Space technology can be defined as the **application of scientific knowledge and engineering principles to design, develop, manufacture, operate, and utilize systems and tools for activities conducted in or related to outer space.**

About Vikram Sarabhai

- is considered the Father of the Indian Space Program.
- Indian National Committee for Space Research (INCOSPAR): • Convinced the Indian government to establish INCOSPAR in 1962. • Served as its first chairman
- Restructured INCOSPAR into ISRO in 1969

Key Contribution :

- Launched India's first satellite, Aryabhata, in 1975. was launched from the former Soviet Union
- Successfully conducted India's first nuclear test in 1974. •
- Played a crucial role in developing India's satellite communication and remote sensing capabilities.

Other Achievements::

- Established the Indian Institute of Management, Ahmedabad (IIMA). •
- Served as the chairman of the Atomic Energy Commission of India. •

What Was the First Satellite in Space?

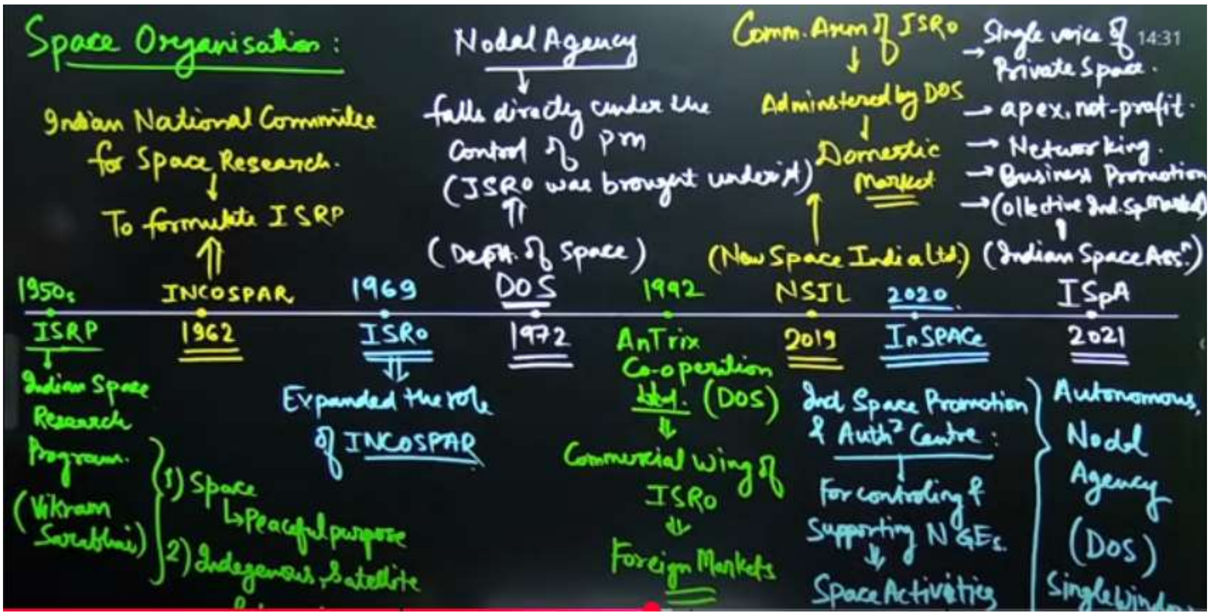
- Sputnik 1 was the first satellite in space. The Soviet Union launched it in 1957
- Explorer 1 satellite in 1958, was America's first man-made satellite.

WORLD SPACE ORGANISATION

Satellites have been launched and operated by :

- **National Aeronautics and Space Administration** : USA : formed 1958,HQ Washington DC
- **Indian Space Research Organisation**, formed 1969, Bengaluru
- **European Space Agency, ESA**, formed 1975 in Paris
- **Roscosmos , of Russia** in 1992 Moscow (1955- 1991 Soviet space progam)
- **China National Space Administration, CNSA** of China, formed 1993, Beijing HQ
- **Japan Aerospace Exploration Agency (JAXA)** , formed 2003 HQ Tokyo

Glonass is Russian Satellite Navigation System considered as counterpart to GPS of US, Galileo of European Union (EU) and Beidou of China and Quasi-Zenith Satellite System of Japan



BACKGROUND :

- 1962 - Formation of INCOSPAR - The Indian National Committee for Space Research (INCOSPAR) in 1962 chaired by Dr.Vikram Sarabhai. (founding father of Space Programme)
- 1963 - Formation of TERLS - Thumba Equatorial Rocket Launching Station (TERLS) in Thiruvananthapuram for upper atmospheric research.
- First Rocket was launched into space by India on 21 November, 1963- Nike Apache -Sounding rocket from TERLS . (Recently ISRO commemorated the 60th anniversary)
- The first rocket, a Nike-Apache, procured from the US
- A sounding rocket is a rocket, which is intended for assessing the physical parameters of the upper atmosphere
- RH stands for 'Rohini' sounding rocket and the numeral indicate the diameter of the rocket in mm.
- India’s first indigenous sounding rocket, RH-75, was launched on November 20, 1967.
- Reason Why Thumba Selected: The geomagnetic equator of the earth passes over Thumba.
- INCOSPAR grew and became ISRO in 1969 within the Department of Atomic Energy   and then in 1972 government of India set up Space commission and DoS , bringing ISRO under it .
- ISRO Formed 15 August, 1969, Bangalore.
- ISRO built First Satellite , Aryabhata , which was launched by the Soviet Space Agency Interkoscoms in 1975
- Prof Udupi Ramachandra Rao was Indian space scientist and former chairman of ISRO, designed Aryabhata. Known For " Satellite Man of India ".

SPACE COMMISSION

- is the apex body in the Indian government responsible for the formulation of policies and overseeing the implementation of the Indian space program. It works under the Department of Space (DOS).
- is a high-level advisory body in India, headed by the Prime Minister, that oversees and formulates the country's space program
- Formed in 1972
- The current Chairman of the Space Commission is **Dr. V. Narayanan**. He assumed office on **January 14, 2025**, succeeding Dr. S. Somanath.

Objective of Space Commission

- **Supreme Decision making body related with Space**
- **Make Space Related Policy**
- **Promotion of Space Technology and Techniques**

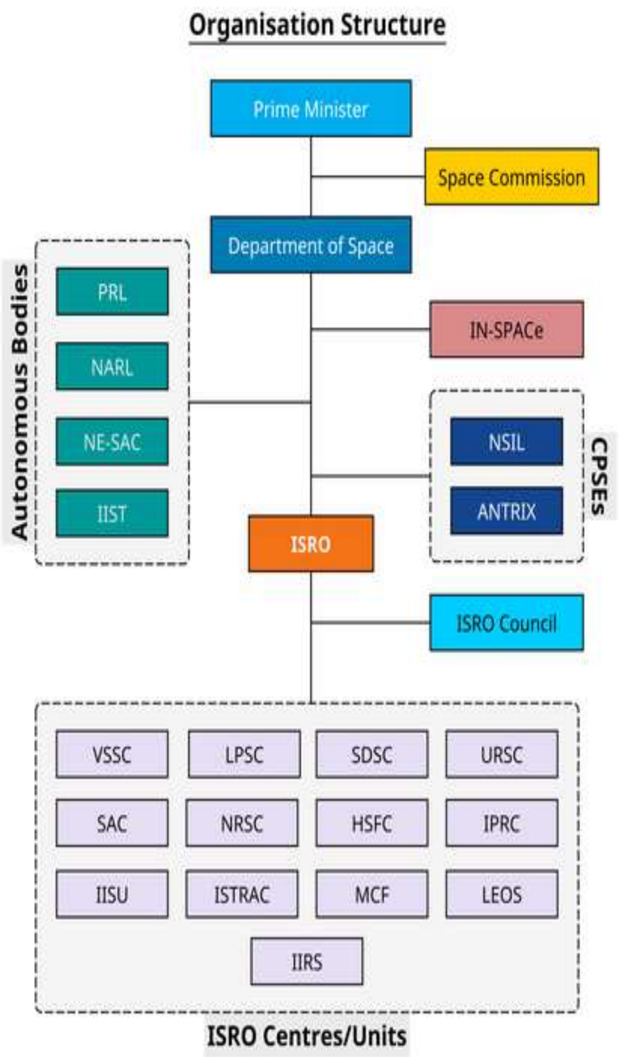
Composition :

- Chairman : Secretary -Department of Space
- Member **Principal Secretary to PM**
- Member: **National Security Advisor to PM**
- Member: **Cabinet Secretary**
- Member **:Principal Scientific Adviser to GOI**
- Member: **Chairman, IN-SPACe**

- **Member : Foreign Secretary**
- **Member : Expenditure Secretary**
- **and other various members**

Chairman List of Space Commission :

- **Dr. Vikram Sarabhai:** 1963 - 1971
- **Prof. M. G. K. Menon:** January 1972 - September 1972
- **Prof. Satish Dhawan:** 1972 - 1984
- **Prof. U. R. Rao:** 1984 - 1994
- **Dr. K. Kasturirangan:** 1994 - 2003
- **Shri G. Madhavan Nair:** 2003 - 2009
- **Dr. K. Radhakrishnan:** [1] 2009 - 2014
- **Dr. Shailesh Nayak** (Interim): January 2015 - January 2015 (for a brief period)
- **Shri A. S. Kiran Kumar:** 2015 - 2018
- **Dr. K. Sivan:** 2018 - January 2022
- **Dr. S. Somanath:** January 2022 - January 2025
- **Dr. V. Narayanan:** January 14, 2025 - Present



List of Abbreviations/Acronyms

ANTRIX: Antrix Corporation Limited
HSFC: Human Space Flight Centre
IIRS: Indian Institute of Remote Sensing
IISU: ISRO Inertial Systems Unit
IIST: Indian Institute of Space Science and Technology
IN-SPACe: Indian National Space Promotion and Authorization Centre
IPRC: ISRO Propulsion Complex
ISTRAC: ISRO Telemetry Tracking and Command Network
LEOS: Laboratory for Electro-Optical Systems
LPSC: Liquid Propulsions System Centre
MCF: Master Control Facility
NARL: National Atmospheric Research Laboratory
NE-SAC: North Eastern Space Applications Centre
NRSC: National Remote Sensing Centre
NSIL: NewSpace India Limited
PRL: Physical Research Laboratory
SAC: Space Applications Centre
SDSC: Shatish Dhawan Space Centre
URSC: U R Rao Satellite Centre
VSSC: Vikram Sarabhai Space Centre

SPACE DEPARTMENT

- **Formed 1972**
- **Hq Bangalore**
- **Implement Policies made by the Space Commission**
- autonomous unit of DOS
- **Key Important Agencies :**

1. **Physical Research Laboratory : Ahmedabad**

2. **National Atmospheric Research Laboratory, Gadanki ,Tirupathi Andhra Pradesh**
3. **North Eastern Space Applications Centre: Umiam, Meghalaya**
4. **Indian Institute of Space Science and Technology- Thiruvananthapuram (Asia First Space University)**

HOW SPACE PROGRAMME BENEFICAL FOR A COUNTRY (INDIA)

- Used in Various Domains and Provide Range of Beneficial Services.
- Immense importance for our economic security and lives
- Play a Big Role in Planning , Governance and Development of both Central and State Ministries
- For natural resources inventory and management
- disaster management support and risk reduction strategies
- Mapping of Mangroves , Coastal Ecosystems, Land degradation and Desertification, Solar and wind atlas
- being used in the crop insurance scheme in the agriculture sector and the soil health cards campaign
- Used in meteorological and early warning services and Communication services INSAT satellites are used for telecommunications, television, streaming, etc
- geostatonary sateliites are used for meteorlogy and weather related monitoring, forecats and disaster managemnt support.
- Used For Space probes: used to study the planets which can bring valuable information about the space bodies.
- **Used in Tele- medicine :** The digital transmission of medical imaging, remote medical diagnosis and treatment of patients by means of telecommunications technology.
- **Used in Tele - health** is the distribution of health-related services and information via electronic information and telecommunication technologies
- **Used in Tele- education :** an education in which the students receive instruction over the Internet, from a video, etc., instead of going to school

So, The synergistic use of remote sensing, communication and navigation satellites is needed for efficient management and conservation of country's natural resources and maximizing the efficiency of the national missions

Now ISRO Referred As India's SOFT POWER

Reason :

ISRO is pursuing international cooperation with space agencies and space related bodies with the objectives of enhancing the capacity of Indian space program, strengthening diplomatic relations and formulating global guidelines on space.

MAJOR AREAS OF INTERNATIONAL COOPERATON OF ISRO

- Realisation of joint satellite missions;
- accommodation of payloads/instruments in Indian satellites;
- establishment of ground station in other countries to support ISRO's missions;
- sharing of satellite data and expertise; and
- contribution to the global initiatives on disaster management

Ex : Two -Joint Satellite Missions of ISRO and CNES (French national space agency)

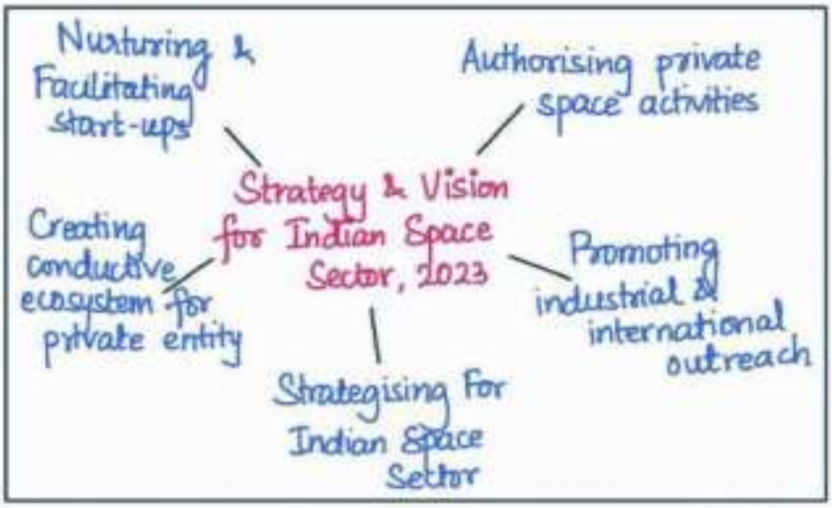
- Megha-Tropiques(launched in 2011)
- SARAL(launched in 2013) : Satellite with ARGOS and ALTIKA (SARAL) is a joint Indo-French satellite mission for oceanographic studies.

ISRO Ground Stations Outside India :

- ISRO is operating Telemetry Tracking and Tele-Command (TTC) ground stations in Indonesia, Brunei and Mauritius.
- ISRO also operates remote sensing data reception station in Antarctica

ISRO SPACE POLICY 2023

- **AIM:** To Promote the growth of the Indian Space Industry
- Involvement of Private Sector/ Parties
- Encourages non-government entities (NGEs) to invest in research and development in the space sector.
- Augment India's Space Capabilities
- Enable and Encourage the Development of Commercial Space Sector in India.
- Pursue International Relations in the Space Sector.



Establishment of a Regulatory Body called (IN-SPACe),

- **The Indian National Space Promotion and Authorisation Centre Under DOS**
- will be responsible for regulating and promoting the commercial space sector in India
- located in Ahmedabad in 2020
- will act as a link between the ISRO and private sector companies

SPACE ORGANISATIONS IN INDIA

Organization	Description
Indian Space Research Organization (ISRO)	• Government of India's nodal agency for space research, under the Department of Space (DOS). • Founded in 1969, headquartered in Bengaluru, Karnataka. • Developed and launched India's own launch vehicles, PSLV and GSLV.
Indian National Space Promotion and Authorization Centre (IN-SPACe)	• Government body established in 2020 to promote private sector participation in space activities. • Facilitates partnerships between ISRO and private companies. • Regulates and encourages Indian industry and startups in satellite construction, rocket development, and commercial launch services.
New Space India Limited (NSIL)	• ISRO's commercial arm, wholly owned by the Government of India. • Collaborates with IN-SPACe to enable industry consortiums to undertake some of ISRO's responsibilities. • Provides commercial services such as satellite launch, ground station services, and data analysis.
Antrix Corporation	• ISRO's commercial arm, founded in 1992. • Promotes and commercializes space products, services, and technology transfer.

Agencies And Institutes: related with ISRO

- Indian Space Research Organisation
  - Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram.
  - Liquid Propulsion Systems Centre (LPSC), Thiruvananthapuram.
  - Satish Dhawan Space Centre (SDSC-SHAR), Sriharikota.
  - ISRO Propulsion Complex (IPRC), Mahendragiri.
  - ISRO Satellite Centre (ISAC), Bangalore.
  - Space Applications Centre (SAC), Ahmedabad.
  - National Remote Sensing Centre (NRSC), Hyderabad.
  - ISRO Inertial Systems Unit (IISU), Thiruvananthapuram.
  - Development and Educational Communication Unit (DECU), Ahmedabad.
  - Laboratory for Electro-Optics Systems (LEOS), Bangalore.
  - Indian Institute of Remote Sensing (IIRS), Dehradun.
  - Master Control Facility (MCF), Hassan, Karnataka and Bhopal**
  - ISRO Telemetry, Tracking and Command Network (ISTRAC), Bangalore.

TT&C (Telemetry, Tracking, and Command) are two fundamental component of space mission, they are crucial for maintaining communication with and control over spacecraft. In the context of space, it's the "eyes and ears" of mission control on Earth

ISRO Ground Stations Outside India :

- ISRO is operating Telemetry Tracking and Tele-Command (TTC) ground stations in Indonesia, Brunei and Mauritius.
- ISRO also operates remote sensing data reception station in Antarctica

ISRO SIX MAJOR CENTRES:

1. Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram;

2. U R Rao Satellite Centre (URSC), Bangalore;
3. Satish Dhawan Space Centre (SDSC – SHAR) at Sriharikota;
4. Liquid Propulsion Systems Centre (LPSC) at Thiruvananthapuram, Bangalore and Mahendragiri,
5. Space Application Centre (SAC), Ahmedabad and
6. National Remote Sensing Centre (NRSC), Hyderabad.

