TARGET PRELIMS 2024
CURRENT AFFAIRS PROGRAM
BOOKLET-1, S&T-1
SPACE AND ASTRONOMY

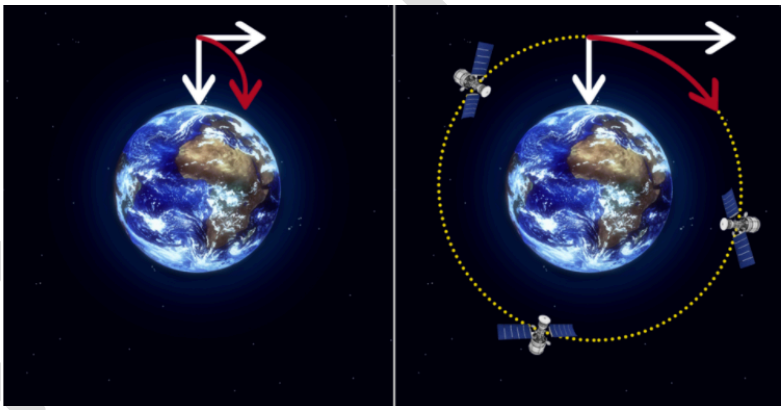
1. TABLE OF CONTENTS

1. SOME BASICS ABOUT SATELLITE ORBITS

1) ORBIT:

- An orbit is the curved path that an object in space (such as a planet, moon, star etc.) takes around another object due to gravity.
    - Objects of similar mass orbit each other with neither object at the centre, whilst small objects orbit around large objects. In our Solar system, earth revolves around sun, Moon revolves around earth.
- **Satellite Orbits:** The path that satellite takes to revolve around a planet due to force of gravity is called satellite orbit.

- **Gravity and Speed of Satellite in an orbit**



- **How are satellites placed in Orbit – Circular vs Elliptical Orbit** - Detailed Class Discussion

- **Orbital Velocity – Circular vs Elliptical**
    - For a circular orbit, it is always the same.
    - However, in the case of an elliptical one this is not the case as the speed changes dependent upon the position in the orbit. It reaches the maximum when it is closest to the earth and it has to combat the greatest gravitational pull, and it is at its lowest speed when it is furthest away.

2) TYPES OF ORBITS: 1. CIRCULAR (LEO, MEO, GSO) 2. ELLIPTICAL ORBITS

A) LOW EARTH ORBIT (CIRCULAR ORBIT)

- A low earth orbit is an orbit around earth with an altitude between 160 kilometers and 2000 Kilometers. Objects below approximately 160 Kilometers will experience very rapid orbit decay and altitude loss.

- It is **used for vast majority** of satellites.
  - Most satellites
  - All human space flights (except manner lunar flight of the Apollo program);
  - All space stations.

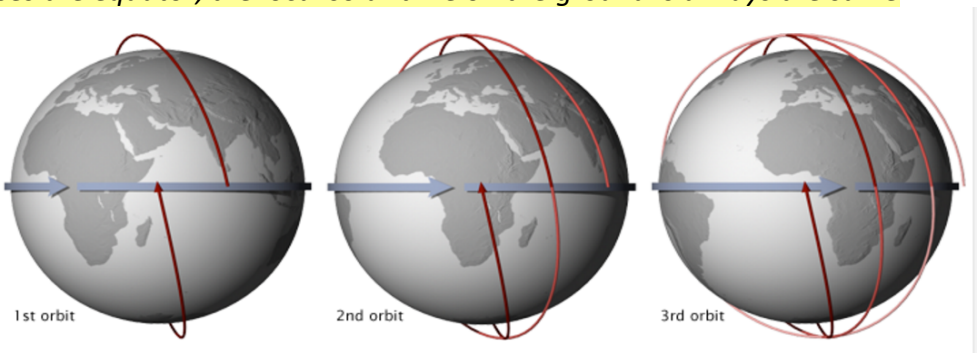
- **Main Characteristics**
  - **Low orbital period**
  - **Satellites closer to earth** -> better visibility -> earth observation/remote sensing satellites.
  - **Easier placement of satellite in orbit**
  - **Lower latency in communication** -> less round-trip time.
  - **Satellites face** lower radiations when compared to satellites at higher altitudes.

- **Applications**
  - **Earth Monitoring Satellites**
    - As they are able to see the surface of the earth more clearly
  - **Communication satellites**
    - Especially the satellite phones
  - **International Space Station** is at a height of 400 km.

