Chapter 15

Aeronautics and astronautics

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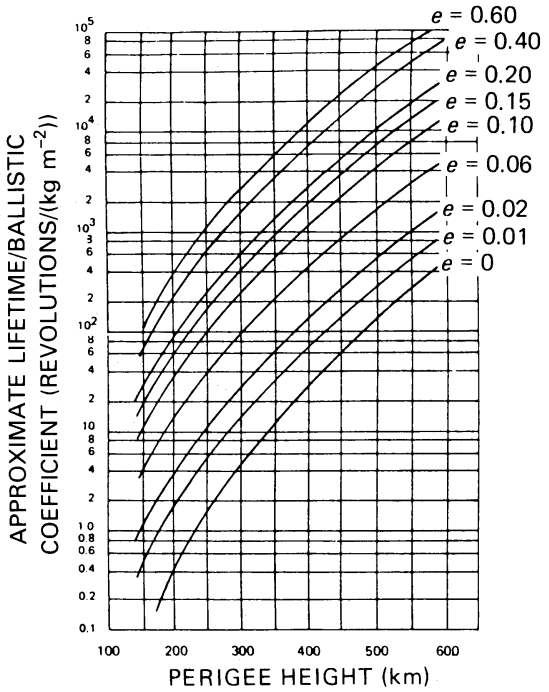
Approximate lifetimes for Earth satellites



$$\text{Lifetime} = NP = N\left[\frac{4\pi^2}{GM_E}\left(\frac{h_p + R_E}{1-e}\right)^3\right]^{1/2},$$

where

N = number of orbit revolutions in the satellite lifetime from the above diagram.

Ballistic coefficient $= m/(C_D A)$ (typically, 25–100 kg m^{-2}),

m = mass of the satellite,

C_D = the drag coefficient ($\approx$ 1–2),

A = satellite cross-sectional area perpendicular to the velocity vector,

G = gravitational constant,

h_p = perigee height,

e = eccentricity of the orbit,

P = satellite period,

M_E = mass of the Earth,

R_E = radius of the Earth.

$$\text{Lifetime (d)} \approx 1.15 \times 10^{-7} \times N \times \left(\frac{6378.14 + h_p\ (\text{km})}{1-e}\right)^{3/2}.$$

Satellite period (hr) $= 1.41(a/R_E)^{3/2}$,

where a = semi-major axis.

(Adapted from Wertz, J., ed., *Spacecraft Attitude Determination and Control*, D. Reidel Publ. Co., 1980.)

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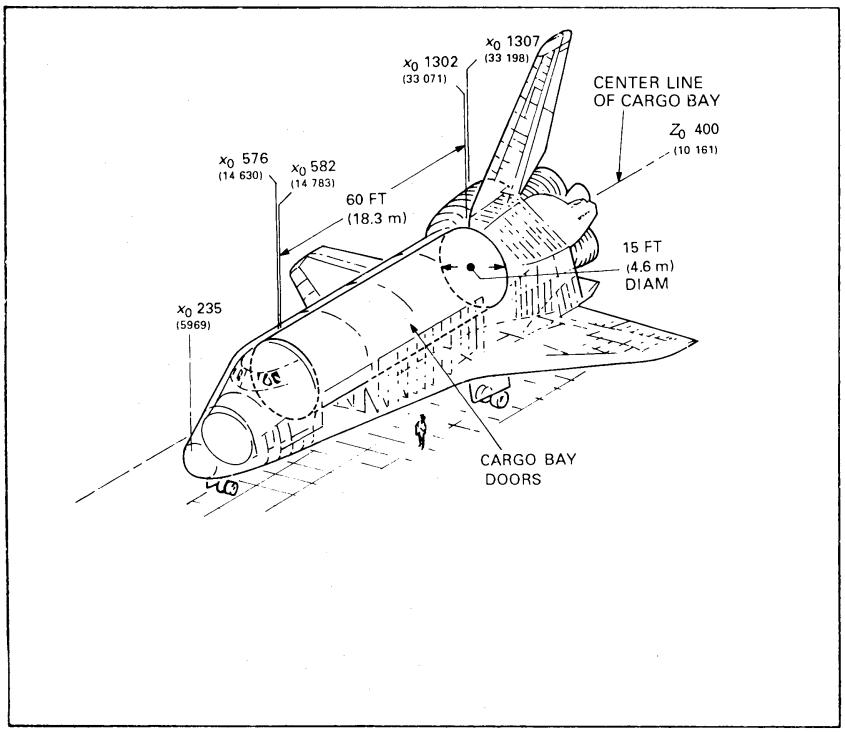
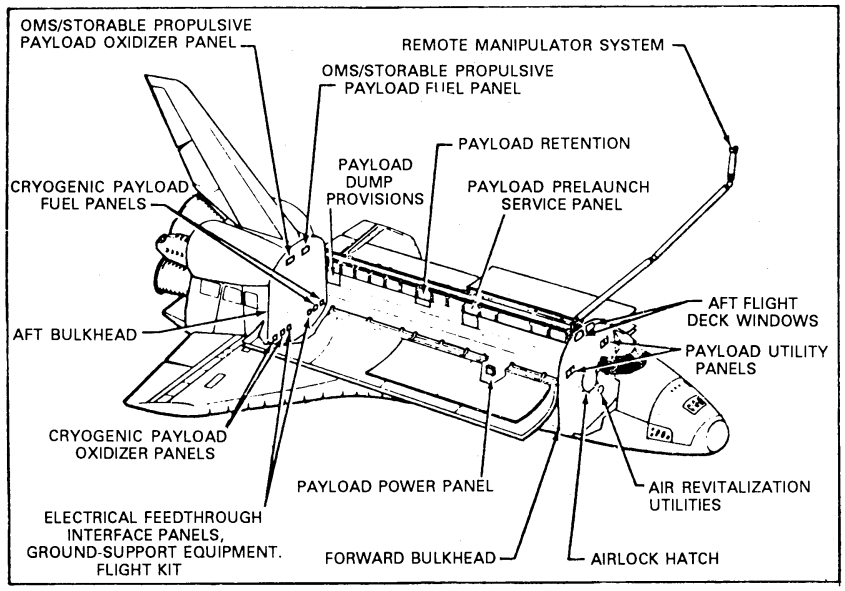
Orbiter coordinate system and cargo bay envelope. The dynamic clearance allowed between the vehicle and the payload at each end is also illustrated.



