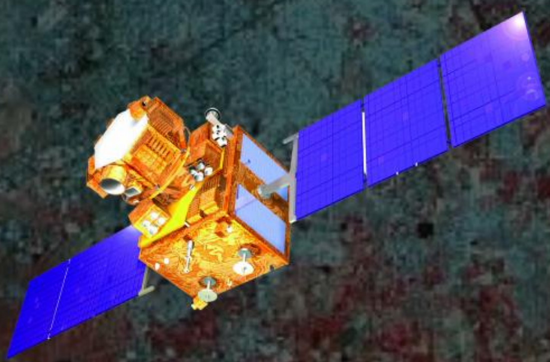
APPLICATIONS OF SATELLITES



APPLICATIONS OF SATELLITES

In the previous chapter, we learnt about Satellites, here in this chapter, let us explore the applications of satellites. Since the first satellite launch in 1957, satellites have entered into wide arenas of global applications in modern times. The early satellites were usually equipped with payloads related to Space Science, Telecommunication and Earth Observation experiments. It is here that we pause and recollect an idea proposed by Arthur C. Clarke in 1945 in his essay titled 'Extra Terrestrial Relays'. Here he proposes the idea of using satellites for worldwide radio coverage, facilitating long-range communications. It is fascinating to learn that the satellites were envisioned to serve global communication long before the first satellite was launched!

The modern-day application of satellites goes way beyond global communication. They are used to serve the purposes of navigation, earth observations and also for performing observations and experiments of outer space environments. The first satellite launched by ISRO in 1975, Aryabhata - was intended to help conduct experiments related to solar physics and cosmic X-rays. Hence, this mission can be classified under missions intended for scientific observations. In the year 1981, ISRO launched APPLE (Ariane Passenger Payload Experiment) as an experimental communication satellite whose success led to the launch of INSAT satellite series marking the birth of operational communication satellites in India.

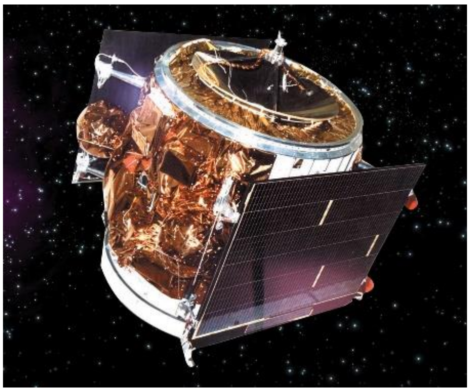


Fig. 1: Araine Passenger Payload Experiment (APPLE)

Applications of Satellites are categorized based on the types of satellites and their payload. That means what task a satellite is assigned to do. For example, if a satellite's task is to capture a picture of the Earth, applications will be based on the data that we can use from the pictures.

Let us learn about the following types of satellites, how are these satellites different in their working method and their applications one by one.

I. Communication Satellite
II. Remote Sensing Satellite
III. Navigation Satellite

Communication Satellites:

Communication Satellites are launched to orbit around the earth or any other planet to collect information and transmit it back to the planet.

On the other hand, they are launched to expand the ability of networks and connections on the planet. Thus, such a satellite can make long-distance communication and information transfer much more effortless. Considering this, we can expand the application of communication satellites and use them for different applications such as Weather forecasts, Navigation, telephone signals, television broadcasting, etc.

Working of Communication Satellite:

The communication between the satellites and the stations on earth takes place by transferring the information. The information is transmitted from the ground stations on the planet. At the same time, the satellites retransmit the data back to the earth using the download link. These satellites are designed in such a way that multiple signals can be simultaneously relayed.

A medium is required to enable communication for receiving and transmitting. In the case of the communications satellite, usually this medium is radio signals. The electromagnetic waves in the meter wave range carry the information to the satellites and back to the earth. Now let us understand how this works.

The basic function of the communication satellite is to gather the signals received from the earth through the radio antennas and retransmit them back to earth. Thus, the process of communicating with satellites will involve four significant steps.

a) A signal transmission will occur from an Uplink Earth station or other equipment transmitting the desired signal to the satellite.
b) The received signal is amplified by the satellite.
c) The signal is transmitted back to the earth as downlink.
d) The antennas or receiving equipment will receive this signal.

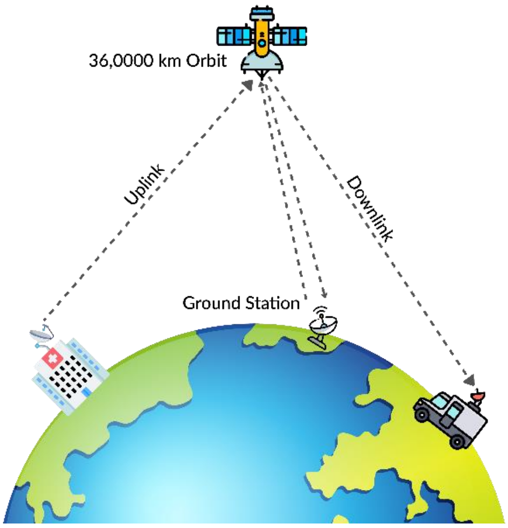


Fig. 2: Working of communication satellite

To ensure continuous communication to a particular area, the satellite shall always be in the view of the site. As the earth is rotating, it is impossible to have continuous coverage unless the satellite also rotates along with the planet in the same direction and position. This is achieved by Geostationary satellites. The height or altitude at which the satellite is positioned to accomplish that synchronous rotation is roughly 36000 km above the earth's surface.

As per the International Telecommunication Union, there are several types of communication services which are supported by satellites

1. Fixed Satellite Services
2. Broadcast Satellite Services
3. Mobile Satellite Services
4. Radio determination Satellite Services
5. Meteorological Satellite Services
6. Radio Navigation Satellite Services
7. Earth Exploration Satellite Services
8. Amateur Satellite Services
9. Inter Satellite Services

Applications and Uses of Communication Satellites

With the goal of outreach and to make remote communication more efficient and versatile, the communication satellites find multiple applications in the current times. The diversity of the applications includes DTH Broadcasting, Television, VSAT, and DSNG. The satellites are used to establish general communication and consistent military communication.

- **Telecommunication:** The communication satellites are used to efficiently provide voice and data communication with the local and far-flung areas. INSAT series of satellites are being used for this purpose. These satellites are also used for TV broadcast and meteorological services and radio networking. Satellites such as VSATs are also being used for advanced communication and networking purposes.

Fig. 3: Telecommunication

- **Telemedicine**: This is one of the unique applications of communication satellite developed especially for rural and remote locations. Through telemedicine, the mobile units are being connected seamlessly to the major hospitals and medical hubs. Through this application, the medical practitioners are able to access the data rapidly and be able to provide medical services in remote locations.

Fig. 4: Telemedicine

- **Tele-education**: The communication satellites are used to make education available to the students and professionals in remote locations. Through this arrangement, the learner can get the education through the video over the internet. This mode of education can be referred to as E-learning.

Fig. 5: Tele-education

'EDUSAT' is the thematic satellite developed by ISRO which is dedicated to remote education. The satellite delivers interactive educational delivery services through video conferencing.

- **Banking:** Currently, the banking industry is one of the world's largest and most important economic activities. Banks and ATMs require a secured and reliable connectivity in order to transmit data from their location to a server and vice versa. Satellites provide that reliable connectivity for all the limitless transactions using the virtual private network (VPN).

Fig. 6: Withdrawing from ATM

- **5G Network:** All the devices are being connected and the ground connections for the cellular network are not enough to provide a seamless connection. Thus, the fifth generation of network development will modernize the foundation of network and communication for the economies as well as militaries. The development of a 5G network will allow the satellites to help connect to more devices. Thus, the future demands of the connection will be addressed. Through this technology, it will also be possible to connect the remote and rural areas in the mainstream network. This technology will also help to develop the Internet of Things technology.