SUN SYNCHRONOUS ORBIT (CIRCULAR OR ALMOST CIRCULAR) (POLAR ORBIT)

- **Satellites in Polar Orbit** usually travel past Earth from north to south rather than from west to east, passing roughly over Earth's pole. They don't have to pass the north pole or south pole precisely. Even a deviation within 20 to 30 degrees is still classed as polar orbit.

- **Sun Synchronous Orbit** is a kind of Polar Orbit. In this orbit, satellites are synchronized to always be in the same fixed position relative to the Sun. This means that the satellite always visits the same spot at the same local time. In this orbit, *whenever and wherever the satellite crosses the equator, the local solar time on the ground is always the same*.



- A sun synchronous combines altitude and inclination in such a way that an object on that orbit will appear to orbit in the same position, from the perspective of the sun, during its orbit around the earth. In other words, it orbits in such a way that **it precesses once a year**. The surface illumination angle will nearly be same every time.

- Typical sun-synchronous orbits are about 600-800 Km in altitude, with periods in the 96-100-minute range, and inclination of around 98 degrees.

- Possible only around **oblate planets like Earth, Mars etc**. The extra mass around the equator makes the precess possible. But Venus is too spherical to have a Sun Synchronous Satellite orbit.

□ **Significance of Sun-Synchronous Orbit**

- SSPO keeps the angle of sunlight on the surface of the earth as consistent as possible, though the angle will change from season to season. This consistency allows scientists to compare images from the same season over several years without worrying about too much extreme changes.

□ **Kinds of satellite put in Sun-Synchronous orbit:** Imaging, Spy and weather satellites (e.g. Cartosat-2 series)

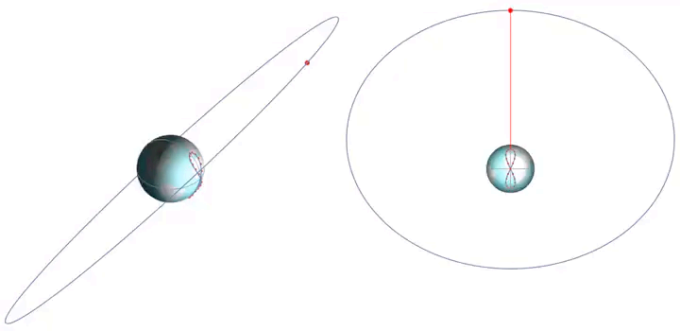
B) MEDIUM EARTH ORBIT

- **Height:** 2000 km to 3,5786 kms
- Satellite speed is lower (compared to LEO)
- **Orbital Period** range from 2 to 24 hours.
- **Most common use** of satellite in this orbit is for navigation, communication, and geodetic/space environment science.
- **Most common altitude** is approximately **20,200 km**, which yields an orbital period of 12 hours as used for examples by GPS.
- **E.g:**
  - GPS Satellites Fly in Medium earth orbit at an altitude of approximately 20,200 km.
  - Galileo (the satnav system of Europe) is also located in MEO.

C) GEOSYNCHRONOUS ORBIT AND GEOSTATIONARY ORBIT

GEO-SYNCHRONOUS ORBIT

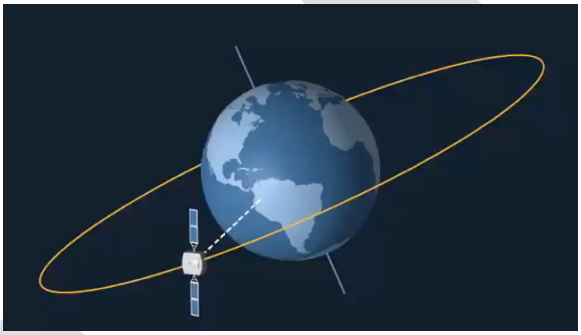
- It is a satellite orbit around the earth with an **orbital period that matches Earth's rotation period on its axis** (i.e., orbital period is **23 hours 56 minutes and 4 seconds**), irrespective of inclination.
  - » A person on a point on Earth, will see a satellite in this orbit in the same place in the sky at the same time of the day, every day.



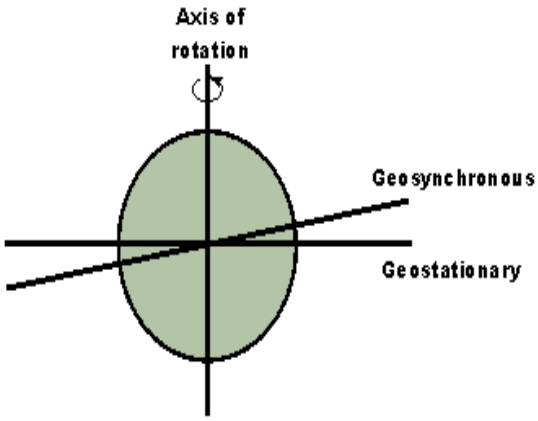
» Over the course of a day, the object's position in the sky traces out a path, typically in a figure-8 form, whose precise characteristics depend on the orbit's inclination and eccentricity.

