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OVERVIEW

of

EUROPEAN AND OTHER NON-US/USSR/JAPAN LAUNCH VEHICLE AND PROPULSION TECHNOLOGY PROGRAMS

Presented

by

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Madison, Wisconsin

Space Transportation Propulsion Technology Symposium
The Pennsylvania State University, University Park, PA
25-29 June 1990

Space Transportation & Propulsion Technologies Reviewed

* Europe (ESA)	Ariane Family & Hermes Space Plane
* Germany	Sanger Aerospace Plane
* United Kingdom	Hotol Aerospace Plane
* France	Star H Aerospace Plane
* China	Long March Family
* India	SLV, ASLV, PSLV & GSLV
* Italy	Advanced Small Launch Vehicle (ASLV)
* Israel	Shavit
* Norway	LittLEO
* Iraq	ABID
* South Korea	New Initiative
* Brazil	Cancelled Program

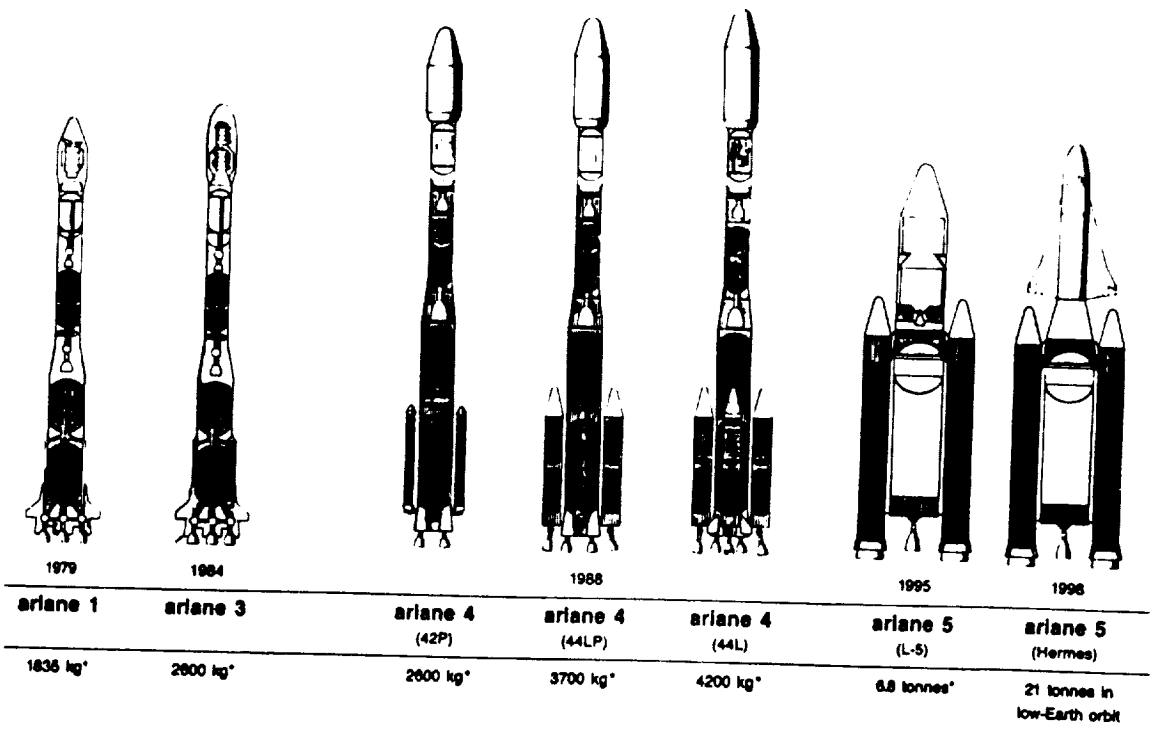
Summary of Europe's Advanced Propulsion Technology Activities

* Majority of Propulsion Technology Development Work Is Directly Related to the ESA's Ariane 5 Program and Heavily Involves SEP in All Areas:
  - Vulcain H/O Engine Is a Major Development Led by SEP; 1st Ignition Sequence in 7/90; 1st Full Power Firing in 12/90
  - Performance Improvements Underway, Including Thrust and Combustion Pressure Increases
  - Solid Propulsion Being Expanded, as SEP & BPD Have Formed Europulsion Company Headquartered in Paris for the Main Purpose of Building Large Solids for Ariane 5; Trying to Reduce Costs and Improve Reliability--Like ALS Objectives, But Not as Ambitious.
  - Man Rating of Ariane 5 for Hermes Flights Will be Accomplished in Parallel With Flights of Unmanned Ariane 5 Flights
* Hermes
  - Composite Applications in Small Storable Rocket Engines (Hermes ACS); Have Accomplished 10,000 s of Firing in 200 N Class Engine
* Advanced Work on Magnetic Bearings for Turbomachinery
* Electric Propulsion, Using Cs and Xe Propellants Being Done By SEP in France, MBB ERNO in West Germany, and by Culham Lab in UK

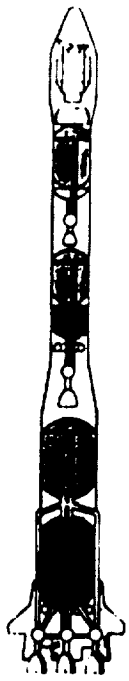
Summary of Europe's Advanced Propulsion Technology Activities (Cont.)

- Successfully Test Fired H/O Composite (Carbon/Silicon Carbide) Nozzle Exit Cone on 3rd Stage of Ariane (HM7)
- Turbine Blades Made of Composites to Allow Increase in Gas Temperature and Improvement in Efficiency
- Combined Cycle (Turboramjet/Rocket) Engine Analysis Work Being Done by Hyperspace, a New Joint Effort of SEP and SCNECMA
- SEP Looking At Future Launchers By Conducting Studies to Determine Advantages of Expendable vs Reusable; Manned vs Unmanned; and Solids vs Liquids
- ESA Advanced Program Studies Looking Beyond Ariane 5: What Payloads Will be Needed in the Future? What Cost Reductions Are Possible? What is Needed For Manned Flight?

European (ESA) Ariane Family



ARIANE 1
SUMMARY



STATUS: INACTIVE

1ST LAUNCH: 1979

LAST LAUNCH: 1986

DRY MASS: 21 MT

LIFT-OFF MASS: 210 MT

PAYLOAD MASS INTO GTO: 1760 kg

11 FLIGHTS

2 FAILURES

ORBITEC

ARIANE 1

VEHICLE STAGE CHARACTERISTICS

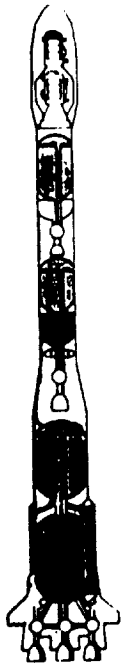
STAGE NO./ MANUFACTURER	1 AEROSPATIALE	2 MBB/ERNO	3 AEROSPATIALE	EQUIPMENT BAY/FAIRING MATRA/ CONTRAVES
STAGE DESIGNATION	L140	L33	H8	
LIFTOFF MASS (kg)	161,000	37,500	9700	323/842
PROPELLANT MASS (kg)	147,600	34,100	8230	
TOTAL THRUST (kN)	2480	726	61	

ENGINE DATA

ENGINE DESIGNATION	Viking V (4)	Viking IV (1)	HM-7 (1)	
ENGINE MANUFACTURER	SEP	SEP	SEP	
THRUST PER ENGINE (kN)	620	726	61	
APPROXIMATE Isp (s)	280	290	425	
PROPELLANTS	UDMH N2O4	UDMH N2O4	LH2 LO2	

ARIANE 2

SUMMARY



ARIANE 2 VEHICLE

LIFT-OFF MASS: 217 MT

DRY MASS: 20.5 MT

PAYLOAD MASS INTO GTO: 2175 kg

ARIANE 2/3 LAUNCH RECORD

STATUS: INACTIVE

1ST LAUNCH: 1984

LAST LAUNCH: 1989

17 FLIGHTS

2 FAILURES

ARIANE 2

VEHICLE STAGE CHARACTERISTICS

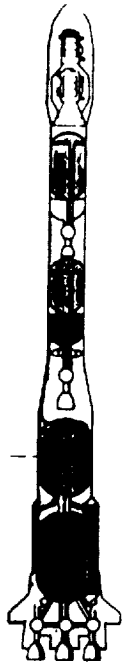
STAGE NO./ MANUFACTURER	1 AEROSPATIALE	2 MBB/ERNO	3 AEROSPATIALE
STAGE DESIGNATION	L140	L33	H8
LIFTOFF MASS (kg)	162,000	39,000	12,300
PROPELLANT MASS (kg)	147,600	35,100	10,700
TOTAL THRUST (kN)	2690	785	63

ENGINE DATA

ENGINE DESIGNATION	Viking V (4)	Viking IV (1)	HM-7B (1)
ENGINE MANUFACTURER	SEP	SEP	SEP
THRUST PER ENGINE (kN)	672	785	63
APPROXIMATE Isp (s)	280	290	435
PROPELLANTS	UH25/H2O N2O4	UH25/N2O4 N2O4	LH2 LO2

