

# **AE 330 Rocket Propulsion Launch Vehicles**

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Kowsik Bodi

Aerospace Engineering, IIT Bombay



# Launch Vehicles

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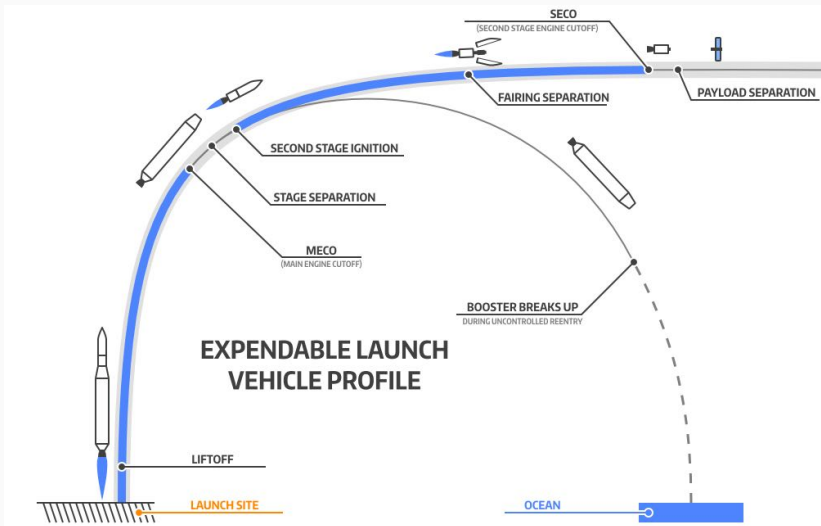
# Countries capable of launching Space Rockets



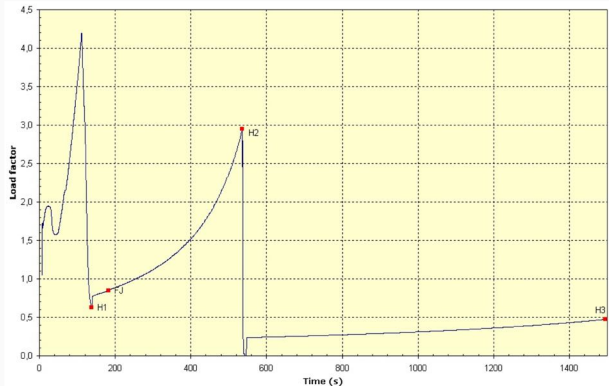
infographic from statista.com



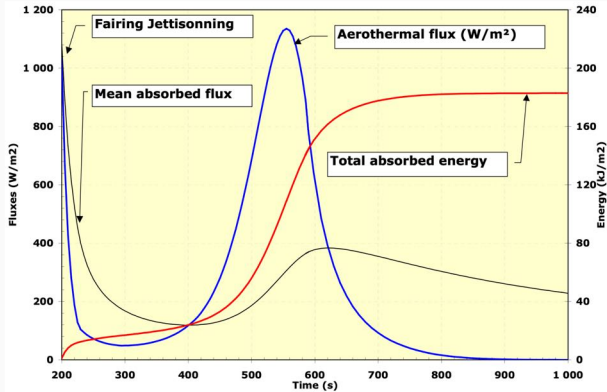
# Launch Profile: Expendable Launch Vehicle



# Ariane 5 Launch Profile: Acceleration



# Ariane 5 Launch Profile: Heat Flux



**PSLV**

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# PSLV C-53

## PSLV-C53



### DS-EO

Co-passenger Satellites-NeuSAR, SCOOB-I

### Third Stage

#### HPS3

Length: 3.6m

Diameter: 2m

Propellant: Solid (HTPB based)

Propellant Mass: 7.65t

### First Stage

#### PS1

### Payload Fairing

### Fourth Stage

#### PS4

Length: 3.0m

Diameter: 1.34m

Liquid Propellant: MMH + MON3

Propellant Mass: 0.8t

### Second Stage

#### PS2

Length: 12.8m

Diameter: 2.8m

Liquid Propellant: UH25 + N<sub>2</sub>O<sub>4</sub>

Propellant Mass: 41t

#### PS1

Length: 20m

Diameter: 2.8m

Propellant: Solid (HTPB based)