- **Requirements:**
  - » **Circular Orbit** of **Height 35786 km**. At this height an orbital period of satellite is equal to earth's rotation period.
  - » **Direction of revolution** of satellite should be same as direction of rotation of earth.

GEO-STATIONARY - A SPECIAL CASE OF GEOSYNCHRONOUS



- A Geostationary Orbit is a particular type of Geosynchronous orbit, the distinction being that while an object in Geosynchronous orbit returns to the same point in the sky at the same time each day, an object in geostationary orbit never leaves that position.
- **Requirements for a satellite to be geostationary?**
  - Geosynchronous requirements
  - The equatorial plane of earth must be coplanar with the orbital plane of the satellite revolution (i.e., angle of inclination of orbit to equator is 0 degrees)
- Communication satellites and weather satellites are often placed in Geostationary orbits, so that satellite antenna which communicate with them don't have to rotate to track them but can be pointed permanently at the position in the sky where they stay.



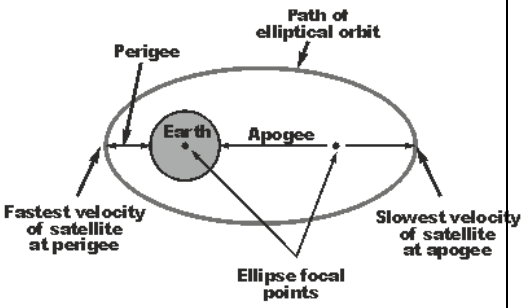
Geostationary orbit can only be over the Equator

- **Advantages**
  - Geo systems have significantly greater available bandwidth that the Low Earth Orbit - LEO and Medium Earth Orbit
  - Covers 1/3rd of Earth's surface.
  - Less expenses on tracking activities
  - Higher life span of satellites

- **Limitations**
  - Would require line of sight communication paths between terrestrial antenna and the satellites.
  - Long path length, and hence losses when compared to LEO, or MEO.
    - Long path length introduces delays.
    - Satellite costlier to install in GEO in view of the greater altitude
    - Geostationary Orbit (GEO) can only be above equator and therefore poles can't be covered.

3) HIGHLY ELLIPTICAL SATELLITE ORBITS

- Elliptical Orbits are often called Highly Elliptical orbits or HEO.
- Key Features
    - Follows the curve of an ellipse.
        - Moves much faster when it is near earth and slower when it is away from earth.
    - There are two focal points and one of the these is the geo-centre of the earth.
    - **Apogee**: Point where the satellite is furthest from Earth - gravitation pull is lowest - satellite moves the slowest
    - **Perigee**: Point where the satellite is nearest from earth - gravitation pull is highest - satellite moves the fastest
    - **How permanent coverage can be achieved?**



Highly elliptical satellite orbit, HEO

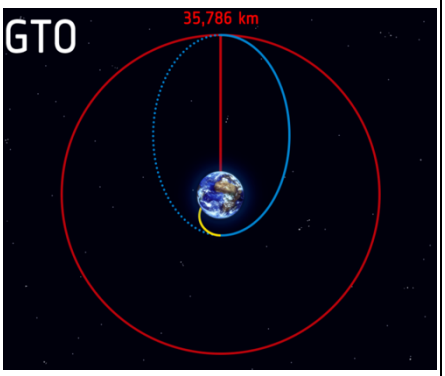
- **Applications**
    - Provide coverage at any point on the globe
        - It may provide high latitude and polar coverage.
            - Countries such as Russia which needs coverage over polar and near polar areas make significant use of highly elliptical orbits.

4) TRANSFER ORBITS

- These are special kind of orbits used to transfer satellites/spaceships from one orbit to another. These orbits are elliptical, with its perigee closer to earth. Satellites are taken to Perigee with the help of a rocket. After reaching this orbit, satellites by using relatively little energy from built in motors, can move to another larger orbit.
- This allows a satellite to reach a very high orbit, without needing the rocket to go to that height. **Geostationary Transfer Orbit (GTO)** is the most common type of transfer orbit.

A) GEOSTATIONARY TRANSFER ORBIT

- It is a Hohmann transfer orbit used to reach, geosynchronous or geostationary orbit. It is highly elliptical earth orbit with an apogee of 42,164 km, or 35786 km above sea level. Perigee can be anywhere above atmosphere, but it is generally restricted to few hundred Kms above the earth's surface.