Major Functions of the Six Centres:

Key Centres of ISRO

ISRO Centres	**Specification**
Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram	Building of Launch Vehicles
U R Rao Satellite Centre (URSC), Bengaluru	Designing and Development of Satellites
Satish Dhawan Space Centre (SDSC), Sriharikota	Integration and launching of satellites
Liquid Propulsion Systems Centre (LPSC), Valiamala and Bengaluru	Development of liquid stages including cryogenic stage
Space Applications Centre (SAC), Ahmedabad	Sensors for Communication and Remote Sensing satellites
National Remote Sensing Centre (NRSC), Hyderabad	Remote Sensing satellite data reception processing and dissemination

- Launch Vehicles are build at VSSC Thiruvananthapuram
- Satellites are designed and developed at URSC, Bangalore;
- Integration and launching of satellites and launch vehicles are carried out from SDSC, Shriharikota;
- Development of liquid stages including cryogenic stage is carried out at LPSC,
- Sensors for Communication and Remote Sensing satellites and application aspects of the space technology are taken up at SAC, Ahmedabad and
- Remote Sensing satellite data reception processing and dissemination by NRSC, Hyderabad.

Important For Exam :

- Indian Institute of Space Science and Technology (IIST), Thiruvananthapuram – India's space university. Asia's first Space University, was established at Thiruvananthapuram in 2007
- **Antrix Corporation – The marketing arm of ISRO**, Bangalore Antrix's job is to promote products, services and technology developed by ISRO. (for Foreign)
- **NewSpace India Limited (NSIL**), 2019, Bangalore; Formed Under Department of Space and it is commercial arm of ISRO with objective : enabling Indian industries to take up high technology space related activities (for India/ Domestic)

INDIANS IN SPACE

- **Indian National Rakesh Sharma**. The first Indian to travel to space. He was a part of Soviet Union's Soyuz T-11 expedition, launched on April 2, 1984, as part of the Inter-cosmos programme.
- **Indian-born Kalpana Chawla** (1997)
- **Indian origin, Sunita Williams** (2006)

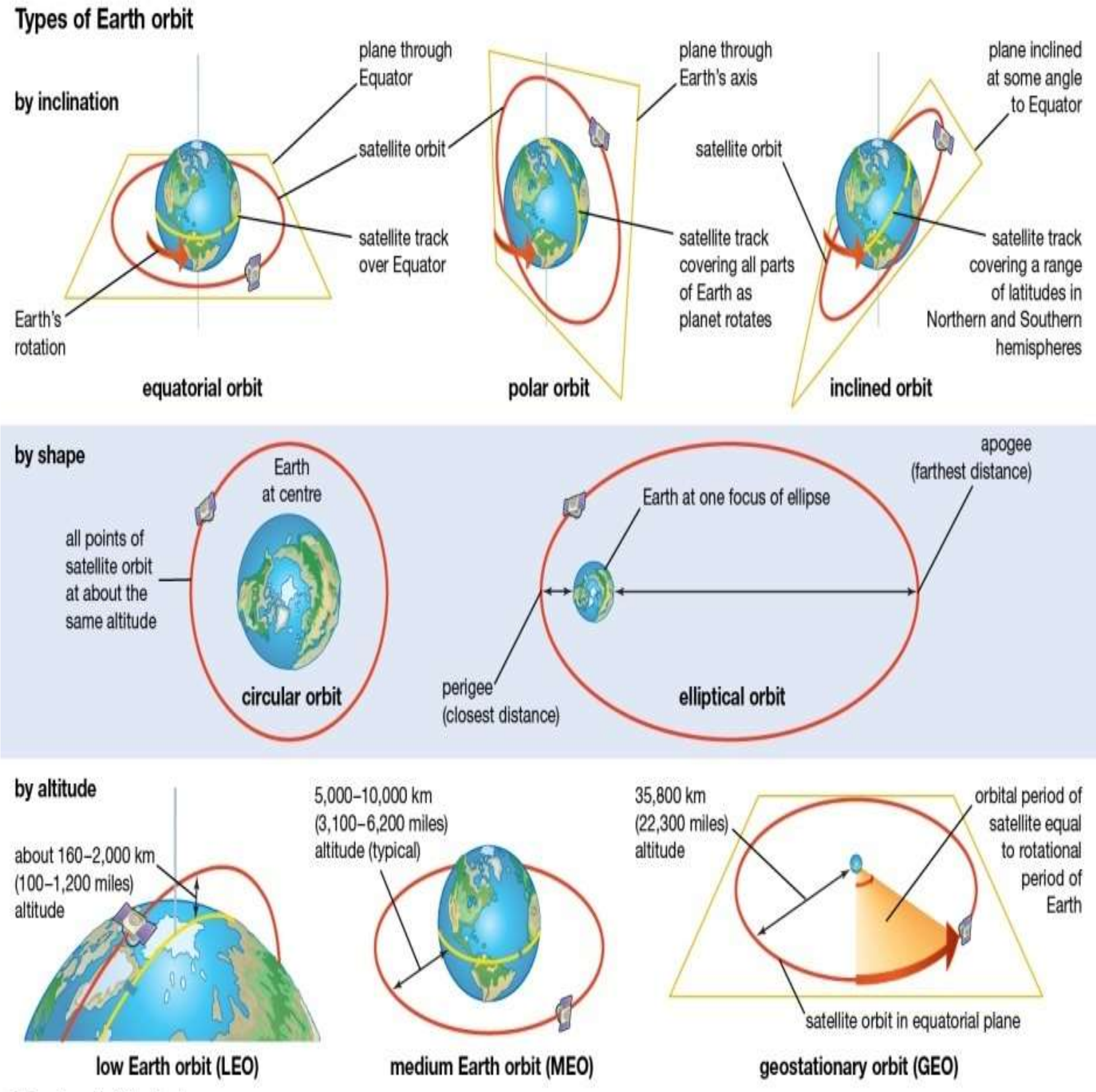
Space Startups in India

New Startup Name	Established	Focus
Dhruva Space Private Limited	2012	Satellite manufacturing and related services
Bellatrix Aerospace	2015	Satellite propulsion systems and technologies
Aadyah Aerospace	2016	Satellite design, manufacturing, launch vehicles, and propulsion
Agnikul Cosmos	2017	Developing a small satellite launch vehicle
Manastu Space	2017	Green technology for space, including alternative fuels, refueling stations, and deorbiting solutions
Skyroot Aerospace	2018	Developing satellite launch vehicles and associated technologies
Satellize	2018	Satellite communication and related services
Pixxel	2019	Building a constellation of Earth observation satellites

Space Start Ups	**Launch Vehicle Name**	**HQ**
Skyroot Aerospace	Vikram series	**Hyderabad**
Agnikul Cosmos	Agnibaan	**Chennai**
Bellatrix Aerospace	**Chetak**	Bengaluru

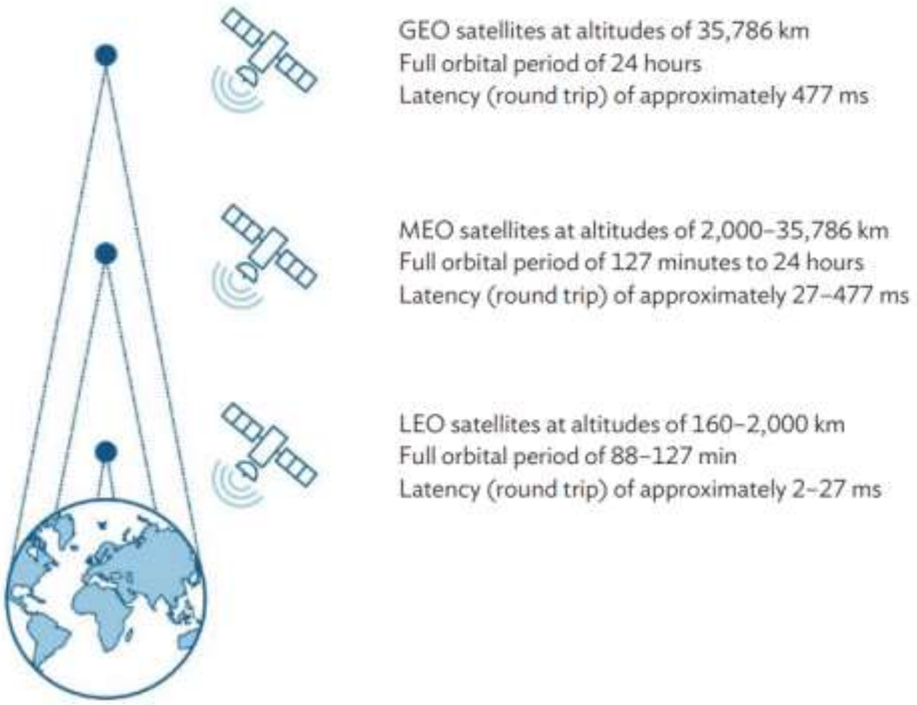
ORBITS

An orbit is the curved path, regular and repeating path that an object in space (such as a star, planet, moon, asteroid or spacecraft) takes around another object due to gravity



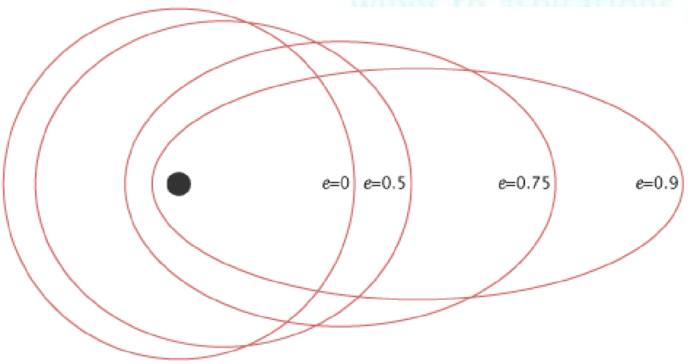
ORBITS CLASSIFICATION

Types of Orbit based on Altitude

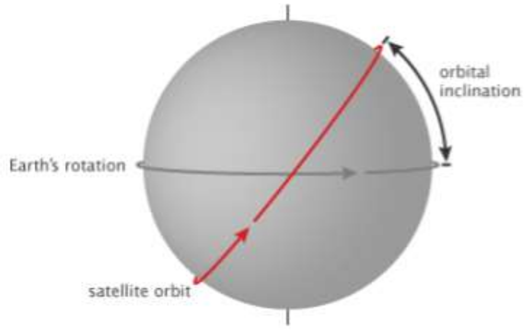


Orbit Name	Altitude (km)	Orbital Period	Applications
High Earth Orbit (HEO)	>35,786	24 hours (geosynchronous)	Communication satellites (GSAT series), weather monitoring
Medium Earth Orbit (MEO)	2,000 - 35,780	12 hours	Global Positioning Systems (GPS, GLONASS, Galileo)
Low Earth Orbit (LEO)	160 - 2,000	90 minutes	Satellite imaging, Earth observation, communication satellites (constellations), International Space Station (ISS)

Speed of Satellite in LEO is More than HEO (due to the higher gravitational force of the Earth acting on the satellite)
The speed of a satellite with respect to earth is inversely proportional to its altitude



Eccentricity of an orbit indicates the deviation of the orbit from a perfect circle. It governs the shape of an orbit (1 or 0) Zero-Circular Orbit and Value 0 or 1 = elliptical orbit
For a **circular orbit**, e=0.- For an **elliptical orbit**, 0<e<1
Orbital inclination: It is the angle between the plane of an orbit and the equator
An orbital inclination of 0°is directly above the equator, and 90°crosses right above the pole (Polar Satellite)



Orbital Inclination

Orbital Period: Time taken by Satellite to complete one revolution. varies between 90 min to 24 H

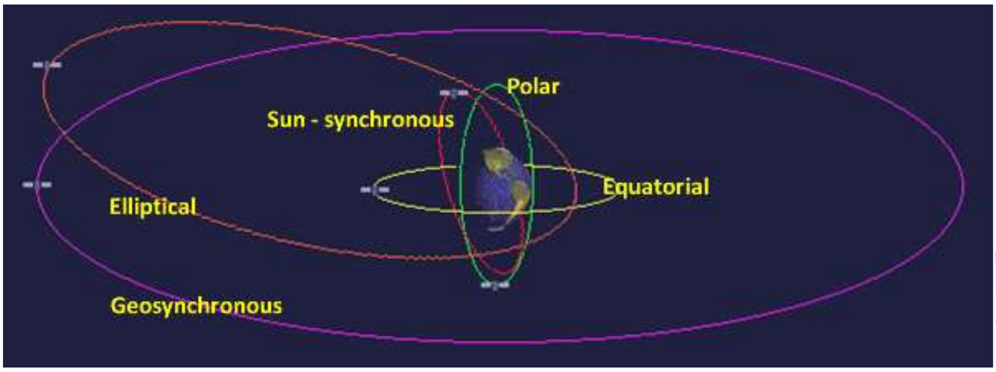
Ex LEO 90 to 100 min (varies 88 – 127) ; MEO - 12 Hours and HEO - 24 Hours

Retrograde and prograde directions describe the motion of satellites in relation to the rotation of body (earth)

Satellite Orbit Moves in Same Direction of Earth Movement - West to East : Prograde Orbit (requires less energy - ex Geostationary communication satellite, International Space station- Inclination Range between 0° and 90° (Equator and Polar Orbit)

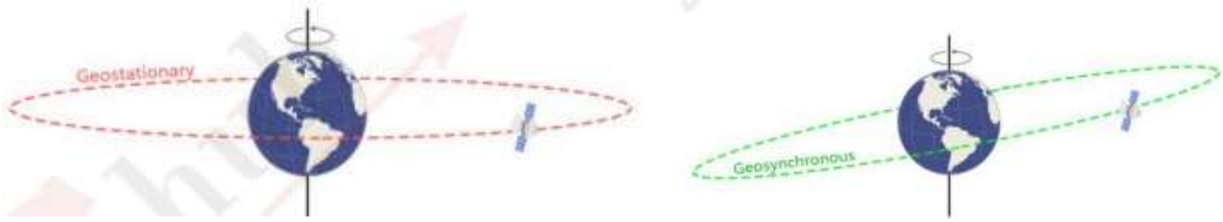
Satellite Orbit Moves in Opposite Direction of Earth Movement : Retrograde Orbit (requires more energy - ex Geostationary communication satellite, International Space station- Inclination Range between 90° and 180°

Ex Israel launches its reconnaissance satellites into retrograde orbits over the Mediterranean Sea to avoid debris falling on populated areas during launch



Types of Orbit based on Functionality

Orbit Type	Description	Altitude (km)	Orbital Period	Applications
Geosynchronous Orbit (GEO)	A high Earth orbit where the satellite appears stationary above a fixed point on Earth.	35,786	24 hours	Weather monitoring, communication, navigation. e..g. INSAT and GSAT series
Polar Orbit	A low Earth orbit passing over Earth's poles.	200-1,000	15 - 16 orbits per day	Earth observation, remote sensing. e.g. Cartosat series of ISRO
Sun-Synchronous Orbit (SSO)	A polar orbit where the satellite passes over the same point on Earth at the same local time.	600-800	~14 orbits per day	Climate change studies, weather prediction, resource management
Transfer Orbits	Intermediate orbits used to move satellites between other orbits.	Varies		Used to transition between different orbits



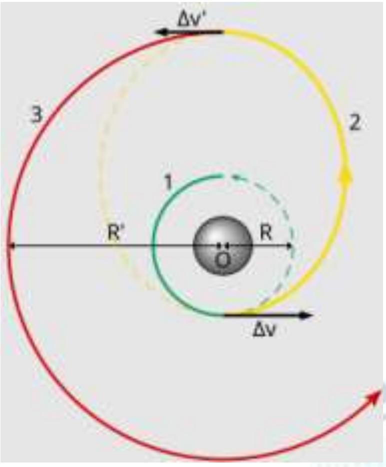
Geostationary Orbit (GSO)

- Distance from Earth remains the Same at all times - 36000km (35784km)-
- circular Path- located only be above Equator(equatorial Plane)
- So there can be only 1 GSO -
- The satellites don't change latitude.
- Orbital Period 24 Hours -
- Zero Eccentricity (circular Orbit) and Zero Inclination(laititude)
- Application : Weather, communication (INSAT and GSAT Series) and global positioning satellites
- 3 geostationary satellites are required to cover entire Earth

Geo Synchronous Orbits (GSnO) or Clarke Orbit

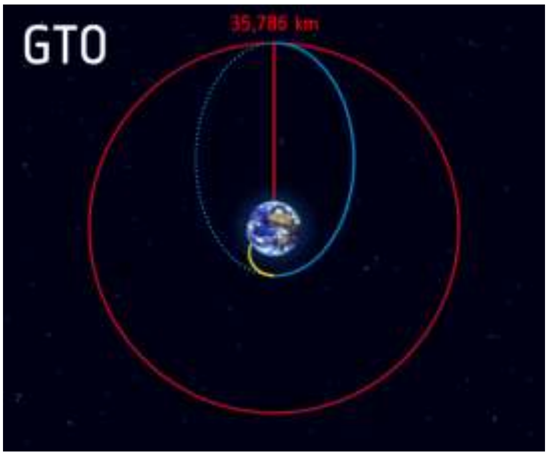
- are almost at a distance of 36,000 km (35,784 km) to the earth.
- The orbit is elliptical ((ie. The distance from the Earth may change)
- The satellites may change latitude
- Orbit may be inclined and may not lie on the equatorial plane. Thus, there can be many geo synchronous orbits.
- Orbital Period: 24 Hours
- Application : monitoring weather, communications and surveillance

Transfer Orbits : are intermediate orbits used to shift a satellite from one orbit to another



Examples:

- **Geostationary Transfer Orbit (GTO):** A very common application. Satellites are launched into a Low Earth Orbit (LEO) and then use a Hohmann transfer to reach Geostationary Orbit (GEO) at approximately 35,786 km above the equator. The GTO is a highly elliptical orbit with its perigee (closest point) in LEO and its apogee near GEO altitude.
- Used to minimizing fuel consumption, optimizing travel time, or leveraging gravitational assists



Statement 1: A transfer orbit allows a spacecraft to directly enter its final operational orbit without any intermediate steps.

