

# GSLV-D5

INDIAN CRYOGENIC ENGINE AND STAGE



GSAT-14



INDIAN SPACE RESEARCH ORGANISATION





**GSLV-D5** is the eighth flight of India's Geosynchronous Satellite Launch Vehicle (GSLV). It is also the fourth developmental flight of GSLV. During this flight, the indigenously developed Cryogenic Upper Stage (CUS) will be flight tested for the second time.

#### GSLV-D5 Mission

<b>Overall Height</b>	: 49.13 metre
<b>Lift-off Mass</b>	: 414.75 Ton
<b>Lift-off Thrust</b>	: 6773 kilo Newton
<b>No. of Stages</b>	: 3

GSLV-D5 will launch 1982 Kg GSAT-14, a communication satellite, into Geosynchronous Transfer Orbit (GTO). After reaching GTO, GSAT-14 will use its own propulsion system to reach its geostationary orbital home and will be stationed at 74° East longitude. GSAT-14 will help provide many satellite based communication services to the country including tele-education and telemedicine.

GSLV-D5/GSAT-14 mission will be launched from the Second Launch Pad at Satish Dhawan Space Centre SHAR (SDSC SHAR), Sriharikota. The flight duration of GSLV-D5 is 17 min 8 sec.

#### Targeted Orbit of GSLV-D5

<b>Perigee</b>	: $180 \pm 5$ km
<b>Apogee</b>	: $35975 \pm 675$ km
<b>Inclination</b>	: $19.3 \pm 0.1$ deg



# GSLV-D5

GSLV is a three-stage launch vehicle with solid, liquid and cryogenic stages. It is designed to inject 2 Ton class of communication satellites to Geosynchronous Transfer Orbit (GTO). The four liquid L40 strap-ons as well as the second stage of GSLV use storable liquid propellants.

GSLV-D5 vehicle is configured with its first and second stages similar to the ones flown during earlier GSLV missions. The third stage is the indigenous cryogenic stage. The metallic payload fairing with a diameter of 3.4 metre is adopted for GSLV-D5.

S-band telemetry and C-band transponders enable GSLV-D5 performance monitoring, tracking, range safety / flight safety and Preliminary Orbit Determination (POD).