- **Hohmann transfer orbit:** It is an elliptical orbit used to transfer between two circular orbits of different radii in the same plane.

5) SOME OTHER BASICS (CLASS DISCUSSION)

Why are satellites generally launched in west to east direction?

Why are satellites generally launched from the east coast?

Why are satellites launched from near the equator?

2. TIMELINE: INDIA IN SPACE, THROUGH THE YEARS

1) **1962:** The Indian **National Committee for Space Research is formed** under the leadership of Vikram Sarabhai and physicist Kalpathi Ramakrishna Ramanathan
2) **21 Nov 1963:** India's space program takes off with **launch of a sounding rocket** from Thumba Equatorial Rocket Launching Station in Kerala. It was for probing upper atmosphere.
3) **Aug 15, 1969:** ISRO is formed.
4) **Aug 19, 1975: Aryabhata** – India's first satellite is launched from a Soviet Kosmos-3M rocket from Kapustin Yar in the Soviet Union. It was designed and built in India.
5) **1979: Bhaskara-1,** the **first experimental remote sensing** satellite built in India, is launched. Images taken by its camera were used in hydrology, forestry and oceanography.
6) **1980: Satellite Launch Vehicle (SLV)-3**, India's **first experimental satellite launch vehicle,** takes off with Rohini Satellite RS-D2. Camera had the ability to use data for classifying ground features like water, vegetation, bare land, clouds and snow.
7) **1982:** INSAT 1-A is launched. Abandoned in 1983 where its altitude control propellant was exhausted.

8) **1984:** Rakesh Sharma, former IAF pilot, becomes the first Indian in space. In a joint India-Soviet Union Mission, Sharma boards the Soyuz T-11 spacecraft to the Salyut 7 orbital station.
9) **2008:** Launch of Chandrayaan-1. It orbits the Moon but doesn't land. It performs high resolution remote sensing aiming, among various missions, to prepare a 3D atlas of both the near and far sides of the moon.
10) **2013:** Launch of Mangalyaan, the Mars Orbiter Mission. Orbiting and studying Mars since Sep 24, 2014.
11) **2016:** All 7 satellites of IRNSS system placed in Orbit
12) **2019:** Chandrayaan-2 launched using GSLV MK-III
13) **2023:** Chandrayaan-3 succeeded in landing on the surface of the moon.

3. ISRO LAUNCHERS (OPERATIONAL)

PSLV, GSLV, Sounding Rockets are three broad categories of rockets (launchers) that ISRO has developed over the years.

Both PSLV (Polar Satellite Launch Vehicle) and GSLV (Geosynchronous Satellite Launch Vehicle) are the satellite launch vehicles (rockets) developed by ISRO.

1) PSLV (POLAR SATELLITE LAUNCH VEHICLE)

- The PSLV is the third-generation satellite launch vehicle of India. It is an expandable system and was the first Indian Launch Vehicle to be equipped with Liquid Stage.
  - **Note:** ISRO has over the years realized **5 generations of rockets** – SLV, ASLV, PSLV, GSLV, and GSLV-MK-III.

- **Where is PSLV used?**
  - It was developed to allow India to launch its Indian Remote Sensing (IRS) satellite into **Sun synchronous orbit**, a service that was, until the advent of the PSLV, commercially available only from Russia.
  - PSLV can also launch small size satellites into **Geostationary Transfer Orbit**.

- It is one of the world's most reliable launch vehicles.

PSLV was developed for Low Earth Orbit satellites into Polar and Sun Synchronous Orbits, and GSLV for heavier INSAT class of Geosynchronous satellites into orbit.

	SLV-3	ASLV	PSLV-XL	GSLV MK-II	GSLV MK-III
Height	22.7 m	23.5 m	44 m	49 m	43.43 m
Liftoff weight	17 t	39 t	320 t	414 t	640 t
Propulsion	All solid	All solid	Solid and liquid	Solid, liquid, and cryogenic	Solid, liquid, and cryogenic
Payload mass	40 kg	150 kg	1860 kg	2200 kg	4000 kg
Orbit	Low Earth Orbit	Low Earth Orbit	475 km Sun Synchronous Polar Orbit*	Geosynchronous Transfer Orbit	Geosynchronous Transfer Orbit

- **Launches So Far**
  - Developed in early 1990s, its first launch in 1993 was a failure.
  - First successful launch of PSLV took place in 1994 and till Jan 2023 (i.e., PSLV C-58), PSLV has had 60 launches with only two failures.