Statement 2: The perigee of a Geostationary Transfer Orbit (GTO) is typically at a low Earth orbit altitude.
Answer: d) Statement 1 is false, and Statement 2 is true. (Transfer orbits are intermediate steps.)
Polar orbit is a Low Earth orbit where satellites travel past Earth from north to south; Polar orbit follows a circular shape; hence, eccentricity is close to zero.; Inclination of the polar orbits around 90 degrees, with a deviation ranging from 20 to 30 degrees Application : Remote Sensing Satellites, Resources and Disaster Management)
What is the defining characteristic of a polar orbit?
a) Its orbital plane is aligned with the Earth's equator.
b) Its orbital plane is inclined at approximately 45 degrees to the Earth's equator.
c) Its orbital plane passes over or very near the Earth's poles.
d) Its orbital plane remains fixed relative to the stars.
Answer: c) Its orbital plane passes over or very near the Earth's poles.
Which of the following applications heavily relies on data from satellites in polar orbits?
a) Telecommunications for fixed locations.
b) Global Positioning System (GPS).
c) Weather forecasting and Earth observation.
d) Direct-to-home television broadcasting.
Answer: c) Weather forecasting and Earth observation.
What is the typical inclination of a sun-synchronous orbit, a special type of polar orbit?
a) 0 degrees
b) 90 degrees
c) Approximately 98 degrees (depending on altitude)
d) 180 degrees
Answer: c) Approximately 98 degrees (depending on altitude)
Que : Consider the Statements:
Statement 1: Satellites in polar orbits experience significant atmospheric drag due to their high altitudes.
Statement 2: Polar orbits are well-suited for monitoring changes in ice caps and deforestation.
Answer: d) Statement 1 is false, and Statement 2 is true. (Polar orbits are often at lower altitudes where drag is more significant, but the statement itself is incorrect about *significant* drag being due to high altitude. Their coverage makes them ideal for monitoring.)
Que : Consider the Statements:
Statement 1: Polar orbits are primarily used for telecommunications because they offer global coverage.
Statement 2: The orbital period of a satellite in a polar orbit is typically 24 hours to allow for consistent daily coverage.
Answer: d) Statement 1 is false, and Statement 2 is true. (Polar orbits are not primary for real-time telecommunications due to the movement relative to ground stations. Their periods are much shorter than 24 hours.)
Molniya Orbit

- Molniya orbit is part of MEO .
- Used for High Altitude Observation in Polar Regions to observe the impact of climate change on polar regions

What is the primary distinguishing feature of a Molniya orbit?
a) It is a circular orbit at a low Earth altitude.
b) It is a geostationary orbit over the equator.
c) It is a highly elliptical orbit with a high inclination (around 63.4 degrees) and a long dwell time over high latitudes.
d) It is a sun-synchronous polar orbit.
Answer: c) It is a highly elliptical orbit with a high inclination (around 63.4 degrees) and a long dwell time over high latitudes.
The high eccentricity of a Molniya orbit results in:
a) Continuous coverage of the entire Earth.
b) A long period of slow movement over one hemisphere and a fast movement over the other.
c) A constant altitude above a specific point on Earth.
d) Minimal atmospheric drag.
Answer: b) A long period of slow movement over one hemisphere and a fast movement over the other.
Molniya orbits are particularly well-suited for providing communication services to:
a) Equatorial regions.

b) Mid-latitude regions.
c) High-latitude regions.
d) Ocean areas.
Answer: c) High-latitude regions.
Consider the Statements :
Statement 1: Molniya orbits are circular, allowing for consistent signal strength throughout their orbit.
Statement 2: The highly elliptical shape of a Molniya orbit causes the satellite to appear to move slowly across the sky at apogee and quickly at perigee for ground observers in the apogee's hemisphere.
Answer: d) Statement 1 is false, and Statement 2 is true.
International Space Station (ISS)

- orbit in LEO, At altitude apprx 400 km
- In Sun Synchronous orbit
- **ISS Orbits West to East covering every Part of Land on the Earth, but excludes the Polar Regions**
- is a joint project between **five participating space agencies:** **NASA** (UniteStates), **Roscosmos** (Russia), **JAXA** (Japan), **ESA** (Europe), and (Canada).
- **China is not related with ISS**
- **Inclination :** 51.65° prograde Low Earth Orbit (LEO)

Tiangong Space Station:

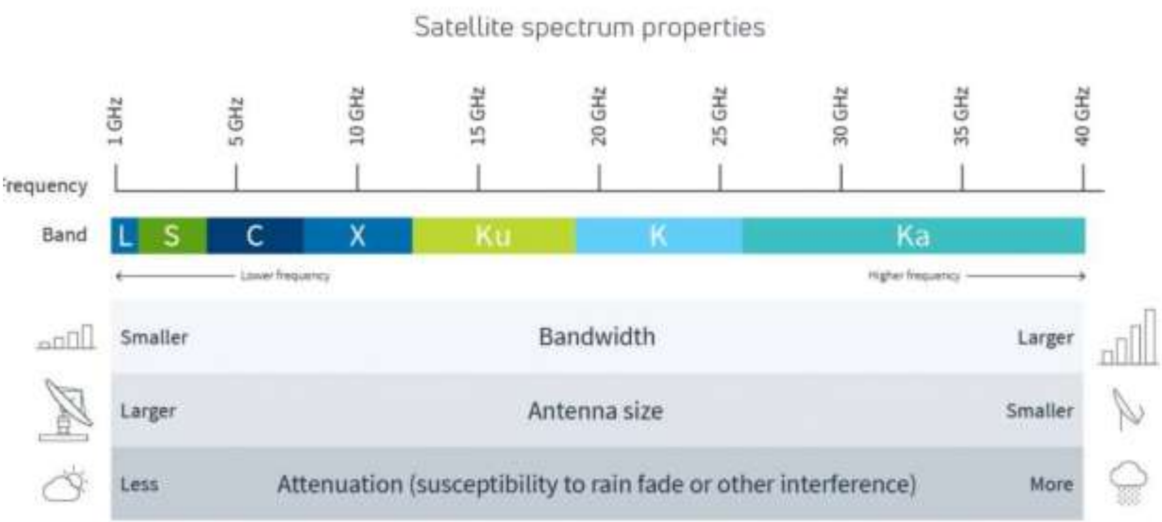
- China's space station in LEO
- Tiangong is **smaller than the International Space Station**
- It can **accommodate up to three astronauts** at a time for six-month stays
- The International Space Station (ISS) orbits at a slightly higher altitude, with different Orbital Inclinations than Tiangong

SATELLITE
Define : Satellites are celestial bodies that orbit larger bodies, such as planets
Types : Natural and Artificial

- Artificial satellites are placed in various orbits using rockets and equipped with instruments for a wide range of applications.
- An artificial satellite orbiting around the Earth does not fall down. This is so because the attraction of Earth Provides the necessary acceleration for its motion. [UPSC 2011]

Why Don't Satellites Crash Into Each Other?

- Actually, they can
- Collisions are rare because when a satellite is launched, it is placed into an orbit designed to avoid other satellites.
- But orbits can change over time. And the chances of a crash increase as more and more satellites are launched into space.
- The motion of satellites in space is highly precise and governed by complex mathematical calculations to ensure they stay on their designated paths and avoid collisions with other satellites or space debris.



Basic Band and Their Use

- L - Band(1 -2 GHz) : Global Positioning System Carriers and Satellite Mobile Phones.
- S - Band(2- 4 GHz) : Radar and Communication Satellites.
- C- Band(4 -8 GHz) : TV network satellite communications
- X- Band(8-12GHz) : meteorological satellite and Military
- Ku -Band (12- 18 GHz): Satellite Communications
- Ka -Band (26- 40 GHz): Satellite Communications (close range high resolutions applications)

SATELLITE USED FREQUENCY BANDS

- L-band (1–2 GHz)
- S-band (2–4 GHz)
- C-band (4–8 GHz)
- X-band (8–12 GHz)
- Ku-band (12–18 GHz)
- Ka-band (26–40 GHz)

GHz: Unit of Frequency: Equal to 1 Billion hertz ; Used to Measure Computer Processing Speed and Electromagnetic Frequencies.

Higher Frequency : Carry More Data ; require More Power ; But More susceptible to Interference

Lower Frequency : Carry Less Data; require Less Power; But Less susceptible to Interference

These Bands are divided on the Basis of Frequency and associated Factors like

- Bandwidth
- Antenna Size
- Attenuation : Susceptibility to rain interference
- Throughput : amount of data that can be transmitted between satellite and ground station in a given amount of time.

Means :

- Low Earth Orbit Satellites : Higher Throughput (Reason Nearness to the Earth
- Geo Stationary Satellites : Lesser Throughput (Reason their distance from the Earth)
- Higher Throughput Means : Higher Frequencies ; Faster Downloads; More Reliable Connections ; increased video streaming quality ; Improved Performance (Think Conversely : Lower Throughput Means

So Increasing Satellite Throughput Capacity can provide range of benefits to Business or Country Economy . (competitive advantage)

- Smaller Antennas : can receive and transmit Less data (Low Throughput Capacity)
- Larger Antennas : can receive and transmit More data (Higher Throughput Capacity)

Latency : delay in signal transmission

LEO : Low Latency

MEO: Medium latency

HEO satellite have high latency Variable latency (low at perigee, high at apogee)

So , When selecting a Satellite System this Factors are More Critical or Essential .

SATELLITE TECHNOLOGY USE FOR

- Telephone/ Mobile Communications
- Broadcasting - Tv, Radio , digital cinema
- Astronomy studies
- Transport ,Communication, Navigation.
- Weather Forecasting
- Internet Access, Data transmission
- Mapping
- Earth Observation, and Space exploration

TYPES OF SATELLITES

Satellites are broadly classified into two, viz., Communication satellites and Remote Sensing satellites.

Type of Satellite	Purpose	Examples
Earth Observation Satellites (EOS)	Long-term observation of Earth's atmosphere, biosphere, lithosphere, and oceans, Weather forecasting, climate monitoring, disaster warning	Cartosat, Oceansat, Resourcesat, EOS-04
Navigation Satellites	Geospatial services, navigation, and positioning	GPS, GLONASS, Galileo, BeiDou, NavIC
Communication Satellites	Telecommunication, broadcasting, internet services	INSAT, Starlink, OneWeb, GSAT31

EARTH OBSERVATION SATELLITES	COMMUNICATION SATELLITES
A remote-sensing satellite studies & gathers data regarding the Earth's **surface** and **atmosphere**. **Applications**: agriculture, water resources, urban planning, rural development, mineral prospecting, environment & biodiversity mapping, forestry, ocean resources and disaster management.	They are used for communicating over large distances, through a wireless communication, using a transponder to send and receive data from Earth. **Applications:** Telecommunications, television broadcasting, satellite newsgathering, societal applications, weather forecasting, disaster warning and Search and Rescue operations.
Indian Remote Sensing (IRS) Satellite system is one of the largest constellations of remote sensing satellites in operation. **Includes:** RESOURCESAT-1, 2, 2A CARTOSAT-1, 2 series, RISAT-1, 2 & 2B, OCEANSAT-2, Megha-Tropiques, SARAL and SCATSAT-1, HysIS etc.	**Indian National Satellite (INSAT)** system is one of the largest domestic communication satellite systems in Asia-Pacific region • **Includes** - INSAT-3A, 3C, 4A, 4B, 4CR, Kalpana and GSAT • **Note:** Kalpana and INSAT 3A are both, a communication & an Earth Observation satellite (source: ISRO) • INSAT 3D & 3DR are Weather satellites (Thus, sometimes included under Earth Observation Satellite) (source: ISRO)
Earth observation satellites are placed mostly in **Sun-synchronous Polar orbit**	All Communication satellites are placed in **Geo-stationary** or **Geo-synchronous orbits**
Earth observation satellites are launched using **PSLV** (Polar Satellite Launch Vehicle)	Communication satellites are primarily launched using **GSLV** (Geo Synchronous Launch Vehicle)

Primary Function	Collect data about Earth's surface, atmosphere, and oceans.	Transmit and relay telecommunication signals (voice, data, video).
Altitude Range	Primarily 160 km to 1,500 km (LEO), but can be up to 36,000 km (GEO).	Primarily 35,786 km (GEO), but can be 160 km to 2,000 km (LEO) or 10,000 km to 20,000 km (MEO).
Ground Station Interaction	Data downlink to specific receiving stations.	Two-way communication link with ground stations (uplink/downlink).
Latency/ Delay	Generally less critical, though real-time data is sometimes required.	Critical for real-time applications (e.g., voice calls, live video). Lower in LEO, higher in GEO.
Coverage Area	Varies by orbit; LEO provides high-resolution, smaller swath; GEO provides wide-area, continuous view.	GEO offers very wide, continuous coverage from a single satellite. LEO constellations offer global coverage with many satellites.
Applications	Weather forecasting, climate monitoring, environmental monitoring, disaster management, mapping, urban planning, agriculture, intelligence/reconnaissance.	Television broadcasting, radio broadcasting, mobile phone services, internet access, telemedicine, military communications, emergency services.

- Geostationary Communication Satellites :
  - **INSAT Series:** Indian National Satellite System (GEO)
  - **GSAT Series**
  - **EDUSAT**
  - **HAMSAT**

A Remote Sensing satellite is intended for natural resource monitoring and management and operates from a Sun Synchronous Polar Orbit (SSPO).

- **Earth Observation Satellites : Used For** Earth, Climate , Ocean , Disaster Observation (USE POLAR ORBITS and LEO)
  - IRS Series : Indian Remote Sensing Satellite , Example like
  - CARTOSAT
  - RESOURCESAT
  - OCEANSAT
  - RISAT
  - ASTROSAT : Astronomy Related Satellite ,
  - Hubble Telescope and James Web Space Telescope
  - Spy Satellites or Reconnaissance Satellite for Intelligence or Military Applications
- **Navigation Satellites :**
  - **GPS :**Global positioning system
  - **GAGAN**

IRNSS Now NAVIC

ISRO SATELITES

Type	Satellite Name	Purpose
Communication	CMS-01	Launched in 2017 for various communication services, including broadband connectivity and satellite newsgathering.
	GSAT 7A (Angry Bird)	Launched in 2018, provides broadband connectivity to remote areas of India.
	GSAT-11	Launched in 2018, offers high-throughput broadband services for various applications.
Earth Observation	OCEANSAT-3	Launched in 2022, studies oceans and atmosphere, providing data for weather forecasting, climate monitoring, and natural resource management.
	RISAT-2	Radar imaging satellite launched in 2019, used for Earth observation, disaster management, and agricultural applications.
Satellite Navigation	NAVIC (Navigation using Indian Constellation)	India's regional navigation satellite system, providing accurate positioning, navigation, and timing services to users in India and the surrounding region.
Sun Studies	ADITYA L1	Solar mission launched in 2023 to study the Sun's outer atmosphere and solar wind. Solar mission placed at the L1 Lagrange point to observe the Sun's corona and other aspects of solar activity.

Global Navigation Satellite System

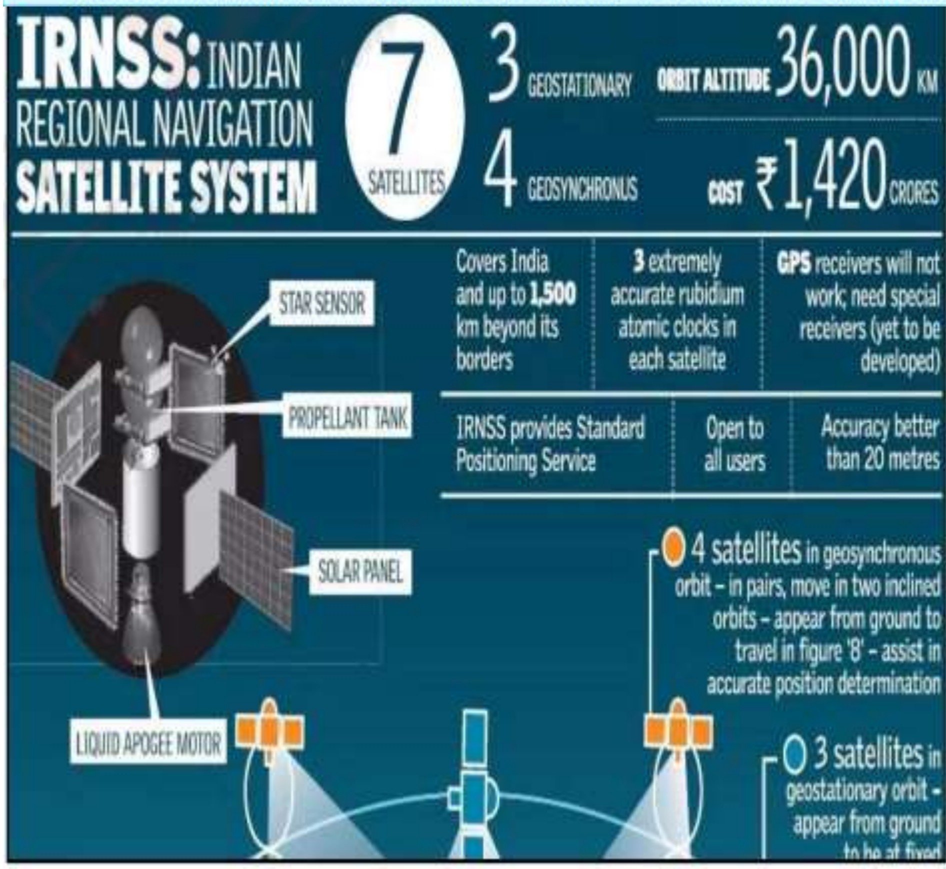
- **About**: Global navigation satellite system (GNSS) is a general term describing any satellite constellation that provides positioning, navigation, and timing (PNT) services on a global or regional basis.
- **Several GNSS constellations around the world**:
  - BeiDou – China
  - Galileo – European Union
  - GLONASS – Russia
  - GPS - United States
  - IRNSS – India (also known as NavIC)
  - QZSS – Japan

GPS Aided GEO Augmented Navigation (GAGAN),

- is implemented jointly by ISRO and Airport Authority of India (AAI).
- The main objectives of GAGAN are to provide Satellite-based Navigation services with accuracy and integrity required for civil aviation applications and to provide better Air Traffic Management over Indian Airspace.

