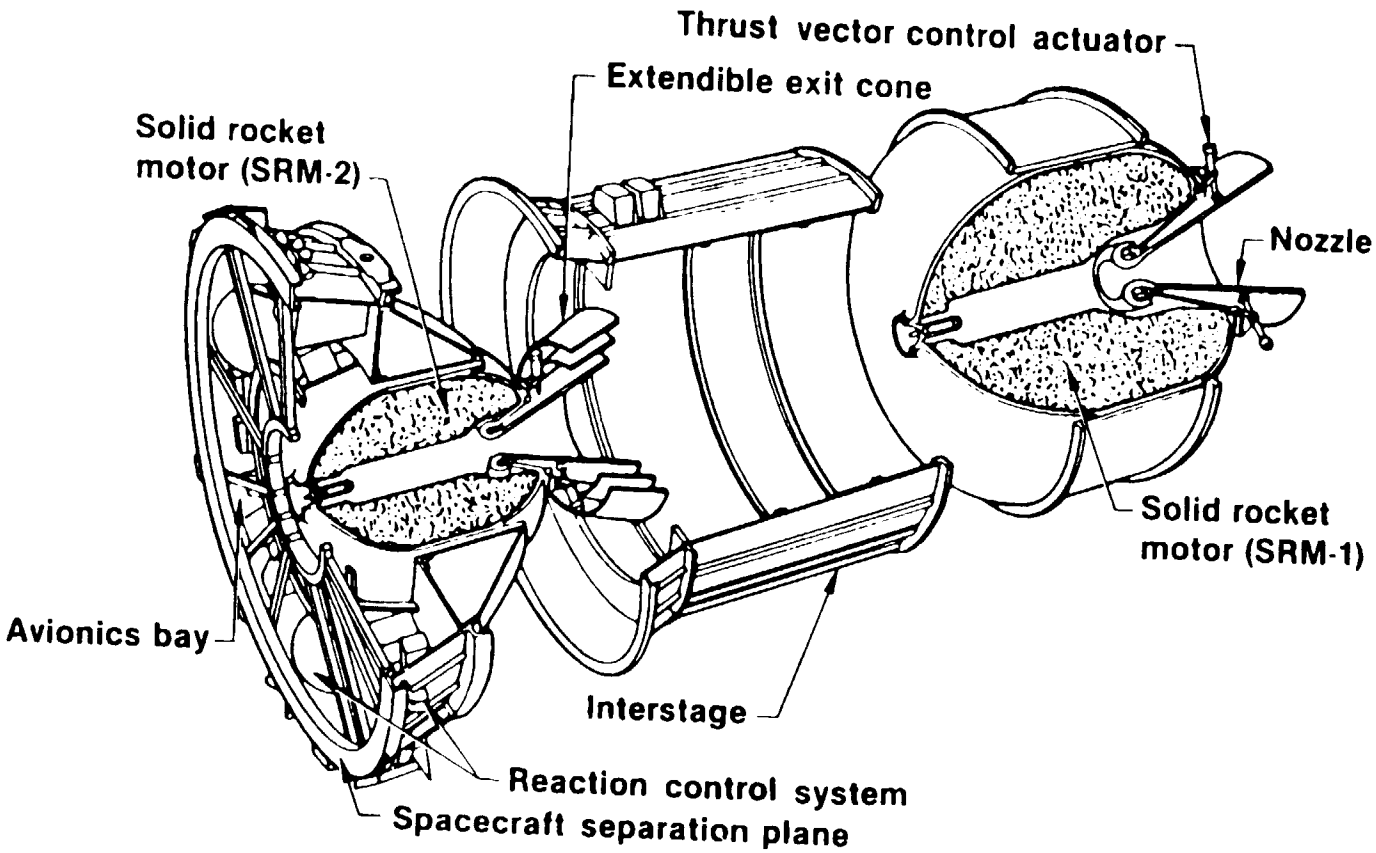
F MAX,LBF	3,320,000
FAVG, LBF	2,590,000
PMAX, PSIA	910
PAVG, PSIA	662
WEB TIME, SEC	111.6
BURN RATE, IN/SEC	0.43

