AE 330 Rocket Propulsion
Launch Vehicles

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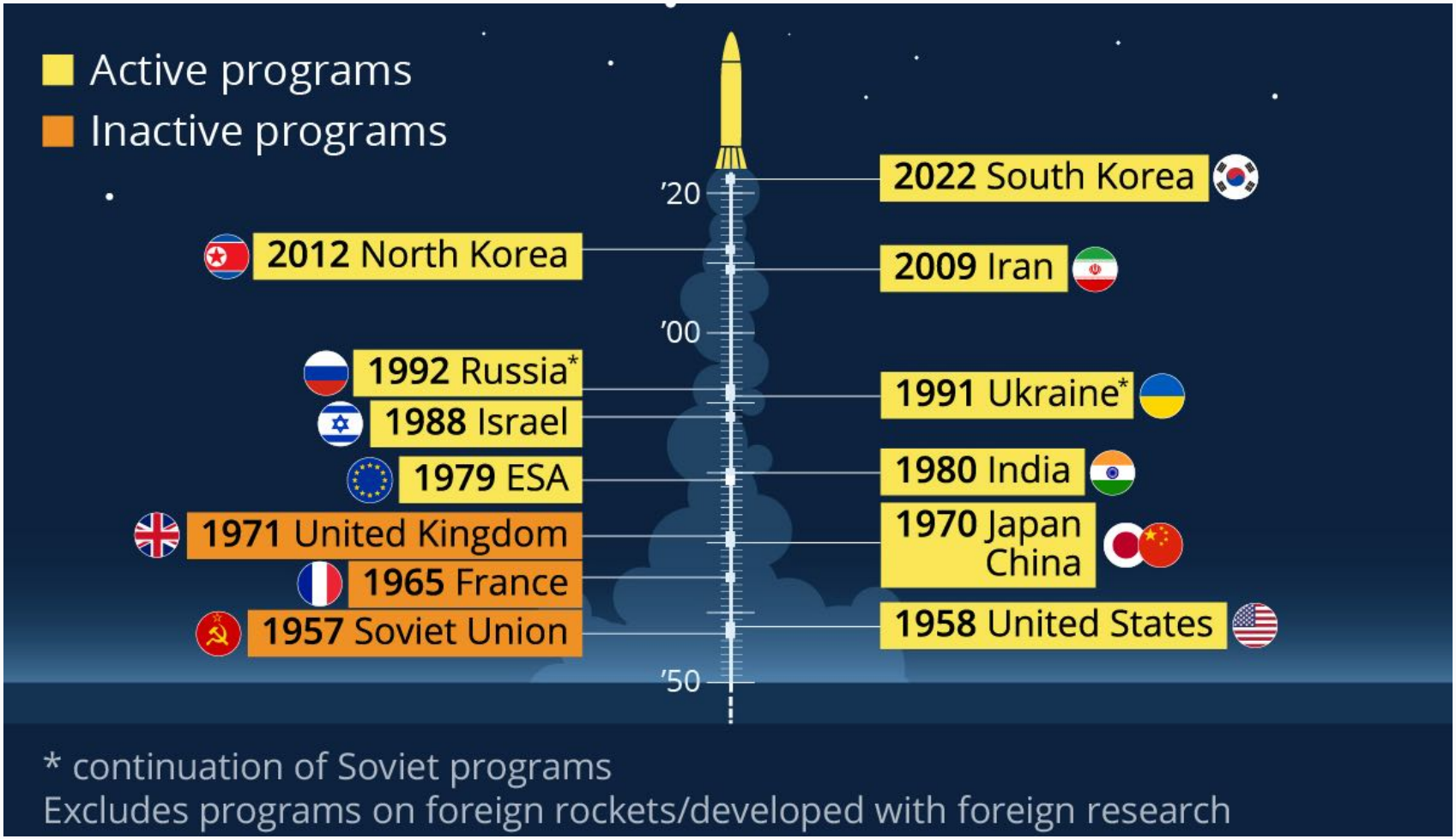
Launch Vehicles

Countries capable of launching Space Rockets



infographic from statista.com

Launch Profile: Expendable Launch Vehicle

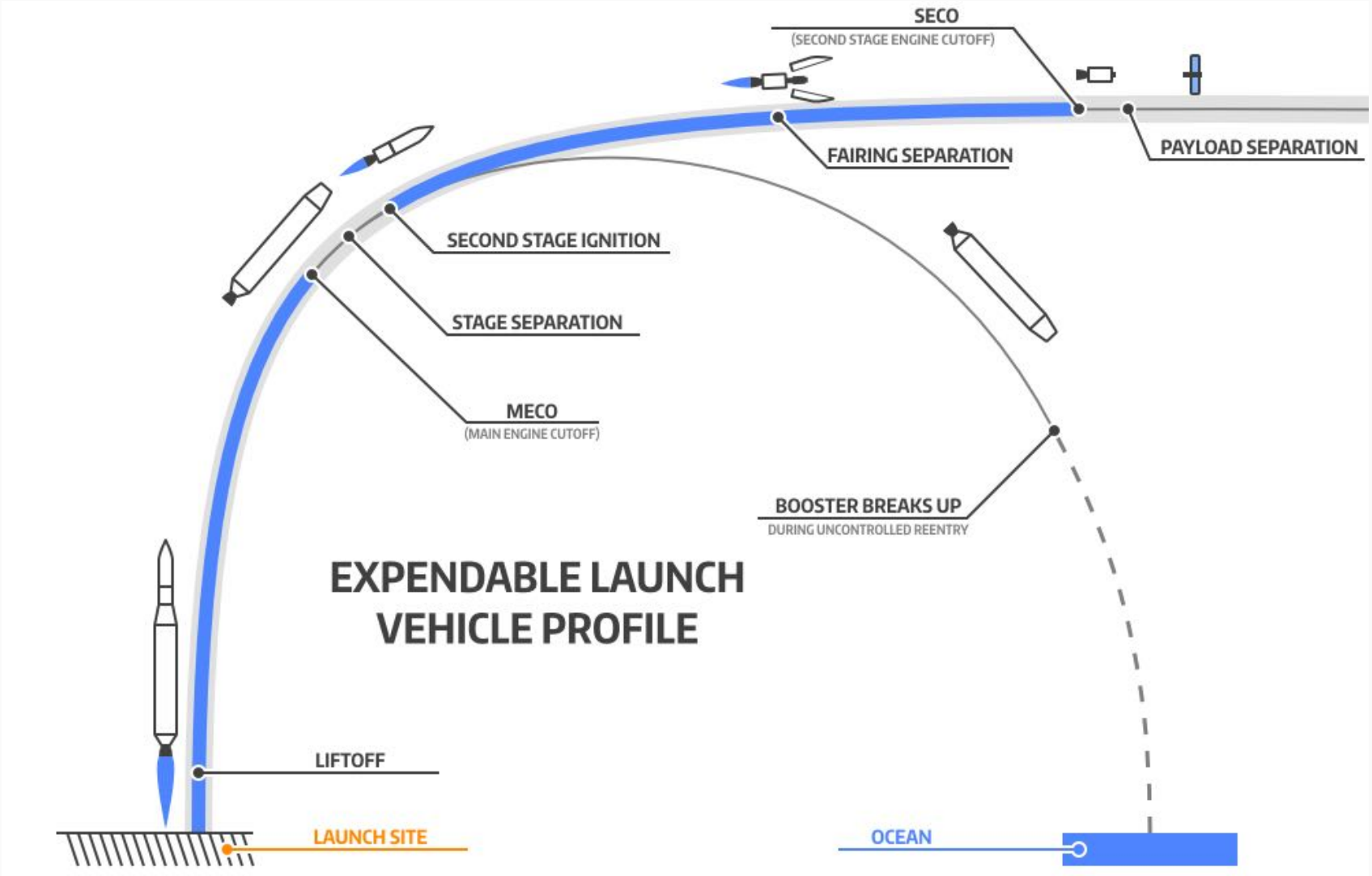
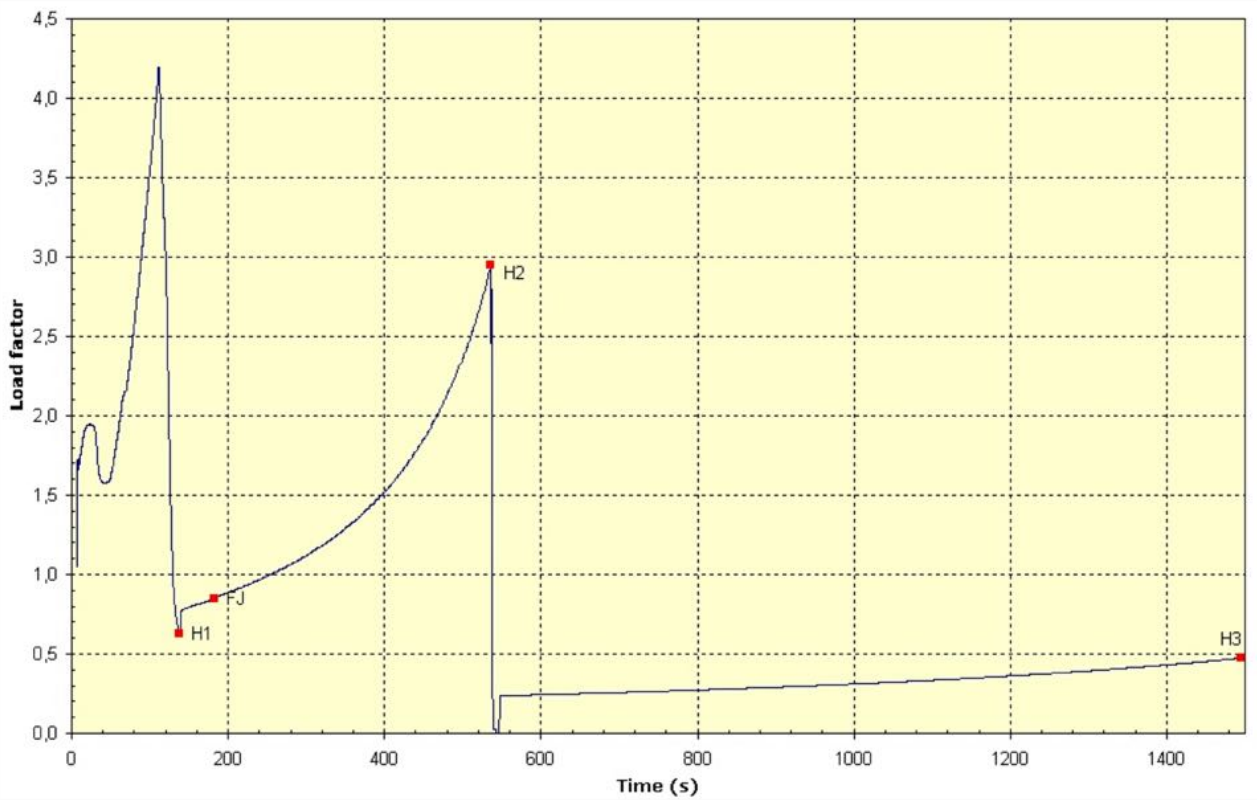
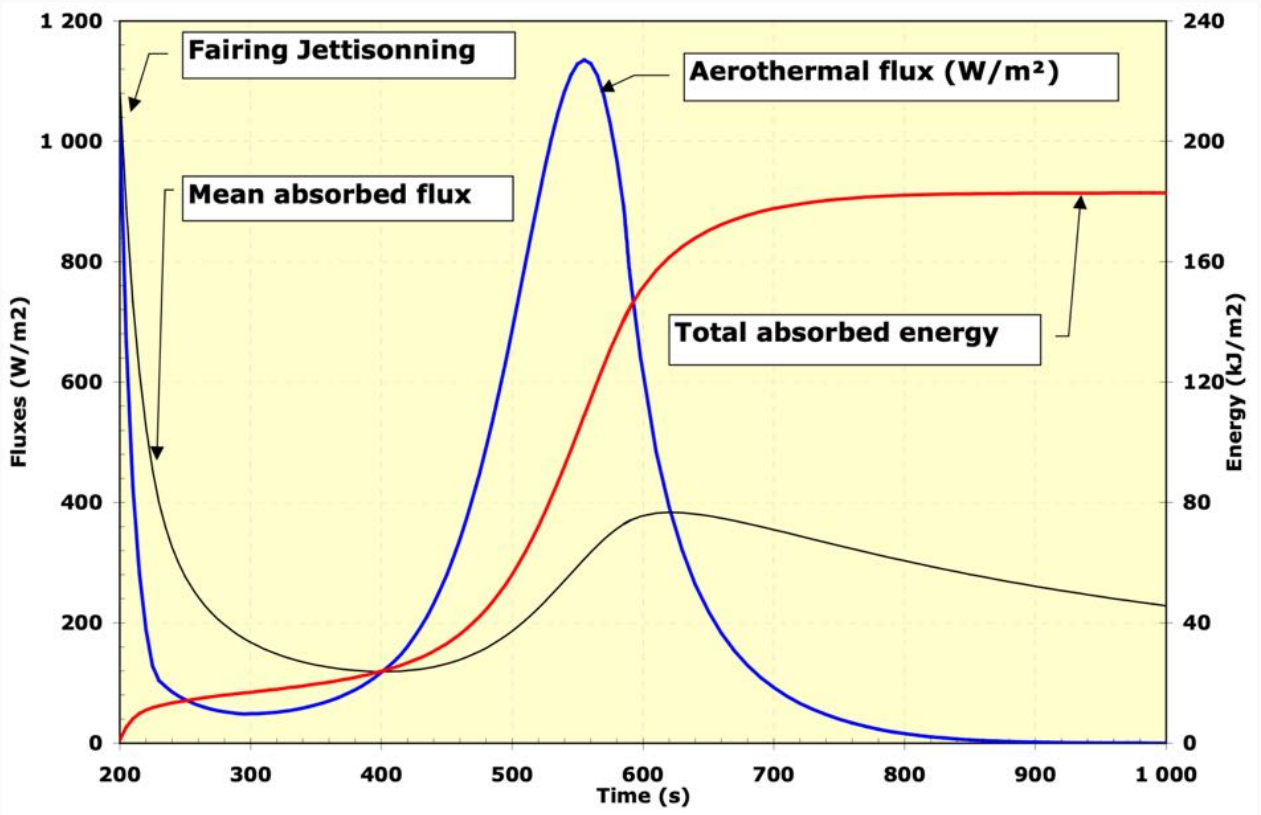