IRNSS-NavIC **[UPSC 2018]**

- The Navigation with Indian Constellation (NavIC) satellite system is an autonomous regional navigation satellite system that provides location data in the Indian area and 1500 kilometers surrounding the Indian landmass.
- IRNSS would offer two types of services Standard Positioning Services, which would be available to all users, and Restricted Services, which would only be available to permitted users.
- There are seven satellites in all. **Three** will be geostationary above the Indian Ocean and **four** will be geosynchronous.



.Q With reference to the Indian Regional Navigation Satellite System (IRNSS), consider the following statements:

1. IRNSS has three satellites in geostationary and four satellites in geosynchronous orbits.
2. IRNSS covers entire India and about 5500 sq. km beyond its borders.
3. India will have its own satellite navigation system with full global coverage by the middle of 2019. Which of the statements given above is/are correct? (2018)

(a) 1 only (b) 1 and 2 only (c) 2 and 3 only (d) None

Ans A

ROCKET TECHNOLOGY

SPACE PORT OF INDIA :

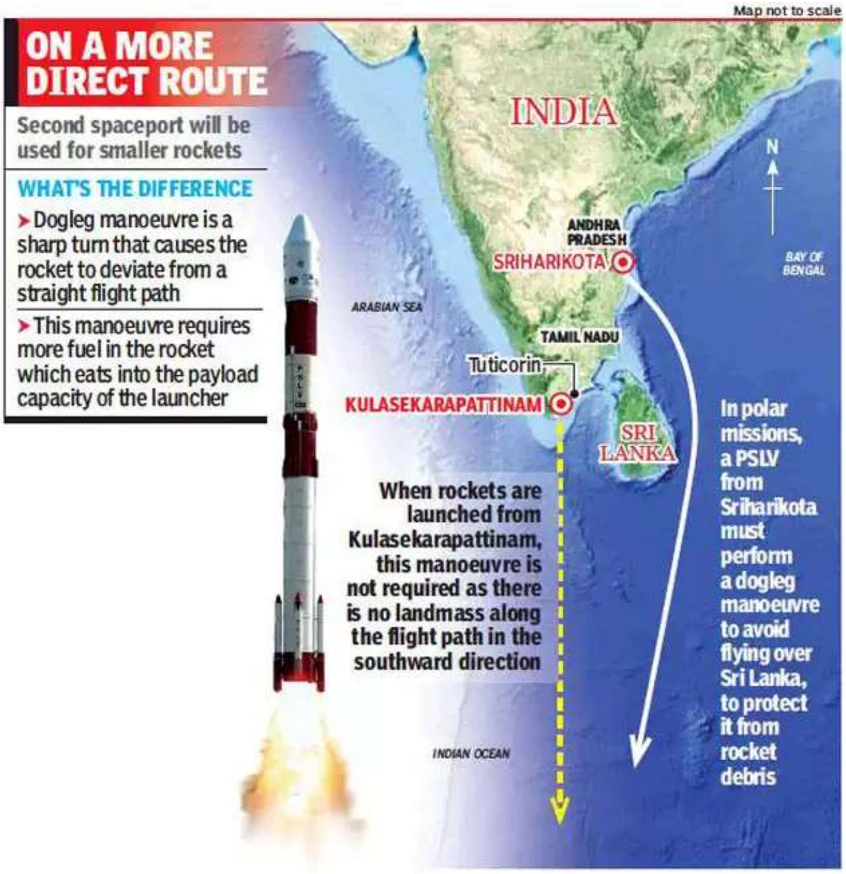
1 Shriharikota :

Location: 13.7178°N 80.2000°E Elevation 1 M

located north of Chennai city.

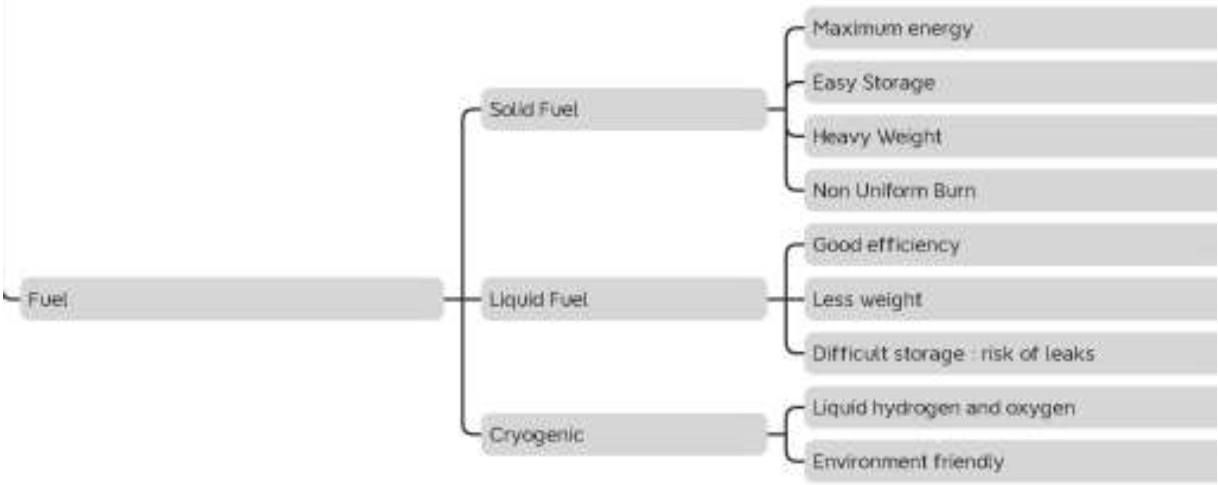
Sriharikota

- Barrier Island Located in Nellore Andhra Pradesh, previously but now part of Tirupati district
- Satish Dawan Space Centre Located Here
- PSLV and GSLV, Sounding rockets launched here
- Impacted Pulicat lake and Nelapattu Bird Sanctuary



Parameter	Satish Dhawan Space Centre (SDSC), SHAR	Thumba Equatorial Rocket Launching Station (TERLS)	SSLV Launch Complex (Kulasekarapattinam)
Location	Sriharikota, Tirupati district, Andhra Pradesh	Thumba, Thiruvananthapuram, Kerala	Kulasekarapattinam, Thoothukudi district, Tamil Nadu
Primary Operator	ISRO (Indian Space Research Organisation)	ISRO (Vikram Sarabhai Space Centre)	ISRO
Current Stat	**Fully Operational**	**Operational (for sounding rockets)**	**Under Construction** (Expected operational in ~2026-2027)
Type of Launches	**Orbital launches:** PSLV, GSLV, LVM3, SSLV (also sounding rockets)	**Sub-orbital launches:** Sounding rockets (e.g., Rohini series)	**Orbital launches:** Primarily Small Satellite Launch Vehicle (SSLV)
Key Advantage/Purpose	**India's primary spaceport** for all major satellite and interplanetary missions. Advantageous for launching to various orbits (LEO, SSO, GTO, GEO) due to its eastward launch path over the Bay of Bengal.	**Proximity to Earth's magnetic equator**, ideal for atmospheric and ionospheric research using sounding rockets. Historically significant as the birthplace of India's space program.	**Optimized for direct southward launches** to polar orbits (Sun-Synchronous Orbit - SSO) without requiring a "dog-leg" maneuver over land, saving fuel and increasing payload capacity for SSLVs.

Launch Vehicles used Rocket Fuel called" Propellant "



Solid Propellants:

- Hydroxyl-terminated polybutadiene (HTPB)
- Ammonium Perchlorate (AP)
- **Aluminium powder:** Added as a fuel to increase the energy output.

Liquid Propellants (Earth-Storable/Hypergolic)

- Unsymmetrical Dimethylhydrazine (UDMH)
- Nitrogen Tetroxide (N_2O_4) (oxidizer)
- Monomethylhydrazine (MMH)

Cryogenic Propellants

- Liquid Hydrogen (LH_2)= Stored at extremely low temperatures (-253°C), it's a highly efficient fuel.
- **Liquid Oxygen (LOX or LO_2):** Stored at -183°C, it's the oxidizer for liquid hydrogen.

- Propellant is the chemical mixture burned to produce thrust in rockets and consists of a ***fuel and an oxidizer***.

Propellant	Description
Solid Propellant	They consist of a casing filled with a mixture of solid compounds (fuel and oxidizer) which burn at a rapid rate, expelling hot gases from a nozzle to produce thrust.
Liquid Propellant	The fuel and oxidizer are stored in separate tanks (liquid form), and are fed to a combustion chamber where they are combined and burned to produce thrust.
Cryogenic Propellants	Cryogenic propellants are liquefied gases stored at very low temperatures Example- ***Liquid hydrogen (LH_2)*** as fuel and ***liquid oxygen (LO_2 or LOX)*** as oxidizer.
Hybrid Propellants	One of the substances is solid, usually the fuel, while the other, usually the oxidizer, is liquid.
Hypergolic Propellants	Hypergolic propellants are fuels and oxidizers that ignite spontaneously on contact with each other and require *no ignition source*.
Green Propellants	The propellants are based on ***Glycidyl Azide Polymer (GAP)*** as fuel and ***Ammonium Di-Nitramide (ADN)*** as oxidizer. Green propellant combinations - *Hydrogen Peroxide (H_2O_2), Kerosene, Liquid Oxygen (LOX), Liquid Methane* ISRO has successfully developed ***ISROSENE***, a rocket grade version of kerosene as an alternative to conventional hydrazine rocket fuel.

Hybrid Propellant : mixture of solid and liquid propellant engines.

CRYOGENIC ENGINE

- **is a low temperature based technology.**
- **makes use of Liquid Oxygen as oxidiser(LOX) and Liquid Hydrogen as fuel (LH2) as propellants which liquefy at -183 deg C and -253 deg C respectively.**
- **The United States, Russia, Japan, India, France and China are the only countries that have operational cryogenic rocket engines.**

VIKAS ENGINE:

- **Vikram Ambalal Sarabhai (VIKAS) is liquid fuel rocket engine built by ISRO**
- **Used to Launch PSLV (second Stage) and GSLV Mark I, II, III**
- LVM3 (Launch Vehicle Mark III) / GSLV Mk III used this engine in core liquid stage
- **Vikas Engine not Used in SSLV**
- **Reusable Launch Vehicle:** Under development, likely to be used in liquid stages.

Applications of Cryogenic Technology

- In Rocket Engine
- Frozen Food
  - Blood Banking
  - Infrared Sensors
  - Electronics
  - X-Rays
  - Preservation of Bodies
  - Grinding
  - Superconductivity
  - used in industrial and medical applications.
  - used for the magnets of magnetic resonance imaging (MRI) systems in most hospitals.
  - fast freezing of some foods and the preservation of some biological materials such as livestock semen as well as human blood, tissue, and embryos.

Disadvantages:

- Storage,
- huge initial capital investment,
- very sophisticated technology requiring high level of technical expertise

Feature	Jet Engine	Rocket Engine
Oxidizer	Atmospheric oxygen (air-breathing)	Carries its own oxidizer
Operating Environment	Primarily within Earth's atmosphere	Operates in atmosphere and vacuum of space
Intake	Requires an air intake for oxygen	No air intake needed
Fuel	Typically kerosene-based fuels (Jet A, etc.)	Variety of fuels (liquid, solid, hybrid) + oxidizer
Combustion	Fuel burns with ingested air	Fuel burns with internally carried oxidizer
Thrust Generation	Acceleration of exhaust gases using intake air	Acceleration of exhaust gases from internal propellants

Restart Capability	Typically can be restarted	Liquid and hybrid can be restarted; solid cannot
Lift	Relies on wings for lift	Generates thrust for both lift and propulsion

AIR BREATHING ENGINES

- These engines utilize atmospheric air for combustion, making them efficient and effective for high-speed flight.
- In the burning of fuel, air-breathing engines utilize oxygen from the environment.
- Efficiency at Various Speeds
- Ex The turbojet, turbofan , ramjet, Scramjet are among them

TYPES OF AIR BREATHING JET ENGINES:

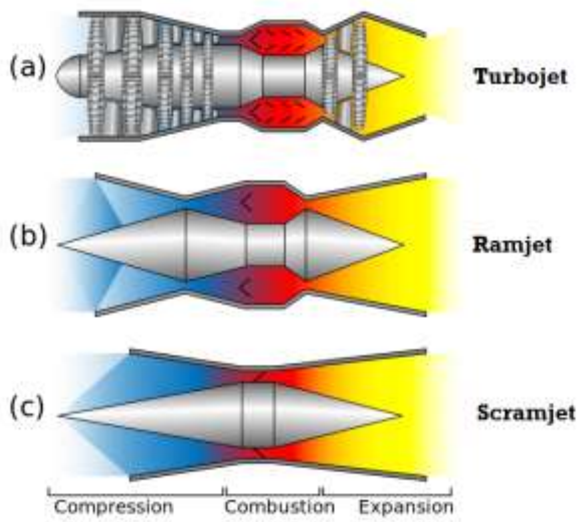
Turbojet - first type of these engines developed for military aviation

They operate by compressing incoming air, mixing it with fuel, and igniting the mixture to produce thrust and known for high speed capabilities but have lower efficiency at subsonic speeds.

Speed Range	Mach Number
Subsonic	< 0.8
Transonic	0.8 - 1.2
Supersonic	1.2 - 5
Hypersonic	5 - 10
High-hypersonic	10 - 25

Turbofan engine :

- More efficient at subsonic speed
- are more fuel-efficient and quieter than turbojets
- it is fusion of turbojet and turboprop engines (use gas turbine to power propeller)
- Modern airliners, military transport, fighters
- Ex : Tejas, Sukhoi 30MKI, MIG-29, Rafale Fighter planes used turbofan engines and commercial aircrafts



Ramjet:

- It is an air breathing propulsion engine operating on the principle of supersonic combustion
- It has the absence of any rotator and relies solely on the forward motion of the engine to compress incoming air
- The ramjet gets its name from this fact; it "rams" the air hard enough to compress it to a combustible pressure.

Scramjet:

- **supersonic combustion ramjet**
- A scramjet engine is superior to a ramjet engine because it can run at hypersonic speeds while still allowing supersonic combustion
- **It carries liquid Hydrogen as fuel and liquid Oxygen for combustion (oxidiser) to generate thrust**

- **Increase Speed, More Fuel Efficient, Good Performance than Ramjet**
- **Speed - greater than Mach 5 to 10**
- **Just like the Ramjet engines, they also have no moving parts**
- The USA, Russia, India, and China (2014), have succeeded at developing scramjet technologies

So Scramjet Technology used in **cruise missiles**, **ballistic missiles**, and **space launch vehicles**

Scramjet Technology Used in Rockets in initial Ascent, to reduce oxidiser load, increasee pay load capacity and reduce launch costs and scramjets cannot be used for the primary propulsion of upper stages that operate outside the Earth's atmosphere. However, they could potentially be used for atmospheric reentry and landing of reusable stages

Dual Mode Ramjet (DMRJ):

- type of jet engine where a **ramjet transforms into a scramjet over Mach 4-8 range,**
- **It** can **efficiently operate both in subsonic and supersonic combustion modes.**

TYPES OF ROCKETS:

- **Sounding Rockets**

Sounding rockets

- are single- or two-stage solid-propellant rockets designed to carry scientific instruments into the upper atmosphere for research purposes. They provide valuable data on atmospheric conditions, ionospheric studies, and other space-related phenomena.
- ISRO's Beginnings: India launched its first sounding rocket, the RH-500, in 1963 from Thumba, near Thiruvananthapuram, marking the beginning of its space program

  The Rohini Sounding Rocket (RSR) Program:

  - Consolidation: Established in 1975, the RSR program consolidated all sounding rocket activities in India.
  - Payloads: These rockets carried various payloads ranging from 8 to 100 kg, including instruments to study the atmosphere, ionosphere, and solar radiation.

To Launch Satellites in Orbit We Need Launch Vehicles :

Launch Vehicles (LV)

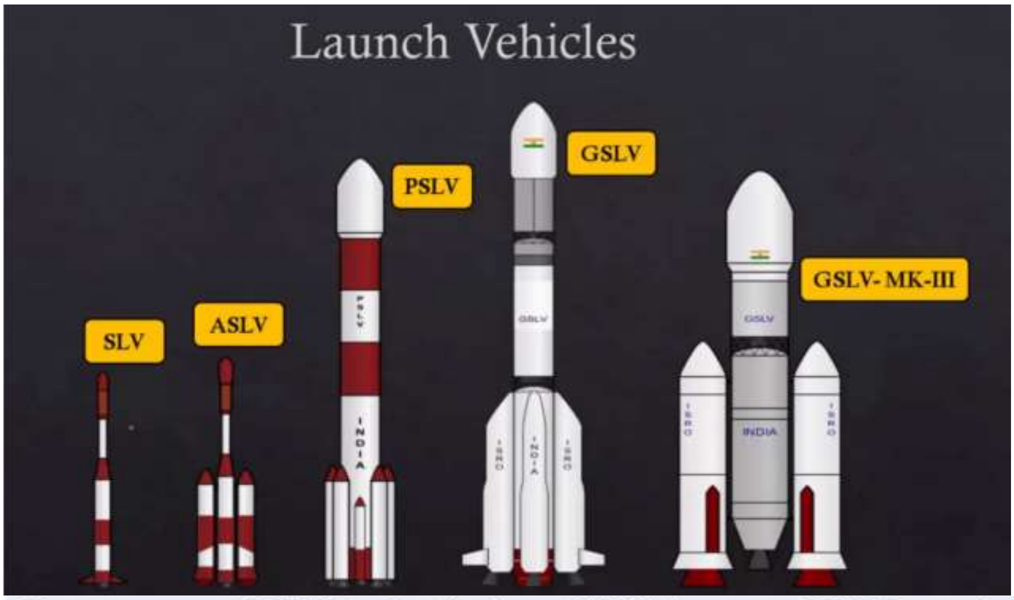
- rocket Powered Vehicle used to transport and put satellites into Space.
- In India LV development Program began in early 1970s.

