

# Session 7+8 - Launch Vehicles

## Space Technology

PSLV, GSLV, LVM3 & other launch vehicles



## Legacy Launch Vehicles

Foundation for Advanced Launch Vehicles

### SLV

- 1. Beginning of India's Space Journey:** The Satellite Launch Vehicle (SLV) program marked India's entry into the domain of satellite launch vehicles.
- 2. SLV-3:** India's first experimental satellite launch vehicle, known as Satellite Launch Vehicle-3 (SLV-3).
- 3. Technical Specifications:** SLV-3 was an all-solid, four-stage vehicle, designed to place 40 kg class payloads into Low Earth Orbit (LEO).
- 3. Initial Launches:** The first experimental flight in August 1979 was partially successful. The significant milestone was achieved on **July 18, 1980**, when SLV-3 successfully placed the Rohini satellite, RS-1, into orbit.
- 4. International Recognition:** The successful deployment of RS-1 positioned India as the sixth nation to join the exclusive club of space-faring nations.
- 5. Subsequent Launches:** There were additional launches in **May 1981** and **April 1983**, which focused on orbiting Rohini satellites equipped with remote sensing sensors.

## ASLV

1. **ASLV Program:** An advancement over the SLV, aimed at increasing payload capacity to **150 kg** for Low Earth Orbits, three times that of SLV-3.
2. **Technical Specifications:** The ASLV was 24 meters tall, with a lift-off weight of 40 tonnes, featuring a five-stage, all-solid propellant design.
3. **Key Technologies:** Included strap-on technology, navigation, a heat shield etc.
4. **Developmental Flights:** Four developmental flights in total, with the first flight on **March 24, 1987**.
5. **Initial Challenges:** Early launches faced failures due to technical challenges.
6. **Significant Achievements:** Successful launch of ASLV-D3 on **May 20, 1992**, carrying the SROSS-C satellite into an orbit of 255 x 430 km.
7. **Final Launch:** ASLV-D4 on **May 4, 1994**, successfully orbited the SROSS-C2 satellite.

## PSLV

### The Work-horse of ISRO



1. **PSLV:** Third generation launch vehicle of India, first to be equipped with liquid stages.
2. **Initial Success:** First successful launch in October 1994, establishing it as a reliable and versatile workhorse launch vehicle.
3. **Diverse Satellite Launches:** Has launched numerous Indian and foreign customer satellites.
4. **Notable Achievements:** Successfully launched Chandrayaan-1 in 2008 and Mars Orbiter Spacecraft in 2013, reaching Moon and Mars respectively. Aditya L1 mission was launched using this.
5. **Milestone:** PSLV-C48 marked the 50th launch of PSLV.
6. **'Workhorse of ISRO':** Earned its title by consistently delivering satellites into low earth orbits, particularly the IRS Series of satellites.
7. **Geosynchronous and Geostationary Orbits:** Used for launching satellites into these orbits, including satellites from the IRNSS Constellation.
8. **Multi-Payload Capability:** Capable of placing multiple payloads into orbit, using multi-payload adaptors in the payload fairing.
9. **Mission Flexibility and Performance:** Evident from multi-orbit and multi-satellite missions, showcasing its versatility and reliability.
10. **Global Market Presence:** Long string of consecutive successes and multi-satellite launch capability reinforces its status as a reliable, versatile, and affordable launcher.

## Payload Capacity

- **Payload Capacity to SSPO:** PSLV can deliver up to **1,750 kg** to Sun-Synchronous Polar Orbits of **600 km altitude**.
- **PSLV as the Workhorse of ISRO:** Earned through consistent delivery of satellites to Low Earth Orbits.
- **Payload to Sub GTO:** PSLV has a capacity of **1,425 kg** for Geosynchronous Transfer Orbit (GTO) missions.
- **IRNSS Constellation Launches:** PSLV has been instrumental in launching satellites into Geosynchronous and Geostationary orbits, particularly for the IRNSS constellation.