ARIANE 3

SUMMARY



ARIANE 3 VEHICLE

LIFT-OFF MASS: 236.8 MT

DRY MASS: 25.5 MT

PAYLOAD MASS INTO GTO: 2580 kg

ARIANE 2/3 LAUNCH RECORD

STATUS: INACTIVE

1ST LAUNCH: 1984

LAST LAUNCH: 1989

17 FLIGHTS

2 FAILURES

ARIANE 3

VEHICLE STAGE CHARACTERISTICS

STAGE NO./ MANUFACTURER	0 AEROSPATIALE	1 AEROSPATIALE	2 MBB/ERNO	3 AEROSPATIALE
STAGE DESIGNATION	BOOSTERS	L140	L33	H8
LIFTOFF MASS (kg)	9750 x 2	162,000	39,000	12,300
PROPELLANT MASS (kg)	7350 x 2	147,600	35,100	10,700
TOTAL THRUST (kN)	600 x 2	2690	785	63

ENGINE DATA

ENGINE DESIGNATION	SOLID BOOSTERS	Viking V (4)	Viking IV (1)	HM-7B (1)
ENGINE MANUFACTURER	SNIA/BPD	SEP	SEP	SEP
THRUST PER ENGINE (kN)	600	672	785	63
APPROXIMATE Isp (s)	230	280	290	435
PROPELLANTS	SOLID CTPB 1613	UH25/H2O N2O4	UH25/H2O N2O4	LH2 LO2

ARIANE 4

SUMMARY

STATUS: ACTIVE

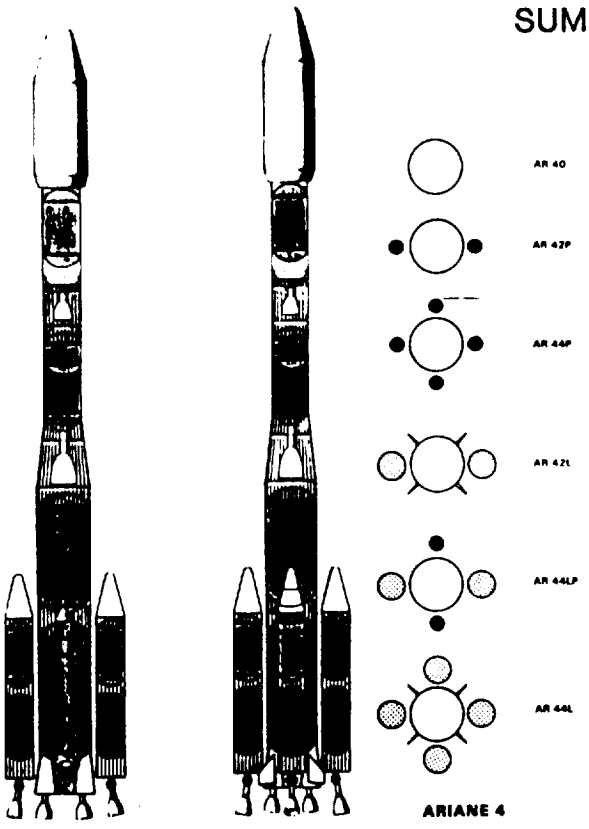
1ST LAUNCH: 1988

8 FLIGHTS

1 FAILURE: H2O FLOW TERMINATION

SIX STRAP-ON CONFIGURATIONS

CONFIGURATION	GTO PAYLOAD (kg)
40	1900
42P	2600
44P	3000
42L	3200
44LP	3700
44L	4200



ARIANE 4

ARIANE 4

VEHICLE STAGE CHARACTERISTICS

STAGE NO./ MANUFACTURER		1 * AEROSPATIALE	2 MBB/ERNO	3 AEROSPATIALE
STAGE DESIGNATION		L220	L33	H10
LIFTOFF MASS (kg)		243,000	37,600	11,900
PROPELLANT MASS (kg)		226,000	34,000	10,700
TOTAL THRUST (kN)		2690	785	63

*ADDITIONAL THRUST MAY BE PROVIDED BY STRAP-ONS

ENGINE DATA

ENGINE DESIGNATION		Viking V (4)	Viking IV (1)	HM-7B (1)
ENGINE MANUFACTURER		SEP	SEP	SEP
THRUST PER ENGINE (kN)		672	785	63
APPROXIMATE Isp (s)		280	290	435
PROPELLANTS		UH25/H2O N2O4	UH25/H2O N204	LH2 LO2

ARIANE 4 CONFIGURATIONS

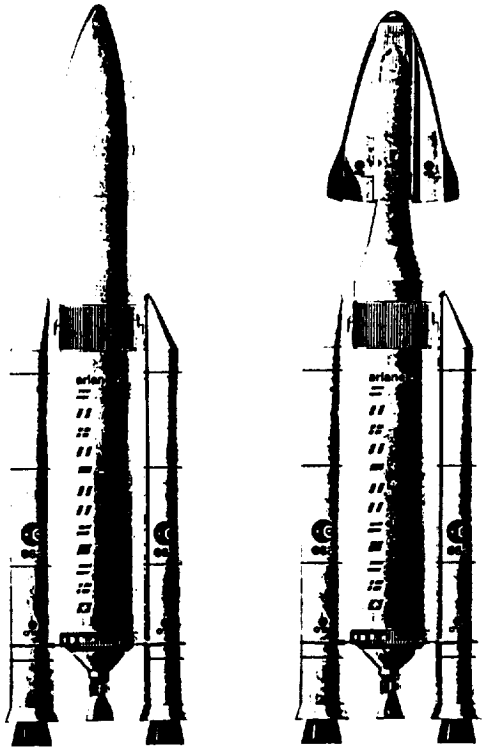
STAGE 1 BOOSTER INFORMATION

	SOLID	LIQUID
BOOSTER DESIGNATION	PAP	PAL
LIFTOFF MASS (kg)	12,700	43,500
PROPELLANT MASS (kg)	9500	39,000
TOTAL THRUST (kN)	625	666
MANUFACTURER	SNIA-BPD	MBB-ERNO/SEP
APPROXIMATE Isp (s)	230	235
PROPELLANTS	CTPB 1613	UH25-H2O/N2O4

STAGE1/BOOSTER CONFIGURATIONS

DESIGNATION	40	42P	44P	42L	44LP	44L
BOOSTERS	NONE	2 PAP'S	4 PAP'S	2 PAL'S	2 PAP'S 2 PAL'S	4 PAL'S
LIFT-OFF THRUST (kN)	2650	3950	5200	4020	5270	5350
PAYLOAD TO GTO (kg)	1900	2600	3000	3200	3700	4200

ARIANE 5
SUMMARY



STATUS: IN DEVELOPMENT

1ST LAUNCH: 1998

ARIANE 5

VEHICLE STAGE CHARACTERISTICS

STAGE NO./ MANUFACTURER	0 EUROPROP.	1 AEROSPATIALE	2 MBB/ERNO	
STAGE DESIGNATION	P 230	H 150	L 7	
LIFTOFF MASS (kg)	270,000 x 2	169,000	8130	
PROPELLANT MASS (kg)	230,000 x 2	156,000	7200	
TOTAL THRUST (kN)	6000 x 2	1025	28	

ENGINE DATA

ENGINE DESIGNATION	P 230	VULCAIN (1)		
ENGINE MANUFACTURER	EUROPROP.	SEP	MBB/ERNO	
THRUST PER ENGINE (kN)	6000	1025	28	
APPROXIMATE Isp (s)				
PROPELLANTS	HTPB/AP/AL	LH2 LOX	MMH N2O4	

ARIANE 5 CONFIGURATIONS

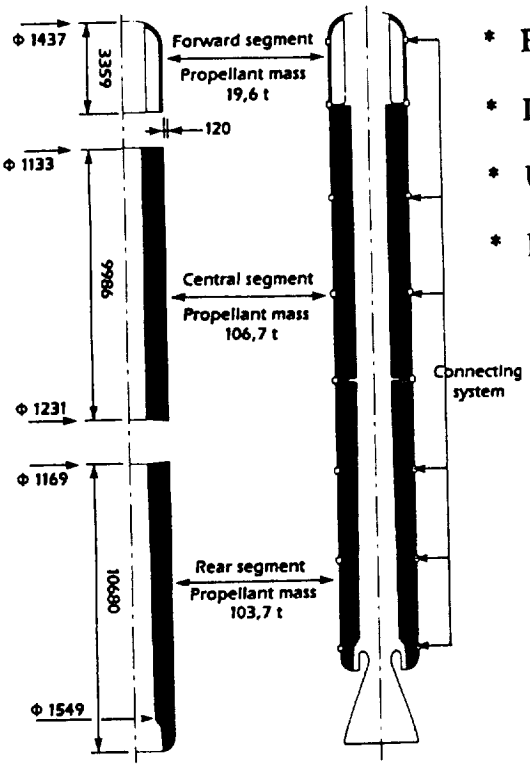
	DOUBLE LAUNCH	SINGLE LAUNCH	HERMES LAUNCH
LIFT-OFF MASS (kg)	721,000	721,000	735,000
LIFT-OFF THRUST (kN)	13,043	13,043	13,043
HEIGHT (m)	49.6	50.4	49.6
PAYLOAD (kg)	5950 GTO	6290 GTO	22,000 LEO

Ariane 5 - Vulcain Engine

* Major Engine Development for SEP and Other Subcontractors
* System Uses Gas Generator; Separate LH_2 and LOX Turbopumps
* Parameters:

Vacuum Thrust	1025 kN (230,000 lb)
Propellant	LH_2/LOX
O/F	5.2
I_{sp} (Vac)	431.6 s
P_c	100 Bars (1450 psi)
Engine Mass	1300 kg (2860 lbs)
LH2 Turbine Speed	34,200 rpm
LOX Turbine Speed	13,000 rpm
LH2 Turbine Power	11,300 kW
LOX Turbine Speed	2,900 kW

Ariane 5 - Solid Propellant Boosters (P 230)



* Being Led by Europulsion
* Development Plan Includes 10 Full-Scale Tests
* Uses Steel Case and HTPB/AP Propellants
* Known Motor Parameters:

Thrust	1,346,000 lb (5987 kN)
Propellant	HTPB/AP/AL
Propellant Mass	230,000 kg
Motor Diameter	3.05 m
Motor Length	30.6 m
Dry Mass	39,400 kg
t_b	125 s

Hermes

* Europe's Answer to Manned Spaceflight Independence; First Flight on Ariane 5 Currently Scheduled for 1998; Flight Rate of 2 Per Year
* Missions to: Columbus Free-Flying Lab, Space Station Freedom, Soviet Space Station Mir
* 3-Manned Crew, Delta-Winged Space Plane that Lands on Runway
* Hermes Consists of: Space Plane (13 m, 15 MT); Resource Module (6 m, 8 MT); and Propulsion Module (1 m); Hermes Robotic Arm (HERA)
* Storable Propellant Propulsion Module Consists of ACS with 32 - 20 & 400 N Class Storable Propellant Engines and 2 Main Orbit Injection Engines with 27.5 kN Thrust Level Each; Four Tanks Holding 7200 kg Propellant
* 3 MT Payload Capability; 2000 km Cross Range Landing Capability
* Includes a Crew Ejection System
* Primary Structure Made of Carbon-Resin Composites
* ~$5 Billion Program; ~170 Organizations with ~1500 People Working Presently, With ~5000 by 1992

Hermes (Cont.)

* Hermes Participants: France 43.5%; Germany 27%; Italy 12.1%; Belgium 5.8%; Spain 4.5%; Netherlands 2.2%; Switzerland 1.5%; Sweden 1.3%, Canada 0.45%; Austria 0.5%; Denmark 0.45% and Norway 0.2%

* Phase B to be Complete Mid-1991; Program Phase C/D Expected to Begin in Late 1991

* Four Major Technology Challenges Identified by ESA:

  - Materials Necessary for Structures and Their Thermal Protection

  - Math Models for Aerodynamic, Aerothermal and Flight Simulations

  - H/O Fuel Cells for Electric Power

  - Flight Electronics and Software

Germany/MBB - Sanger Aerospace Plane

* Manned Reusable 2-Stage Winged HTO Vehicle Concept

* GLOW 340 MT; Airbreathing to M = 6.8 at 31 km; Uses Airbreathing LH_2 Turboramjet

* Aircraft Version Can Cruise at M = 4.4, and Carry 230 Passengers From Frankfurt to LA in Less Than 3 Hours

* Nominal Takeoff Thrust Level 1500 kN with 5 Engines

* Employs Expendable Stage CARGUS (Cargo Upper Stage) for 15 MT Payloads; From Ariane 5 Core Stage; Engine (HM.60) Thrust 1050 kN; LOX/LH_2

* Reusable Stage HORUS (Hypersonic Orbital Reusable Upper Stage) for Manned Missions; Main Engine Thrust 1200 kN; Expansion Ratio 325; I_{sp} = 472 s; O/F = 6.7; OMS Thrust 80 kN; I_{sp} = 437 s; Payload = 3300 kg

* MBB Is Conducting Technology Work on the Turboramjet for the First Stage of the Sanger; MBB Testing a GH_2 Ramjet Prototype in Mach 5 Wind Tunnel

* Funded at a $225 M Level Through 1992

* Will Likely Be a $10 B Demonstrator Program Funded by ESA

United Kingdom/British Aerospace - Hotol Aerospace Plane

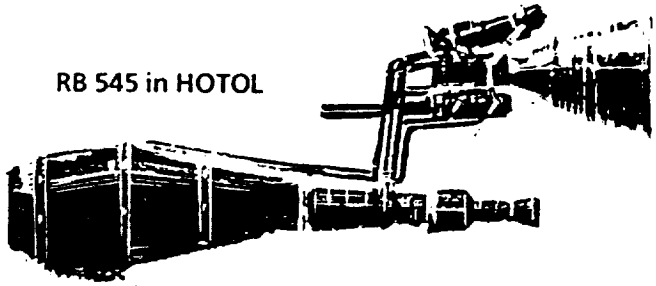
* Horizontal Take Off and Horizontal Landing -- Hotol
* Manned Reusable Single-Stage-to-Orbit Vehicle Concept
* Uses Launch Trolley; GLOW 250 MT; Airbreathing to M=5 at 85 kft
* Employs Hybrid RB545 (Remains Classified) - Dual Mode Rocket Chamber that Utilizes Air as Oxidant in Lower Atmosphere
* H/O OMS; GH_2 RCS Thrusters
* Metal or Composite TPS, No Tiles
* Deliver 7 to 8 MT Into LEO
* Operational Cost ~ $4 to 5 M per Flight
* Proof of Concept in 1988; Wind Tunnel Tests from M = 5 to 18

Hotol Propulsion System

Propulsion System Comparison

Olympus in Concorde

RB 545 in HOTOL



Olympus Power Plant Mass = 4080Kg

RB545 Power Plant Mass = 2840Kg

France - Star H Aerospace Plane

* French CNES Supported Study by Dassault/SNECMA/SEP/ONERA
* A Two-Stage to Orbit Aerospace Plane
* Reusable First Stage With Air-Breathing Engines
* An Expendable Second Stage With a HM-60 Cryogenic Engine
* Reusable Orbiter Derived from Hermes
* 400 MT GLOW; 280 MT 1st Stage; 120 MT 2nd Stage
* Studying Various Engine Cycles; Testing Scramjet; Wind Tunnel Tests

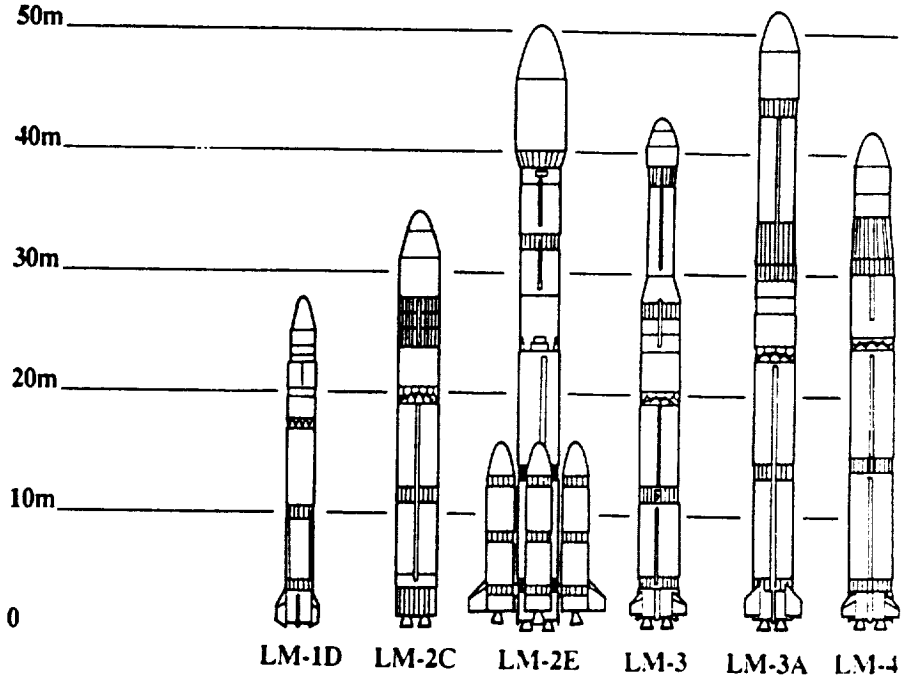
China - Long March Family

* China's Space Activities Date Back to the Late 1950's
* In 1964, China Launched It's First Launch Vehicle
* On April 24, 1970, China Launched it's First Earth Orbiting Spacecraft with Long March-1 (LM-1)
* In November 1975, China Launched a Recoverable Satellite Using LM-2
* In April 1984, LM-3 Was Successfully Launched
* China Has Now Developed a Successful, Reliable and Significantly Competitive Launch Capability

Long March Family of Launch Vehicles

Model	LM-1D	LM-2C	LM-2E	LM-3	LM-3A	LM-4
Overall length(m)	28	35	51	43.85	52.3	42
Lift-off weight(t)	80	191	464	202	240	249
Lift-off thrust(t)	112	284	600	284	300	300
Payload capability in LEO (kg)	700-750	2500	8800			2,500 (SSO)*
Payload capability in geostationary transfer orbit (kg)				1,400	2,500	
Available for commercial service	1991	1982	1990	1986	1992	1988