Principal Orbiter interfaces with payloads.



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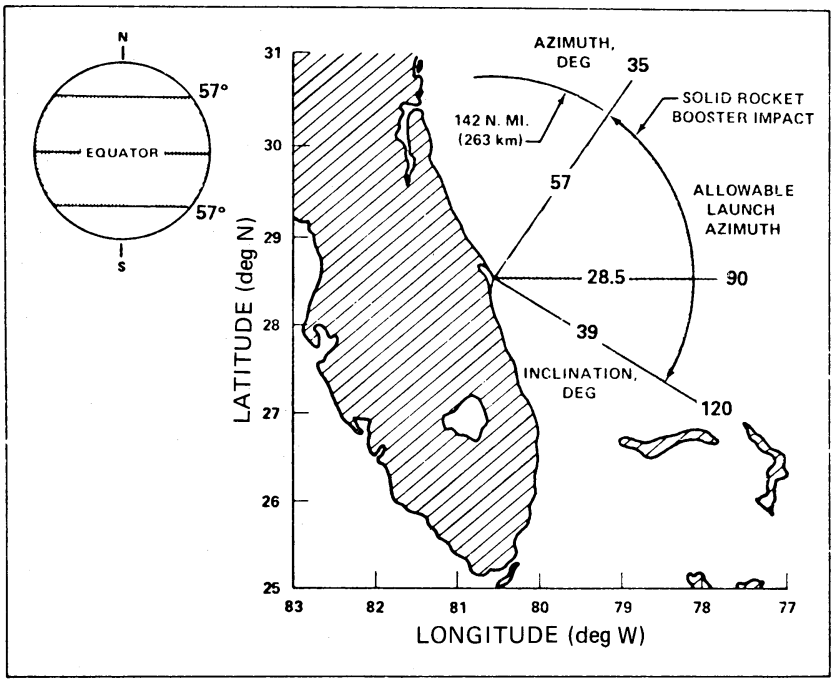
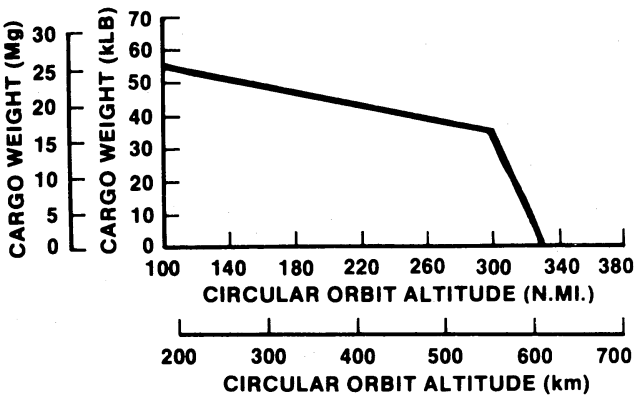
Launch azimuth and inclination limits from KSC in Florida. The inset globe illustrates the extent of coverage possible when launches are made from KSC.



Cargo capability for a KSC (28.45 degree inclination) launch.



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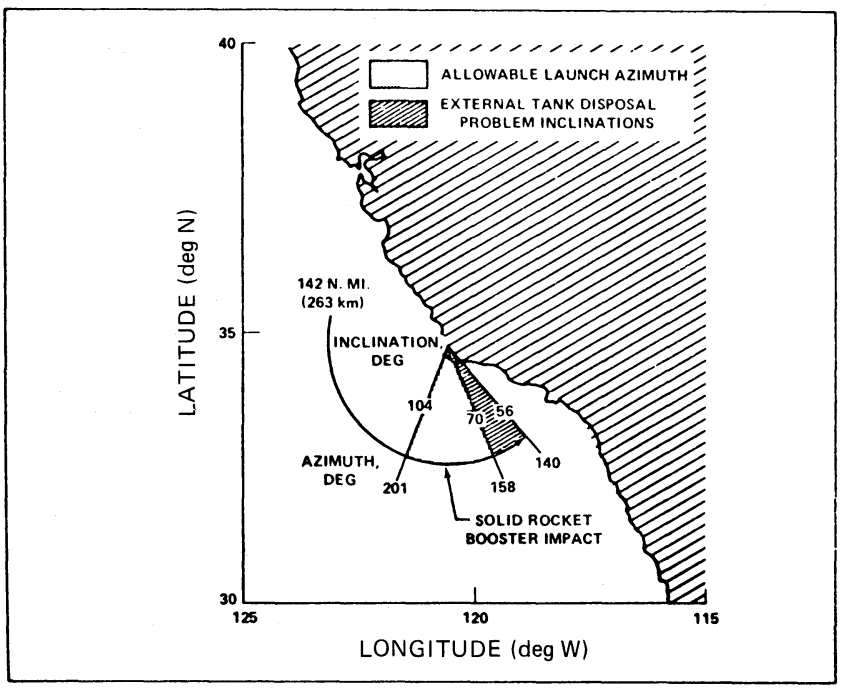
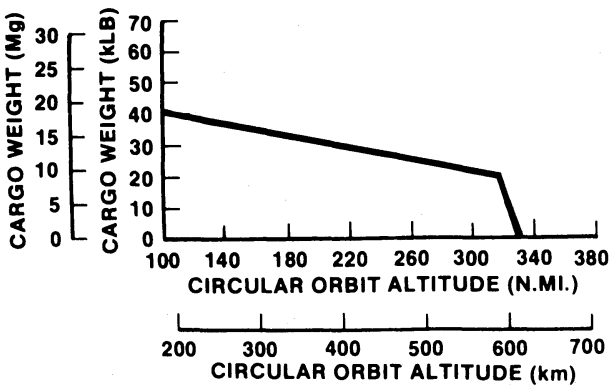
Launch azimuth and inclination limits from VAFB in California. Note added in proof: no longer to be used for shuttle launches.