image from Just A. Tinker

Ariane 5 Launch Profile: Acceleration



Ariane 5 Launch Profile: Heat Flux



PSLV

PSLV C-53

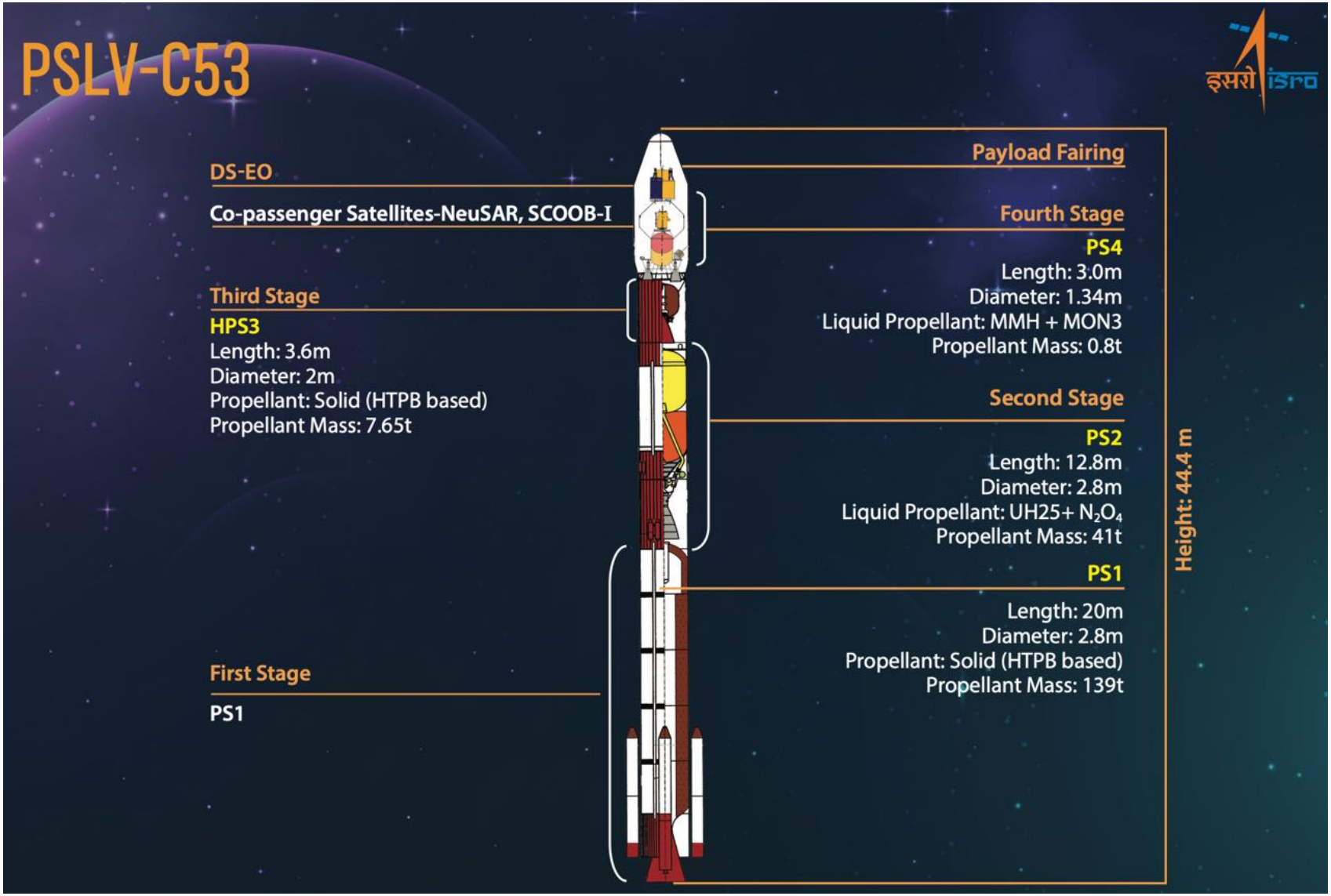
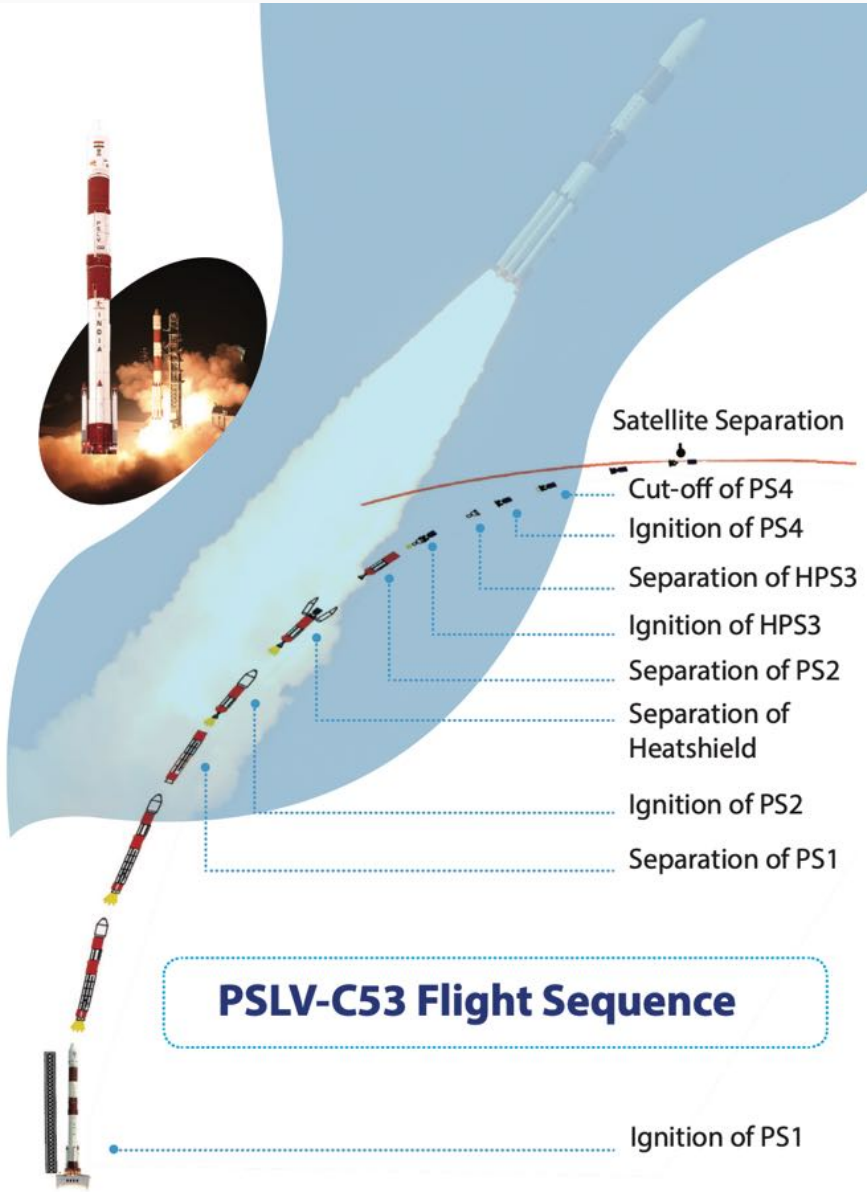