## Launches

- 60 Launches | 58 Successful

SI No. ↕	Name ↕	Launch Date ↕	Launcher Type ↕	Payload ↕
60	<a href="#">PSLV-C58/XPoSat Mission</a>	Jan 01, 2024	PSLV-DL	<a href="#">XPoSat</a>
59	<a href="#">PSLV-C57/Aditya-L1 Mission</a>	Sep 02, 2023	PSLV-XL	<a href="#">Aditya-L1 payloads</a>
58	<a href="#">PSLV-C56/DS-SAR Mission</a>	July 30, 2023	PSLV-CA	<a href="#">DS-SAR</a>
57	<a href="#">PSLV-C55/TeLEOS-2 Mission</a>	Apr 22, 2023	PSLV-CA	<a href="#">TeLEOS-2</a>
56	<a href="#">PSLV-C54/EOS-06 Mission</a>	Nov 26, 2022	PSLV-XL	<a href="#">EOS_06</a>
55	<a href="#">PSLV-C53/DS-EO Mission</a>	Jun 30, 2022		
54	<a href="#">PSLV-C52/EOS-04 Mission</a>	Feb 14, 2022	PSLV-XL	

## 4 Stages

4 stages	Stage	Engine	Fuel	Fuel Type
	Fourth: PS4	2 x PS-4	Mixed Oxides of Nitrogen (MON) + Monomethylhydrazine (MMH)	Liquid
	Third: PS3	S7	Hydroxyl-terminated polybutadiene (HTPB)	Solid
	Second: PS2	Vikas	Unsymmetrical Dimethylhydrazine (UDMH) + Nitrogen Tetroxide (N <sub>2</sub> O <sub>4</sub> )	Liquid
	First: PS1	S139	Hydroxyl-terminated polybutadiene (HTPB)	Solid

### Strap-on Motors: To augment first stage thrust.

#### PSLV Variants and Strap-on Motors:

- PSLV-XL uses **6** solid rocket strap-on motors
- PSLV-QL uses **4** solid rocket strap-on motors
- PSLV-DL uses **2** solid rocket strap-on motors
- **PSLV-CA**: The core alone version, does not use strap-on motors.
- **Fuel Used: Hydroxyl-terminated polybutadiene (HTPB).**

### Notable Missions

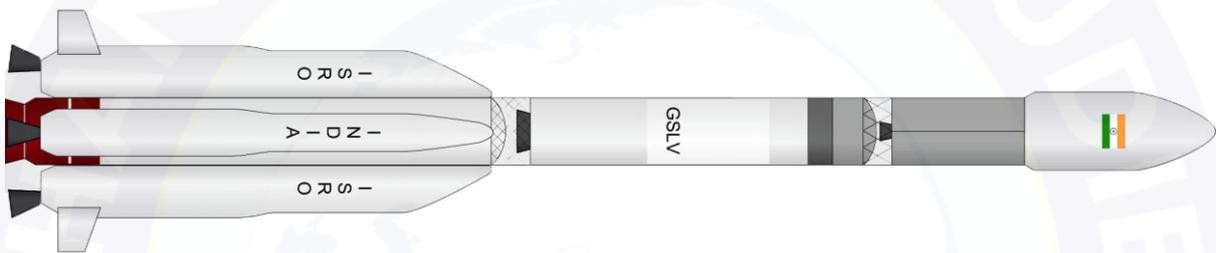
- **Chandrayaan-1**: India's first lunar probe, launched by PSLV in **2008**.
- **Mars Orbiter Mission (Mangalyaan)**: India's first interplanetary mission, launched by PSLV.
- **Astrosat**: India's first space observatory, launched by PSLV.
- **Aditya-L1**: India's first Solar mission, launched by PSLV.
- **PSLV-C37**: Mission that launched the Cartosat-2 series satellite and **103 co-passenger satellites**.
- **Navigation Satellites**: All of India's IRNSS satellites for navigation were launched by PSLV.