- **Satellite internet using LEO constellation:** The renowned private companies across the world are working on the development of low-cost internet at remote locations with low latency. These mega constellations of the satellites are small communication satellites in the Low Earth Orbits, unlike conventional GEO orbits. The main advantage is the offer the broad band internet to users at very high speeds and low latency.

Fig. 7: Satellite Internet

- **Development of Internet of Things technology through smallsats:** The technology of the Internet of Things allows unconnected or non-connectable objects to be connected to the internet. The change of the data can be recorded for the given unconnected object. Through the launch of small communication satellites in the low earth orbits, the number of IoT devices being connected with the internet can be increased and a consistent network can be provided. Thus, autonomous cars and instruments as well as remote connectivity can be made possible.

- **Real-time tracking:** With the future developments in communication satellites, it will be possible to track the real-time data for earth observations such as climate change, disaster management, and also for military applications.

- **TV Broadcasting and DTH:** Various programs such as Movies, Live Sports and Live News are available on Television through **direct broadcast satellite** (DBS) and direct-to-home(DTH) service providers, such as DishTV or Tata Play, in which communication satellites play a key role.

Fig. 8: Television

- **News Broadcasting:** Communication satellites enable the Outside Broadcasting (OB) Van to connect to the TV Studio for broadcasting real-time information.

Fig. 9: OB Vans of Doordarshan Channel

How does a TV Work?

There are five major components in a DTH or DBS satellite system:

a) **Programming sources:** These are the content prepared by a third party, which has to be made available on TVs. Example: Nat Geo Channel or Star Sports that would live stream some sports tournament. The programming sources take the rights for these contents to play on TVs.

b) **Broadcast centre:** The TV provider receives signals from various programming sources as mentioned above and beams a broadcasting signal to the satellites in geosynchronous orbit from the broadcast centre.

c) **Satellites:** Satellites in geosynchronous orbit receive the signals from the broadcast station and rebroadcast them to Earth.

d) **Dish:** Individual dishes at homes pick up the signals from the satellite or multiple satellites and pass them on to the receiver in the viewer's house.

e) **Receiver:** It processes the satellite's signal and passes it on to a standard TV.

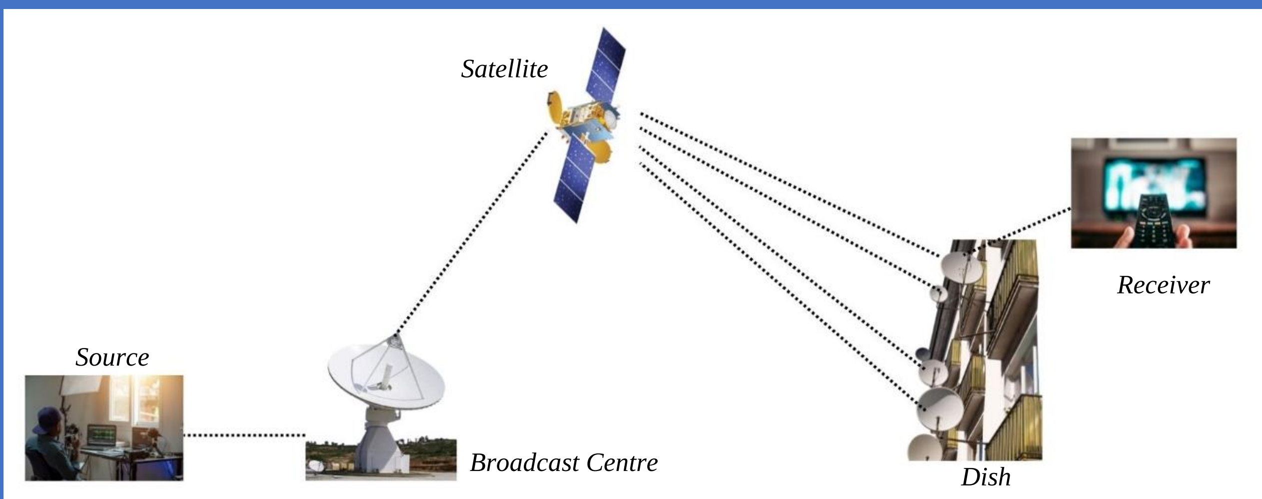


Fig.10. Block diagram of Satellite TV

- **Radio Broadcast:** It is a type of digital broadcast that transmits high fidelity programme channels for national as well as regional radio stations. The audio signals with greater clarity in the audio and consistency than conventional radio are covered over large areas. A satellite radio provider uses satellites to broadcast audio channels of entertainment, sports, and news programs to customers at home, work or in vehicles in both rural and urban centres.

Fig. 11: Radio Broadcast

- **Search and Rescue:** The search and rescue activities are carried out by Coast Guard, Navy and Air Force, where satellites establish connectivity among the people at remote locations for fishermen and victims of the cyclone. In 2013, ISRO's search and rescue support for 14 distress incidents in the Indian service area through the Indian system contributed to saving 94 human lives.

Fig. 12: Search Rescue operated with the help of ISRO

Earth Observational Satellite:

Satellite remote sensing is another major technology that finds wide range of applications like meteorology, disaster monitoring and prediction, land cover classifications and others. They enable data collection over large coverage areas and continuous monitoring of surfaces with frequent revisits compared to other remote sensing technology.

All surfaces emit radiations based on their temperature or reflect a certain portion of the incident radiations based on their reflecting properties. Satellite remote sensing, in simple terms, refers to the collection and recording of information about these emitted or reflected radiations at different wavelengths by the onboard satellite sensors. This information is used to determine various other crucial parameters in different applications. Based on the source of the light used for remote sensing, it can be classified into the following types.

1. **Active remote sensing:** In this method, the satellites have their very own artificial source of radiation that is used to illuminate the region of interest. The radiation reflected or scattered by the region is detected and recorded by the sensors.
2. **Passive remote sensing:** These systems are used to detect the solar radiations reflected by the surface or the thermal radiations emitted by the surfaces. They do not use an active radiation source for illuminating the region of interest.

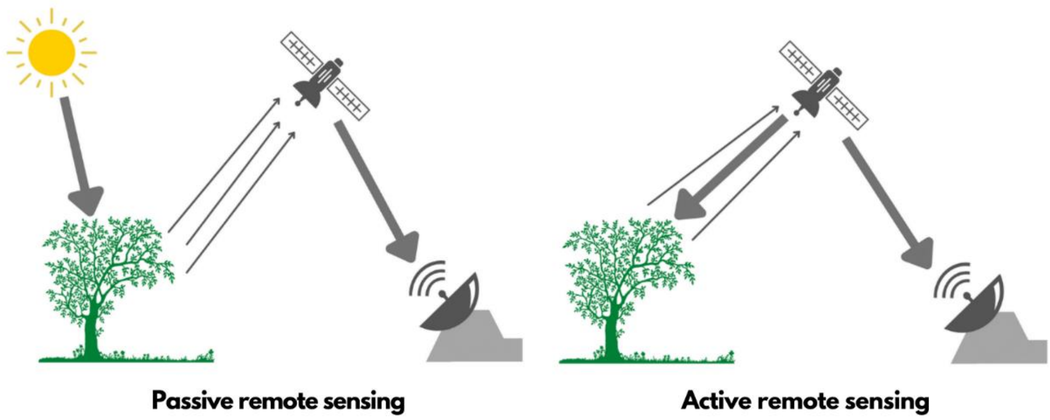


Fig. 13: Types of Remote Sensing

Most of the remote sensing applications are based on passive remote sensing. Active remote sensing satellites usually incorporate a microwave or laser-based system as the source of illumination.