  1. Satellite Launch Vehicle (SLV) 1980s
  2 Augmented Satellite Launch Vehicle (ASLV) 1990s
  3. Polar Satellite Launch Vehicle (PSLV)

4. Geosynchronous Satellite Launch Vehicle (GSLV)

Augmented SLV

- second generation launch vehicle
- Five stage , all solid Propellant
- weighing 40 tonnes
- Height 23.8 m
- capable of orbiting 150 kg class satellites into 400 km circular orbits



Feature	PSLV (Polar Satellite Launch Vehicle)	GSLV (Geosynchronous Satellite Launch Vehicle)
Primary Orbit Type	Sun-Synchronous Polar Orbit (SSPO), Low Earth Orbit (LEO)	Geosynchronous Transfer Orbit (GTO), Geostationary Orbit (GEO)
Main Payload Focus	**Earth observation**, remote sensing satellites, navigation (IRNSS)	**Communication** and heavier satellites
Number of Stages	Four	**Three** (GSLV Mk II), **Three with strap-ons** (LVM3/GSLV Mk III)
Stage Propulsion	Stage 1: Solid; Stage 2: Liquid (Vikas); Stage 3: Solid; Stage 4: Liquid	GSLV Mk II: Stage 1: Solid with liquid strap-ons (Vikas); Stage 2: Liquid (Vikas); Stage 3: Cryogenic LVM3: Stage 1: Solid Strap-ons; Stage 2: Liquid (Vikas - Dual Engine); Stage 3: Cryogenic
Strap-on Boosters	Uses **solid** strap-on motors (various configurations: 0, 2, 4, 6)	Uses **liquid** strap-on boosters (4 Vikas engines in GSLV Mk II & LVM3)
Upper Stage	Liquid propellant engines	**Cryogenic Upper Stage (CUS)** using liquid hydrogen and liquid oxygen
Payload Capacity to LEO	~1750 kg (to SSPO of 600 km)	~5 tonnes (LVM3 can carry ~8 tonnes)
Payload Capacity to GTO	~1425 kg	~2.2 tonnes (GSLV Mk II), ~4 tonnes (LVM3)
Reliability	Considered a **very reliable workhorse** of ISRO	Initial flights had lower success rates, reliability has improved significantly
Key Missions	Chandrayaan-1, Mars Orbiter Mission, Aditya-L1, IRNSS constellation	INSAT series, GSAT series, Chandrayaan-2

With reference to India's satellite launch vehicles, consider the following statements:

1. Polar satellite launch vehicles (PSLVs) launch satellites useful for Earth resources monitoring whereas Geosynchronous Satellite Launch Vehicle (GSLVs) are designed mainly to launch communication satellites.

2. Satellites launched by PSLV appear to remain permanently fixed in the same position in the sky, as viewed from a particular location on Earth.

3. GSLV Mk III is a four-stage launch vehicle with the first and third stages using solid rocket motors, and the second and fourth stages using liquid rocket engines.

Which of the statements given above is/are correct? (2018)

(a) 1 only

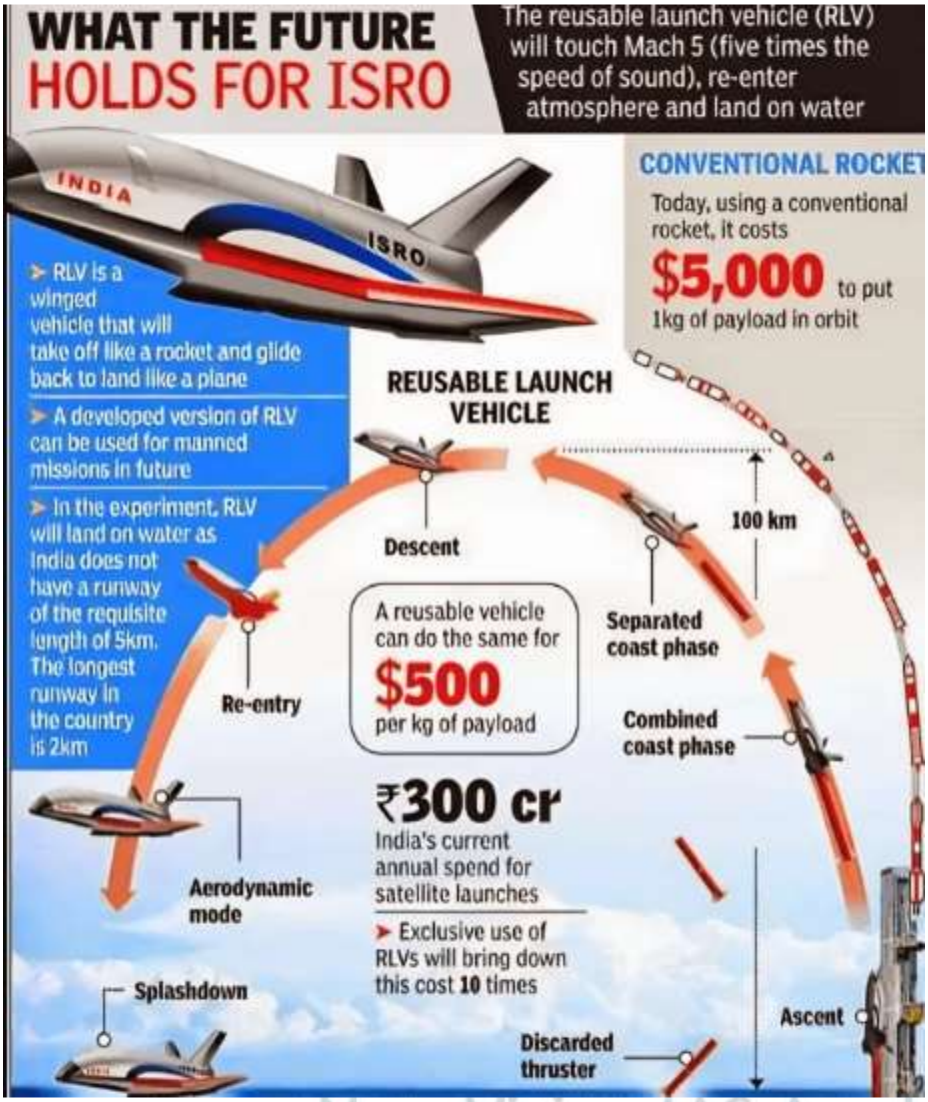
(b) 2 and 3

(c) 1 and 2

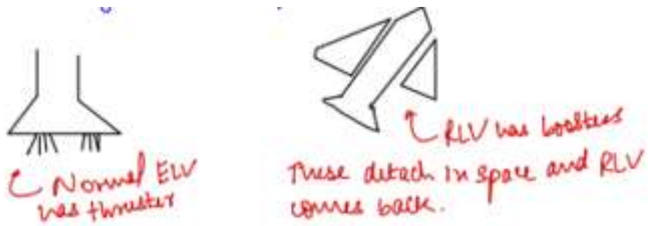
(d) 3 only

Ans A

Pushpak : ISRO RLV- Reusable Lauch Vehicle- In a first in the world, a winged body has been carried to an altitude of 4.5 km by a helicopter and released for carrying out an autonomous landing on a runway.



- RLV uses a winged air-craft which re enters and returned back to the earth
- Use Boosters to go to outer space.
- 2 stage to orbit launch vehicle
- RLV is more cost effective wrt ELV



Satellite Launch Vehicle (SLV)

- India's first experimental satellite launch vehicle
- all solid Fuel
- It is a 3-stage launch vehicle configured with three Solid Propulsion Stages and liquid propulsion-based Velocity Trimming Module (VTM) as a terminal stage.
- It will be a four stage launching vehicle
- Payload capability - 500 kg to 500 km planar orbit or 300 kg to Sun Synchronous Polar Orbit.
- Unlike the PSLV and GSLV, the SSLV can be assembled both vertically and horizontally
- It would help to meet the demand of the global launch services market for small satellites (nano, micro etc).
- New Space India Limited (NSIL), a PSU, will be the sole nodal agency responsible for providing end-to end SSLV Launch services.
- It had a height of 22m and

NGLV -NEXT GENERATION LAUNCH VEHICLE

- The Union Cabinet has approved the development of the Next Generation Launch Vehicle (NGLV) in September 2024.
- NGLV will offer higher payload capacity and will have modular green propulsion systems.
- NGLV will allow for multiple reuses, reducing operational costs and increasing operational efficiency of the booster.

Aim:

To develop a new generation of human rated launch vehicles with high payload capability & reusability.

Completion is expected by 2032.

Specifications :

- NGLV is a three-stage partially reusable Heavy-lift launch vehicle, currently under development by the Indian Space Research Organisation (ISRO).
- Reusability: It will have a reusable first stage, which would be utilised 15 to 20 times, to make the launches more affordable.
- Length: NGLV is projected to have a liftoff mass of 1,000 tons and a height of 91 meters, significantly larger than the 43-meter LVM3.
- Fuel: NGLV will have semi-cryogenic propulsion (refined kerosene as fuel with liquid oxygen (LOX) as oxidiser) for the booster stages.
- Maximum payload capability: 30 tonnes to Low Earth Orbit (LEO).
- Currently, ISRO has achieved self-reliance in launching satellites through operational vehicles like PSLV, GSLV, LVM3, and SSLV.
- LVM3 has a maximum payload capacity of 10 tonnes to LEO and 4 tonnes to Geo-Synchronous Transfer Orbit (GTO).
- NGLV will have 3 fold payload capacity compared to LVM3, while its cost will be only 1.5 times more.

Vikram Launch Vehicle:

- refers to a **family of small-lift launch vehicles** developed by **Skyroot Aerospace**, a private Indian space company of Hyderabad
- **Vikram-S** was the first rocket in this family and also India's first privately built rocket

- **Vikram series** (Vikram I, Vikram II, and Vikram III)

Dhawan Engines

- **skyroot Aerospace** has developed its own series of cryogenic rocket engines named the **Dhawan series**, in honor of **Dr. Satish Dhawan**, another prominent figure in Indian space research and a former chairman of ISRO

  Agniban Launch Vehicle and mobile launchpad called 'Dhanush,of Agnikul Cosmos

  , a private space company, chennai

- launched the world's first rocket, **Agnibaan Sub Orbital Technology Demonstrator (SOrTeD),** powered by a fully 3D-printed engine. It uses **liquid oxygen and kerosene as propellant** . t reached an altitude of about 20 kilometers before splashing down in the Bay of Bengal.
- Launch was supported by the **Indian Space Research Organisation (ISRO)** and the **Indian National Space Promotion and Authorisation Centre (IN-SPACe).**

  3D printing refers to an **additive manufacturing** process used to create the rocket's "Agnilet" engine.

  3D printing or **Additive Manufacturing:** Unlike traditional manufacturing where material is cut away (subtractive) or molded, 3D printing builds objects layer by layer from a digital design.

3D Printing:

- 3D printing is also known **as additive manufacturing** which uses materials such as plastics and metals to **convert products envisaged on computer-aided design** to real three-dimensional items..

  How 3 D Printing Technology Help Space Domain

- **Less Material Waste:** Additive manufacturing uses only the necessary material, minimizing waste compared to traditional subtractive methods like machining.

General Benefits:

- **Lightweighting:** Reduced mass for lower launch costs and fuel consumption.
- **Design Flexibility:** Creation of complex and optimized geometries.
- **Part Consolidation:** Fewer parts, simplified assembly, increased reliability.
- **Rapid Prototyping:** Faster design cycles and testing.
- **Customization:** Tailored parts for specific mission needs.
- **Reduced Waste:** Efficient material usage.
- **Cost Reduction:** Lower manufacturing and inventory costs.
- **On-Demand Manufacturing:** Production of parts when and where needed.
- By enabling on-site manufacturing, 3D printing reduces the need for extensive inventories of spare parts and reliance on multiple suppliers, streamlining the supply chain.

Advanced Capabilities:

- **Topology Optimization:** Creating lightweight yet strong structures.
- **Advanced Materials:** Utilizing specialized materials for extreme space environments.
- **Integrated Functionality:** Printing parts with embedded sensors or circuits.
- **Self-Healing Materials:** Potential for future self-repairing structures.
- **Miniaturization:** Creating smaller and more efficient components.

ISRO'S INTERPLANETARY MISSION

ASTROSAT: INDIA'S FIRST MULTI-WAVELENGTH SPACE OBSERVATORY

- First Indian dedicated astronomy mission
- **Launched:** September 28, 2015
- **ISRO:** Indian Space Research Organisation
- **Multi-wavelength:** Simultaneous observation (UV, Optical, X-ray)
- **Orbit:** 650 km, near-equatorial
- **Mission Life:** Initially 5 years (extended)
- Objective to Study neutron stars, black holes, X-ray sources , X-ray sky monitoring,Deep field UV survey
- Ground control at ISTRAC (Bengaluru)

XPoSat Mission

Context

: Recently ISRO has Succesfully Launched its XPoSat Mission (X ray Polarimeter Satellite)

XPOSAT - is Astronomy Observational Satellite (telescope to study Universe at high altitude to get clear view - No Dust, No Pollution, No light)

This is India's third Space Observatory after Aditya L1 Mission and Astrosat

India is Second Country after USA (IXPE Mission)for studying X rays in Universe

Polarimeter

- **is optical instruments provide a clarity and undistorted image about Universe Objects**
- **Launch**: Successfully launched on January 1, 2024, aboard the PSLV-C58 rocket.
- **Orbit:** Low Earth orbit at an altitude of approximately 650 km.
- **Mission Duration:** Expected to operate for at least five years

Scientific Payloads : POLIX (Polarimeter Instrument in X-rays) and XSPECT (X-ray Spectroscopy and Timing)

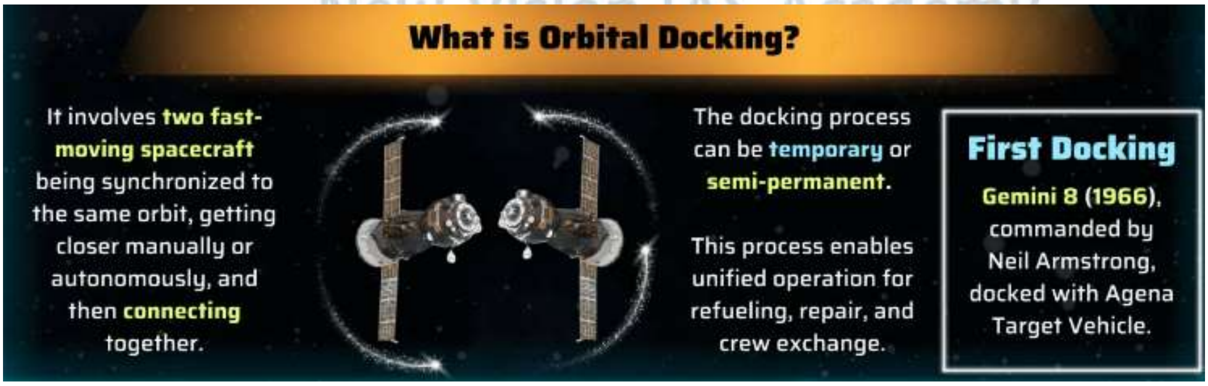
Purpose : to study polarization of X-rays emission from celestial sources including X-ray pulsars, black hole binaries, neutron stars etc

After Launching a Satellite with rocket, the last part of rocket just floats like Space Debris

It is Zero Debris mission ?

- **They used the last part of the rocket as a mini-space lab.** They attached some experiments to it.
- **called (POEM- 3) experiment will be executed**
- -due to innovative use of the PSLV's fourth stage as an orbital platform called POEM-3 (PSLV Orbital Experimental Module-3).
- After the experiments were done, they steered this mini-lab to a lower path around Earth.
- This lower path has more air, which acts like a brake.
- They also made sure there was no fuel left in the mini-lab that could cause an explosion.
- **Controlled Re-entry:** Due to the lowered orbit and natural atmospheric drag, POEM-3 re-entered the Earth's atmosphere on March 21, 2024, and burned up over the North Pacific Ocean. This ensured that no long-lasting debris was left in orbit from this mission.

SPADEX MISSION



What is Space Docking?

Docking is the process of bringing two fast-moving spacecraft into the same orbit, moving them closer, and finally joining them together. It is essential for missions involving heavy spacecraft, space stations, and sample return missions.

Why is Docking-Undocking Important?

- It enables assembly of large spacecraft in orbit (reducing launch weight constraints).
- It is critical for space stations (India plans to have its own space station by 2035).
- It is essential for lunar missions (e.g., Chandrayaan4's sample return mission).
- It supports human spaceflight missions (India aims to send astronauts to the Moon by 2040

Spa DEx

- CONTEXT : Recently Space Docking Experiment (Spa Dex) has been successfully executed by ISRO (Jan 2025)
- SpaDeX Mission is a cost-effective technology demonstrator mission that will demonstrate in-space docking using two small spacecraft ('Chaser' and 'Target') launched by from a single PSLV class vehicle and to dock at an altitude of about 700 kilometres.