# GSLV Mk II

## GSLV

- Indian-made launch vehicle for communication satellites in GEO transfer orbit.
- Operator: Indian Space Research Organisation (ISRO)
- Launches: 15 since 2001
- Initiation: 1990
- Components: Borrowed from PSLV—S125/S139 solid rocket, Vikas liquid engine
- Challenge: Originally lacked LOX/LH2 Cryogenic engine for third stage

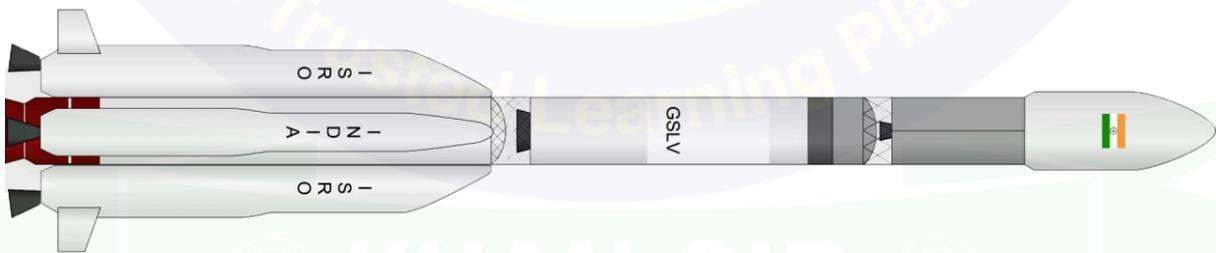
## Configuration



### A 3 stage launch vehicle

- First Stage: GS1  
Engine: S139, derived from PSLV's PS1.  
Fuel: HTPB
- Second Stage: GS2  
Engine: Vikas  
Fuel: UH25 + N2O4
- Third Stage: CUS (Cryogenic Upper Stage)  
Engine: CE-7.5, India's first cryogenic engine.  
Fuel: LOX + LH2

## Boosters



### L40 Strap-on Boosters

- Quantity: 4 liquid strap-on motors
- Engine: Vikas engine for each strap-on
- Role: Augment thrust of solid rocket core in first stage
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## Orbits and Payload Capacity

- To GTO: 2,250 kg  
Used for INSAT and GSAT communication satellites in Geostationary orbits.
- To LEO: 6,000 kg  
Allows launching of both heavy and multiple smaller satellites.

## Recent Launches

15	GSLV-F12/NVS-01 Mission	May 29, 2023	GSLV	GTO (Geosynchronous Transfer Orbit)	NVS-01	
14	GSLV-F10 / EOS-03	Aug 12, 2021	GSLV	GTO (Geosynchronous Transfer Orbit)	EOS-03	Mission unsuccessful
13	GSLV-F11 / GSAT-7A Mission	Dec 19, 2018	GSLV		GSAT-7A	
12	GSLV-F08/GSAT-6A Mission	Mar 29, 2018	GSLV	GSO (Geosynchronous Orbit)	GSAT-6A	
11	GSLV-F09 / GSAT-9	May 05, 2017	GSLV	GSO (Geosynchronous Orbit)	GSAT-9	
10	GSLV-F05 / INSAT-3DR	Sep 08, 2016	GSLV-MK-II	GTO (Geosynchronous Transfer Orbit)	INSAT-3DR	

## LVM3 / GSLV-MkIII



## Key facts

- Configuration: Three stages with two solid strap-on motors (S200), a liquid core stage (L110), and a high thrust cryogenic upper stage (C25).
  1. S200 Solid Motor: Among the world's largest, containing 204 tonnes of solid propellant - HTPB
  2. L110 Liquid Stage: Twin liquid Vikas engine with 115 tonnes of propellant - UDMH + H<sub>2</sub>O.
  3. C25 Cryogenic Stage: Uses indigenous high thrust cryogenic engine (CE20) with 28 tonnes of propellant – LOX+LH<sub>2</sub>

## Capabilities & Function

1. Purpose: Launches spacecraft weighing up to 4,000 kg to GTO.
2. Lift-off: Begins with simultaneous ignition of the two S200 boosters, followed by the L110 ignition at 113s.

## Payloads

- Payload to GTO: 4,000 kg
- Capable of launching 4 tonne class GSAT series satellites into Geosynchronous Transfer Orbits.
- Payload to LEO: 8,000 kg
- With its powerful cryogenic stage, it can place heavy payloads into 600 km altitude Low Earth Orbits.

