General Science

Short Answers

Compiled by:

Dr. Saket Bihari

Indian Institute of Public Administration
New Delhi

Space Technology

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CHAPTER 4: SPACE TECHNOLOGY

CONTENTS

4.1 INTRODUCTION TO SPACE TECHNOLOGY

Space programs and activities of India started in early 1960 with the beginning of scientific investigations and experiments of the upper atmosphere and ionosphere using small rockets. These programs were conducted over the magnetic equatorial region passing through THUMBA, in Thiruvananthapuram (Kerala). It was Dr. Vikram Sarabhai who realized the immense potential of the Space program and technology for the country and its development as well as solving the problems and challenges of the common man.

With the establishment of the Indian National Committee for Space Research (INCOSPAR) by the Government of India in 1962, India thought of making an effort to start its space program. ISRO (Indian Space Research Organisation) Superseded INCOSPAR in 1969 under the able leadership of Vikram Sarabhai. The initial thrust and leadership to utilize space research to solve the problem of the common man were started under the visionary leadership of Vikram Sarabhai. ISRO's main objectives were capacity building, self-reliance, to advance the causes of the Space program and research for Nation Building and Development of the people.

4.2 INDIAN SPACE RESEARCH ORGANISATION (ISRO)

Formation:

- The Indian National Committee for Space Research (INCOSPAR) was established by Jawaharlal Nehru in 1962 under the Department of Atomic Energy (DAE).
- Eminent scientist Dr. Vikram Sarabhai had a big role in this development. He understood the need for space research and was convinced of the role it can play in helping a nation develop.
- INCOSPAR set up the Thumba Equatorial Rocket Launching Station (TERLS) at Thumba, near Thiruvananthapuram at India's southern tip. TERLS is a spaceport used to launch rockets.
- The INCOSPAR became ISRO in 1969.
- The Department of Space was created in 1972 and ISRO became a part of it and remains so to date. The Space Department reports directly to the Prime Minister of the country.

About ISRO:

ISRO or Indian Space Research Organisation is India's space agency founded in 1969 to help develop an indigenous Indian space program. It is one of the 6 largest space agencies in the world today. ISRO maintains one of the biggest fleets of remote sensing (IRS) and communication (INSAT) satellites catering to the needs of the nation through a network of centers, offices and research institutes in different parts of the country. ISRO functions in the following areas: broadcasting, weather forecasting, disaster management, geographic information systems, navigation, cartography (maps), tele-medicine, distance education satellites, etc.

ISRO is headquartered in Bengaluru

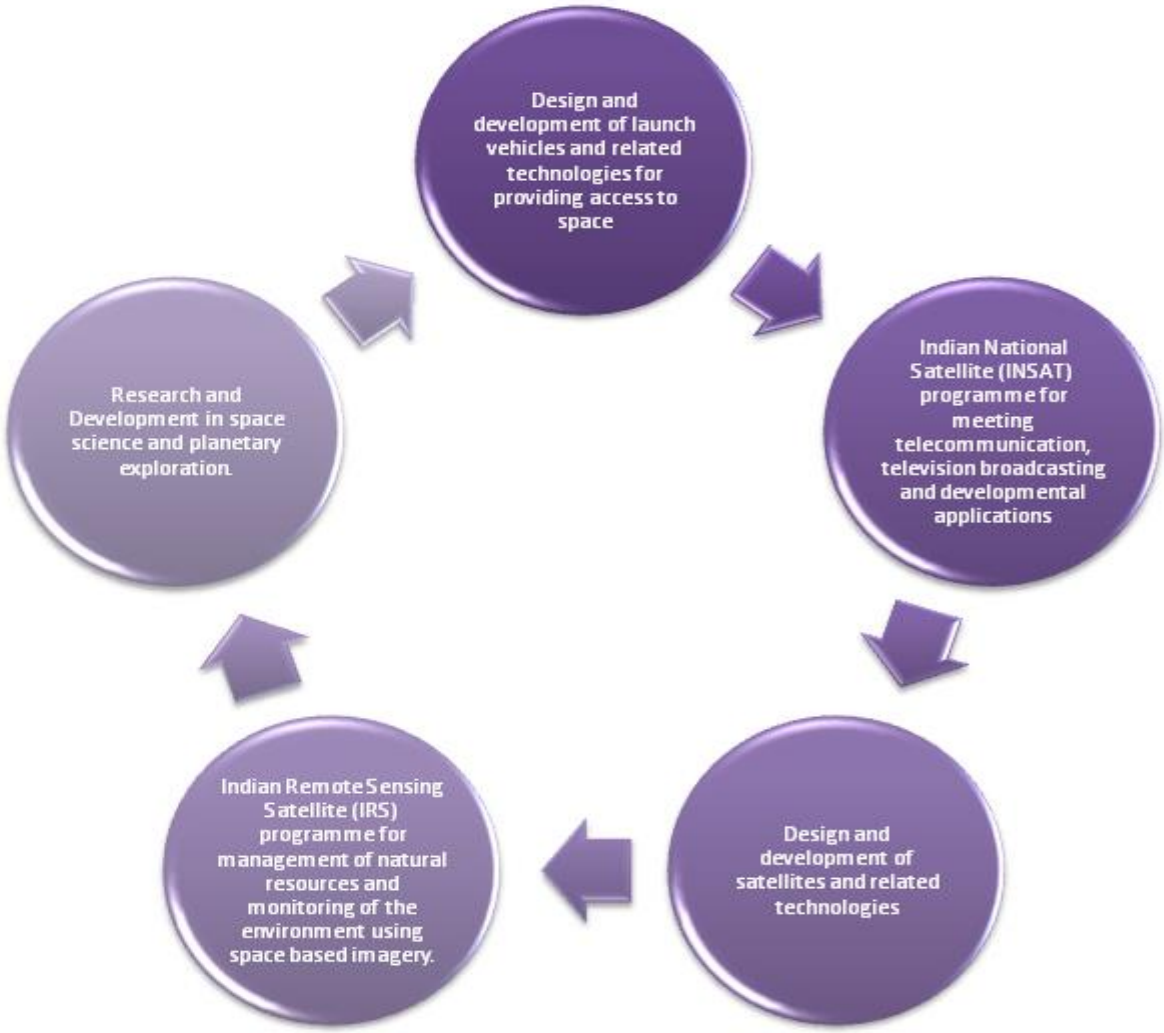
ISRO has many facilities each dedicated to a specialized field of study in space. A few of them are as follows:

- Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram
- Liquid Propulsion Systems Centre (LPSC), Thiruvananthapuram
- Satish Dhawan Space Centre (SDSC-SHAR), Sriharikota
- Space Applications Centre (SAC), Ahmedabad
- National Remote Sensing Centre (NRSC), Hyderabad

Vision, Mission, and Objectives:

ISRO's vision is stated as "Harness space technology for national development while pursuing space science research and planetary exploration."

<u>ISRO Mission</u>:-



Timelines of ISRO Achievements:

- The first Indian-made satellite was the RH-75 (Rohini-75). It was launched from TERLS in 1967. It was considered a ‘toy rocket’ and weighed just 32 kg.
- ISRO built its first satellite in 1975 and named it Aryabhatta. This was launched by the Soviet Union.
- The first Indian-built launch vehicle was SLV-3 and it was used to launch the Rohini satellite in 1980.
- ISRO launched the first INSAT in 1988. It was a communication satellite.
- ISRO also launched the first IRS (remote-sensing satellite) in 1988.
- ISRO has developed three types of launch vehicles (or rockets) namely, the PSLV (Polar Satellite Launch Vehicle), the GSLV (Geosynchronous Satellite Launch Vehicle) and Geosynchronous Satellite Launch Vehicle Mark III (GSLV Mark III or LVM).
- ISRO launched its first lunar mission Chandrayaan I in 2008.
- It also launched the Mars Orbiter Mission or the Mangalyaan in 2014. With this, India became the first country to achieve success in putting a satellite on Mars orbit in its maiden attempt and the fourth space agency and the first Asian agency to do so.
- In 2017, ISRO created another world record by launching 104 satellites in a single rocket. It launched its heaviest rocket yet, the Geosynchronous Satellite Launch Vehicle-Mark III and placed the GSAT 19 in orbit. There are future plans for a human spaceflight (Gaganyaan), interplanetary probes and a solar mission as well.

4.3 INDIAN NATIONAL SATELLITE SYSTEM (INSAT)

The INSAT series of satellites that were commissioned in the year 1983 have now become one of the most compatible and reliable systems of ISRO. The Indian Remote Sensing Satellite System. The remote sensing satellites are continuously relaying signals and spatial resolutions of various imageries. The Indian Remote Sensing Satellites were commissioned in the year 1998 with launch of IRS-1A.

Indian Space programme has become self-reliant today with the commissioning of two launch vehicles

- **Polar Satellite Launch Vehicle** for launching Indian Remote Sensing Satellite into Polar orbit
- **Geosynchronous Satellite Launch Vehicle** for launching communication satellites into Geosynchronous orbit.

SATELLITES AND APPLICATIONS:

Major applications Of Satellites system of the INSAT CLASSES INCLUDES the following:

Major Applications of INSAT System are:

1. Edusat Programme
2. Gramsat Programme
3. Telemedicine
4. Television
5. Radio Networking
6. Satellite News Gathering And Dissemination
7. Telecommunications
8. Mobile Satellite Services
9. Meteorology
10. Satellite Aided Search And Rescue
11. Satellite Navigation
12. Disaster Management Support (DMS) Programme
13. Village Resource Centres

Fig 4.1: APPLICATIONS OF SATELLITE SYSTEM

(Image source: Byjus)

In the last few decades, the INSAT systems and Satellites Communication Technologies (SATCOM) have been offering several ranges of services ranging from Social and Economic development services which are reliable, seamless and reach the widest possible distances in the remotest corner of the country. Since its initiations the Satellite program of ISRO have covered diverse areas of applications :

- Telecommunications
- Tele-education
- Data Services
- DTH and Cable TV
- Rural areas connectivity
- Village resources
- Disaster management and rescue operations, And many more

Edusat Programme:

EDUSAT', India's first thematic satellite dedicated exclusively for educational services, was used extensively to cater to a wide range of interactive educational delivery modes like a one-way TV broadcast, video conferencing, computer conferencing, web-based instructions, etc. it had many objectives like supplementing the curriculum-based teaching, effective teacher training, providing access to quality resource persons and new technologies, thus finally resulting in taking education to every nook and corner of India. EDUSAT provided connectivity to schools, colleges and higher levels of education and supported non-formal education including development communication.

EDUSAT Programme was implemented in three phases: pilot, semi-operational and operational phases. Pilot projects were conducted during 2004 in Karnataka, Maharashtra and Madhya Pradesh with 300 terminals. The experiences of pilot projects were adopted in semi-operational and operational phases. During the semi-operational phase, almost all the states and major national agencies were covered under the EDUSAT program. The networks were expanded under the operational phase with funding by respective state governments/user agencies.

The EDUSAT (GSAT-3) satellite provided its services till September-2010, supporting Tele-education, Telemedicine and Village Resource Centres (VRC) projects of ISRO. After its decommissioning, the traffic of Tele-education networks was migrated to other ISRO satellites. Most of the tele-education networks operating in Ku-band were migrated from GSAT-3 to INSAT-4CR and those in Ext. C-band networks were migrated to INSAT-3A, INSAT-3C and GSAT-12. The migration of the remaining few networks is in the pipeline.

Gramsat:

Keeping in mind the urgent need to eradicate illiteracy in the rural belt which is necessary for the all-round development of the nation ISRO has come up with the concept of dedicated GRAMSAT satellites.This satellite is carrying six to eight high powered C-band transponders, which can disseminate regional and cultural specific audio-visual programs together with video compression techniques.

The high power in C-band has enabled even remote area viewers outside the reach of the TV transmitters to receive programmers of their choice in a direct reception mode with a simple dish antenna.

The following features are provided by Gramsat Satellite:-

1. Its communications networks are at the state level connecting the state capital to districts, blocks and enabling a reach to villages.
2. Tele-health and telemedicine services
3. It is also providing computer connectivity data broadcasting, TV-broadcasting facilities having applications like e-governance, development information, teleconferencing, helping disaster management
4. Providing rural-education broadcasting.

Telemedicine:

Telemedicine allows health care professionals to evaluate, diagnose and treat patients at a distance using telecommunications technology. The approach has been through a striking evolution in the last decade and it is becoming an increasingly important part of the American healthcare infrastructure.

Telemedicine or Telehealth is the distribution of health-related services and information via electronic information and telecommunication technologies.It allows long-distance patient and clinician contact, care, advice, reminders, education, intervention, monitoring, and remote admissions. Telemedicine is used in a more limited sense to describe remote clinical services, such as diagnosis and monitoring. When rural settings, lack of transport, a lack of mobility, decreased funding, or a lack of staff restricts access to care, telehealth may bridge the gap.

Telehealth includes two or more clinicians discussing a case over video conference;or a robotic surgery occurring through remote access;, live feed and application combinations; tests being forwarded between facilities for interpretation by a higher specialist; physical therapy done via digital monitoring instruments, home monitoring through continuous sending of patient health data; etc.

Agriculture and Soil:

Satellite observations provide Reliable information regarding crop acreages, timely forecasts of production & yields. ISRO has launched two projects namely - National Agricultural Drought Assessment and Management System (NADAMS) and Forecasting Agricultural output using Space, Agrometeorology and Land-based observations (FASAL), respectively.

Water Resources:

Space technology provides comprehensive inputs on surface water, snow cover, groundwater etc. ISRO is actively involved in several projects to make the inventory and monitor the water resources in the country.

Ocean:

Operational oceanography has now become a reality and it relies heavily on ground-based and satellite-based observations. Ocean color observations, Sea Surface Temperature (SST), Wave Height (SWH), ocean chlorophyll, sea ice parameters and ocean surface winds are analyzed using satellite data.

Satellite-based oceanographic observations generate data products on Potential Fishing Zone Advisories, Photosynthetically Active Radiation (PAR), ocean primary production, aerosol optical depth, total suspended sediments, suspended sediment concentration and ocean state forecast. The satellite derived Suspended Sediment Concentration (SSC) maps are essentially used in maintaining the navigational channels, safeguarding marine installations and protection of the vital coastal habitats. The freshwater budget can be derived from Sea Surface Salinity (SSS) and sea ice parameters.

Weather and Climate:

Weather refers to the instantaneous state of the atmosphere and climate is the long term average state of the atmosphere. Weather prediction and climate monitoring require an in-situ observational network of Automatic Weather Stations (AWS), Doppler Weather Radar, Wind Profiler etc., as well as satellite measurements. ISRO has established a network of 1158 Automatic Weather Stations (AWS) across the country.ISRO has developed technology for many of these observing instruments in house. The data from these AWS are used for initializing numerical weather prediction as well as validating the forecasts.

Energy:

India has a clear direction of utilizing renewable energy for meeting the country's requirements. Satellite remote sensing provides synoptic data, covering larger areas continuously for longer periods. Earth Observation data helps analyze Winds, solar and wave energy resources.

Rural Development:

For planning, monitoring and impact assessment viz. Integrated Watershed Management Programme (IWMP), Space-Based Information Support for Decentralized Planning (SISDP), and MGNREGA, Various programs are carried out by ISRO addressing the developmental priorities of the country

Urban Development:

The urban environment of cities faces several challenges such as the rate of population increase, urban sprawl etcThese changes f by way of increased spatial accuracy and frequent revisit periods which allows planners to construct action scenarios and compile the accurate database of spatial environments. information regarding changes in land-use patterns over the past for carrying out various urban planning, planning alternatives and management activities can be obtained through the use of satellite data.

For diverse applications like Television, DTH Broadcasting, VSAT etc. Satellite Communication utilization has become widespread. The technology has matured substantially over the past three decades and is being used on a commercial basis for a large number of applications. Most of us are touched by satellite communication in more ways than we realise.

The potential of the technology for societal applications continues to fascinate ISRO and efforts are on to leverage the benefits of technology to the betterment of mankind. Tele-education, Tele-medicine, Village Resource Centre (VRC) and Disaster Management System (DMS) Programmes are some important initiatives pursued by ISRO towards societal development. The potential of space technology for applications of national development is enormous.

Disaster Management Services:

ISRO is actively involved in providing space inputs on a near real-time basis for major natural disasters in the country, such as floods, cyclones, landslides, earthquakes and so on. The information on fire alerts (forest fire, stubble burning) are also provided to the concerned. While operational drought assessments are provided by the Mahalanobis National Crop Forecast Centre (MNCFC), necessary R&D products are also undertaken by the National Remote Sensing Centre (NRSC), ISRO. Disaster Support Centre (DSC), NRSC has extended the satellite-based support to Central and State Departments. For example, floods in eight States, viz., Assam, Bihar, Uttar Pradesh, Delhi, Odisha, Mizoram, Tripura have been monitored using satellite data by NRSC, ISRO.