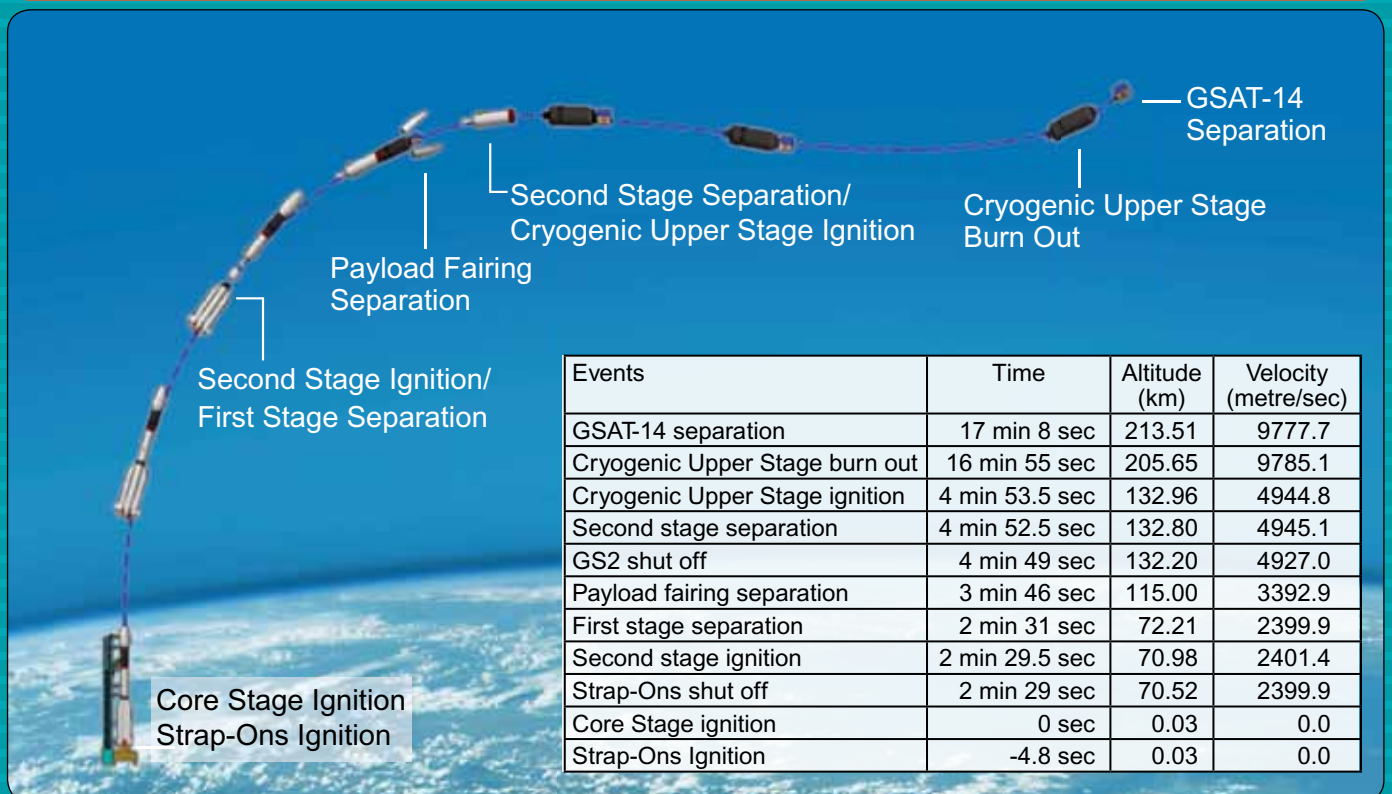


GSLV-D5 core stage integration at Vehicle Assembly Building



One of L40 Strap-ons being assembled to the core stage

## GSLV-D5 Flight Profile



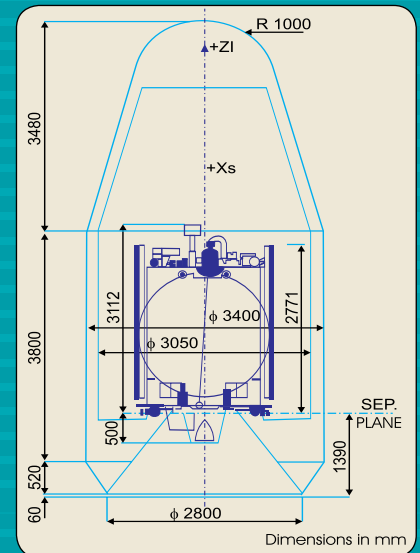
## GSLV-D5 at a glance

Parameters	Stages			
	FIRST STAGE		SECOND STAGE	THIRD STAGE
	Strap-Ons (4 L40 Hs)	Core Stage (S139)		
Length (m)	19.7	20.1	11.6	8.7
Diameter (m)	2.1	2.8	2.8	2.8
Propellants	UH25 & N <sub>2</sub> O <sub>4</sub>	HTPB	UH25 & N <sub>2</sub> O <sub>4</sub>	LH <sub>2</sub> & 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

HTPB : Hydroxyl Terminated Poly Butadiene, 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-D5 second stage being transferred to the Vehicle Assembly Building



GSAT-14 in GSLV-D5 payload envelope



Indigenous Cryogenic Upper Stage of GSLV-D5



# Indigenous Cryogenic Upper Stage



*Cryogenic stage integration to the vehicle in progress*

test facilities, transportation and handling of cryo fluids and related safety aspects.

ISRO's Cryogenic Upper Stage Project (CUSP) envisaged the design and development of the indigenous Cryogenic Upper Stage to replace the stage procured from Russia and used in GSLV flights. The main engine and two smaller steering engines of CUS together develop a nominal thrust of 73.55 kN in vacuum. During the flight, CUS fires for a nominal duration of 720 seconds.

Liquid Oxygen (LOX) and Liquid Hydrogen (LH<sub>2</sub>) from the respective tanks are fed by individual booster pumps to the main turbopump to ensure a high flow rate of propellants into the combustion chamber. Thrust control and mixture ratio control are achieved by two independent regulators. Two gimbaled steering engines provide for control of the stage during its thrusting phase.

A Cryogenic rocket stage is more efficient and provides more thrust for every kilogram of propellant it burns compared to solid and earth-storable liquid propellant rocket stages. Specific impulse (a measure of the efficiency) achievable with cryogenic propellants (liquid Hydrogen and liquid Oxygen) is much higher compared to earth storable liquid and solid propellants, giving it a substantial payload advantage.

However, cryogenic stage is technically a very complex system compared to solid or earth-storable liquid propellant stages due to its use of propellants at extremely low temperatures and the associated thermal and structural problems.