Propellant Mass: 139t

Height: 44.4 m

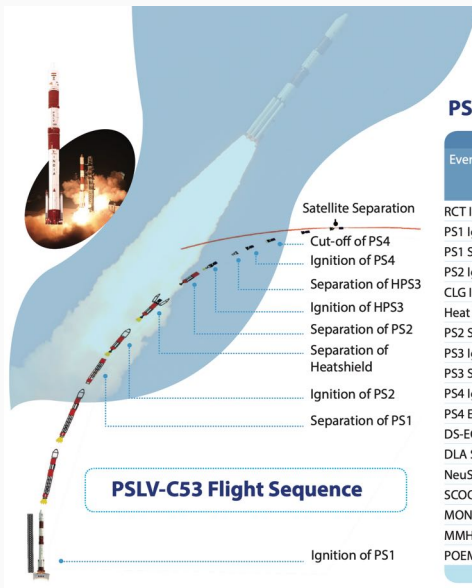


image from ISRO brochure for PSLV C-53





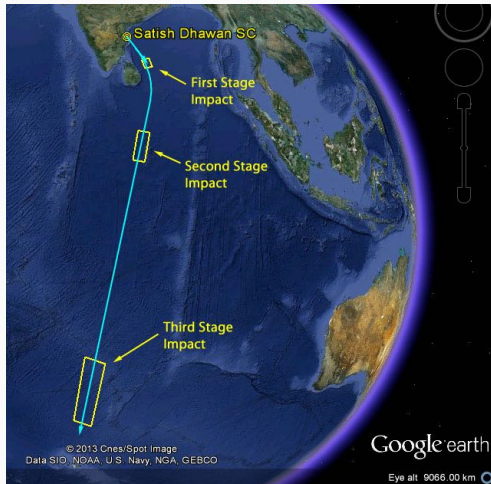
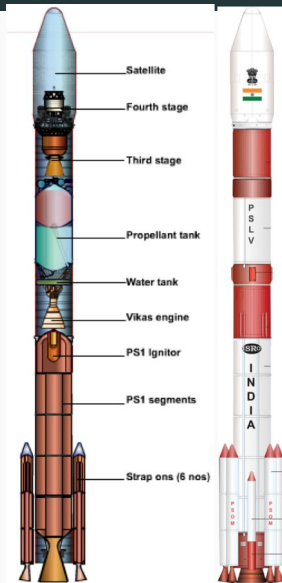
# PSLV C-53



## 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

# “Dog-leg” launch path



**GSLV**

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## GSLV at a glance !

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

GSLV: Geo-Synchronous Satellite Launch Vehicle

HTPB: Hydroxyl terminated Polybutadiene, LH<sub>2</sub>: Liquid Hydrogen,

LOX: Liquid Oxygen, N<sub>2</sub>O<sub>4</sub>: Nitrogen Tetroxide,

UH25: Unsymmetrical Dimethyl Hydrazine + 25% Hydrazine Hydrate



# GSLV Mk-II *F11*

## Payload Fairing

Diameter: 3.4m

## Third Stage

GS3 (CUS15)

Height : 9.894m

Diameter : 2.8m

Propellant: LH2 & LOX

## First Stage

GS1 (S139 + 4 x L40H)

### S139

Height : 20.176m

Diameter : 2.8m

Propellant: HTPB

## Liquid strap-ons(4 x L40)

Height : 19.682m

Diameter : 2.1m

Propellant: UH25 & N<sub>2</sub>O<sub>4</sub>

## GSAT-7A

Mass: 2250 kg

## Second Stage

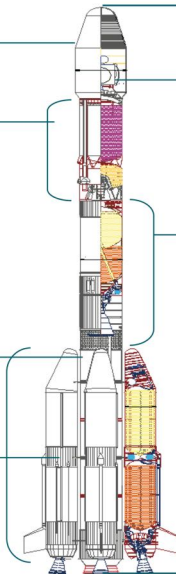
GS2 (GL40)

Height : 11.938m

Diameter : 2.8m

Propellant: UH25 & N<sub>2</sub>O<sub>4</sub>

Height : 50.926 m



# GSLV Mk-III *M1* (Chandrayaan-2)

## GEOSYNCHRONOUS SATELLITE LAUNCH VEHICLE MARK-III (GSLV Mk-III)

The GSLV Mk-III will carry Chandrayaan 2 to its designated orbit. **This three-stage vehicle is India's most powerful launcher to date**, and is capable of launching 4-tonne class of satellites to the Geosynchronous Transfer Orbit (GTO).