Flood inundation in KERALA was monitored in recent times by NRSC.Apart from regular flood maps, flood persistence map, showing the areas under persistent floods, was also provided to Kerala. ISRO has extended the satellite images based support to central and state government departments in providing near real-time inputs from space on all major disasters in the country During July-August, 2018, . Through the sharing of valuable data, it has helped the MHA, NDMA, NDRF and State Disaster Management Departments. Considering the high intensity of the disasters, an international charter was also activated for obtaining more frequent high-resolution satellite datasets. FOR public use all information related to disaster is disseminated via BHUVAN satellite.

Landslides:

Landslides cause huge damages, particularly along pilgrim routes. ISRO prepared Landslide Hazard Zonation maps for pilgrim routes in Himachal Pradesh, Uttarakhand and Meghalaya.Also, ISRO is preparing seasonal landslide inventory regularly.These satellite-based inputs are very useful for preparedness.

Experimental Landslide Early Warning System for Rainfall Triggered Landslides is carried out for the following routes namely Rishikesh-Badrinath, Rishikesh-Uttarkashi-Gomukh, Chamoli-Ukhimath Rudraprayag-Kedarnath and Pithoragarh-Malpa in Uttarakhand during specific seasons

Near real-time information on landslides is derived regularly during major landslide events in the country and disseminated through Bhuvan geoportal. A real extent of a landslide is also estimated using satellite data and DSMs. Also, in case of river blockade due to landslides, necessary inputs are provided to the Govt. from time to time.

Cyclones:

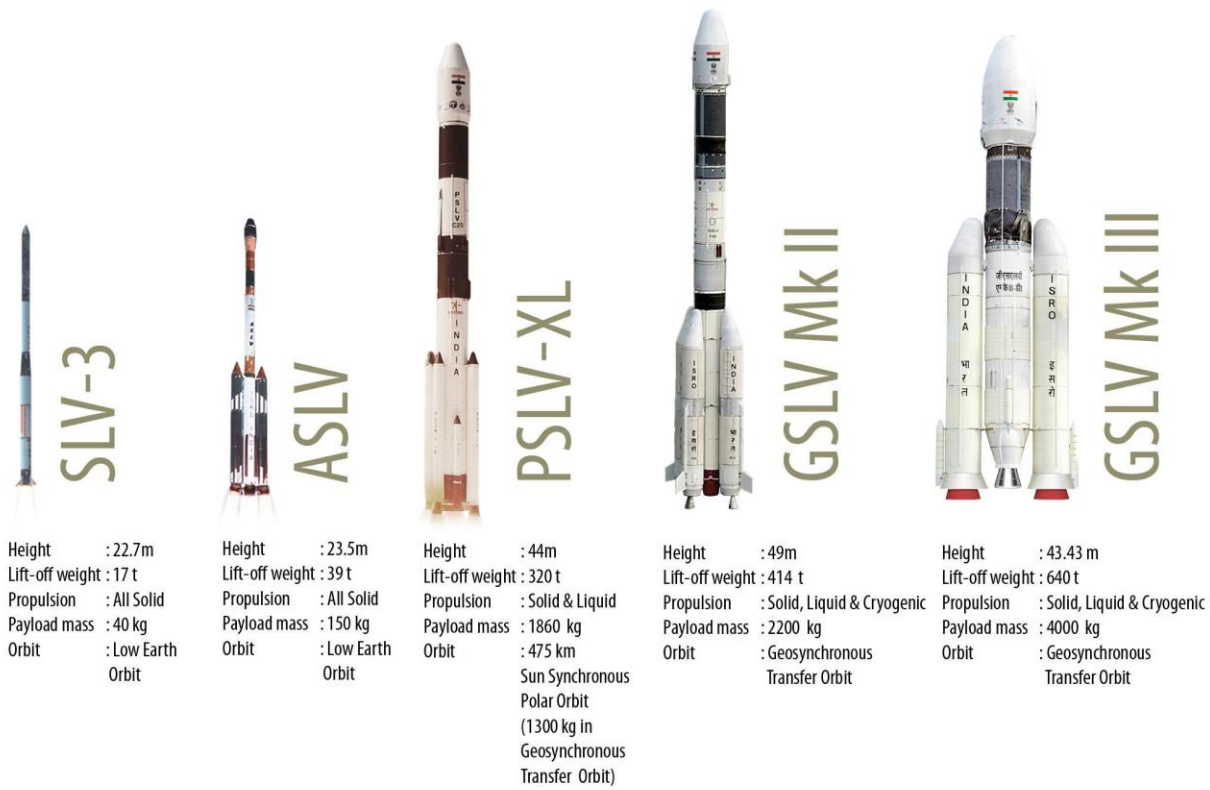
With a large coastline, India is susceptible for cyclones. It is important to understand the impacts of cyclones, concerning its earlier footprints, low lying areas, etc, wherein satellite images provide such inputs. Using historical satellite data and Digital surface models, these inputs are derived. ISRO uses geo-stationary and low earth orbit satellites for providing experimental inputs on cyclogenesis, cyclone track, cyclone intensity. INSAT series of satellites with frequent imaging provide the cyclone parameters for near real-time analysis.ISRO monitors the formation of cyclones and carries out cyclone track prediction. Besides, near real-time inundation mapping due to cyclones are also prepared.

Earthquakes:

Very high-resolution satellite data is used by ISRO to provide inputs on damage assessment for major earthquake events. During 2015, the Nepal government was supported by ISRO which provided satellite-based inputs on damages done by the earthquake that rocked the area.

4.4 SATELLITE LAUNCH VEHICLES

A launch vehicle or carrier rocket is a rocket-propelled vehicle used to carry a payload from Earth's surface to space, usually to Earth orbit or beyond. Orbital launch vehicles can be grouped based on many different factors, most notably payload mass, although price points are a major concern for some users. Most launch vehicles have been developed by or for national space programs, with considerable national prestige attached to spaceflight accomplishments. Payloads include crewed spacecraft, satellites, robotic spacecraft, scientific probes, landers, rovers, and many more.



<u>**Fig 4.2 ISRO Launch Vehicles Over the Years**</u>

(Image source: ISRO.GOV.IN)

Satellite Launch Vehicle -3(SLV-3):

It was successfully launched on July 18, 1980, from Sriharikota Range (SHAR), when Rohini satellite, RS-1, was placed in orbit, thereby making India the sixth member of an exclusive club of space-faring nations. The SLV-3 was India's first experimental satellite launch vehicle, having all solid, four-stage vehicles weighing 17 tonnes with a height of 22m and capable of placing 40 kg class payloads in Low Earth Orbit (LEO)... SLV-3 employed open-loop guidance (with stored pitch program) to steer the vehicle in flight along a predetermined trajectory. The first experimental flight of SLV-3, in 1979, was only a partial success. There were two more launches held in May 1981 and April 1983, Apart from July 1980, orbiting Rohini satellites carrying remote sensing sensors.

The success of the project paved the way for advanced launch vehicle projects such as the Augmented Satellite Launch Vehicle (ASLV), Polar Satellite Launch Vehicle (PSLV) and the Geosynchronous Satellite Launch Vehicle (GSLV).

Augmented Satellite Launch Vehicle (ASLV):

The Augmented Satellite Launch Vehicle (ASLV) Programme was designed to augment the payload capacity to 150 kg, thrice that of SLV-3, for Low Earth Orbits (LEO). While building upon the experience gained from the SLV-3 missions, ASLV proved to be a low-cost intermediate vehicle to demonstrate and validate critical technologies that would be needed for the future launch vehicles like strap-on technology, inertial navigation, bulbous heat shield, vertical integration and closed-loop guidance.

Under the ASLV program four developmental flights were conducted. The first developmental flight took place on March 24, 1987, and the second on July 13, 1988. The third developmental flight, ASLV-D3 was successfully launched on May 20, 1992, when SROSS-C (106 kg) was put into an orbit of 255 x 430 km. ASLV-D4 launched on May 4, 1994, orbited SROSS-C2 weighing 106 kg. It had two payloads, Gamma Ray Burst (GRB) Experiment and Retarding Potential Analyser (RPA) and functioned for seven years.

Polar Satellite Launch Vehicle (PSLV):

Polar Satellite Launch Vehicle (PSLV) is the third generation launch vehicle of India. It is the first Indian launch vehicle to be equipped with liquid stages. After its first successful launch in October 1994, PSLV emerged as the reliable and versatile workhorse launch vehicle of India with 39 consecutively successful missions by June 2017. During the 1994-2017 period, the vehicle has launched 48 Indian satellites and 209 satellites for customers from abroad.

Besides, the vehicle successfully launched two spacecraft – Chandrayaan-1 in 2008 and Mars Orbiter Spacecraft in 2013 – that later traveled to Moon and Mars respectively.

PSLV earned its title 'the Workhorse of ISRO' through consistently delivering various satellites to Low Earth Orbits, particularly the IRS series of satellites. It can take up to 1,750 kg of payload to Sun-Synchronous Polar Orbits of 600 km altitude.

Due to its unmatched reliability, PSLV has also been used to launch various satellites into Geosynchronous and Geostationary orbits, like satellites from the IRNSS constellation.

- The uppermost stage of PSLV is PS 4, which comprises two Earth storable liquid engines.
- The third stage of PSLV is a solid rocket motor that provides the upper stages of high thrust after the atmospheric phase of the launch.

- PSLV uses an Earth storable liquid rocket engine for its second stage, known as the Vikas engine, developed by Liquid Propulsion Systems Centre.
- PSLV uses the S139 solid rocket motor that is augmented by 6 solid strap-on boosters.
- PSLV uses 6 solid rocket strap-on motors to augment the thrust provided by the first stage in its PSLV-G and PSLV-XL variants. However, strap-ons are not used in the core alone version (PSLV-CA).

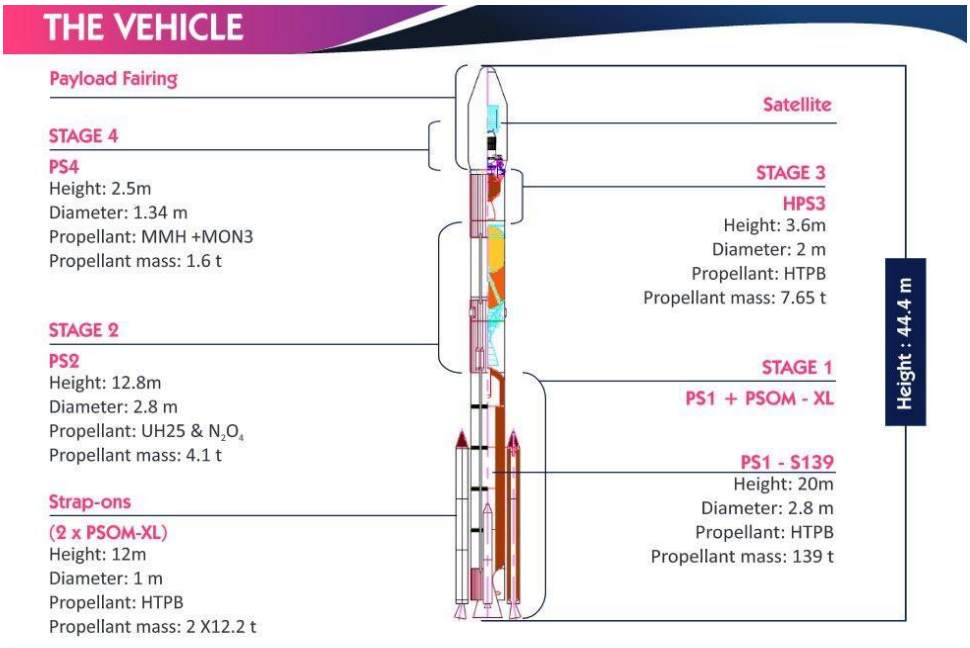


Fig 4.3 Polar Satellite Launch Vehicle

(Image source: Spaceflightnow)

Polar Satellite Launch Vehicle -XL:

- It is the upgraded version of PSLV and boosted by more powerful, stretched strap-on boosters with 12-tonne propellant load in its standard configuration
- It Weighs 320 tonne at lift-off and uses larger strap-on motors (PSOM-XL or S12) to achieve higher payload capability. On 29 December 2005, ISRO successfully tested the improved version of the strap-on booster for the PSLV.
- PSLV-XL was first used during the launch of Chandrayaan-1 by PSLV C11. The payload capability for this variant is 1,800 kg to SSO.

Polar Satellite Launch Vehicle -DL:

PSLV-DL variant has only two strap-on boosters with a 12-tonne propellant load on them. PSLV-C44 on 24 January 2019 was the first flight to use the PSLV-DL variant of Polar Satellite Launch Vehicle.

Polar Satellite Launch Vehicle -QL:

PSLV-QL variant has four ground-lit strap-on boosters, each with 12 tonnes of propellant. PSLV-C45 on 1 April 2019 was the first flight of PSLV-QL.

Geosynchronous Satellite Launch Vehicle (GSLV):

Geosynchronous Satellite Launch Vehicle Mark-II (GSLV Mk II) is the largest launch vehicle developed by India, which is currently in operation. This fourth-generation launch vehicle is a three-stage vehicle with four liquid strap-ons. The indigenously developed cryogenic Upper Stage (CUS), which is flight-proven, forms the third stage of GSLV Mk II. From January 2014, the vehicle has achieved four consecutive successes.

GSLV's primary payloads are INSAT class of communication satellites that operate from Geostationary orbits and hence are placed in Geosynchronous Transfer Orbits by GSLV.

Further, GSLV's capability of placing up to 5 tonnes in Low Earth Orbits broadens the scope of payloads from heavy satellites to multiple smaller satellites.

Developed under the Cryogenic Upper Stage Project (CUSP), the CE-7.5 is India's first cryogenic engine, developed by the Liquid Propulsion Systems Centre. CE-7.5 has a staged combustion operating cycle.

One Vikas engine is used in the second stage of GSLV. The stage was derived from the PS2 of PSLV where the Vikas engine has proved its reliability.

The first stage of GSLV was also derived from the PSLV's PS1. The 138-tonne solid rocket motor is augmented by 4 liquid strap-ons.

The four liquid engine strap-ons used in GSLV are heavier derivatives of PSLV's PS2 and use one Vikas engine each.

Geosynchronous Satellite Launch Vehicle Mark III (GSLV MK-III):

GSLV MkIII, chosen to launch Chandrayaan-2 spacecraft, is a three-stage heavy-lift launch vehicle developed by ISRO. The vehicle has two solid strap-ons, a core liquid booster, and a cryogenic upper stage.

GSLV Mk III is designed to carry a 4 ton class of satellites into Geosynchronous Transfer Orbit (GTO) or about 10 tons to Low Earth Orbit (LEO), which is about twice the capability of the GSLV Mk II.

The two strap-on motors of GSLV Mk III are located on either side of its core liquid booster. Designated as ‘S200’, each carries 205 tons of composite solid propellant and their ignition results in vehicle lift-off. S200s function for 140 seconds. During the strap-ons functioning phase, the two clustered Vikas liquid Engines of L110 liquid core booster will ignite 114 sec after liftoff to further augment the thrust of the vehicle. These two engines continue to function after the separation of the strap-ons at about 140 seconds after lift-off.

On December 18, 2014, The first experimental flight of LVM3 mission lifted off from Sriharikota,and successfully tested the atmospheric phase of flight. In this flight,the Crew module Atmospheric Re-entry Experiment was also carried out. The module re-entered the atmosphere, deployed the parachutes and splashed down in the Bay of Bengal.

On June 05, 2017, GSAT-19 satellite,was placed successfully in Geosynchronous Transfer Orbit (GTO) from SDSC SHAR, Sriharikota by the GSLV-Mk III-D1

GSLV MK III D2, The second developmental flight of GSLV MkIII was successfully launched and carried GSAT-29, a high throughput communication satellite on November 14, 2018 from Satish Dhawan Space Centre SHAR, Sriharikota

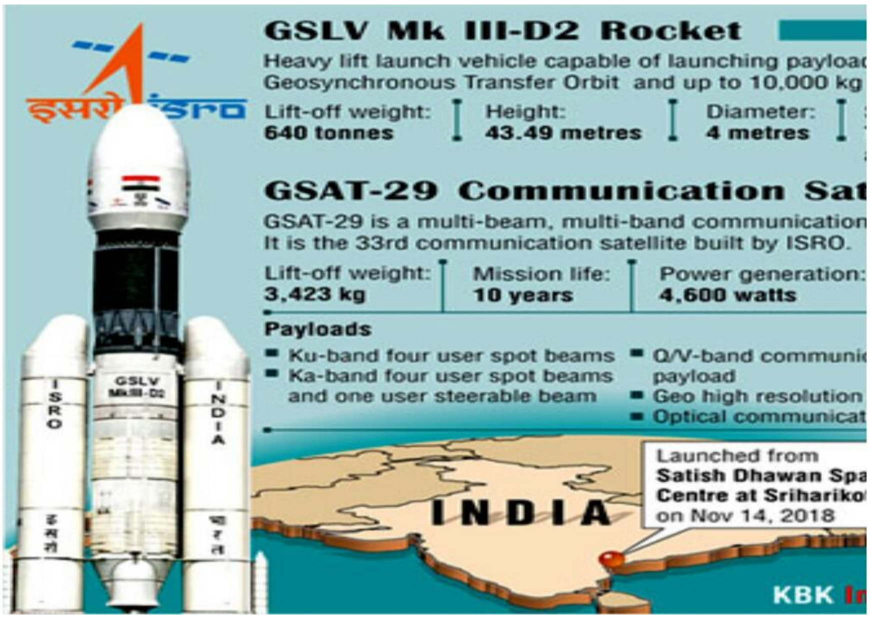


Fig 4.4 GEOSYNCHRONOUS SATELLITE LAUNCH VEHICLE MKIII D-2

(*Image source*: ISRO.GOV.IN)

CHANDRAYAAN 2, India's second Lunar Mission, was successfully placed by GSLV MkIII-M1, into Earth Parking Orbit on July 22, 2019 from Satish Dhawan Space Centre SHAR, Sriharikota.