Cargo capability for a KSC (57 degree inclination) launch.



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Launch vehicles

Current US space launch capabilities

Vehicle	Stages	Thrust, kilonewtons (pounds × 1000)	Launch sites†	Orbit, kilometers (nautical miles)	Inclination (degrees)	Payload weight, kilograms (pounds)
SCOUT	1. Algol III A 2. Castor II A 3. Antares III A 4. Altair III A	431.1(96.9) 285.2(64.1) 83.1(18.7) 25.6(5.8)	SLC-5 WSMC	556(300)	0	181(400)
Delta 3914	0. 9 Castor IVs 1. Extended long tank 2. Standard 2nd stage 3. TE-M-364-4 solid rocket motor	378.0(85.0) ea 921.0(207.0) 41.8(9.4) 65.8(14.8)	LC-17 A&B ESMC SLC-2W WSCS	185 × 35 786 (100 × 19 323)	27	937(2065)
Delta 3910/ PAM	0. 9 Castor IVs 1. Extended long tank 2. Standard 2nd stage 3. Payload assist module (PAM)	378.0(85.0) ea 921.0(207.0) 41.8(9.4) 84.5(19.0)	LC-17 A&B ESMC SLC-2W WSMC	296 × 35 786 (160 × 19.323)	27	1111(2450)
Delta 3920/ PAM	0. 9 Castor IVs 1. Extended long tank 2. Improved 2nd stage 3. Payload assist module (PAM)	378.0(85.0) ea 921.0(207.0) 41.8(9.4) 84.5(19.0)	LC-17 A&B ESMC SLC-2W WSMC	296 × 35 786 (160 × 19 323)	27	1270(2800)

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Atlas E	1. MA-3 2-Boosters 1-Sustainer	1748.1(393.0)	SLC-3 WSMC	157 × 20 198 (85 × 10 900)	63	1088(2398)
	2. SGS II	65.8(14.8)				
Atlas H	1. MA-5 2-Boosters 1-Sustainer	1948.2(438.0)	LC-36 ESMC SLC-3 WSMC	157 × 20 198 (85 × 10 900)	55	1225(2700)
	2. SGS II	65.8(14.8)				
Atlas SLV-3D Centaur	1. MA-5 2-Boosters 1-Sustainer	1912.6(430.0)	LC-36 ESMC	185 × 35 786 (100 × 19 323)	27	1996(4400)
	2. Centaur DI-A (RL-10)	133.4(30.0)				
Atlas G Centaur	1. MA-5 2-Boosters 1-Sustainer	1948.2(438.0)	LC-36 ESMC	185 × 35 786 (100 × 19 323)	27	2359(5200)
	2. Centaur (RL-10-3A)	146.8(33.0)				
Titan 34B Agena	1. LR-87 2. LR-91 3. Ascent Agena	2059.4(463.0) 449.2(101.0) 75.6(17.0)	SLC-4 WSMC	185(100) Circular	90	3583(7900)
Titan 34D NUS	0. Two $5\frac{1}{2}$ segment SRMs 1. LR-87 2. LR-91	12 454.4(2800.0) 2353.0(529.0) 449.2(101.0)	SLC-4 WSMC	185(100) Circular	90	12 520(27 600)
Titan 34D Transtage	0. Two $5\frac{1}{2}$ segment SRMs 1. LR-87 2. LR-91 3. Transtage	12 454.4(2800.0) 2353.0(529.0) 449.2(101.0) 71.2(16.0)	LC-40 ESMC	35 876(19 323) Circular	0	843(1859)

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Current US space launch capabilities (*cont.*)