## In total 7 launches till July 2023

SINo	Title	Launch Date	Launcher Type	Payload
7	LVM3 M4 / Chandrayaan-3 Moon Mission	July 14, 2023	LVM3	Chandrayaan-3
6	LVM3 M3 / OneWeb India-2 Mission	Mar 26, 2023	LVM3	OneWeb Gen-1
5	LVM3 M2 / OneWeb India-1 Mission	Oct 23, 2022	LVM3	OneWeb Gen-1
4	LVM3 - M1 / Chandrayaan-2 Mission	Jul 22, 2019	LVM3	Chandrayaan2
3	LVM3 -D2 / GSAT-29 Mission	Nov 14, 2018	LVM3	GSAT-29
2	LVM3 -D1/GSAT-19 Mission	Jun 05, 2017	LVM3	GSAT-19
1	LVM-3/CARE Mission	Dec 18, 2014	LVM3	Crew module Atmospheric Re-entry Experiment (CARE)

## Importance for future missions

- LVM-3's successful launch of Chandrayaan-3 as pivotal for the Gaganyaan mission.
- Chandrayaan-3 used multiple systems rated for humans: human-rated S200 solid strap-on motors and the L110 Vikas engine.
- Gaganyaan project aims to showcase India's human spaceflight capability:
- three astronauts will be launched to a 400 km orbit for three days and will return safely to earth, landing in Indian seas.

## OneWeb at a glance

- UK based firm - Building global communication network from space for governments, businesses, and communities.
- Implements Low Earth Orbit (LEO) satellite constellation of 618 satellites, sent in 18 launches in total; 3 in this year
- Bharti Enterprises of India: major investor and shareholder.
- Achieved global service readiness, a first for LEO operators. Soon to launch global coverage.
- ISRO launched 36 OneWeb satellites from Sriharikota in March 2023; earlier also launched 36 satellites in Oct 2022.
- Commercial partnership: OneWeb Group Company (UK) and ISRO's NewSpace India Limited (NSIL)

## SSLV



## Small Satellite Launch Vehicle (SSLV)

- Configuration: 3-stage Launch Vehicle with three Solid Propulsion Stages and a liquid propulsion based Velocity Trimming Module (VTM).
- Capability: Launches Mini, Micro, or Nanosatellites (10 to 500 kg mass) into a 500km Low Earth Orbits on 'launch-on-demand' basis from SDSC/SHAR.
- Features: Low cost, quick turn-around, multiple satellite accommodation, launch on demand, and minimal infrastructure.
- Payload Capability
- Single Satellite: Up to 500kg in 500km planar orbit.

- Multiple Satellites: Three satellites ranging from 10kg to 300kg into a 500km Planar Orbit.
- Technical Specifications
- Stage 1 (SS1): HTPB based Solid Propellant
- Stage 2 (SS2): HTPB based Solid Propellant
- Stage 3 (SS3): HTPB based Solid Propellant
- Velocity Trimming Module (VTM):. Fuel is MMH + MON-3 (Liquid). It achieves desired velocity for the insertion of the satellites into the intended orbit.

## 2 launches till Feb 2023

SINo	Title	Launch Date	Launcher Type	Payload	Remarks
2	SSLV-D2/EOS-07 MISSION	Feb 10, 2023	SSLV	EOS-07	
1	SSLV-D1/EOS-02 Mission	Aug 07, 2022	SSLV	EOS-02	

- 2<sup>nd</sup> Launch in February 2023
- Mission: Launch of EOS-07, Janus-1, and AzaadiSAT-2 satellites
- Orbit: 450 km circular orbit, 37-degree inclination
- The previous flight, SSLV-D1 on August 7, 2022, had shortcomings and failed to place the satellites.
- Satellite Information
- EOS-07: An Earth Observation Satellite by ISRO, weighing 153.6 kg.
- Janus-1: A technology demonstration satellite weighing 10.2 kg, from ANTARIS, USA.
- AzaadiSAT-2: Weighing 8.8 kg, realised by Space Kidz India. Integrated with scientific payloads developed by 750 girl students across India.