image from ISRO brochure for PSLV C-53

PSLV C-53

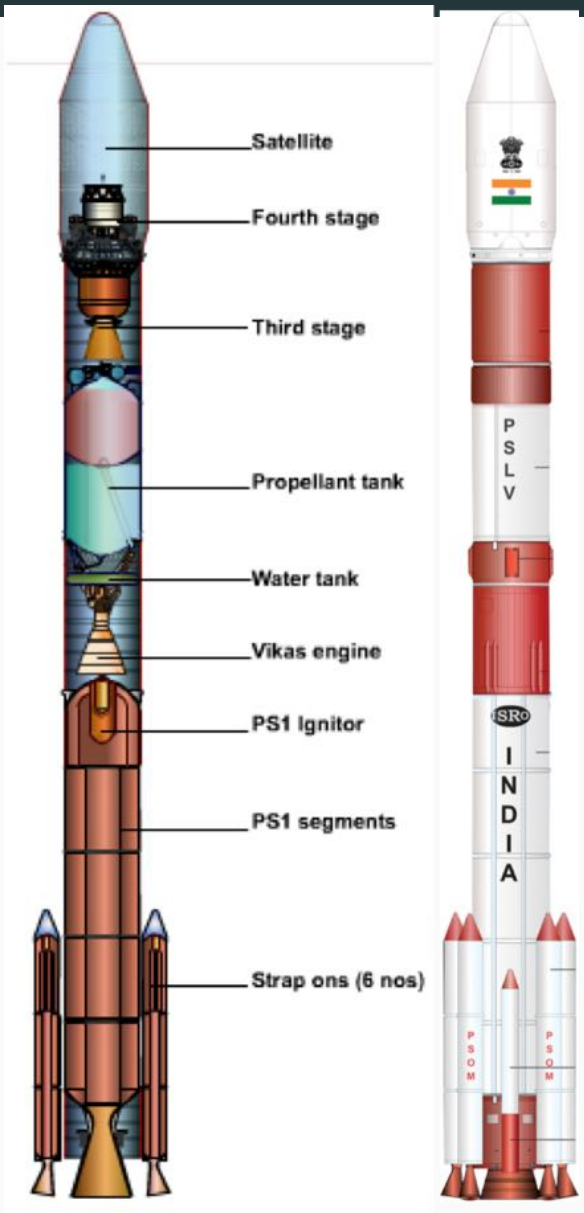


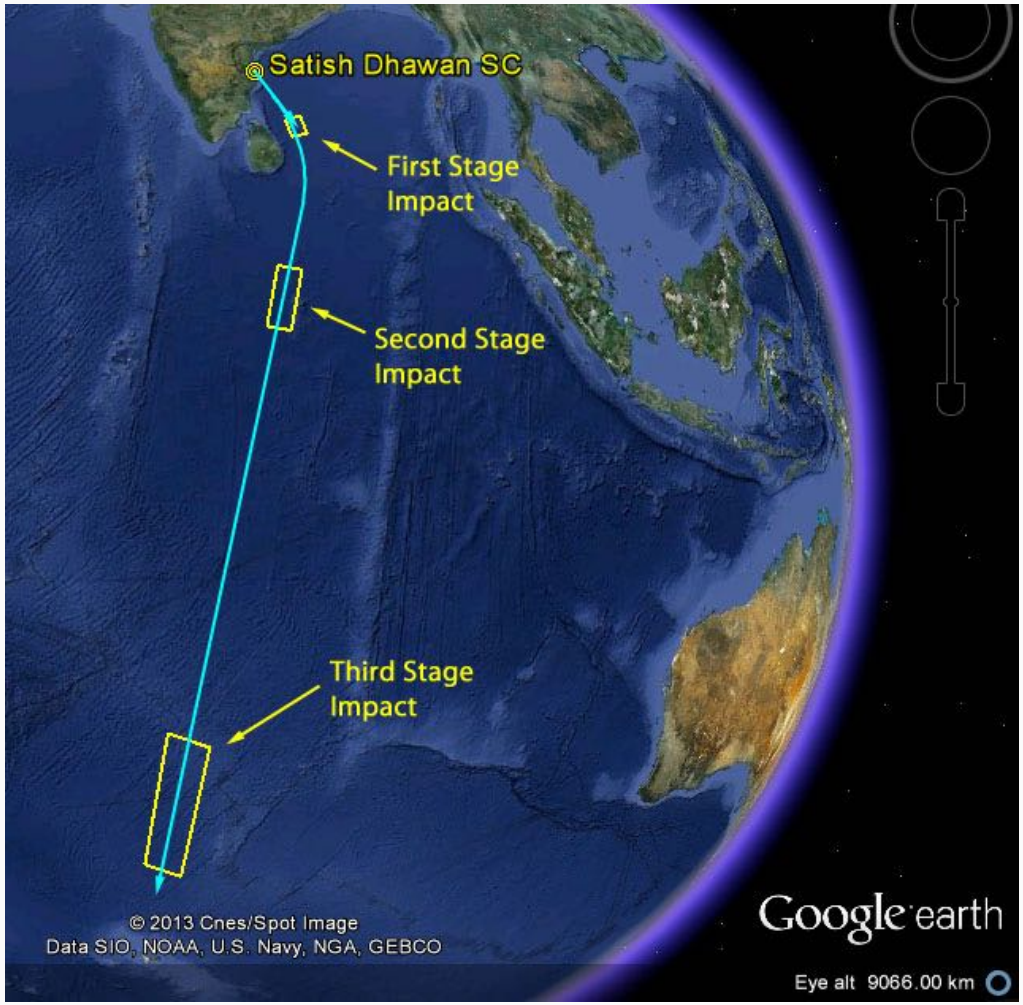
PSLV-C53 Typical Flight Profile

Event	Time (s)	Local Altitude (km)	Inertial Velocity (m/s)
RCT Ignition	-3	0.027	451.9
PS1 Ignition	0	0.027	451.9
PS1 Separation	108.20	50.728	1719.3
PS2 Ignition	108.40	50.926	1718.3
CLG Initiation	113.40	55.812	1736.5
Heat Shield Separation	176.60	113.032	2476.9
PS2 Separation	258.04	174.136	4580.8
PS3 Ignition	259.24	174.891	4579.3
PS3 Separation	583.82	364.583	7581.2
PS4 Ignition	888.42	535.827	7385.7
PS4 Engine Cut-off	1021.04	570.547	7572.1
DS-EO Separation	1078.04	570.516	7574.2
DLA Separation	1118.04	570.475	7574.3
NeuSAR Separation	1158.04	570.420	7574.4
SCOOB-I Separation	1162.04	570.414	7574.4
MON Passivation Start	1271.04	570.166	7573.7
MMH Passivation Start	1911.04	558.455	7582.1
POEM Start	2241.04	550.029	7591.5

image from ISRO brochure for PSLV C-53

“Dog-leg” launch path





GSLV

GSLV Mk-II

GSLV at a glance !

	1st stage		2nd stage	3rd stage
	Strap-ons	Core stage		
Length (m)	19.7	20.1	11.6	8.7
Diameter (m)	2.1	2.8	2.8	2.8
Propellants	UH25 & N_2O_4	HTPB	UH25 & N_2O_4	LH_2 & LOX
Propellant mass (T)	4 x 42.6	138.2	39.5	12.8
Max. Thrust (kN)	680	4800	720	75
Duration (sec)	148	100	150	720

GSLV: Geo-Synchronous Satellite Launch Vehicle
HTPB: Hydroxyl terminated Polybutadiene, LH_2: Liquid Hydrogen,
LOX: Liquid Oxygen, N_2O_4: Nitrogen Tetroxide,
UH25: Unsymmetrical Dimethyl Hydrazine + 25% Hydrazine Hydrate

image from ISRO brochure for GSLV D5

GSLV Mk-II *F11*

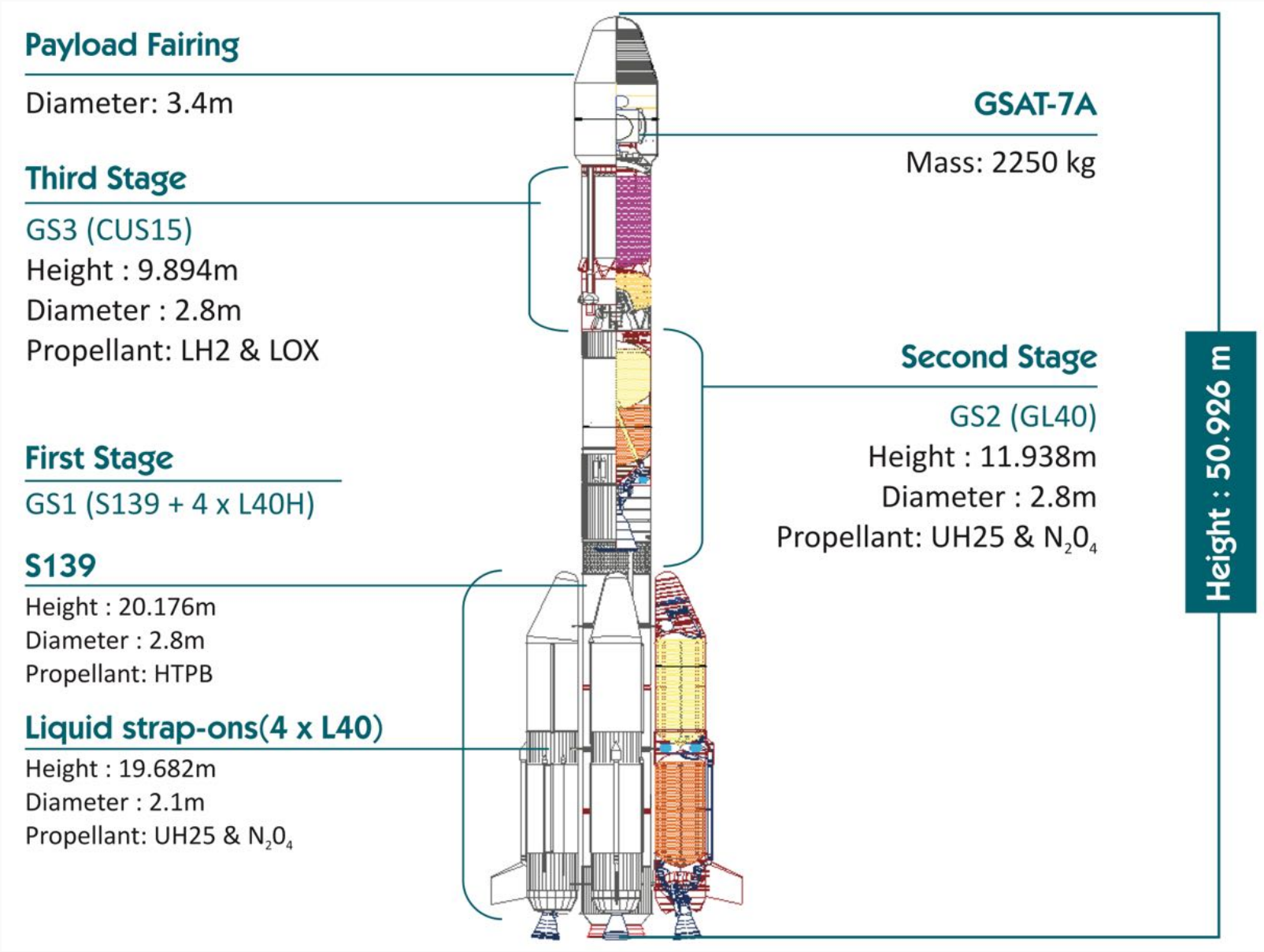


image from ISRO brochure for GSLV F11

GSLV Mk-III $M1$ (Chandrayaan-2)

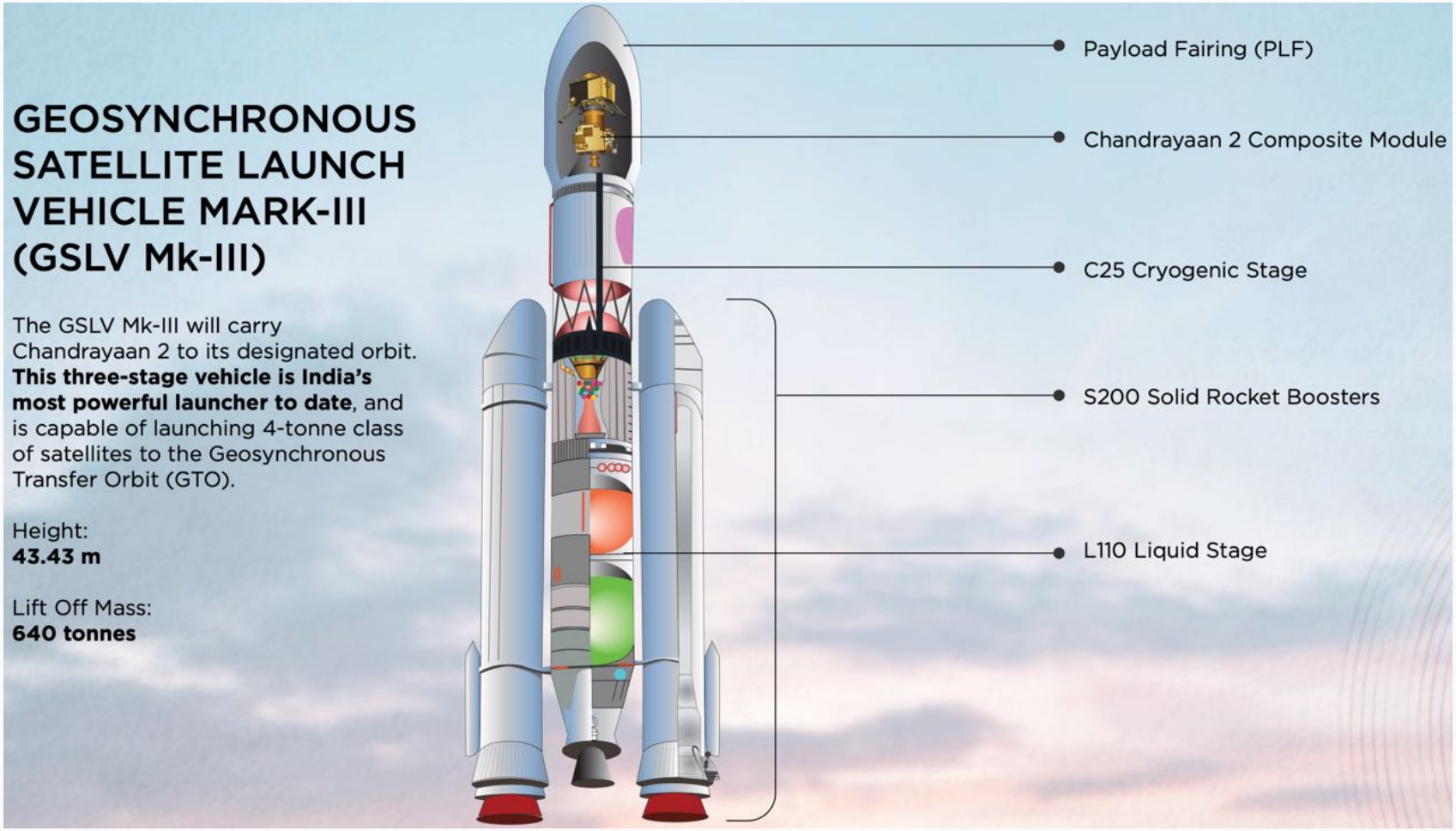
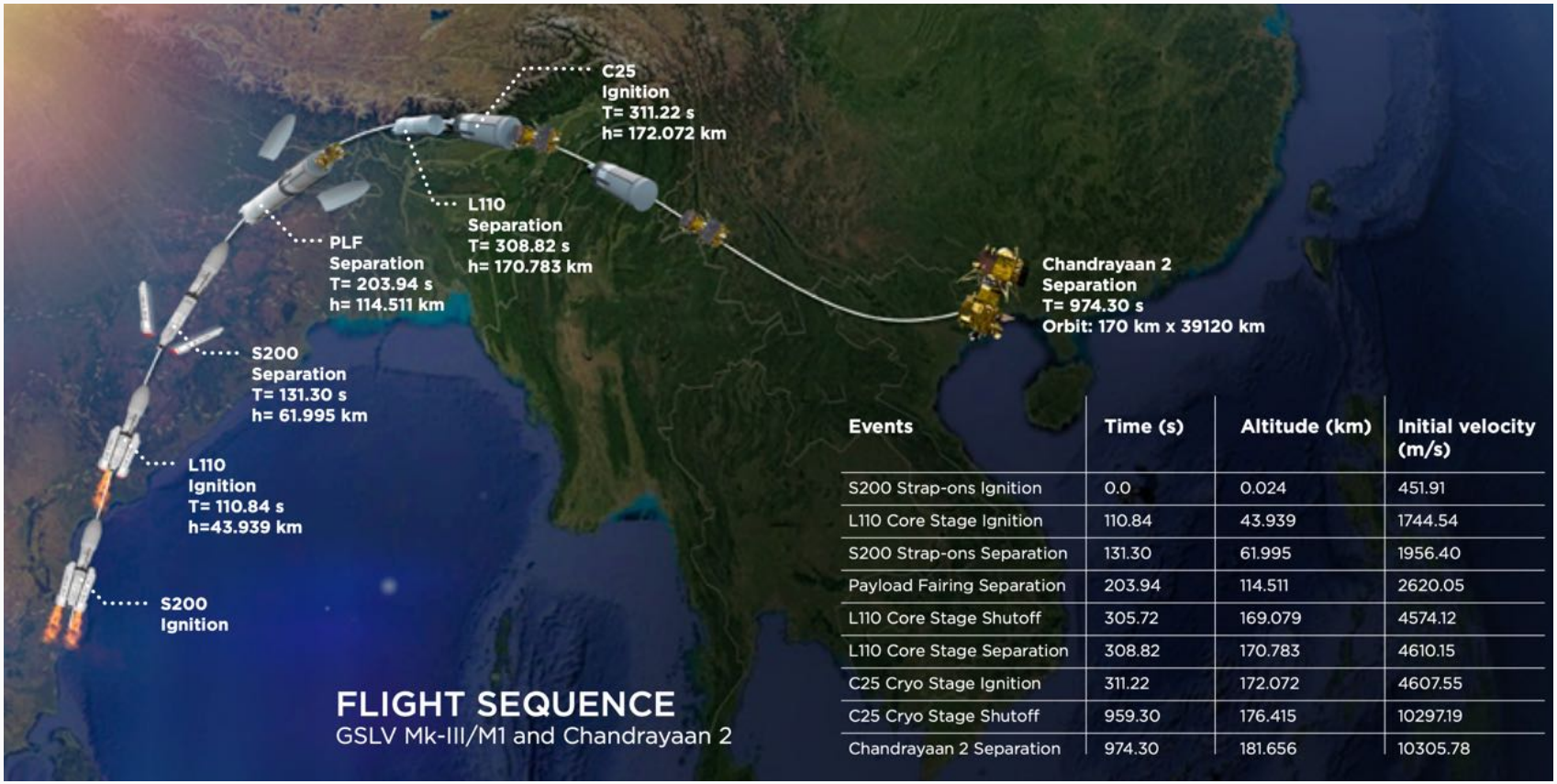


