अन्तरिक्ष भारत

SPACE INDIA

भारतीय अन्तरिक्ष अनुसंधान संगठन

Indian Space Research Organisation

सितंबर 2013 - दिसंबर 2014 September 2013 - December 2014

The Indian Space Programme

Space activities in the country were initiated with the setting up of Indian National Committee for Space Research (INCOSPAR) in 1962. In the same year, work on Thumba Equatorial Rocket Launching Station (TERLS), near Thiruvananthapuram, was also started. The Indian space programme was institutionalised in November 1969 with the formation of Indian Space Research Organisation (ISRO). Government of India constituted the Space Commission and established the Department of Space (DOS) in June 1972 and brought ISRO under DOS in September 1972.

Department of Space has the primary responsibility of promoting development of space science, technology and applications towards achieving self reliance and assisting in all round development of the nation. Towards this, DOS has evolved the following programmes:

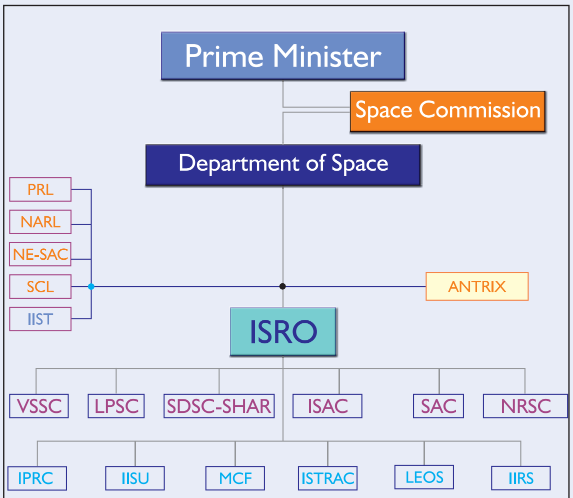
- Indian National Satellite (INSAT) programme for telecommunications, TV broadcasting, meteorology, developmental education, etc.
- Remote Sensing programme for the application of satellite imagery for various developmental purposes
- Indigenous capability for design and development of spacecraft and associated technologies for communications, resources survey and space sciences
- Design and development of launch vehicles with indigenous technology for access to space and orbiting INSAT, IRS spacecraft and space science missions
- Research and development in space sciences and technologies as well as application programme for national development

The Space Commission formulates the policies and oversees the implementation of the Indian space programme to promote the development and application of space science and technology for the socio-economic benefit of the country. DOS implements these programmes through, mainly, Indian Space Research Organisation, Physical Research Laboratory (PRL), National Atmospheric Research Laboratory (NARL), North Eastern-Space Applications Centre (NE-SAC) and Semi-Conductor Laboratory (SCL).

Antrix Corporation, established in 1992 as a government owned company, markets space products and services.

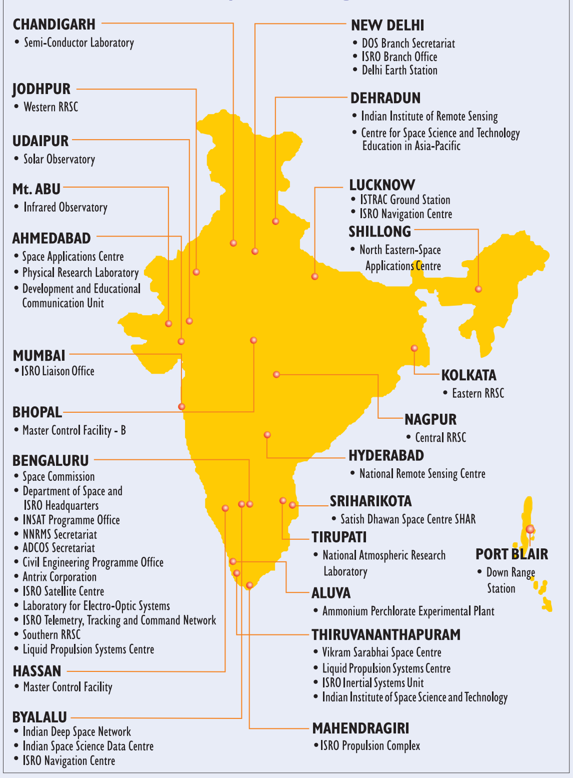
Both the DOS and ISRO Headquarters are located at Bengaluru. The developmental activities are carried out at the Centres and Units spread over the country.

So far, 77 Indian Satellite Missions (including satellites built by students, SRE-1 and CARE Module) and 45 Launches from Sriharikota have been conducted.



PRL: Physical Research Laboratory **NARL:** National Atmospheric Research Laboratory **NE-SAC:** North Eastern Space Applications Centre **SCL:** Semi-Conductor Laboratory **IIST:** Indian Institute of Space Science and Technology **ISRO:** Indian Space Research Organisation **Antrix:** Antrix Corporation Limited **VSSC:** Vikram Sarabhai Space Centre **LPSC:** Liquid Propulsion Systems Centre **IPRC:** ISRO Propulsion Complex **SDSC:** Satish Dhawan Space Centre **ISAC:** ISRO Satellite Centre **NRSC:** National Remote Sensing Centre **SAC:** Space Applications Centre **IISU:** ISRO Inertial Systems Unit **DECU:** Development and Educational Communication Unit **MCF:** Master Control Facility **ISTRAC:** ISRO Telemetry, Tracking and Command Network **LEOS:** Laboratory for Electro-optic Systems **IIRS:** Indian Institute of Remote Sensing

The Centres of Indian Space Programme



अन्तरिक्ष भारत SPACE INDIA

भारतीय अन्तरिक्ष अनुसंधान संगठन
Indian Space Research Organisation

सितंबर 2013 - दिसंबर 2014 September 2013 - December 2014

Contents

Editors

Deviprasad Karnik
A S Padmavathy
B R Guruprasad

'SPACE INDIA' is published by the Indian Space Research Organisation for limited circulation. Articles appearing in SPACE INDIA may be reproduced, accompanied by the credit line "Reprinted from SPACE INDIA" along with the date of issue.

Editorial / Circulation Office
Publications & Public Relations Unit, ISRO Headquarters, Antariksh Bhavan, New BEL Road, Bengaluru - 560 231, India.
www.isro.gov.in Designed by Imagic Creatives and Printed at Precision Fototype Services, Bengaluru.

Indigenous Cryogenic Upper Stage Successfully Flight Tested On-board GSLV-D5

The Indigenous Cryogenic Upper Stage was successfully flight-tested onboard GSLV-D5 launch vehicle on January 05, 2014 from Satish Dhawan Space Centre SHAR, Sriharikota. In this successful flight of GSLV-D5, a 1982 kg communication satellite - GSAT-14 - was launched very precisely to its intended Geosynchronous Transfer Orbit.

After a smooth countdown of 29 hours, GSLV-D5 lifted off at 1618 hours IST at the opening of the launch window. All the important flight phases, namely, the core stage and strap-on stage propulsion, payload fairing separation, second stage propulsion, cryogenic stage propulsion and spacecraft separation, were executed as planned.

After a flight of 17 minutes 5 seconds, GSAT-14 satellite was precisely injected into a Geosynchronous Transfer Orbit with a Perigee (nearest point to Earth) of 175 km and an Apogee (farthest point to Earth) of 35,945 km with an orbital inclination of 19.3 degree with respect to the equator.

Immediately after the injection, ISRO's Master Control Facility at Hassan took over the control and commanding of GSAT-14. The solar panels of the satellite were deployed as planned, the satellite health was found normal and the satellite was oriented towards the Sun. GSAT-14 was placed successfully into the intended geostationary orbit after three raising operations.

GSLV-D5

GSLV-D5 was the eighth flight of India's

Panoramic view of GSLV-D5 at the Second Launch Pad

Geosynchronous Satellite Launch Vehicle (GSLV). It was also the fourth developmental flight of GSLV. During this flight, the indigenously developed Cryogenic Upper Stage (CUS) was flight tested for the second time.

After reaching Geosynchronous Transfer Orbit (GTO) on board GSLV-D5, GSAT-14 used its own propulsion system to reach its geostationary orbital home and stationed at 74° East longitude. GSAT-14 is intended to provide many satellite based communication services to the country including tele-education and telemedicine.

GSLV-D5 was a three-stage launch vehicle with solid, liquid and cryogenic stages. It was designed to inject

GSLV-D5 Salient features

Overall Height	:	49.13 metre
Lift-off Mass	:	414.75 Ton
Lift-off Thrust	:	6773 kilo Newton
No. of Stages	:	3
Payload	:	GSAT-14

2 Ton class of communication satellites to GTO. The four liquid L40 strap-ons as well as the second stage of GSLV used storable liquid propellants. GSLV-D5 vehicle was configured with its first and second stages similar to the ones flown during earlier GSLV missions. The third stage was the indigenous cryogenic stage. The metallic payload fairing with a diameter of 3.4 metre was adopted for GSLV-D5. S-band telemetry and C-band transponders enabled GSLV-D5 performance monitoring, tracking, range safety / flight safety and Preliminary Orbit Determination (POD).

Indigenous Cryogenic Upper Stage

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

Indigenous Cryogenic Upper Stage of GSLV-D5 at Stage Preparation Facility

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 liquefies 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 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_2) from the respective tanks are fed by individual booster pumps to the main turbo pump 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.

GSAT-14

GSAT-14 is the twenty third geostationary communication satellite of India built by ISRO. Four predecessors of GSAT-14 were launched by GSLV

GSAT-14 in clean room with one of its solar panels deployed

during 2001, 2003, 2004 and 2007 respectively. After its commissioning, GSAT-14 joined 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 flown on GSAT-14 are:

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

After its injection into Geosynchronous Transfer Orbit (GTO) by GSLV-D5, ISRO's Master Control Facility (MCF) at Hassan took control of GSAT-14 and performed the initial orbit raising manoeuvres in three steps by 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 was performed. GSAT-14 is 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 further augmented the capacity in the INSAT/ GSAT system.

Payloads of GSAT-14

- Six extended C-band transponders for Indian mainland and island coverage
- Six Ku-band transponders covering the mainland India
- Two Ka-band Beacons operating at 20.2 GHz and 30.5 GHz to carry out attenuation studies

PSLV-C24 Successfully Launches India's Second Dedicated Navigation Satellite IRNSS-1B

ISRO's Polar Satellite Launch Vehicle, PSLV-C24 successfully launched IRNSS-1B, the second satellite in the Indian Regional Navigation Satellite System (IRNSS) on April 04, 2014 at 1714 hours IST from Satish Dhawan Space Centre SHAR, Sriharikota. This was the twenty fifth consecutively successful mission of PSLV. The 'XL' configuration of PSLV was used for this mission. Previously, the same configuration of the vehicle was used five times to launch Chandrayaan-1, GSAT-12, RISAT-1, IRNSS-1A and Mars Orbiter Spacecraft.

Mobile Service Tower (in the background) withdrawal exercise during launch rehearsal

After the lift-off with the ignition of the first stage, the important flight events, namely, stage and strap-on ignitions, heat-shield separation, stage and strap-on separations and satellite injection took place exactly as planned. After a flight of about 19 minutes, IRNSS-1B Satellite, weighing 1432 kg, was injected to an elliptical orbit of 283 km X 20,630 km, very close to the intended orbit.

After injection, the solar panels of IRNSS-1B were deployed automatically. ISRO's Master Control Facility (at Hassan, Karnataka) assumed the control of the satellite. Five orbit manoeuvres were conducted from Master Control Facility to position the satellite in its Geosynchronous Circular Orbit at 55 deg East longitude.

IRNSS-1B is the second of the seven satellites constituting the space segment of the Indian Regional Navigation Satellite System. IRNSS-1A, the first satellite of the constellation, was successfully launched by PSLV on July 02, 2013.

IRNSS is an independent regional navigation satellite system designed to provide position information in the Indian region and 1500 km around the Indian mainland.

The entire IRNSS constellation of seven satellites is planned to be completed by 2016.

IRNSS-1B

IRNSS-1B has a lift-off mass of 1432 kg. The configuration of IRNSS-1B is similar to that of IRNSS-1A. The satellite has been realised in less than seven months after the launch of its predecessor.

The two solar panels of IRNSS-1B consisting of Ultra Triple Junction solar cells generate about

IRNSS-1B Satellite positioned on top of PSLV-C24 Fourth Stage

1660 Watts of electrical power. Sun and Star sensors as well as gyroscopes provide orientation reference for the satellite. Special thermal control schemes have been designed and implemented for some of the critical elements such as atomic clocks. The attitude and Orbit Control System (AOCS) of IRNSS-1B maintains the satellite's orientation with the help of reaction wheels, magnetic torquers and thrusters. Its propulsion system consists of a Liquid Apogee Motor (LAM) and thrusters.