Height:  
**43.43 m**

Lift Off Mass:  
**640 tonnes**

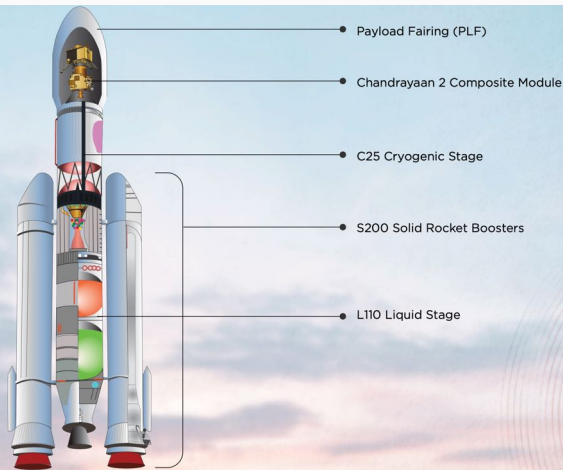


image from ISRO brochure for GSLV Mk-III M1



# GSLV Mk-III *M1* (Chandrayaan-2)

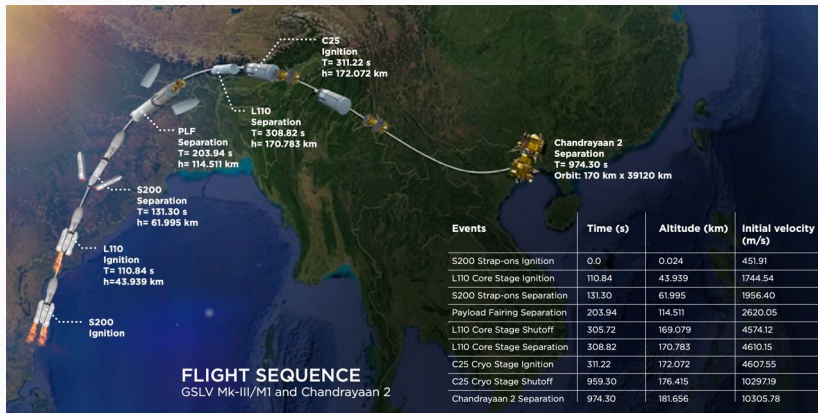
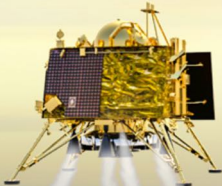


image from ISRO brochure for GSLV Mk-III M1



# Vikram Lander (Chandrayaan-2)

## VIKRAM LANDER



Weight  
**1,471 kg**



Power  
**650 W**



Payloads  
**3**  
**1 passive experiment**



Dimensions  
**2.54 x 2 x 1.2 m**



Mission Life  
**1 lunar day**

Chandrayaan 2's lander is named Vikram after Dr Vikram A Sarabhai, the Father of the Indian Space Programme. **It is designed to function for one lunar day, which is equivalent to about 14 Earth days.** Vikram has the capability to communicate with IDSN at Byalalu near Bangalore, as well as with the Orbiter and Pragyan rover. The lander is designed to execute a soft landing on the lunar surface at a touchdown velocity of 2 metres per second.

**Landing Site:** High plain between two craters, Manzinus C and Simpelius N, at a latitude of about 70.9° South 22.7° East