image from ISRO brochure for GSLV Mk-III M1

GSLV Mk-III $M1$ (Chandrayaan-2)



Events	Time (s)	Altitude (km)	Initial velocity (m/s)
S200 Strap-ons Ignition	0.0	0.024	451.91
L110 Core Stage Ignition	110.84	43.939	1744.54
S200 Strap-ons Separation	131.30	61.995	1956.40
Payload Fairing Separation	203.94	114.511	2620.05
L110 Core Stage Shutoff	305.72	169.079	4574.12
L110 Core Stage Separation	308.82	170.783	4610.15
C25 Cryo Stage Ignition	311.22	172.072	4607.55
C25 Cryo Stage Shutoff	959.30	176.415	10297.19
Chandrayaan 2 Separation	974.30	181.656	10305.78

image from ISRO brochure for GSLV Mk-III M1

Vikram Lander (Chandrayaan-2)

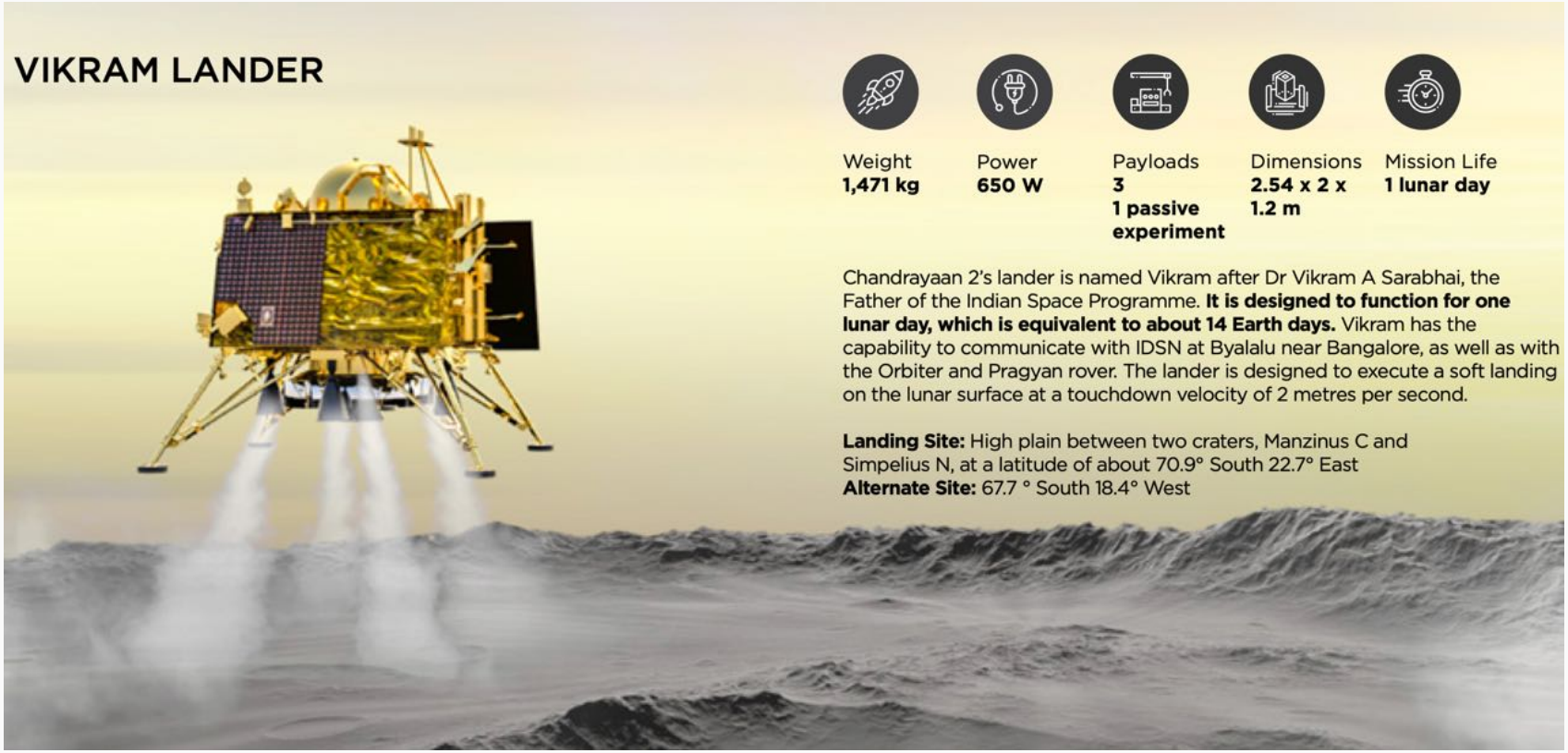


image from ISRO brochure for GSLV Mk-III M1

ISRO Launch Vehicles

SLV-3

Height : 22.7m
Lift-off weight : 17 t
Propulsion : All Solid
Payload mass : 40 kg
Orbit : Low Earth Orbit

ASLV

Height : 23.5m
Lift-off weight : 39 t
Propulsion : All Solid
Payload mass : 150 kg
Orbit : Low Earth Orbit

PSLV-XL

Height : 44m
Lift-off weight : 320 t
Propulsion : Solid & Liquid
Payload mass : 1860 kg
Orbit : 475 km Sun Synchronous Polar Orbit (1300 kg in Geosynchronous Transfer Orbit)

GSLV Mk II

Height : 49m
Lift-off weight : 414 t
Propulsion : Solid, Liquid & Cryogenic
Payload mass : 2200 kg
Orbit : Geosynchronous Transfer Orbit

GSLV Mk III

Height : 43.43 m
Lift-off weight : 640 t
Propulsion : Solid, Liquid & Cryogenic
Payload mass : 4000 kg
Orbit : Geosynchronous Transfer Orbit