Payloads

IRNSS -1B carries two types of payloads - navigation payload and ranging payload.The navigation payload of IRNSS-1B will transmit navigation service signals to the users. This payload will be operating in L5 band (1176.45 MHz) and S band (2492.028 MHz). A highly accurate Rubidium atomic clock is part of the navigation payload of the satellite. The ranging payload of IRNSS-1B consists of a C-band transponder which facilitates accurate determination of the range of the satellite. IRNSS-1B also carries Corner Cube Retro Reflectors for laser ranging.

IRNSS Overview

IRNSS is an independent regional navigation satellite system being developed by India. It is designed to provide accurate position information service to users in India as well as the region extending up to 1500 km from its boundary, which is the primary service area of IRNSS. The Extended Service Area lies between primary service area and area enclosed by the rectangle from Latitude 30 deg South to 50 deg North, Longitude 30 deg East to 130 deg East.

IRNSS will provide two types of services, namely, Standard Positioning Service (SPS) which is provided to all the users and Restricted Service (RS), which is an encrypted service provided only to the authorised users. The IRNSS System is expected to provide a position accuracy of better than 20 m in the primary service area.

IRNSS comprises of a space segment and a ground segment. The IRNSS space segment consists of seven satellites, with three satellites in geostationary orbit and four satellites in inclined geosynchronous orbit.

IRNSS ground segment is responsible for navigation parameter generation and transmission, satellite control, ranging and integrity monitoring as well as time keeping.

Disaster Management Support during 2014

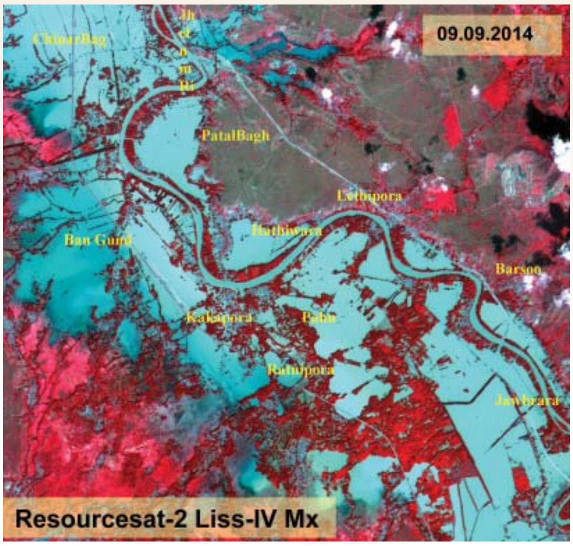
The Disaster management in India is becoming more and more structurally aligned with assigned roles and responsibilities for the various Government agencies. Space based inputs – both through remote sensing and communication satellites are an essential component in all the phases of disaster management and ISRO ensures the space based support through its Disaster management Support (DMS) Programme. The DMS-Decision Support Centre (DMS-DSC) established at National Remote Sensing Centre (NRSC) is actively engaged in monitoring natural disasters such as flood, cyclone, agricultural drought, landslides, earthquakes and forest fires.

Information generated from aerospace systems are disseminated to the concerned in near real time for aiding in assessment, management and decision-making. A communication network connecting the various State headquarters is operational and additional augmentation required during the disaster is also being carried out. The DSC also supports the information needs during any major disaster globally.

Two major disasters India faced in 2014 are J&K Floods in September 2014 and Hudhud cyclone in October 2014.

J&K Floods, September, 2014

The floods in Jammu & Kashmir during September 2014 were unprecedented. The status of flooding was continuously monitored using Indian Remote sensing satellites RISAT-1 & 2, Resourcesat and Cartosat-2. Major flood inundation was observed in the districts of Baramula, Pulwama, Badgam, Srinagar and Anantnag districts. The monitoring continued till the waters receded from most of the areas. Between 8th September to 23rd September 2014, 37 flood maps were sent to the concerned authorities at MHA, NDMA, and the State headquarters. These maps include the inundation status, inundated areas using high resolution optical satellites, flood progression/regression maps during consecutive days, etc. Figure shows False Colour Composite of LiSS-IV multispectral data of September 9, 2015 of Srinagar South.



Flood Situation in Srinagar South: Ratnipora Region (Inundated areas in light blue colour)

Due to the floods, the communication network in the State Headquarters was disrupted affecting the normal functions. A thirteen member team from ISRO reached Srinagar on 14 September 2014 and deployed four VSAT nodes to support emergency communication at HariNiwas, Civil Secretariat, Raj Bhawan and Air Force Station, Srinagar. These VSAT nodes connect to the DMS VPN which is established in the country connecting 20 state nodes, 10 data providing nodes such as NRSC, IMD, CWC, etc. and monitoring nodes such as cabinet secretariat, Ministry of Home affairs etc. This has enabled telephony and Internet facilities for the State functionaries. Each VSAT extends the voice connectivity to PSTN network, GSM/CDMA networks anywhere in India and also supports Internet connectivity using Gateway node at Space Applications Centre, ISRO, Ahmedabad. The VSATs also support local Wi-Fi zone, which allows the use of commercial Wi-Fi gadgets like smart phones, mobile phones and tablets to be used for voice and internet connectivity.

Hudhud Cyclone, October 12, 2014

A Severe cyclone Hudhud made landfall at Visakhapatnam on October12, 2014. The track of cyclone, intensity, landfall time and location using satellite inputs were carried out and the information was regularly updated on the MOSDAC website (http://www.mosdac.gov.in) as part of information dissemination.

Realising the severity of the Hudhud cyclone, proactive actions were taken in programming Indian Remote Sensing satellites and also opened an

Cartosat-1 data of 16.10.2014 showing HPCL Plant with rooftops flown-off during the cyclone

exclusive Webpage on ISRO-Bhuvan GeoPortal for near real-time data display and analysis on October 10, 2014 itself. Based on the predicted rainfall, likely runoff estimations were also made available with information on possible inundations. Andhra Pradesh Government was appraised on the model based inputs on rainfall and runoff predictions, possible technological interventions to combat cyclone impact.

Immediately after the landfall, District-wise inundation statistics were generated and disseminated within 8 hours of acquisition of data. Assessment of damage to infrastructure like roads, railways, etc., was also taken up using the high resolution data and provided to Government of Andhra Pradesh as well as hosted on Bhuvan portal on near real-time basis. The available rainfall data were used in estimating the total rainfall and also the runoff both in Vamsadhara and Nagavalli river system on a continuous basis. These were mailed to the important decision makers as an advance warning with respect possible flooding in the affected areas.

An aircraft of NRSC with very high resolution digital camera (resolution 12 cm) was deployed over Visakhapatnam area and aerial photographs were acquired and analysed. Information on damages such as road blocks, uprooted trees and structural damages like shattered roof tops were identified with respect to geographic locations, village names and provided to Government for organising relief and rescue operations.

An Android based Mobile Application linking Bhuvan portal for crowd sourcing of damage information was developed for enabling the citizens to upload information on the damages in the Visakhapatnam city. More than 25,000 damage details were collected which helped the district authorities to attend to the problems. The Government of Andhra Pradesh integrated Bhuvan services into the AP Online portal for Hudhud Cyclone Damage Assessment and Monitoring activities.

PSLV-C23 Successfully Launches SPOT-7 and other four small Satellites

In its twenty seventh flight (PSLV-C23) conducted from Satish Dhawan Space Centre (SDSC) SHAR, Sriharikota on June 30, 2014, ISRO's Polar Satellite Launch Vehicle PSLV-C23 successfully launched the 714 kg French Earth Observation Satellite SPOT-7, along with four co-passenger satellites from Germany, Canada and Singapore into the required 655 km polar Sun Synchronous Orbit. These five satellites were launched as per the agreements that ANTRIX entered with the respective foreign agencies. This was the twenty sixth consecutively successful flight of PSLV.

PSLV-C23 was launched in its lightest 'Core Alone' version without the six strap-on motors of the first stage. This flight was unique since for the first time, PSLV exclusively carried five foreign satellites during a single launch. Till now, PSLV has successfully launched 40 satellites for foreign customers including the five satellites of this launch. Another reason for the uniqueness of PSLV-C23 was the Advanced Inertial Navigation System (AINS), which it carried for the first time. AINS enabled PSLV to further improve its performance.

Through 26 successful flights during 1994-2014, PSLV has launched a total of 70 satellites, comprising 26 satellites of ISRO, four student satellites, besides 40 satellites for foreign customers. The vehicle has repeatedly proved its reliability and versatility by successfully launching satellites into a variety of orbits including polar Sun Synchronous, Geosynchronous Transfer and Low Earth orbits thereby emerging as the workhorse launch vehicle of India.

After a 49 hour smooth count down, the 230 ton PSLV-C23 lifted off from the First Launch Pad (SLP) at SDSC SHAR at 9:52 am with the ignition of the first stage. SPOT-7, along with four small satellites was delivered to Sun Synchronous Orbit around 655 kms. The four other smaller satellites are: the 14 kg AISAT of Germany, NLS7.1 (CAN-X4) and NLS7.2 (CAN-X5) of Canada, each of 15 kg mass and the 7 kg VELOX-1 of Singapore.

PSLV-C23 Lift-off

SPOT-7

SPOT-7 is a French Earth Observation Satellite identical to SPOT-6 launched earlier on-board

PSLV- C23 Stages at a Glance

	STAGE-1	STAGE-2	STAGE-3	STAGE-4
Nomenclature	PS1	PS2	PS3	PS4
Propellant	Solid (HTPB Based)	Liquid (UH25 + N_2O_4)	Solid (HTPB Based)	Liquid (MMH + MON-3)
Mass (Tonne)	138	41	7.6	2.5
Max Thrust (kN)	4787	804	242	7.3 x 2
Burn Time (sec)	102	148	110	526
Stage Dia (m)	2.8	2.8	2.0	2.8
Stage Length (m)	20	12.8	3.6	3.0

PSLV-C21 during September 2012. SPOT-7, after its injection into Sun Synchronous Orbit, will be phased and placed diametrically opposite to SPOT-6 and will form part of the existing earth observation constellation. SPOT-7 satellite is built by AIRBUS DEFENCE & SPACE, a leading European space technology company.

PSLV-C23 Second Stage at Stage Preparation Facility

Other Co-passengers Satellites:

AISAT from DLR Germany weighing 14 kg is the First DLR Satellite in the nano-satellite class. Mission objective is Global sea-traffic monitoring system with special emphasis on high traffic zones using AIS signals.

NLS7.1 (CAN-X4) & NLS7.2 (CAN-X5) from UTIAS/SFL Canada, identical in design weighing 15 kg each. the primary objective of the two CAN-X satellites is the technology demonstration. Mission objectives is two spacecraft Precision Formation Flying using differential GPS with cm-level accurate position control system.

VELOX-1 from NTU Singapore with a weight of 7 kg is also a Technology demonstration. This will be used for in-house design of image sensor, MEMS-based attitude determination and control system, inter-satellite RF link.

Text speech of PM Narendra Modi at PSLV-C23 launch at Sriharikota

The following is the text speech of the Prime Minister at the launch of PSLV-C23 on the morning of 30th June 2014.

My congratulations to our brilliant space scientists, and the Department of Space; for yet another successful launch of the Polar Satellite Launch Vehicle! We have perfectly placed 5 satellites into their orbits 660 km above the Earth.

This fills every Indian's heart with pride. And I can see it reflected in the joy and satisfaction on your faces.

Fascinated by Space Technology, I feel specially privileged to witness this event in person.

India's advanced Space Program, puts her in an elite global group of 5-6 countries today. This is one domain, in which we are at the international cutting edge. A domain in which we have pushed beyond mediocrity to achieve excellence.

We have launched satellites of advanced nations. PSLV itself has launched 67 satellites; of which 40 have been foreign satellites, coming from 19 countries. Even today's satellites, are all from developed nations – France, Canada, Germany and Singapore. Truly, this is a global endorsement of India's space capabilities.

Inspired by Atal ji's vision, we have sent a mission to the Moon. Another is on its way to Mars as we speak. I personally follow it with great interest. We have also developed our own satellite-based navigation system. I am told this will be fully deployed by 2015.

Moreover, we can be proud that our space program is Indigenous. We have developed it despite international hurdles.

Generations of our space scientists have worked to make India a self-reliant space power. We owe them a big thank you.

Our journey into Space has come a long way from its humble beginnings. It has been a journey of many constraints and resource limitations. I have seen photographs of rocket cones being transported on bicycles. Our first satellite, Aryabhata, was made in industrial sheds in Bangalore.