- The development of GSLV Mk III will facilitate placing the 4 tonne class satellites of the GSAT series into Geosynchronous Transfer Orbits.
- Heavy payloads into Low Earth Orbits of 600 km altitude. Can be placed by The powerful cryogenic stage of GSLV Mk III
- GSLV Mk III uses two S200 solid rocket boosters to provide the huge amount of thrust required for lift off. The S200 was developed at Vikram Sarabhai Space Centre
- The Cryogenic Upper Stage (C25) is powered by CE-20, India's largest cryogenic engine, designed and developed by the Liquid Propulsion Systems Centre.
- The L110 liquid stage is powered by two Vikas engines designed and developed at the Liquid Propulsion Systems Centre.

4.5 REUSABLE LAUNCH VEHICLE -TECHNOLOGY DEMONSTRATOR (RLV-TD)

Reusable Launch Vehicle – Technology Demonstrator (RLV-TD) is one of the most technologically challenging endeavors of ISRO towards developing essential technologies for a fully reusable launch vehicle to enable low cost access to space. The configuration of RLV-TD is similar to that of an aircraft and combines the complexity of both launch vehicles and aircraft.

The winged RLV-TD has been configured to act as a flying test bed to evaluate various technologies, namely, hypersonic flight, autonomous landing and powered cruise flight. In future, this vehicle will be scaled up to become the first stage of India's reusable two stage orbital launch vehicle.

RLV-TD consists of a fuselage (body), a nose cap, double delta wings and twin vertical tails. It also features symmetrically placed active control surfaces called Elevons and Rudder.This technology demonstrator was boosted to Mach no: 5 by a conventional solid booster (HS9) designed for low burn rate.

The selection of materials like special alloys, composites and insulation materials for developing an RLV-TD and the crafting of its parts is very complex and demands highly skilled manpower. Many high technology machinery and test equipment were utilised for building this vehicle.

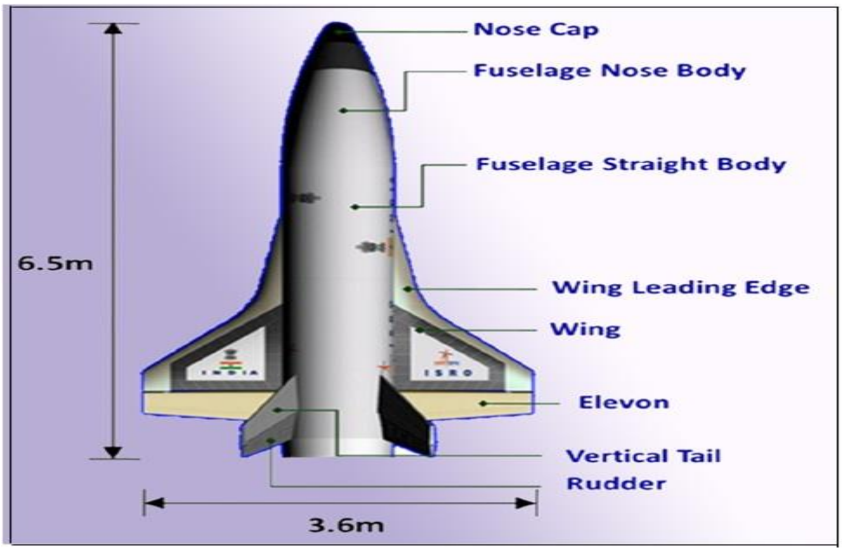


Fig 4.5 Reusable Launch Vehicle

(Image source: ISRO.GOV.IN)

Objectives of RLV-TD:

- Hypersonic aero thermodynamic characterisation of wing body
- Evaluation of autonomous Navigation, Guidance and Control (NGC) schemes
- Integrated flight management
- Thermal Protection System Evaluation

Achievements:

RLV-TD was successfully flight tested on May 23, 2016 from SDSC SHAR Sriharikota validating the critical technologies such as autonomous navigation, guidance & control, reusable thermal protection system and re-entry mission management.

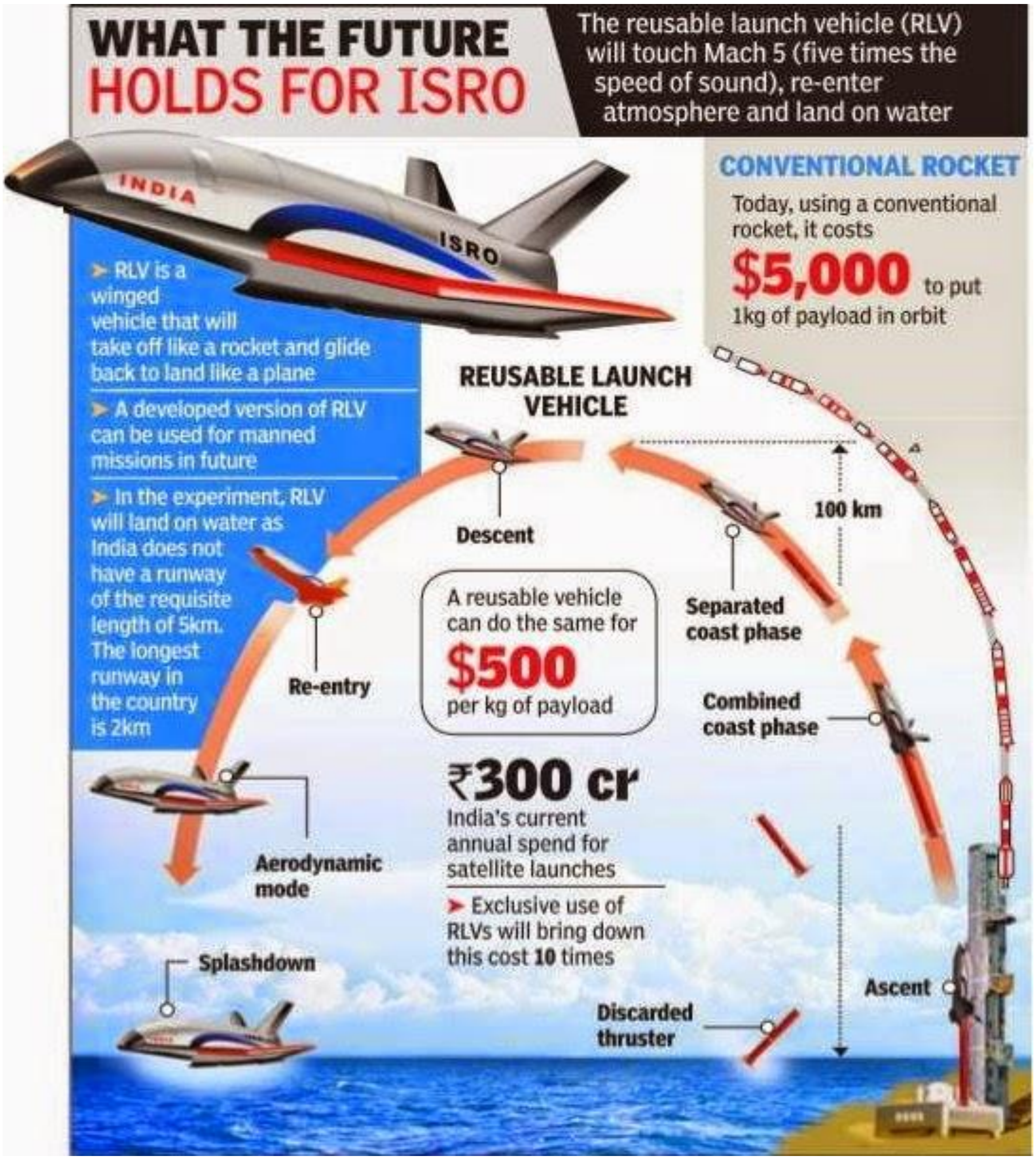


Fig 4.6 Flight Trajectory

(image source: The Hindu)

Scramjet Engine:

The first experimental mission of ISRO's Scramjet Engine towards the realization of an Air Breathing Propulsion System was successfully conducted on August 28, 2016, from Satish Dhawan Space Centre SHAR, Sriharikota.

After a flight of about 300 seconds, the vehicle touched down in the Bay of Bengal, approximately 320 km from Sriharikota. The vehicle was successfully tracked during its flight from the ground stations at Sriharikota. With this flight, critical technologies such as ignition of air-breathing engines at supersonic speed, holding the flame at supersonic speed, air intake mechanism, and fuel injection systems have been successfully demonstrated.

The Scramjet engine designed by ISRO uses Hydrogen as fuel and the Oxygen from the atmospheric air as the oxidizer. This test was the maiden short duration experimental test of ISRO's Scramjet engine with a hypersonic flight at Mach 6. ISRO's Advanced Technology Vehicle (ATV), which is an advanced sounding rocket, was the solid rocket booster used for the test of Scramjet engines at supersonic conditions. ATV carrying Scramjet engines weighed 3277 kg at lift-off.

4.6 INDIAN SATELLITES

From the last four decades, the Indian Space Research Organisation (ISRO) has been involved in several satellite launches beginning with the INSAT satellite systems then gradually progressing towards the launches of **Remote Sensing Satellites** for resource mapping, weather Advisories, disaster management, etc.

Other systems of Satellites belong to the group of **Geosynchronous** and **Geostationary** satellites.

Remote Sensing Satellite:

This technology is used in numerous fields like geography, hydrology, ecology, oceanography, glaciology, geology to gather information and collect reliable data. GIS (geographical information system) is used for mapping and analyzing feature events on Earth. The statistical analysis and query, with maps, is combined utilized by GIS and remote sensing technology for collecting data and information. The GIS manages information on locations and provides tools for analysis and display of different statistics that include population, economic development, characteristics and vegetation. It also allows linking databases to make dynamic displays. These abilities make GIS different from other systems and make it a wide range of private and public remote sensing applications for planning and predicting outcomes from remote sensing satellites.

There are three essential elements for Remote Sensing:

- A platform to hold the instrument
- A target or object
- An instrument or sensor (to observe the target)

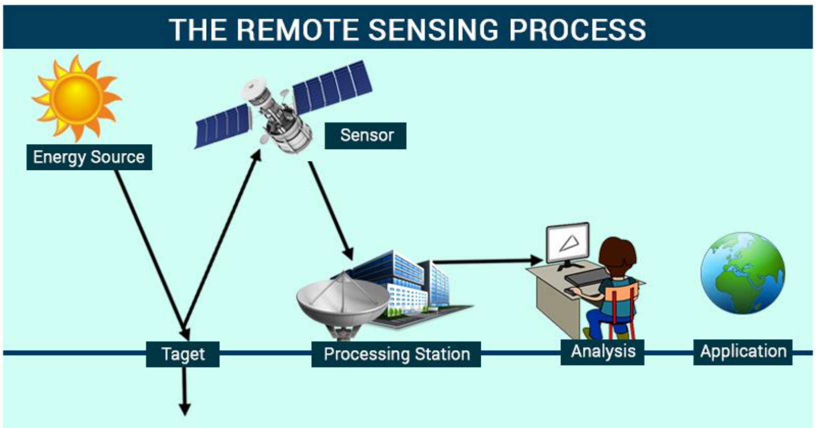


Fig 4.7 Remote Sensing Satellite

(Image source: researchgate)

Applications of Remote Sensing Satellites:

In determining soil moisture crop production, Land-use pattern mapping .	To make an inventory of potential landslides	To measure albedo for Earth's radiation budget
The satellites help Measuring sea levels and glacial flow	using thermal remote sensing to monitor active volcanoes	It helps in improving efficiency and safety of air traffic control
To observe the flow of ocean currents and circulation	To further scientific research, It helps in mapping ocean floors.	Locating missing aircraft in case of plane accidents.
To map the degradation and loss of wetland ecosystems	Remote sensing satellites are going to make imperishable contribution in further climate change research	Military surveillance
Precision farming.	To Study geology of earth's surface	It can help in tracking of displaced refugees to help deliver aid and services using satellite imagery.

Category of Remote Sensing Satellite

Polar satellites

Polar satellites are a category of Remote Sensing Satellites that revolve around the earth in a north-south direction as opposed to east-west like the geostationary satellites. They are very useful in applications where the field vision of the entire earth is required in a single day. Since the entire earth moves below them, this can be done easily. They are used in weather applications where predicting weather and climate-based disasters can be done in a short time. They are also used as relay stations.

Geosynchronous Satellite:

When a satellite has an orbital period the same as the Earth's rotation period, it is called a GEOSYNCHRONOUS SATELLITE..the geosynchronous satellite returns to the similar position in the sky after every sidereal day, and during a day, it traces out a path in the sky that is typically some form of the analemma. A geostationary satellite is one special case of geosynchronous satellite, which has a geostationary orbit – a circular geosynchronous orbit directly above the Earth's equator.

Geostationary Satellites:

These satellites are placed into orbit at a distance of around 35,800 km from the earth's surface. They rotate in the same direction as the earth and one revolution of such satellites is the same as one day on earth (roughly 24 hours). This means that, as seen from earth, these satellites will appear to be at the same spot throughout. Hence, the name "geostationary" satellites. These satellites are used as communication satellites and for weather-based applications.

4.7 REMOTE SENSING SATELLITE MISSIONS BY ISRO

RESOURCESAT-2

- RESOURCESAT-2 is a follow-on mission to RESOURCESAT-1 and the eighteenth Remote Sensing satellite built by ISRO.
- RESOURCESAT-2 is intended to continue the remote sensing data services to global users provided by RESOURCESAT-1, and to provide data with enhanced multispectral and spatial coverage as well.

CARTOSAT- SERIES

1. Cartosat -1: CARTOSAT–1 is the first Indian Remote Sensing Satellite capable of providing in-orbit stereo images. The images were used for Cartographic applications meeting the global requirements. Cameras of this satellite have a resolution of 2.5m (can distinguish a small car).

2. Cartosat-2: Cartosat-2 Series Satellite is the primary satellite carried by PSLV-C40. This remote sensing satellite is similar in configuration to earlier satellites in the series and is intended to augment data services to the users.

The imagery sent by satellite will be useful for cartographic applications, urban and rural applications, coastal land use and regulation, utility management like road network monitoring, water distribution, creation of land use maps, change detection to bring out geographical and manmade features and various other Land Information System (LIS) as well as Geographical Information System (GIS) applications.

3. Cartosat-2 A: CARTOSAT – 2A is the thirteenth satellite in the Indian Remote Sensing Satellite series (IRS). Imageries from this satellite were used for cartographic applications like mapping, urban and rural infrastructure development and management, as well as application in Land Information (LIS) and Geographical Information System (GIS).

4. Cartosat-2 B: CARTOSAT - 2B is the seventeenth satellite in the Indian Remote Sensing Satellite series (IRS). CARTOSAT-2B carries a Panchromatic camera (PAN) similar to those of its predecessors - CARTOSAT-2 and 2A.

5. Cartosat-2C: it is an Earth observation satellite that is placed in a sun-synchronous orbit. It is a fifth flight unit of the Cartosat series of satellites. It was built at the space application center Ahmedabad. It was launched on 22 June 2016.

6. Cartosat-3: it is a third-generation satellite that is highly advanced and has a high-resolution mapping capability. Under this mission launch, 13 Commercial satellites from the USA were also successfully injected into orbit, under commercial arrangement with NewSpace India Limited (NSIL), the commercial arm of ISRO).

Fig 4.8: Cartosat-3

(Image source: ISRO.GOV.IN)

RISAT-2B:

- RISAT-2B is a radar imaging earth observation satellite weighing about 615 kg.
- The satellite is intended to provide services in the field of Agriculture, Forestry and Disaster Management.