*SSO: Sunsynchronous orbit



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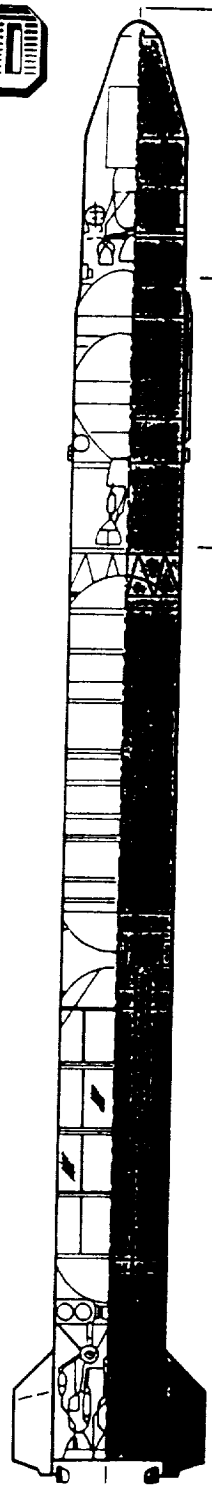
China's Launch History

		Launch Date	Launch Vehicle
1	Dong Fang Hong 1	24-4-1970	LM-1
2	Shi Jian 1	3-3-1971	LM-1
3	Technical Experiment	26-7-1975	LM-2A
4	Recoverable	26-11-1975	LM-2C
5	Technical Experiment	16-12-1975	FB-1
6	Technical Experiment	30-8-1976	FB-1
7	Recoverable	7-12-1976	LM-2C
8	Recoverable	26-1-1978	LM-2C
9	Shi Jian 2	20-9-1981	FB-1
10	Shi Jian 2A		
11	Shi Jian 2B		
12	Recoverable	9-9-1982	LM-2C
13	Recoverable	19-8-1983	LM-2C
14	Experimental	29-1-1984	LM-3
15	Experimental Geostationary Communications	8-4-1984	LM-3
16	Recoverable	12-9-1984	LM-2C
17	Recoverable	18-9-1985	LM-2C
18	Operational Geostationary Communications	1-2-1986	LM-3
19	Recoverable	6-10-1986	LM-2C
20	Recoverable	5-8-1987	LM-2C
21	Recoverable	9-9-1987	LM-2C
22	Operational Geostationary Communications	7-3-1988	LM-3
23	Recoverable	5-8-1988	LM-2C
24	Meteorological	7-9-1988	LM-4
25	Operational Geostationary Communications	22-12-1988	LM-3

Long March - 1D

LM - 1D



Fairing

maximum diameter	2.054m
static effective diameter	1.754m

Third Stage

propellant (solid)	0.625t
diameter	2.05m

Second Stage

propellant ($UDMH/N_2O_4$)	12.2t
diameter	2.25m

First Stage

propellant ($UDMH/HNO_3$-27S)	60t
diameter	2.25m

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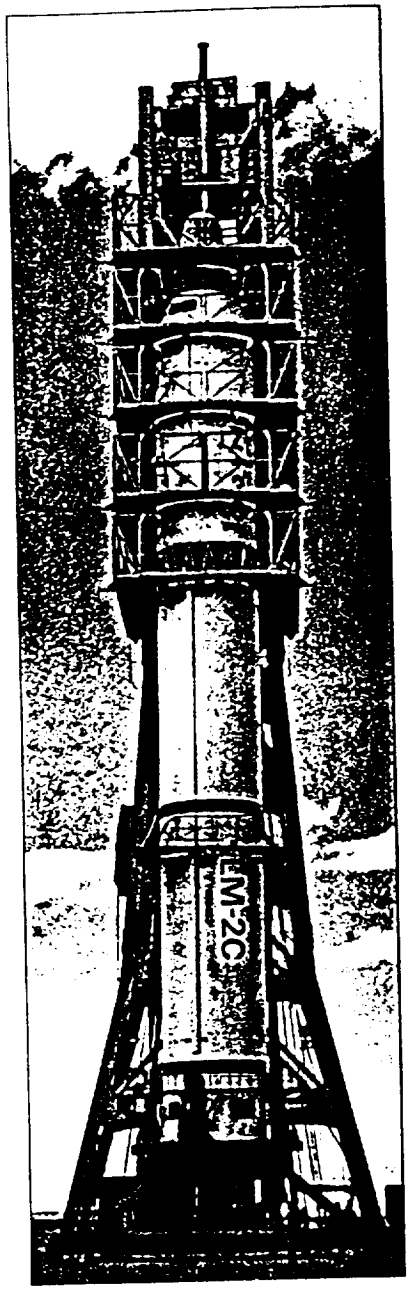
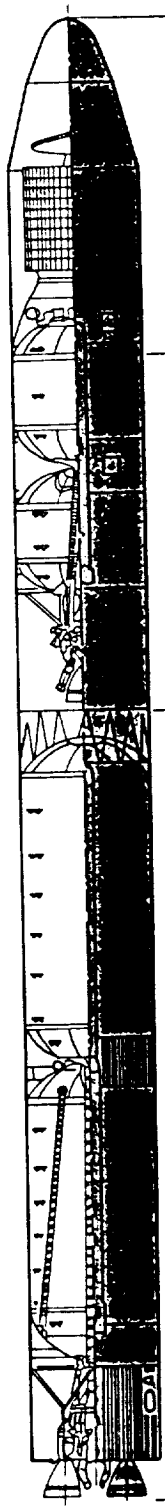
Long March - 2C

LM-2C





Fairing

maximum external diameter	3.35m
static effective diameter	3.07m

Second Stage

propellant ($UDMH/N_2O_4$)	35t
diameter	3.35m

First Stage

propellant ($UDMH/N_2O_4$)	144t
diameter	3.35m

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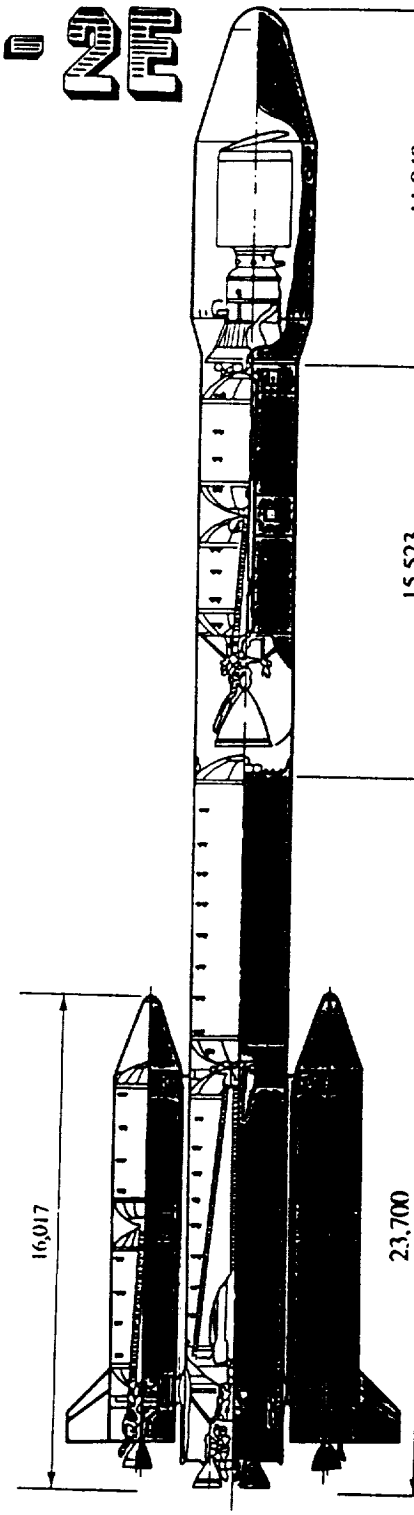
Long March - 2E

LM-2E



Fairing

maximum external diameter	4.2m
static effective diameter	3.8m

Second Stage

propellant ($UDMH/N_2O_4$)	86t
diameter	3.35m

First Stage

propellant ($UDMH/N_2O_4$)	187t
diameter	3.35m

Liquid Strap-on Boosters

propellant ($UDMH/N_2O_4$)	4x37.5t
diameter	2.25m

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Long March - 3

LM-3

Fairing	(A)	(B)
maximum external diameter	2.60m	3.00m
static effective diameter	2.32m	2.72m

Third Stage

propellant (LH/LOX)	8.5t
diameter	2.25m

Second Stage

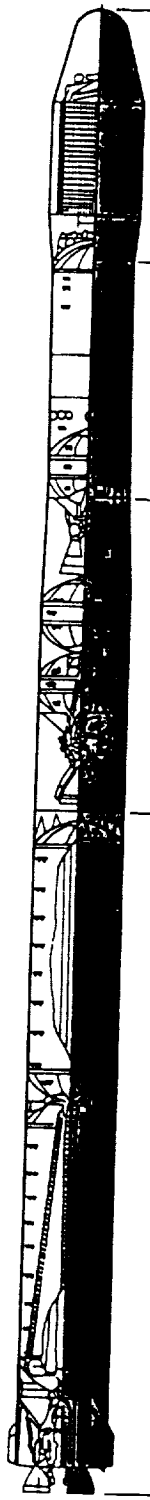
propellant ($UDMH/N_2O_4$)	35t
diameter	3.35m