Satellite remote sensing is also classified based on the region of the electromagnetic spectrum used for the study. They are

1. Optical remote sensing (includes visible region and near IR region)
2. Thermal Infrared remote sensing (includes mid wave and long wave IR region)
3. Microwave remote sensing

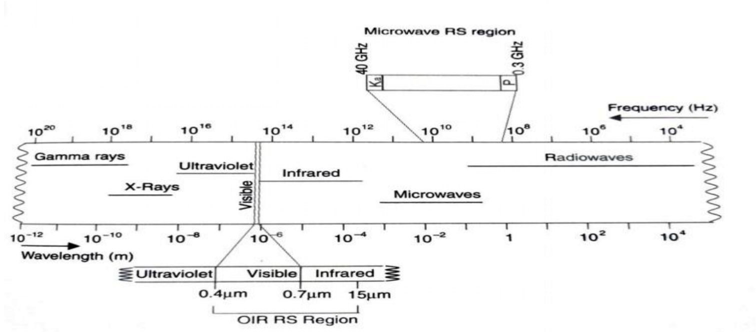


Fig. 14: Electromagnetic Spectrum

Optical remote sensing finds its application in imaging the Earth in visible regions, the study of vegetation covers, the study of water bodies and other applications. Thermal infrared remote sensing is mainly employed for studying the temperatures of different surfaces. 'Landsat' satellite series, a joint program by NASA and USGS, is one of the longest running Earth observation satellite programs. It employs both optical remote sensing and thermal infrared remote sensing for imaging Earth.

The Indian Remote Sensing program started off with the launch of the Bhaskara -1 satellite in 1979 and IRS-1A satellite in 1988. IRS-1A was the first operational satellite, followed by a series of IRS satellites dedicated to specific applications like natural resource management, disaster management and support, water resources information, and forest and land mappings. The Earth Observation programs in India are overlooked by the National Natural Resources Management System (NNRMS), which is a national level inter-agency system. It facilitates the remote sensing application into national, state, and local level projects. The Oceansat satellite series launched by ISRO under the IRS program is dedicated specifically for oceanographic and atmospheric studies. They help measure parameters like sea surface

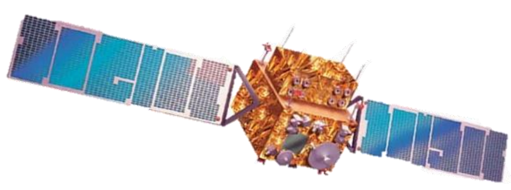


Fig. 15: IRS -1 Satellite

temperature, sea surface wind speed, water vapour content in the atmosphere, cloud liquid water content, coastal circulations, etc. These parameters are then used in marine weather forecasting, monsoon predictions and studying cyclones. Cartosat series of satellites are used for obtaining high-resolution imagery. ISRO has also created a geoportal named 'Bhuvan' in order to enable easy access to the remote sensing data by people who want to innovate and develop downstream applications.

Applications of Earth Observational Satellites:

- **Agriculture and Soil:** Information on crop statistics such as distribution and storage of food grains, Govt. policies, pricing, procurement and food security and so are required for planning and decision-making purposes in the Agricultural domain. Remote Sensing based acreage and yield forecasts based on weather parameters or spectral indices are used to provide production forecasts. Remote sensing data addresses many critical aspects, such as crop area estimation, crop yield & production estimation, crop condition, deriving basic soil information, cropping system studies, effects of droughts on crops, experimental crop insurance, etc. ISRO is also actively involved in the national level assessment of Horticultural Crops and their coverage across the agro-climatic regions in the country.

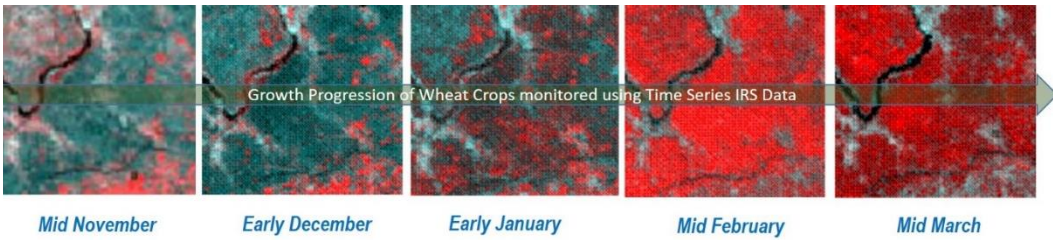


Fig. 16: Growth Progression of Wheat Crops

- **Renewable Energy:** Satellite remote sensing provides a synoptic view, covering larger areas continuously for longer periods. Winds, solar and wave energy resources can be assessed with the help of Earth Observation data. Assessment of solar energy from Geostationary satellites like INSAT 3D & 3DR, ocean wind energy from Scatterometer data and ocean wave energy from Altimeter data & numerical models are being carried out. A mobile app such as VEDAS allows individuals to assess rooftop solar energy based on geolocation inputs.

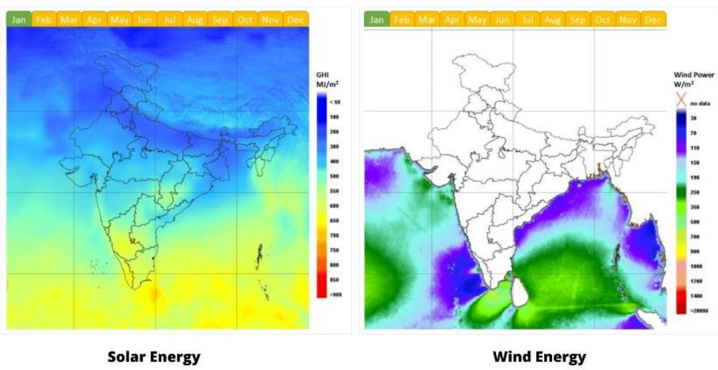


Fig. 17: Solar and Wind Energy

- **Forest and Environment:** Remote sensing data is used for various applications in forestry and the environment, such as Biodiversity characterization, Wetlands, Forest & Biomass mapping, Land Degradation and Desertification processes, Coastal wetlands, Coral reefs, Mangroves, Glaciers, Air and Water pollution assessment, etc. The multi-resolution satellite data are used for historical change assessment, biomass estimation, automated annual forest changes, etc. Forest fires are routinely monitored using multi-temporal data and near real-time satellite data.

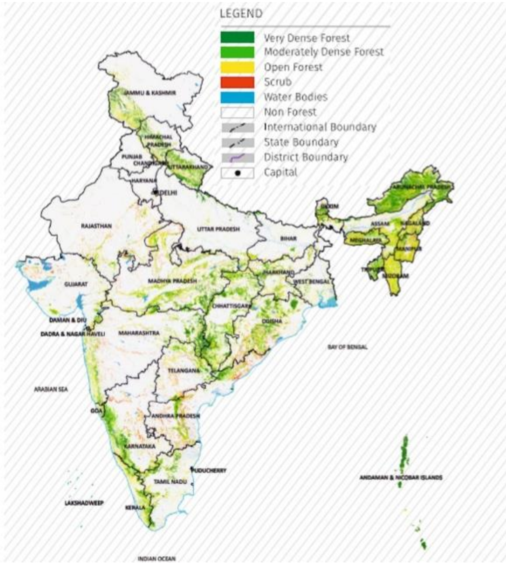


Fig. 17: Forest Cover Map, India. (Credits: FSI)

- **Geology and Geomorphology:** Remote sensing is used by significant exploration programmes in the country, such as Mines, Steel, Petroleum and Natural Gas, and Atomic Energy. The synoptic view provided by Remote sensing data helps in Lithological, Geomorphological and Structural mapping. In contrast, spectral characteristics are used for lithological & mineralogical discrimination and for mapping regions of hydrothermal alterations indicative of mineralization.