PROGRAM MILESTONES

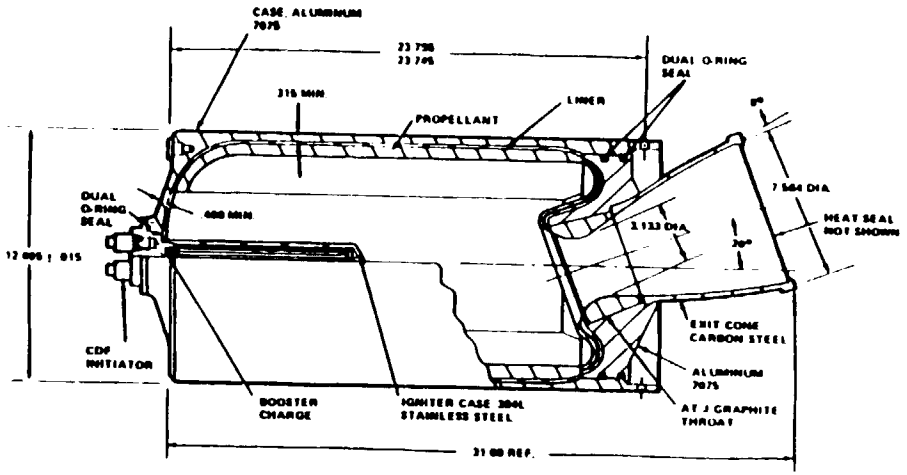
DEV COMPLETE	MARCH, 1979
QUAL COMPLETE	FEBRUARY, 1980

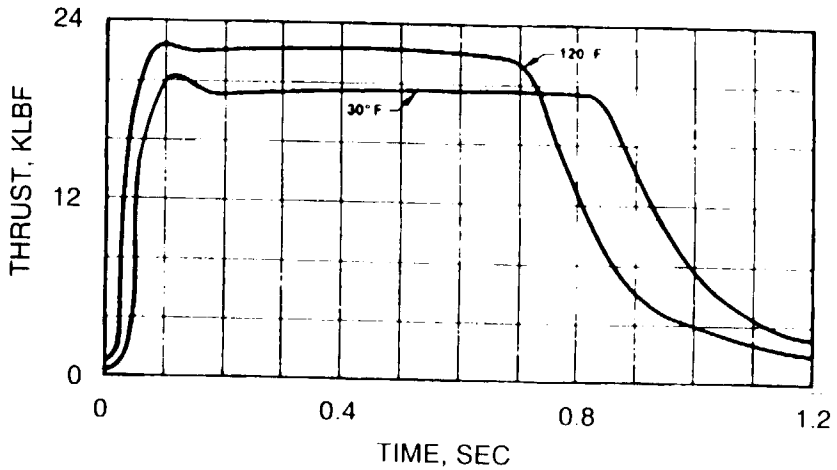
WEIGHTS, LBM

IGNITER	485
CASE	98,750
INSULATION	20,532
NOZZLE	23,922
MISC	5,622
PROPELLANT	1,106,280


Thrust vector control actuator
Extendible exit cone
Solid rocket motor (SRM-2)
Nozzle
Solid rocket motor (SRM-1)
Avionics bay
Interstage
Reaction control system
Spacecraft separation plane