Even today, our program stands out as the most cost effective in the world. The story of our Mars Mission costing less than the Hollywood movie Gravity, had gone viral on social media recently. Our scientists have shown the world, a new paradigm of Frugal Engineering, and the power of Imagination. Friends, this success of ours has deep historical roots.

India has a rich heritage of science and technology, including in the field of space. An understanding of the cosmos, and its relationship to Life and Science; is deeply rooted in our ancient thought and knowledge. Our ancestors had conceived of ideas like 'Shunya' and 'flying objects', long before others. The works of visionaries like Bhaskaracharya and Aryabhata, continue to inspire scientists.

Many misunderstand space technology to be for the elite. That it has nothing to do with the common man. I however believe, such technology is fundamentally connected with the common man. As a change

agent, it can empower and connect, to transform his life. Technology opens up new opportunities of development. And gives us new ways of addressing our challenges.

Space may seem distant, but is an integral part of our daily life today. It drives our modern communication, connecting even the remotest family to the mainstream. It empowers the child in the farthest village with quality education, through Long-distance Learning. It ensures quality healthcare to the most distant person, through Tele-medicine. It enables the youth in a small town, with various new job opportunities. Satellite technology has made distance irrelevant. It effectively enables us to reach the unreached. It helps us connect virtually, where physical connections are difficult.

It has a critical role, in realizing the vision of a Digital India – the power of 125 crore connected Indians.

GIS technology has transformed policy planning, and implementation. Space imaging enables modern management, and conservation of water resources – through GIS-driven watershed development. It has been deployed in our urban planning, to scientifically manage our growing towns and cities. It has also become an important tool, in better managing, and conserving our natural resources. Whether it be the Himalayan glaciers, oceans and forests, coastal resources or our mineral wealth. Space imagery is improving our land management systems, bringing wasteland into productive use. Our next frontier, should be to extend the same to land records, bringing in accuracy and transparency for the common man.

Space technology has also evolved into an invaluable asset in disaster management. Satellite communication channels, often end up being the only mode of communication. Accurate advanced warning, and tracking of Cyclone Phailin, saved countless lives recently.

We must as a nation, fully harness this expertise in space technology, in our developmental process. For social change, economic development, and resource conservation. The possibilities are limitless. The benefits enormous. I urge the Department of Space, to proactively engage with all stakeholders, to maximize the use of space science in Governance and Development. Deepening of State involvement will be critical for the same.

Friends, India is rooted in our age-old ethos of Vasudeiva Kutumbakam. Of the whole world being one family. India's Space program, is thus driven by a vision of service to humanity. Not by a desire of power. For us, it is an important instrument of our human progress.

We must therefore, share the fruits of our technological advancement, with those who do not enjoy the same. The developing world, and our neighbours in particular. We already share Disaster Management data with over 30 countries. We provide benefits of Tele medicine to Afghanistan and African countries. But we must do more!

Today, I ask our Space community, to take up the challenge, of developing a SAARC Satellite – that we can dedicated to our neighbourhood, as a gift from India. A satellite, that provides a full range of applications and services, to all our neighbours. I also ask you, to enlarge the footprint of our satellite-based navigation system, to cover all of South Asia.

Friends, continued progress in space must remain a national mission. We must keep enhancing our space capabilities. We must develop more advanced satellites; with higher computing, imaging and transmitting power. We must expand our satellite footprint, in terms of frequency and quality. We must also strengthen our international partnerships in all areas of Space technology.

India has the potential, to be the launch service provider of the world. We must work towards this goal. Construct the required new launch infrastructure. And extend our launching capabilities to heavier satellites.

Development of human resources, will be critical for our future success. I was very pleased to meet our young scientists here. I admire their work and their achievements. Let us link up with more universities and colleges, to develop our future leaders in this area. We must also involve our youth at large, with Space.

You have already started putting a lot of space-related data online, through your Bhuvan space portal. What steps can we take to further increase access to data, by students and researchers? Let us use Social Media to further engage with our youth. Let us invite school and college children, to witness launches and visit Space centres. Could we also think of developing, a state-of-the-art, interactive, digital Space Museum?

In conclusion, I want to emphasize how Technology is central to Development. It touches one and all, and is an important instrument of our national progress.

India's Space program is a perfect example of my vision of Scale, Speed and Skill. Our Space scientists have made us global leaders, in one of the most complex areas of modern technology. This shows that we can be the best. If we apply ourselves, we can meet the aspirations of our people.

Let us take inspiration from today's mission. Dedicate ourselves to accelerate our nation's progress. I am confident We Can!

I thank the Department of Space, for this opportunity to witness the launch. I commend Dr. K. Radhakrishnan for his leadership. I wish the team the very best, as you prepare to put our spacecraft into the Mars Orbit, in a few months from now. I wish you every success, as you strive to master new technologies, and conquer new frontiers of Space. May all your endeavours meet with success!

Thank you!

Mars Orbiter Mission

Mars Orbiter Mission (MOM), India's first interplanetary mission to planet Mars, was launched onboard PSLV-C25 on November 05, 2013 from Satish Dhawan Space Centre, Sriharikota and successfully put in Martian orbit on September 24, 2014. With this, ISRO became the fourth space agency to successfully send a spacecraft to Mars orbit. Prior to Indian Mars Mission, only 21 out of 51 Missions succeeded in reaching Mars (success rate of 42%). This is due to the complexity and large number of variables involved in an interplanetary journey. Against this backdrop, it is very pertinent to note that India has succeeded in placing MOM in an orbit around Mars in its very first attempt.

After launch and the initial earth bound orbits, the Trans Mars Injection manoeuvre was successfully performed on December 01, 2013 to set the course of the spacecraft towards Mars through a Sun-centric trajectory. Enroute to Mars, three Trajectory Correction Manoeuvres were carried out to achieve the precise path towards Mars Orbit. The spacecraft traversed about 666 million kilometres of inter planetary space to reach close to Mars.

The most crucial manoeuvre of Mars Orbit Insertion (MOI) was successfully carried out on September 24, 2014, with which the Mars Orbiter Spacecraft successfully entered into an elliptical orbit of 422 km by 76,994 km around Mars. During the passage of Comet C/2013 A1 Siding Spring, near Mars in the spacecraft and subsystems were protected by tuning the orbit in such a way that the spacecraft was behind the planet during peak flux from the Comet.

PSLV-C25

PSLV-C25, the 25th mission of PSLV and fifth in the 'XL' configuration, successfully launched the Mars Orbiter Spacecraft on November 05, 2013 from the First Launch Pad at Satish Dhawan Space Centre SHAR, Sriharikota. India's first interplanetary mission, the Mars Orbiter spacecraft weighing 1337 Kg, was precisely injected into the elliptical earth orbit of 246.9 x 23,566 km. The major technical challenges for the launch vehicle in accomplishing this mission were the longest flight duration of 43 minutes, long coasting duration of 23 minutes between third stage separation and fourth stage ignition and larger argument of perigee in order to minimise the energy required in transferring the satellite from the Earth to Mars. Subsequently, six orbit raising maneuvers took place on November 07, 08, 09, 11,

PSLV-C25 Lift-off

12 and 16 to raise the apogee of the spacecraft to 28,825 km, 40,186 km, 71,636 km, 78,276 km, 1,18,642 km and 1,92,874 km respectively. After these orbit raising manoeuvres, the Mars Orbiter Spacecraft was injected into the Mars Transfer Trajectory on December 01, 2013 and reached Martian orbit on September 24, 2014.

Mars Orbiter mission can be termed as a challenging technological and science mission considering the critical mission operations and stringent requirements on propulsion, navigation, communications and other bus systems of the spacecraft, and the development of low mass sensitive payloads to observe the Martian surface and outer layers of its atmosphere.

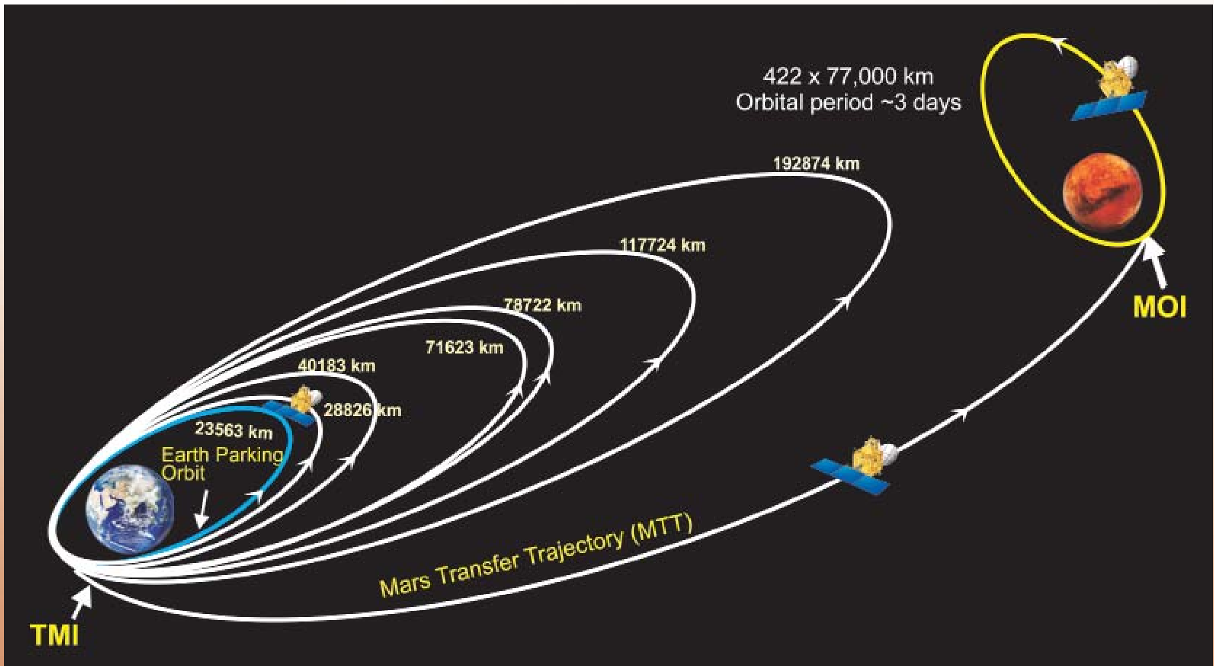
Ground Station Support

ISRO Telemetry Tracking and Command Network (ISTRAC) provided support of the TTC ground stations, communications network between ground stations and control centre, Control centre including computers, storage, data network and control room facilities, and the support of Indian Space Science Data Center (ISSDC) for the mission. The ground segment systems formed an integrated system supporting both launch phase, and orbital phase of the mission.

The ground stations at Sriharikota, Port Blair and Brunei provided continuous tracking of the PSLV-C25 from lift-off till the burnout of third stage. Two ships (Yamuna and Nalanda) carrying Ship Borne Terminals (SBT) were deployed at suitable locations in the South Pacific Ocean, to support the tracking of the launch vehicle from fourth stage ignition till spacecraft separation. After that, spacecraft operations were performed from the Spacecraft Control

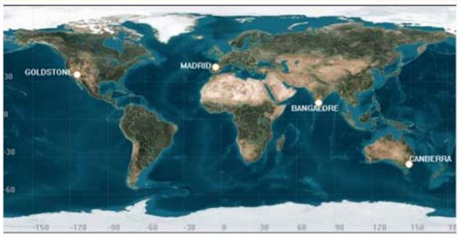
PSLV- C25 Stages at a Glance

	Stage-I	PSOM-XL	Stage 2	Stage 3	Stage 4
Length	20	12	12.8	3.6	2.7
Diameter (m)	2.8	1	2.8	2	2.8
Propellant	Solid (HTPB Based)	Solid (HTPB Based)	Liquid (UH25 + N_2O_4)	Solid (HTPB Based)	Liquid (MMH + MON3)
Propellant Mass (t)	138	12.2	42	7.6	2.5
Peak Thrust (KN)	4800	718	799	247	7.3x2
Burn Time (s)	103	50	148	112	525



Ground Station Support During MOI

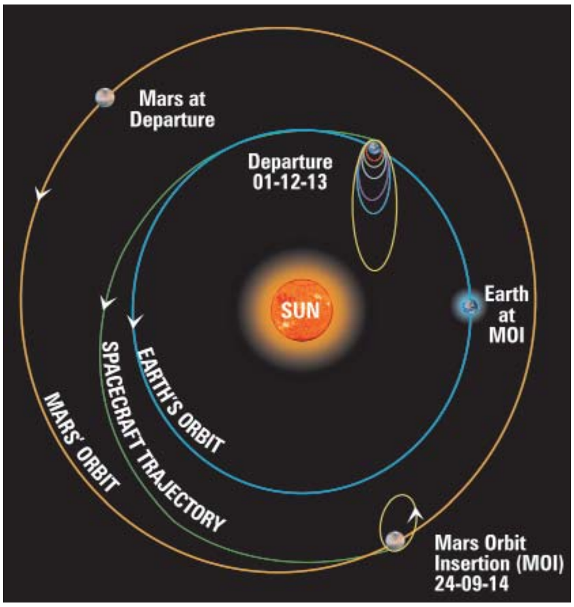
Mars Orbiter Mission



Indian Deep Space Network	India
Goldstone	USA
Madrid	Spain
Canberra	Australia

Centre (SCC) at ISTRAC in Bengaluru. To ensure complete coverage, ISTRAC ground stations were supplemented by Alcantara and Cuiaba TTC stations of INPE, Brazil, Hartebeestoek TTC station of SANSA and the DSN network of JPL, NASA.