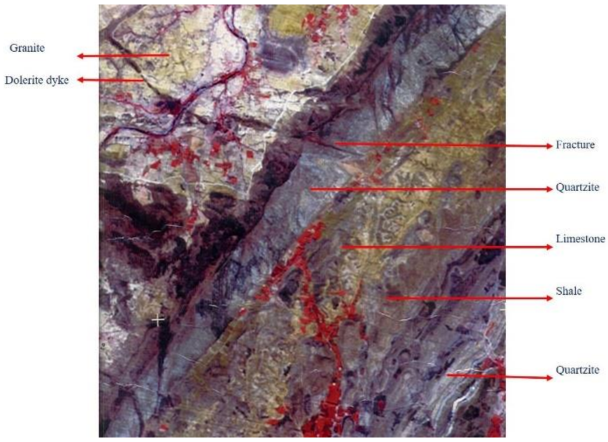


Fig. 18: Satellite Image showing Types of Rocks

- **Land Resources:** Effective management of natural resources is a very important aspect of sustaining a healthy economy. Space-based observations provide synoptic and multi-temporal coverage of natural resources. Monitoring them using EO data helps to plan appropriate management strategies for their optimal utilisation. Land use /cover, Land degeneration mapping, wasteland mapping, and desertification status mapping are the major areas/themes where space data is used to manage the country's natural resources.

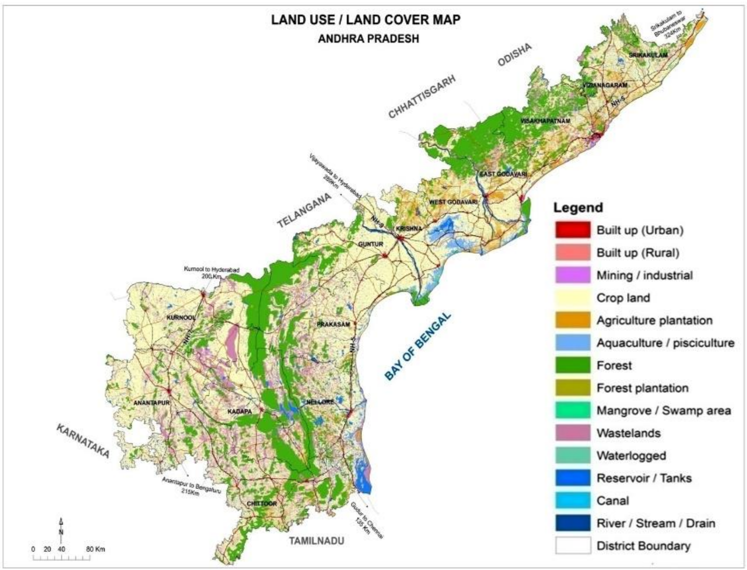


Fig. 19: Land Use Land Cover Map of Andhra Pradesh, 2015-16

- **Ocean Science:** The major applications of data from satellites observing the water bodies are identification of potential fishing zones, sea state forecasting, coastal zone studies and inputs for weather forecasting and climatic studies. The satellites also provide ocean surface wind vector data for weather forecasting, cyclone detection and tracking, and ocean state monitoring and prediction. **SARAL** is an Indo-French satellite designed to study ocean circulation and sea surface elevation leading to a better understanding of the ocean mesoscale variability. SARAL also includes monitoring the main continental waters level (lakes, rivers, closed seas), mean sea level variations, the observation of polar oceans, and the study of continental ices and sea ices.

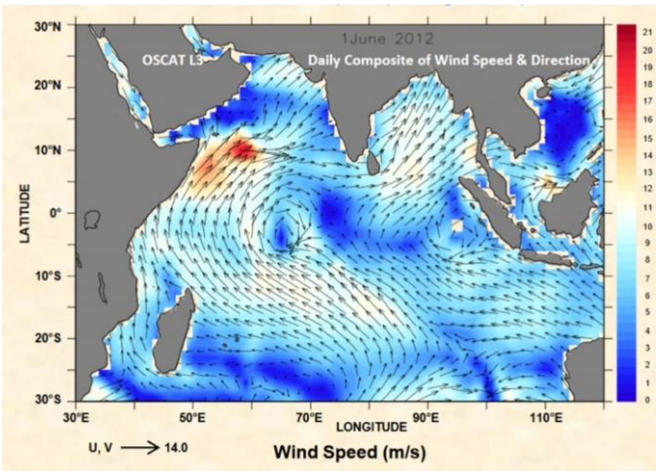


Fig. 20: Satellite image of Water Current

- **Urban Development:** Traditional mapping methods are not feasible to keep up with such rapid changes, preventing successful sustainable 'smart city' development. High-resolution satellite data provides information on the increase in the rate of population, changes in land usage, urban sprawl, etc., which can be managed and planned for a broad expansion of urban environments. Satellite-based remote sensing is advantageous in monitoring urban land use dynamics because of the extensive spatial coverage for mapping applications, frequent revisit periods, and wide availability. Urban planners use satellite imagery as an invaluable source of information supporting planning decisions for,
    - Zoning and Urban planning
    - Pollution, traffic analysis and carbon footprint
    - 3D modelling for digital city creation
    - Modelling City infrastructure

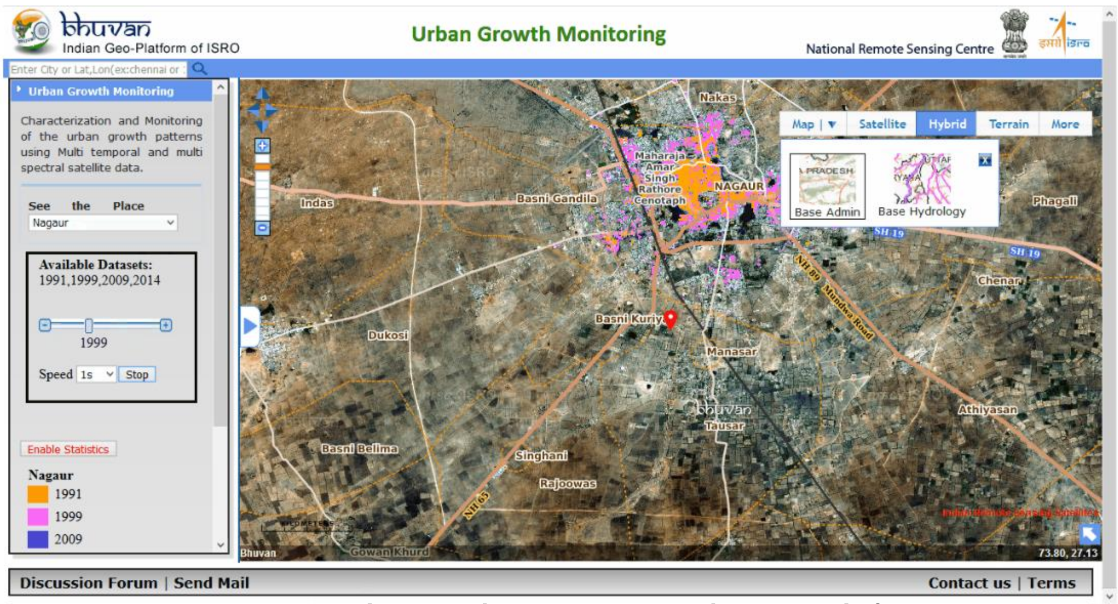


Fig. 21: Urban Growth Monitoring using Bhuvan Portal of ISRO

- **Water Resources:** Remote Sensing helps in better assessing and managing water resources due to the synoptic coverage of the EO constellation of satellites. Majorly, surface water and groundwater can be monitored. While surface water manifests in terms of water bodies, reservoirs, river channels, snow cover etc., Space data is used for drawing hydrological models on groundwater level, short-term and seasonal snow-melt runoff, drinking and sanitation water level, etc.