Reusable Launch Vehicle

Space Shuttle: Reusable Launch Vehicle

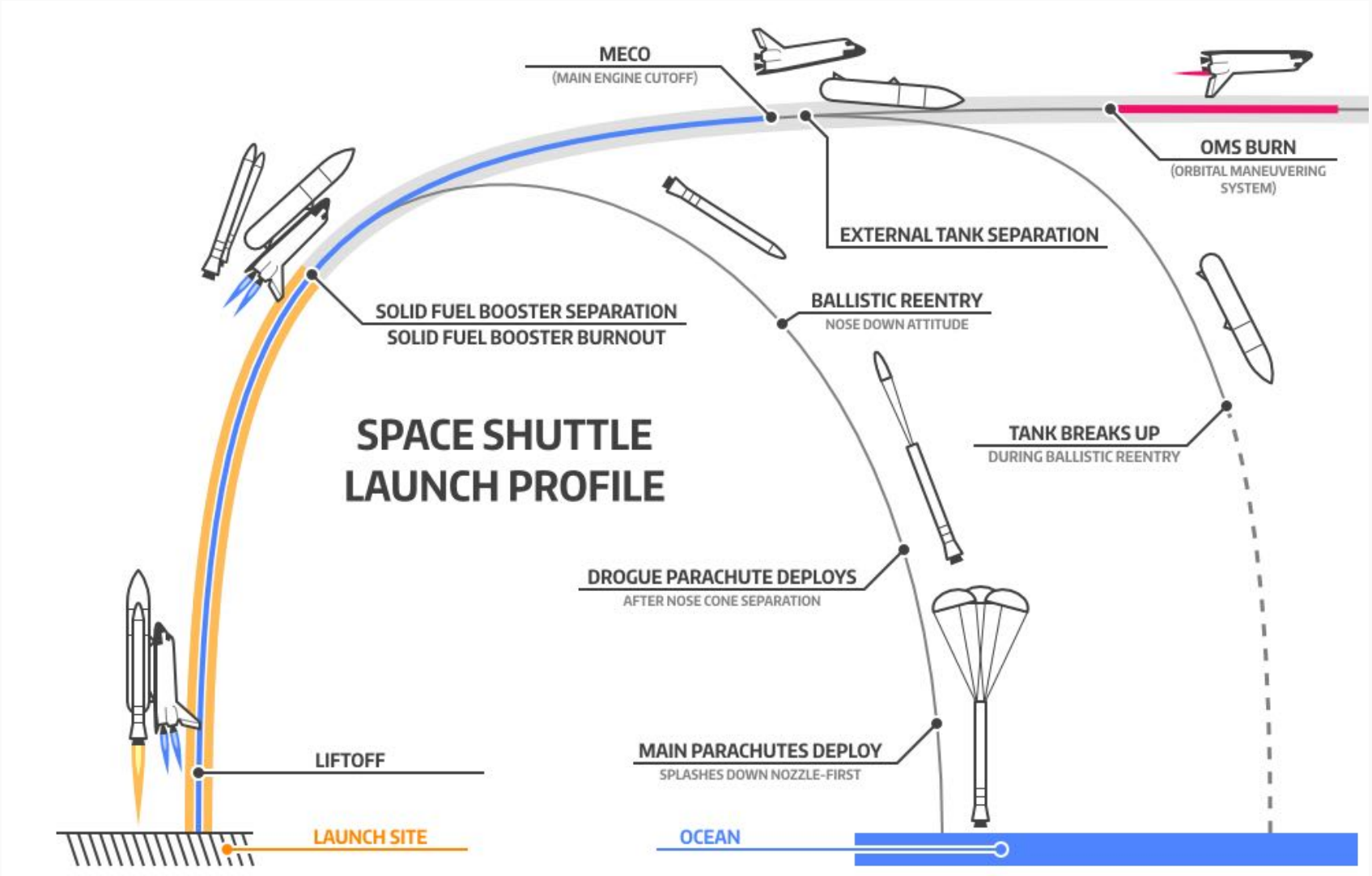


image from Just A. Tinker

Space Shuttle: Reusable Launch Vehicle

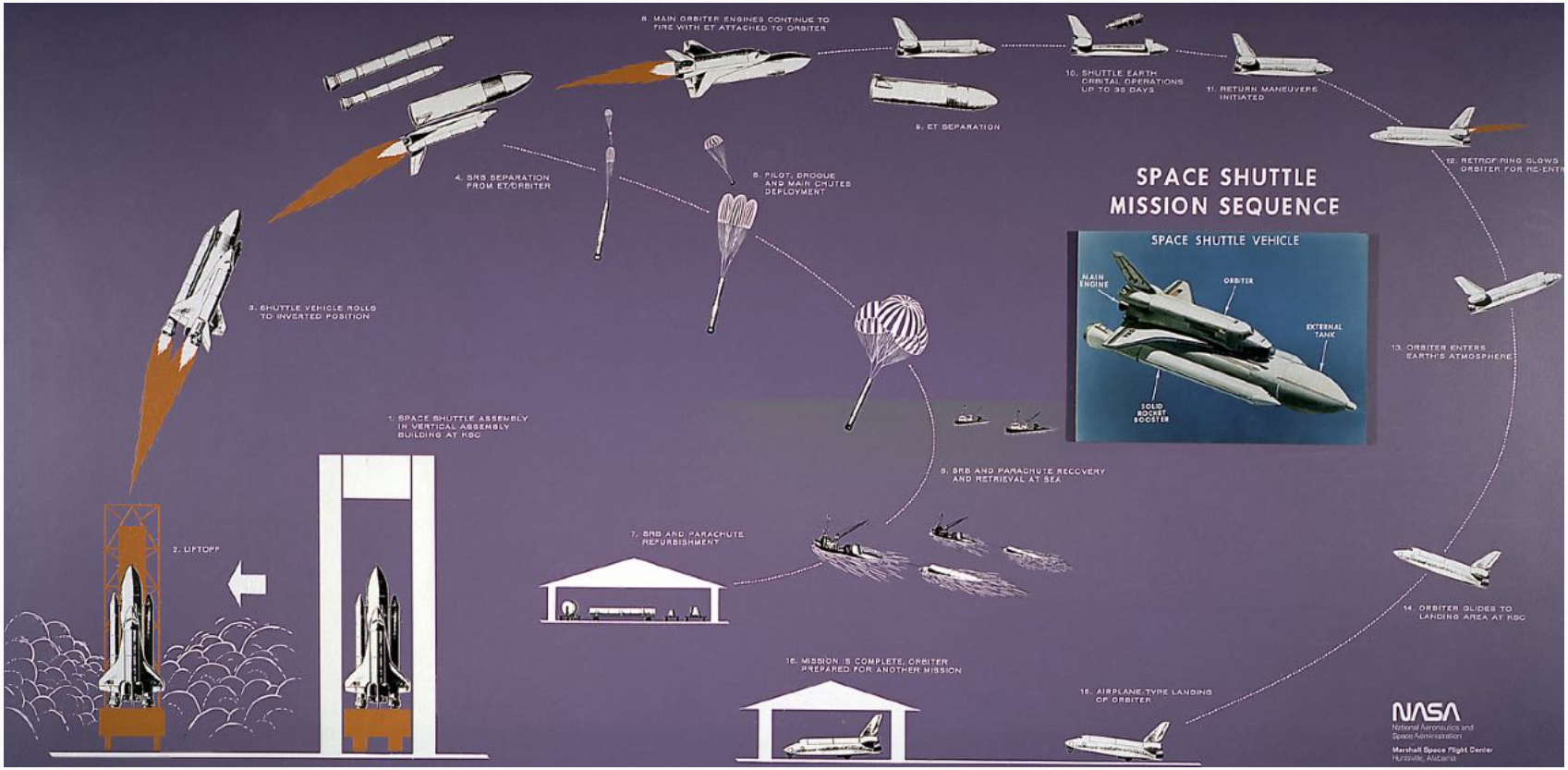
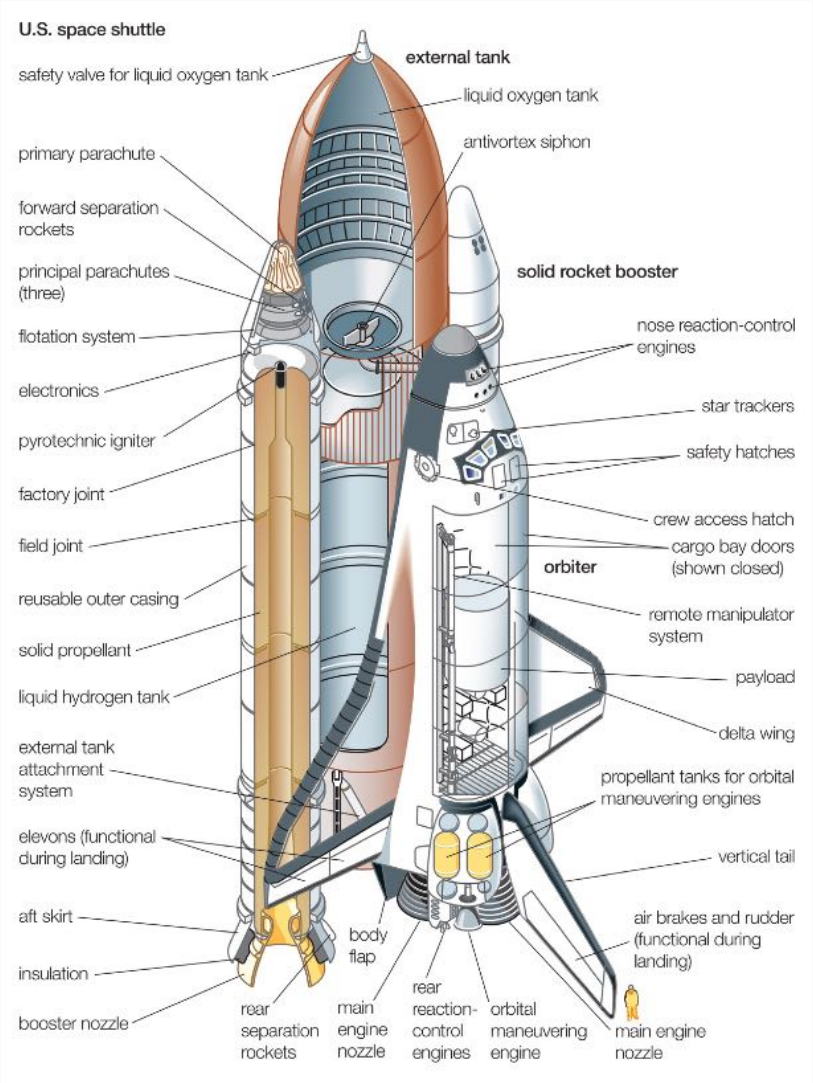