- ISRO successfully completed docking and undocking operations of SpaDeX satellites, marking a major milestone
- ISRO Launched its PSLV-C60 mission, marking a historic moment in space technology
- The Satellites carefully align with each other to perform a "Space Handshake" and connect . NASA said docking as mating operations
- aims: to develop satellite docking technologies for future space missions like crew transfers and satellite servicing.
- This accomplishment made India the fourth country after USA, Russia and China in the world to achieve the feat.

Project NETRA of ISRO

Project NETRA (Network for Space Object Tracking and Analysis) is an initiative by the Indian Space Research Organisation (ISRO) to establish an early warning system for space debris and other hazards to Indian satellites

Objective / Applications :

- **Space Situational Awareness (SSA):** To give India its own capability to monitor and track objects in space, including active satellites, space debris, and other potential threats.
- **Protecting Indian Space Assets:** To safeguard Indian satellites from collisions with space debris, which can cause significant damage and loss of functionality.
- **Early Warning System:** To detect and track space objects as small as 10 cm in diameter in lower Earth orbits (LEO) and up to 30 cm in geostationary orbit (GEO).
- **Collision Avoidance:** To provide timely warnings of potential collisions, enabling ISRO to take necessary avoidance maneuvers to protect its satellites.
- **Contributing to Global Efforts:** To share data and analysis with international space monitoring networks, enhancing overall space safety and sustainability.

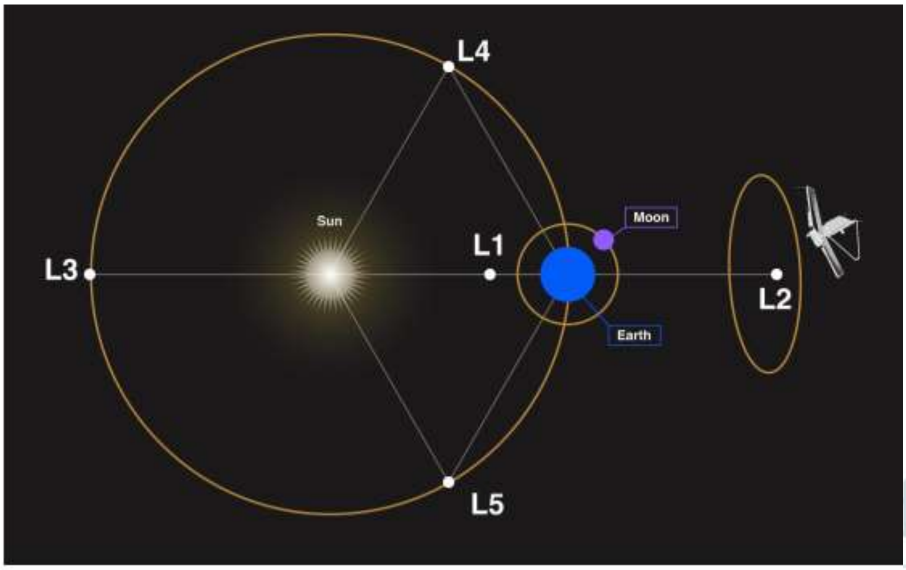
Significance of the project:

- used to ‘predict’ threats from debris to Indian satellites.
- Increase India's Space capability .
- The effort would make India a part of international efforts towards tracking, warning about and mitigating space debris.

Optical Telescopes: High-precision, long-range telescopes are planned for locations like Leh, Ponmudi, and Mount Abu to get a broader view of space. These telescopes are equipped with high-speed cameras to capture fast-moving debris.
The Indian Astronomical Observatory is already located in Hanle, near Leh, highlighting the region's suitability for optical telescopes.
Ponmudi , Thiruvanthapuram (Kerala): Located in the Western Ghats, Ponmudi offers a strategic southern vantage point for observing space
Mount Abu (Rajasthan): This location in the Aravalli Range provides a western observing point. The Mount Abu Observatory, managed by the Physical Research Laboratory (PRL)
Control Center: The ISRO SSA Control Centre, located at the ISTRAC (ISRO Telemetry, Tracking and Command Network) campus in Bangalore, serves as the hub for data processing, analysis, and coordination.

Lagrange point (L-points)/Halo Orbit

- Lagrange points are five special points of enhanced regions of attraction and repulsion between the Sun and the Earth system. It is named after Joseph-Louis Lagrange, an Italian-French mathematician
- These points , offer stable positions for spacecraft to maintain their relative position to the Earth andSun. allowing the object to remain in a stable or semi-stable position relative to the two bodies



Lagrange Points

L1 is unstable point , here satellite revolving in vertical direction

- In a two-body gravitational system, there are five Lagrangian points, labeled L1, L2, L3, L4, and L5.
  - L1, L2, and L3: These points are unstable.
  - L4 and L5: These points are stable.The stability of the L4 and L5 points is due to the Coriolis force and the mass ratio of the primary and secondary bodies.
- Significance:
  - Reduced fuel consumption.
  - The L1 point provides continuous observation of the Sun.
  - 'Parking spots' for spacecraft in space to remain in a fixed position with minimal fuel consumption.

Lagrange Point	Location	Purpose
L1	Between Earth and Sun	Observing the Sun (e.g., Aditya-L1 mission)
L2	Behind Earth, opposite the Sun	Observing the larger universe (e.g., James Webb Space Telescope)
L3, L4, and L5	Equilateral triangles with Earth and Sun	Potential for future missions and observations

Aditya-L1 Mission: It is the first space-based observatory-class Indian solar mission to study the Sun. It is placed in a halo orbit around the Lagrangian point (L1)

The L1 point is home to the Solar and Heliospheric Observatory Satellite (SOHO), an international collaboration project of NASA & European Space Agency (ESA).

L2: It is located behind the Earth. Earth is between the L2 and Sun. It is a significant place to observe the larger Universe. The James Webb Space Telescope is placed at L2

Lagrange points are locations in space where:

a) The gravitational forces of two large bodies cancel each other out completely.

b) A small object placed there will remain stationary relative to the two large bodies due to a balance of gravitational and centrifugal forces.

c) Spacecraft require the least amount of fuel to maintain their position.

d) The magnetic fields of two large bodies are strongest.

Answer: b) A small object placed there will remain stationary relative to the two large bodies due to a balance of gravitational and centrifugal forces.

Q : Which Lagrange point is located directly between the two large bodies?

a) L1

b) L2

c) L3

d) L4

Answer: a) L1

Q The James Webb Space Telescope is currently located near which Lagrange point of the Sun-Earth system?

a) L1

b) L2

c) L3

d) L4

Answer: b) L2

Consider the Statements :

1 Objects placed at Lagrange points require no energy to maintain their position relative to the two large bodies.

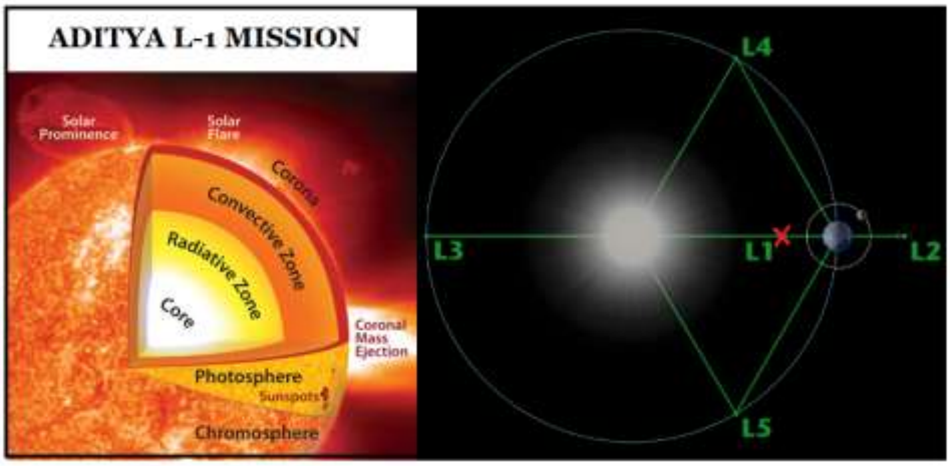
2 The L1 Lagrange point of the Earth-Sun system is a good location for solar observatories because it provides an unobstructed view of the Sun.

1 false (less energy require) 2 True

3 The L2 Lagrange point of the Earth-Moon system is an ideal location for telescopes observing the distant universe because it is far from both Earth and Moon. (true)

4 Lagrange points exist only in the Sun-Earth and Earth-Moon systems. (false. (Lagrange points exist in any two-body gravitational system.))

ISRO Placed Aditya L1 in Halo Orbit



India's first space-based solar observatory.

Aim : comprehensive study of the Sun

Launch Vehicle : PSLV C 57

 It is placed in a halo orbit around the Lagrange point 1 (L1) of the Sun-Earth system, about 1.5 million km from Earth. (1 Au)
 A key advantage of the L1 point is the continuous, unobstructed view of the Sun.
 The spacecraft carries seven scientific payloads to observe the photosphere, chromosphere, and corona.
It will contribute to understanding the Sun's influence on Earth's climate.
L1 Sites :

- **Aditya**
- **SOHO (Solar and Heliospheric Observatory): SOHO is also located in a halo orbit around the Sun-Earth Lagrange Point 1 (L1). SOHO is a collaborative project between the European Space Agency (ESA) and NASA.**
- **China's Kuafu-1 (ASO-S - Advanced Space-based Solar Observatory): This satellite, part of the Kuafu project, is indeed located at the Sun-Earth Lagrange Point 1 (L1).**
- **Parkar Solar Probe of NASA to study Sun Outer Corona located near L1**

Sun Internal to External Layer

Core	This is the Sun's center where nuclear fusion happens.	Core, Nuclear Fusion, Energy Generation
Radiative Zone	Energy from the core travels outward as radiation here.	Radiative Zone, Radiation, Energy Transport
Convective Zone	Hot gas rises and cooler gas sinks, moving energy.	Convective Zone, Convection, Heat Transfer
Photosphere	This is the visible surface of the Sun we usually see.	Photosphere, Visible Surface, Sunspots
Chromosphere	A reddish layer above the visible surface.	Chromosphere, Reddish Layer, Spicules
Transition Region	A thin, hot layer between the chromosphere and corona.	Transition Region, Rapid Temperature Rise
Corona	The Sun's outermost, very hot atmosphere.	Corona, Outermost Atmosphere, Coronal Loops

Solar Wind and Solar Flares and Coronal Mass Ejection are Same ? No

Recently, **the Sun emitted an X-class solar flare, disrupting radio communications** over parts of the **United States** and the **Pacific Ocean.**

Feature	Solar Wind	Solar Flare	Solar Prominence (Filament)	Coronal Mass Ejection (CME)
Nature	Continuous stream of charged particles (plasma)	Sudden, intense burst of electromagnetic radiation	Large, cooler, dense cloud of plasma and magnetic field anchored to the Sun's surface	Large expulsion of plasma and magnetic field from the Sun's corona
Composition	Mostly protons and electrons, some heavier ions	Electromagnetic spectrum (X-rays, UV, visible, radio)	Cooler plasma (hydrogen, helium) held by magnetic fields	Hot plasma and magnetic field lines
Earth Effects	Can cause auroras, geomagnetic storms (minor to moderate), and impact satellites	Can cause radio blackouts, communication disruptions, and increased radiation near Earth	Generally doesn't directly impact Earth unless associated with a CME	Can cause significant geomagnetic storms, auroras, disruptions to power grids, communication systems, and GPS

Q. If a major solar storm (solar flare) reaches the Earth, which of the following are the possible effects on the Earth?(2022)

1. GPS and navigation systems could fail.
2. Tsunamis could occur at equatorial regions.
3. Power grids could be damaged.
4. Intense auroras could occur over much of the Earth.
5. Forest fires could take place over much of the planet.
6. Orbits of the satellites could be disturbed.
7. Shortwave radio communication of the aircraft flying over polar regions could be interrupted.

Select the correct answer using the code given below:

(a) 1, 2, 4 and 5 only
(b) 2, 3, 5, 6 and 7 only
(c) 1, 3, 4, 6 and 7 only
(d) 1, 2, 3, 4, 5, 6 and 7

Ans: (c)

News : INDIA'S ADITYA-L1 MISSION CAPTURES SOLAR FLARE

Context: India's first solar mission, Aditya-L1, has made a historic advancement in solar research. Through its instrument, the Solar Ultraviolet Imaging Telescope (SUIT), Aditya-L1 has captured an extraordinary observation of a powerful solar flare, providing new insights into solar activity

Aditya-L1 is India's inaugural mission designed to study the Sun. It is a key part of the country's space exploration program and is equipped with advanced instruments, including the Solar Ultraviolet Imaging Telescope (SUIT), to monitor solar phenomena It is positioned at Lagrange Point L1, about 1.5 million km from Earth. The mission aims to improve our understanding of solar activities and their effects on space weather, which can impact Earth's atmosphere and technological systems.

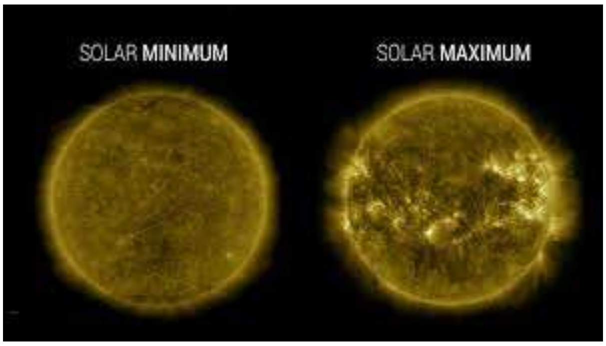
What is solar flare?

- A **solar flare** is a sudden burst of energy caused by the release of magnetic energy in the Sun's atmosphere.
- A solar flare is an intense burst of radiation coming from the release of magnetic energy associated with sunspots.
- Flares are the solar system's largest explosive events.
- They are seen as bright areas on the sun and they can last from minutes to hours.
- The primary ways to monitor flares are **in x-rays and optical light**. Flares are also sites where particles (electrons, protons, and heavier particles) are accelerated.
- **Impact:** These events can have significant consequences for space weather, impacting **satellite operations, radio communications, power grids,** and even posing **risks to astronauts** and airline passengers in high-altitude flights.

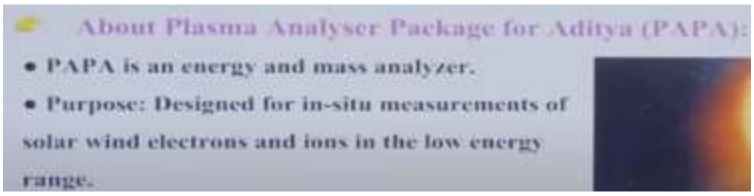
Sunspots : Temporary dark spots on the photosphere of strong magnetic fields on the surface of the sun. They can spawn eruptive disturbances such as solar flares and coronal mass ejections (CMEs). These regions of the sun appear darker because they are cooler than their surroundings.

Solar Cycle :

- periodic 11-year change in the Sun's activity measured in terms of variations in the number of observed sunspots on the Sun's surface.
- The beginning of a solar cycle is a **solar minimum/** when the Sun has the least sunspots
- The middle of the solar cycle is the **solar maximum (sunspots increases)**
- As the cycle ends, it fades back to the solar minimum and then a new cycle begins.



PAPA: Plasma Analyser Package for Aditya (PAPA) payload onboard the Aditya L1 Mission detected solar wind impact of Coronal Mass Ejections



- **Objectives:**

  - To understand the characteristics of the solar wind near Earth.
  - To analyze the different ion species present in the solar wind.
  - To study how the solar wind interacts with the environment in interplanetary space.
  - To contribute to a better understanding of space weather phenomena.
- **Developer:** Space Physics Laboratory, Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram.

AMATERASU PARTICLES

- **Context:** Scientists recently detected the most powerful cosmic ray seen in more than three decades, which has been named ‘Amaterasu’.
- **Define** - refers to an ultra-high-energy cosmic ray detected by Telescope Array experiment in Utah, USA
- **Name:** It was named "Amaterasu" after the sun goddess in Japanese mythology, reflecting its immense energy and mysterious origin.
- Energy Level : Its energy was estimated to be **244 exa-electron volts (EeV)-** That is millions of times more than particles produced in the Large Hadron Collider, the most powerful accelerator ever built
- Mystery: Scientists are unsure what the particle is exactly and what kind of astronomical phenomenon could have accelerated it to such extreme energies.
- Comparison to "Oh-My-God" Particle: The Amaterasu particle's energy is comparable to the "Oh-My-God" particle (320 EeV detected in 1991), the most energetic cosmic ray ever recorded.
- The Amaterasu particle presents a significant mystery in astrophysics, potentially pointing towards unknown astronomical phenomena or even physics beyond the Standard Model
- the "Amaterasu particle" is not a new type of fundamental particle but rather an extraordinarily energetic cosmic ray whose detection poses a significant mystery in astrophysics, prompting further investigation into the universe's most extreme phenomena and the laws of physics that govern them.

Mars Orbiter Mission (MOM) [UPSC 2016]

Mission: India’s first interplanetary space mission.

Launch: November 5, 2013, aboard PSLV-C25.

Significance: Made India the first Asian country and the fourth in the world to reach Mars in 2014.

Objectives: Study the Martian atmosphere, surface features, mineralogy, and morphology. Develop technologies for interplanetary missions.