Fig. 22: Ground Water Prospects Map: Multiple GIS Layers Integrated

- **Weather and Climate:** Weather plays an essential role in the nation's overall activities. Weather satellites carry instruments called radiometers that scan the Earth to form images. These instruments usually carry a small telescope or antenna, a scanning mechanism, and one or more detectors for visible, infrared, or microwave radiation. Through these data, the scientific community can predict if there are any hurricanes, tornadoes, heavy rainfall, cloudy sky and even the high temperature in summer, drought outlooks, etc., and create awareness about them before in hand.

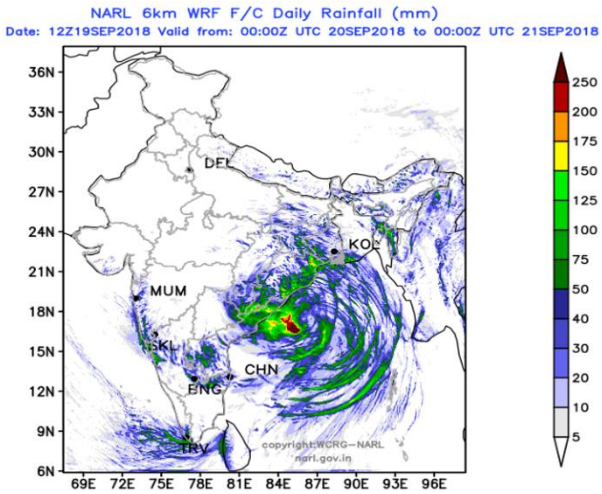


Fig. 23: Accumulated Daily Rain Forecast for 20th September 2018

Difference between Weather and Climate:
Weather refers to the instantaneous state of the atmosphere, and Climate is the long-term average state of the atmosphere (typically a few decades). For example, we say, "The weather is hot today" and "Climate is hot this year compared to others".

Navigational Satellites:

All are very well aware of GPS used in smartphones, cars, watches, etc. That same GPS functions based on the information sent by satellites orbiting earth continuously to provide navigation aid. In simple terms, navigation with satellite aid can be called Satellite-based Navigation. GPS is a Navigation Satellite system developed by the USA. Many more Satellite Navigation systems, including the Indian IRNSS satellite system (NaVic), are now available.

Satellite-based navigation systems have revolutionized the modern world with their wide potential. Their ability to provide accurate positioning and cover a large area makes satellite-based navigation systems more reliable and popular. The principle of operation of the Satellite Navigational System is of two types.

1. **Doppler effect-based systems:** The first satellite system explicitly intended for navigation was developed in the 1960s by the US Navy, called as Transit system or Navy Navigation Satellite System (NNSS). It was based on the principle of the doppler effect. The satellite transmits signals that contain information regarding its path and time. The onboard atomic clock provides the precise time data for the satellite. The receiver station on the ground measures the doppler shift patterns in the satellite signals as it passes over the station. This pattern, along with the information on satellite orbit, time of signal transmission, and signal reception, is used to determine the location of the receiver station. In this method, a satellite transmitting in one frequency is sufficient for determining the location of the receiver. However, two frequency systems were employed in Transit to increase the accuracy for military applications.

2. **Trilateration based systems:** The US Navy launched two Timation satellites to increase the time ranging accuracy, one in 1967 and the other in 1969. The success of Timation satellites combined with the NNSS system led to the conceiving of a Global Positioning System. As a result, Navigation Satellite Timing and Ranging (NAVSTAR) GPS was launched by the US Navy in 1978. The NAVSTAR GPS works on the principle of trilateration. It is simply an extension of a Doppler effect based navigational system, but with signals from three satellites used for determining the location of the receiver station. Suppose one imagines the distance between the receiver station and the satellites as the radius of three spheres with satellites located at the center of those spheres. In that case, the receiver station will be located at the point of intersection of these spheres. The modern global navigation systems like GPS from USA, GLONASS from Russia, and Galileo from ESA employ the trilateration method to determine the receiver's position.

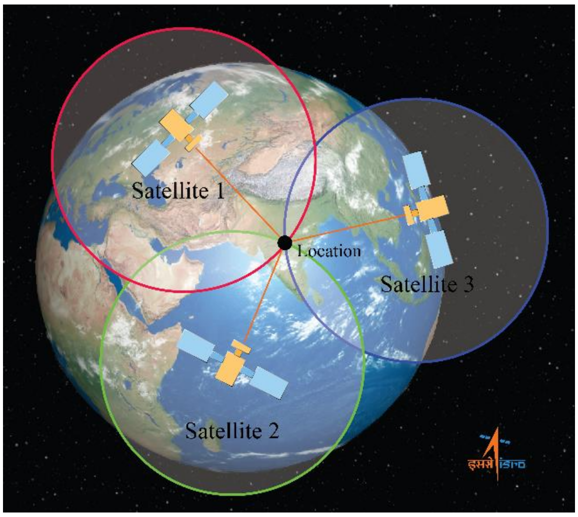


Fig. 24: Trilateration

India launched a regional satellite-based augmentation system called GPS Aided – GEO Augmented Navigation (GAGAN) in 2001. This was intended to develop and certify a satellite-based augmented system for civil aviation applications. Augmentation is a method of improving the accuracy of the navigational satellite system receivers by making use of other additional reference signals into the calculations. The success of GAGAN paved the way for the development of an independent regional navigation satellite system by ISRO called as

Indian Regional Navigation Satellite System (IRNSS). It goes by the operational name Navigation with Indian Constellation – NavIC. The space segment of NavIC consists of 7 satellites with three satellites in GEO and four satellites in inclined Geosynchronous Orbits. Satellite-based navigation finds its application in geodesy, telecom services, transportation, maritime security, surveying and disaster management.

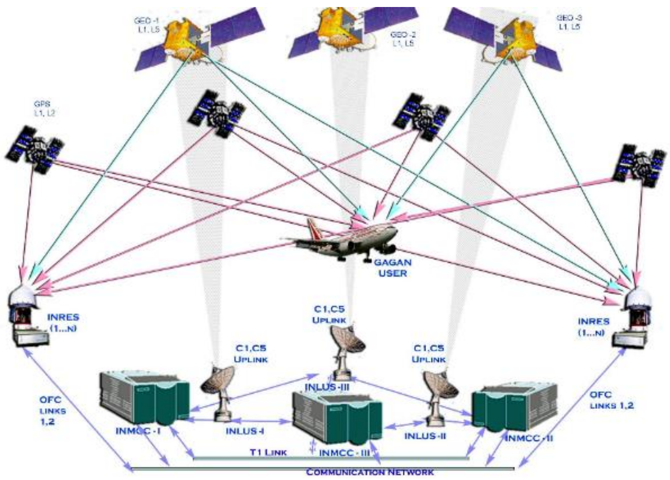


Fig. 25: GAGAN Working System

Applications of Satellite Navigation (SATNAV):

SATNAV has many more applications than the intended design objectives during the 1980s. Artificial Intelligence combined with satnav technology made life easy with almost zero effort job profiles. We will discuss its importance and applications now.

I. Civilian Applications:

a. Travel: Satellite navigation made travel to unknown places made simple. Everyone is familiar with google maps and can safely travel to almost any place with the best AI recommended routes for less duration and uninterrupted paths.

b. Tracking & Monitoring: It has become common to track a package location, whether a parcel or food delivery. Ridesharing companies like Uber, Ola, and Rapido made travel safe by providing live route monitoring options.