Vehicle	Stages	Thrust, kilonewtons (pounds × 1000)	Launch sites†	Orbit, kilometers (nautical miles)	Inclination (degrees)	Payload weight, kilograms (pounds)
Titan 34D IUS	0. Two 5½ segment SRMs	12 454.4(2800.0)	LC-40	35 876(19 323)	0	843(1859)
	1. LR-87	2353.0(529.0)	ESMC	Circular		
	2. LR-91	449.2(101.0)				
	3. IUS					
	Stage 1	186.8(42.0)				
	Stage 2	75.6(17.0)				
STS	0. 2 Solid rocket boosters	11 155.0(2508.0) ea	LC-39	278(150)	28.5	29 500
	1. 3 Main engines	1668.0(375.0) ea	ESMC	Circular		(65 000)
	2. Inertial upper stage					
	(Two stage)	196.0(44.1)	STS	35 786(19 323)	0	2267(5000)
		74.7(16.8)	Parking orbit	Circular		
	or 2. Inertial upper stage					
	(Twin stage)	196.2(44.1)	STS	Planetary	N/A	4993(11 009)
		196.2(44.1)	Parking orbit	missions		
	or 2. PAM-D	84.5(19.0)	STS	278 × 35 786	27	1052(2320)
			Parking orbit	(150 × 19 323)		

† Launch sites at the Eastern Space and Missile Center (ESMC) are designated as launch complexes (LC) and if served by the same launch control center, are further designated as A or B. Launch sites at the Western Space and Missile Center (WSMC) are designated as Space Launch complexes (SLC) and if served by the same launch control center are further designated as E(ast) or W(est).

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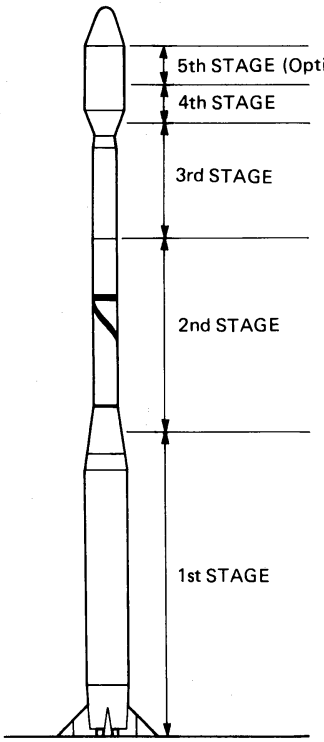
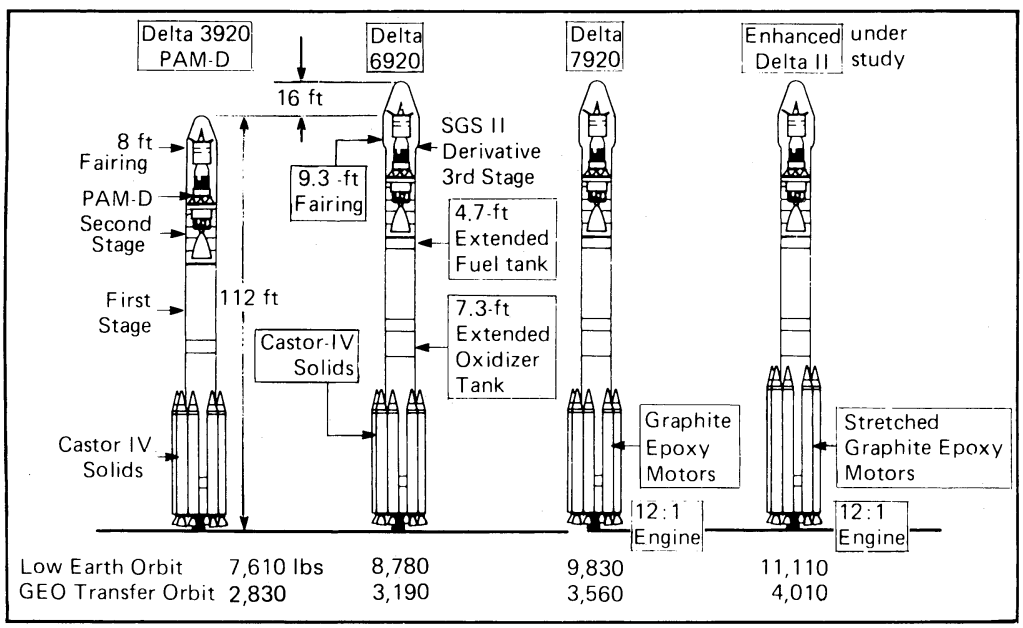
US launch vehicles



STAGE IV		
Height	m (feet)	1.2 (4.0)
Diameter	m (feet)	0.7 (2.1)
Thrust	kn (pounds X 1000)	25.6 (5.8)
STAGE III		
Height	m (feet)	3.4 (11.2)
Diameter	m (feet)	0.8 (2.5)
Thrust	kn (pounds X 1000)	83.1 (18.7)
STAGE II		
Height	m (feet)	6.3 (20.7)
Diameter	m (feet)	0.8 (2.6)
Thrust	kn (pounds X 1000)	285.2 (64.1)
STAGE I		
Height	m (feet)	9.4 (30.8)
Diameter	m (feet)	1.1 (3.8)
Thrust	kn (pounds X 1000)	431.1 (96.9)

Scout

(Ling–Temco–Vogt.)



Delta

(McDonnell Douglas Astronautics Co.)