Achievements of The Mars Orbiter Mission:

- India became the **fourth space agency** to achieve Mars orbit.
- India became the **first Asian nation** to reach the Martian orbit.
- India became the **first nation** in the world to do so on its **maiden attempt.**
- The MOM mission was a success on a **budget of just $73 million.**

Consider the following statements: (2016)
The Mangalyaan launched by ISRO

1. is also called the Mars Orbiter Mission
2. made India the second country to have a spacecraft orbit the Mars after USA
3. made India the only country to be successful in making its spacecraft orbit the Mars in its very first attempt

Which of the statements given above is/are correct?
(a) 1 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3
Ans: (c)
India is the only 4th country after the USA, Russia and Europe to have a spacecraft orbiting the Mars. **Hence, statement 2 is not correct.**
As of 2023, the Soviet Union, United States and China have conducted Mars landings successfully
MARS MISSION

- Perseverance, Curosity , Odyssey - USA
- Hope Mission - UAE
- Tianwen 1 - China
- Mars Moon Expolaration mission - Japan

VENUS: SHUKRAYAAN-1
Mission: India's first planned mission to Venus, designed to study the planet's surface, atmosphere, and geological features.
Launch Vehicle: GSLV Mk II rocket.
Orbiter: A spacecraft of approximately 2500 kg will orbit Venus to gather data.
Objectives: Understand Venus's climate and its evolution, Explore signs of active volcanoes and seismic activity.
Other Missions to Venus:

- Soviet Union (Venera Program)
- •United States (Mariner & Pioneer Venus)
- Venus Express: By European Space Agency (ESA), which orbited the planet from 2006 until 2016, and
- Akatsuki Venus Climate Orbiter: By Japan, which has been in orbit since 2016.

WHY STUDY MOON?

- Moon provides the best linkage to Earth's early history.
- It offers an undisturbed historical record of the inner Solar system environment and its origins.
- The Moon is the closest cosmic body at which space discovery can be attempted and documented.
- It is also a promising test bed to demonstrate technologies required for deep-space missions.

FAR SIDE OF THE MOON

- **Far side** refers to hemisphere of Moon that always **faces away** from Earth (visible side is called the 'near side')
- From Earth, only **59%** of the moon is visible over a period of time because:
  - Earth's gravity has slowed the Moon's rotation in such a way that the Moon takes **same amount of time** (27.3 days or a Sidereal Month) to revolve around the Earth as it takes to rotate around its spin axis (w.r.t **background stars**).
  - Thus, the far side is never visible from Earth.
  - Ideally 50% of the moon should be visible but we see 59% because of north-south rocking and east-west wobbling of moon – called as **lunar vibrations.**

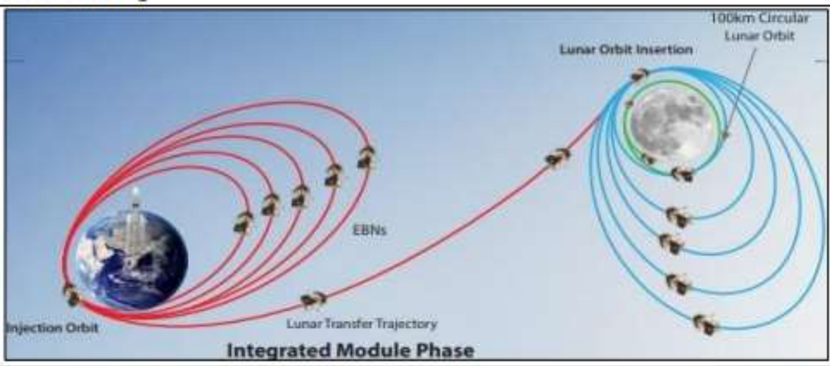
LUNAR DAY

- A lunar day is period of time for Earth's Moon to complete **one rotation** on its axis **with respect to the Sun**.
- In this sense, a Lunar day in terms of Earth time is 29.5 days or a Synodic month.
- But, if it refers to amount of time a particular spot-on Moon is in sunlight, then **1 Lunar Day = 14 Earth Days**
- Due to tidal locking, it is also the time the Moon takes to complete **one orbit** around Earth and **return to the same phase** (from new Moon to new Moon).
- The difference between the **sidereal** and **synodic months** occurs because as Moon moves around Earth, the Earth also moves around Sun.
- Thus, Moon must travel a little farther in its path to make up for the added distance & complete the phase cycle.

India's Missions to Moon

- **Chandrayaan-1**
  - India's first mission to the Moon, was launched in 2008.
  - Chandrayaan-1 reached the lunar orbit 21 days after its launch and after making 3400 orbits around the Moon and transmitting data.
  - In late November 2008, Chandrayaan-1 began experiencing abnormally high temperatures.
  - The last contact with Chandrayaan-1 was on August 28, 2009. It still circles around the Moon.
- **Chandrayaan-2**
  - The failure of Chandrayaan-2, India's second mission to the Moon, to make a soft-landing on the lunar surface had led to much disappointment.
  - The lander and rover malfunctioned in the final moments and crash-landed, getting destroyed in the process
  - But that did not mean the entire mission had been wasted. The Orbiter part of the mission has been functioning normally.

The Vikram lander and the Pragyan rover

Details	Specifications
Launch Vehicle	Launch Vehicle Mark-3 (LVM-3) rocket LVM3.
Launched from	Satish Dhawan Space Centre in Sriharikota.
Mission Life (Lander & Rover)	One lunar day (~14 Earth days).
Mass	**Propulsion Module**: 2148 kg **Lander Module**: 1752 kg including Rover of 26 kg **Total**: 3900 kg
Trajectory of Chandrayaan-3	

Reason for Landing on South Pole:

- **The region hosts water in the form of ice:**

Name of landing Site

Jawahar Point	Chandrayaan-1	Crash site on Lunar surface in 2008
Tiranga Point	Chandrayaan-2	**crash-landed** on the Moon in **2019**.
Shivshakti Point	Chandrayaan -3	achieved a **soft landing** on the Moon's South Pole on **August 23, 2023**.

- **Chandrayaan-3**
  - The Chandrayaan-3 mission consists of a lander module, a propulsion module, and a rover.
  - The Chandrayaan-3 Lander has solar panels on four sides, instead of only two in Chandrayaan-2.
  - Chandrayaan-3 is a follow-on mission to Chandrayaan-2 to demonstrate end-to-end capability in safe landing and roving on the lunar surface.
  - The spacecraft departed from the Satish Dhawan Space Centre in Sriharikota on July 14, 2023, and smoothly entered lunar orbit by August 5, 2023.
  - The lander achieved a flawless touchdown near the lunar south pole on August 23, 2023.
  - The total weight of Chandrayaan-3 is 3,900 kg, with the propulsion module weighing 2,148 kg and the lander and the rover both weighing 1,752 kg.

FIRST DETAILED GEOLOGICAL MAP OF THE MOON'S SOUTH POLAR REGION

This mission has resulted in the first-ever detailed geological map of the moon's south polar region, created by Indian scientists. The map is shedding new light on the moon's history, its formation, and its geological makeup

The detailed geological map was created using data from the Pragyan rover, which was deployed by the Vikram lander.

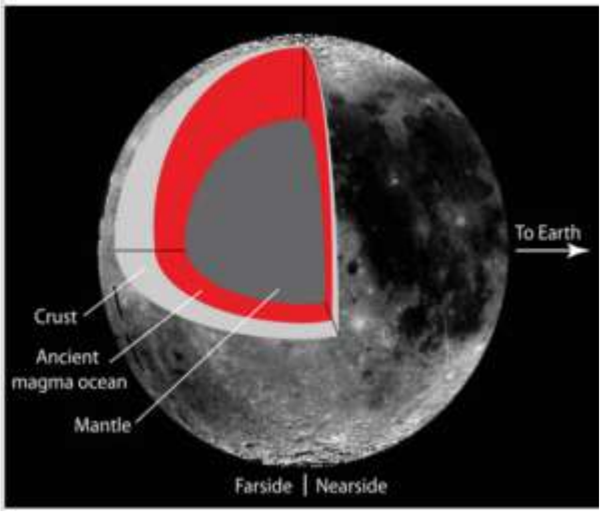
The map shows an undulating landscape, including highlands and flat plains, surrounding the landing site

It highlights the Schomberger crater, which was identified as the primary source of debris around the landing zone

This crater is part of the lunar impact history, and its study helps understand the moon's evolution

Magma Beneath the Surface: Data from Chandrayaan-3 confirmed that magma lies beneath the moon's surface in the south pole region. This supports earlier data from other missions, but it is the first confirmation of this in the high-latitude area.

Common Origin of Earth and Moon: The study revealed that Earth and the moon share a similar geochemical history and likely originated from the same molten cloud of material about 5 billion years ago



Note : China has become the first country to successfully collect and return samples from the far side of the Moon, marking a significant milestone in lunar exploration and space technology.

Chang'e-6 mission landed on the Moon's far side and collected from the South Pole-Aitken Basin

The far side of the Moon is the side not visible from Earth, a result of a phenomenon called "tidal locking."

In contrast, the near side, which constitutes 60% of the Moon's surface, is always visible from Earth

This side isn't actually dark; it receives ample sunlight and experiences lunar day and night cycles, just like the near side.

Day and Night: A lunar day lasts over 29 Earth days, while a lunar night is roughly two weeks long. This extended cycle is due to the Moon's rotation around its axis and its orbit around Earth, resulting in the same side always facing our planet.

Lunar Probe Exploration Mission (LUPEX)

Joint Mission: A collaborative venture between the Indian Space Research Organization (ISRO) and the Japan Aerospace Exploration Agency (JAXA).

Objective: To explore the Moon's south polar region, focusing on the presence of water and other resources.

Launch Vehicle: Japan's H3 rocket is scheduled to launch the mission.

Timeline: Targeted for launch in 2025.

Key Features:

- Lander and Rover: LUPEX will consist of a lander and a rover, developed by ISRO and JAXA respectively.
- Scientific Instruments: The rover will carry instruments to measure the water content of lunar regolith, drill and sample lunar materials, and conduct other scientific experiments.
- International Collaboration: The mission will also include instruments from NASA and the European Space Agency (ESA).
- Significance: Water on the Moon, Future Exploration, Technological Advancement.

GAGANYAAN MISSION

- It is India's first manned space mission that will be fully indigenously developed by ISRO
- Aim : sending humans into orbit
- Significance: It will make India one of the only 4 countries in the world to launch a human spaceflight mission (after USA, Russia and China).
- It consists of three planned flights: two unmanned missions and one crewed mission
- Crewed Mission: The final mission will carry three Indian astronauts into space.
- Objectives: Gaganyaan aims to demonstrate India's capability in human spaceflight and conduct scientific experiments in microgravity

Context: Gaganyaan, the Indian Space Research Organisation (ISRO)'s first human spaceflight mission, is now likely to take flight only by 2026. Before the final mission, however, the Indian space agency will undertake an uncrewed mission with Vyom Mitra, a humanoid robot, tentatively around the first half of 2025.

About:

Vyom Mitra is half-humanoid and her body stops at the torso and has no legs

Key-features:

- It is capable of switching panel operations, performing Environment Control and Life Support Systems (ECLSS) functions, conversations with the astronauts, recognising them and solving their queries.
- It can detect and give out warnings if the environment changes within the cabin.
- The humanoid has been developed by the ISRO Inertial Systems Unit, Thiruvananthapuram.

Key Details of Mission :

Launch Vehicle: The GSLV Mk III (Launch Vehicle Mark-3) is the powerful rocket chosen to launch Gaganyaan.

Orbital Module: The spacecraft carrying the astronauts will be the Orbital Module

Mission Duration: The crewed mission will orbit Earth at a low-earth-orbit altitude of 300-400 kilometers for 5-7 days

Astronauts: Three Indian astronauts, including a woman, will participate in the crewed mission.

GAGAN: INDIA'S GLOBAL NAVIGATION SYSTEM

Collaboration: Developed by ISRO and the Airports Authority of India, GAGAN is India's first satellite-based global positioning system.

Satellite Network: GAGAN relies on ISRO's GSAT satellites for precise positioning and navigation services.

Limitation: While GAGAN offers accurate positioning, it currently only supports one-way communication. This means that users cannot make calls using GAGAN.

GPS-Aided Geo Augmented Navigation (GAGAN) uses a system of ground stations to provide necessary augmentation. Which of the following statements is/are correct in respect of GAGAN?

I. It is designed to provide additional accuracy and integrity.
II. It will allow more uniform and high quality air traffic management.
III. It will provide benefits only in aviation but not in other modes of transportation.
Select the correct answer using the code given below.
(a) I, II and III
(b) I only
(c) II and III only
(d) I and II only
III Statement is Incorrect
Its accurate positioning data can be used in diverse fields such as:

- **Railways:** For train tracking, signaling, and safety.
- **Maritime:** For navigation, port operations, and search and rescue.
- **Road transport:** For intelligent transportation systems, fleet management, and navigation.
- **Surveying and mapping:** For precise location data.
- **Agriculture:** For precision farming and land management.

- **Disaster management:** For emergency response and relief operations

GEMINI: GAGAN ENABLED MARINER'S INSTRUMENT FOR NAVIGATION AND INFORMATION

The GEMINI device, developed by ISRO, is a portable satellite receiver that can be used for communication in areas beyond the reach of traditional cellular networks

- It offers a valuable tool for disaster management, especially in remote regions or during emergencies.

Key Features:

- Satellite Connectivity: GEMINI connects to ISRO's satellites, enabling communication over long distances.
- Wide Coverage: The device can transmit signals up to 300 nautical miles, extending communication reach beyond the limitations of cellular networks.
- Disaster Management: GEMINI is particularly useful during storms, strong seas, or tsunamis, providing a reliable communication channel in emergency situations.

MISSION SHAKTI

- On March 27, 2019, India successfully conducted its first Anti-Satellite (ASAT) missile test, named Mission Shakti.
- This mission, carried out by the Defence Research and Development Organisation (DRDO) from Dr. APJ Abdul Kalam Island in Odisha, demonstrated India's capability to develop and deploy a complex missile system with potential applications in space warfare.
- The objective was to destroy a defunct Indian satellite in Low Earth Orbit (LEO) at an altitude of approximately 283 kilometers
- Focus on Indigenous Development: The successful launch emphasized India's ability to develop and execute such intricate missions with entirely indigenous technology
- Missile Used: The mission employed the Prithvi Delivery Vehicle Mark-II (PDV MK-II), developed by DRDO. This missile successfully intercepted and destroyed the targeted Indian Microsat-R satellite.

NISAR Mission (NASA-ISRO Synthetic Aperture Radar)

Purpose: **To study Earth's surface changes, monitor natural hazards, analyze climate patterns, and understand dynamic ecosystems.**

Collaboration: **A joint mission between NASA and ISRO (Indian Space Research Organization).**

Launch: **Scheduled for 2025.**

Category: **Earth observation satellite**

Launch Vehicle: **GSLV Mk II**

Launch Site: **Satish Dhawan Space Center, ISRO**

Orbit: **Sun-synchronous orbit (LEO) at an altitude of 747 km**

Significance: **Comprehensive Earth Observation, Disaster Monitoring, Climate Change Research, Resource Management**

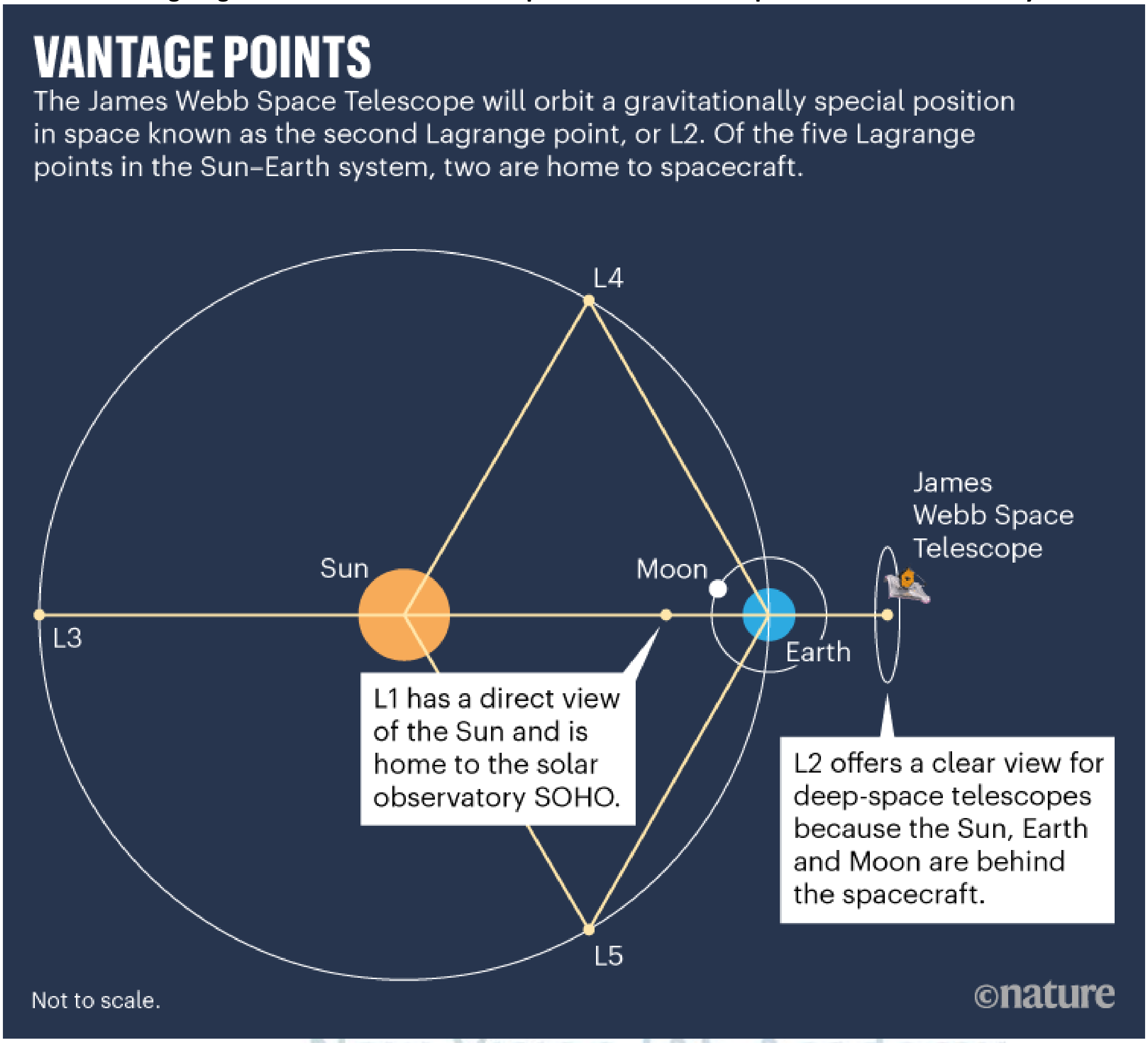
Difference Between James Webb and Hubble Telescope

JAMES WEBB SPACE TELESCOPE	HUBBLE SPACE TELESCOPE
Work on Infrared radiations	Work on Ultraviolet radiations
Large Mirror Diameter Capacity 6.5m	Small Mirror 2.5m
Provide large view and proper image	Provide small view
Not orbiting the Earth	Orbiting the Earth
Orbiting the Sun at L2 approx 1.5 million km from the Earth	Orbits at Altitude of 575 km from the Earth
Provide Extra advantage to Studies ;about baby galaxies or new galaxies, exoplanets etc	

James Webb Space Telescope

- The telescope is the **result of an international collaboration** between **NASA,** the **European Space Agency (ESA) and the Canadian Space Agency which was launched in December 2021.**
  - It was launched on an Ariane 5 ECA rocket from French Guiana in South America.
  - It's the largest, most powerful infrared space telescope ever built.
  - It's the successor to Hubble Telescope.
  - It is currently at a point in space known as the Sun-Earth **L2 Lagrange point,** approximately 1.5 million km beyond Earth's orbit around the Sun.