Fig 4.9: RISAT-2B

(Image source: ISRO)

In India radar imaging are used for crop estimation because our main crop growing season of kharif is in May-September when it rains and gets cloudy. We have used this data extensively for forestry, soil, land use, geology and during floods and cyclone. Due to an all-weather seeing feature, the satellite becomes special for security forces and disaster relief agencies.

RISAT 2BR1:

India's Polar Satellite Launch Vehicle, in its fiftieth flight (PSLV-C48), successfully launched RISAT-2BR1, an earth observation satellite, along with nine commercial satellites of Israel, Italy, Japan and USA from Satish Dhawan Space Centre (SDSC) SHAR, Sriharikota.

PSLV-C48 was the 75th launch vehicle mission from SDSC SHAR, Sriharikota. This is the 2nd flight of PSLV in 'QL' configuration (with 4 solid strap-on motors).

RISAT-2BR1 is a radar imaging earth observation satellite weighing about 628 kg. The satellite will provide services in the field of Agriculture, Forestry and Disaster Management. The mission life of RISAT-2BR1 is 5 years. 9 Commercial satellites were also successfully injected into designated orbit.

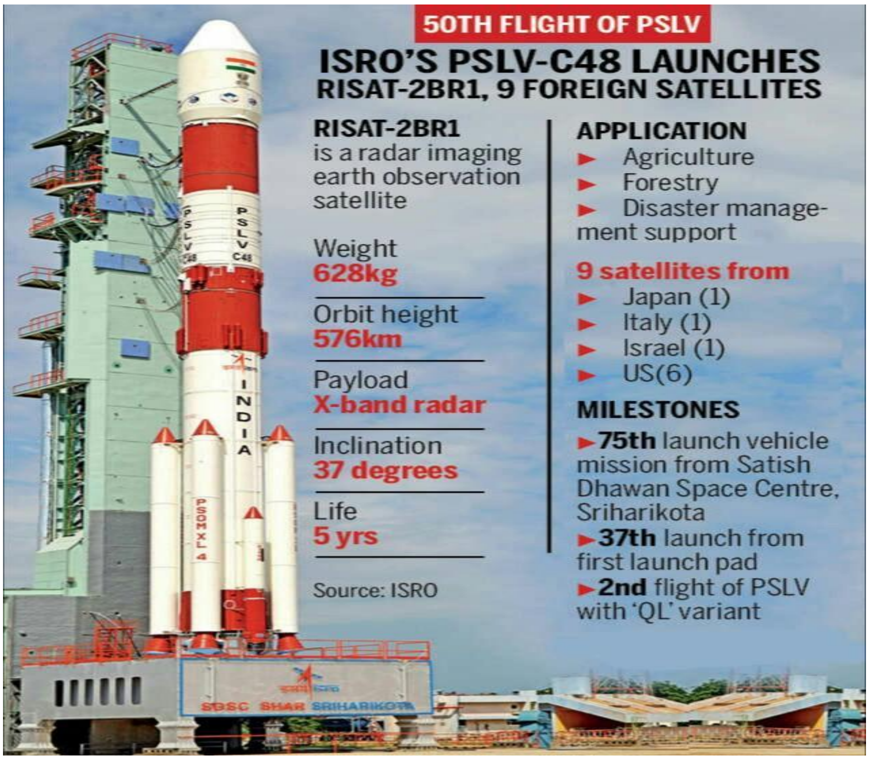


Fig 4.10 RISAT 2BR1

(Image source: Times of India)

4.8 CHANDRAYAAN-1 MISSION

India's maiden lunar probe Chandrayaan-1 (meaning moon craft) was launched by ISRO using a Polar Satellite Launch Vehicle (PSLV).

The probe weighed 1304 kg at launch and 590 kg at lunar orbit. The mission entered into lunar orbit on 8 November 2008. It was orbiting the moon at a distance of 100 km from the lunar surface.

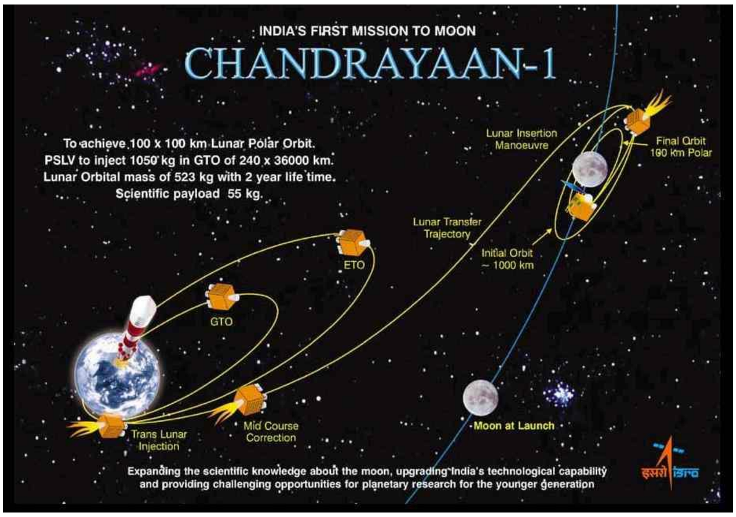


Fig 4.11: Chandrayaan-1

(Image source: Geospatial world)

Objectives of the Mission:

The purpose of the mission was chemical, mineralogical and photo-geologic mapping of the moon	Conducting scientific experiments using instruments on the spacecraft which would yield data for preparing a 3-D atlas of both the near and far sides of the moon; for chemical and mineralogical mapping of the lunar surface at high spatial resolution with particular focus on magnesium, aluminium, silicon, iron, calcium, titanium, uranium, radon and thorium; for increasing scientific knowledge; and for testing the impact of a sub-satellite on the moon's surface for future soft-landing missions.
Designing, developing, launching and orbiting a spacecraft around the moon using an Indian-made launch vehicle	Detecting water-ice on the moon

Achievements:

- Chandrayaan-1 carried 11 scientific instruments built in India, the USA, Germany, UK, Sweden and Bulgaria. Five of these instruments were built in India.
- The mission made more than 3400 orbits around the moon.
- The mission sent back to earth 70000 images of the lunar surface. Some of the images had a good resolution of 5 m while many other moon missions provided only a 100 m resolution.
- The mission sent its first image of the entire earth on 25 March 2009. These images were captured by the Terrain Mapping Camera (TMC) which was one of the scientific payloads of the mission.
- The mission also carried a Moon Impact Probe (MIP) whose purpose was to crash land on the lunar surface and send information that would help in preparing a rover to land on the surface in a future mission.
- The MIP was successfully deployed and data received from it confirmed the presence of water on the moon's surface.
- Chandrayaan has confirmed the magma ocean hypothesis which implies that the moon was completely molten once.
- The TMC also captured images of the landing site of the U.S. spacecraft Apollo 15.
- The mission also detected titanium, confirmed the presence of calcium and also acquired the most accurate measurements of iron, aluminum and magnesium on the moon.
- Scientists from ISRO and other participating agencies have termed the mission success with 90% of the stated objectives being seen through.

The estimated project cost was Rs.386 Crore or US$60 million. Although the mission was intended to last for two years, it ended on 28 August 2009 when communications to the probe were lost suddenly. The probe lasted for 312 days or 10 months and 6 days.

4.9 CHANDRAYAAN-2 MISSION

Chandrayaan – 2 is the second lunar mission of India after the success of Chandrayaan 1. This mission was conducted for topographical research and mineralogical studies to have a better understanding of the Moon's origin and evolution. Chandrayaan 2 Mission was launched from the Satish Dhawan Space on July 22, 2019, by GSLV Mk III. The main aim of Chandrayaan 2 was to trace the location and abundance of lunar water on the moon's surface.

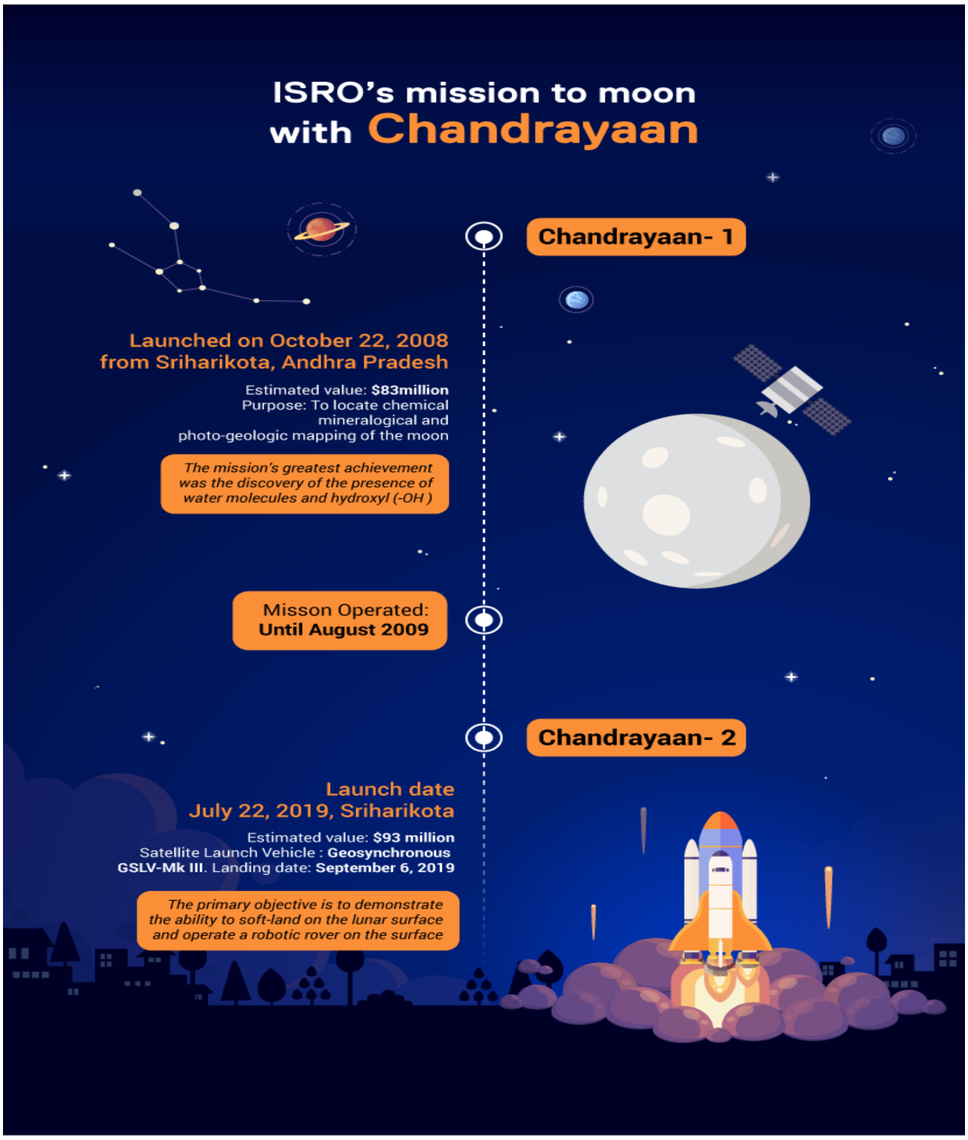


Fig 4.12 India's Lunar Missions

(Image source: Byjus)

Objectives of Chandrayaan-2:

- Chandrayaan 2 fostered the findings of Chandrayaan 1 as reported by the ISRO.
- The mission will target the "South Polar region" of the Moon which is completely unexplored.
- The mission focused on the extensive mapping of the lunar surface for studying variations in its composition and tracing the Moon's origin and evolution.
- Chandrayaan 2 was considered as a challenging mission as the South Polar Region of the Moon was totally unexplored by any space agency before.

<u>Components of Chandrayaan-2:</u>

Note:- All the parts/components were indigenously developed in India.

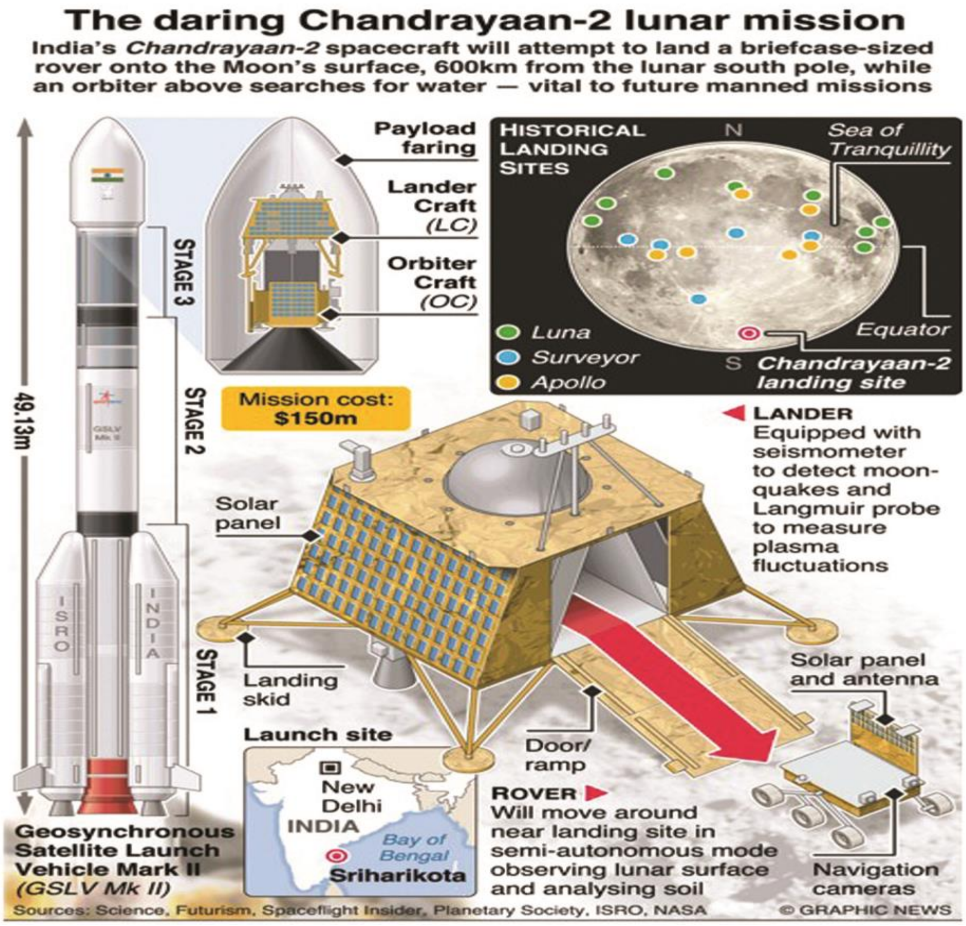


Fig 4.13: Chandrayaan-2 mission features

(image source:THE HINDU)

The orbiter, lander and rover collectively carried 14 scientific payloads, including a Laser Retro Reflector Array from NASA that provided precise measurements of the distance between the Moon and the Earth. Chandrayaan-2's orbiter shall continue its mission for around a year.

Significance of The Mission:

- In all the space missions, no country has ever attempted to land a spacecraft in the polar regions of the moon. This gave India a lead in space exploration on an international level.
- Due to the moon's axis, few regions on the South Pole always remain dark, especially the craters and have higher chances of containing water.
- The craters might have never received sunlight because it at very low angles in the Polar Regions and thus, increasing the chances of presence of ice on such surfaces.

- The lunar surface area at the south pole of the Moon that remains in shadow is much larger than the North Pole thus making the moon's South Pole interesting. This also increases the probability of the existence of water in permanently shadowed areas around it.

4.10 MARS ORBITER MISSION (MANGALYAAN)

Mars Orbiter Mission (MOM) or Mission Mangalyaan is the first interplanetary space mission of Indian Space Research Organisation (ISRO). It was successfully launched on 5th November 2013. The space probe of this mission has been orbiting Mars since 24th September 2014.

Highlights Of The Mission:

- ISRO is the 4th space agency to reach the orbit of Mars after Roscosmos, NASA, European Space Agency (ESA).
- India is the first nation to reach the orbit of Mars on the very first attempt.
- India is the first Asian country to reach the orbit of Mars.
- Mars Orbiter Mission (MOM) was launched using Polar Satellite Launch Vehicle (PSLV XL – C25) from Satish Dhawan Space Centre, Sriharikota, Nellore District of Andhra Pradesh. It took 298 days for the Mars probe to reach the orbit of Mars. The probe is being tracked from ISRO centres located in Bangalore.

