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Distance Learning Programme (DLP)

SCIENCE & TECHNOLOGY

(UPSC PRELIMS)

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SCIENCE & TECHNOLOGY

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CHAPTER

SPACE SCIENCE & TECHNOLOGY

Outer Space refers to the void that exists between celestial bodies. There is no boundary where outer space said to begin, but according to space treaties Kármán line located at an altitude of 100 km above sea level is conventionally used as the start of outer space.

Space can also be regarded as resource available for exploitation because it forms part of man's environment similar to land, air and water. Space research involves dual use technology with application in both civilian and defence sectors. Indian space research also involves dual use technology and other countries that possess this technology include Russia, USA, European Union, Israel, Japan and China.

Types of Orbits

On the Basis of Altitude

- **Near Earth Orbit (NEO):** It lies at an altitude of about 400 km above the surface of the earth. Being the orbit closest to the Earth, satellite orbiting here has to overcome greater gravitational pull of the earth. Generally experimental satellites are launched in the NEO. Ex. Aryabhatt and Rohini.
- **Low Earth Orbit (LEO):** The LEO lies between 650 km to 2000 km from the earth's surface. It is circular orbit in which Remote Sensing Satellites (RSS) are launched. Remote Sensing Satellites follows a circular orbit moving from North pole to South pole ; therefore this orbit is also known as Polar Orbit. In a 24 hour period, polar orbiting satellites will view most of the Earth twice: once in daylight and once in darkness.
- **Middle Earth Orbit (MEO):** MEO is the region of space around the Earth above low Earth orbit and below geostationary orbit. The most common use for satellites in this region is for navigation, such as the GPS, Glonass and Galileo constellations. Communications satellites that cover the North and South Pole are also put in MEO. The orbital periods of MEO satellites range from about 2 to 24 hours.
- **Geosynchronous Orbit (GEO):** Satellites in the geosynchronous orbit have a height of 36000 kilometres and an orbital period equal to the earth's rotational period around its axis. Hence, the satellite in this orbit travels around the earth exactly once each day and comes to rest above the same spot on the earth's surface after a revolution around the earth.

On the Basis of Application

- **Geostationary Orbit (GSO):** The geostationary orbit is a special case of geosynchronous orbit in which a satellite moves in a circular geosynchronous orbit in the equatorial plane in the direction of the earth's rotation. The satellite in this orbit has the same orbital period as the rotation of the earth around its axis, making it appear stationary relative to a fixed spot on the earth. This allows for them to provide constant coverage of an area. This orbit is good for providing television broadcasting, weather monitoring and communication services.

- **Sun Synchronous Orbit:** It is a special type of polar orbit. Here the orbital plane of the satellite has been always at the same constant angle relative to the sun-earth line during all seasons. A Sun-synchronous orbit crosses over the equator at approximately the same local time each day (and night). This orbit keeps the angle of sunlight on the surface of the earth as consistent as possible, though the angle will change from season to season. This consistency means that scientists can compare images from the same season over several years. Generally, remote sensing satellites are launched in this orbit.
- **Highly Elliptical Orbit:** Satellites in Highly Elliptical Orbit have orbits that are close to the earth at one point of their orbit, but are much farther away from the earth at other times. Often highly-elliptical orbits are used to serve areas to the far north or south of the earth, which cannot be reached using geostationary satellites.
- **Transfer Orbit:** Transfer orbit is an intermediate orbit into which a spacecraft is first launched and from where the satellite subsequently lifts off, with the help of its propulsion system, to its designated orbit.
- **Polar Transfer Orbit (PTO):** It is an orbit at an altitude of about 100 km below the Polar or Low Earth Orbit. Remote Sensing satellites are launched in this orbit first and then using its own propulsion system it lifts itself to the desired orbit.
- **Geo-Stationary Transfer Orbit (GTO):** This orbit is located at a height of about 200 km below the geo stationary orbit. GSS are first launched in GTO and then lifts itself using its own propulsion system to the desired orbit.

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Space Probes

- **Sounding Rockets:** Sounding rockets are one or two stage solid propellant rockets used for probing the upper atmospheric regions and for space research. They also serve as easily affordable platforms to test or prove prototypes of new components or subsystems intended for use in launch vehicles and satellites. They carry instruments into the upper atmosphere and into space near the Earth. These instruments may measure the temperature and pressure of the atmosphere as well as radiations from space.
- **Lunar Spacecraft:** They explore the moon to prepare the way for astronauts to land there.
- **Interplanetary Probes:** They explore the space between the planets. However, they do not reach a specific body in space. These may fly past the target planet, go into orbit around it and land on it.