The primary driving technological objective of the mission was to design and realise a spacecraft with a capability to perform Earth Bound Manoeuvres (EBM), Martian Transfer Trajectory (MTT) and Mars Orbit Insertion (MOI) phases and the related deep space mission planning and communication management at a distance of nearly 400 million km.



Mars Orbit Insertion (MOI)

India's Mars Orbiter Spacecraft successfully entered into an orbit around planet Mars on September 24, 2014 by firing its 440 Newton Liquid Apogee Motor (LAM) along with eight smaller liquid engines. This Liquid Engines firing operation which began at 07:17:32 Hrs IST lasted for 1388.67 seconds which changed the velocity of the spacecraft by 1099 metre/sec. With this operation, the spacecraft entered into an elliptical orbit around Mars. Honourable Prime Minister of India, Mr Narendra Modi, was present at ISRO's Telemetry, Tracking and Command Network (ISTRAC) in Bangalore to witness this important event.

The events related to Mars Orbit Insertion progressed satisfactorily and the spacecraft performance was normal. The Spacecraft was made to circle Mars in an orbit whose nearest point to Mars (periapsis) was at 421.7 km and farthest point (apoapsis) at 76,993.6 km. The inclination of orbit with respect to the equatorial plane of Mars was 150 degree, as intended. In this orbit, the spacecraft took 72 hours 51 minutes 51 seconds to go round the Mars once.

Mars Orbiter Spacecraft

The spacecraft configuration is a balanced mix of design from flight proven IRS/INSAT/Chandrayaan-I bus. Modifications required for Mars mission were in the areas of Communication, Power, Propulsion systems (mainly related to Liquid Engine restart after nearly 10 months) and on-board autonomy.

- 390 litres capacity propellant tanks accommodated a maximum of 852 kg of propellant which was adequate with sufficient margins.
- A Liquid Engine of 440 N thrust was used for orbit raising and insertion in Martian Orbit.
- The spacecraft required three solar panels (size 1800 x 1400 mm) to compensate for the lower solar irradiance.
- Antenna System consisted of Low Gain Antenna (LGA), Medium Gain Antenna (MGA), and High Gain Antenna (HGA). The High Gain Antenna system is based on a single 2.2 meter reflector illuminated by a feed at S-band. It is used to transmit/receive the Telemetry, Tracking data and Commands (TTC) and data to/from the Indian Deep Space Network
- On-board autonomy functions were incorporated as the large distance does not permit real time interventions.

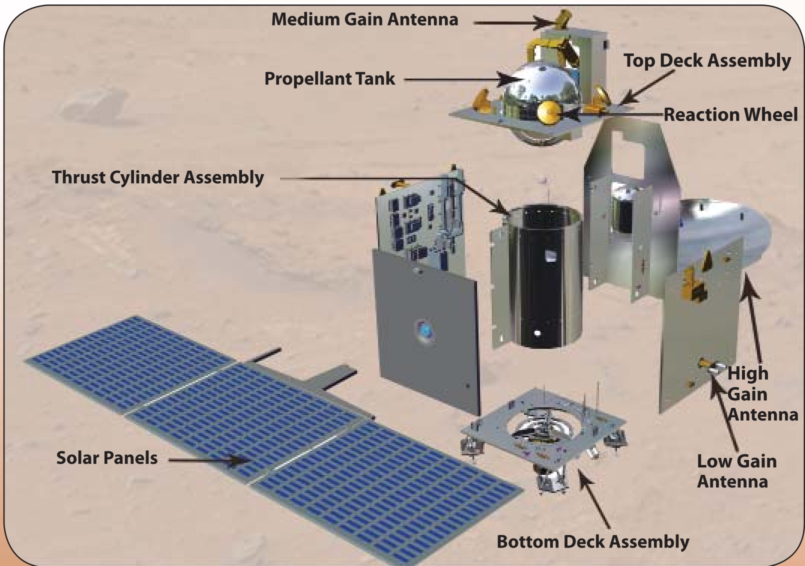
Mars Orbit Insertion witnessed by the Honorable Prime Minister of India

Mission Objectives

The objectives of this mission are primarily technological and include design, realisation and launch of a Mars Orbiter spacecraft capable of operating with sufficient autonomy during the journey phase of 300 days; Mars orbit insertion / capture and in-orbit phase around Mars.

Technological objectives:

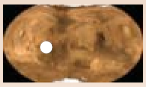
- Design and realisation of a Mars orbiter spacecraft with the capability to survive and perform Earth bound manoeuvres, cruise phase, Mars orbit insertion and capture, and on-orbit phase around Mars
- Deep space communication, navigation, mission planning and management

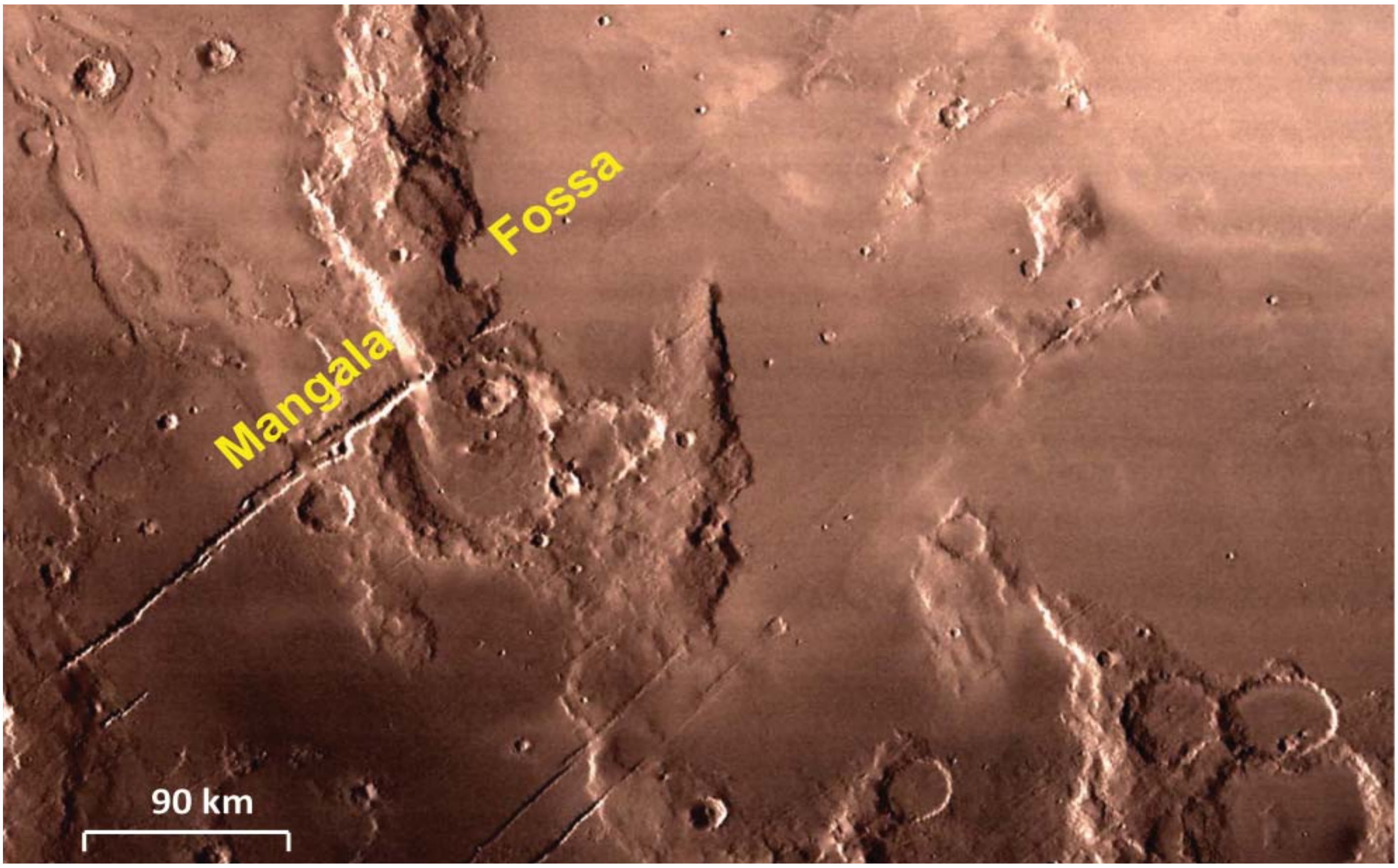


Disassembled view of Mars Orbiter Mission spacecraft

MOM Spacecraft sitting on the top of PSLV-C25 fourth stage

Images of Planet Mars sent


Images of Valles Marineris and adjoining regions of Mars taken by Mars Colour Camera on board MOM on Dec 05, 2014 at a spatial resolution of 1.2 km from an altitude of 24,000 km. Valles Marineris is largest canyon system, about 4000 km long and 200 km wide and 7 km deep.



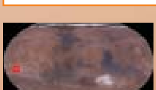
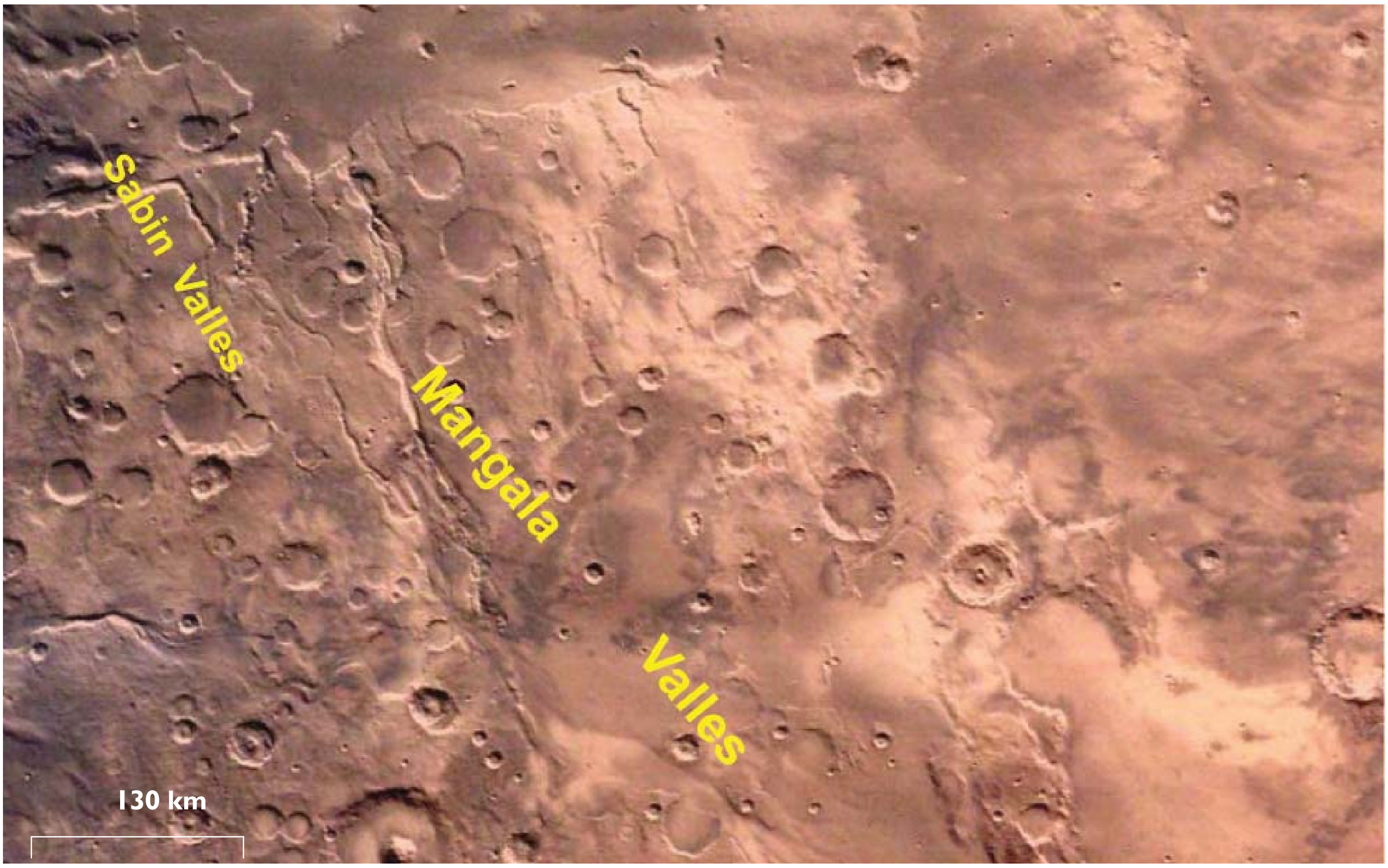