## Sounding Rockets

### About Sounding Rockets-1

- Sounding rockets are one or two-stage rockets with solid propellants.
- Used for upper atmospheric research and space research.
- Serve as test platforms for new components for launch vehicles and satellites.
- Historical Context
- Thumba Equatorial Rocket Launching Station (TERLS) established in 1963.
- First sounding rocket launch on 21 November 1963 marked the start of the Indian Space Programme.
- Initial rockets were imported from Russia (M-100) and France (Centaure).

### About Sounding Rockets-2

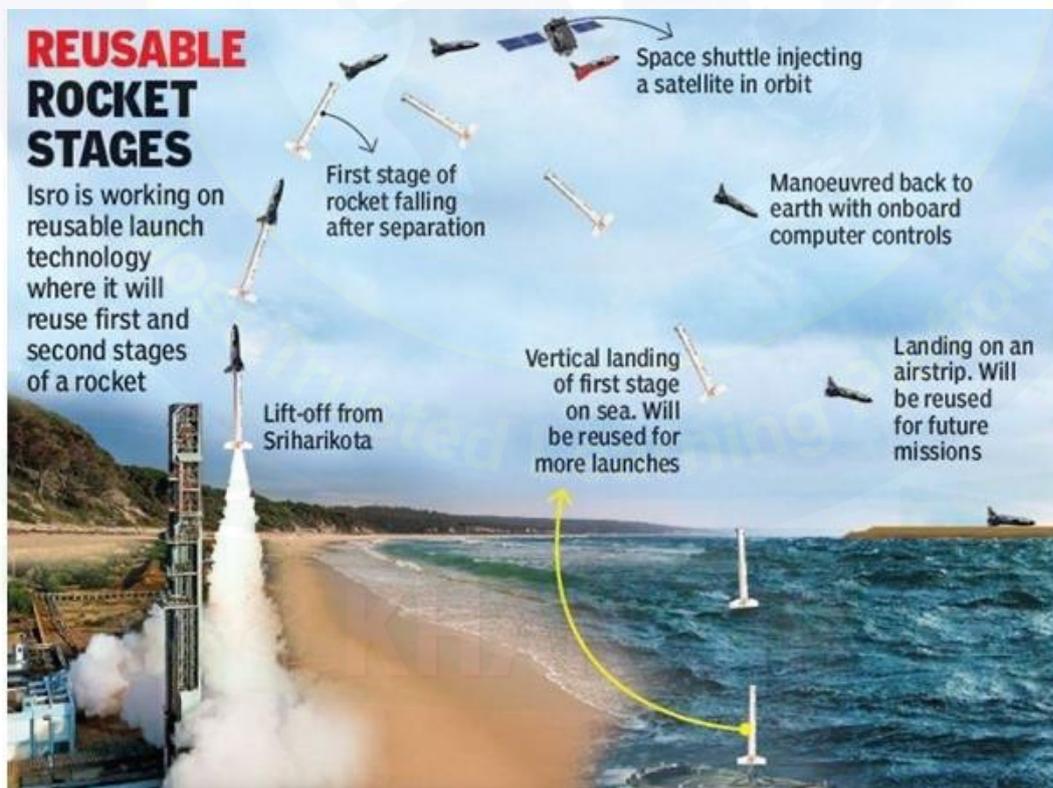
- Development in India
- Indigenous sounding rockets launched from 1965.
- Rohini Sounding Rocket (RSR) Programme consolidated all activities in 1975. RH-75 was the first truly Indian sounding rocket in 1967, followed by RH-100 and RH-125.