image from NASA

Space Shuttle Configuration



infographic from tarzan1941.tumblr

Space Shuttle Launch Profile

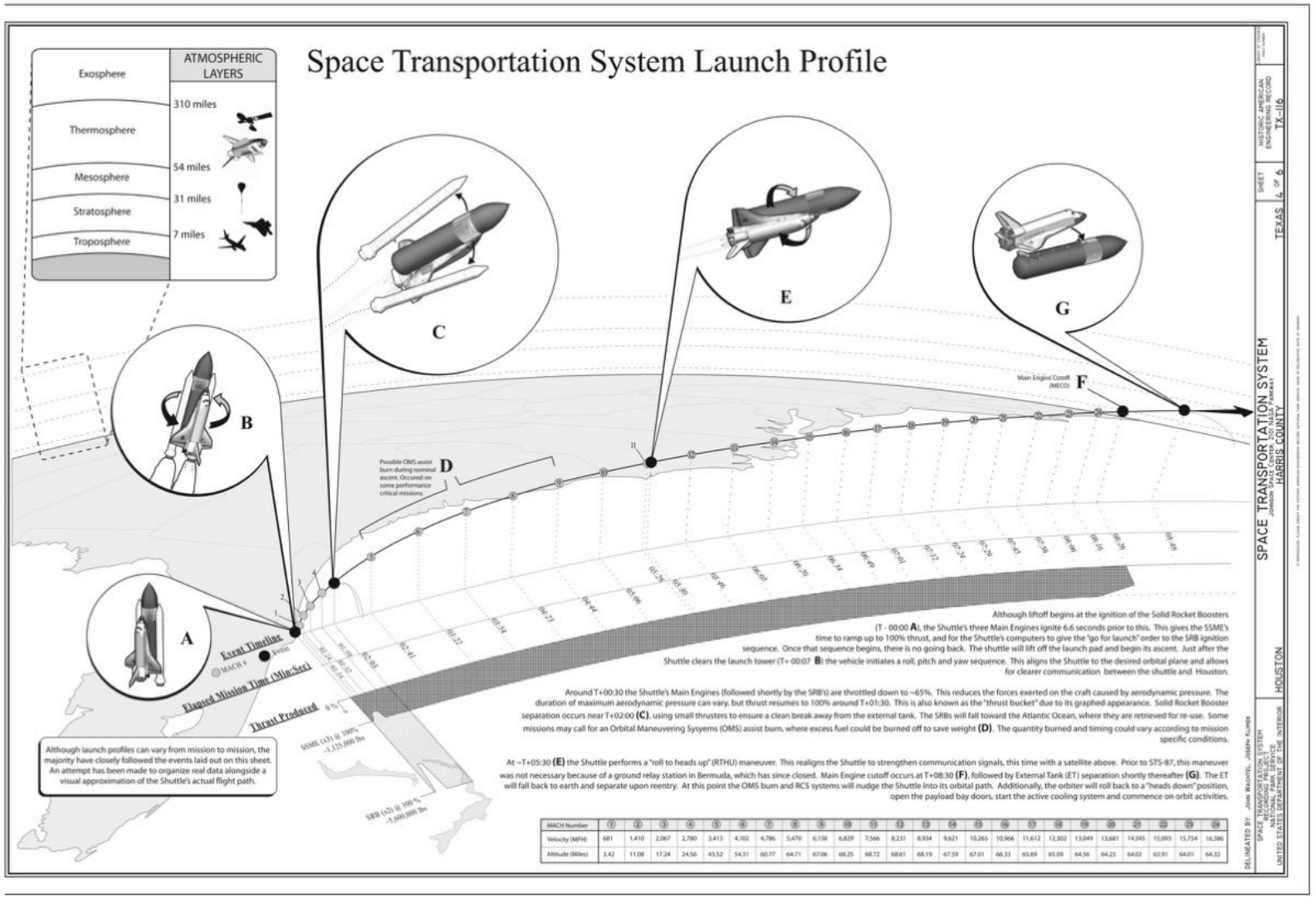


image from NASA

Falcon (SpaceX): Reusable Launch Vehicle

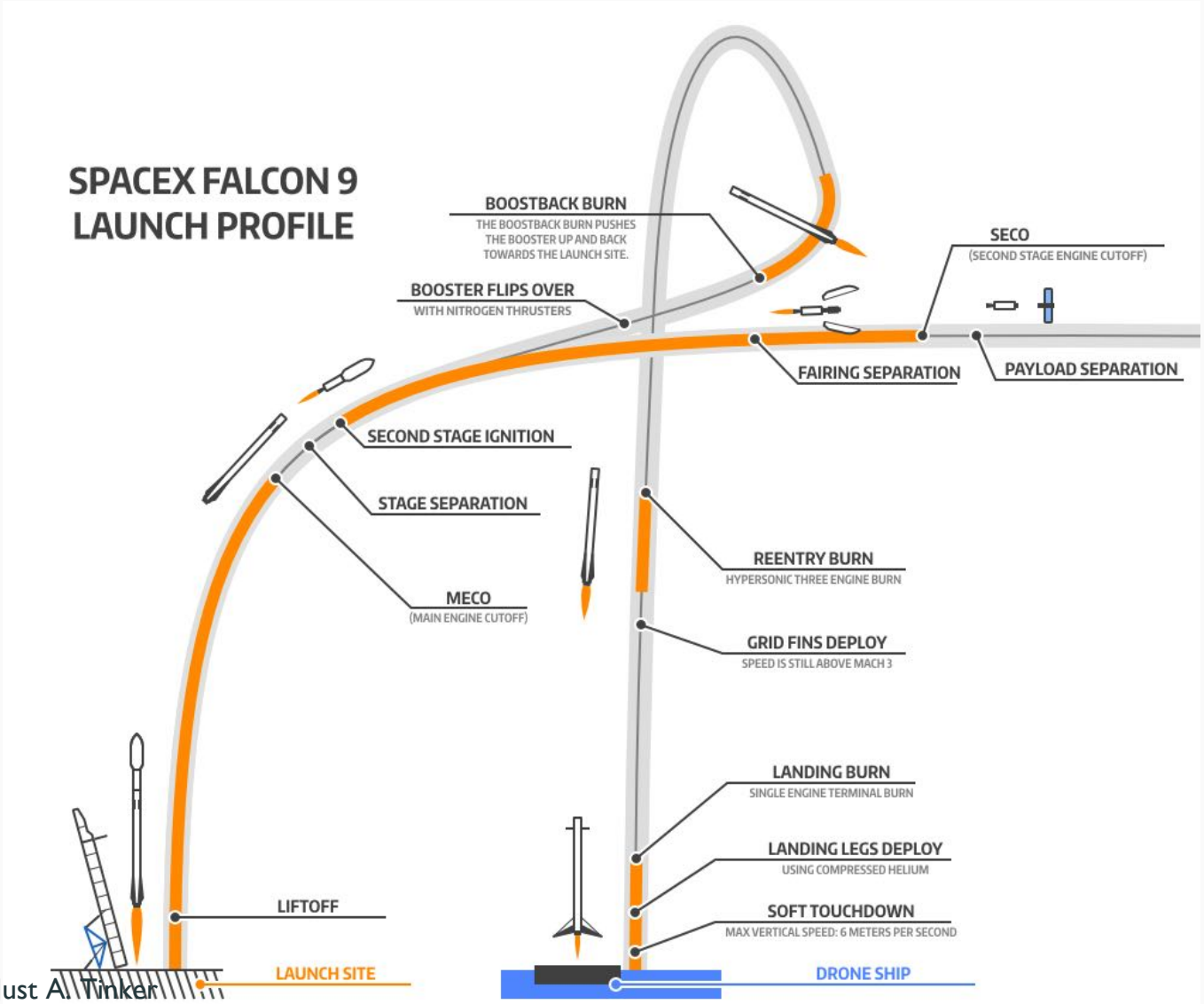
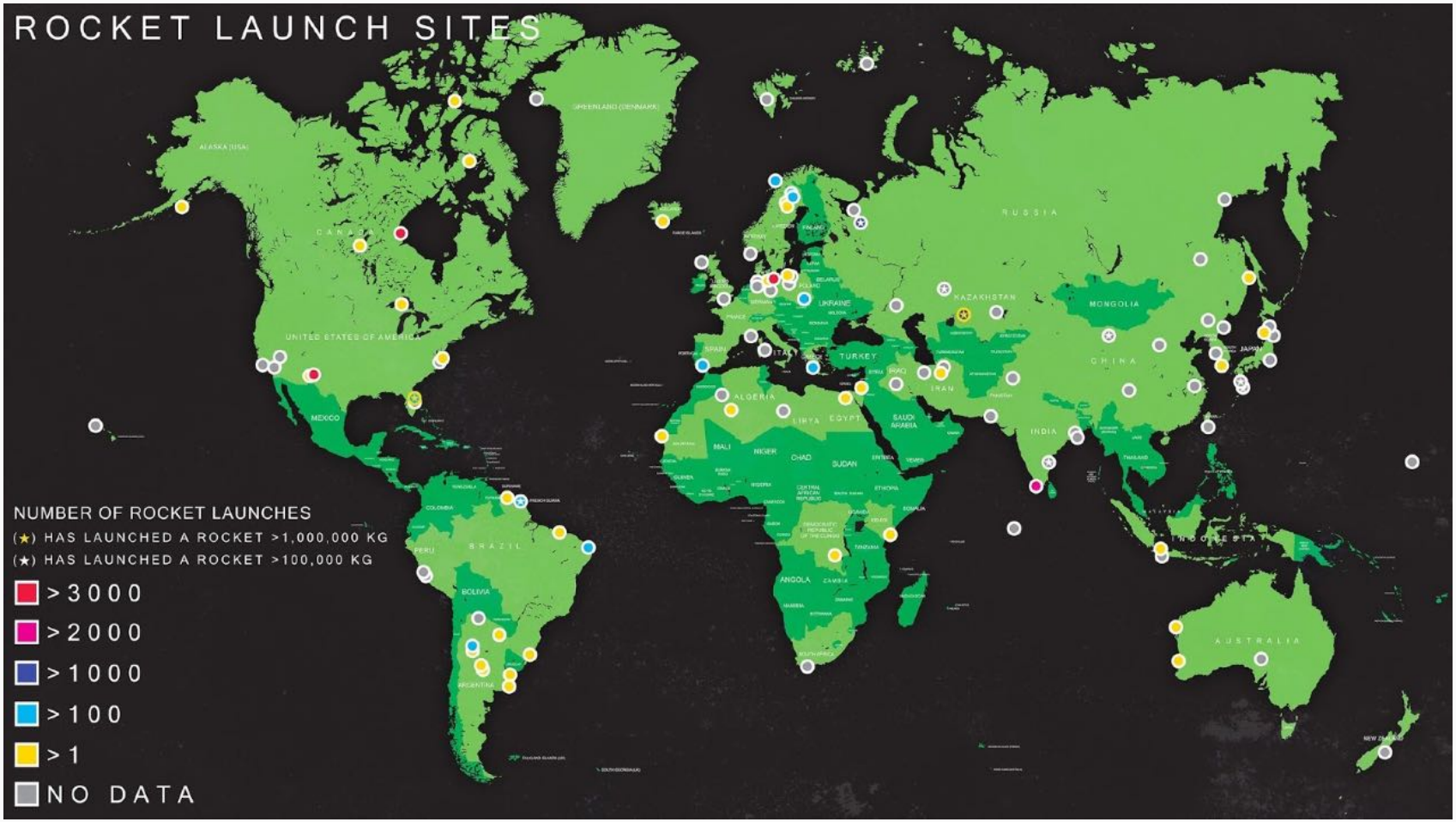