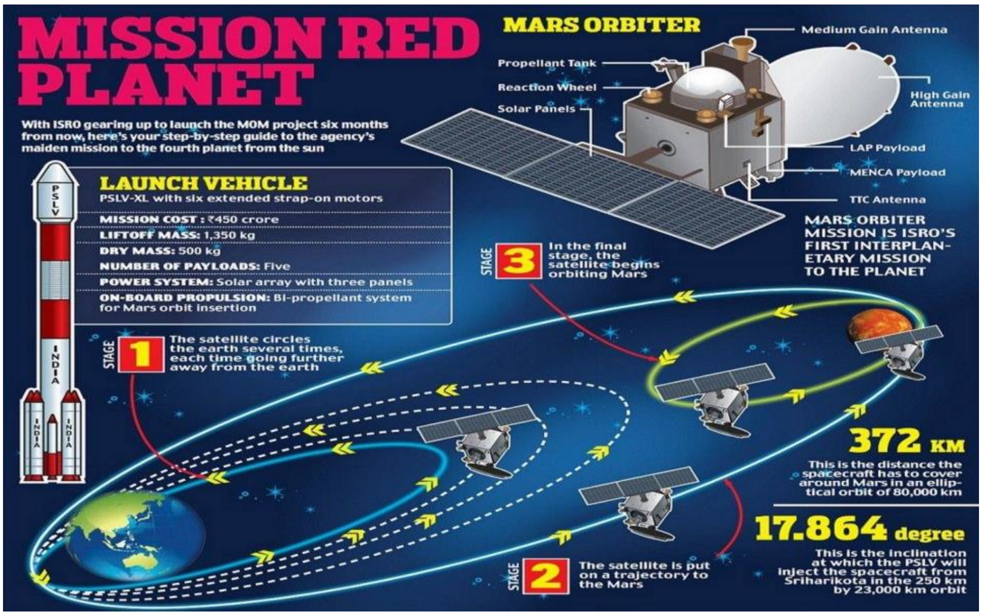
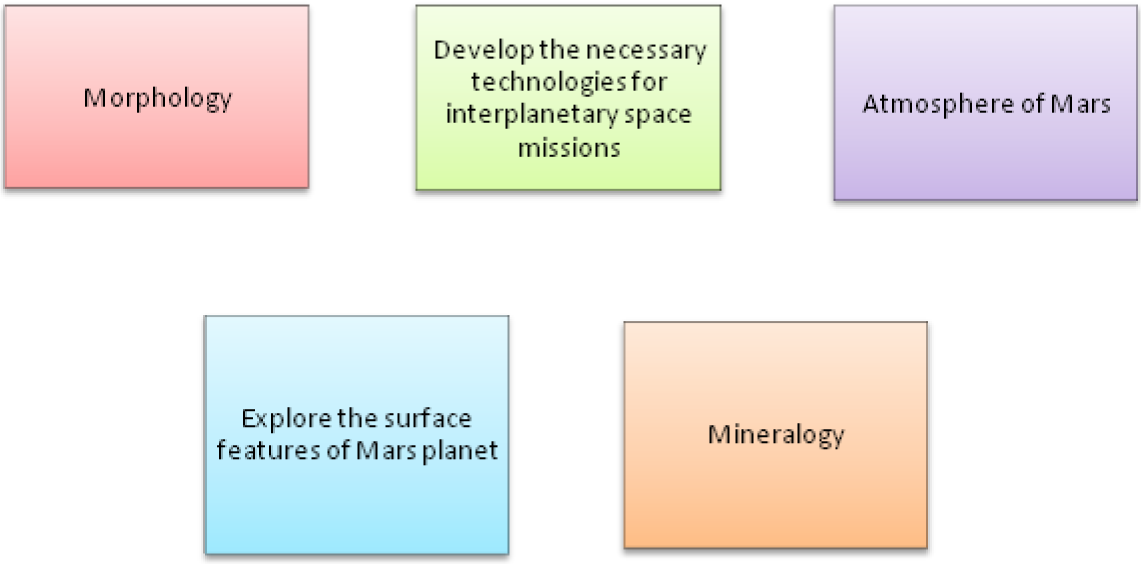


Fig 4.14: Mars Orbiter Mission

(Image source: Americaspace.com)

Objectives of The Mission:



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Payloads On The Mangalyaan:

The payload in the Mars Orbiter Mission (MOM) was made of 5 scientific instruments:-

- LAP (Lyman-alpha Photometer)
- MSM (Methane Sensor for Mars)
- MENCA (Mars Exospheric Neutral Composition Analyser)
- TIS (Thermal Infrared Imaging Spectrometer)
- MCC (Mars Colour Camera)

4.11GPS-AIDED GEO-AUGMENTED NAVIGATION (GAGAN)

The GPS-aided GEO augmented navigation (GAGAN) is an implementation of a regional satellite-based augmentation system (SBAS) by the Government of India. The (Airports Authority of India). AAI's efforts towards implementation of operational SBAS can be viewed as the first step towards the introduction of modern Communication, navigation and surveillance/Air Traffic Management system over Indian airspace.

With the help of reference stations, navigation land uplink stations, 3 Indian mission control centers, and installation of all associated software and communication links that have been set up, GAGAN will be able to help pilots to navigate in the Indian airspace by an accuracy of 3 m. hence this will facilitate landing aircraft in marginal weather and difficult approaches

INDIAN REGIONAL NAVIGATION SATELLITE SYSTEM (IRNSS) -NAVIC:-

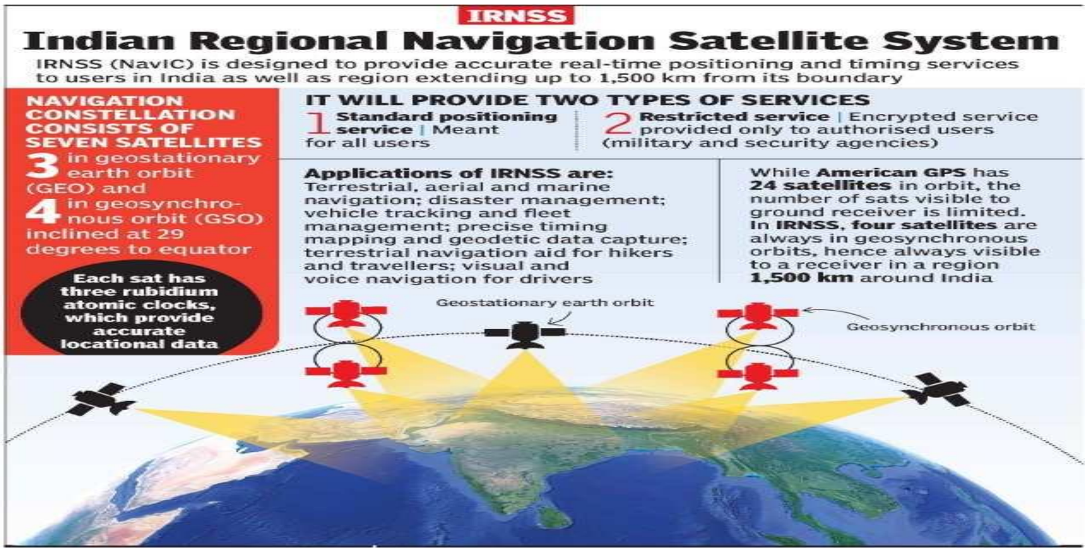
The Indian Space Research Organisation (ISRO) and its commercial wing ANTRIX developed the Indian Regional Navigation Satellite System or IRNSS with its operational name of NAVIC (Navigation with Indian Constellation). It is a Navigation Satellite System that will provide accurate real-time positioning and timing services over India and the region around the country.

Features of NAVIC:

- It consists of 7 satellites at an altitude of approximately 36000 km above sea level.
    - 3 are in Geostationary Orbit
    - 4 are in Geosynchronous Orbit
- The objective of the NavIC is to provide navigation, timing and reliable positioning services in and around India.
- Working of the NavIC is very similar to the GPS (Global Positioning System) implemented by the United States.
- The NavIC is certified by 3GPP (3rd Generation Partnership Project) which is responsible for coordinating mobile telephony standards globally.

Objectives:

- It is an independent regional navigational satellite system developed by India.
- It is being designed to give precise position data service to users located in India and also to users in the area out-spreading up to 1500 km from India's boundary.
- The two kinds of services provided by IRNSS will be:
    - Standard Positioning Service (SPS) and
    - Restricted Service (RS).
- The system can offer a position accuracy of more than 20 m within India which is the primary area of service.
- The IRNSS is being constructed by the Indian Space Research Organisation (ISRO) and is wholly under the Indian government's control. The need for such a system of navigation is that the availability of global satellite navigation systems like the GPS is not assured in hostile conditions.



<u>**Fig 4.15 Indian Regional Navigation Satellite System**</u>

(Image source: Times of India)

There are a few recent developments in the NAVIC (Navigation with Indian Constellation) according to ISRO:

- **The leading semiconductor manufacturer Qualcomm Technologies Inc. developed and tested NavIC-friendly chipsets.**
- **This will help NAVIC support upcoming Automotive, Mobile and IoT applications and platforms.**
- **The collaboration will enable superior location-based services to India's industries and technology ecosystem.**

4.12 HYPERSPECTRAL IMAGING SATELLITE (HySYS)

HysYS is an earth observation satellite built around ISRO's Mini Satellite2 (IMS-2) bus weighing about 380kg. The mission life of the satellite is five years. The primary goal of HysYS is to study the earth's surface in both the visible, near infrared and shortwave infrared regions of the electromagnetic spectrum.

Highlights:

HySYS carries two payloads:

- Visible Near Infrared (VNIR) with spectral range of 0.4 to 0.95 micrometres with 60 contiguous spectral bands
- Shortwave Infrared Range (SWIR) with spectral range of 0.85 to 2.4 micrometres with a 10 nanometre bandwidth and 256 contiguous spectral bands.
- PSLV-C43 carrying HySYS and 30 secondary payloads was launched on 29 November 2018 from the First Launch Pad of Satish Dhawan Space Centre.
- HySYS was successfully placed in a planned sun-synchronous polar orbit at around 645 km.

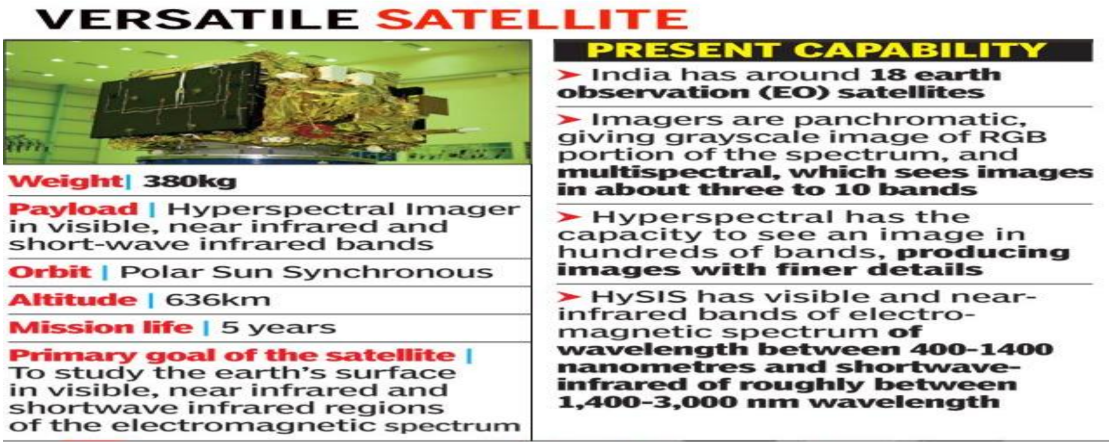


Fig 4.16 HySYS

(Image source: Times of India)

4.13 GSAT SERIES SATELLITES

GSAT -6

- GSAT-6 is the twenty fifth geostationary communication satellite of India built by ISRO and twelfth in the GSAT series
- Five of GSAT-6's predecessors were launched by GSLV during 2001, 2003, 2004, 2007 and 2014 respectively
- After its commissioning, GSAT-6 has joined the group of India's other operational geostationary satellites
- GSAT-6 Satellite provides communication through five spot beams in S-band and a national beam in C-band for strategic users
- It was launched using GSLV-D6 (Explained below in GSLV Missions)

GSAT-6A

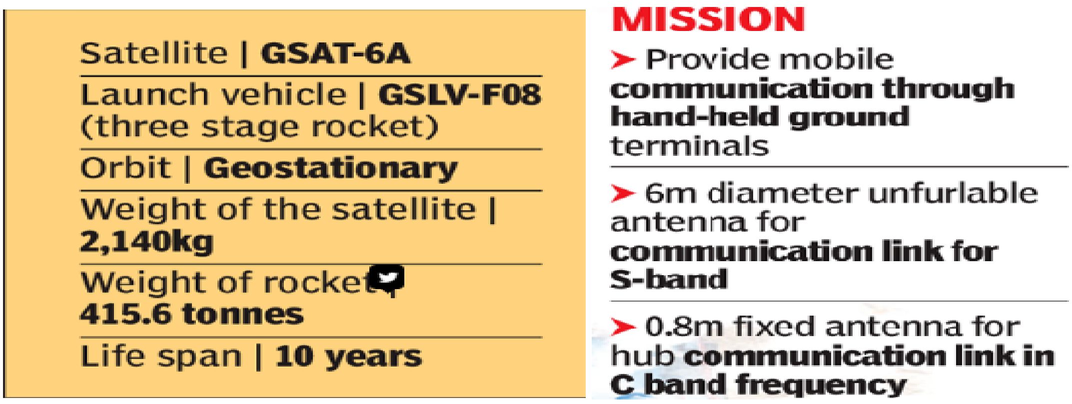


Fig 4.17: GSAT-6A

Iimage source: The Hindu)

GSAT -15

GSAT-15, India's latest Communication Satellite is a high power satellite being inducted into the INSAT/GSAT system. Weighing 3164 kg at lift-off, GSAT-15 carried a total of 24 communication transponders in Ku-band, as well as a GPS Aided GEO, Augmented Navigation (GAGAN) payload operating in L1 and L5 bands. GSAT-15 is the third satellite to carry GAGAN payload after GAST-8 and GSAT-10, which are already providing navigation services from orbit. GSAT-15, carried a Ku-band beacon as well to help in accurately pointing ground antennas towards the satellite. GSAT-15 was launched by Ariane-5 VA-227 launch vehicle from Kourou, French Guiana on the early morning of November 11, 2015

GSAT-16:

- GSAT-16, an advanced communication satellite, weighing 3181.6 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 carried a Ku-band beacon as well to help accurately pointing ground antennas towards the satellite.
- The designed on-orbit operational life of GSAT-16 is 12 years.
- The communication transponders on-board GSAT-16 together ensure continuity of various services currently provided by the INSAT-GSAT system and serve as on-orbit spares to meet contingency requirements or for the augmentation of such services.
- GSAT-16 is 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 maneuvers using the satellite's on-board Liquid Apogee Motor (LAM), finally placing it in the vicinity of circular Geostationary Orbit.
- After this, the deployment of appendages such as the solar panels, antennas and three-axis stabilization of the satellite was performed.
- GSAT-16 is positioned at 55 deg East longitude in the Geostationary orbit and co-located with GSAT-8, IRNSS-1A and IRNSS-1B satellites.

GSAT 7A:

GSLV-F11 successfully launched GSAT-7A, ISRO's 39th communication satellite, on December 19, 2018, at 1610 hrs (IST) from the Second Launch Pad (SLP) of Satish Dhawan Space Centre SHAR, Sriharikota.

GSLV-F11 is the 13th flight of India's Geosynchronous Satellite Launch Vehicle (GSLV) and its 7th flight with the indigenous Cryogenic Upper Stage (CUS).

GSLV – F11 is ISRO's fourth generation launch vehicle with three stages. The four liquid strap-ons and a solid rocket motor at the core form the first stage. The second stage of the vehicle is equipped with a high thrust engine using liquid fuel. The Cryogenic Upper Stage forms the third and final stage of the vehicle.GSAT-7A.

GSAT-7A with a lift-off mass of 2250 kg, is a geostationary satellite carrying communication transponders in Ku-band. The Satellite is built to provide communication capability to the users over the Indian region.

4.14 GSAT-9 /SOUTH ASIA SATELLITE

The South Asia Satellite (designated GSAT-9), formerly known as SAARC Satellite, is geostationary communication and meteorology satellite operated by the Indian Space Research Organisation for the South Asian Association for Regional Cooperation (SAARC) region.

The satellite was launched on 5 May 2017. During the 18th SAARC summit held in Nepal in 2014, Indian Prime Minister Narendra Modi mooted the idea of a satellite serving the needs of SAARC member nations as a part of his neighborhood first policy. Afghanistan, Bangladesh, Bhutan, Maldives, Nepal and Sri Lanka are the users of the multi-dimensional facilities provided by the satellite.

GSAT-31:

India's telecommunication satellite, GSAT-31 was successfully launched on February 06, 2019, from Kourou launch base, French Guiana by Ariane-5 VA-247.

GSAT-31 is configured on ISRO's enhanced I-2K Bus, utilizing the maximum bus capabilities of this type. This satellite will augment the Ku-band transponder capacity in Geostationary Orbit.