Natural Satellite vs. Artificial Satellite

- Natural satellite is a celestial body smaller than a planet, which revolves around a planet. They are also called Moon after Earth's satellite.
- Artificial satellite is a man-made device that orbits round the earth and helps in meteorology, communication, remote sensing, navigation, spying and other applications.

Satellite Launching

A satellite is sent into space on top of a rocket. A satellite is said to be launched when it is put into space. The rocket that is used to launch a satellite is called a "launch vehicle." A launch vehicle is made up of several different segments, or "stages, with each stage playing a different role.

The first stage of the launch vehicle contains the rockets and fuel that are needed to lift the satellite and launch vehicle off the ground and into the sky. After all the fuel has been used up, the first stage is no longer needed and breaks off and falls to the ground in an uninhabited area.

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Location of Satellite Launching Station

Satellite Launching Stations are generally located on the east coast and as close as possible to the equator.

- This is done because eastern side of the east coast has a water body. Whereas the eastern side of the west coast lies a landmass inhabited by people. As the Earth rotates from west to east, launch vehicle also moves in the same direction. In case of an accident in case of launching satellite from the west coast may result in loss of life and property.
- These are also as close to the equator as possible because the radius of the earth is more at the equator than at the poles. Now, since acceleration due to gravity is inversely proportional to the square of the radius. Therefore the gravitational force of attraction is minimum for a satellite near the equator.
- West to east motion of the earth provides extra velocity to the launch vehicle from the east coast toward the eastern direction.

The second stage contains smaller rockets that ignite after the first stage is finished. The rockets of the second stage have their own fuel tanks. The second stage is used to send the satellite into space. The upper stage of the launch vehicle is connected to the satellite itself. The rockets of the upper stage fire after the satellite is in space and put the satellite in the exact spot where it is needed. The satellite is then sent into a "transfer orbit" that sends the satellite higher into space.

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SpaceX Reuses a Rocket to Launch a Satellite

SpaceX launched a communications satellite from the Kennedy Space Center in Florida using a rocket stage that had already been to space and back.

It marked the first time in the history of spaceflight that the same rocket has been used on two separate missions to orbit.

After successfully launching a satellite towards the geosynchronous orbit (35,786 km miles into space) the rocket then returned to Earth and landed on a remotely piloted platform, known as a drone-ship, in the Atlantic Ocean. It was the company's sixth successful landing on a seaborne platform.

SpaceX

- Space Exploration Technologies Corporation, better known as SpaceX, is a private American aerospace manufacturer and space transport services company.
- **Goal:** To reduce space transportation costs and enabling the colonization of Mars.
- **Headquarters:** Hawthorne, California
- **Founder:** Elon Musk
- Achievements
  - SpaceX has since developed the Falcon launch vehicle family and the Dragon spacecraft family, which both currently deliver payloads into Earth orbit.
  - It was the first privately funded liquid-propellant rocket to reach orbit.
  - It was the first private company to send a spacecraft to the International Space Station.
  - With the launch of CRS-8, SpaceX successfully vertically landed a first stage on an ocean drone-ship landing platform.

Components of a Satellite

The elements common to all types of satellites are:

- **Payload:** It refers to the equipment required by a satellite needs to do its job. For example: antennas, cameras, radar and electronics. Payload is different for every satellite.
- **Bus:** Bus is that part of the satellite which carries the payload into space. It holds all the satellite parts together and provides electrical power, computing power and propulsion to the spacecraft.
- **Altitude Control System:** The altitude control system keeps the satellite pointed towards the desired location.
- **Power System:** The power system generates electricity from solar cells placed on panels outside of the satellite.
- **Telemetry and Command System:** It consists of antennas and computers on board the satellite that allows people on the earth to tell the station what to do and to monitor the health of the satellite.

Transponder

The communications system of a satellite consists of one or more antennas and communication receivers & transmitter units known as transponders. Transponder, essentially a repeater, receives the signals at microwave frequencies from the earth, perform frequency conversion, amplify them and retransmit them to be received on the earth's surface.

For example, C-band transponder covers a wide geographical area, but provides low power transmission requiring large antennas for reception and hence is more suitable for fixed satellite services like telephone. The Ku-band transponder however, provides higher power transmission over a smaller geographical area, enabling reception via smaller sized antennas and is therefore suitable for broadcasting satellite services like Direct-to-Home (DTH) services.