A HISTORY OF SOLID PROPULSION AT THE MARSHALL SPACE FLIGHT CENTER JULY 15, 1998





IDENTIFICATION

NAME	BOOSTER SEPARATION MTR
MFR	CHEMICAL SYSTEMS DIV
USE	SPACE SHUTTLE
MOTORS/VEHICLE	16

PERFORMANCE, NOMINAL

F MAX,LBF	22,130
FAVG, LBF	21,020
PMAX, PSIA	1,790
PAVG, PSIA	1,745
WEB TIME, SEC	0.71
BURN RATE, IN/SEC	0.8

PROGRAM MILESTONES

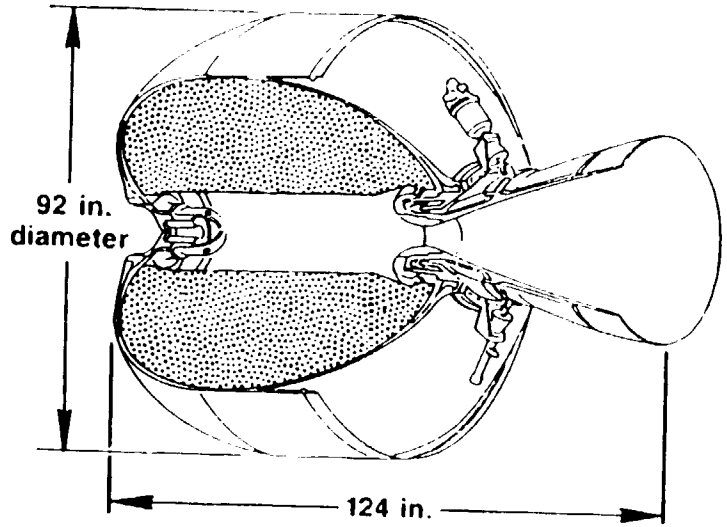
DEV COMPLETE	1977
QUAL COMPLETE	

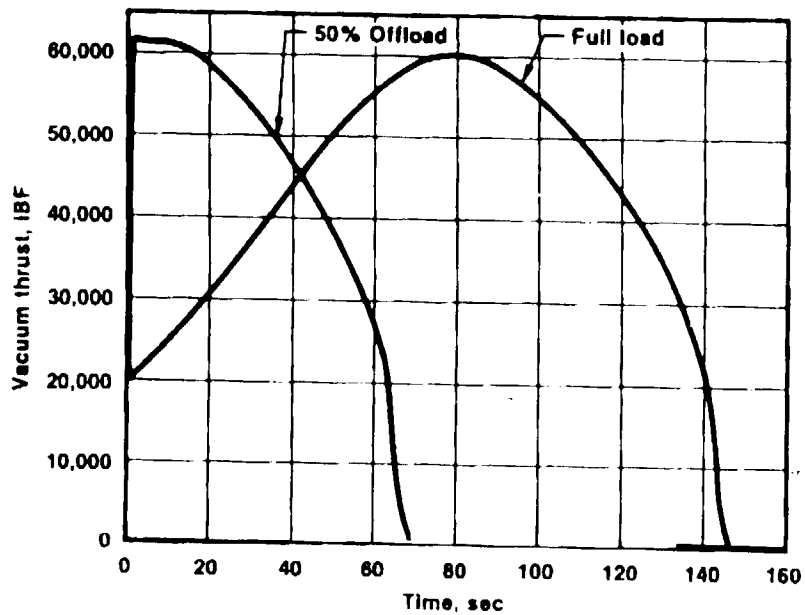
WEIGHTS, LBM

IGNITER	4.4
CASE	43.1
INSULATION	1.9
NOZZLE	29
MISC	-
PROPELLANT	77

A HISTORY OF SOLID PROPULSION AT THE MARSHALL SPACE FLIGHT CENTER

JULY 15, 1998





IDENTIFICATION

NAME	IUS SRM-1 (ORBUS 21)
MFR	CHEMICAL SYSTEMS
DIV	
USE	UPPER STAGE

PERFORMANCE, NOMINAL

F MAX,LBF	60,200
FAVG, LBF	44,000
PMAX, PSIA	886
PAVG, PSIA	651
WEB TIME, SEC	146
BURN RATE, IN/SEC	0.276

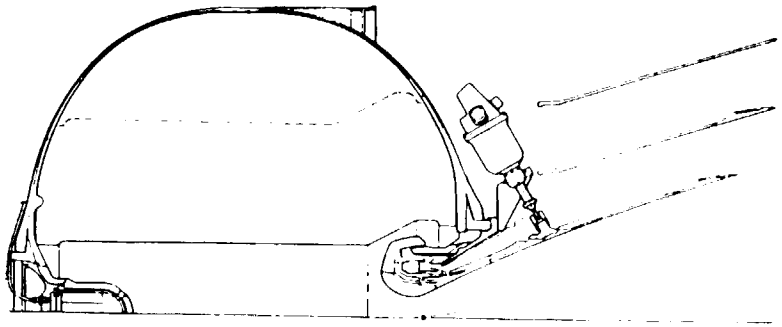
PROGRAM MILESTONES

DEV COMPLETE	
QUAL COMPLETE	1982

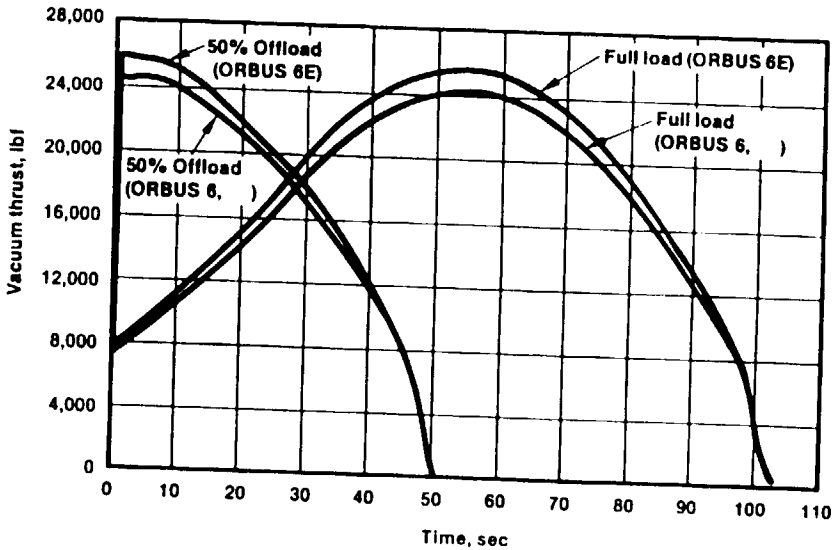
WEIGHTS, LBM

IGNITER	31
CASE	780
INSULATION	319
NOZZLE	315
MISC	25
PROPELLANT	21,404

A HISTORY OF SOLID PROPULSION AT THE MARSHALL SPACE FLIGHT CENTER JULY 15, 1998



Orbus 6E Thrust Histories Versus Propellant Load (60°F)