**Alternate Site:** 67.7 ° South 18.4° West

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

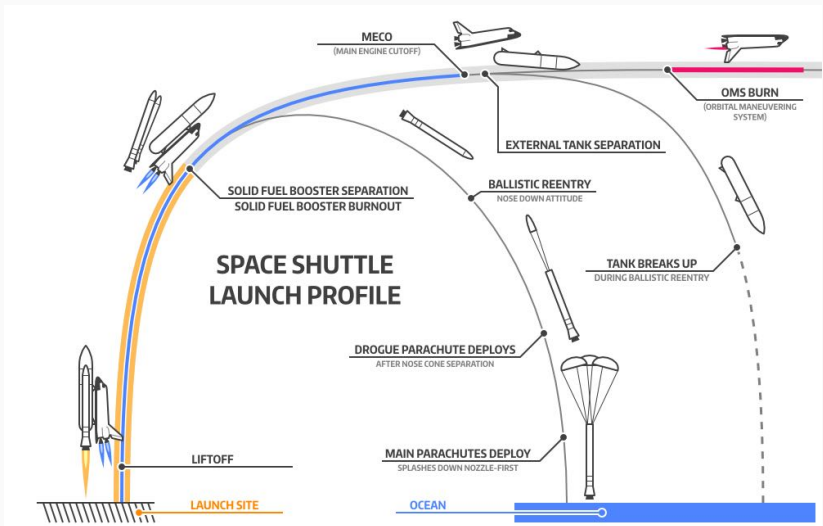
Height : 43.43 m  
Lift-off weight : 640 t  
Propulsion : Solid, Liquid & Cryogenic  
Payload mass : 4000 kg  
Orbit : Geosynchronous  
Transfer Orbit



# **Reusable Launch Vehicle**

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# Space Shuttle: Reusable Launch Vehicle



## Space Shuttle: Reusable Launch Vehicle

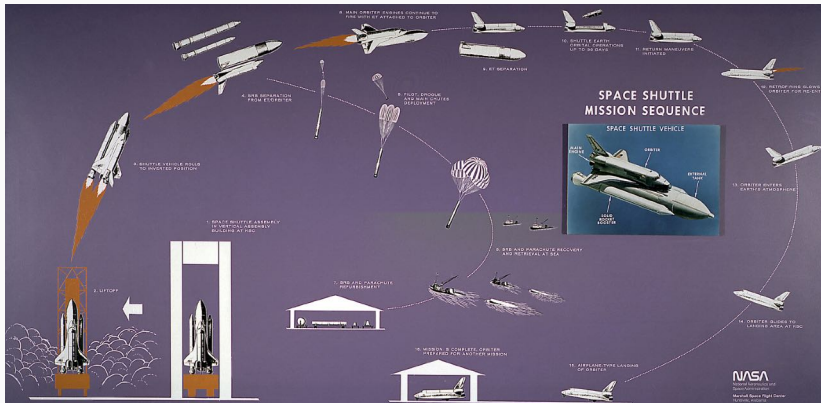
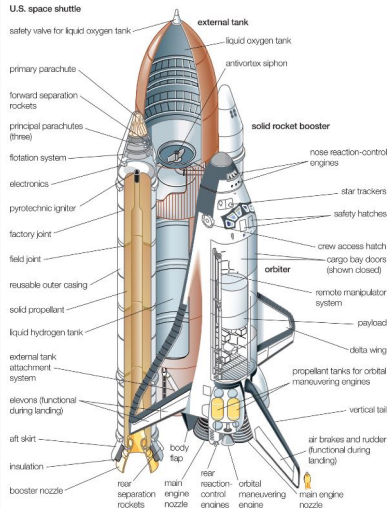