Satellite Frequency Band and Use

- **L-band (1-2 GHz):** Global Positioning System (GPS) carriers and also satellite mobile phones, such as Iridium; Inmarsat provides communications at sea, land and air; WorldSpace satellite radio.
- **S-band (2-4 GHz):** Weather radar, surface ship radar, and some communications satellites, especially those of NASA for communication with ISS and Space Shuttle.
- **C-band (4-8 GHz):** Primarily used for satellite communications, for full-time satellite TV networks or raw satellite feeds. Commonly used in areas that is subject to tropical rainfall, since it is less susceptible to rain-fade than Ku band.
- **X-band (8-12 GHz):** Primarily used by the military. Used in radar applications including continuous-wave, pulsed, single-polarisation, dual- polarisation, synthetic aperture radar and phased arrays. X-band radar frequency sub-bands are used in civil, military and government institutions for weather monitoring, air traffic control, maritime vessel traffic control, defence tracking and vehicle speed detection for law enforcement.
- **Ku-band (12-18 GHz):** Used for satellite communications. In Europe, Ku-band downlink is used from 10.7 GHz to 12.75 GHz for direct broadcast satellite services.

- **Ka-band (26-40 GHz):** Communications satellites, uplink in either the 27.5 GHz and 31 GHz bands, and high-resolution, close-range targeting radars on military aircraft.

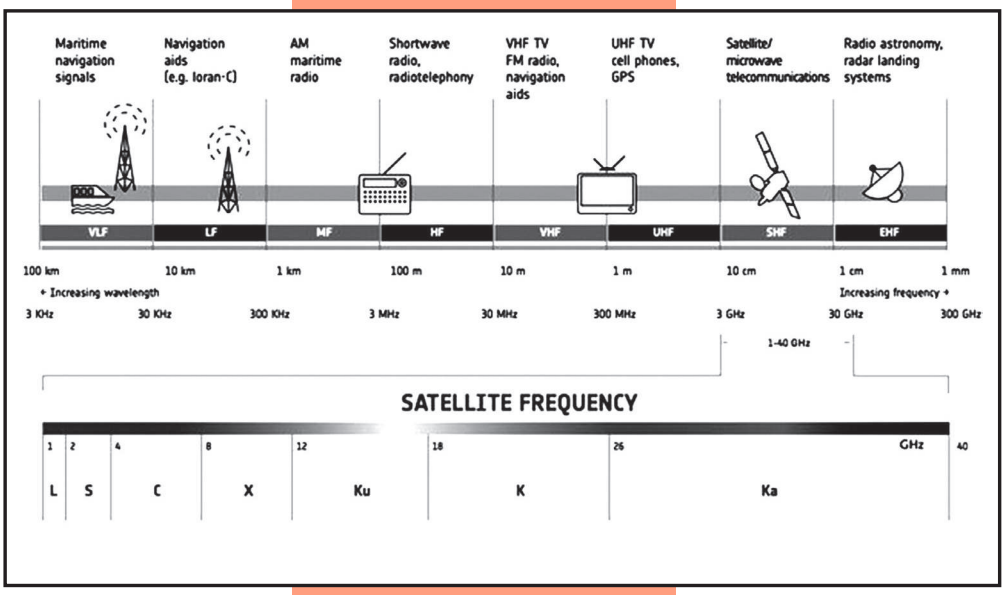

Fig. *Band for satellite and Use*

Indian Space Programme

- The space programme in India was initiated with the setting up of the Indian National Committee for Space Research (INCOSPAR) in 1962. In the same year, work on Thumba Equatorial Rocket Launching Station (TERLS) was also started under the guidance of Dr. Vikram Sarabhai.
- Indian Space Research Organization (ISRO) was established in 1969. The Government of India constituted the Space Commission and established the Department of Space (DOS) in 1972 and ISRO was brought under DOS. Initially India relied on foreign satellites so that a beginning could be made.
- The first major breakthrough came with the development of first Indian satellite 'Aryabhata' which was launched in 1975 using a Soviet Launcher.
- Another major landmark was the development of the first launch vehicle SLV-3, which had its first successful flight in 1980.
- Experimental satellite missions Bhaskara-I & II were pioneering steps in the remote sensing area, whereas 'Ariane Passenger Payload Experiment (APPLE)' became the forerunner for the future communication satellite system.
- Development of Augmented Satellite Launch Vehicle (ASLV) also demonstrated newer technologies. This paved the way for learning many nuances of launch vehicle design for complex missions, leading the way for realisation of operational launch vehicles such as PSLV and GSLV.
- During the operational phase in 90's, major space infrastructure was created under two broad classes: one for the communication, broadcasting and meteorology through a multi-purpose Indian National Satellite system (INSAT), and the other for Indian Remote Sensing Satellite (IRS) system.

During the formative decade of 1960s space research was conducted by India mainly with the help of Sounding Rockets.