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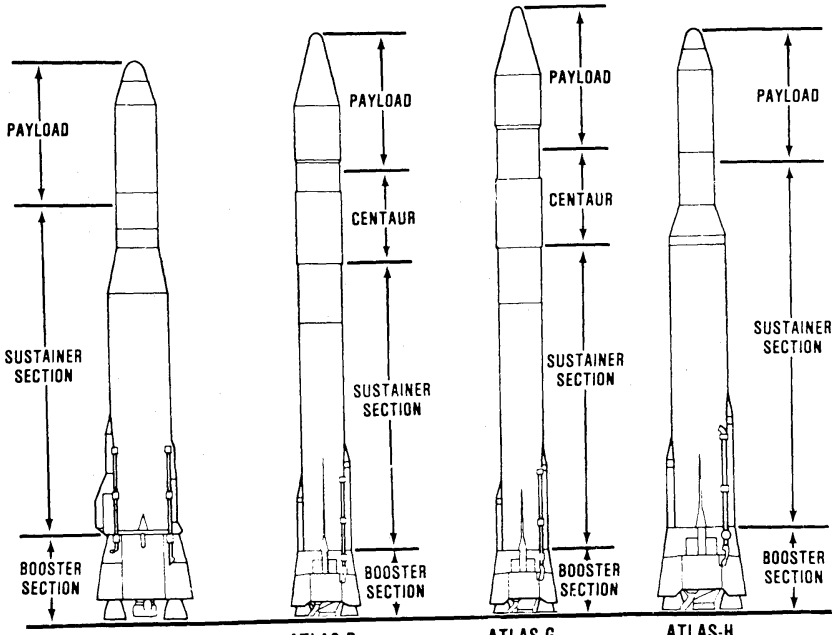
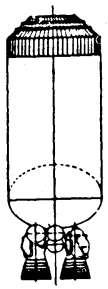
US launch vehicles (*cont.*)



		ATLAS-E	ATLAS-D	ATLAS-G	ATLAS-H
Height	m (feet)	20.6 (67.3)	20.2 (65.9)	22.2 (72.6)	20.2 (65.9)
Diameter	m (feet)	3.0 (10.0)	3.0 (10.0)	3.0 (10.0)	3.0 (10.0)
Thrust	kn (pounds × 1,000)				
Liftoff		1,748.1 (393.0)	1,645.8 (370.0)	1,681.3 (378.0)	1,681.3 (378.0)
Sustainer		253.5 (57.0)	266.8 (60.0)	266.8 (60.0)	266.8 (60.0)

Atlas



Centaur

(General Dynamics Convair Division.)

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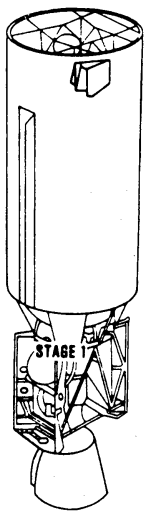

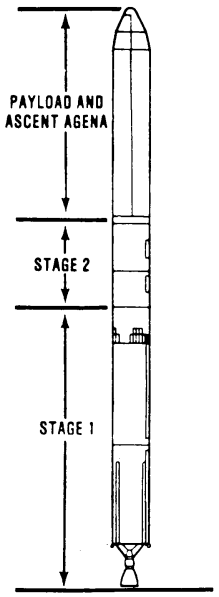

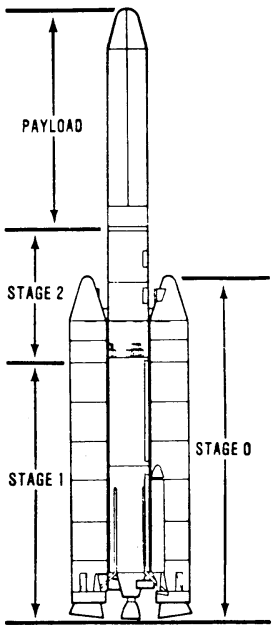

		Ascent Agena	TITAN 34B	TITAN 34D/ No Upper Stage
STAGE II				
Height	m (feet)		9.6 (31.3)	9.6 (31.3)
Diameter	m (feet)		3.1 (10.1)	3.1 (10.0)
Thrust	kn (pounds × 1,000)		449.2 (101.0)	449.2 (101.0)
STAGE I				
Height	m (feet)		23.8 (77.8)	23.8 (77.8)
Diameter	m (feet)		3.1 (10.0)	3.1 (10.0)
Thrust	kn (pounds × 1,000)		2,059.4 (463.0)	2,353.0 (529.0)
STAGE 0			N/A	
Height	m (feet)			27.6 (90.4)
Diameter	m (feet)			3.1 (10.2) ea
Thrust	kn (pounds × 1,000)			6,227.2 (1,400.0) ea

Titan

(Martin Marietta Denver Aerospace.)