Image of Mangala Fossa and Mangala Valles regions of Mars taken by Mars color camera on board MOM on Nov 16, 2014 at a spatial resolution of 300 m from an altitude of 5969 km. Mangala Fossa is regional graben oriented along SE-NW direction having the length of 695 km, cutting across Mangala Valles region and crater. Graben is formed by extensional stresses on planetary surface. Parallel Faults located to the south of Mangala Fossa region are also clearly seen in this image.

by Mars Orbiter Spacecraft



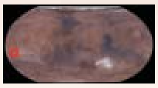
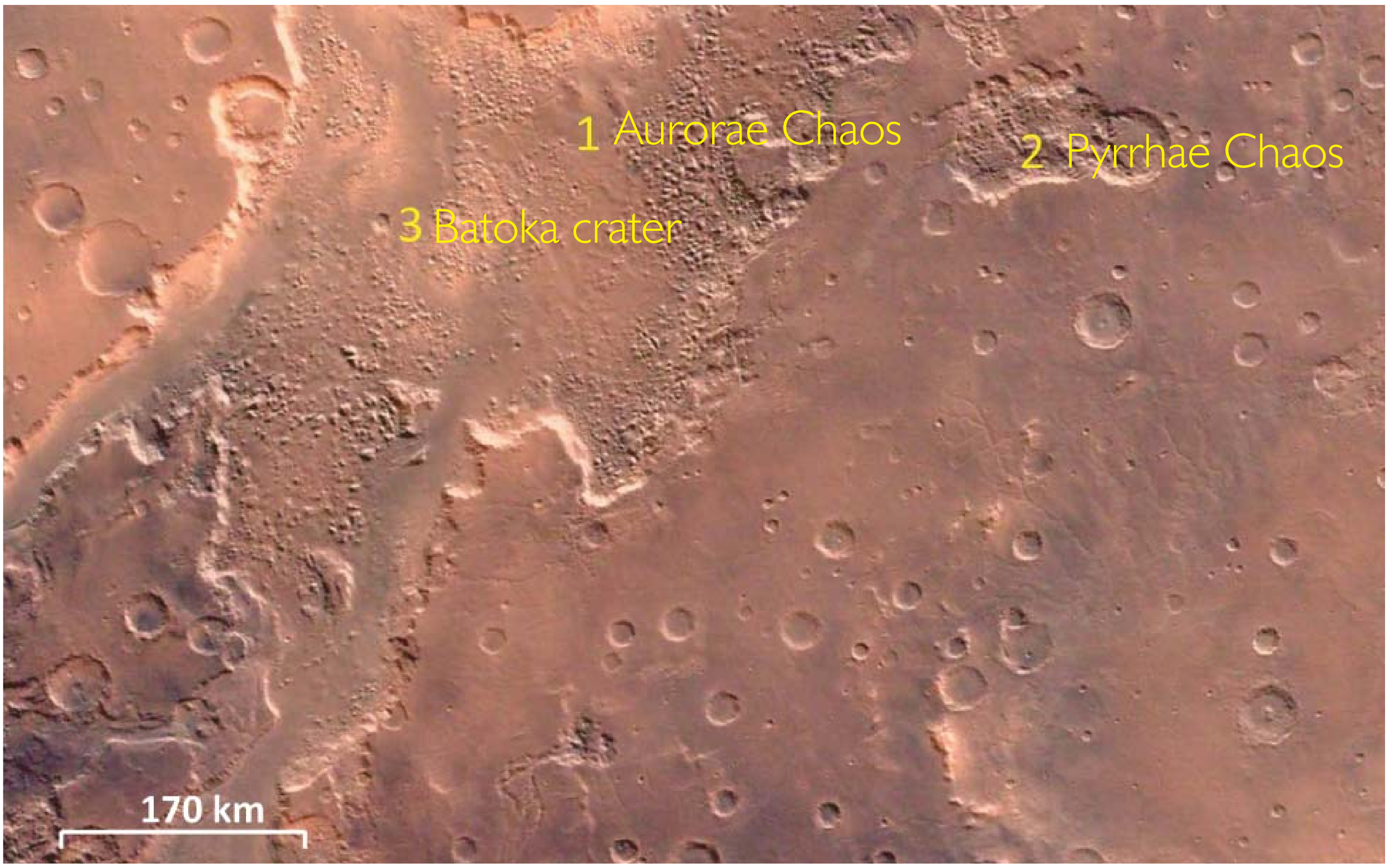


Image of Mangala Valles and part of Sabis Valles regions of Mars taken by Mars Color Camera on board MOM on Dec 02, 2014 at a spatial resolution of 470 m from an altitude of 9,032 km. Image clearly shows the flow pattern in the Mangala Valles region. Channel bar in the MCC image indicates release of vast quantities of water in this area by catastrophic floods.



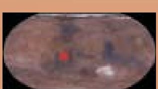


Image of Aurorae Chaos, Pyrrhae Chaos (Chaos means broken terrain with in canyon) and adjoining regions of Mars taken by Mars color camera on board Mars orbiter mission on Dec 05, 2014 at a spatial resolution of 535 m from an altitude of 10274 km. Region shown in the image located at the eastern end of Valles Marineris region. This image shows eroded floor of canyon, which indicates fluvial activity in the past geological history of Mars.

Salient Features of Mars Orbiter Mission Spacecraft

Lift-off Mass	1337 kg
Structure	Aluminum and Composite Fiber Reinforced Plastic (CFRP) sandwich construction-modified I-1 K Bus
Mechanism	Solar Panel Drive Mechanism (SPDM), Reflector and Solar panel deployment
Propulsion	Bi propellant system (MMH + N_2O_4) with additional safety and redundancy features for MOI. Propellant mass: 852 kg
Thermal System	Passive thermal control system
Power System	Single Solar Array-1.8m x 1.4 m - 3 panels - 840 W Generation (in Martian orbit), Battery: 36 Ah Li-ion
Attitude and Orbit Control System	AOCE (Attitude and Orbit Control Electronics): with MAR31750 Processor Sensors: Star sensor (two), Solar Panel Sun Sensor (one), Coarse Analogue Sun Sensor Actuators: Reaction Wheels (four), Thrusters (eight), 440N Liquid Engine
Antennas	Low Gain Antenna (LGA), Mid Gain Antenna (MGA) and High Gain Antenna (HGA)
Launch Date	Nov 05, 2013
Launch Site	SDSC SHAR Centre, Sriharikota, India
Launch Vehicle	PSLV - C25

- Incorporate autonomous features to handle contingency situations

Scientific objectives:

- Exploration of Mars surface features, morphology, mineralogy and Martian atmosphere by indigenous scientific instruments

Payloads:

Mars Orbiter Mission carries five scientific payloads to observe Martian surface, atmosphere and exosphere extending up to 80,000 km for a detailed understanding of the evolution of that planet, especially the related geologic and the possible biogenic processes on that interesting planet. These payloads consist of a camera, two spectrometers, a radiometer and a photometer. Together, they have a weight of about 15 kg. Following are the scientific payloads developed indigenously:

1. Mars Colour Camera (MCC)

This tri-colour Mars Colour Camera provide a images and information about the surface features and composition of Martian surface. They are useful to monitor the dynamic events and weather of Mars. MCC will also be used for probing the two satellites of Mars (Phobos and Deimos).

2. Thermal Infrared Imaging Spectrometer (TIS)

TIS measures the thermal emission and can be operated during both day and night. Temperature and emissivity are the two basic physical parameters estimated from thermal emission measurement. Many minerals and soil types have characteristic spectra in TIR region. TIS can map surface composition and mineralogy of Mars.

3. Methane Sensor for Mars (MSM)

This is designed to measure Methane (CH_4) in the Martian atmosphere with Parts Per Billion (PPB) accuracy and map its sources. Data is acquired only over illuminated scene as the sensor measures reflected solar radiation. Methane concentration in the Martian atmosphere undergoes spatial and temporal variations.

4. Mars Exospheric Neutral Composition Analyser (MENCA)

MENCA is a quadruple mass spectrometer capable of analysing the neutral composition in the range of 1 to 300 atmospheric mass unit (amu) with unit mass resolution. The heritage of this payload is from Chandra's Altitudinal Composition Explorer (CHANCE) payload.

5. Lyman Alpha Photometer (LAP)

Lyman Alpha Photometer is an absorption cell photometer. It measures the relative abundance of Deuterium and Hydrogen from Lyman alpha emission in the Martian upper atmosphere. This measurement allows us to understand especially the loss process of water from the planet.

The first four of the above payloads (MCC, TIS, MSM and MENCA) were operated during the earth bound orbits and the LAP payload was operated during the cruise phase, primarily for health checks and performance verification. The performance of the payloads was found to be satisfactory. The accompanying figure shows the first image of the Earth by Mars Color Camera (MCC) taken on Nov 19, 2013 at 13:50 hrs (IST) from 67,975 km altitude with a resolution of 3.53 km.

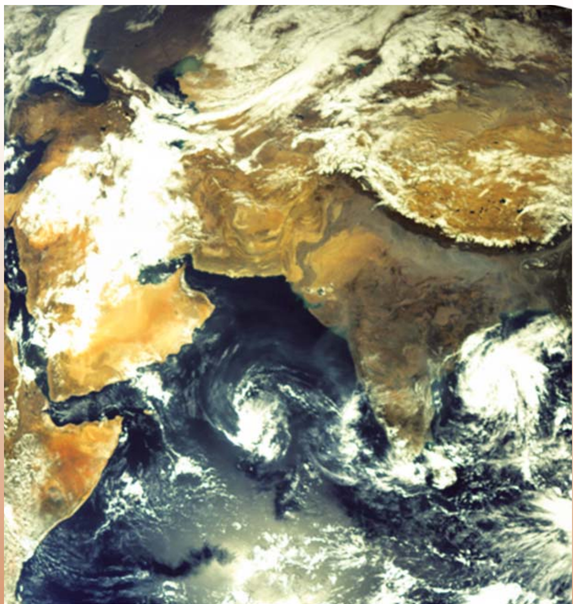
Preliminary observations

ISRO has been continuously monitoring the Spacecraft and its five scientific instruments which are in good health. All the scientific instruments have been operated and tested successfully. The Mars Colour Camera has provided more than 300 images including several breathtaking pictures of the Martian surface and its weather patterns such as dust storms. Scientific analysis of the data being received from the Mars Orbiter spacecraft is in progress.

The other four instruments, namely, Methane Sensor for Mars (MSM), Lyman Alpha Photometer (LAP), Mars Exospheric Neutral Composition Analyser (MENCA) and Thermal Infrared Imaging Spectrometer (TIS) have been conducting experiments and the analysis of data is in progress.

Payloads of MOM Spacecraft

Payload	Primary Objective	Weight (Kg)
Mars Colour Camera (MCC)	Optical imaging	1.27
Thermal Infrared Imaging Spectrometer (TIS)	Map surface composition and mineralogy	3.2
Methane Sensor for Mars (MSM)	Detection of Methane presence	2.94
Mars Enospheric Neutral Composition Analyser (MENCA)	Study of the neutral composition of Martian upper atmosphere	3.56
Lyman Alpha Photometer (LAP)	Study of Escape processes of Martian upper atmosphere through Deuterium/Hydrogen	1.97



First image of the Earth by Mars Colour Camera onboard MOM

Mars Colour Camera has provided many full disc images of Mars. The Olympus Mons, the highest volcano in the solar system and the famous Arsia, Pavonis and Ascraeus collinear mons adjacent to Valles Marineris, the longest canyon in the solar system, can be seen in the figure. The Image of "Valles Marineris" and adjoining regions of Mars taken by MCC on board Mars Orbiter spacecraft on December 05, 2014 at a spatial resolution of 1.2 km from an altitude of 24,000 km. Valles Marineris is about 4000 km long and 200 km wide and 7 km deep. Dust trapped in the valley is seen as smoky haze.