image from Just A. Tinker

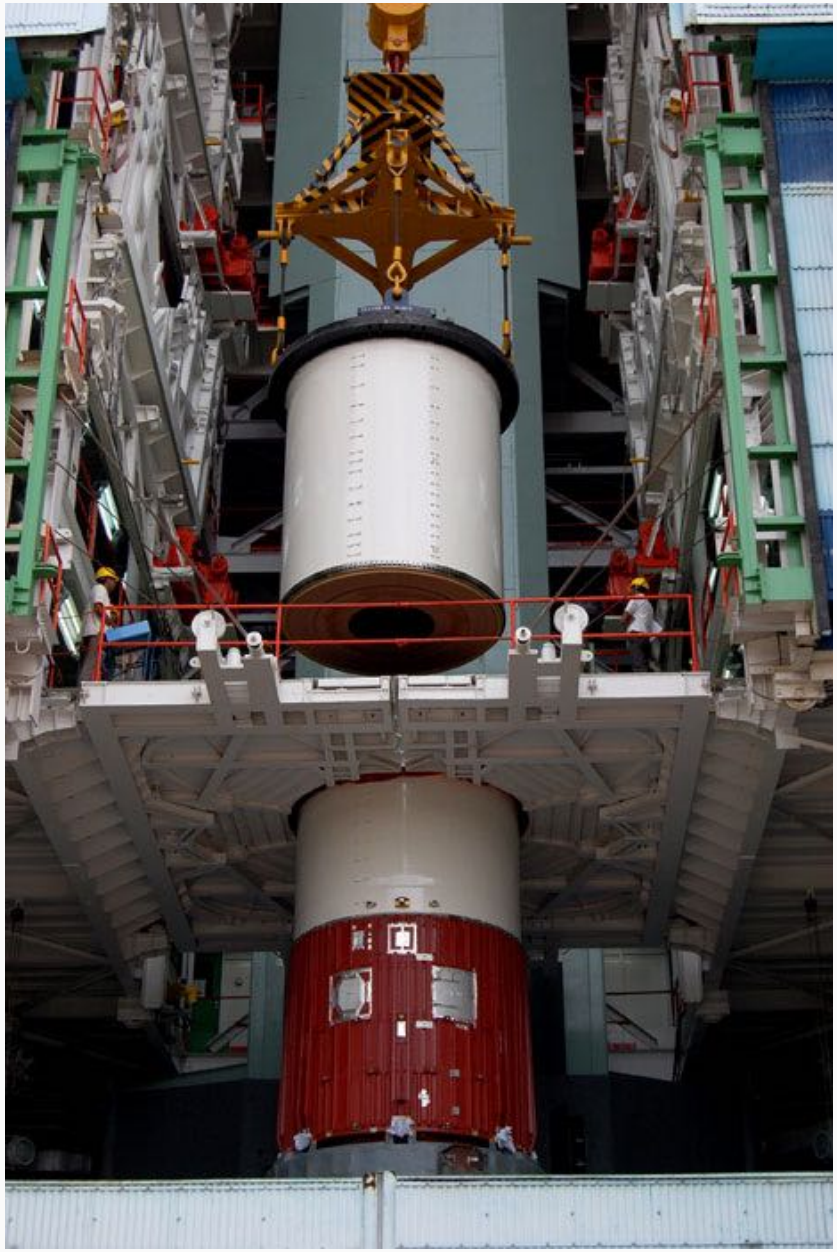
Launch facilities

Launch Sites in India

Launch Sites across the World



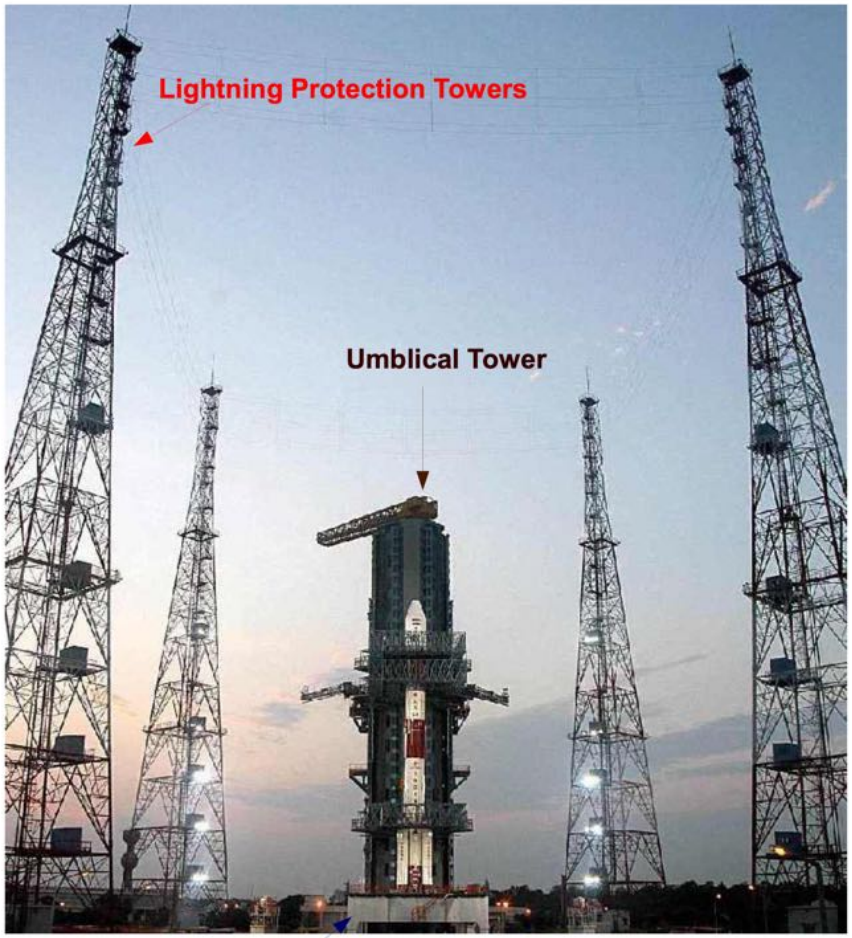
Launch Pad: Assembling PSLV



Launch Pad – Ariane V

Launch Pad – Buran

Launch Pad – SHAR

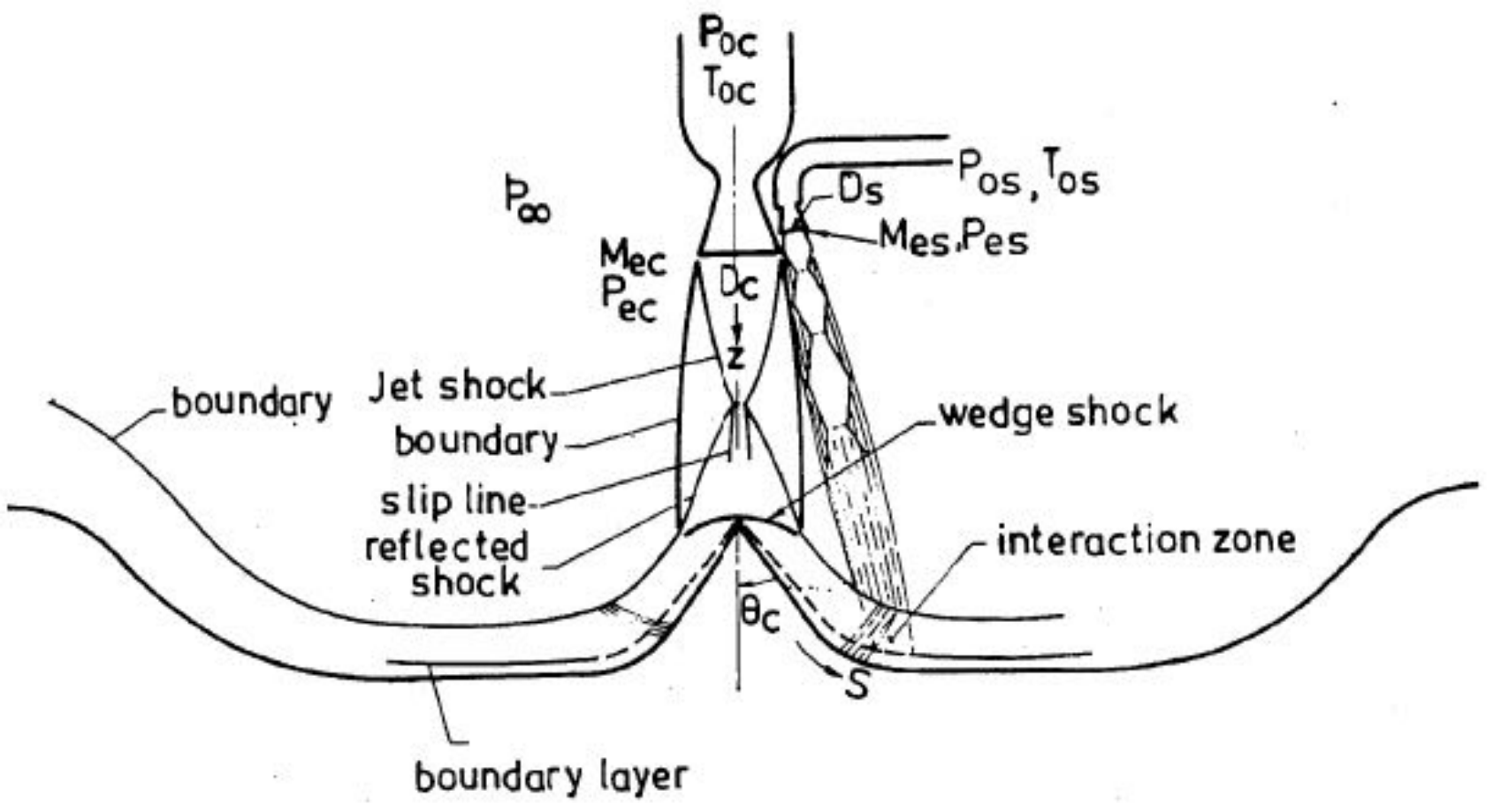


Space Shuttle Launchpad

image from NASA

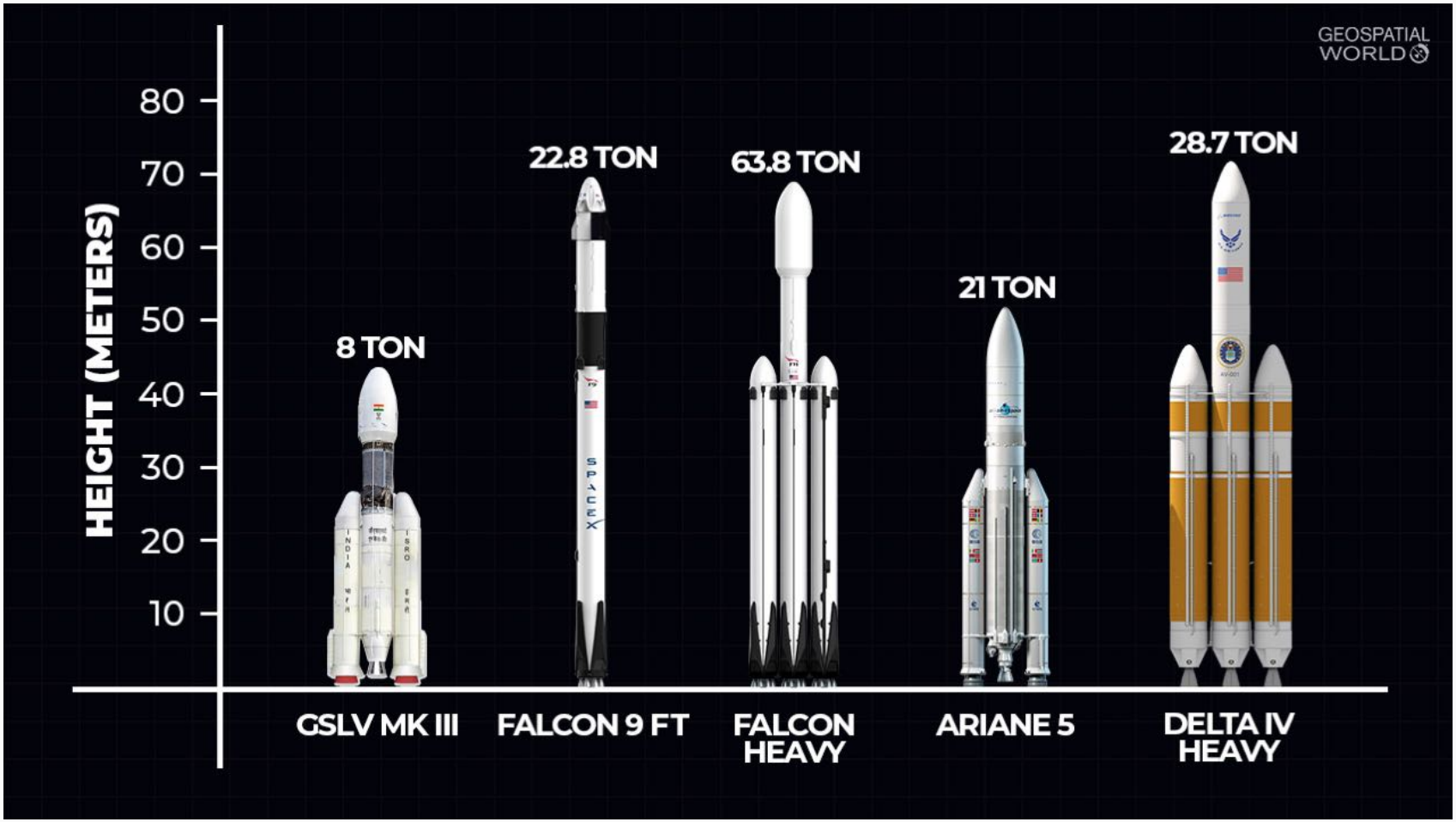
Space Shuttle Launch

Launch Pad Heat Transfer

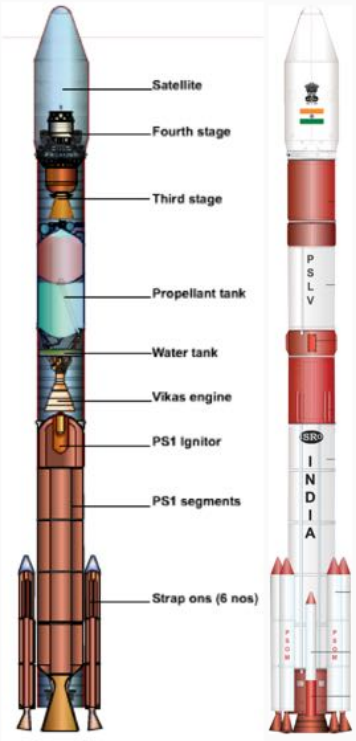


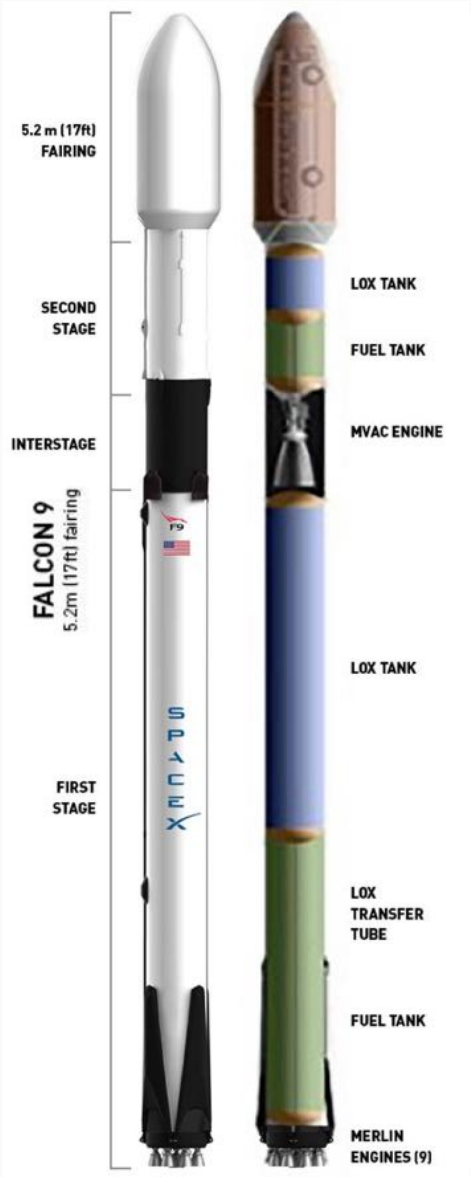
Comparing Launch Vehicles

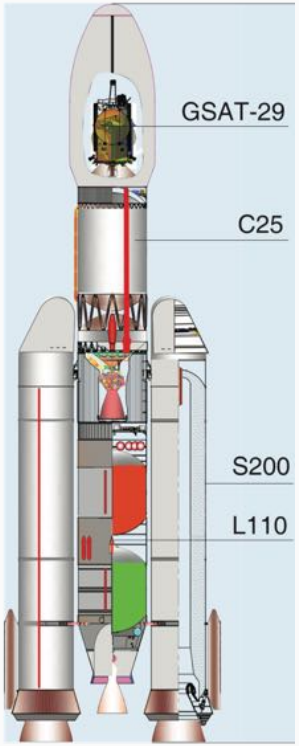
GSLV vs Similar Vehicles



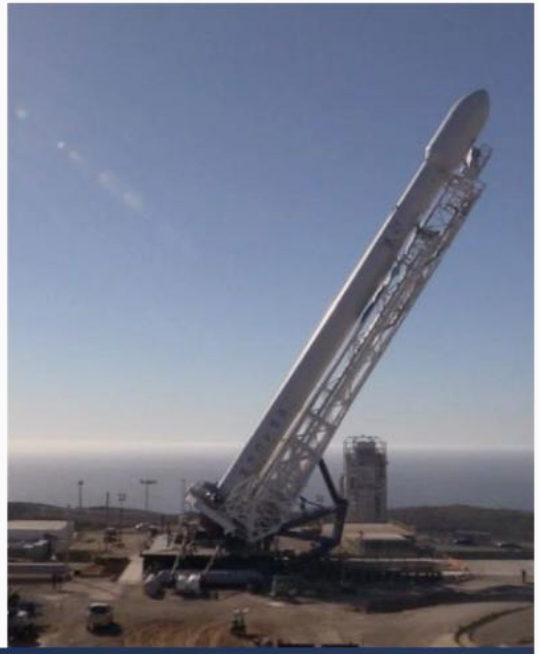
PSLV, GSLV, and SpaceX Falcon Series







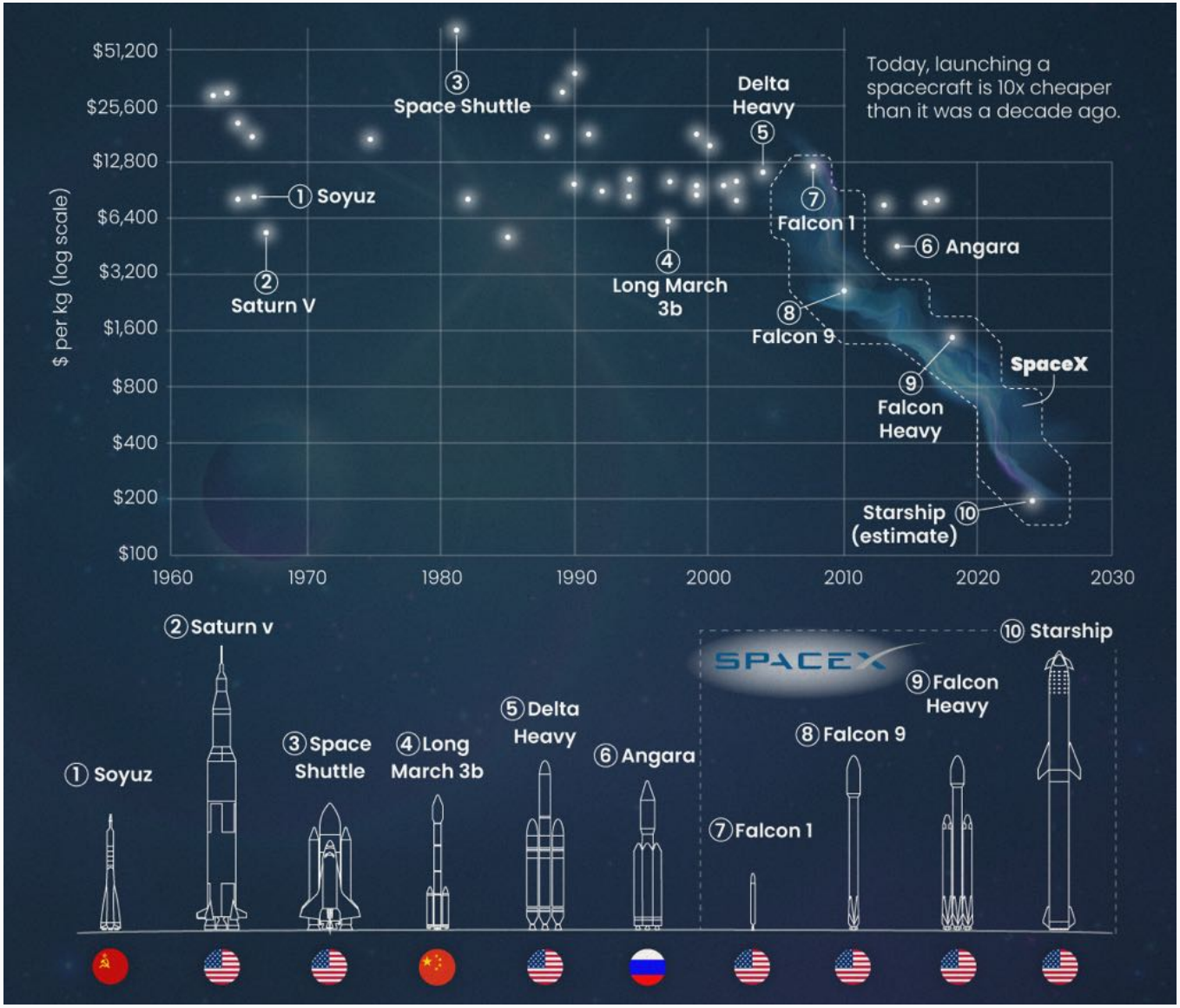
SpaceX Falcon-9



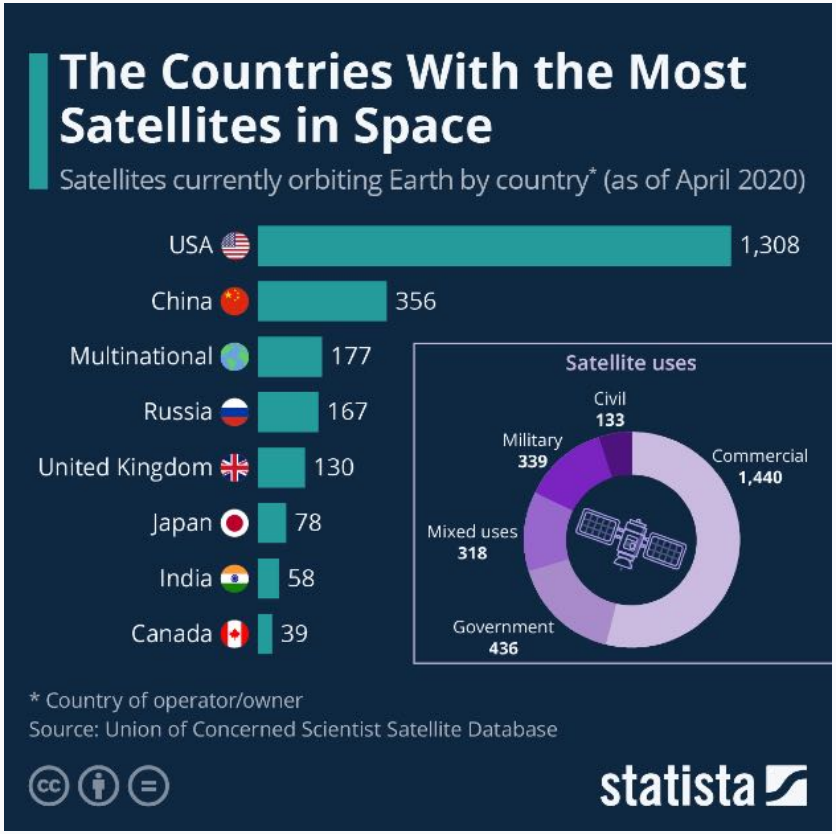