First Stage

propellant ($UDMH/N_2O_4$)	142t
diameter	3.35m

Long March - 3A

LM-3A



8,887

Fairing

maximum external diameter 3.35m

static effective diameter 3.00m

8,835

Third Stage

propellant (LH/LOX) 17.6t

diameter 3.00m

11,526

Second Stage

propellant ($UDMH/N_2O_4$) 29.6t

diameter 3.35m

23,075

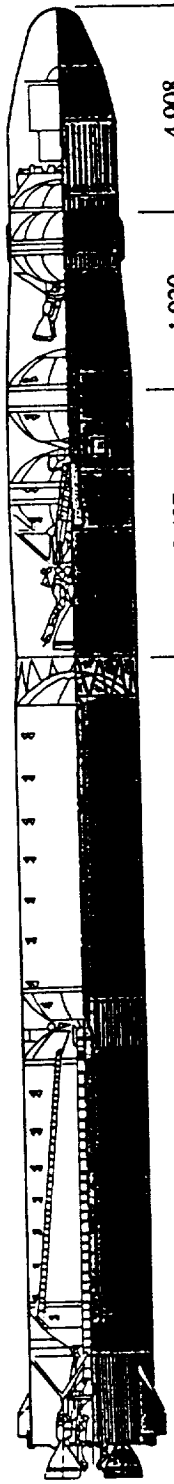
First Stage

propellant ($UDMH/N_2O_4$) 170t

diameter 3.35m

Long March - 4

LM-4



Fairing

maximum external diameter	2.90m
static effective diameter	2.36m

Third Stage

propellant ($UDMH/N_2O_4$)	14.15t
diameter	2.90m

Second Stage

propellant ($UDMH/N_2O_4$)	35.55t
diameter	3.35m

First Stage

propellant ($UDMH/N_2O_4$)	183.20t
diameter	3.35m

India's Launch Vehicle Systems

* Satellite Launch Vehicle (SLV-3)
  - Approximately 15 MT Liftoff Mass
  - 23 m Long; 1 m Diameter Base
  - 4 Solid Propellant Stages; Segmenting Used on 1st Stage
  - 40 kg Payload Up to 800 km Circular at 45°
  - 4 Launches, 3 Successes in 1980 to 1983

* Augmented Satellite Launch Vehicle (ASLV)
  - SLV with 2 Solid Propellant Strapon Boosters
  - 150 kg Payload to LEO
  - 2 Failed Launches in 1987 and 1988
  - 2 Launched Scheduled Through 1993

* Polar Satellite Launch Vehicle (PSLV)
  - Approximately 275 MT Liftoff Mass
  - 44 m Long; 2.8 m Diameter Base
  - 4 Solid Propellant Stages; Solid/Liquid/Solid/Liquid
  - 1st Stage Has 6 Solid Motor Strapons
  - 1000 kg Payload Up to 900 km Circular at 90-100°
  - 3 Launches Scheduled Through 1994

* Geosynchronous Launch Vehicle (GSLV)
  - In Phase A/B; Goal Is 2 MT to GTO; Launches Planned in 1993-1995
  - Use Existing/Improved Stages, Plus New H/O Stage 3

India Propulsion Technology - PSLV Focused

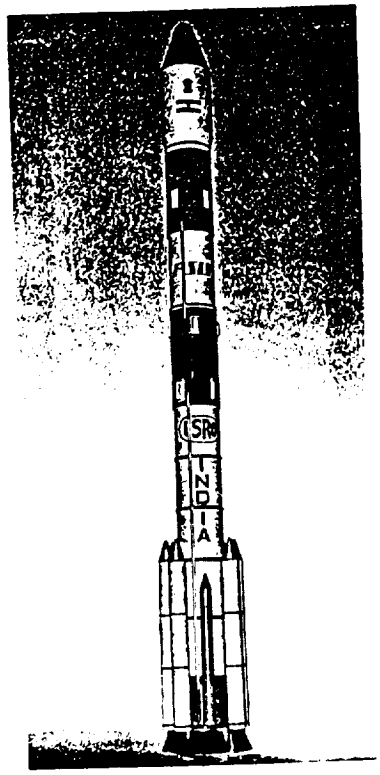
* 1st Stage (5 Segments) Is the 3rd Largest in the World
  - Motor Is 20 m Long and 2.8 m in Diameter
  - Uses HTPB-Based Propellant
  - Secondary Injection TVC Uses Strontium Perchlorate
  - Steel Case; Silicon Carbide Phenolic Composite Nozzle Liner
  - Successfully Static Tested on 10/21/89

* 2nd Stage Liquid
  - Viking Engine Licensed from SEP
  - UDMH/NTO Propellants
  - 8 Tests with 820 s Firing Time Completed

* 3rd Stage Solid
  - Motor is 2 m Long and 2 m in Diameter
  - Uses HTPB-Based Propellant
  - Submerged, Flex Seal Nozzle System
  - Kevlar Case
  - 2 Static Test Firings Completed in 4/89 and 1/90

* 4th Stage Liquid
  - Restart Capability
  - Engines Gimballed for TVC
  - Ti/Al Tankage and Structure
  - "Battleship" (Steel) Version Tested 7/89

India PSLV Model



Other Launch Vehicles

* Italy - Advanced Small Launch Vehicle (ASLV)
  - Fiat (Italy) and LTV (US) Formed Partnership in 11/89
  - Fait's SNIA BPD Subsidiary to Build Scout 2
  - Scout 2 is Scout with 2 Strapon Boosters
  - SNIA BPD to Market Europe; LTV North America
  - Launch from San Marcos, Wallops, Vandenberg
  - 460 kg Payload to 555 km Circular (San Marcos)
  - 4 Strapon Configuration Planned

* Israel - Shavit
  - Derived from Jericho Missile
  - 2 Successful Launches, 9/88 and 4/90
  - 160 kg Payload to 210 x 1500 km at 143°
  - 3-Stage, Solid Propellant

* Iraq Has a Launcher Called ABID, a 3-Stage Missile System

* South Korea Has Announced Plans to Build Satellites and Develop an Independent Launch Capability