Three dimensional view of Arsia Mons created by draping the Mars Color Camera (MCC) image on

Topography of the region derived from Mars Orbiter Laser Altimter (MOLA)- the instrument on the Mars Global Surveyor (MGS) of NASA is shown in figure. This Image was taken by Mars Color Camera at a spatial resolution of 556 m from an altitude of 10,707 km.

Mars has two natural satellites – Phobos and Deimos. Phobos was a mean diameter of 22 km, was imaged by Mars color camera on October 14, 2014 at a spatial resolution of 550 m from an altitude of 16,057 km. from Mars. Phobos (dark) is seen in the backdrop of Mars (bright). Deimos with an average diameter of 12.4 km was also imaged by MCC on October 14, 2014 at an altitude of 24,457 km with a resolution of about 250 m.

Achievements

The achievements of the Mars Orbiter Mission (MOM) including its planned life span are detailed below:

- First interplanetary mission by India and a "Make in India" satellite with fully home grown innovative technologies
- Unique launch vehicle trajectory and mission concept adopted to suit the capabilities of ISRO for an interplanetary mission
- First Indian spacecraft to successfully to survive 39 Van Allen belt crossing
- First Indian spacecraft to incorporate full scale on-board autonomy to overcome the long distances and the communication gaps due to non-visibility periods
- First mission to use Ship Borne Terminals to track the launch vehicle and satellite over Pacific Ocean by ISRO
- First Indian spacecraft to escape the Sphere Of Influence of Earth and orbit the Sun
- First Mars mission in the world to succeed Mars Orbit Insertion in first attempt
- Most economical interplanetary mission in the world and paved way for cheaper access to deep space. Realized with a budget of INR 450 crores (about US $ 80 million) including launch Vehicle, Spacecraft and Ground Segment
- Shortest Project Schedule-Realised in a schedule of 15 Months-from conceptualisation to launch (space, launch and ground segments)

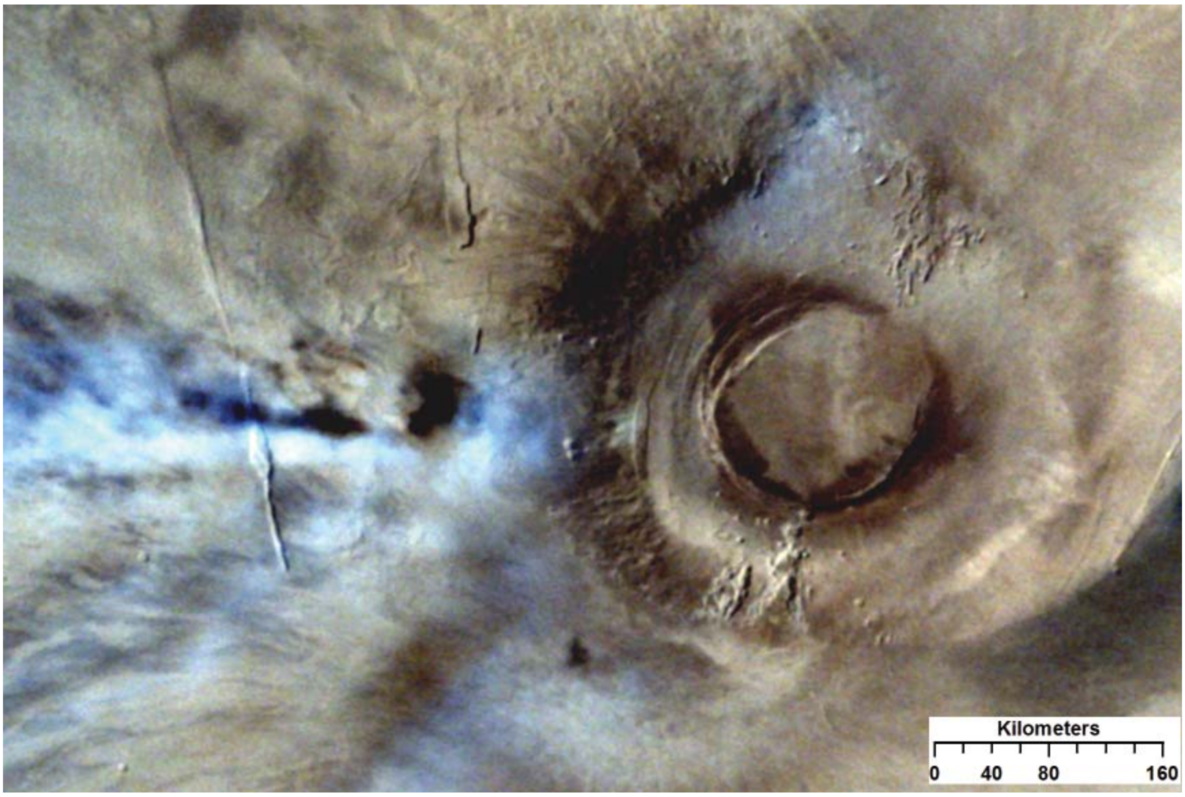
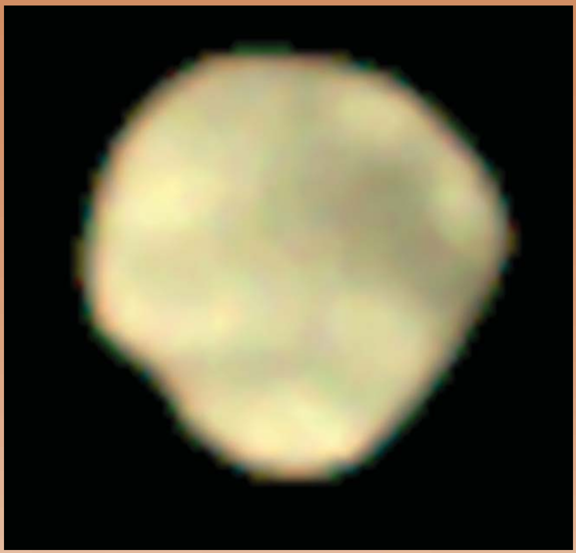



Image of Arsia Mons region taken by Mars Colour Camera on at a spatial resolution of 556 m from an altitude of 10707 km. This is one among of large volcanic mountains located in Tharsis region of Mars. Water Vapour clouds around Arsia Mons are seen on the left of volcanic mountain.



Phobos and Deimos the two natural satellites of Mars imaged by MCC

Normally, for a healthy spacecraft, the life limiting parameter under nominal orbital conditions is the availability of propellant to maintain its orbit around the planet. As there is a reserve of 37 kg of propellant, the mission has been extended for another six months on completion of its designed life of six months. Extended life of MOM will help to further explore the red planet and its atmosphere for the coming seasons too.

PSLV-C26 Successfully Launches India's third Navigation Satellite IRNSS-1C

ISRO's Polar Satellite Launch Vehicle, PSLV-C26, successfully launched IRNSS-1C, the third satellite in the Indian Regional Navigation Satellite System (IRNSS), in the early morning hours of October 16, 2014 at 0132 hours IST from Satish Dhawan Space Centre, Sriharikota. This is the twenty seventh consecutively successful mission of PSLV. The 'XL' configuration of PSLV was used for this mission. Previously, the same configuration of the vehicle was successfully used six times.

After the lift-off of PSLV-C26 with the ignition of the first stage, the important flight events, namely, stage and strap-on ignitions, heat-shield separation, stage and strap-on separations and satellite injection, took place as planned. After a flight of about 20 minutes 18 seconds, IRNSS-1C Satellite, weighing 1425 kg, was injected to an elliptical orbit of 282.56 km x 20,670 km, which is very close to the intended orbit.

PSLV-C26 inside Moible Service Tower prior to Satellite Integration

After injection, the solar panels of IRNSS-1C were deployed automatically. ISRO's Master Control Facility (MCF) at Hassan, Karnataka assumed the control of the satellite. Later, four orbit manoeuvres were conducted from MCF to position the satellite in the Geostationary Orbit at 83 deg East longitude.

IRNSS-1C is the third of the seven satellites, joins the first two satellites (IRNSS-1A and IRNSS-1B) of the IRNSS constellation. IRNSS is an independent regional navigation satellite system designed to provide position information in the Indian region and 1500 km around the Indian mainland. IRNSS would provide two types of services, namely, Standard Positioning Services (SPS) - provided to all users - and Restricted Services (RS), provided to authorised users.

A number of ground stations responsible for the generation and transmission of navigation parameters, satellite control, satellite ranging and monitoring, etc., have been established in as many as 15 locations across the country.

In the coming months, the next satellite of this constellation, namely, IRNSS-1D, is scheduled to be launched by PSLV. The entire IRNSS constellation of seven satellites is planned to be completed by 2016.

IRNSS -1C

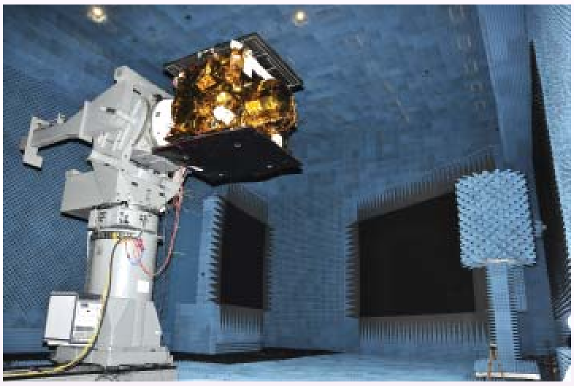
IRNSS-1C is the third navigation satellite of the seven satellites constituting the IRNSS space segment.

PSLV- C26 Stages at a Glance

	STAGE-1	STAGE-2	STAGE-3	STAGE-4
Nomenclature	Core PS1 + 6 strap-on motors	PS2	PS3	PS4
Propellant	Solid (HTPB Based)	Liquid (UH25 + N_2O_4)	Solid (HTPB Based)	Liquid (MMH + MON-3)
Mass (Tonne)	138.2 (Core), 6X12.2 (Strap-on)	42.0	7.6	2.5
Max Thrust (kN)	4819 (Core), 6X716 (Strap-on)	804	240	7.3 X 2
Burn Time (sec)	102	148	110	526
Stage Dia (m)	2.8 (Core), 1 (Strap-on)	2.8	2.0	2.8
Stage Length (m)	20 (Core), 12 (Strap-on)	12.8	3.6	3.0

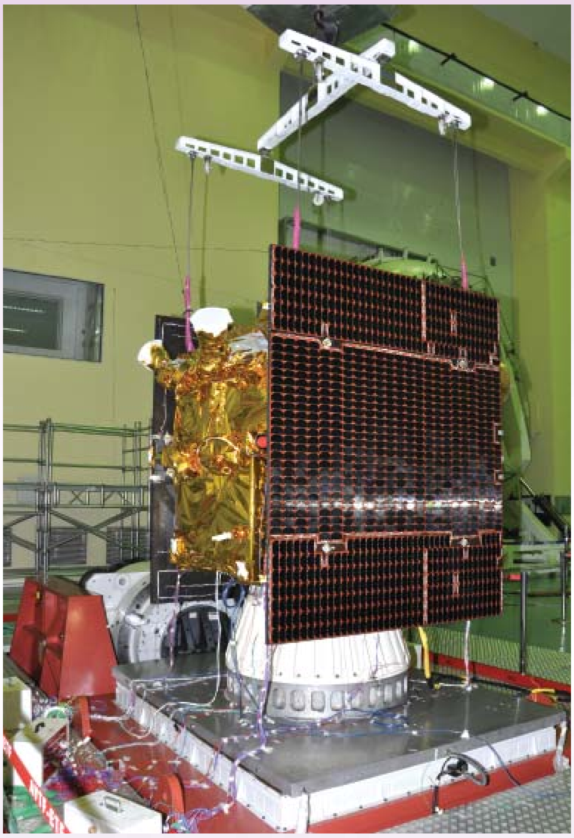
Its predecessors, IRNSS-1A and IRNSS-1B were launched by PSLV-C22 and PSLV-C24 in July 2013 and April 2014 respectively. IRNSS-1C has a lift-off mass of 1425.4 kg. The configuration of IRNSS-1C is similar to that of IRNSS-1A and IRNSS-1B. The satellite has been realized in less than six months after the launch of its predecessor.