GSLV vs Similar Vehicles

	Payload (tons)			LEO Launch Cost ($ million)			Height (m)	Diameter (m)	Lift-off Mass (tons)
	LEO	GTO	LTO/TLI	Total	per-ton				
PSLV	3.8	1.2	0.55	20	5.3	India	44	2.8	320
GSLV Mk III	10	4	2.18	54	5.4		43.5	4	640
Proton	23	6.8	5.7	65	2.8	Russia	53	7.4	694
Ariane 5	21	10		180	8.6	ESA	52	5.4	777
Long March 3B	11.5	5.5		70	6.1	China	56	3.4	459
Long March 5	25	14	9				57	5	855
Delta IV Heavy	28.8	14.2	10	350	12.2	ULA	72	5	733
Falcon 9	22.8	8.3		67	2.9	SpaceX	70	3.66	549
Falcon Heavy	63.8	26.7		97	1.5		70	3.66	1420
Saturn V	140		44	185 (1200)	(8.6)	NASA	111	10	2965

Cost of launches

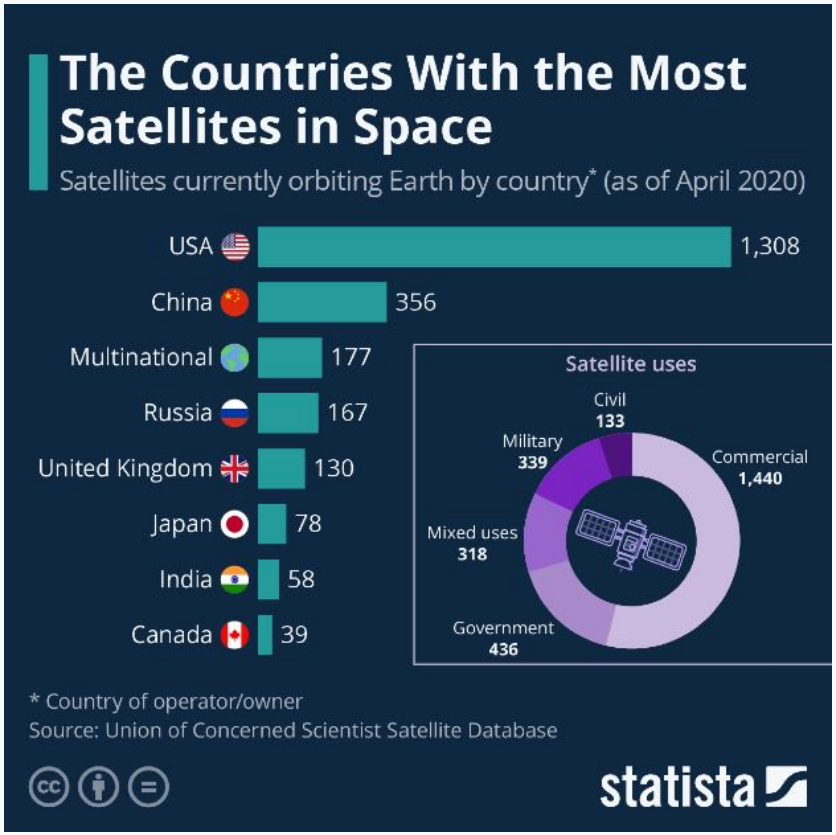


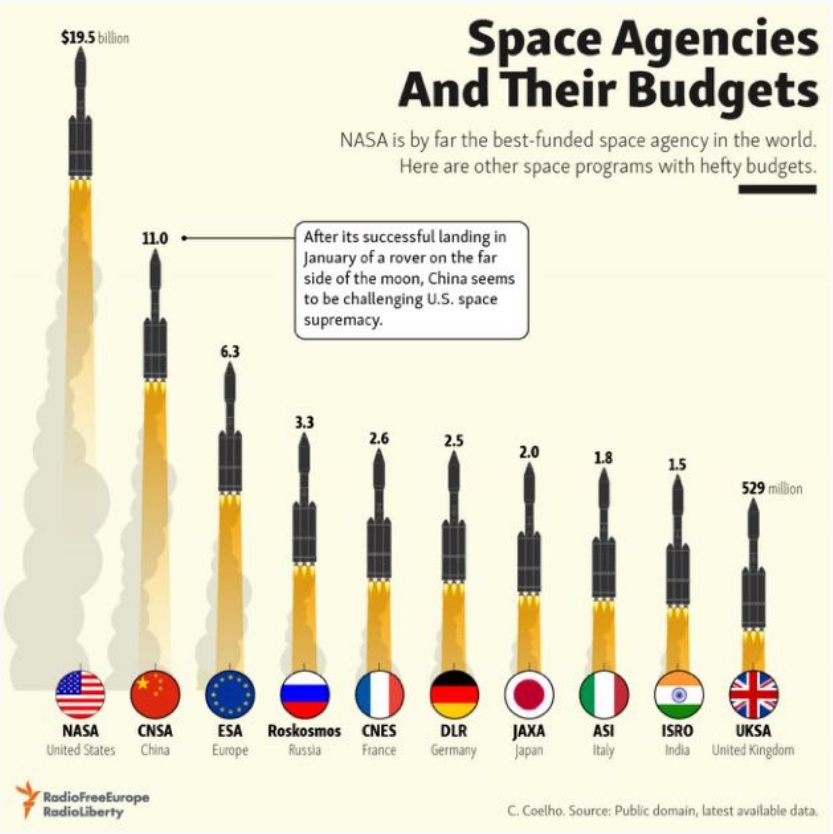
Satellites in Space



infographic from statista.com

Satellites in Space





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