* Norway is Developing LittLEO, a Scout-Class Launcher; 1st Launch in 1991

* Brazil Just Cancelled It's Program by the New Government

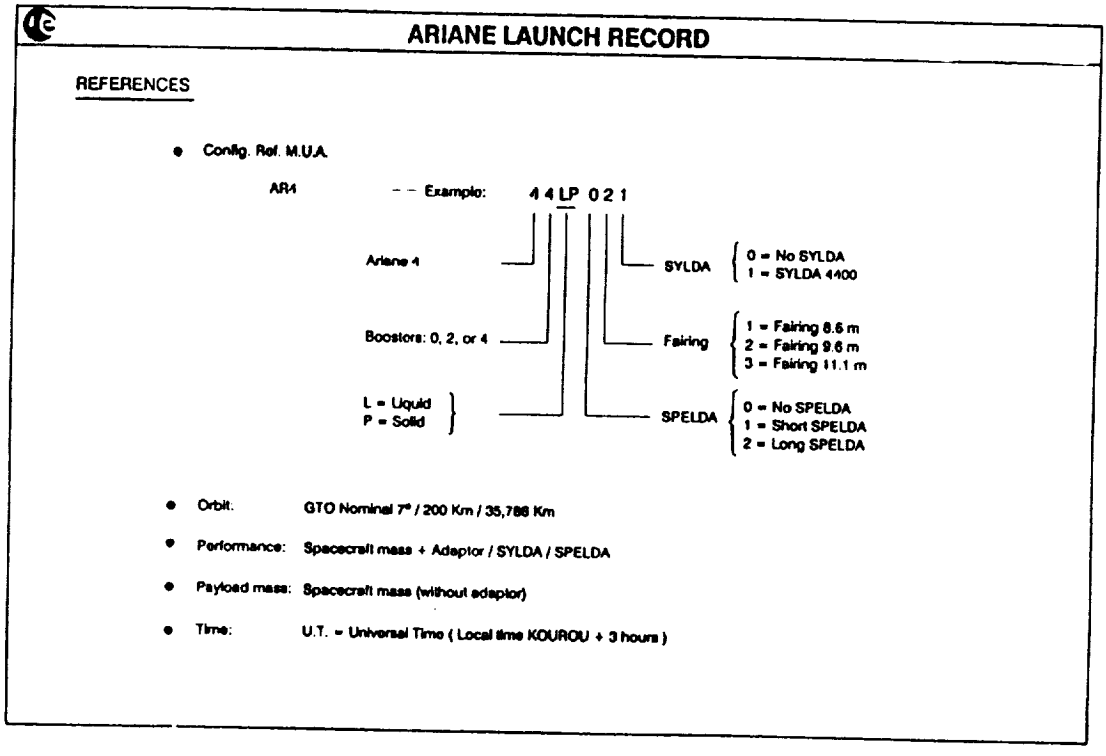
ORBITEC

Ariane Launch Record

Issue: V36

by

European Space Agency



ARIANE LAUNCH RECORD

LAUNCHER				IGNITION		PAYLOAD				ESA REPORT	REMARKS
FLIGHT N°	CONFIG. Ref. M.U.A.	PERFORM. Kg	ORBIT	DATE	TIME U.T.	CUSTOMER / MANUFACTURER	NAME	MASS Kg	MISSION / FINAL ORBIT	ESA/PB-AR	
L01	AR1 ACU 1194	1645 (49.2)	GTO 17.5°	24-12-79	17h14'38"	ESA / AEROSPATIALE	CAT / BALLAST	1602	TECHNOLOGICAL / GTO	(80)1 (80)8 (80)17	1st ARIANE 1 1st QUALIFICATION FLIGHT
L02	AR1 ACU 1194	1643	[GTO 17.5°]	23-05-80	14h29'39"	MAX PLANK INST. / MBB AMSAT CORP. / AMSAT ESA / AEROSPATIALE	FIREWHEEL OSCAR 9 CAT	1080 82 340	SCIENTIFIC / [GTO] RADIO AMATEURS / [ELLIPTIC] TECHNOLOGICAL / [GTO]	(80)21 (80)29 (80)40	2nd QUALIFICATION FLIGHT FAILURE OF FIRST STAGE
L03	AR1 ACU 1194	1678	GTO 10.5°	19-06-81	12h32'59"	ESA / AEROSPATIALE INDIAN SPACE RESEARCH ORG. / ISRO ESA / AEROSPATIALE	METEOSAT APPLE CAT	717 630 140	METEOROLOGICAL / GEO COMMs & TECHNO. / GEO TECHNOLOGICAL / GTO	(81)26	3rd QUALIFICATION FLIGHT
L04	AR1 ACU 1194	1699	GTO	20-12-81	01h29'00"	ESA / BAe ESA / MATRA ESA / AEROSPATIALE	MARECS - A VID CAT & (THESEE)	995 503 158	MARITIME COMMs / GEO TECHNOLOGICAL / GTO TECHNO. & (SCIENTIF.) / GTO	(82)1	4th QUALIFICATION FLIGHT
L5	AR1 / SYLDA 3900	1617 (184)	[GTO 8°]	10-09-82	02h12'00"	ESA / BAe ESA / CNI	MARECS-B SIRIO 2	1014 419.5	MARITIME COMMs / [GEO] COMMs & TIME SYNCHRO. / [GEO]	(82)31	FAILURE OF THIRD STAGE
L6	AR1 / SYLDA 3900	1381	GTO 8.6°	16-06-83	11h59'03"	ESA / BAe AMSAT CORP. / AMSAT	ECS-1 AMSAT Ph IIIB	1043 130	COMMUNICATIONS / GEO RADIO AMATEURS / ELLIPTIC.	(83)30	COLLISION 3rd STAGE / AMSAT AFTER SEPARATION
L7	AR1 Attach fitting ACU 1497	1861 (21) (27)	GTO 8.5° 185Km	19-10-83	00h45'36"	INTELSAT / FORD	INTELSAT V / F7	1813	COMMUNICATIONS / GEO	(83)46	
L8	AR1 Attach fitting ACU 1497	1861 (21) (27)	GTO 8.5° 185Km	05-03-84	00h50'03"	INTELSAT / FORD	INTELSAT V / F8	1833	COMMUNICATIONS / GEO	(84)13	

ALL LAUNCHES FROM ELA 1

ARIANE LAUNCH RECORD

LAUNCHER				IGNITION		PAYLOAD				ESA REPORT	REMARKS
FLIGHT N°	CONFIG. Ref. M.U.A.	PERFORM Kg	ORBIT	DATE	TIME U.T.	CUSTOMER / MANUFACTURER	NAME	MASS Kg	MISSION / FINAL ORBIT	ESA/PB-AR	
V9	AR1 ACU 937	1237 (47)	GTO	23-05-84	01h33'29"	GTE / RCA	SPACENET F1	1195	COMMUNICATIONS / GEO	AMN/58	1st COMMERCIAL FLIGHT
V10	AR3 SYLDA 4400 Att. Ring TC1	2578 (12) (208)	GTO	04-08-84	13h32'54"	ESA / BAe FRENCH PTT / MATRA	ECS-2 TELECOM 1A	1172 1186	COMMUNICATIONS / GEO COMMUNICATIONS / GEO	(84)46	1st ARIANE 3
V11	AR3 SYLDA 4400 SH.	2445 (197.4) (68.4)	GTO	10-11-84	01h14'15"	ESA / BAe GTE / RCA	MARECS-B2 SPACENET F2	1060 1196	MARITIME COMMs / GEO COMMUNICATIONS / GEO	(84)61	
V12	AR3 SYLDA 4400	2552	GTO	08-02-85	23h22'00"	ARABSAT SATEL. COMM ORG. / AEROSPATIALE EMBRATEL / SPAR	ARABSAT F1 BRASILSAT F1	1215 1140	COMMUNICATIONS / GEO COMMUNICATIONS / GEO	(85)8	
V13	AR3 SYLDA 4400 Att. Ring TC1	2645.4 (204.5)	GTO	08-05-85	01h15'38"	GTE / RCA FRENCH PTT / MATRA	G-STAR 1 TELECOM 1B	1230.4 1210.5	COMMUNICATIONS / GEO COMMUNICATIONS / GEO	(85)30	
V14	AR1 ACU 937	1005.5 (48)	GTO	02-07-85	11h23'13"	ESA / BAe	GIOTTO	957.5	SCIENTIFIC / HELIOCENTRIC	(85)37	ATTEMPT RECOVERY 1st STAGE FAILED
V15	AR3 SYLDA 4400	2565.1 (195.6)	[GTO]	12-09-85	23h26'00"	GTE / RCA ESA / BAe	SPACENET F3 ECS-3	1195.8 1173.7	COMMUNICATIONS / [GEO] COMMUNICATIONS / [GEO]	(85)54	FAILURE 3rd STAGE
V16	AR1 ACU 1194	2422 (49)	SSO 98.4° 836.5 / 816.5 Km	22-02-86	01h44'35"	CNES / MATRA SWEDISH SPACE CORP. / SAAB	SPOT-1 VIKING	1835 538	EARTH OBSERVATION / SUNSYNCHRONOUS SCIENTIFIC / POLAR, 800-15,000 Km	(86)11	LAST ARIANE 1 1st NORTHWARD LAUNCH

ALL LAUNCHES FROM ELA 1

ARIANE LAUNCH RECORD

LAUNCHER				IGNITION		PAYLOAD				ESA REPORT	REMARKS
FLIGHT N°	CONFIG. Ref. M.U.A.	PERFORM. Kg	ORBIT	DATE	TIME U.T.	CUSTOMER / MANUFACTURER	NAME	MASS Kg	MISSION / FINAL ORBIT	ESA/PB AR	
V17 *	AR3 SYLDA 4400	2631.1 (193.7)	GTO	28-03-86	23h00'00"	GTE / RCA EMBRATEL / SPAR	G-STAR 2 BRASILSAT F2	1242.6 1194.8	COMMUNICATIONS / GEO COMMUNICATIONS / GEO	(86)18	1st LAUNCH FROM ELA 2
V18	AR2 ACU 1497 Alt. Mting	2004.3 (27) (20)	[GTO 8° 463 Km]	31-05-86	00h53'00"	INTELSAT / FORD	INTELSAT V F14	1956.5	COMMUNICATIONS / [GEO]	(86)30	1st ARIANE 2 FAILURE OF 3rd STAGE
V19	AR3 SYLDA 4400	2562.5 (193.5)	GTO	16-09-87	00h45'28"	AUSSAT Pty Ltd / HUGHES	AUSSAT K3	1195.6	COMMUNICATIONS / GEO	(87)60	
						ESA / BAe	ECS-4	1173.4	COMMUNICATIONS / GEO		
V20 *	AR2 Specific ACU	2134 (53)	GTO 4°	21-11-87	02h19'00"	MIN. FOR RESEARCH AND TECHN. OF RFD / EUROSATELLITE	TV SAT 1	2081	COMMUNICATIONS / GEO	(87)70	
V21	AR3 SYLDA 4400	2632.8 (190.9)	GTO	11-03-88	23h28'00"	SPACENET / RCA	SPACENET IIIC / GEOSTAR R01	1216.8	COMMUNICATIONS / GEO	(88)17	
	TCI ACU ring Clampband	(4.5) (6.6)				FRANCE TELECOM / MATRA	TELECOM 1C	1214	COMMUNICATIONS / GEO		
V23	AR2 ACU 1497 Alt. Ring	2024 (27) (21)	GTO 8° 463 Km	17-05-88	23h58'00"	INTELSAT / FORD	INTELSAT V F13	1978	COMMUNICATIONS / GEO	(88)32	
A401 (V22) *	AR44LP 120 SPELDA (SP. H.) Carr. struct ACU 937 Ballast	3497 (409.7) (193.8) (767.5) (47.35) (222)	GTO 10° 220 Km	15-06-88	11h19'01"	ESA / AEROSPATIALE	METEOSAT P2	696	METEO & TIMESYNCHRO / GEO	(88)33	1st ARIANE 4 DEMONSTRATION FLIGHT
						AMSAT CORP. / AMSAT	OSCAR 13	144	RADIO AMATEURS / ELLIPTIC		
						PAN AMERICAN SATELLITE / RCA	PAN AMERICAN SATELLITE	1220	COMMUNICATIONS / GEO		
V24	AR3 SYLDA 4400	2565.9 (189.4)	GTO	21-07-88	23h12'00"	INDIAN SPACE RESEARC ORG. / ISRO	INSAT 1C	1191.1	COMMs & METEO / GEO	(88)39	
						ESA / BAe	ECS-5	1185.4	COMMUNICATIONS / GEO		