- **Technical Specifications of PSLV**
  - **Payload Capacity**: SSPO (1,860 Kg); GTO (1,425 Kg)

- **Key features of PSLV Engines**: PSLV has four stages using solid and liquid propulsion alternatively.

- **Expansion of capabilities: Strap on Motors**

  - PSLV uses 6 solid rocket strap-on motors to augment the thrust provided by the first stage in its PSLV-G (1678 kg in SSPO) and PSLV-XL (1750 kg to SSPO) variants. PSLV-DL, PSLV-QL versions use 2 and 4 straps on motors respectively. PSLV-CA (1100 kg in LEO) uses no strap on motors.

» **Key Significance and Achievements of PSLV**

- **Reliability**: Only 2 failures in almost 3 decades of service and 60 launches.
- **Commercial use**: PSLV has launched **more than 350 foreign satellites** from 34 different countries so far.
- It has played **significant role in various major ISRO missions** (including Chandryaan-1, MOM, IRNSS system etc.)
- **Strengthen India's Soft Power**
- Many **learnings** from the development of PSLV has helped scientists develop several non-space applications like fire resistant tiles, better engines for missiles etc.

A) SOLID FUEL ENGINE VS LIQUID FUEL ENGINE (EXTRA GYAN)

» **A solid rocket fuel** has its fuel and oxidant mixed together as fine powders and then pressed into solid cake.

- **Key characteristics**
  - **Higher Thrust** -> Higher force to launch the vehicle.
  - **Less volume**
  - **One time burn** -> all fuel burns at the same time, i.e., once it has been lit it will carry on burning until it is used up.
  - **Produces a lot of smoke -> large particles** when fired

» **A liquid fuel engine** uses liquid fuel which can have following advantages

- **Controlling Thrust**
- **Engine can be shut down and restarted**
- **Higher energy density** (joules per kg of propellant) is higher.
- **Higher Specific Impulse** (impulse (in Newton second) per kg of propellent)
- E.g., a modern solid fuel rocket has specific impulse of around 2500 N s Kg^{-1}, while a good liquid fuel rocket produces an impulse of about 4500 N s Kg^{-1}.
- **Disadvantage: More complicated Engine requirements and thus more expensive and heavier engine** -> pumps, piping, separate storage for the fuel and oxidant means that extra mass has to be carried by the launch vehicle.

» **Why Hybrid Engines**
  - Vastly reduce overall system weight and cost. It increases reliability (a smaller number of components which can fail)

B) PSLV C-58

- ISRO's PSLV C-58 has launched **XPOSAT Satellite** into an eastward low inclination orbit on 1st Jan 2024.
- After injection of XPOSAT, the PS4 stage was restarted twice to reduce the orbit into **350 km circular orbit** for orbital platform (OP) experiments. The PSLV Orbital Experiment Module-3 (POEM-3) experiment was executed to meet the objective of **10 identified payloads**, supplied by ISRO and IN-SPACe.
  - » These 10 payloads are developed by start-ups, education institutions and ISRO Centres.
  - » They are:
    - The Radiation Shielding Experimental Module (RSEM) by TakeMe2Space;
    - Women Engineered Satellite (WESAT) by LBS Institute of Technology for Women;
    - BeliefSa-t0 Amateur radio satellite by K.J. Somaiya Institute of Technology;
    - Green Impulse TrAnsmitter (GITA) by Inspecity Space Labs Private Limited;
    - Launching Expeditions for Aspiring Technologies -Technology Demonstrator (LEAP-TD) by Dhruva Space Private Limited
    - RUDRA 0.3 HPGP by Bellatrix Aerospace Private Limited;
    - ARKA-200 by Bellatrix Aerospace Private Limited;
    - Dust Experiment (DEX) by PRL;
    - ISRO Fuel cell Power System (**FCPS**) by VSSC, ISRO and;
    - FCPS payload is significant as it has potential applications in India's space station which is proposed to come up by 2035.
    - Si-based High Energy cell by VSSC, ISRO
- **Note**: This is the third time ISRO has operated the PSLV fourth stage in this way.
- **Thus**, it can be said that the PSLV-C58 mission represents a union of the aspirations of professional scientists, aspiring students of science, and India's private spaceflight sector.