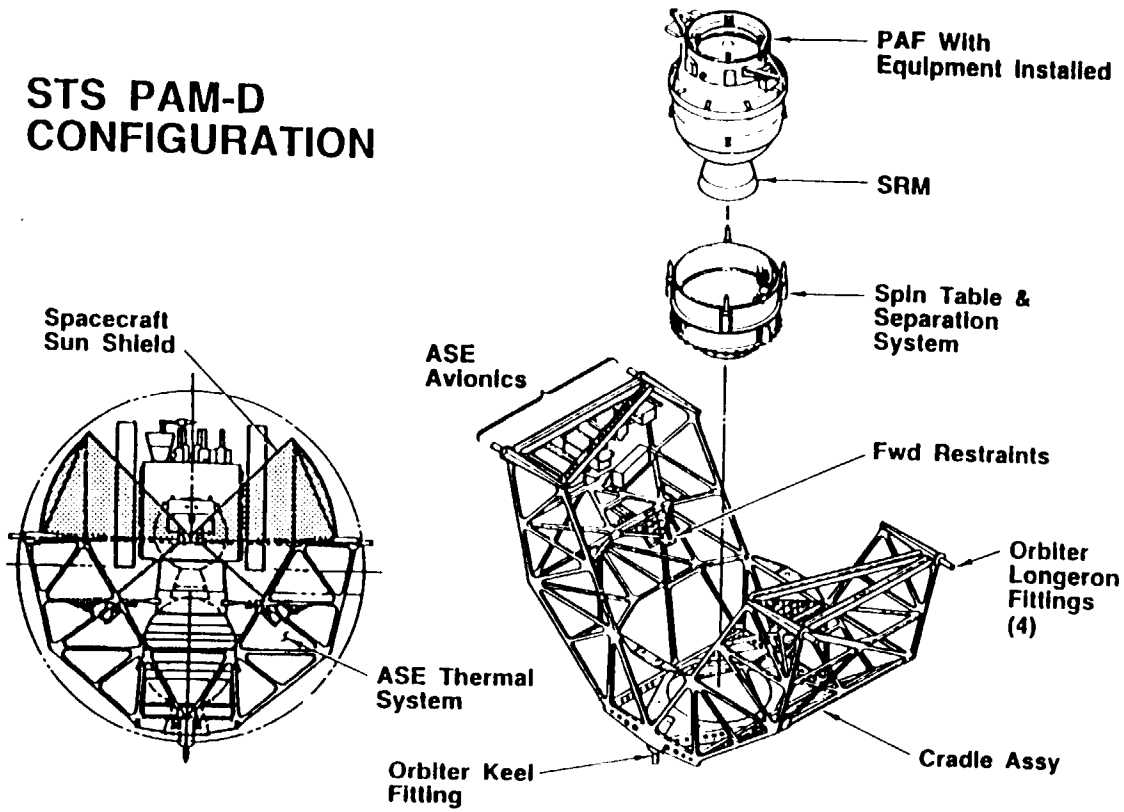
IDENTIFICATION	
NAME	IUS SRM-2 (ORBUS 6/6E)
MFR	CHEMICAL SYSTEMS DIV
USE	UPPER STAGE

PERFORMANCE	NOMINAL	W/EEC
F MAX,LBF	23,800	24,970
FAVG, LBF	17,180	18,020
PMAX, PSIA	839	
PAVG, PSIA	611	
WEB TIME, SEC	101	
BURN RATE, IN/SEC	0.276	