Weighing about 2536 kg, GSAT-31 will provide continuity to operational services on some of the in-orbit satellites. The satellite derives its heritage from ISRO's earlier INSAT/GSAT satellite series. The satellite provides Indian mainland and island coverage.

The designed in-orbit operational life of GSAT-31 is about 15 years.

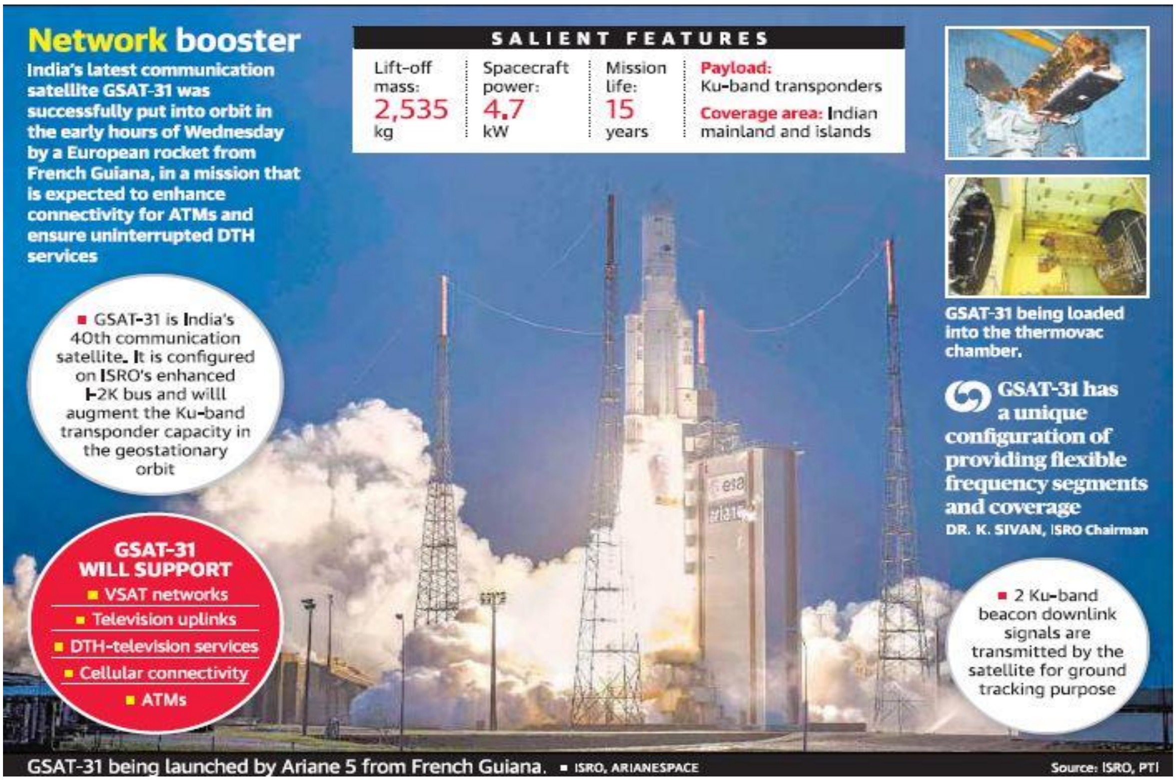


Fig 4.18 GSAT -31

(Image source: ISRO.GOV.IN)

GSAT -30:

- India's latest communication satellite GSAT-30 was successfully launched from the Spaceport in French Guiana during the early hours today.
- The launch vehicle Ariane 5 VA-251 lifted off from Kourou Launch Base. After a flight lasting 38 minutes 25 seconds, GSAT-30 separated from the Ariane 5 upper stage in an elliptical Geosynchronous Transfer Orbit.
- With a lift-off mass of 3357 kg, GSAT-30 will provide continuity to operational services on some of the in-orbit satellites.
- GSAT-30 derives its heritage from ISRO's earlier INSAT/GSAT satellite series and replaces INSAT-4A in orbit.
- GSAT-30 has a unique configuration of providing flexible frequency segments and flexible coverage.
- The satellite will provide communication services to Indian mainland and islands through Ku-band and wide coverage covering Gulf countries, a large number of Asian countries and Australia through C-band.

Fig 4.19 GSAT -30

(Image source:rediff.com)

ASTROSAT MISSION

- Astrosat satellite is a dedicated mission of ISRO on Astronomy.

- It is a mission to observe the celestial sources simultaneously in X-Ray, Optical and UV Spectral bands simultaneously.
- Astrosat satellite was launched from Sriharikota, Andhra Pradesh. The launch centre is named as Satish Dhawan Space Centre (SDSC) or Sriharikota Range (SHAR). The satellite was launched on September 28, 2015, using the launch vehicle Polar Satellite Launch Vehicle (PSLV) C-30.
- The satellite was placed into an orbit of 650 Km. The mission was planned for a period of 5 years.

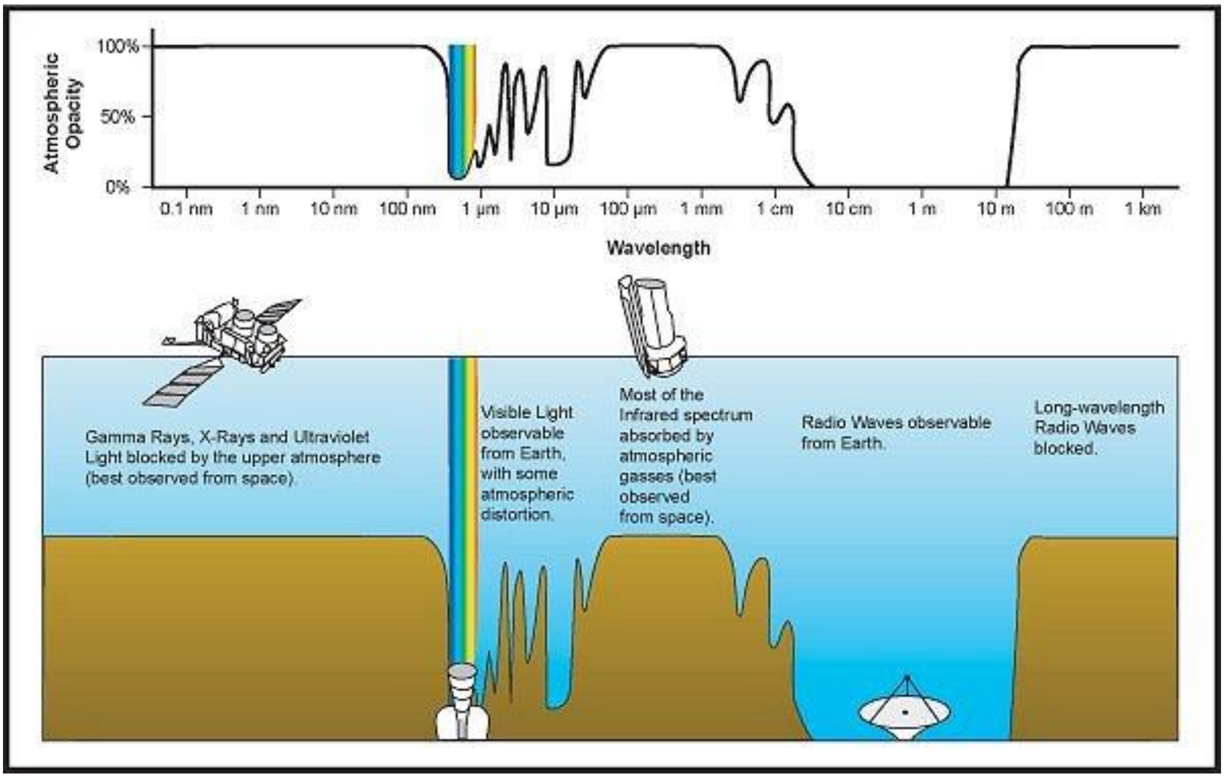


Fig. 4.20 Wavelength

(*Image source: the wire)*

GROUND FACILITIES OF ISRO

Launch Facility:

Satish Dhawan Space Centre (SDSC) or Sriharikota Range (SHAR) is a rocket launch center operated by the Indian Space Research Organisation (ISRO). It is located in Sriharikota in Andhra Pradesh. Sriharikota Range was renamed in 2002 after ISRO's former chairman Satish Dhawan.

The SLV launchpad:

It was used by the Satellite Launch Vehicle and Augmented Satellite Launch Vehicle is located at the southern tip of the current launch site.

First Launch Pad:

The modern First Launch Pad was built in the early 1990s for the Polar Satellite Launch Vehicle. It has also been used by the Geosynchronous Satellite Launch Vehicle. The First Launch Pad is undergoing major expansion with PIF (PSLV Integration Facilities) project worth 475 crores. Once complete, the First Launch Pad is expected to cater to around 15 launches per year.

Second LaunchPad:

Second Launch Complex became operational in 2005 and unlike First Launch Pad operates on the philosophy of Integrate Transfer & Launch. SLP is configured as a universal launch pad capable of accommodating PSLV, GSLV and GSLV Mk III launch vehicles of ISRO.

Tracking Facilities:

ISRO Telemetry, Tracking and Command Network (ISTRAC), Bengaluru is entrusted with the major responsibility to provide tracking support for all the satellite and launch vehicle missions of ISRO. The major objectives of the centre are: carrying out mission operations of all operational remote sensing and scientific satellites, providing Telemetry, Tracking and Command (TTC) services from launch vehicle lift-off till injection of the satellite into orbit and to estimate its preliminary orbit in space and hardware and software developmental activities that enhance the capabilities of ISTRAC for providing flawless TTC and Mission Operations services. Towards these objectives, ISTRAC has established a network of ground stations at Bengaluru, Lucknow, Mauritius, Sriharikota, Port Blair, Thiruvananthapuram, Brunei, Biak (Indonesia) and the Deep Space Network Stations.

In keeping with its long-established TTC support responsibility, ISTRAC has also been mandated to provide space operations support for Deep Space Missions of ISRO, undertake the development of radar systems for launch vehicle tracking and meteorological applications, establish and operationalize the ground segment for Indian Regional Navigational Satellite System, provide Search & Rescue and Disaster Management Services and support space-based services like telemedicine, Village Resource Centre (VRC) and tele-education.

Data Reception and Dissemination:

National Remote Sensing Centre (NRSC) at Hyderabad is responsible for remote sensing satellite data acquisition and processing, data dissemination, aerial remote sensing and decision support for disaster management. NRSC has a data reception station at Shadnagar near Hyderabad for acquiring data from Indian remote sensing satellites as well as others.

NRSC Ground station at Shadnagar acquires Earth Observation data from Indian remote-sensing satellites as well as from different foreign satellites. NRSC is also engaged in executing remote sensing application projects in collaboration with the users. The Aerial Services and Digital Mapping (ASDM) Area provides end-to-end Aerial Remote Sensing services and value-added solutions for various large scale applications like aerial photography and digital mapping, infrastructure planning, scanner surveys, aeromagnetic surveys, large scale base map, topographic and cadastral level mapping, etc.

Regional Remote Sensing Centres (RRSCs) support various remote sensing tasks specific to their regions as well as at the national level.

4.15 NATIONAL NATURAL RESOURCES MANAGEMENT SYSTEM (NNRMS)

National Natural Resources Management System is an integrated natural resource management system of India which aggregates the data about natural resources from the remote sensing satellites and other conventional techniques. NNRMS activities are coordinated at the National level by the Planning Committee of NNRMS (PC-NNRMS) which frames guidelines for implementation of the systems and oversees the progress of remote sensing applications for natural resources management in the country.

ISRO CENTRES

Vikram Sarabhai Space Centre (VSSC):

Vikram Sarabhai Space Centre (VSSC) at Thiruvananthapuram is the major centre of ISRO, where the design and development activities of satellite launch vehicles and sounding rockets are carried out and made ready for launch operations. The centre pursues research and development activities for associated technologies such as launch vehicle design, propellants, solid propulsion technology, aerodynamics, aero structural and aerothermal aspects, avionics, polymers and composites, guidance, control, and simulation, computer and information, mechanical engineering, aerospace mechanisms, vehicle integration and testing, space ordnance, chemicals and materials.

The Space Physics Laboratory at VSSC carries out research and studies in atmospheric science and other related space science activities. Ammonium Perchlorate Experimental Plant (APEP) at Aluva in Kerala is a part of VSSC.

The major programmes at VSSC include launch vehicle projects of Polar Satellite Launch Vehicles (PSLV), Geosynchronous Satellite Launch Vehicles (GSLV Mark II and Mark III), Rohini Sounding Rockets, Space-capsule Recovery Experiments, Reusable Launch Vehicles and Air Breathing Propulsion for Advanced Reusable Launch Vehicles.

UR Rao Satellite Centre:

U R Rao Satellite Centre (URSC), Bengaluru, formerly known as ISRO Satellite Centre (ISAC) is the lead centre for building satellites and developing associated satellite technologies. These spacecraft are used for providing applications to various users in the area of Communication, Navigation, Meteorology, Remote Sensing, Space Science and interplanetary explorations. The Centre is also pursuing advanced technologies for future missions. URSC is housed with state-of-the-art facilities for building satellites on an end-to-end basis.

URSC has a unit called Laboratory for Electro-Optics System (LEOS), which is situated in Peenya, Bengaluru and is mainly responsible for research, development and productionisation of Sensors for ISRO programmes. Since inception, URSC has the distinction of building more than 100 satellites for various applications like scientific, communication, Navigation and remote sensing.

Satish Dhawan Space Centre:

Satish Dhawan Space Centre (SDSC) SHAR, Sriharikota, the Spaceport of India, is responsible for providing Launch Base Infrastructure for the Indian Space Programme. This Centre has the facilities for solid propellant processing, static testing of solid motors, launch vehicle integration and launch operations, range operations comprising telemetry, tracking and command network and mission control centre.

The Centre has two launch pads from where the rocket launching operations of PSLV and GSLV are carried out. The centre also provides the necessary launch base infrastructure for sounding rockets of ISRO and assembly, integration and launch of sounding rockets and payloads.

Liquid Propulsion Systems Centre (LPSC):

Liquid Propulsion Systems Centre (LPSC) is the centre for design, development and realization of liquid propulsion stages for ISRO's Launch Vehicles. Development of fluid control valves, transducers, propellant management devices for vacuum conditions and other key components of liquid propulsion systems are also under the purview of this centre. LPSC activities and facilities are spread across its two campuses namely, LPSC, Valiamala, Thiruvananthapuram and LPSC, Bengaluru, Karnataka.

Master Control Facility:

Master Control Facility (MCF) at Hassan in Karnataka and Bhopal in Madhya Pradesh monitors and controls all the Geostationary / Geosynchronous satellites of ISRO, namely, INSAT, GSAT, Kalpana and IRNSS series of satellites. MCF is responsible for the Orbit Raising of satellites, In-orbit payload testing, and On-orbit operations all through the life of these satellites. MCF activities include round-the-clock Tracking, Telemetry & Commanding (TT&C) operations, and special operations like Eclipse management, Station-keeping maneuvers and recovery actions in case of contingencies. MCF interacts with User Agencies for effective utilisation of the satellite payloads and to minimize the service disturbances during special operations.

ISRO Propulsion Centre:

ISRO Propulsion Complex (IPRC), Mahendragiri is equipped with the state-of-the-art facilities necessary for realising the cutting edge propulsion technology products for the Indian space programme. Formerly, IPRC was known as LPSC, Mahendragiri and taking cognizance of the future growth of the space program of our nation and the concomitant expansion at Mahendragiri, it was elevated as IPRC with effect from February 01, 2014.

The activities carried out at IPRC, Mahendragiri are: assembly, integration and testing of earth storable propellant engines, cryogenic engines and stages for launch vehicles; high altitude testing of upper-stage engines and spacecraft thrusters as well as testing of its subsystems; production and supply of cryogenic propellants for Indian cryogenic rocket programme, etc. A Semi-cryogenic Cold Flow Test facility (SCFT) has been established at IPRC, Mahendragiri for the development, qualification and acceptance testing of semi cryogenic engine subsystems.

IPRC is responsible for the supply of Storable Liquid Propellants for ISRO's launch vehicles and satellite programmes.

ISRO Inertial System Unit(IISU):

ISRO Inertial Systems Unit (IISU), Thiruvananthapuram is responsible for the design and development of Inertial Systems for Launch Vehicles and Spacecraft programmes of ISRO. Major systems like Inertial Navigation Systems based on mechanical gyros and optical gyros, Attitude Reference Systems, Rate Gyro Packages and Accelerometer Packages are developed indigenously and used in various missions of ISRO. IISU also designs and develops Actuators and Mechanisms for spacecraft and allied applications. IISU is engaged in continuous research and Development too.

Indian Institute of Remote Sensing (IIRS):

Indian Institute of Remote Sensing (IIRS) at Dehradun is a premier institute with the objective of capacity building in Remote Sensing and Geo-informatics and their applications through education and training programmes at the postgraduate level. The Institute also hosts and provides support to the Centre for Space Science and Technology Education in Asia and the Pacific (CSSTE-AP), affiliated to the United Nations.