ISRO SUCCESSFULLY TESTS POLYMER ELECTROLYTE MEMBRANE FUEL CELL ON PSLV'S-C58'S ORBITAL PLATFORM POEM3 (JAN 2024)

- ISRO successfully tested a 100 W class **Polymer Electrolyte Membrane Fuel Cell** based power system in its orbital platform, **POEM-3** which was launched onboard PSLV-C58 on 1st Jan 2024.
- The **objective** of the experiment was to **assess Polymer Electrolyte Membrane Fuel Cell operation in space** and to **collect data to facilitate the design systems for future mission**.
- **Outcome of the test**:
  - » During the short duration test onboard POEM, 180 W power was generated from Hydrogen and Oxygen gases stored onboard in **high pressure vessels**. It provided a wealth of data on performance of various static and dynamic systems.

C) PSLV C-57/ ADITYA-L1 MISSION (SEP 2023)

D) PSLV-C56 / DS-SAR MISSION (JULY 2023)

- The launch of PSLV C-56 carrying DS-SAR satellite, along with 6 co-passengers [all 7 Singaporean satellites] was accomplished successfully on July 30, 2023.
- PSLV C-56 was configured in **core alone model**, similar to C-55.
- **DS-SAR** is a 360 kg satellite into a Near-equatorial Orbit (NEO) at 5 degrees inclination and 535 km altitude.
    - DS-SAR satellite is used for satellite imagery requirements of various agencies within the government of Singapore.
    - It carries a Synthetic Aperture Radar (SAR) payload developed by Israel Aerospace Industries (IAI). This allows DS-SAR to provide all weather day and night coverage, and capable of imaging at 1m-resolution at full polarimetry.
- After the launcher placed all the seven satellites into a 535 km circular orbit, **PS4 stage was brought back to a lower orbit of 295 km X 300 orbit**. This has been done so that the stage spends less time in space, reducing its duration from over two decades to less than two months, before re-entering into the earth's orbit.

E) PSLV C-55/TELEOS-2 MISSION (APRIL 2023)

- **PSLV C-55/ TeLEOS-2** was launched successfully on April 22, 2023, from SDSC-SHAR, Sriharikota.
- This is a dedicated commercial mission through NSIL with **TeLEOS-2** as primary satellite and **Lumelite-4** as a co-passenger satellite.
- The satellite weigh about **741 kg** and **16 kg** respectively. Both belong to **Singapore**.

POEM-2: The mission has the PSLV Orbital Experiment Module (**POEM)**, where the spent PS4 stage of the launch vehicle would be utilized as an orbital platform to carryout scientific experiment through non-separating payloads. The payloads belong to ISRO, Bellatrix, Dhruva Space, and Indian Institute of Astrophysics.

2) GSLV (GEOSYNCHRONOUS SATELLITE LAUNCH VEHICLE)

- **Background of GSLV**
  - » GSLV is an expandable launch system operated by ISRO.
  - » First launch in 2001. First successful flight in 2003: successfully placed GSAT-2 in 2003.
  - » **Main Purpose**: GSLV was primarily developed to launch INSAT class of satellites into Geosynchronous Transfer Orbits. GSLV is being used for launching GSAT series of satellites.
  - » **Payload to GTO:** Presently GSLV-mk-II can inject **2.5 ton** (GSLV Mk-2) of communication satellite into Geosynchronous Transfer Orbit.
  - » **Payload to LEO:** GSLV's capability of placing up to **5 tonnes in LEO** broadens the scope of payloads from heavy satellite to multiple smaller satellites.

- **Three Stage Launcher (GSLV-Mk-2) (one solid motor stage (expandable with four liquid engine strap ons), one earth Storable Liquid stage, and one cryogenic stage)**

- **Third Stage: CUS**
  - Developed under Cryogenic Upper Stage Project (CUSP), the **CE7.5** is India's first cryogenic engine, developed by Liquid Propulsion Systems Centre in Mahendragarh, Tamil Nadu. CE-7.5 has a staged combustion operating cycle.
    - Fuel: LOX + LH_2 (Liquid Oxygen + Liquid Hydrogen)
    - Max Thrust: 75 KN

- **Variants**
  - **GSLV Mk 1(a,b,c)** - Not important
  - **GSLV Mk 2 (Operational)**
    - This variant uses an Indian cryogenic engine, the CE-7.5, and is capable of launching 2500 Kg into Geostationary transfer orbit. Previous GSLV vehicles (GSLV Mk1) have used Russian cryogenic engines.

A) LAUNCH VEHICLE MARK 3 (LMV3 OR GSLV MARK 3)

- LVM3 is a **3-stage** heavy lift launch vehicle developed by ISRO.
  1) **Solid Rocket Boosters: S200 –** GSLV MK III uses two S200 solid rockets boosters to provide the huge amount of thrust required for lift off. Fuel: **HTPB**.
  2) **A liquid Propellant core stage (L110):** The L110 liquid stage is powered by 2 Vikas engines.
  3) **A Cryogenic Stage (C25):** The C25 is an improvement on CE-20 Cryogenic engine, India's largest cryogenic engine, designed and developed by the Liquid Propulsion System Center
     a. Fuel: LOx + LH_2

- **Capability:** GSLV-Mk III can launch 4 tons class of satellites to Geosynchronous Transfer orbit (GTO) or about 8-10 tons to LEO, which is twice the capability of GSLV Mk II.