- Tracking migratory animals (birds, animals, etc., using collars)
- Collision Avoidance of trains, Automatic Level crossings of railways

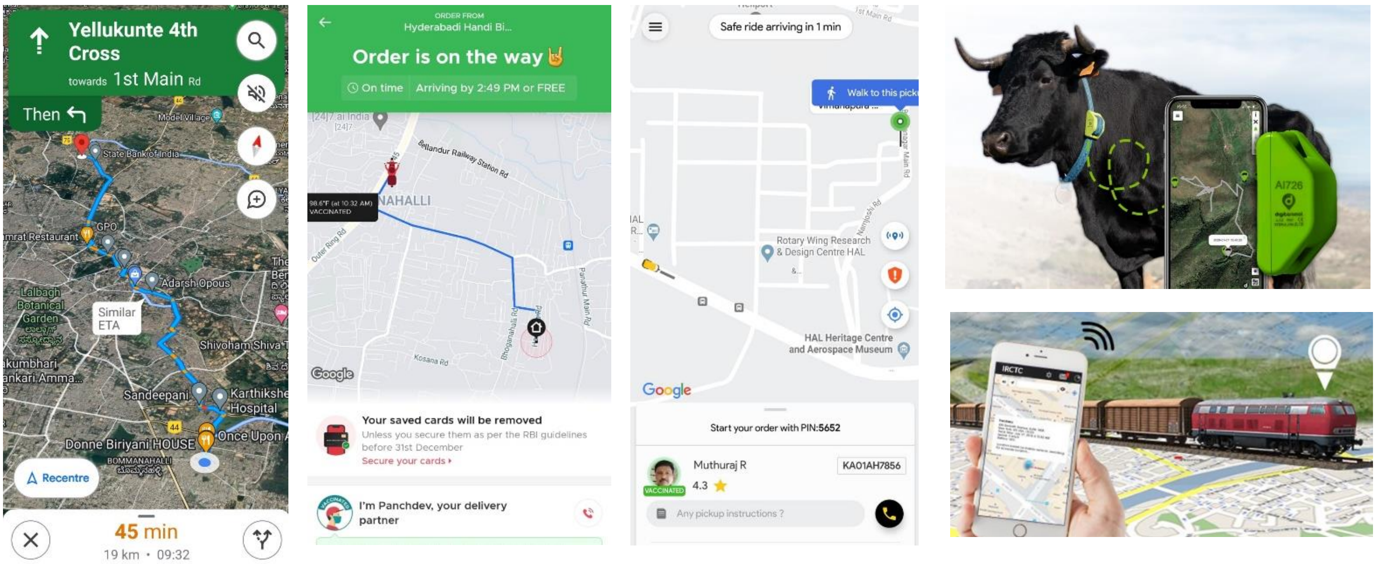


Fig. 26: Applications of Satellite Navigation

c. Safety of Hikers, Climbers were increased by carrying a satnav device so they can find their way back if lost. If Hikers themselves cannot find their way back, it still helps the rescue team reach the lost person before it's too late.

d. Automobile: Satellite navigation is available is now available in almost every current generation automobile with non-internet-based connections helping to reach the destination safely. It also helps in tracking lost and robbed vehicles. Civilian UAVs and Driverless vehicles use SATNAV for navigation.

Fig. 27: Sat Nav enabled Automobiles

e. Marine: Boats and ships can be easily lost in the vast seas and oceans. With satellite navigation aid, self-steering and automatic chart plotters technology made sailing easy. Having a satnav receiver helps in rescue operations and also improves security.

Fig. 28: Sat Nav enabled Ships

f. Aviation: Aircraft with satnav services decreases the load on the pilot and decreases accidents. Flying through zero visibility conditions like storms and fog can be handled smoothly.

Fig. 29: Aircraft tracking

II. Surveying, Mining and other applications:

a. Surveying: Building, Roads and other construction companies used satnav technologies for precise and accurate readings for surveying over vast lands making budget estimation and construction planning simple.

b. Mining and Archaeology: Both sectors use satnav for 3D mapping of sites for excavation and detailed site features.

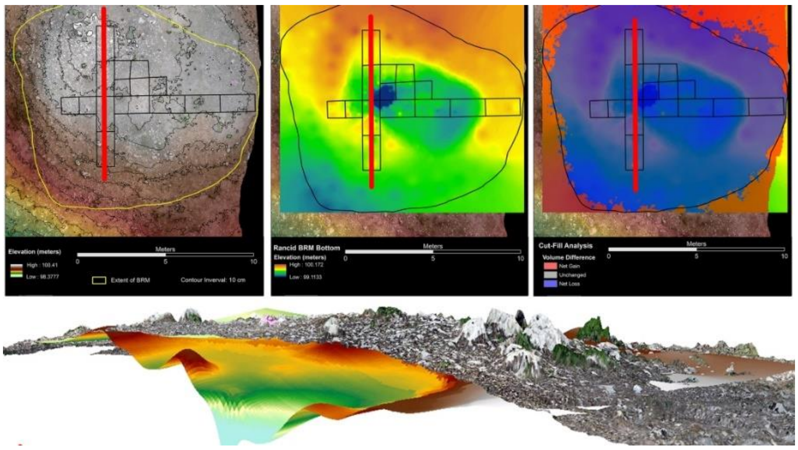


Fig. 30: 3D Mapping of Dump area

c. Agriculture: Agriculture technology advanced a lot after integrating satnav with agricultural equipment. Sowing, Harvesting and other agriculture operations are now automated.

d. Geophysics: Earth tectonics move continuously with changing landscapes and terrain features. Placing satnav receiver sensors at the desired site helps to conduct study remotely and get accurate and precise data in real-time.

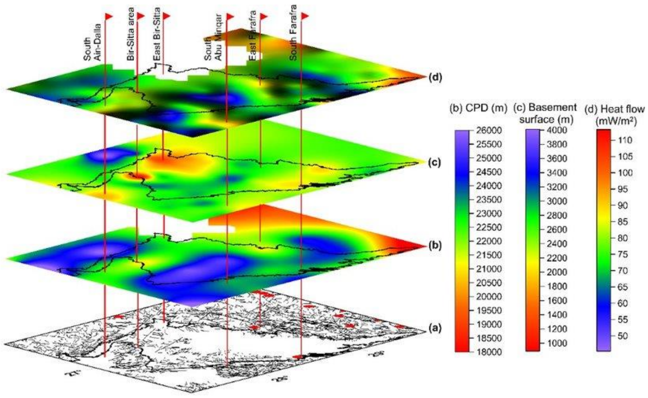


Fig. 31: Layers of Earth using Satellites

e. Space Applications: Spacecraft with satnav receivers enables orbit determination precisely. It also helps in performing autonomous navigation and rendezvous tasks.

f. Military Operations: Unmanned Aerial Vehicles (UAV), Missiles, and Bombers are updated with guided technology that was achieved with the integration of satnav technology. This makes damage minimal by reaching the targeted destination precisely.

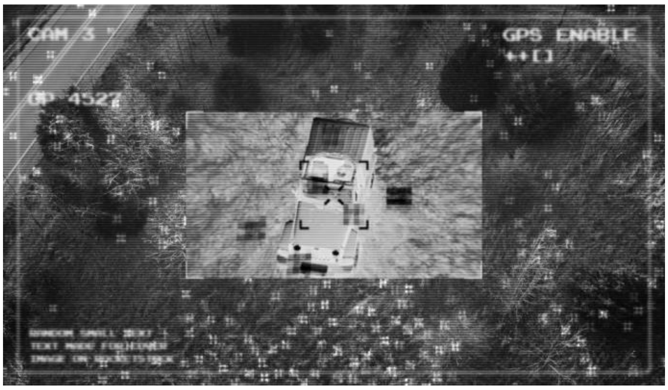


Fig. 32: Military Operations using Space Technology

g. Law and order: Apart from rescue and search operations, law enforcement uses GPS anklets to monitor their activity to keep a tab on criminals on parole. Geo-fencing and GPS trackers are some other devices used by the police force.

Fig. 33: Geo-fencing and tracking using Satellites

Scientific and Space Study Applications:

Outer space contains radiations from all the regions of the electromagnetic spectrum. Earth's atmosphere is opaque to a large portion of the electromagnetic spectrum allowing only specific wavelengths of the incoming radiations to reach the surface. We cannot see any wavelengths that lie outside the visible spectrum with our naked eyes, but we do have sensors and techniques to detect these wavelengths. A satellite equipped with these special sensors will allow us to observe the universe in different spectral regions like UV, Gamma, and X-rays. Such observations are important for us as they help us understand the history, evolution and current state of the celestial systems around us. This is the very motive behind the development of space telescopes.