ANTRIX Corporation Limited:

Antrix Corporation Limited (ACL), Bengaluru is a wholly-owned Government of India Company under the administrative control of the Department of Space. Antrix Corporation Limited was incorporated as a private limited company owned by the Government of India in September 1992 as a Marketing arm of ISRO for promotion and commercial exploitation of space products, technical consultancy services and transfer of technologies developed by ISRO. Another major objective is to facilitate the development of space-related industrial capabilities in India.

As the commercial and marketing arm of ISRO, Antrix is engaged in providing Space products and services to international customers worldwide. With fully equipped state-of-the-art facilities, Antrix provides an end-to-end solution for many of the space products, ranging from supply of hardware and software including simple subsystems to a complex spacecraft, for varied applications covering communications, earth observation and scientific missions; space-related services including remote sensing data service, Transponder lease service; Launch services through the operational launch vehicles (PSLV and GSLV); Mission support services; and a host of consultancy and training services.

New Space India Limited (NSIL):

New Space India Limited (NSIL), incorporated on 6 March 2019 (under the Companies Act, 2013) is a wholly-owned Government of India company, under the administrative control of the Department of Space (DOS).NSIL is the commercial arm of the Indian Space Research Organisation (ISRO) with the primary responsibility of enabling Indian industries to take up high technology space-related activities and is also responsible for the promotion and commercial exploitation of the products and services emanating from the Indian space programme. To satisfy the needs of its customers, NAIL draws upon the proven heritage of the Indian Space Program and ISRO's vast experience in diverse branches of Space Technology.

The major business areas of NAIL include:

- Production of Polar Satellite Launch Vehicle (PSLV) and Small Satellite Launch Vehicle (SSLV) through industry;
- Production and marketing of space-based services, including launch services and space-based applications like transponder leasing, remote sensing and mission support services;
- The building of Satellites (both Communication and Earth Observation) as per user requirements.
- Transfer of technology developed by ISRO centres/ units and constituent institutions of Dept. of Space;
- Marketing spin-off technologies and products/ services emanating out of ISRO activities
- Consultancy services.

Northeast Space Application centre:

North Eastern-Space Applications Centre (NE-SAC), located at Shillong, is a joint initiative of DOS and North Eastern Council (NEC) to provide developmental support to the North Eastern Region (NER) using space science and technology. The centre has the mandate to develop high technology infrastructure support to play the catalytic role in the holistic development of NER of India by providing space science and technology support.

The centre also coordinates with the State Remote Sensing Application Centres of NER and acts as a nodal centre for implementation of major national and regional programmes on natural resource management, infrastructure planning, healthcare, education, emergency communication, early warnings for disaster management support and atmospheric science research.

4.16 MISCELLANEOUS

PLANNED MISSIONS OF ISRO

GAGANYAAN:

- In 2018, India's first manned space mission was announced by Prime Minister Narendra Modi in his Independence Day speech.
- Gaganyaan will be the Indian crewed orbital spacecraft intended to be the basis of the Indian Human Space Flight Program.
- With Gaganyaan, India will become only the 4th country after Russia, the USA and China to send humans to space.
- It will be ISRO's next big project after the anticipated soft landing of Chandrayaan 2 on the lunar
- The target is to launch it before the 75-year celebration of India's independence.
- Before the manned mission scheduled for December 2021, two unmanned tests will be carried out in December 2020 and July 2021.
- ISRO's indigenous mission will be assisted by a few other countries in selecting and training astronauts.
- According to ISRO, a budget of Rs 10,000 Cr. has been set aside for putting the infrastructure in place.
- It is described as a national mission rather than an ISRO mission.

Spacecraft:

- The spacecraft will take 3 Indian astronauts, who will be known as 'vyomanauts' (in Sanskrit 'vyom' means space.
- It will circle the earth for 7 days from a distance of 300-400 km.
- It will be launched by India's biggest rocket GSLV Mk 3 from Sriharikota.
- The 7-ton spacecraft will orbit the earth at an altitude of 400km for up to 7 days.
- ISRO has developed most of the critical technology needed for the mission.
- Its service module will be powered by two liquid-propellant engines.
- It will have life support and environmental control systems.
- It will be smaller than the current Russian and Chinese ones or NASA's Apollo or the planned Orion
- But it will be slightly larger than the U.S Gemini
- ISRO Telemetry Tracking and Command Centre in Peenya will monitor it round the clock.

Crew Module:

- The crew module is a twin-walled sealed structure that recreates earth-like conditions.
- It will be equipped with an Emergency Mission Abort and Emergency Escape System.

- The crew escape system is an emergency system to help the crew pull away from the launch vehicle when the mission has to be aborted. It can be done at the 1st and 2nd stages of the rocket.
- Crew escape system ensures that the crew module gets warning if anything goes wrong with the rocket.
- It pulls the crew module away to a safe distance and can be landed either on sea or land with parachutes.

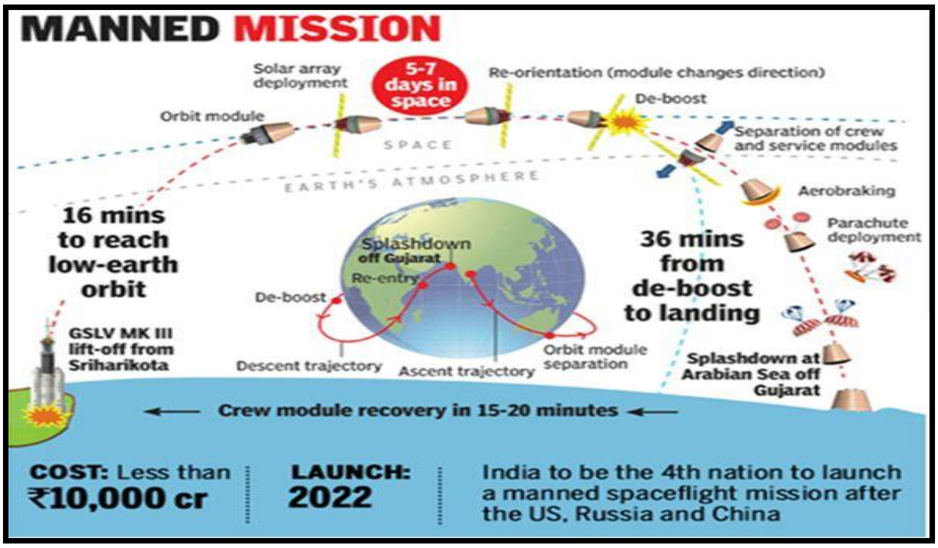


Fig 4.21 Gaganyaan

(Image source: The Times of India)

ADITYA MISSION

Aditya L-1 Mission is India's first solar mission planned by the Indian Space Research Organisation (ISRO). Earlier the name was Aditya -1, which has been renamed as Aditya L-1 Mission.

ADITYA L1 payloads

Payloads	Science/Capability
Visible Emission Line Coronagraph (VELC)	Corona/ Imaging , Spectroscopy & Spectopolarimetry (1.05 – 3.0 Solar radii)
Solar Ultraviolet Imaging Telescope (SUIT)	Photosphere and Chromosphere/ Imaging (200-400 nm)
Aditya Solar wind Particle Experiment (ASPEX)	Solar wind/ Particle Analyzer/ spectrometer (H, α, ions 0.1 keV – 5 MeV)
Plasma Analyser Package For Aditya (PAPA)	Solar wind/ In-situ measurement (Ions 0.01 – 25 keV; Ele 0.01 – 3 kev)
Solar Low Energy X-ray Spectrometer (SoLEXS)	Soft X-ray/ spectrometer (1 – 30 keV)
High Energy L1 Orbiting X-ray Spectrometer (HEL1OS)	Hard X-ray/ spectrometer (10 -150 keV)
Advanced Triaxial High Resolution Digital Magnetometers	Measure Magnetic Field/ In-situ measurement (Range: $\pm$ 256 nT; Accu 0.5 nT)

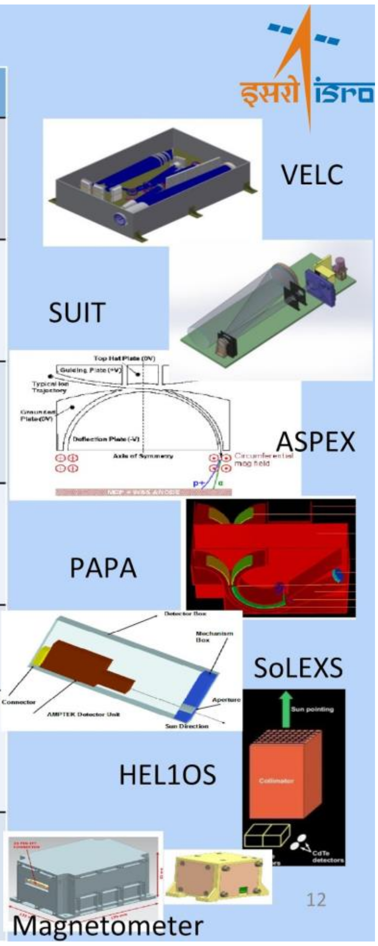


Fig 4.22 Mission Components

(Image source: ISRO)

Objectives:

- The objective of the Aditya L-1 mission is to study Sun's Corona, Chromosphere and Photosphere.
- Besides, it will study the particle flux emanating from Sun, and the variation of magnetic field strength
- The Aditya-1 mission was planned for observing only the Corona of Sun. The reason behind Corona getting heated to very high temperatures is still a mystery in Solar Physics.
- Aditya -1 mission involved placing the satellite in 800 Km low earth orbit.
- Later ISRO planned to place the satellite in the halo orbit around the Lagrangian Point (L1). L1 is 1.5 Million Km from the Earth. This point provides the advantage of observing the Sun continuously without any disturbance. Hence the mission was renamed as Aditya L-1 mission.

The satellite will be launched by the PSLV-XL launch vehicle from Sriharikota.

LUNAR POLAR EXPLORATION PROBE:

- It is a robotic lunar mission concept by Indian Space Research Organisation (ISRO) in partnership with Japan Aerospace Exploration Agency (JAXA)
- The purpose of this mission would be to send a lunar rover and land for exploring the South Pole region of the Moon by 2024.
- while ISRO would be responsible for the lander, JAXA is likely to provide the under-development H3 launch vehicle and the rover

Objectives of Mission:

- It would demonstrate new surface exploration technologies related to vehicular transport and lunar night survival for sustainable lunar exploration in polar regions
- For precision landing, it would utilize feature matching algorithm and navigational equipment derived from JAXA
- The lander's payload capacity would be nearly 500 kg including 350 kg rover.
- The rover would carry multiple instruments by JAXA and ISRO including a drill to collect sub-surface samples from 1.5 m depth.
- Water prospecting and analysis are likely to be mission objectives.
- Payload proposals from other space agencies might be sought.

NISAR (NASA-ISRO Synthetic Aperture Radar) MISSION:

NISAR mission is a joint project between NASA and ISRO to co-develop and launch a dual frequency synthetic aperture radar satellite.

It is slated to be launched in 2020-21.

Objectives:

- Measure the changes on earth’s land surface, ice surface, glaciers, earthquakes and volcanoes.
- Find the causes and consequences of such changes.
- NISAR will be the first satellite mission to use two different radar frequencies (L-band and S-band). Hence it can capture resolution even less than a centimeter of earth’s surface.
- The L-band SAR is being developed by JPL/NASA, while ISRO is developing S-band SAR.
- The data obtained from the NISAR mission is not meant for building climate resilience.

Significance:

- Understanding climate change
- Predicting natural disasters in advance.

- The L & S-band microwave data obtained from this satellite will be useful for a variety of application, which includes natural resources mapping & monitoring; estimating agricultural biomass over the full duration of crop cycle; assessing soil moisture; monitoring of floods and oil slicks; coastal erosion, coastline changes & variation of winds in coastal waters; assessment of mangroves; surface deformation studies, ice sheet collapses & dynamics, etc.

However, the data acquired from this mission will be useful in developing certain applications, which include –

- identifying crevasses in the glaciers hidden by fresh snow, where human movement takes place,
- identifying the snowpack parameters as an input in Avalanche forecasts,
- studying Glacial Lake Outburst Floods (GLOF) hazards, and
- Identifying inundated areas due to floods/ cyclones. These applications could help in taking measures to minimize the loss of human lives.

MANGALYAAN -2:

- Mangalyaan-2 or the MARS ORBITER ROVER MISSION 2 is India's second interplanetary mission planned for launch to Mars by the Indian Space Research Organisation (ISRO).
- EARLIER the mission was to only carry an orbiter but it will now also carry a lander and a rover.

SHUKRAYAAN -1:

Shukraya 1-1is a proposed orbiter to Venus by the Indian Space Research Organisation (ISRO) to study the surface and atmosphere of Venus.

Objectives:

The mission will enter the atmosphere of Venus and conduct the following researches;

- surface/subsurface studies;
- It will Study of the composition of the atmosphere, its chemistry and their dynamics, and
- It will also analyze the atmospheric interaction of Venus with solar radiation and solar wind.

4.17 SPACE TECHNOLOGY-RELATED DEVELOPMENTS

HIGGS BOSON:

Scientists at the European Organization for Nuclear Research (CERN) discovered a new Subatomic particle called HIGGS BOSON or God's Particle in the year 2012.

This discovery had opened several vistas in the arena of Space Technology research and understanding of the dark matter.

The discovery validated the Standard Model of physics, which also predicts that about 60% of the time a Higgs boson will decay to a pair of bottom quarks. In the 1960s Peter Higgs was the first person to suggest that this particle might exist. The Standard Model of particle physics is the theory that describes three of the four known fundamental forces (the electromagnetic, weak, and strong interactions, and not including the gravitational force) in the universe, as well as classifies all known elementary particles.

Scientists do not yet know how to combine gravity with the Standard Model. The Higgs particle is a boson. Bosons are thought to be particles that are responsible for all physical forces. Other known bosons are the photon, the W and Z bosons, and the gluon.

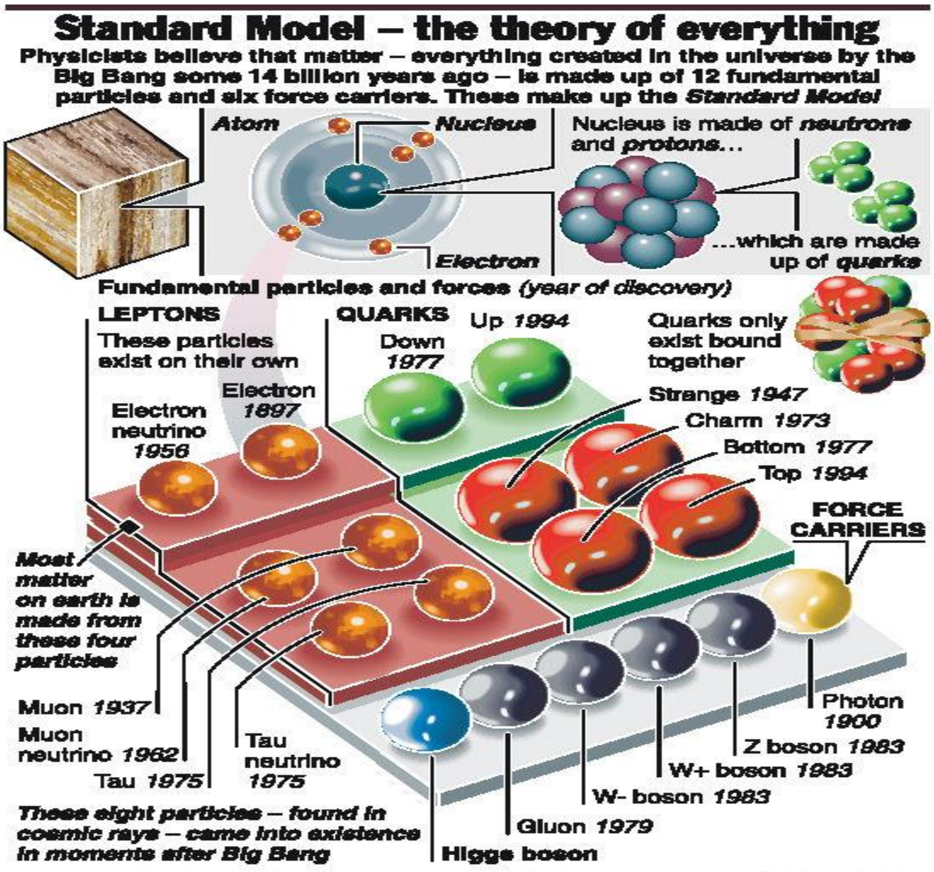


Fig 4.23 History of everything: Standard Model

(Image source: CERN)

GRAVITATIONAL WAVE OBSERVATORY IN INDIA

LIGO stands for Laser Interferometer Gravitational-Wave Observatory. It is a large-scale Physics experiment carried out to detect Gravitational waves. LIGO-India is a planned Gravitational-Wave Observatory that will be located in India as part of the worldwide network. This project will be a collaboration between Ligo-USA, India, Germany, Australia and UK LIGO project operates three gravitational wave detectors. 2 of them are located at Hanford in Washington, USA and the other at Livingston in Louisiana, USA. Currently, all three detectors are undergoing upgradation, and the plan is to shift one of the gravitational wave detectors from Hanford to India.