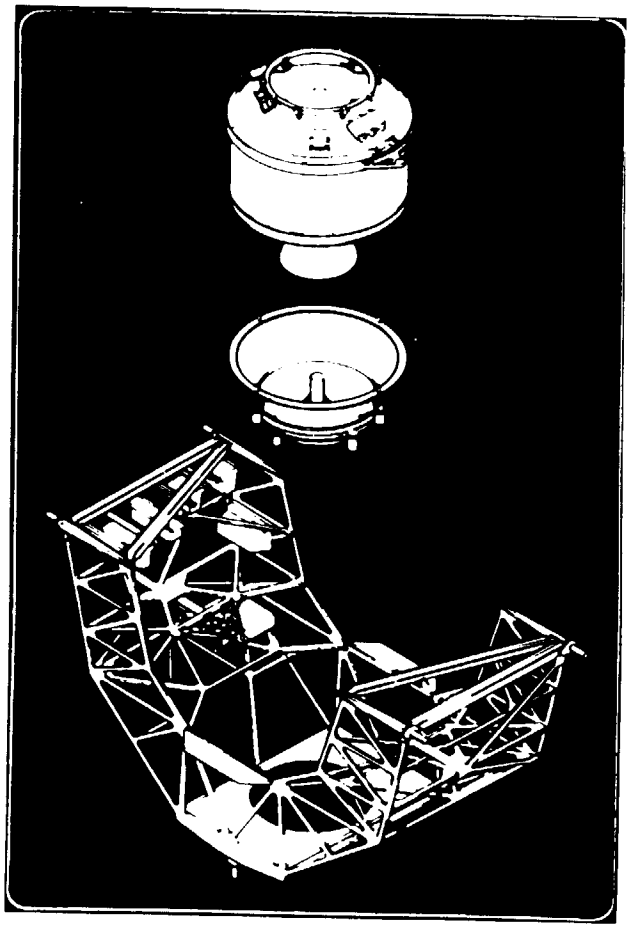
PROGRAM MILESTONES	
DEV COMPLETE	
QUAL COMPLETE	1982

WEIGHTS, LBM	
IGNITER	21
CASE	200
INSULATION	141
NOZZLE	143
TVC	49
PROPELLANT	6002

STS PAM-D CONFIGURATION

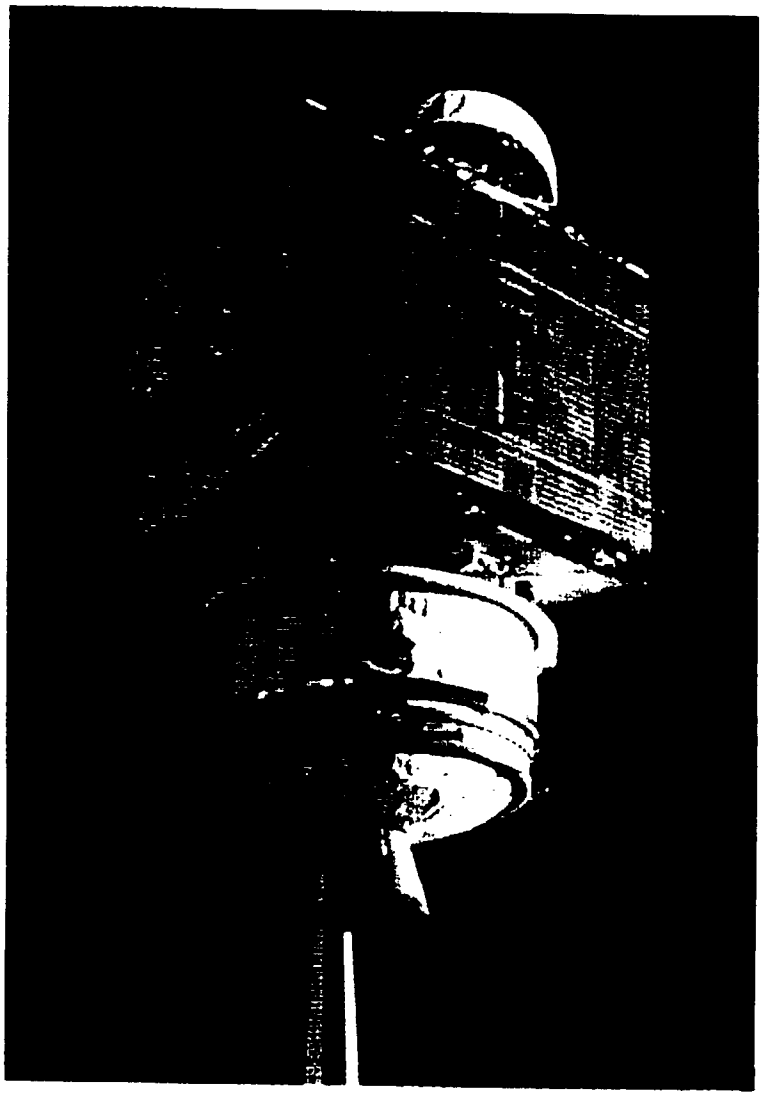


STS PAM DII CONFIGURATION

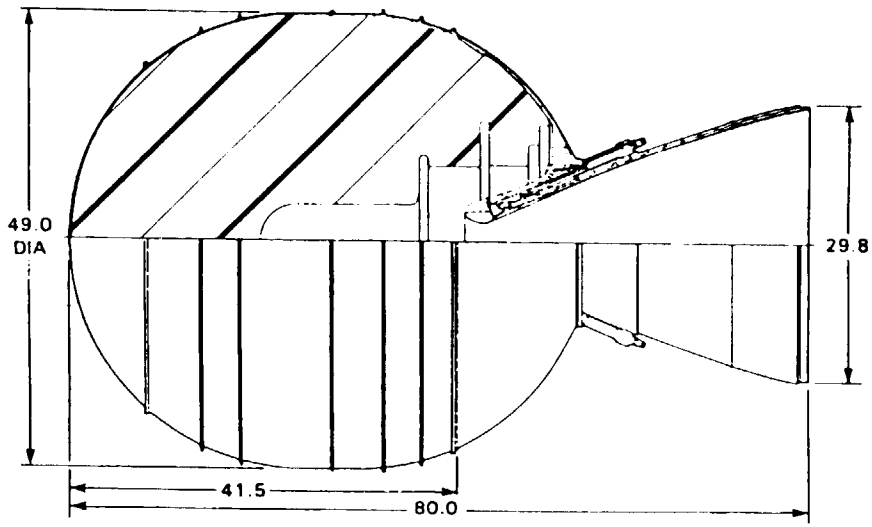


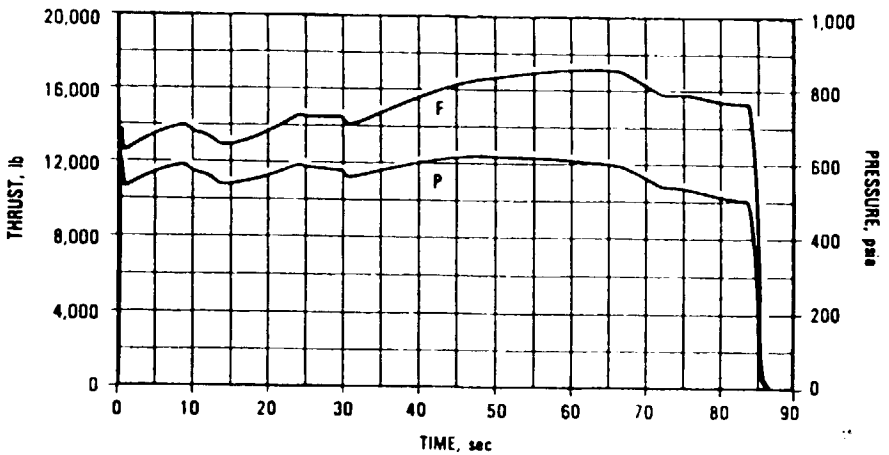
A HISTORY OF SOLID PROPULSION AT THE MARSHALL SPACE FLIGHT CENTER JULY 15, 1998

FIRST COMMERCIAL SPACECRAFT DEPLOYED
FROM SPACE SHUTTLE ON NOVEMBER 11, 1982