Oxygen liquifies at  $-183$  deg C and Hydrogen at  $-253$  deg C. The propellants, at these low temperatures are to be pumped using turbo pumps running at around 40,000 rpm. It also entails complex ground support systems like propellant storage and filling systems, cryo engine and stage



*Indigenous Cryogenic Engine*

## Design Improvements in GSLV-D5

Based on its performance during the earlier missions, end-to-end design of GSLV as well as indigenous cryogenic stage systems have been re-examined. Design modifications are implemented wherever required along with rigorous ground testing and improvements are made with respect to the fabrication and quality control to enhance the reliability.

These include:

- Redesign of Lower Shroud which protects the cryogenic engine during atmospheric flight of GSLV-D5
- Redesign of the wire tunnel of the cryo stage to withstand larger forces during flight
- Revised Aerodynamic characterisation of the entire launch vehicle
- Inclusion of Video Imaging System to monitor lower shroud movement during various phases of flight
- Improvements in the Cryogenic upper Stage:
  - Modified design of the Fuel Booster Turbo Pump (FBTP), taking care of the expansion and contraction of the bearings and casing at cryogenic temperatures
  - Modification of Ignition Sequence to ensure the smooth, successful and sustained ignition for Main Engine (ME), Steering Engine (SE) and Gas Generator (GG)



Cryogenic Engine being tested at High Altitude Test (HAT) facility

In addition, indigenisation of many critical systems including Liquid Hydrogen Propellant Acquisition System (to prevent the possibility of contamination), Polyimide pipelines and Liquid Oxygen & Liquid Hydrogen Level Sensors has been successfully accomplished.

In order to validate the design improvements, the following extensive qualification tests have been carried out on the engine at the Main Engine Test (MET) facility and the High Altitude Test (HAT) facility:

- Two acceptance tests for flight unit of FBTP
- High altitude tests to confirm the ignition sequence in flight under vacuum
- Cryogenic Main Engine (200 sec) and Steering Engine (100 sec) acceptance tests

All the improvements have been thoroughly reviewed by expert committees including eminent national experts.



A panoramic view of Cryogenic Upper Stage HAT Facility



# GSAT-14

GSAT-14 is the twenty third geostationary communication satellite of India built by ISRO. Four of GSAT-14's predecessors were launched by GSLV during 2001, 2003, 2004 and 2007 respectively. After its commissioning, GSAT-14 will join the group of India's nine operational geostationary satellites.

The main objectives of GSAT-14 mission are:

- To augment the in-orbit capacity of Extended C and Ku-band transponders
- To provide a platform for new experiments

The cuboid shaped GSAT-14 has a lift-off mass of 1982 kg and the dry mass of the satellite is 851 kg.

GSAT-14 structure is based on ISRO's 2 ton class platform (I-2K satellite bus). The two solar arrays (each with two panels) of GSAT-14 together generate about 2600 W of power, while the light weight Lithium-Ion Batteries supply power during eclipse period.

Some of the new experiments being flown on GSAT-14 are:

- Fiber Optic Gyro
- Active Pixel Sun Sensor
- Ka band beacon propagation studies
- Thermal control coating experiments