image from NASA



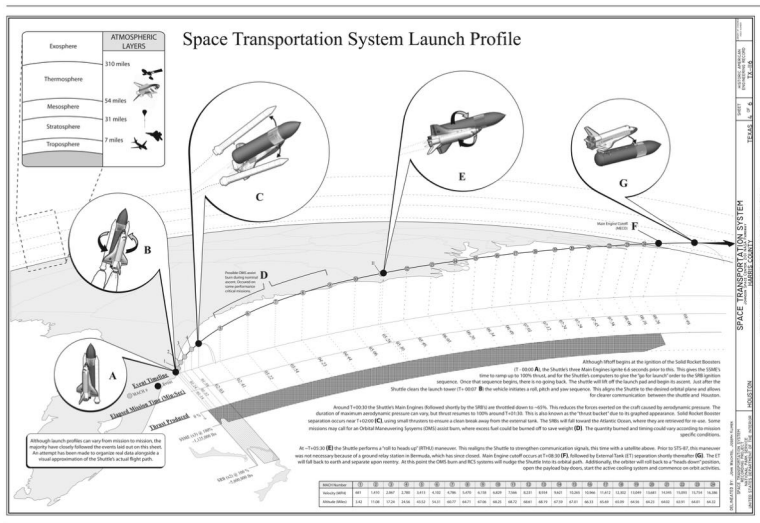
# Space Shuttle Configuration



infographic from tarzan1941.tumblr



# Space Shuttle Launch Profile



# Falcon (SpaceX): Reusable Launch Vehicle

## SPACEX FALCON 9 LAUNCH PROFILE

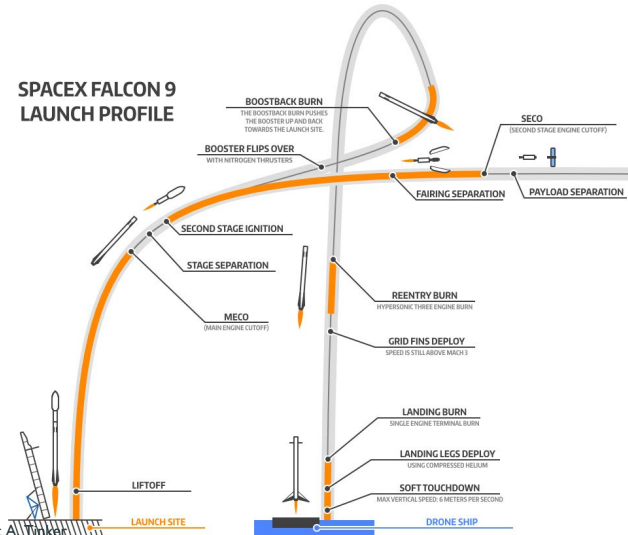


image from Just A Tinker

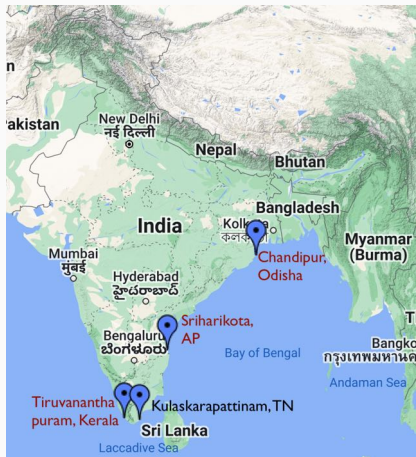


# Launch facilities

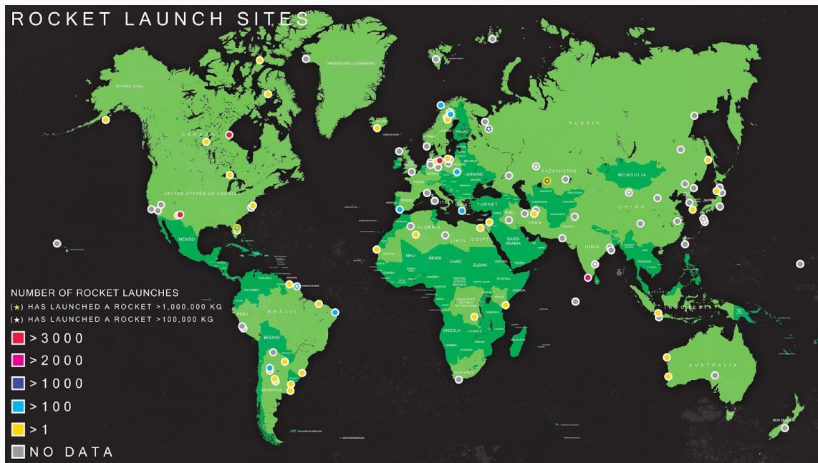
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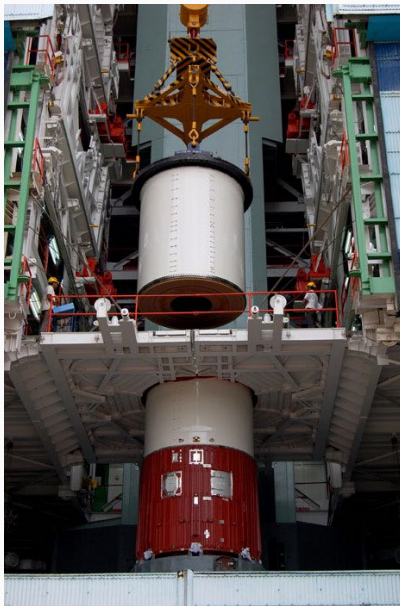
# Launch Sites in India