STAR (IPSM) 63D PKM FOR RCA SATCOM KUBAND SATELLITE,
NOVEMBER 26, 1985





IDENTIFICATION

NAME	STAR 48B
MFR	THIOKOL
USE	PAM-D, PAM-S
MOTORS/VEHICLE	1

PERFORMANCE, NOMINAL

F MAX,LBF	17,110
FAVG, LBF	15,100
PMAX, PSIA	618
PAVG, PSIA	579
WEB TIME, SEC	84.1
BURN RATE, IN/SEC	0.281

PROGRAM MILESTONES

DEV COMPLETE

QUAL COMPLETE

WEIGHTS, LBM

IGNITER	-
CASE	128.5
NOZZLE	61.9
MISC	2.7
PROPELLANT	4431.2

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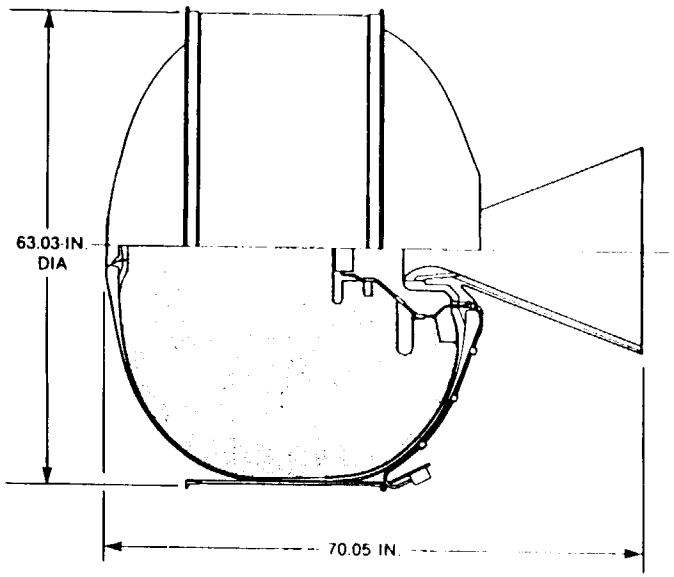
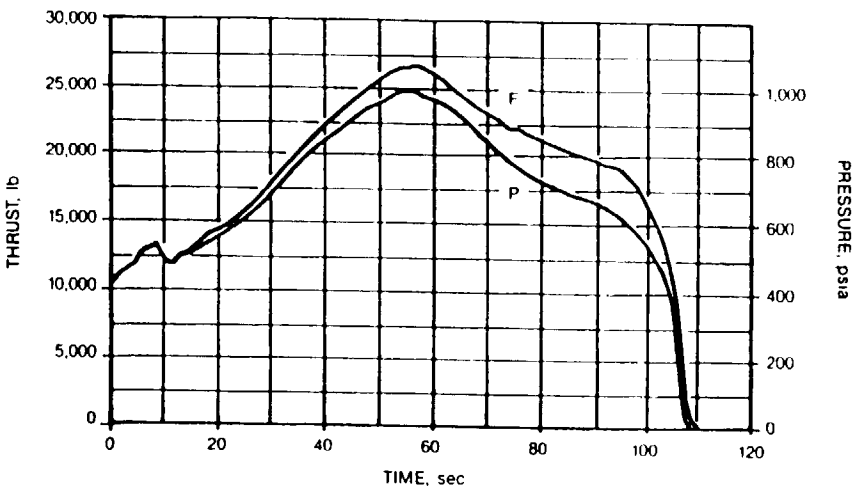