Close-up view of GSAT-14 in clean room

## GSAT-14 Salient Features

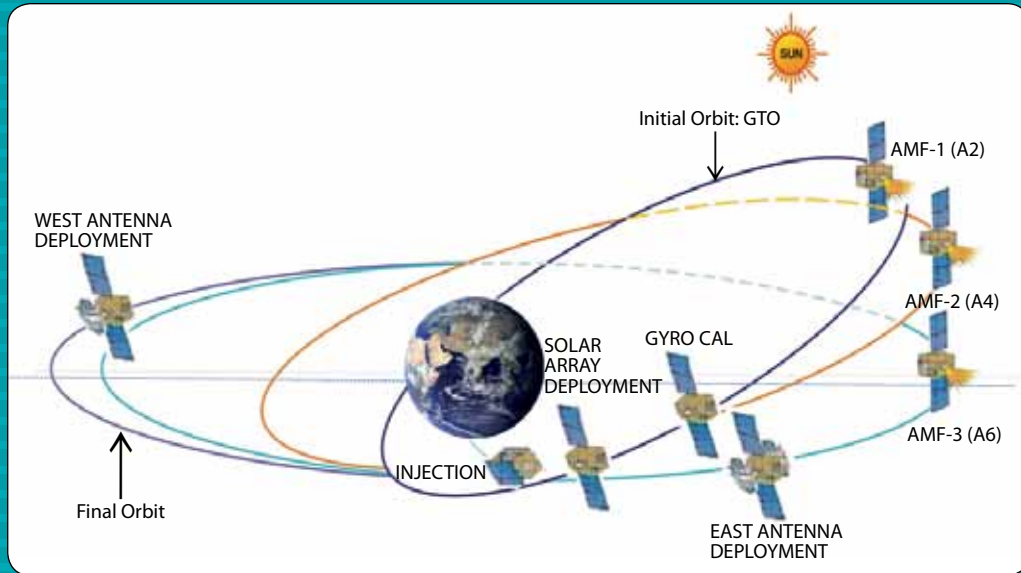


GSAT-14 undergoing vibration test

Configuration	Lift off Mass : 1982 kg Main Structure : I-2K Overall size (m) : 2.0 x 2.0 x 3.6
Antennae	One 2 m and one 2.2 m single shell shaped reflector Antennae (transmit and receive)
Power	2600 W
Attitude and Orbit Control System (AOCS)	Momentum biased 3-axis stabilized mode
Propulsion System	Bi propellant–Mono Methyl Hydrazine and Mixed Oxides of Nitrogen (MON-3)
Communication Payloads	6 Extended C-Band transponders 6 Ku-band transponders 2 Ka-band beacons
Mission life	12 years
Orbital Location	74 deg East longitude in geostationary orbit

After its injection into Geosynchronous Transfer Orbit (GTO) by GSLV-D5, ISRO's Master Control Facility (MCF) at Hassan takes control of GSAT-14 and performs the initial orbit raising manoeuvres in three steps, firing the satellite's Liquid Apogee Motor (LAM), finally placing it in the circular Geostationary Orbit. Following this, the deployment of the antennae and three axis stabilisation of the satellite will be performed. GSAT-14 will be positioned at 74 deg East longitude and co-located with INSAT-3C, INSAT-4CR and KALPANA-1 satellites. The 12 communication transponders onboard GSAT-14 will further augment the capacity in the INSAT/ GSAT system.

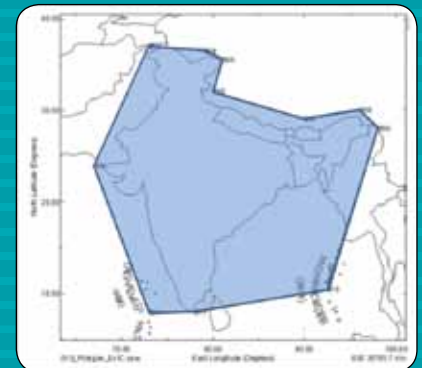
### GSAT-14 Mission Profile



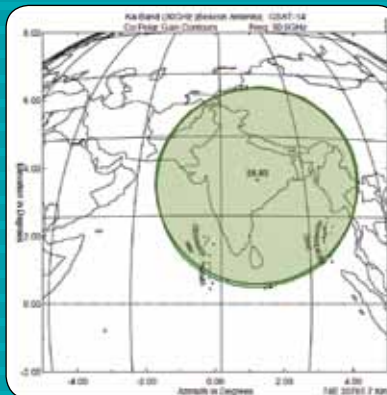
- Six extended C-band transponders for Indian mainland and island coverage with 36 dBW Edge Of Coverage-Effective Isotropic Radiated Power (EOC-EIRP)
- Six Ku-band transponders covering the mainland India with 51.5 dBW EOC-EIRP
- Two Ka-band Beacons operating at 20.2 GHz and 30.5 GHz to carry out attenuation studies



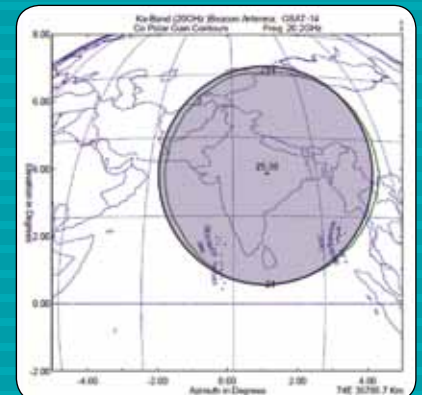
*Ku band Coverage*



*Extended C band Coverage*



*Ka band 30 GHz Coverage*



*Ka band 20 GHz Coverage*



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