# Launch Sites across the World



# Launch Pad: Assembling PSLV



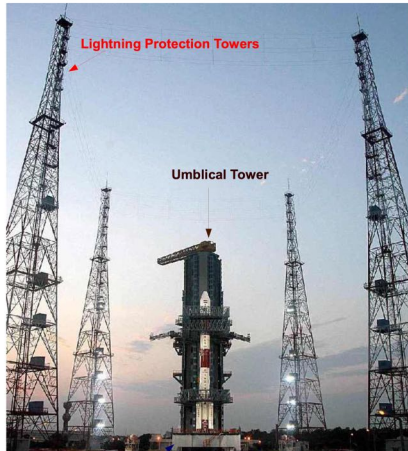
# Launch Pad – Ariane V



# Launch Pad – Buran



# Launch Pad – SHAR



# Space Shuttle Launchpad

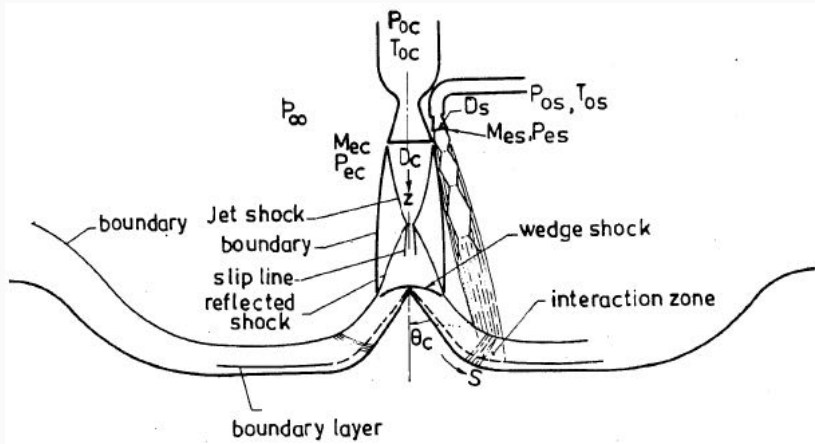


# Space Shuttle Launch





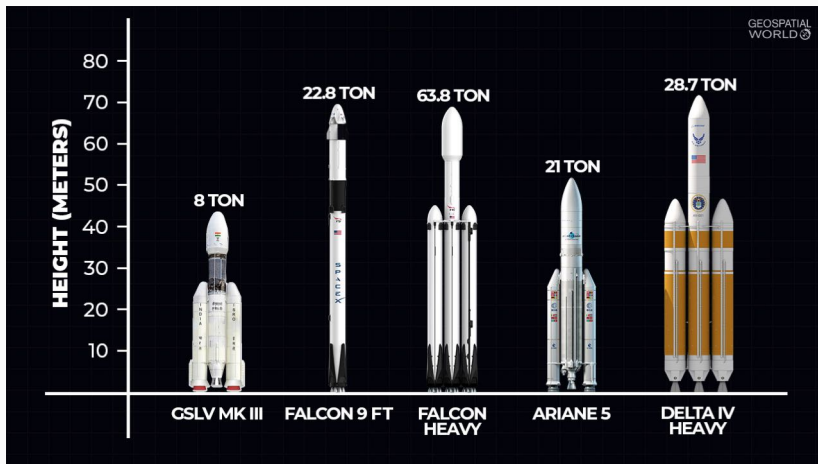
# Launch Pad Heat Transfer



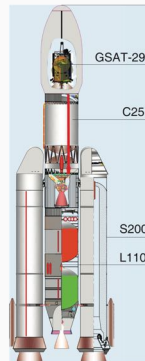
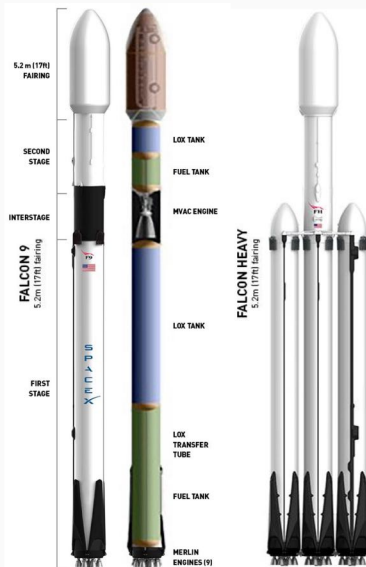
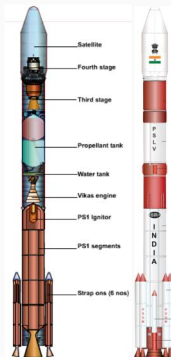
# Comparing Launch Vehicles

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# GSLV vs Similar Vehicles



# PSLV, GSLV, and SpaceX Falcon Series



# SpaceX Falcon-9

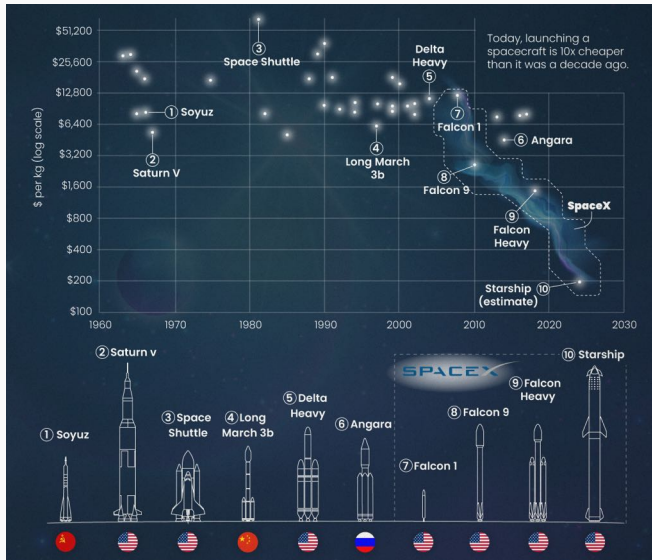


# GSLV vs Similar Vehicles

	Payload (tons)			LEO Launch Cost (\$ million)			Height	Diameter	Lift-off Mass
	LEO	GTO	LTO/TLI	Total	per-ton		(m)	(m)	(tons)