IDENTIFICATION

NAME	STAR 63D
MFR	THIOKOL
USE	PAM-DII
MOTORS/VEHICLE	

PERFORMANCE, NOMINAL

F MAX,LBF	26,710
FAVG, LBF	19,050
PMAX, PSIA	957
PAVG, PSIA	607
WEB TIME, SEC	118
BURN RATE, IN/SEC	0.297

PROGRAM MILESTONES

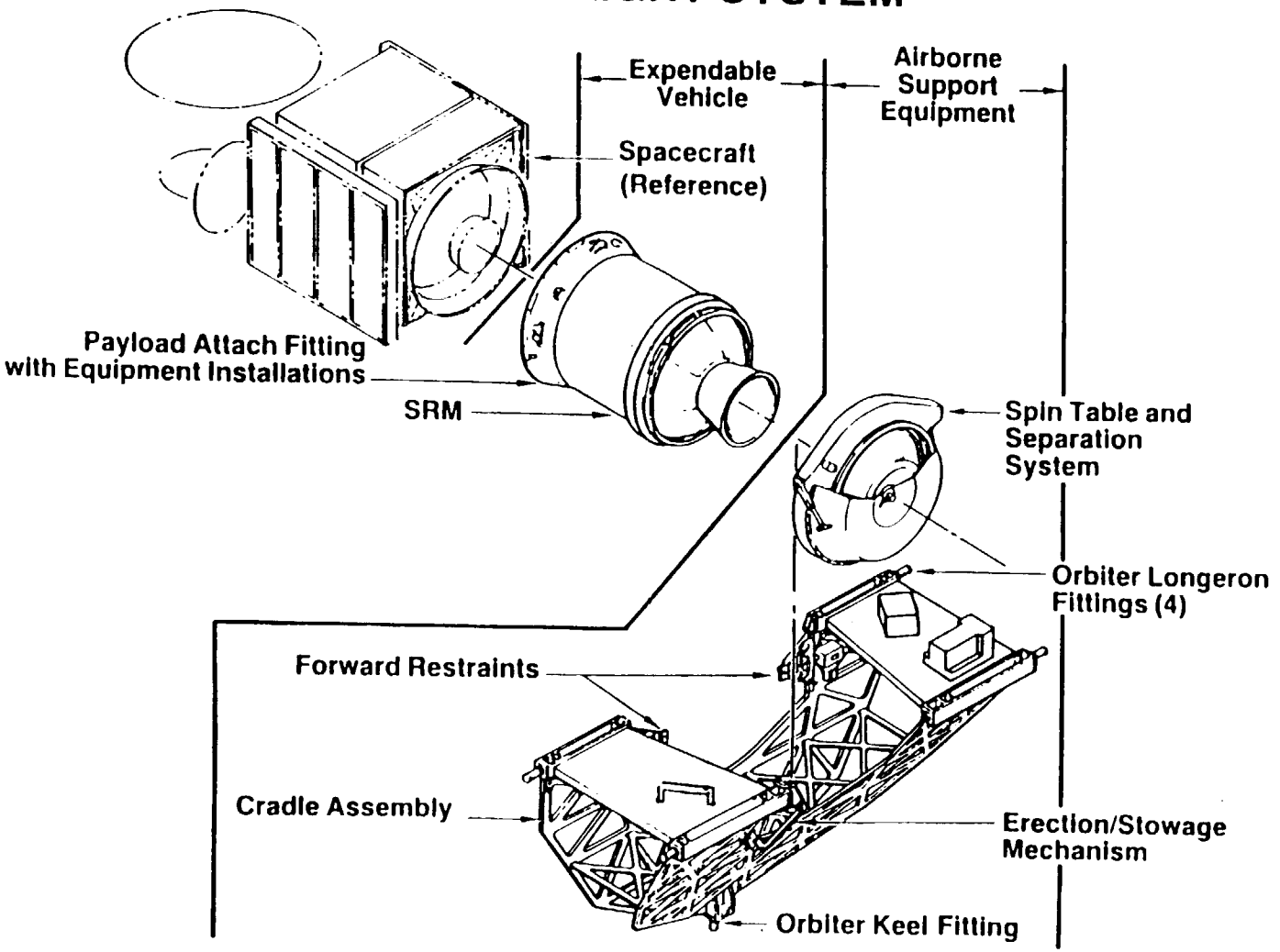
DEV COMPLETE

QUAL COMPLETE

WEIGHTS, LBM

IGNITER	2.1
CASE	234.4
INSULATION	180.1
NOZZLE	134
MISC	2.9
PROPELLANT	7166.5

PAM-A FLIGHT SYSTEM