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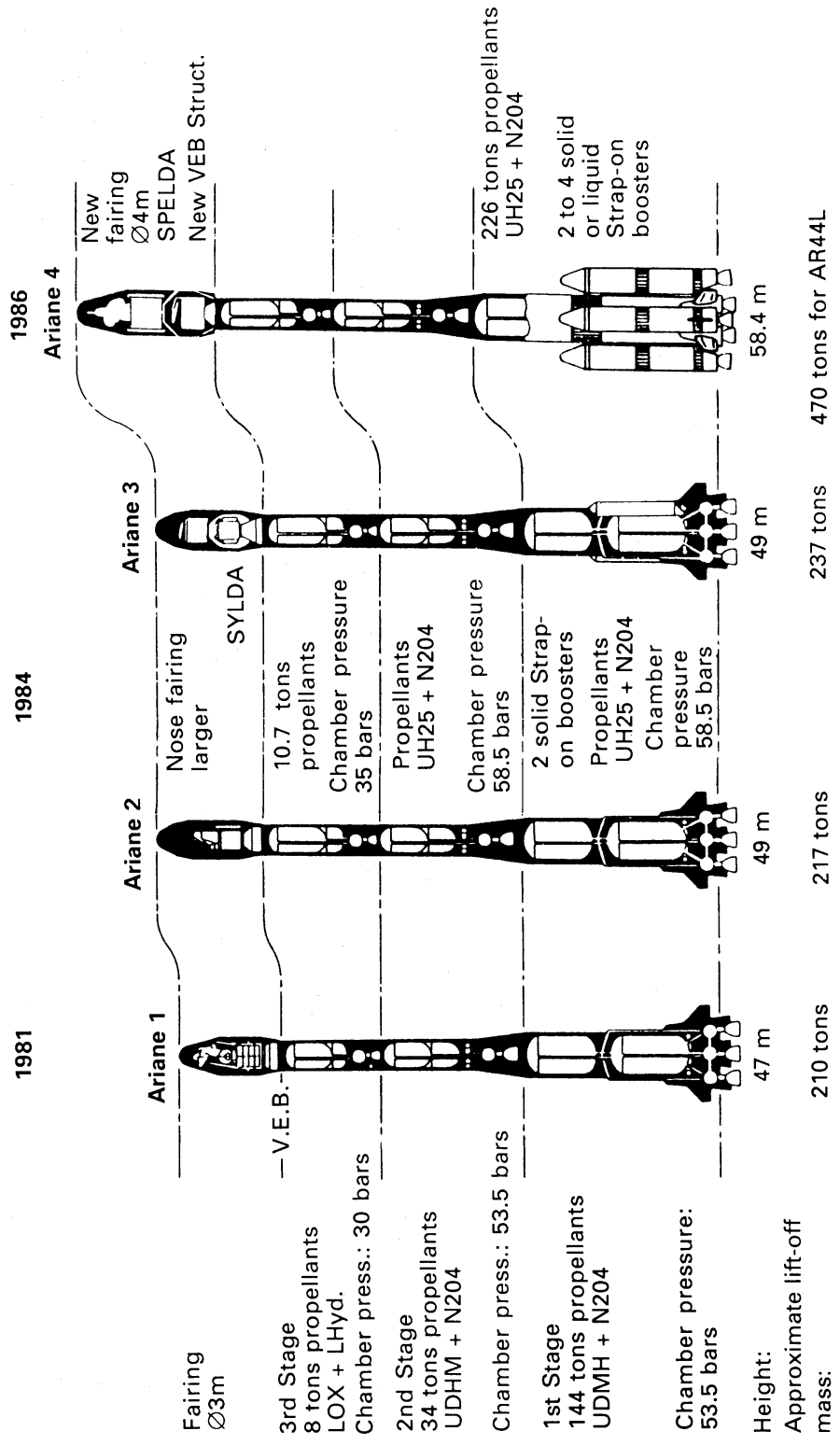
French launch vehicles



(Diagrams courtesy Arianespace.)

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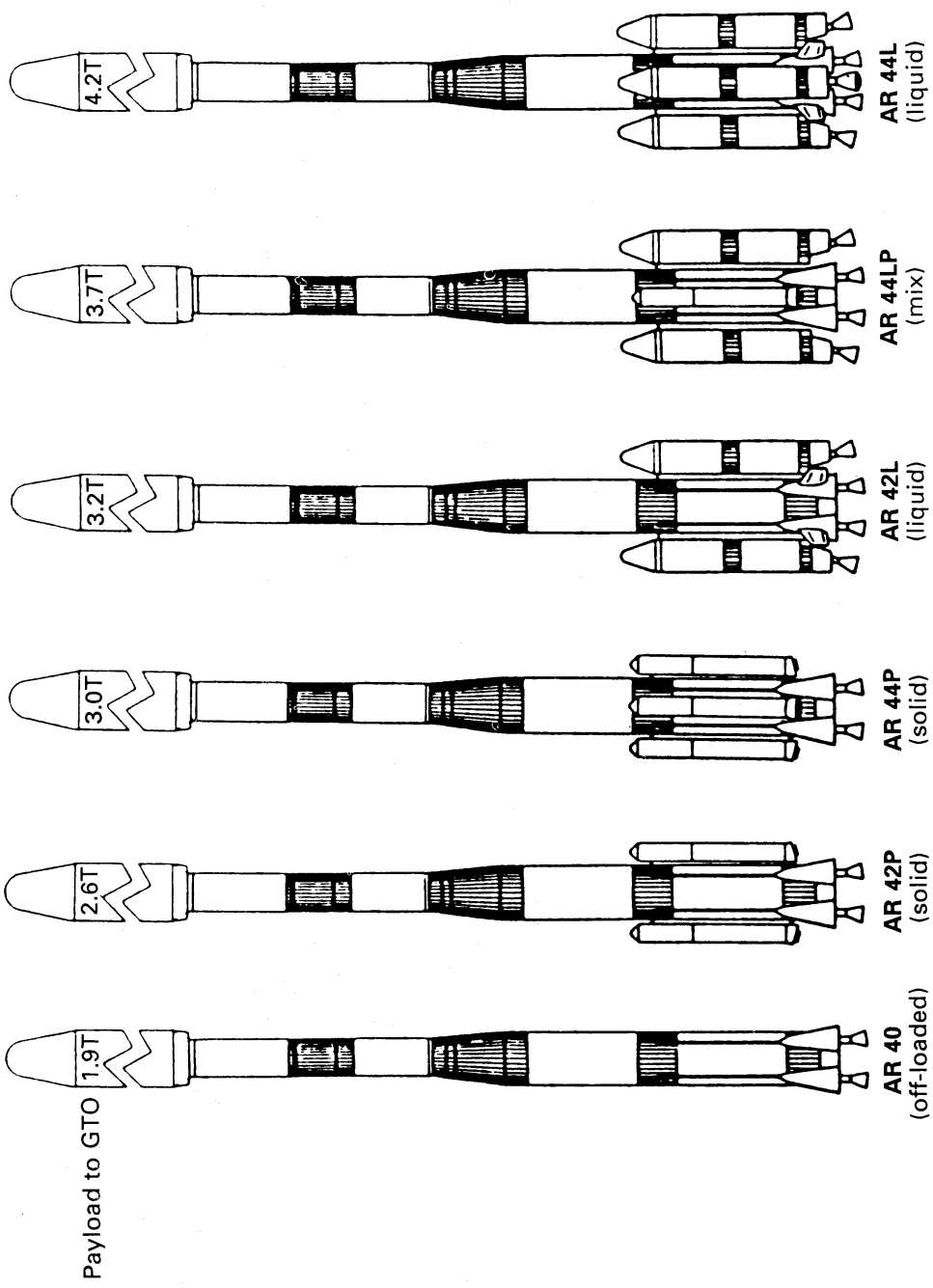