After injection into this preliminary orbit, the Master Control Facility (MCF) at Hassan took control of



IRNSS-1C spacecraft undergoing Electro- Magetic Interference and Electro-Magetic Compatibility (EMI-EMC) tests

the satellite and performed the initial orbit raising manoeuvres consisting of one manoeuvre at perigee (nearest point to earth) and three at apogee (farthest point to earth). For these manoeuvres, the Liquid Apogee Motor (LAM) of the satellite was used,



IRNSS-1C spacecraft undergoing vibration test

thereby finally placing it in the circular geostationary orbit at its designated location.

IRNSS-1C carries two types of payloads – navigation payload and ranging payload.

Procedures for SatCom Policy Implementation

The Union Cabinet on 12th January 2000 approved the implementation details for SatCom Services in India and the highlights are as under:

The steep growth in the Satellite-based communication services as well as newly emerging services in this area require substantial private sector participation. This is consistent with the liberalisation in telecom sector as well as the global trends in this area.

Based on the overall frame-work for the satellite communications policy approved by the Union Cabinet in June 1997, the detailed procedures for implementation have been worked out with the involvement of the concerned Ministries/Departments. The norms, guidelines and procedures fall under three categories, namely, Use of INSAT capacity by non-governmental agencies; Establishment and operation of Indian Satellite Systems; Use of foreign satellites for SatCom Services.

Establishment and Operation of Indian Satellites:

Indian registered companies with a foreign investment not exceeding 74% will be allowed to establish and operate satellite systems. Those who have got the operating licence for specific services from respective Ministries / Departments are eligible to apply. Applications will be processed for approval by an inter-Ministerial Committee chaired by DOS. The WPC Wing of the Ministry of Communications will represent the orbit-spectrum requirements of the private Indian satellites in international fora.

Usage of INSAT Capacity by non-governmental agencies:

INSAT capacity will continue to be allocated to Department of Telecommunications, Doordarshan and All India Radio through INSAT Co-ordination Committee (ICC). In addition, ICC will also earmark certain INSAT capacity for non-government users. This additional capacity will be provided to non-governmental users by the Department of Space (DOS) on a commercial basis.

Use of Foreign Satellites:

In the interest of early introduction/expansion of services, use of foreign satellites will be allowed in special cases until such capacity can be provided by Indian satellites. The concerned administrative departments will consult DOS before authorising operations through foreign satellites.

Engineer's Conclave-2014

The second Engineer's Conclave, EC-2014 was organised by Indian National Academy of Engineering (INAE) and Indian Space Research Organisation (ISRO) during Oct 30-Nov 01, 2014 at the J N Tata Auditorium, National Science Seminar Complex, Indian Institute of Science (IISc), Bangalore.

The objective of this event is to provide a platform to all Professional Engineers/Scientists of the country to address some of the major engineering challenges relevant to society as well as the country and to suggest suitable engineering solutions. The Conclave had two themes, namely:

1. Emerging Space Applications
2. Technologies for the Hill Regions

The focus of the two themes was on finding engineering solutions to the problems being faced by people and make specific recommendations for development / implementation. Though these two themes appear to be different, both have a few common technology solutions. The space segment plays a very important role in technology solutions for hilly regions and finding applications of space in the hilly regions is a priority for space, particularly in the context of 2013 landslide/floods in Uttarkhand.

Eminent experts and senior functionaries from National and State Centres / Departments, Academia, Industry, ISRO, DRDO and INAE fellows participated in large numbers to deliberate on the above two themes of EC-2014.

Dr. K Radhakrishnan, Prof. U R Rao and Dr. Baldev Raj during inauguration of EC-2014

Three plenary talks were organized to focus on some of the issues like: "Impact of Technology on Economy", "Challenges in Maintaining Infrastructure in Himalayan Region" and "Improvements in Weather and Ocean state Forecasts". In addition, a brainstorming luncheon session on Climate Change was organized with participation of senior functionaries of the GOI and scientific community, requiring space based observations soon after the inaugural session.

Theme -I: Emerging Space Applications:

Under the theme 'Emerging Space Applications', deliberations were organized in the following five technical sessions (i) Energy & Infrastructure, (ii) Weather & Climate, (iii) Natural resources monitoring management & e-governance, (iv) Early warning systems and (v) Communications & Navigation.

Theme-II Technologies for Hilly Regions

The main aim of the Theme II "Technologies for Hilly Regions" was to come up with technological solutions for the development of hilly regions and mitigation of recurring disasters. The agenda of the theme was to suggest the engineering strategies for hilly regions to mitigate the effect of natural disasters and to propose solutions to reduce the impact and scale of disasters. Theme-II was further divided into following five sessions, (i) Mountain Weather, (ii) Gravity flows & Associated Hazards, (iii) Communications for Hazards conditions in Hilly Regions, (iv) Earthquake Hazards in Himalayan Regions & its Mitigation, (v) Glacier, Snow cover, Water Management & Energy in Hill Regions.

There were ten technical sessions under these two themes and three invited talks in each of the technical sessions. The presentations covered present scenario, gap areas & future requirements in each of the above five emerging areas of space applications which are important in the context of the societal development of our country.

Recommendations:

The two panels of Theme-I and Theme-II met separately and consolidated the recommendations of the technical sessions. The recommendations were further presented and discussed in the Valedictory Session. Following are the major recommendations:

- Large Area Coverage Satellite with C, Extended C or S band transponders for Communications Coverage over Islands and Ocean areas surrounding Indian Mainland
- More detailed observation (data) plan for hilly regions by establishing more number of X and Ku band weather Radar network by IMD, IITM and SASE particularly regions of high density population, tourists places is required
- Densification of Automatic Weather Stations and more number of Radiometers are recommended
- Recognize and expand SASE as National Agency for Avalanches forecast for the entire Hilly region, not just for interest of Army – Manpower, budget to commensurate with the additional responsibility
- Deployment of a SAR formation Satellite by ISRO for precise DEM for all vulnerable regions continuous mapping of Himalayas and providing data to SASE in real time
- Formulate a plan for data collection and regular monitoring of glacial lakes
- Development of mathematical models for simulation of river flow by IIT Roorkee
- Expansion / revamping of Disaster Management System (DMS) network and integrating it with terrestrial network
- Development of early warning systems by IMD supported by strong governance and organizational coordination mechanism with state governments
- Network with advanced waveform & technologies to be expedited and Integration of diverse technologies like GSM/CDMA/Wi-Fi /FM broadcast with satellite on-field VSAT nodes for wide area communication
- Towards Earthquake impact mitigation, Micirozonation of high density locations, Formulation of site based guidelines for buildings in Hilly region cities, Master plan for Earthquake impact mitigation is recommended

India's Communication Satellite GSAT-16 Launched Successfully

India's communication satellite, GSAT-16, was successfully launched at 0210 hrs IST on December 7, 2014 by the Ariane-5 launch vehicle VA221 of Arianespace from Kourou, French Guiana. Ariane-5 precisely placed GSAT-16 into the intended Geosynchronous Transfer Orbit (GTO), after a flight of 32 minutes and 20.4 Seconds duration.

ISRO's Master Control Facility (MCF) at Hassan in Karnataka started acquiring the signal from the satellite at 0241 hrs IST and the commanding of the satellite was initiated. Initial checks have indicated normal health of the satellite.

Three orbit raising manoeuvres were conducted by the firing of GSAT-16's Liquid Apogee Motor (LAM) Engine, and the satellite was placed in the Geostationary Orbit. Subsequently the satellite's communication transponders was switched on for in-orbit testing.

GSAT – 16

Indian national Satellite (INSAT) system, established in 1983, is one of the largest domestic communication satellite systems in the Asia Pacific Region. It presently comprises of ten satellites - INSAT-3A, INSAT-3C, INSAT-4A, INSAT-4B, INSAT-4CR, GSAT-7, GSAT-8, GSAT-10, GSAT-12 and GSAT-14 – providing transponders in S, C, Extended-C and Ku-bands.

GSAT-16, an advanced communication satellite, weighing 3180 kg at lift-off, is being inducted into the INSAT/GSAT system. GSAT-16 is configured to carry a total of 48 communication transponders, the largest number of transponders carried by a communication satellite developed by ISRO so far, in normal C-band, upper extended C-band and Ku-band. GSAT-16 carries a Ku-band beacon as well to help accurately point ground antennas towards the satellite.

GSAT-16 Satellite undergoing test in clean room

The designed in-orbit operational life of GSAT-16 is 12 years. The 48 communication transponders onboard GSAT-16 together ensure continuity of various services currently provided by INSAT/GSAT system and serve as on-orbit spares to meet contingency requirements or for the augmentation of such services.

GSAT-16 was launched into a Geosynchronous Transfer Orbit (GTO) by Ariane-5 VA-221 launch vehicle from Kourou, French Guiana. After its injection into GTO, ISRO's Master Control Facility (MCF) at Hassan took control of the satellite and performed the initial orbit raising manoeuvres using the Liquid Apogee Motor (LAM) in the vicinity of circular Geostationary Orbit. After this, the deployment of appendages such as the solar panels, antennas and three axis stabilisation of the satellite were performed. GSAT-16 was positioned at 55 deg East longitude in the Geostationary orbit and co-located with GSAT-8, IRNSS-1A and IRNSS-1B satellites.

Salient Features

Orbit	Geostationary (55 deg East longitude), co-located with GSAT-8, IRNSS-1A and IRNSS-1B
Lift-off Mass	3181.6 kg
Dry Mass	1457.7 kg
Physical Dimensions	2.0 m x 1.77 m x 3.1 m cuboid
Propulsion	440 Newton Liquid Apogee Motor (LAM) with Mono Methyl Hydrazine (MMH) as fuel and Mixed Oxides of Nitrogen (MON-3) as oxidiser for orbit raising
Stabilisation	3-axis body stabilised in orbit using Earth Sensors, Sun Sensors, Momentum and Reaction Wheels, Magnetic Torquers and eight 10 Newton and eight 22 Newton bipropellant thrusters
Power	Solar array providing 6000 Watts and two 180 AH Lithium Ion batteries
Antennas	Ku Band : 2.2 m x 2.4 m dia elliptical deployable Dual Grid Reflector (DGR)
	C-band : 2.2 m x 2.4 m dia elliptical deployable DGR for transmission
	1.4 m dia shaped prime focal antenna for C-band reception (Earth Viewing Face - Top)
Mission Life	12 years

GSAT-16 in clean room undergoing pre-launch tests

Payloads

- 12 Ku-band transponders each with 36 MHz usable bandwidth with footprint covering Indian mainland and Andaman & Nicobar islands
- 24 C-band transponders each with 36 MHz usable bandwidth with footprint covering Indian mainland and island territories
- 12 Upper Extended C-band transponders each with 36 MHz usable bandwidth with footprint covering Indian mainland and island territories

First Experimental Flight of India's Next Generation Launch Vehicle GSLV Mk-III Successful

The first experimental flight (GSLV Mk-III X/CARE) of India's next generation launch vehicle GSLV Mk-III was successfully conducted on December 18, 2014 from Satish Dhawan Space Centre SHAR, Sriharikota. Also known as LVM3-X/CARE, this suborbital experimental mission was intended to test the vehicle performance during the critical atmospheric phase of its flight and thus carried a passive (non-functional) cryogenic upper stage.

The mission began with the launch of GSLV Mk-III at 9:30 am IST from the Second Launch Pad as scheduled and about five and a half minutes later, carried its payload - the 3775 kg Crew Module Atmospheric Re-entry Experiment (CARE) - to the intended height of 126 km. Following this, CARE separated from the upper stage of GSLV Mk-III and re-entered the atmosphere and safely landed over Bay of Bengal with the help of its parachutes about 20 minutes 43 seconds after lift-off.

Two massive S-200 solid strap-on boosters, each carrying 207 tons of solid propellants, ignited at vehicle lift-off and after functioning normally, separated 153.5 seconds later. L110 liquid stage ignited 120 seconds after lift-off, while S200s were still functioning, and carried forward for the next 204.6 seconds.

CARE separated from the passive C25 cryogenic upper stage of GSLV Mk-III 330.8 seconds after lift-off and began its guided descent for atmospheric re-entry.

After the successful re-entry phase, CARE module's parachutes opened, following which it gently landed over Andaman Sea about 1600 km from Sriharikota, there by successfully concluding the GSLV Mk-III X/CARE mission. With this successful GSLV Mk-III X / CARE mission, the vehicle has moved a step closer to its first developmental flight with the functional C25 cryogenic upper stage.

LVM3

The next generation Launch vehicle GSLV Mk-III, known as LVM3, is the latest heavy-lift launch vehicle of ISRO. Proposed as the logical next step in enhancing the payload capability towards meeting our national requirements, LVM3 can also offer cost effective launch services to international customers.