- **GSLV MK-III Flights so far**:
  - » GSLV-Mk III – D1 (2017): GSAT-19 to GTO

» GSLV-MK III – D2 (2018): GSAT-29 to GTO
» GSLV-MK III – M1 (2019): Chandrayaan-2
» GSLV-MK III – M2 (2022): OneWeb India-1 Mission
» GSLV MK III – M3 (2023): OneWeb India-2 Mission
» GSLV MK III – M4 (2023): Chandrayaan-3

- **GSLV MK-III – M2/ OneWeb India-1 Mission (Oct 2022)**
  - It was only the second operational flight of LVM3 (after Chandryaan-2 mission). It was a dedicated commercial satellite mission of NewSpace India Limited (NSIL). This mission was undertaken as part of the commercial arrangement between NSIL and m/s Network Access Associates Limited (m/s OneWeb Ltd), a UK based company. A total of **36 OneWeb Gen-1** satellites of about 150 Kg each totaling about **5,796 Kg** were launched to a **circular LEO of about 601 km** with a 87.4 degree inclination.
  - This was one of the biggest commercial orders executed by ISRO.
  - **Note: Some Unique features of the Mission**
    - First Commercial Mission of LVM3
    - First multi-satellite mission with 36 OneWeb Satellites onboard
    - First launch of LVM3 to LEO
    - First Indian rocket with six-ton payload
    - First NSIL Mission with LVM3
    - First OneWeb Mission with NSIL/DoS

LVM3 M3/ OneWeb India-2 Mission Accomplished Successfully (March 2023)

- In its sixth consecutive successfully flight of LVM3, the vehicle placed 36 satellites belonging to the OneWeb Group company in their intended 450 km circular orbit with an inclination of 87.4 degrees.
- The total weight of the payload was 5,805 kg.

LVM3 M4/ Chandrayaan 3.0 Mission was accomplished in July 2023

B) INDIA'S JOURNEY TOWARDS DEVELOPING ITS OWN CRYOGENIC ENGINE

- **Basics about Cryogenic Engine**
  - **Cryogenic engine** is a rocket engine that uses cryogenic fuel or oxidizer, i.e. its fuel or oxidizer (or both) are gases liquified and stored at very low temperatures.
  - **Note:** All Cryogenic engines are also, liquid propellent rocket engines or hybrid rocket engines.
  - **Fuel:** Combination of Liquid hydrogen and Liquid Oxygen is the most commonly used propellant in cryogenic engine. The fuel provides **very high specific impulse**.

- **Difficulties in developing Cryogenic engine:** Burning super cooled fuel at extremely high temperature; Developing material that can withstand high temperature and pressure during combustion.

  - **Advantages**
    - More efficient and provides more thrust for every kg of propellant it burns.

- **Current status**
  - CE-7.5 being used in GSLV MK-II.
  - CE-20 is being used in GSLV MK-III. It is indigenously developed for LVM-3.

- **Further upgradation:**
  - In Nov 2022, **ISRO has successfully conducted a hot test of CE20 cryogenic engine**. This successful hot test was at an **uprated thrust level of 21.8 tonne** for the first time.
  - This will **enhance the LVM3 payload capability upto 450 Kg with additional propellant loading**. The major modification carried out on this test article compared to previous engines was introduction of Thrust Control valve (TCV) for thrust control.
  - In addition to the hot test, a 3D printed LOX and LH2 turbine exhaust casings were also inducted in the engine for the first time.

4) SOUNDING ROCKETS

- Sounding rockets are one or two stage solid propellant rockets used for probing the upper atmospheric regions and for space research.
- They also serve as easily affordable platforms **to test or prove prototypes of new components** or subsystems intended for use in launch vehicles and satellites.
  - With the establishment of the **Thumba Equatorial Rocket Launching Station (TERLS) in 1963** at Thumba, a location close to the magnetic equator, there was a quantum jump in the scope for aeronomy and atmospheric sciences in India.
    - The launch of **the first sounding rocket** from Thumba near Thiruvananthapuram, Kerala on 21 November **1963, marked the beginning of the Indian Space Programme**. The rocket was **US Nike Apache**.
  - **Operational Sounding Rockets**
    - **Currently 3 versions** are offered as operational sounding rockets, which cover a payload range of 8-100 Kg and an apogee range of 80-475 Km.