The Hubble Space Telescope, launched by NASA in 1990, scanned the skies in the UV, visible and near IR regions of the spectrum and captured some of the most spectacular celestial events.

The AstroSat, launched by ISRO in 2015, consists of five payloads, namely Ultraviolet Imaging Telescope (UVIT), Large Area X-ray Proportional Counter (LAXPC), Soft X-ray Telescope (SXT), Cadmium Zinc Telluride Imager (CZTI) and Scanning Sky Monitor (SSM). The first payload allows for observation in the visible and UV region of the electromagnetic spectrum. The remaining payloads are intended for different studies to be performed in the X-ray regime.

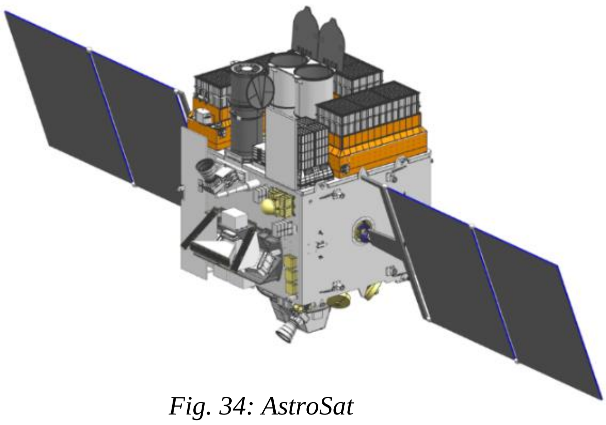


Fig. 34: AstroSat

The Cadmium Zinc Telluride Imager (CZTI) on board AstroSat has just witnessed the birth of black holes for the five hundredth time. This is a milestone for the Indian astrophysics' community. One way of looking for black holes are the deaths of massive stars through "Gamma-Ray Bursts" (GRBs). These explosions are so powerful that they send intense jets of light and high-energy radiation shooting across the universe.

The first-ever AstroSat observation was of a GRB through CZTI. A unique flagship feature of CZTI is to study the X-ray polarization and provide information on the newly formed black hole.

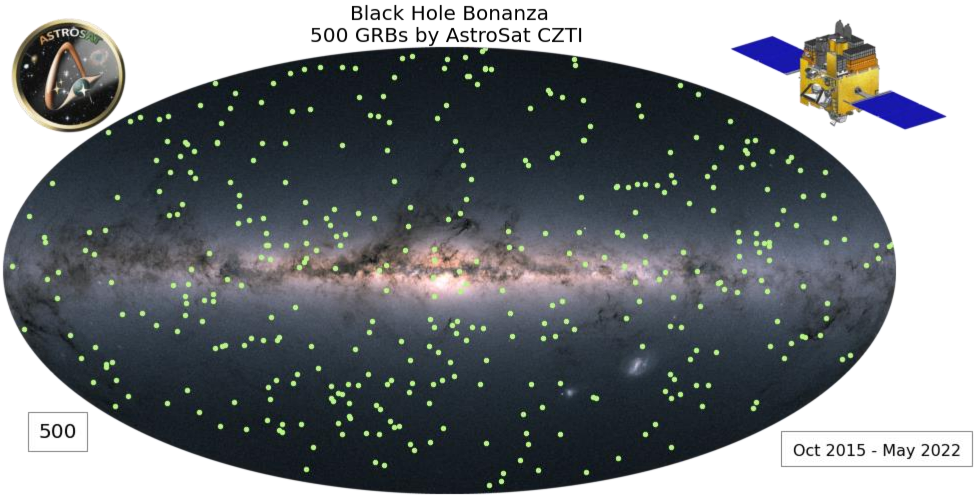


Fig. 35: Image showing the 500 GRBs observed by AstroSat CZTI.
(Credits: IUCAA)

Mangalyaan (Mars Orbiter Mission):

Mars Orbiter Mission (MOM), popularly known as Mangalyaan, marks India's first venture into interplanetary space. MOM was designed to explore and observe the Mars surface features, mineralogy and the Martian atmosphere. Further, it also performed a focused, research in search of methane in the Martian atmosphere to enquire about the possibility or the past existence of life on the planet.

The far distances involved in interplanetary missions presented a demanding challenge. However, developing and mastering the technologies essential for these missions opened endless possibilities for space exploration. After leaving Earth, the Orbiter endured the interplanetary space for 300 days before Mars captured it. Apart from deep space communications and navigation-guidance-control capabilities, the mission required autonomy at the spacecraft end to handle contingencies. Some of the payloads on the orbit:

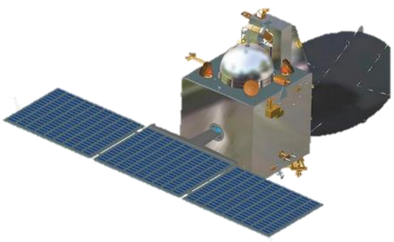


Fig. 36: MOM Satellite

- **Lyman Alpha Photometer** (**LAP**) is an absorption cell photometer. It measures the relative abundance of Deuterium and Hydrogen from spectral studies of the Martian upper atmosphere (Exosphere and Exobase).
- **Methane Sensor for Mars (MSM)** was designed to measure methane in the Martian atmosphere with a particle-per-billion accuracy and also capacity to map the sources.
- **Mars Exospheric Neutral Composition Analyser** (MENCA) is a quadrupole mass spectrometer capable of analysing the neutral composition in the range of 1 to 300 amu, the range in which the bulk proportion of gases of the Martian atmosphere falls.
- **Mars Colour Camera** (MCC) images give useful inputs about the surface features and composition of the Martian surface and to monitor the dynamic events and weather of Mars.
- **Thermal Imaging Spectrometer (TIS)** is for surface and atmospheric exploration using thermal remote sensing and also detecting the sources of thermal radiation in the Martian environment.

The spacecraft launched on November 5, 2013, arrived safely into Mars orbit on September 24, 2014. As a result, India made history by becoming the first-ever country to reach Mars on the first attempt and it was done on a light budget.

Mangalyaan was planned for a mission life of six months. However, due to fuel-saving manoeuvres and accurate orbital injections and firings saved 20 Kg of fuel, making 40 Kg of fuel at the time of Mars's high elliptical orbit insertion. The functioning of instruments with no or less degradation even after six months of working under such harsh conditions is another great feat of the orbiter for its ongoing mission life.

ISRO utilized this opportunity to make use of the data and worked towards familiarizing the Martian conditions. Control and Command Unit made necessary orbital corrections to further prolong the life of MOM to endure solar eclipse, bursts, flares and other mission unplanned phenomena. MOM instruments' prolonged functioning also helps to understand the response and health of the instrument to work in such harsh conditions.

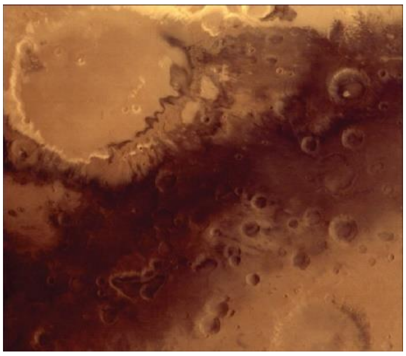


Fig. 37: Schiaparelli Crater captured by MOM

Fig. 38: Noctis Labyrinyhus captured by MOM

Intersecting valleys or ridges present in between Valles Marineris and the Tharsis region on Mars. This region is characterised by a system of steep-walled canyons and valleys that give it the aspect of a naturally formed maze or labyrinth. This image is captured by Mars Colour Camera (MCC) from 10,392 km above.