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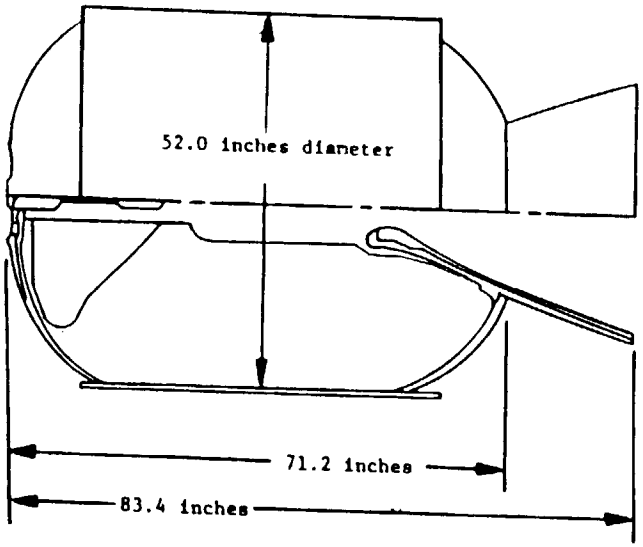

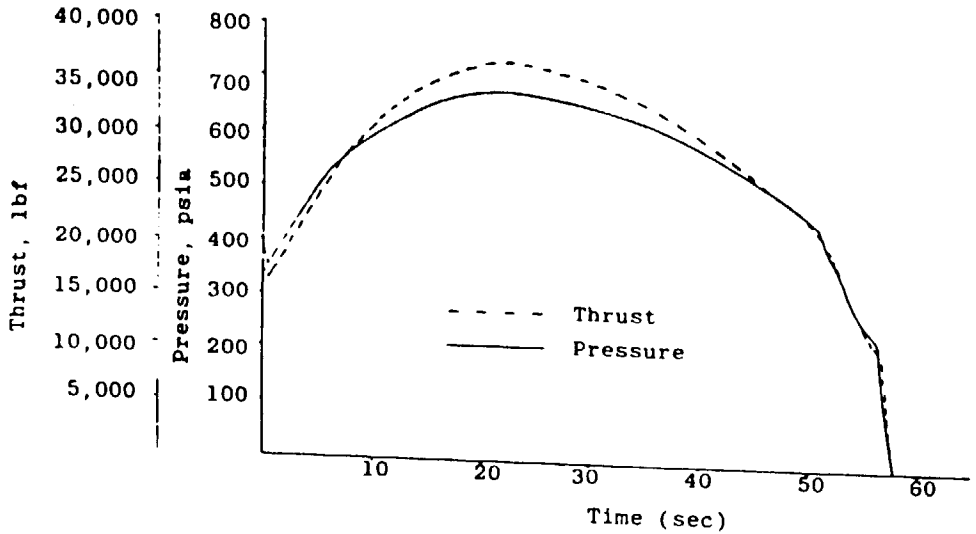

IDENTIFICATION

NAME	SSUS-A
MFR	THIOKOL
USE	PAM-A
MOTORS/VEHICLE	1

PERFORMANCE, NOMINAL

F MAX,LBF	35,850
FAVG, LBF	27,595
PMAX, PSIA	665
PAVG, PSIA	542
WEB TIME, SEC	59.2
BURN RATE, IN/SEC	0.412

PROGRAM MILESTONES EARLY '80'S

DEV COMPLETE
QUAL COMPLETE

WEIGHTS, LBM

IGNITER	11
CASE PLUS INSULATION	404
NOZZLE	119
MISC	
PROPELLANT	7562