It is a collaboration between LIGO Laboratory and three other institutions which are given below.

- Institute of Plasma Research (IPR), Gandhinagar.
- Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune.
- Raja Ramanna Centre for Advanced Technology (RRCAT), Indore.
- The Indian Ligo Observatory project will be connected to Ligo observatories in the USA and Virgo in Italy.

India’s Laser Interferometer Gravitational-Wave Observatory (LIGO) will be set up at AundhaNagnath, Hingoli District in Maharashtra.

About Gravitational Waves:

Gravitational waves are 'ripples' in the fabric of spacetime caused by some of the most violent and energetic processes in the universe.When an object accelerates, it creates ripples in spacetime, just like a boat causes ripples in a pond.These spacetime ripples are gravitational waves. They are extremely weak, so they are very difficult to detect.Two objects orbiting each other in a planar orbit such as a planet orbiting the Sun or a binary star system or the merging of two black holes will radiate Gravitational waves.

Albert Einstein predicted the existence of gravitational waves in 1916 in his general theory of relativity.Einstein's mathematics showed that massive accelerating objects (such as neutron stars or black holes orbiting each other) would disrupt spacetime in such a way that 'waves' of distorted space would radiate from the source.Furthermore, these ripples would travel at the speed of light through the universe.G- Waves can pass through any intervening matter without being scattered significantly.While light from distant stars may be blocked out by interstellar dust, gravitational waves will pass through essentially unimpeded. This feature allows G-Waves to carry information about astronomical phenomena never before observed by humans.Colliding black holes send ripples through spacetime that can be detected on Earth. The Advanced Laser Interferometer Gravitational-Wave Observatory, or Advanced LIGO, which has detectors in Louisiana and Washington, has directly observed these gravitational waves.

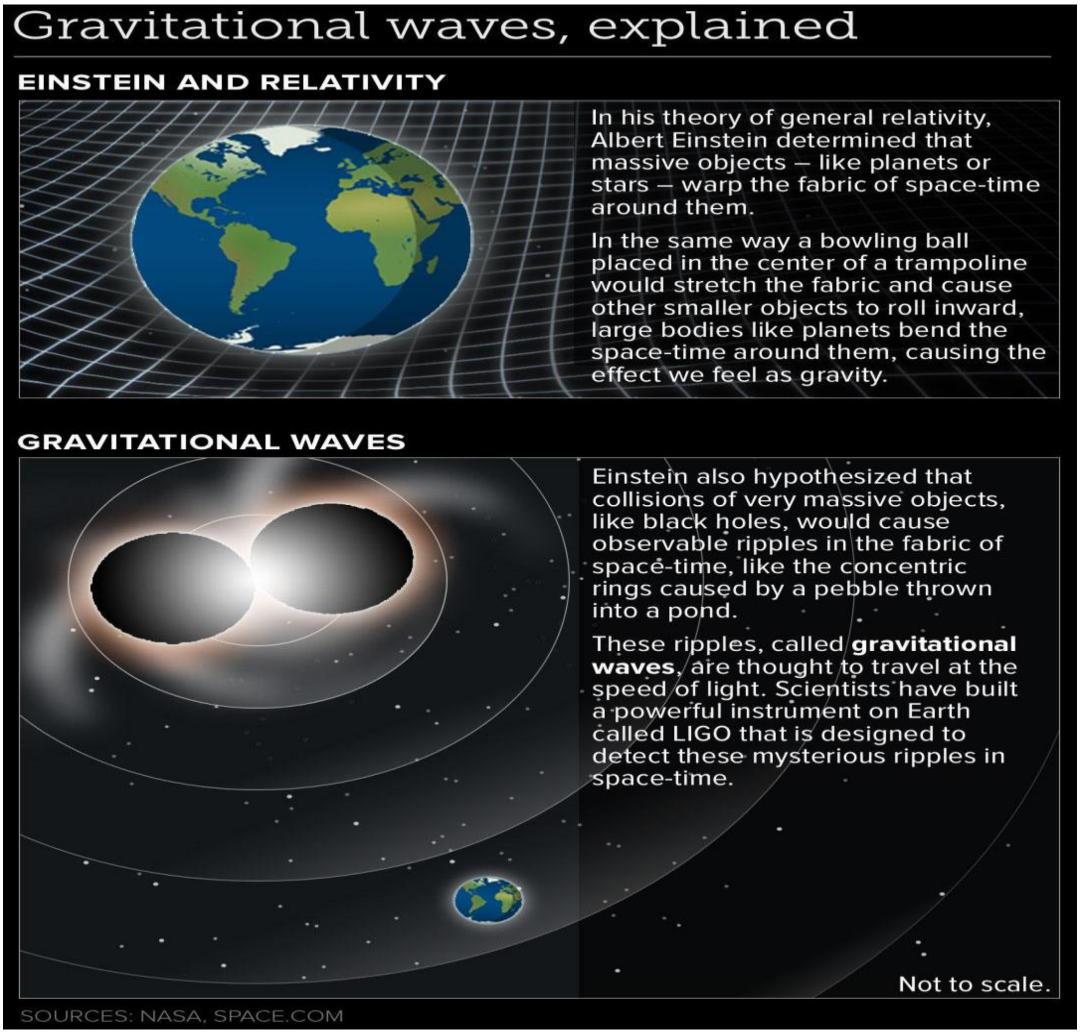


Fig 4.23 Gravitational waves

(Image source: Down to Earth)

OUTER SPACE TREATY

- The Outer Space Treaty, formally the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, is a treaty that forms the basis of international space law.
- The treaty was opened for signature in the United States, the United Kingdom, and the Soviet Union on 27 January 1967, and entered into force on 10 October 1967.
- As of June 2019, 109 countries are parties to the treaty, while another 23 have signed the treaty but have not completed ratification.
- Besides, Taiwan, which is currently recognized by 14 UN member states, ratified the treaty before the United Nations General Assembly's vote to transfer China's seat to the People's Republic of China (PRC) in 1971
- It prohibits the placing of nuclear weapons in space

- It limits the use of the Moon and all other celestial bodies to peaceful purposes only and establishes that space shall be free for exploration and use by all nations, but that no nation may claim sovereignty of outer space or any celestial body.
- The Outer Space Treaty does not ban military activities within space, military space forces, or the weaponization of space, except for the placement of weapons of mass destruction in space.
- It is mostly a non-armament treaty and offers insufficient and ambiguous regulations to newer space activities such as lunar and asteroid mining.

MOON TREATY

The Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, better known as the Moon Treaty or Moon Agreement, is a multilateral treaty that turns the jurisdiction of all celestial bodies (including the orbits around such bodies) over to the participant countries. Thus, all activities would conform to international law, including the United Nations Charter.

The countries or states who are intending to or have been engaging in self-launched human spaceflight, have not ratified the treaty (e.g. the United States, many members of the European Space Agency, Russia, China and Japan). Due to this, it has little to no relevance in international law. Till 2019, 18 states are parties to the treaty.

4.18 INDIA BASED NEUTRINO OBSERVATORY (INO) - PROJECT

Approval has been granted by the Union cabinet for setting up of a Neutrino Observatory for studying fundamental particles called the neutrinos. The location of the Observatory would be in the Bodi West Hills region of the Theni district, about 110 kilometers west of Madurai in Tamil Nadu.

- INO involves the construction of an underground laboratory.
- The project location was initially decided to be located in the Nilgiris but later, on grounds that it was too close to tiger habitat, was moved to a cavern under a rocky mountain in the Bodi West Hills.
- It involves the Inter-Institutional Centre for High Energy Physics (IICHEP) and Iron Calorimeter Detector (ICAL).
- Approval has also been granted to construct a magnetized Iron Calorimeter to study the properties of the neutrino, specifically, the mass hierarchy in various types of neutrino.
- It will be the largest in the world weighing over 50,000 tonnes.
- The Department of Science and Technology and the Department of Atomic Energy jointly support the project.

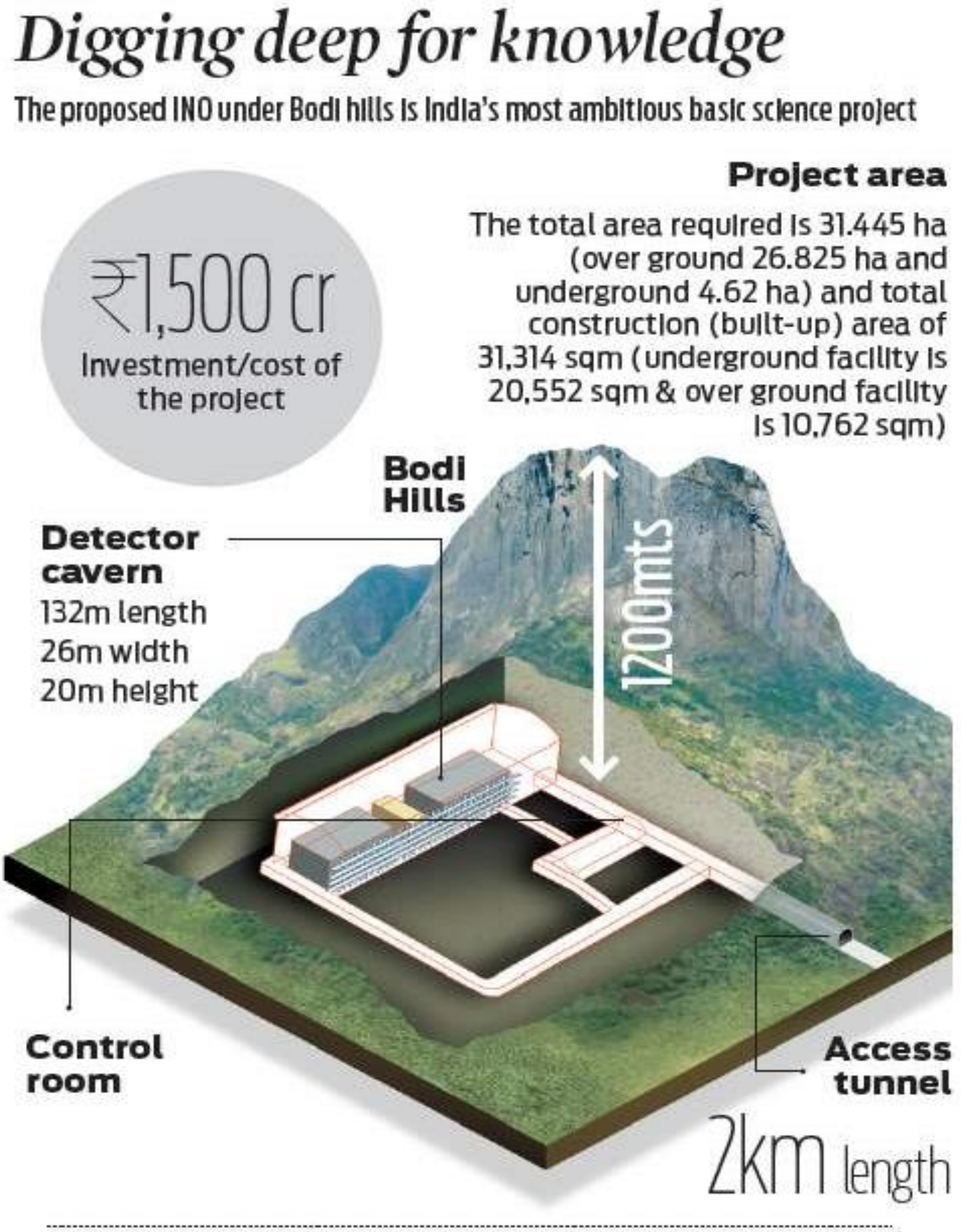


Fig 4.24 Indo Project

(Image source: INDIAN EXPRESS)

What are Neutrinos?

These are subatomic particles very similar to an electron, but they don't have any electrical charge and a very small mass, which might even be zero. Neutrinos are one of the most abundant particles in the universe, but they are very difficult to be detected because of their little interaction with matter.

Nuclear forces treat electrons and neutrinos identically; neither participate in the strong nuclear force, but both participate equally in the weak nuclear force. Particles with this property are termed leptons. In addition to the electron (and its antiparticle, the positron), the charged leptons include the muon (with a mass 200 times greater than that of the electron), the tau (with mass 3,500 times greater than that of the electron) and their anti-particles.Similar to an electron, the muon and the tau, have accompanying neutrinos, which are called the muon-neutrino and tau-neutrino. The three neutrino types appear to be different.

To detect neutrinos, very large and very sensitive detectors are required. Typically, a low-energy neutrino will travel through many light-years of normal matter before interacting with anything. Consequently, all terrestrial neutrino experiments rely on measuring the tiny fraction of neutrinos that interact in reasonably sized detectors. For example, in the Sudbury Neutrino Observatory, a 1000 ton heavy water solar-neutrino detector picks up about 10^{12} neutrinos each second. About 30 neutrinos per day are detected.

In 2015, the Nobel prize in physics was awarded to Takaaki Kajita and Arthur B. Mcdonald for discovering neutrino oscillations demonstrating that neutrinos have mass.Neutrinos are the least harmful of all elementary particles, as they almost never react with solid bodies.The mass of a neutron is 1.67×10-27 kg while the mass of a neutrino is of the order of 1×10-37kg. Hence, a neutrino is about 17 billion times lighter than a neutron. The two are incomparable.

Importance of INO:

- It will be the largest experimental facility to come up in the country. It will facilitate the development of cutting-edge technology and build sophisticated instruments.
- Neutrinos may have a role to play in nuclear non-proliferation through the remote monitoring of nuclear reactors.
- Understanding neutrinos could help in detection of oil and mineral deposits.
- They may open up a faster way to send data than the current 'around the earth' model, using towers, cables or satellites as they can pass through the Earth.
- Neutrinos will help in unraveling the deepest mystery of the universe, as they are believed to carry a lot of information.

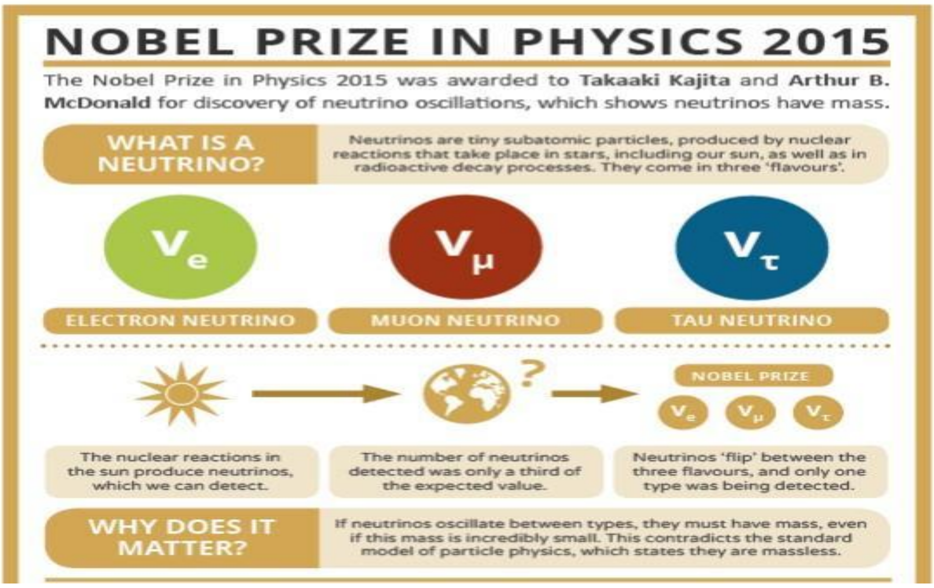


Fig 4.25 Neutrinos

(Image source: chemeurope.com)

Recent Development In Space Sector:

BOOSTING PRIVATE PARTICIPATION IN SPACE ACTIVITIES-

Under the **ATMANIRBHAR BHARAT ABHIYAAN** package and Reforms, it was announced that ;

- There shall be a level playing field provided to private companies in satellites, launches and space-based services.
- Predictable policy and regulatory environment to private players will be provided.
- Private sector will be allowed to use ISRO facilities and other relevant assets to improve their capacities.
- Future projects for planetary exploration, outer space travel etc shall also be open for the private sector.
- There will be liberal **Geo-spatial Data Policy** for providing remote-sensing data to tech-entrepreneurs.

IN-SPACE

Fig 4.26 In Space model