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



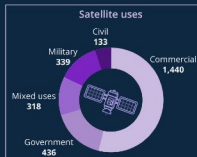
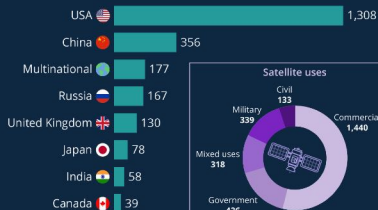
# Cost of launches



# Satellites in Space

## The Countries With the Most Satellites in Space

Satellites currently orbiting Earth by country\* (as of April 2020)



\* Country of operator/owner

Source: Union of Concerned Scientist Satellite Database



statista

infographic from statista.com

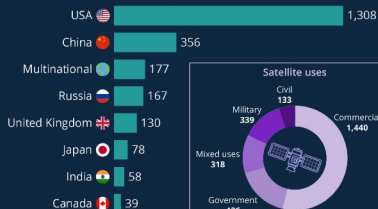




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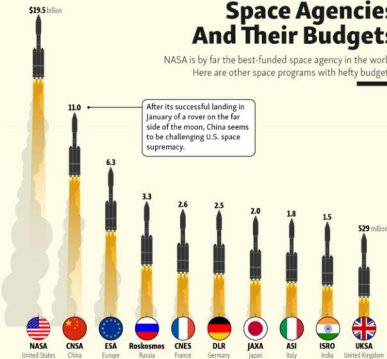
Source: Union of Concerned Scientist Satellite Database



statista

## Space Agencies And Their Budgets

NASA is by far the best-funded space agency in the world. Here are other space programs with hefty budgets.



RadioFreeEurope  
RadioLiberty

C. Coelho. Source: Public domain, latest available data.