Mangalyaan has helped publish 30+ research papers so far and has more than 2 TB of picture data consisting of images of Mars natural satellites-Phobos and Deimos, Olympus Mountain and other craters and valleys.

Did you know?

The Indian mission to Mars, Mangalyaan, cost less than the budget of the movie ‘Martian’

Chandrayaan I:

Chandrayaan I was India's first Moon mission. The mission had 11 payloads built by India, the UK, the USA, Germany, Bulgaria and Sweden. Chandrayaan mission, launched on a PSLV rocket on October 22, 2008 from Sriharikota, was designed to collect data about the topography of the Moon. The spacecraft was orbiting around the Moon at the height of 100 km from the lunar surface. It collected data on chemical, mineralogical and photo-geologic mapping of the Moon. The data from Chandrayaan helped discover the presence of water on the Moon in September 2009. Indian payloads include Terrain Mapping Camera in the panchromatic band with 5m resolution and 40 km swath to prepare high-resolution atlas of moon and hyperspectral images for mineralogical mapping, Lunar Laser Ranging Instrument for topographical mapping, High Energy X-ray Spectrometer and Moon Impact Probe. The scientific payloads of partner countries were also carried aboard. The Moon Impact Probe carrying the Indian Flag, hard-landed on the Moon surface on November 14, 2009.

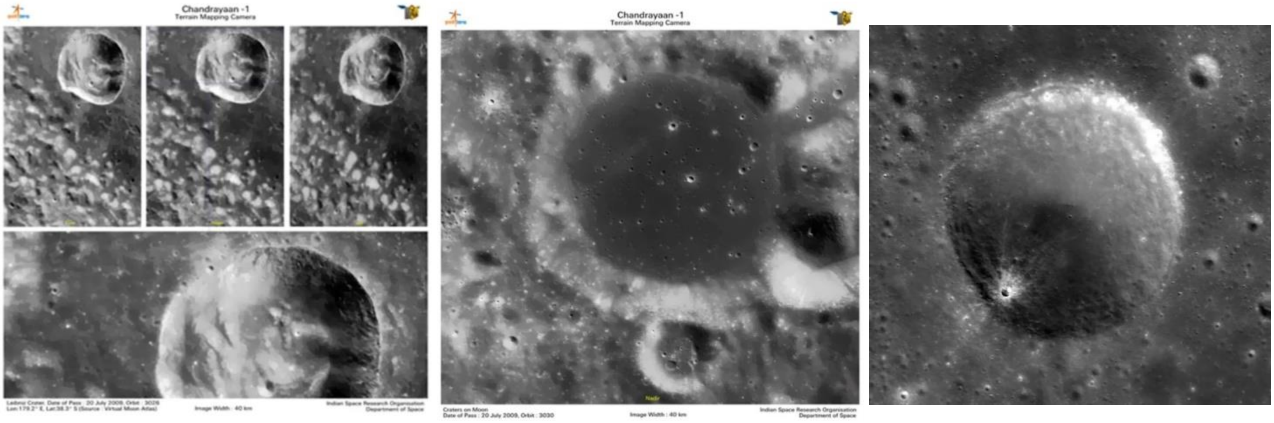


Fig. 39: Lunar Terrain Mapping using TMC

Chandrayaan II:

The successor of Chandrayaan I, Chandrayaan II, was designed to explore the south pole of the Moon. It consisted of an orbiter, a lander named Vikram and a rover named Pragyan. Launched on July 22, 2019 using a GSLV from Sriharikota, Chandrayaan II aimed to study topography, surface mineralogy and elemental abundances of the Moon specifically, examining the traces of hydroxyl and water ice.

The Chandrayaan II orbiter is orbiting the Moon in a polar orbit at an altitude of 100 km, and it carries eight scientific instruments. The instruments on the orbiter include Terrain Mapping Camera (TMC-2), Chandrayaan II Large Area Soft X-ray Spectrometer (CLASS), Solar X-ray Monitor (XSM), Orbiter High-Resolution Camera (OHRC), Imaging Infrared Spectrometer (IIRS), Dual Frequency L-band and S-band Synthetic Aperture Radar (DFSAR), Chandrayaan-II Atmospheric Compositional Explorer 2 (ChACE-2) and Dual-Frequency Radio Science Experiment.

The Vikram lander was India's first attempt to do a soft landing on the surface of the Moon. If it were successful, we would have been the fourth country to achieve this feat. It was named after Vikram Sarabhai, the Father of Indian space program. Apart from the rover, the Vikram lander contained three different experiments, Radio Anatomy of Moon Bound Hypersensitive Ionosphere and Atmosphere (RAMBHA), Chandra's Surface Thermophysical Experiment (ChaSTE) and Instrument for Lunar Seismic Activity (ILSA).

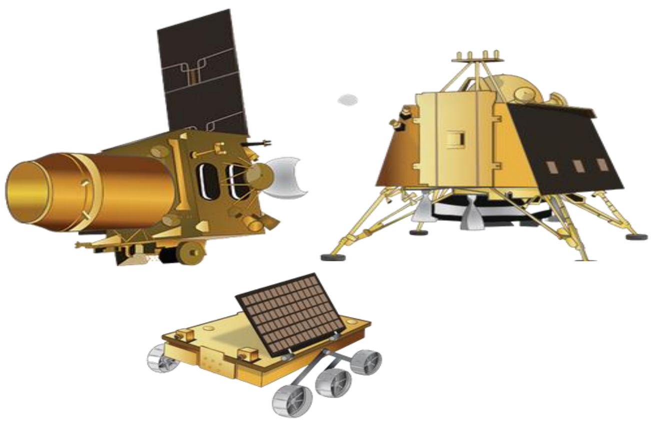


Fig. 40: Chandrayaan II modules

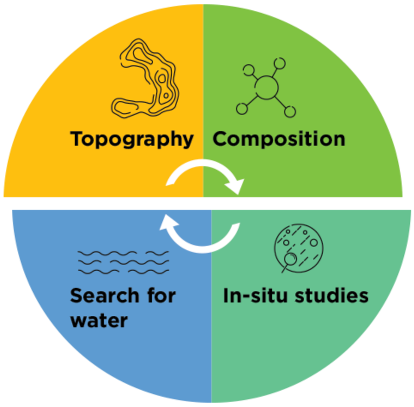


Fig. 41: Scientific Experiment of Chandrayaan II

The functioning of Chandrayaan II orbiter is almost similar to Chandrayaan-1's orbiter with additional research instruments. Chandrayaan II's designed lifetime is two years, but it is now expected to last around 7.5 years after the perfect launch. Orbiter payload includes experiments to study high-resolution topographic mapping, determination and three-dimensional mapping of water, hydroxyl, mineral and elemental composition on the lunar surface, the study of lunar exosphere & ionosphere, and observing the x-rays emitted from the sun and its corona.

Chandrayaan II has three different modules which have different lifetimes. Rover Pragyan and lander Vikram were expected to have a lifetime of 14 days after landing on the Moon. The Orbiter was expected to be functional for approximately 7.5 years. All three modules of Chandrayaan II have their own different role in helping humankind reach one step closer to the Moon.

After four days of de-orbiting, during the first phase of landing from 30 km to 7.4 km, Vikram's onboard computer decreased its descent speed as planned mission profile. In the second phase, due to some software glitch, Vikram began to deviate from its landing trajectory and lost contact with ISRO at around 2 km from the lunar surface.

Current Status:

Chandrayaan-2 orbiter is currently around the lunar orbit and providing excellent science data resulting in several firsts. For example, the OHRC onboard Chandrayaan-2 provides the highest ever resolution images of Moon.

ISRO’s future missions include AdityaL1 to study the Sun, Venus Mission, Mission to study Exoplanets, Human Space Mission and Space recovery Module.

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