The Ariane 4 configurations

(Diagrams courtesy Arianespace.)

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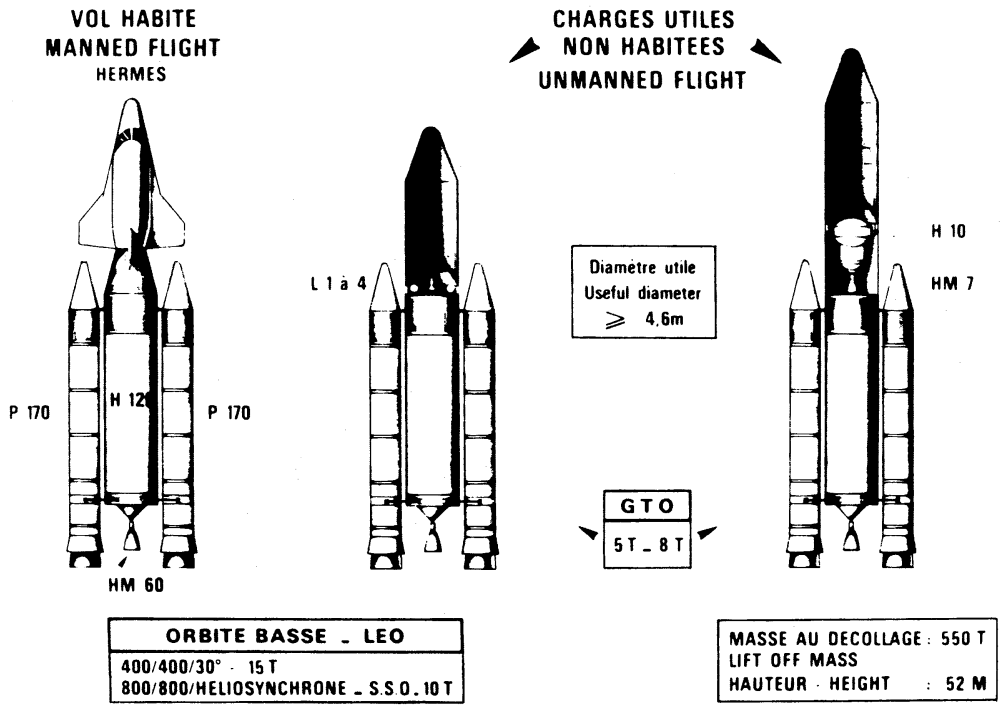
ARIANE 5



(Aérospatiale.)

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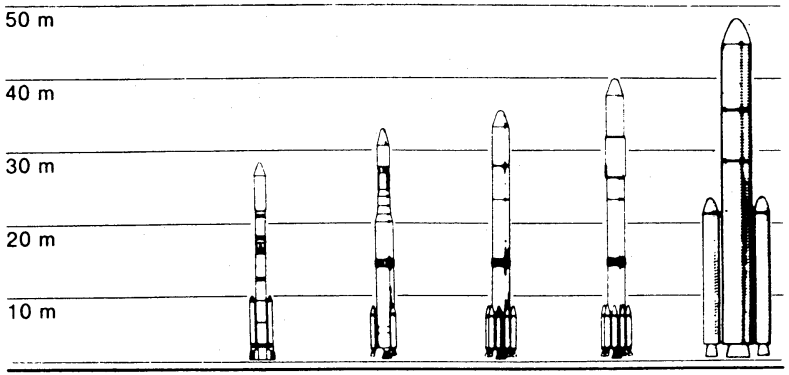
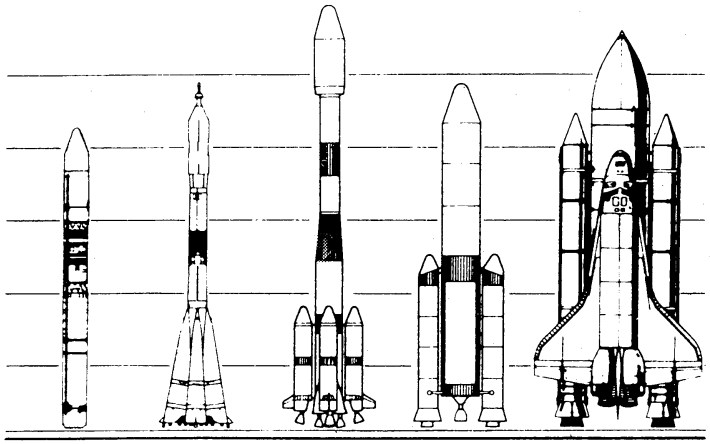
Japanese launch vehicles