* LAUNCHES FROM ELA 2

ARIANE LAUNCH RECORD

LAUNCHER				IGNITION		PAYLOAD				ESA REPORT	REMARKS
FLIGHT N°	CONFIG. Ref. M.U.A.	PERFORM. Kg	ORBIT	DATE	TIME U.T.	CUSTOMER / MANUFACTURER	NAME	MASS Kg	MISSION / FINAL ORBIT	ESA/PB AR	
V25 *	AR3 SYLDA 4400	2699.8 (189.3)	GTO	06-09-88	23h00'00"	GTE / RCA	G-STAR III / GEOSTAR 802	1271.5	COMMUNICATIONS / GEO	(88)51	
						SAT. TRANSPONDER LEASING / HUGHES	SBS 5	1230	COMMUNICATIONS / GEO		
V26	AR2 Specific ACU	2130.7 (54)	GTO 4° 265 Km	28-10-88	02h17'03"	TELEDIFFUSION DE FRANCE / EUROSATELLITE	TDF 1	2076.7	TV BROADCASTING / GEO	(88)66	
V27 *	AR44LP 120 ACU 937 SPELDA ACU 1194	3710 (494) (417) (434)	GTO	11-12-88	00h03'38"	UK MINISTRY OF DEFENCE / BAe	SKYNET 4B	1429.1	MILITARY COMMs / GEO	(89)1	
						SOCIETE EUROP DES SATELLITES / RCA	ASTRA 1	1767.7	TV BROADCASTING / GEO		
V28	AR2 ACU 1497 Attach fitting	2027 (26) (20)	GTO 8° 463 Km	27-01-89	01h21'00"	INTELSAT / FORD	INTELSAT V F15	1981	COMMUNICATIONS / GEO	(89)2	
V29 *	AR44LP 120 ACU 1666A SPELDA ACU 937C	3475.1 (487) (412) (526)	GTO	06-03-89	23h29'00"	JAPAN COMM. SAT. COMPANY / HUGHES	JC-SAT 1	2280	COMMUNICATIONS / GEO	(89)16	
						ESA / AEROSPATIALE	MOP 1	681.5	METEOROLOGICAL / GEO		
V30	AR2 Specific ACU	2142 (52)	GTO 4° 250 Km	02-04-89	02h28'00"	NORDIC SAT. CPNY / EUROSATELLITE	TELE-X	2090	TV BROADCASTING / GEO	(89)25	LAST ARIANE 2
V31 *	AR44L 110 ACU 1194B SPELDA ACU 937	4418 (627) (405.4) (484)	GTO	05-06-89	22h37'18"	SPACE COMM. CORP / FORD	SUPERBIRD A	2489.2	COMMUNICATIONS / GEO	(89)36	FIRST AR44L / UPGRADED PERFORMANCE (213 Kg ABOVE SPECIFIED MAXIMUM)
						DEUTSCHE BUNDES POST / KONSORTIUM II DFS	DFS KOPERNIKUS	1415.8	COMMUNICATIONS / GEO		
V32	AR3 ACU 1194	2660.3 (483)	GTO	12-07-89	00h14'00"	ESA / BAe	OLYMPUS	2612	COMMUNICATIONS / GEO	(89)37	LAST ARIANE 3 LAST LAUNCH FROM ELA 1

* LAUNCHES FROM ELA 2

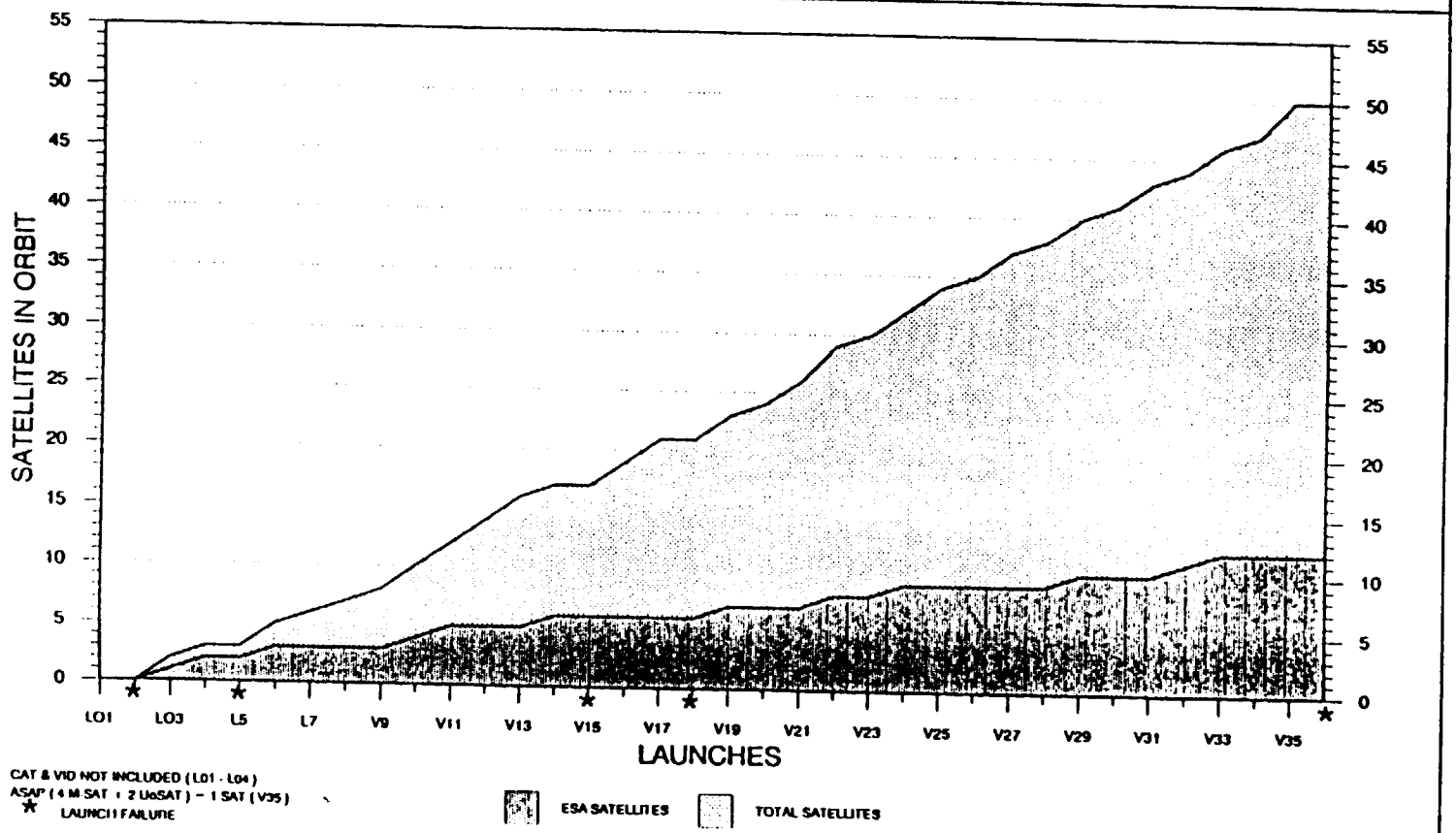
ARIANE LAUNCH RECORD

LAUNCHER				IGNITION		PAYLOAD				ESA REPORT	REMARKS
FLIGHT N°	CONFIG. Ref. M.U.A.	PERFORM Kg	ORBIT	DATE	TIME U.T.	CUSTOMER / MANUFACTURER	NAME	MASS Kg	MISSION / FINAL ORBIT	ESA/PB-AR	
V33	AR44LP 120 Specific ACU SPELDA ACU 937	3730 (53) (417.6) (47.4)	GTO	08-08-89	23h25'53"	MIN. FOR RESEARCH AND TECHN. OF FRG / EUROSATELLITE	TV SAT 2	2073	COMMUNICATIONS / GEO	(89)38	
						ESA / MATRA	HIPPARCOS	1139	ASTRONOMETRY MISSION / GTO		
V34	AR44L 020 Specific ACU	4286 (75)	GTO	27-10-89	23h05'00"	INTELSAT / HUGHES	INTELSAT VI F2	4211	COMMUNICATIONS / GEO	(89)58	
V35	AH40 020 ACU 1194 BALLAST A.S.A.P.	2215.2 (57.4) (81.2) (60.65)	SSO	22-01-90	01h05'27"	CNES / MATRA	SPOT-2	1875	EARTH OBSERVATION / SUNSYNCHRONOUS	(90)4	
						UoSAT/SST / UNIVERSITY OF SURREY - UK	UoSAT D	46	EXP. SCIENTIFIC, TELECOM, TECHNO. DEMO. / POLAR		
							UoSAT E	47			
						AMSAT N.A. - USA	Microsat A	13.34	EDUCATION AND COMMUNICATION / POLAR		
							Microsat B	12.92			
							Microsat C	16.03			
							Microsat D	13.76			
V36	AR44L 120 ACU 1194B SPELDA ACU 937	4250 (49) (403.3) (46.5)	[GTO]	22-02-90	23h17'00"	Space Communication Corporation (SCC) / FORD	SUPERBIRD - B	2501.3	COMMUNICATIONS / [GEO]	(90)12	FAILURE OF FIRST STAGE
						Nippon Hoso Kyokai (NHK) / GE Astro Space Division	BS - 2X	1249.8	COMMUNICATIONS / [GEO]		