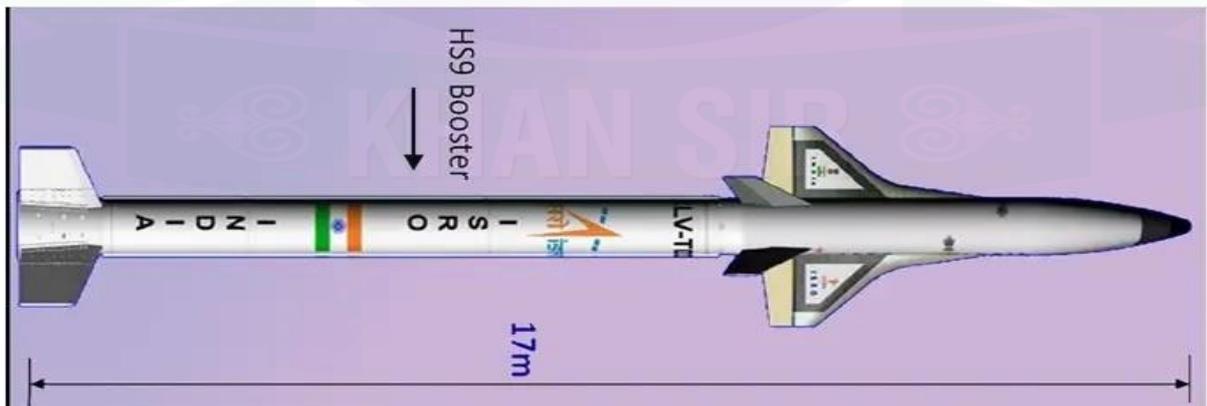
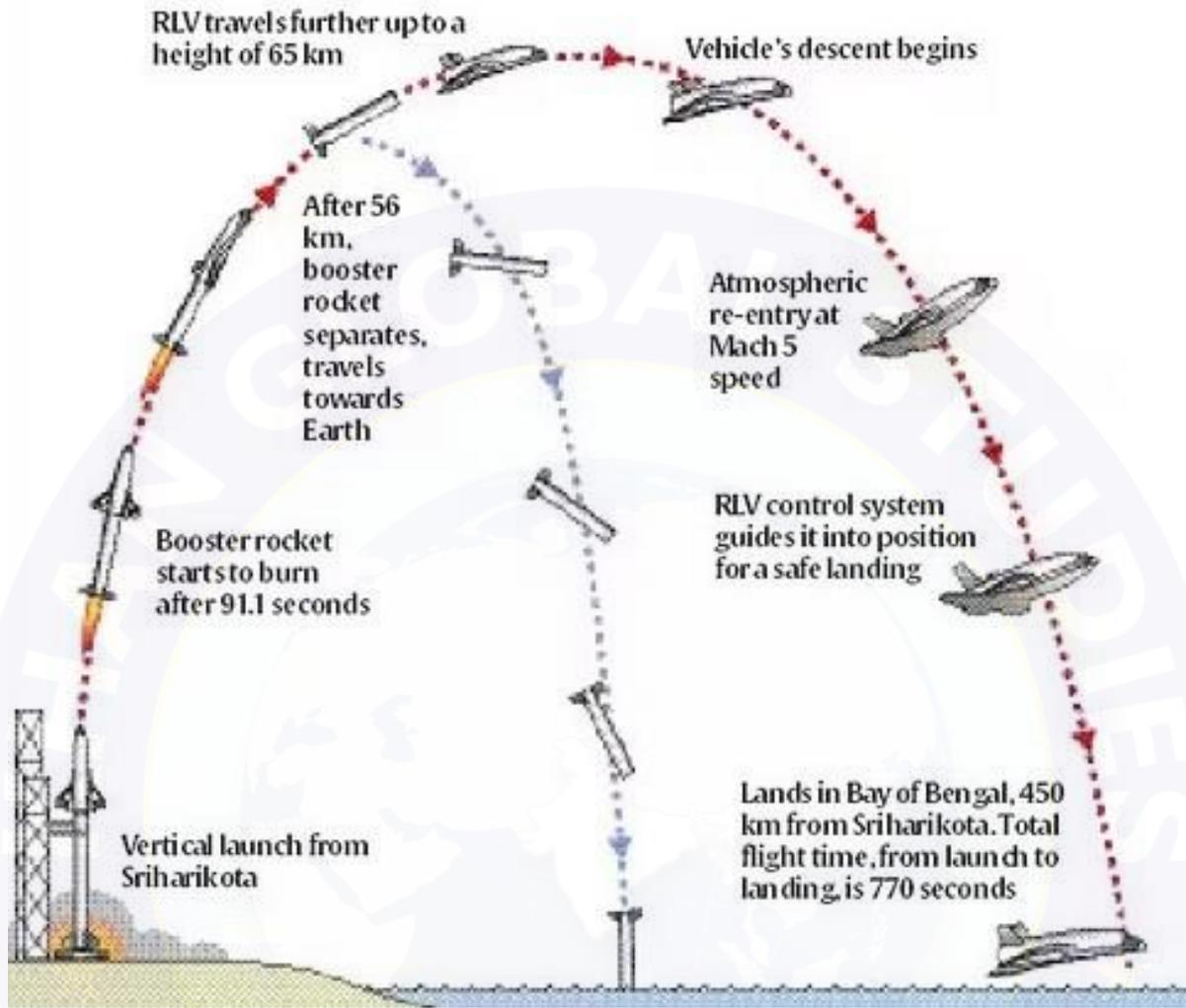
- Operational Capabilities
- Three versions: RH-200, RH-300-Mk-II, RH-560-MK-II.
- Payload range from 8-100 Kg.
- Altitude range from 80-475 km.
- Launch Sites
- Thumba, Balasore, and SDSC-SHAR are primary launch pads.
- Significance
- The sounding rocket programme laid the foundation for advanced launch vehicle technology in India.