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1970s was the era of experimentation during which experimental satellite programmes like ARYABHATA, BHASKARA, ROHINI and APPLE were conducted.

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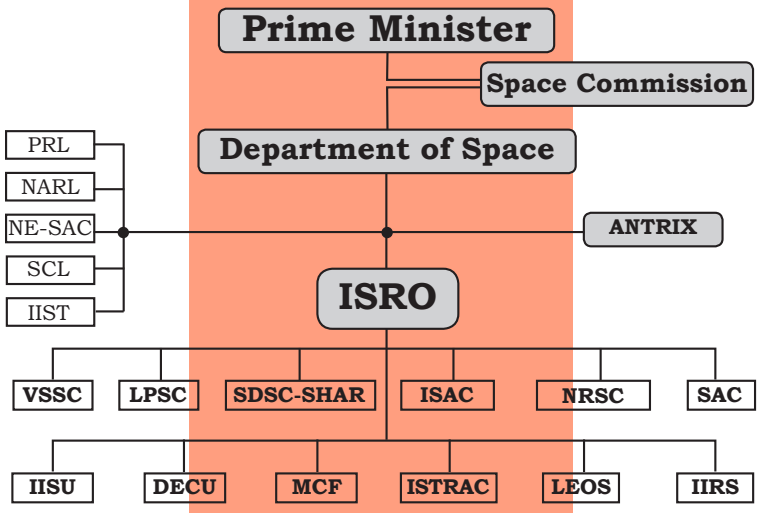
The success of these programs led to the era of operationalisation in 1980s during which operational satellite programmes like INSAT and IRS came into being.

Fig: *Evolution of Indian Space Programme*

Organisational Setup

The Space Commission formulates the policies and oversees the implementation of the Indian space programme to promote the development and application of space science and technology for the socio-economic benefit of the country.

Department of Space (DOS) implements these programmes through, mainly Indian Space Research Organisation (ISRO), Physical Research Laboratory (PRL), National Atmospheric Research Laboratory (NARL), North Eastern-Space Applications Centre (NE -SAC) and Semiconductor Laboratory (SCL). The Antrix Corporation, established in 1992 as a government owned company, markets the space products and services.



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

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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. It was incorporated as a private limited company owned by the Government of India in September 1992 as the 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 development of space related industrial capabilities in India.

- **Vikram Sarabhai Space Centre, Thiruvananthapuram:** It is the major centre of ISRO, where the design and development of satellite launch vehicles and sounding rockets is carried out.
- **Liquid Propulsion Systems Centre, Thiruvananthapuram:** It is the centre of excellence in the area of Liquid Propulsion for ISRO's Launch Vehicle and Spacecraft programmes.
- **Satish Dhawan Space Centre (SDSC) – SHAR, Sriharikota:** SDSC SHAR, with two launch pads is the main launch centre of ISRO located 100 km north of Chennai. SDSC SHAR has the necessary infrastructure for launching satellites into low earth orbit, polar orbit and geostationary transfer orbit.
- **ISRO Satellite Centre, Bengaluru:** It is engaged in developing satellite technology and implementation of satellite systems for scientific, technological and application missions.
- **Space Applications Centre (SAC), Ahmedabad:** It is a unique centre dealing with a wide variety of disciplines comprising design and development of payloads, societal applications, capacity building and space sciences, thereby creating a synergy of technology, science and applications.
- **National Remote Sensing Centre, Hyderabad:** It is responsible for remote sensing satellite data acquisition and processing, data dissemination, aerial remote sensing and decision support for disaster management.
- **Master Control Facility, Hassan:** It monitors and controls all the geostationary/ geosynchronous satellites of ISRO, namely, INSAT, GSAT, Kalpana and IRNSS series of satellites.

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A Supercluster of Galaxies – Saraswati

A massive supercluster of galaxies has been discovered by astronomers at Inter-University Centre for Astronomy and Astrophysics (IUCAA) and Indian Institutes of Science Education and Research (IISER) in Pune along with NIT, Jamshedpur and Newman College, Thodupuzha.

This supercluster, named Saraswati, is about 4 billion light years (distance travelled by light in one year) away and spreads over a "great wall" about 600 million light years across, making it one of the largest and also the farthest superclusters to be discovered.

Superclusters are the largest coherent structures seen in the universe. They are group of clusters of galaxies separated by voids.

The first supercluster of galaxies discovered in 1989 was the Shapley Supercluster, and the second, the Sloan Great Wall in 2003.

The Milky Way galaxy is part of the Laniakea Supercluster discovered in 2014. Given the belief that the universe is 13.8 billion years old, the discovery implies that such a huge structure existed even when the universe was just about ten billion years old.