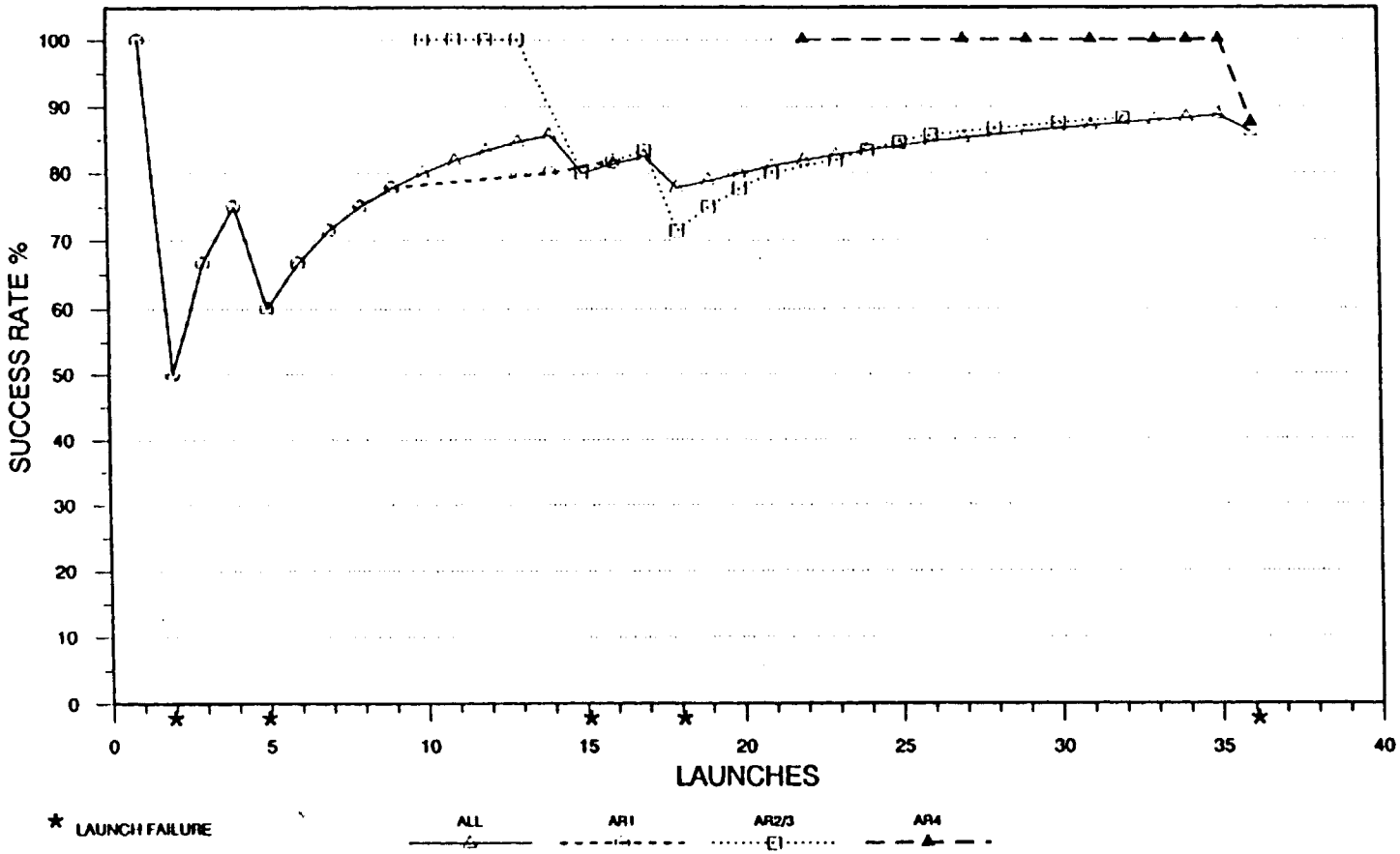
ALL LAUNCHES FROM ELA 2

ARIANE LAUNCH RECORD

Ref. STS/AO/CU/GW PAGE A1



ARIANE LAUNCH RECORD



ENVIRONMENTAL CONSIDERATIONS

Joyce Jatko NASA HQ

ENVIRONMENTAL CONCERNS IN PROPULSION TECHNOLOGY

ENVIRONMENTAL MEDIA

- AIR EMISSIONS
  - RESTRICTIONS DEPENDENT ON LOCATION OF TESTING
  - REGULATED BY TOTAL EMISSIONS OR CHANGE TO AMBIENT AIR QUALITY
  - CONTROL TECHNOLOGY NOT ALWAYS AVAILABLE (DEVELOPMENTAL REQMT)
  - CHLOROFLUOROCARBONS (CFCs) - RESTRICTIONS ON AVAILABILITY

- NUCLEAR
  - PUBLIC CONCERN OVER SAFETY
  - DOE PROBLEMS AND RESULTANT PUBLIC PERCEPTIONS

- HAZARDOUS WASTE MANAGEMENT
  - REGULATIONS BECOMING MORE RESTRICTIVE
  - EXOTIC FUELS MORE DIFFICULT TO DISPOSE OF
  - DISPOSAL COSTS ACCELERATING
  - WASTE PROPELLANT DISPOSAL OPTIONS BECOMING MORE LIMITED

- NATIONAL ENVIRONMENTAL POLICY ACT (NEPA)
  - NEPA CONCERNS MUCH GREATER VISIBILITY THAN IN PAST
  - PROCESS REQUIRED PRIOR TO IMPLEMENTING NEW PROGRAMS
  - 12-18 MONTH PROCEDURE BEFORE RECORD OF DECISION CAN BE ISSUED

IMPACT TO PROGRAM

- SCHEDULE: NEED TO PLAN ON TIME FOR:
  - NEPA PROCESS (NEW TEST SITES)
  - PERMITS (AIR AND/OR WATER DISCHARGES, HAZARDOUS WASTE

- COST (INCREASED COSTS FOR TESTING PROGRAMS)
  - HAZARDOUS WASTE DISPOSAL COSTS INCREASING SHARPLY
  - CFC's INCREASING IN COST, DECREASING AVAILABILITY
  - FUNDING OF R&D EFFORT FOR:
    - CLEANER PROPELLANT
    - WASTE MINIMIZATION
    - MATERIALS SUBSTITUTION

- LOCATION OF TESTING
  - SOME SITES MAY REPRESENT INCREASED ENVIRONMENTAL COSTS
  - TESTING MAY NEED TO BE PERFORMED AT SITE ALREADY PERMITTED
  - THERE MAY BE RESTRICTIONS ON EXPANSION OF EXISTING FACILITIES

NEED FOR GREATER COOPERATION AMONG CENTERS

- SUPPORT FOR TEST PROGRAMS IN LESS ENVIRONMENTALLY SENSITIVE AREAS

- MORE SHARING OF TEST FACILITIES

- PLANNING FOR ENVIRONMENTAL COMPLIANCE
  - ADVANCED PLANNING AND COORDINATION
  - COST AND SCHEDULE IMPACTS

NASA PROPULSION ENGINEERING RESEARCH CENTER AT PENN STATE SECOND ANNUAL SYMPOSIUM

PENNSTATE

NASA Propulsion Engineering Research Center at Penn State

Second Annual Symposium

Thursday, June 28, 1990
Kern Auditorium
The Pennsylvania State University
University Park, PA

AGENDA

Session A: Liquid Propellant Combustion
Rm. 112 Kern

Session Chairman: Dr. Robert J. Santoro

2:00	Dr. Charles L. Merkle, Director	Center Overview
2:30	Dr. Kenneth K. Kuo and Dr. Robert J. Santoro	Cryogenic Combustion Laboratory
3:00	Dr. Stephen R. Turns	Ignition and Combustion of Metallized Propellants
3:30	Dr. Vigor Yang	Theoretical Study of Combustion Instabilities in Liquid-Propellant Rocket Motors
4:00	Dr. Harold R. Jacobs and Dr. Robert J. Santoro	Spray Combustion under Oscillatory Pressure Conditions
4:30	Dr. Fan-Bill Cheung and Dr. Kenneth K. Kuo	Liquid Jet Breakup and Atomization in Rocket Chambers under Dense Spray Conditions with Compression/Shock Wave Interaction
5:00	Dr. Domenic Santavicca	Turbulence-Droplet Interactions in Vaporizing Sprays
		Laser Spark Ignition

Session B: Liquid Propulsion Technologies
Rm. 101 Kern

Session Chairman: Dr. Michael M. Micci

2:00	Dr. Charles L. Merkle, Director	Center Overview **(Rm. 112 Kern)**
2:30	Dr. Robert Pangborn and Dr. Richard A. Queeney	Hydrogen Management in Materials for High Pressure Hydrogen/Oxygen Engines
3:00	Dr. Alok Sinha and Dr. Kon-Well Wang	Robust and Real-Time Control of Magnetic Bearings for Advanced Propulsion Rockets
3:30	Dr. Marc Carpino	Analysis of Foil Bearings for High Speed Operation in Cryogenic Applications
4:00	Dr. Laura Pauley	A Study of Methods to Investigate Nozzle Boundary Layer Transition
4:30	Dr. Michael M. Micci	Optical Diagnostic Investigation of Low Reynolds Number Nozzle Flows
5:00	Dr. Charles L. Merkle	Flowfield Analysis of Low Reynolds Number Rocket Engines

LIQUID PROPELLANT COMBUSTION