Rockets of Japan and other typical rockets in the world



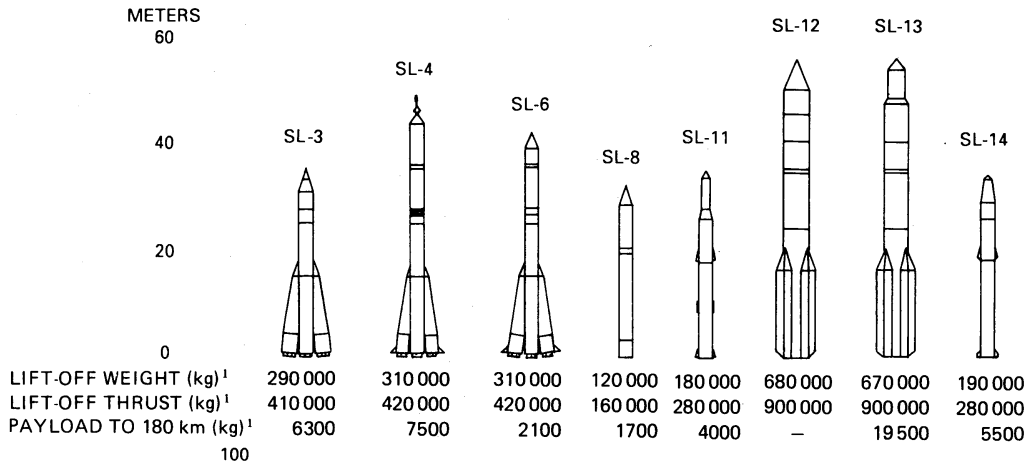


Rocket name	M-3SII (ISAS)	N-I (NASDA)	N-II (NASDA)	H-I (NASDA)	H-II (NASDA)	CZ-3 (CHINA)	A-2 (USSR)	ARIANE 4 (ESA)	ARIANE 5 (ESA)	Space Shuttle (USA)
Total weight (t)	61	90	135	140	258	–	–	460	500	2041
Payload capacity into LEO†(kg)	670	1200	2000	3000	8000	5000	–	8000	15 000	29 500
Payload capacity into GEO†(kg)	–	130	350	550	2000	–	–	2200	4000	2400 (using upper stage)

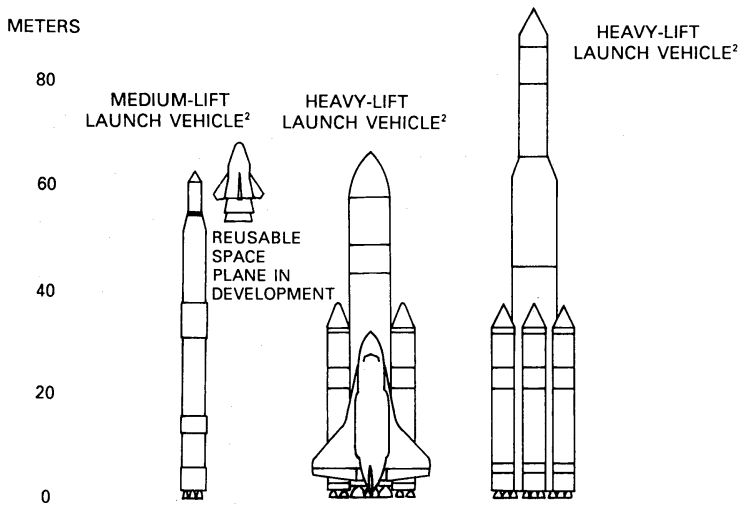
Reproduced from General Outline of H-II Rocket, *published by NASDA, the National Space Development Agency of Japan. (ISAS refers to the Japanese Institute of Space and Astronomical Science, ESA to the European Space Agency.)*

†LEO: Low Earth Orbit
†GEO: Geostationary Earth Orbit

Soviet launch vehicles



	SL-3	SL-4	SL-6	SL-8	SL-11	SL-12	SL-13	SL-14
LIFT-OFF WEIGHT (kg)[1]	290 000	310 000	310 000	120 000	180 000	680 000	670 000	190 000
LIFT-OFF THRUST (kg)[1]	410 000	420 000	420 000	160 000	280 000	900 000	900 000	280 000
PAYLOAD TO 180 km (kg)[1]	6300	7500	2100	1700	4000	–	19 500	5500



	MEDIUM-LIFT LAUNCH VEHICLE[2]	HEAVY-LIFT LAUNCH VEHICLE[2]	HEAVY-LIFT LAUNCH VEHICLE[2] WITH 6 OR MORE STRAP ON BOOSTERS
LIFT-OFF WEIGHT (kg)[1]	400 000	2 000 000	4 000 000
LIFT-OFF THRUST (kg)[1]	600 000	3 000 000	4 000 000
PAYLOAD TO 180 km (kg)[1]	15 000 +	30 000	150 000

[1] Approximate
[2] In final stages of development

US Department of Defense.

Bibliography

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