## Achievements

- The first sounding rocket to be launched from Thumba was the American Nike-Apache - on November 21, 1963.
- After that, two-stage rockets imported from Russia (M-100) and France (Centaure) were flown.
- The ISRO launched its own version - Rohini RH-75 - in 1967.
- The ISRO has launched more than 1,600 RH-200 rockets so far.
- The rocket celebrated its 100th consecutive successful mission on July 15, 2015.
- It celebrated the 200th successful launch of the Rohini RH-200 sounding rocket in 2022.

## Reusable Launch Vehicle – Technology Demonstrator (RLV-TD)







## RLV-TD

- Conceived by the Indian Space Research Organisation (ISRO).
- Aimed at developing a Two Stage To Orbit (TSTO) reusable launch vehicle.
- Began in 2012, Tests started in 2016
- Configuration and Objectives
- The RLV-TD is a winged vehicle.
- Evaluates technologies like powered cruise flight, hypersonic flight, and autonomous landing.
- Utilises air-breathing propulsion for these tests.

## RLV-TD

- Recent Milestones: ISRO successfully carried out the landing experiment on April 2, 2023.
  - Executed at the Aeronautical Test Range in Challakere, Chitradurga.
  - Second test, LEX, validated integrated navigation, guidance, and control system.
- Programme Objectives
  - Develop a scalable version of a fully reusable Two Stage To Orbit (TSTO) system.
- Long-term Impact
  - Aims to reduce launch costs by a factor of 10.
  - Contributes to making space exploration more accessible and sustainable.
  - Timeline
    - Final version expected to take 10 to 15 years for development.

## Comparison with Starship of Space X

- Development Stage
  - ✓ RLV-TD: Experimental phase, successful landing experiment on April 2, 2023.
  - ✓ Starship: More advanced stage of development.
- Design
  - ✓ Both designed as Two Stage to Orbit (TSTO) systems.
- Payload Capacity
  - ✓ RLV-TD: Not disclosed.
  - ✓ Starship: Higher but varies based on mission.
- Mission Scope
  - ✓ Both aim for accessible and sustainable space exploration.
  - ✓ Starship: Also designed for human missions to Mars.

## Space Shuttle Programme of NASA

- Fourth human spaceflight program by NASA.
- Operational from 1981 to 2011.
- Routine Earth-to-orbit crew and cargo transportation.
- Composed of an orbiter and two reusable solid rocket boosters.
- Carried up to eight astronauts and 50,000 lb (23,000 kg) of payload to low Earth orbit (LEO).
- Only winged crewed spacecraft to achieve orbit and landing.
- Large payload deliveries to various orbits, including ISS.
- Crew rotation for ISS and Hubble Space Telescope service missions.
- Designed for 100 launches or 10 years' operational life.
- Final mission, STS-135, ended on July 21, 2011, at Kennedy Space Center in Florida.