The development of LVM3 relies up on its rich technological heritage, but successfully adapting the technological improvements, resulting in increased reliability and performance.

LVM-3 Lift-off

Configuration

Propulsion	:	2 (S200) Solid stages +
modules	:	L110 Liquid stage + C25 Cryo stage
Vehicle height	:	43.43 m
Lift-off Mass	:	640 tons
Core stage	:	4 m (dia)
Heat shield	:	5 m (dia)

Specifications for LVM3 Generic Mission

Payload mass	:	4 ton to Geosynchronous Transfer Orbit (GTO)
GTO Orbit	:	180 x 36000 km
Argument of Perigee	:	178 ± 0.2 deg
Inclination	:	19.2 ± 0.06 deg

LVM3 is a versatile launch vehicle towards achieving self-reliance in accessing space. LVM3 has the potential to evolve into a human rated launch vehicle with 10 ton payload capability to Low Earth Orbit (LEO). The proposed Heavy Lift Launch Vehicle (HLV) will also be derived out of the propulsion modules and architecture of LVM3.

S200 Solid Stage

The first stage of LVM3 is powered by two strap-on solid boosters delivering a combined initial thrust of 950 tons. The three segmented S200 motors are fabricated with M250 grade maraging steel and after processing, integrated through wet joints.

Attitude control during S200 regime is achieved through the thrust vectoring of submerged flex nozzle, achieved by two electro hydraulic actuators. The Flex Nozzle Control (FNC) system provides the adequate control capability of ±7.8° in Pitch and Yaw planes.

S200 is the biggest solid booster developed by ISRO and is the fourth largest in the world.

L110 Liquid Stage

L110 stage forms the lower part of the core, configured with twin Vikas Engines that generates a combined thrust of 1598 kN for 200 sec duration. The major development challenges were;

- Clustering of two high thrust Vikas engines with common feed system from the propellant tanks
- Qualification of high pressure Vikas engines for extended burn duration with indigenously developed Silica Phenolic throat
- Thermal management of the base region of the stage, that is exposed to extreme thermal environments during flight, due to the interacting plumes of S200 and L110
- Control system assisted by Electro-Mechanical actuators
- Largest liquid stage, developed by ISRO

C25 Cryo Stage Development

C25 forms the third stage of LVM3 and is one of the largest cryogenic upper stages being developed world over. The experience gained in realising and testing of the indigenously developed Cryogenic Upper Stage (CUS) is maximally utilised in this endeavour.

Realisation of a new cryogenic engine operating on Gas Generator (GG) cycle, development of a cryogenic stage with massive propellant loading, realisation of complex test facilities and a comparatively longer qualification cycle make it the most technologically challenging activity in the whole development of LVM3.

C25 stage is loaded with 27 tons of propellants, Liquid Oxygen and Liquid Hydrogen (LOX and LH2), and is powered by a 186 kN thrust engine (CE20) working on the GG Cycle, with independent turbines running on LH2 and LOX pumps. The stage has an overall length of 13.5 m and a diameter, 4 m.

The engine operating cycle allows independent development of each sub-system before the integrated engine test and thus reducing the development uncertainties in the final stage.

Major subsystem developments including the Gas Generator, LH2 and LOX turbo pumps have been successfully completed. Thrust chamber tests in nominal conditions are also completed. The first

CE20 Engine assembly is completed and the Hot test activities are fast progressing.

Though the philosophy and configuration of the C25 stage draws similarities from the CUS stage of GSLV, significant functional and operational changes have been introduced in the realisation of the new stage.

LVM3-X

In LVM3-X mission, S200 and L110 were functional stages whereas the C25 stage was passive one. The C25 stage was realised with flight identical structures and interfaces. The LOX tank was filled with liquid Nitrogen and the LH2 tank with gaseous Nitrogen. The mass simulated engine was held in null position with active control actuation system.

The external vehicle configuration of LVM3-X mission was identical to that of LVM3-D1 mission.

Encapsulated Assembly with CARE Module

In CARE mission, the Crew Module, which was separated from the launch vehicle at an altitude of 126 km, re-entered Earth's atmosphere at about 80 km and descended further in ballistic mode. Three axis control of CM using 100N thrusters was envisaged during the exo-atmospheric phase of flight, for controlling the rates and to ensure benign conditions for re-entry.

GSLV MK-III X Stages at a Glance

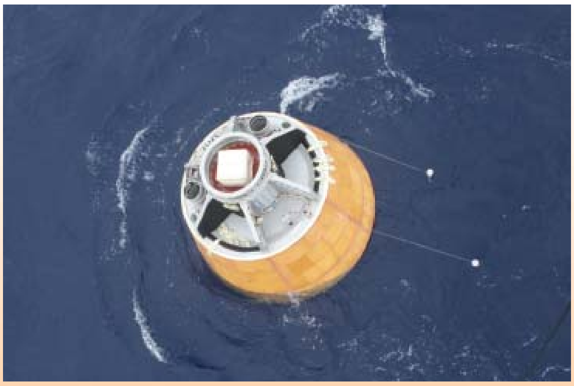
Parameter	Stages		
	S200	**L110**	**C25-X**
Length (m)	25.75	21.26	13.32
Diameter (m)	3.2	4.0	4.0
Propellants	HTPB	UH25 & N_2O_4	LN_2 (for mass simulation)
Propellant mass (T)	207	115	15
Stage mass at Lift off (t)	238	125.6	18.3

The Equipment Bay, Payload Adaptor, Payload Fairing and the spacecraft separation system were identical to generic vehicle.

Crew Module Atmospheric Re-entry Experiment [CARE]

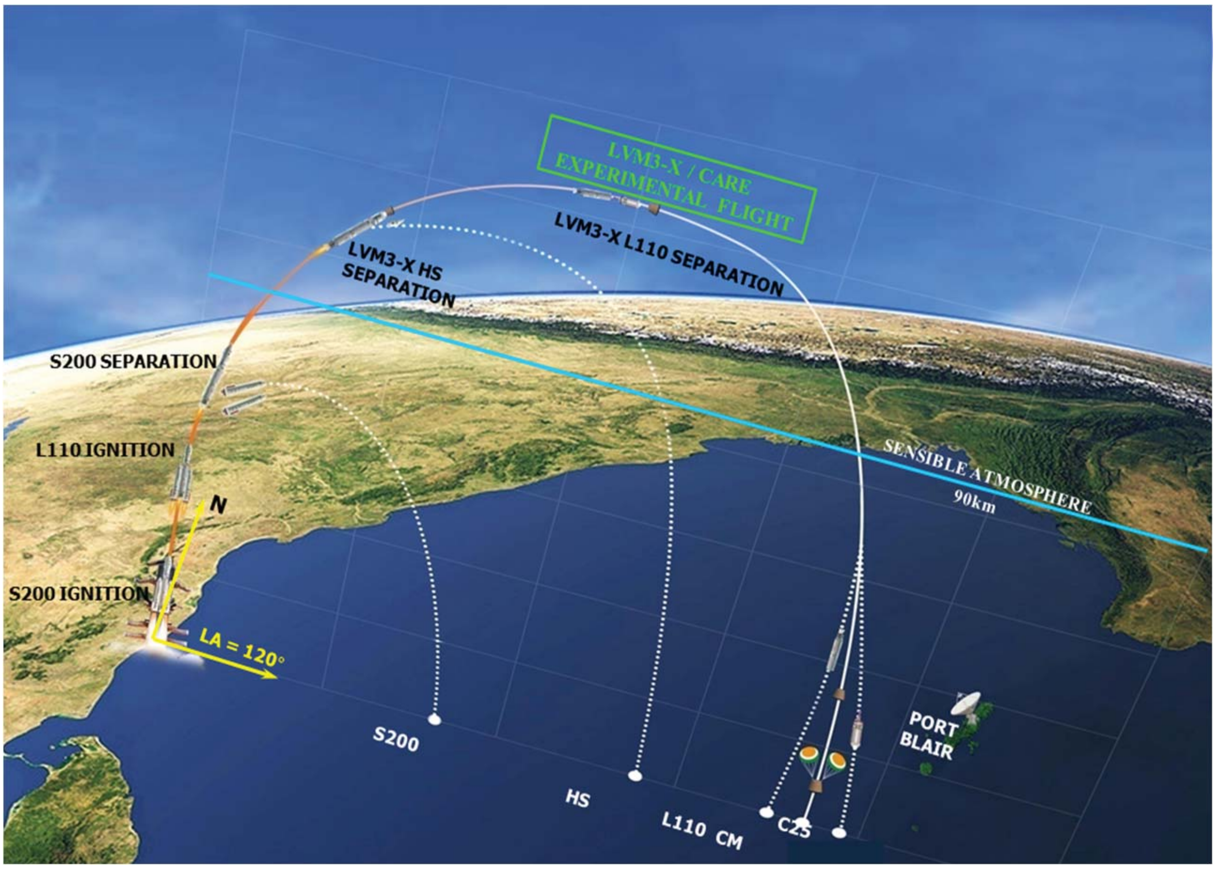
CARE, weighing around 3700 kg, was identified as the payload in LVM3-X mission. The mission was used as a platform for testing the re-entry technologies envisaged for Crew Module (CM) and validating the performance of deceleration systems.

Crew Module configuration for CARE had the same external geometry as in manned version. CM was positioned on the LVM3 PLA in an inverted position which ensured a favourable attitude during re-entry.



Care Module Floating -Top View

The deceleration system chain was initiated after separation of the apex cover using mortar deployed parachutes at 15 km altitude. Two pilot parachutes were then deployed using mortar which independently extracted two drogue parachutes.



Mission profile for LVM3-X

The drogue parachute further extracted two 31 m diameter main parachutes with single stage reefing, which decelerated the module to the final touch down velocity of 7 m/s. The Crew Module was impacted at 180 km away from the nearest land mass of Andaman and Nicobar islands from where it was recovered by the Indian Coast Guard.

For LVM3-X mission, the overall mission design was carried out on the similar lines of LVM3-D1 mission. This was to simulate similar type of trajectory and vehicle loads to validate all the subsystems in LVM3 generic flight conditions, during the atmospheric regime.

The launch scheduled from the Second Launch Pad (SLP) at SDSC with an azimuth of 120 degree was selected considering the range safety. All mission design and software got validated through LVM3-X mission, as intended.

ISRO Bags Padma Bhushan and Padma Shri Awards

ISRO got the much prominent recognition as many eminent people from ISRO are awarded with Padma Bhushan and Padma shri awards for the year 2013. Photos of the awardees receiving the award by The President, Shri Pranab Mukherjee.

2013

Dr. K Radhakrishnan, Chairman ISRO, receiving Padma Bhushan

Shri A S Kiran Kumar, Director SAC, receiving Padma Shri

Shri M. Chandradathan, Director VSSC, receiving Padma Shri

Shri M Y S Prasad, Director SDSC SHAR, receiving Padma Shri

Space India is very proud and congratulates these awardees for their achievement

GAGAN System Certified for RNP0.1 Operations

The Directorate General of Civil Aviation (DGCA), India has provisionally certified the ambitious Satellite Based Augmentation System (SBAS) programme of India - GPS Aided Geo Augmented Navigation (GAGAN) system - to RNP0.1 (Required Navigation Performance, 0.1 Nautical Mile) service level on December 30, 2013. The certification will enable the aircraft fitted with SBAS equipment to use GAGAN signal in space for En-Route Navigation and Non-Precision Approaches without vertical guidance over Indian air space. India is the fourth country to offer safety of life, space based satellite navigation services to aviation sector in the world. The availability of GAGAN Signal in space will bridge the gap between European Union's EGNOS and Japan's MSAS coverage areas, thereby offering seamless navigation to the aviation industry.

The GAGAN System, jointly developed by the Indian Space Research Organisation (ISRO) and Airports Authority of India (AAI), is a giant leap forward in the development of Global Navigation Satellite System (GNSS) services in India and will pave the way for more growth and enhancement in the days to come. The GAGAN System is poised to APV1/1.5 level of certification in the near future to offer precision approach services over the Indian land mass. The GAGAN signal is being broadcast through two Geostationary Earth Orbit (GEO) satellites – GSAT-8 and GSAT-10 – covering the whole Indian Flight Information Region (FIR) and beyond. An on-orbit spare GAGAN transponder will be flown on GSAT-15.

Image of Mars taken by MCC from an altitude of 66, 543 km. Dark region towards south of the cloud formation is Elysium - the second largest volcanic province on Mars

Antariksh Bhavan, New BEL Road, Bengaluru - 560 231, India.
www.isro.gov.in