- The Lagrange Point 2 is **one of the five points in the orbital plane of the Earth-Sun system.**



L2 is ideal for astronomy because a spacecraft is close enough to readily communicate with Earth, can keep Sun, Earth and Moon behind the spacecraft for solar power and (with appropriate shielding) provides a clear view of deep space for our telescopes.

- **Goal:**
  - To **search for the first galaxies** that formed after the Big Bang.
  - To **determine how galaxies evolved** from their earlier formation until now.
  - To **observe the formation of stars** from the first stages to the formation of planetary systems.
  - To **measure the physical and chemical properties** of planetary systems and investigate the potential for life in such systems.

The James Webb Space Telescope (JWST), Gaia and Euclid are some of the important astronomical probes which are presently in orbit around L2

ISRO'S SUCCESSFUL SPACE FARMING

Context: The Indian Space Research Organisation (ISRO) sent lobia (black-eyed pea) seeds into space as part of its Compact Research Module for Orbital Plant Studies (CROPS). These seeds successfully germinated marking a significant step in space farming research.

How Are Plants Grown in Space?

There are various methods for growing plants in space:

- Hydroponics: Plants grow without soil, using a nutrient-rich liquid solution.
- Aeroponics: Plants grow in the air with minimal water usage, absorbing nutrients from the air.
- Soil-like Media: Some plants grow in soil-like substances that provide structure and nutrients

How ISRO Grew Lobia

- ISRO used a mini greenhouse (CROPS box) with Soil-like medium: Porous clay pellets for water and nutrient absorption.
- LED lights: Simulated day and night cycles for photosynthesis.

- Controlled temperature & air: Maintained Earth-like conditions
- The lobia seeds sprouted in four days, showcasing the potential of space farming

Ideal Plants for Space

- Leafy greens: Lettuce, spinach, and kale.
- Beans and peas: High in protein and help improve soil.
- Root vegetables: Radishes and carrots.
- Cereals: Wheat and rice for long-term sustenance.

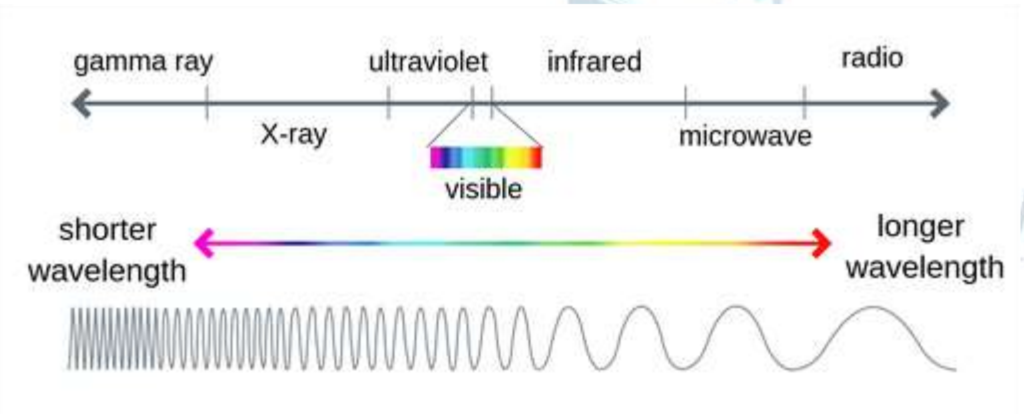
PRATUSH - INDIA'S MOON BASED TELESCOPE

- Context: PRATUSH is a radio telescope designed to be placed on the far side of the moon. It is built by Raman Research Institute (RRI), Bengaluru and Indian Space Research Organisation (ISRO).

About PRATUSH

- **PRATUSH (Probing ReionizATion of the Universe using Signal from Hydrogen)** is being built by the Raman Research Institute (RRI) in Bengaluru with active collaboration from the **Indian Space Research Organisation (ISRO).**
- Initially, ISRO will place PRATUSH into orbit around the earth. After some fine-tuning, the space agency will launch it moonwards.

- **Main roles:** It will be to **detect signals** from the **first stars and galaxies**, reveal the cosmic dawn of the universe, answering the question when the first stars formed, the nature of the first stars and what was the light from the first stars.



What are Radio waves?

These are a type of electromagnetic radiation. A radio wave has a much longer wavelength than visible light. Humans use radio waves extensively for communications. This radio tower has both rectangular and circular antennas to transmit and receive radio frequency energy.

NASA INITIATIVES

GREAT OBSERVATORY PROGRAMME

- was a series of four major space-based telescopes launched by NASA between 1990 and 2003.
- Each telescope was designed to observe a specific range of the electromagnetic spectrum, providing a comprehensive view of the universe

Telescope Name	Wavelength Range	Purpose	Key Discoveries
Hubble Space Telescope (HST)	Visible and ultraviolet light	Imaging distant galaxies, stars, and nebulae	Age of the universe, evidence for dark energy, formation of stars and galaxies
Compton Gamma Ray Observatory (CGRO)	Gamma rays	Studying high-energy astronomical phenomena	New types of gamma-ray sources (gamma-ray bursts, active galactic nuclei)
Chandra X-ray Observatory (CXO)	X-rays	Observing hot, high-energy objects	Detailed images of hot gas surrounding galaxies and clusters
Spitzer Space Telescope (SST)	Infrared	Observing cool, dusty objects	Exoplanets, galaxy formation, star-forming regions

NASA PERSEVERANCE ROVER MISSION on Mars to study Astrobiology: Searching for signs of ancient microbial life and Sample Collection: Gathering rock and regolith samples for potential return to Earth

Parker Solar Probe:

- NASA's Parker Solar Probe mission designed to study the Sun's outer atmosphere, the corona.
- Launch-Launched in 2018,
- Objective: To understand the mechanisms that heat the corona and accelerate the solar wind.
- Significance : Sun's behavior and its influence on the solar system, understanding of solar physics, astrophysics, and space weather.

Lucy Mission- To study Jupiter's Trojan asteroids, remnants of our solar system's formation. launched in 2021.

MISSIONS TO MOON

Crewed Missions: Apollo Program (United States)

- Apollo 8: The first crewed mission to orbit the Moon in 1968.
- Apollo 11: The historic mission that saw Neil Armstrong and Buzz Aldrin become the first humans to walk on the Moon in July 1969.
- Total Crewed Missions: A total of twelve astronauts have walked on the Moon, with the last mission being Apollo 17 in 1972.

NASA's Artemis Program: Aims to land the first woman and first person of color on the Moon, using innovative technologies to explore more of the lunar surface.

OUTER SPACE GOVERNANCE - Foreign Space Policy

Existing Outer Space Governance Framework

UN COPUOS: Established in 1958 by the UN General Assembly to oversee space exploration and use.

UNOOSA: Supports UN COPUOS in its work.

Key Treaties: •

- Outer Space Treaty (1967): Establishes principles for space exploration and use. •
- Rescue Agreement (1968): Addresses rescue and return of astronauts and space objects.
- Liability Convention (1972): Establishes liability for damage caused by space objects.
- Registration Convention (1976): Requires registration of space objects. •
- Moon Agreement (1979): Governs activities on the Moon and other celestial bodies (India has not ratified).
- India is a signatory to all five of these treaties but has not ratified the Moon Agreement

Artemis Accords , 2020

- Developed by NASA and seven global space agency Australia, Canada, Italy, Japan, Luxembourg, UAE, UK
- Non Binding Global Principles
- Purpose: to guide the civil exploration and use of outer space and Sets Global principles for peaceful exploration and use of outer space, Moon, Mars, comets, and asteroids.
- Foundation: Based on the Outer Space Treaty of 1967.
- Signatories: India is the 27th signatory, joining other nations committed to these principles
- As of April 2025, 54 countries have signed the Artemis Accords

Artemis Moon Mission Program led by NASA. it include Mission Like **Artemis I** 2022 (uncrewed test), **Artemis II 2026** (crewed flyby), and **Artemis III** (crewed landing on the South Pole).

Manned Moon Mission - Artemis

INTERNATIONAL SPACE STATION

The International Space Station (ISS) is a large, habitable spacecraft orbiting Earth at an altitude of approximately 400 kilometers.

- Countries: NASA (United States), Roscosmos (Russia), ESA (Europe), JAXA (Japan), and CSA (Canada).
- Orbit: Circles Earth every 90 minutes at a speed of about 28,000 kilometers per hour.
- Inhabitation: Continuously inhabited since 2011, serving as a home for astronauts from participating countries.
- Scientific Research: Serves as a platform for conducting various scientific experiments in microgravity, expanding our knowledge of space and its implications for Earth

Recent Developments

● India is seeking to launch its own space station by 2030, joining the league of US, Russia, and China to an elite space club.

● China has been operating its completed Tiangong Space Station for almost two years now and is looking to expand its capabilities with new modules and spacecraft. The three-module, T-shaped

Tiangong space station was fully assembled in November 2022, with the arrival of the Mengtian science module

DEFINE SPACE-BASED INTERNET

- satellite internet, is a type of internet connectivity that utilizes satellites orbiting the Earth to provide broadband service

This technology offers a potential solution for areas with limited or no access to traditional internet infrastructure, such as rural regions, remote locations, and developing countries.

Key Technologies:

- **Satellite Constellations:** Large networks of satellites are deployed in low Earth orbit (LEO) or geostationary orbit (GEO) to provide global coverage.
- **Ground Stations:** These stations receive signals from the satellites and transmit them to internet service providers.
- **User Terminals:** Customers require specialized antennas and modems to connect to the satellite network.

Benefits of Space-Based Internet: Global Coverage, High Speed, Low Latency, Disaster Recovery.

Challenges and Considerations: High cost, Weather Interference, Regulatory Challenges.

Prominent Space-Based Internet Projects: Starlink (SpaceX), OneWeb, Amazon Kuiper, JioSpace Fiber (Reliance Jio)

Starlink is a satellite internet system launched by SpaceX.

It uses a constellation of low Earth orbit satellites to provide high-speed, low-latency broadband internet to users, especially in remote or underserved areas

Context: Billionaire Elon Musk has recently denied claims that his space company SpaceX's Starlink satellite internet technology is being used by militants in Manipur, following the discovery of Starlink devices seized by the Indian Army and police.

India has strict regulations around satellite-based communication systems

Under the Indian Wireless Act and Indian Telegraph Act, the use of satellite phones and services like Starlink without proper authorization is illegal

Quw : Which one of the following countries has its own Satellite Navigation System? (2023) (a) Australia (b) Canada (c) Israel (d) Japan

Q . In which of the following activities are Indian Remote Sensing (IRS) satellites used?

1. Assessment of crop productivity
2. Locating groundwater resources
3. Mineral exploration
4. Telecommunications

5. Traffic studies

Select the correct answer using the code given below. (2015)

(a) 1, 2 and 3 only

(b) 4 and 5 only

(c) 1 and 2 only

(d) 1, 2, 3, 4 and 5

Ans A

Q1. In the context of space technology, what is "Bhuvan", recently in the news? (2010)

(a) A mini satellite launched by ISRO for promoting the distance education in India

(b) The name given to the next Moon Impact Probe, for Chandrayaan-II

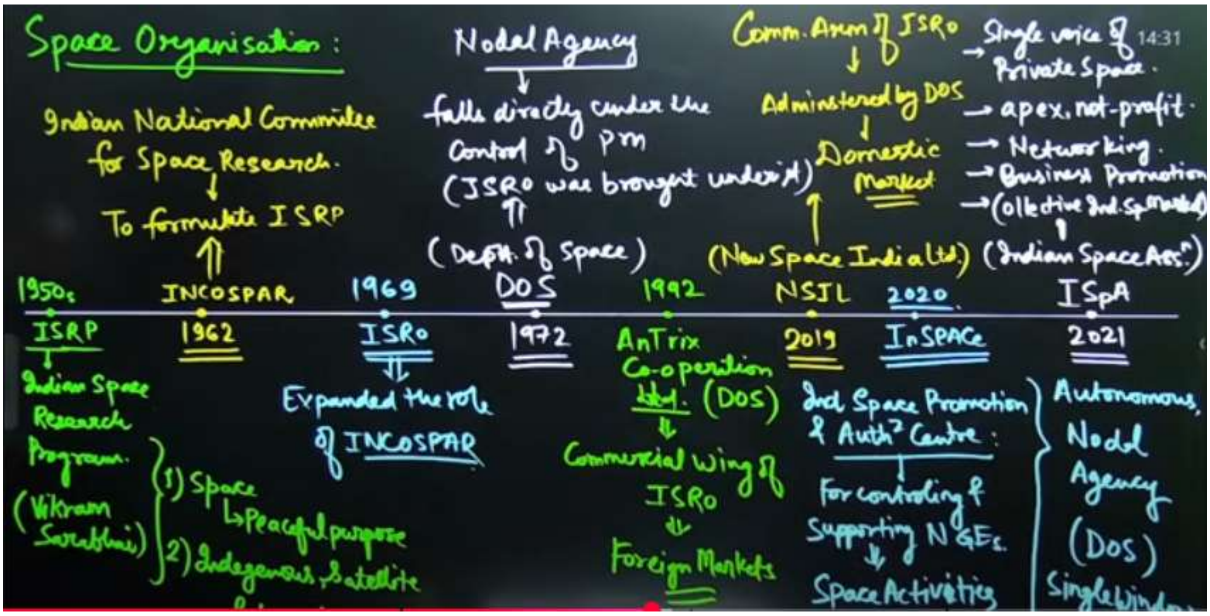
(c) A geoportal of ISRO with 3D imaging capabilities of India

(d) A space telescope developed by India

Ans: (c)

Bhuvan

- is Geospatial portal, web-based platform that allows users to explore a rich set of geographical data and imagery of India.
- Offers 2D and 3D views of the Earth's surface, with high-resolution satellite imagery specifically focused on India
- developed by NRSC, ISRO



Consider the following space missions:

I. Axiom-4

II. SpaDeX

III. Gaganyaan

How many of the space missions given above encourage and support microgravity research?

(a) Only one

(b) Only two

(c) All three

(d) None

What is Microgravity?

Microgravity isn't the complete absence of gravity, but rather a state of continuous freefall.

is the condition in which people or objects appear to be weightless

Key Areas of Microgravity Research:

- **Biological and Life Sciences**
- Physical Sciences
- Advancements in Medicine and Healthcare
- Improved Materials and Manufacturing
- Enhanced Understanding of Fundamental Processes and understanding of how the universe works

About Axiom Mission 4 :

- Ax-4 is the fourth private human spaceflight mission by Axiom Space to the ISS, designed to advance international collaboration and conduct cutting-edge research in microgravity.
- **Organizations Involved:**
    - Axiom Space (Mission organizer)
    - NASA (Host at ISS)
    - SpaceX (Launch vehicle and Dragon capsule provider)
- **Launch Site & Timeline:**
    - **Launch Pad:** LC-39A, Kennedy Space Center, Florida
    - **Launch On:** June 25, 2025.
    - **Mission Duration:** ~14 days aboard the ISS
- **Mission Objectives:**
    - **Microgravity Research:**
        - Over 60 experiments covering life sciences, material science, human physiology, and Earth observation.
    - **International Outreach & Collaboration:**
        - Fosters cooperation in low-Earth orbit research, setting a precedent for future **global partnerships** in space.
    - **National Program Development:**
        - Enables participating countries to **leap forward in their human spaceflight capabilities**.
    - **Crew Members:**
        - **Peggy Whitson (USA)** – Commander, holds the U.S. record for longest cumulative time in space.
        - **Shubhanshu Shukla (India)** – Pilot, first Indian to reach ISS and second Indian in space.
        - **Sławosz Uznański (Poland)** – ESA Mission Specialist, second Polish astronaut after 1978.
        - **Tibor Kapu (Hungary)** – Mission Specialist, second Hungarian astronaut after 1980.
        - **Zero-G Indicator:** "Joy" the baby swan toy—selected by Shukla and his 6-year-old son Sid.
    - **Significance to India:**
        - **Revival of Human Spaceflight:**
            - Shukla becomes the **first Indian to enter ISS** and only the second Indian in space since 1984.
        - **Boost to Gaganyaan & Space Station Plans:**
            - Mission complements India's ambition to launch its own **crewed space mission (Gaganyaan)** and build an **Indian space station by 2035**.
        - **Scientific Leadership:**
        - India leads and participates in multiple experiments, expanding **India's role in space science diplomacy**.