Vehicle	RH-200	RH-300-Mk-II	RH-560-MK-II
Payload (in kg)	10	60	100
Altitude (in km)	80	160	470
Purpose	Meteorology	Aeronomy	Aeronomy
Launch Pad	Thumba, Kerala	SDSC-SHAR	SDSC-SHAR

  - **Rohini (Rocket Family)** is a series of sounding rockets developed by ISRO for meteorological and atmospheric study.
  - **ISRO's RH-200 sounding rocket records 200th consecutive successful flight** (Nov 2022)

- The small rocket lifted off from the launchpad at the **Thumba Equatorial Rocket Launching Station (TERLS)** at the Vikram Sarabhai Space Centre (VSSC).
- **Example of Experiment: Air Breathing Propulsion Experiment** using RH-560 rocket fitted with a supersonic combustion (Scramjet) engine on Aug 28 from Sriharikota. (Aug 2016)

4. OTHER ENGINES AND RELATED PROJECTS IN NEWS

1) ISRO'S NEXT-GEN LAUNCH VEHICLE (NGLV) MAY ASSUME PSLV'S ROLE

- ISRO is developing a Next-Gen Launch Vehicle (NGLV), which will one day replace operational systems like PSLV. Here ISRO is planning a three stage to orbit, reusable heavy lift vehicle with payload capacity of 10 tons to GTO.
- It will feature semi-cryogenic propulsion; simple and robust design (allowing bulk manufacturing, modularity and minimal turnaround time)

2) SEMI-CRYOGENIC ENGINE (UNDER DEVELOPMENT)

- Semi-Cryogenic Engine is an Indian Liquid fuel rocket engine using a combination of liquid oxygen (LOX) and refined kerosene (Isrosene) as propellants. It is being developed for future heavy lift launch vehicles and reusable launch vehicles.
- It is being developed by Liquid Propulsion System Centre, a subsidiary of ISRO.
  - Project Codename: SCE-200

- Where will it be used?
  - Immediate Application: One of the immediate applications will be to replace the liquid core (L110) engine of GSLV Mark-3 with the SCE-200 to boost the payload capacity of the rocket from 4 to six tonnes.
- **SCE-200: Other Details**
  - Cost of project: 1800 crore (Cabinet cleared the project in 2008).
  - Currently, only US and Russia have this technology.
  - In 2015, ISRO signed an MoU with Russian Space Agency to boost its plan for Semi-Cryogenic Launch Vehicle

3) DIFFERENCES BETWEEN CRYOGENIC ENGINE AND SEMI-CRYOGENIC ENGINE

	Cryogenic	**Semi-Cryogenic**
Fuel	Liquid Hydrogen + Liquid Oxygen	Isrosene + Liquid Oxygen
Temperature	Liquid hydrogen required to be stored at -253-degree celsius	Kerosene can be stored at normal temperatures
Weight	LH2 + LO2 is heavier than Kerosene and has to be stored	Lighter than liquid fuel and can be stored at normal temperature.

	at freezing temperature of -253 degree celsius.	Therefore, **kerosene occupies less space, and more propellant can be packed** in the semi-cryogenic engine's fuel compartment.
Specific Impulse	Cryogenic engine offers higher specific impulse then SCE	
Thrust to weight Ratio		It offers better thrust to weight ratio upto 180. Higher density of the exhaust gas in case of the SCE contribute to high mass flow rates making it easier to develop high thrust engines.
Stage	Higher specific impulse is valuable for upper stage, where mass comes at a premium price. So Cryogenic is used at upper stage.	• SCE have been preferred in lower stages when high thrust is must-have over specific impulse.

4) REUSABLE ROCKETS: REVOLUTIONIZING ACCESS TO OUTER SPACE

- **Details**
  - Reusable launch system is a launch system that includes the recovery of some or all of the component stages and reuse of these components in another launch.
  - **Till now**, several **fully reusable sub-orbital system** and **partially reusable orbital systems** have been flown. During 21st century, the interest in reusable launch system has grown considerably, with several active launchers.
    - **SpaceX's Falcon 9** rocket has a reusable first stage and expendable second stage. Plans for the second stage of the Falcon 9 to be made reusable, creating a fully reusable system, have been cancelled, with the SpaceX starship being planned as a fully reusable launch vehicle.
  - If ISRO is able to develop this technology, it will reduce the cost of launch by 70-80% and increase the competitiveness of ISRO in satellite launch market.

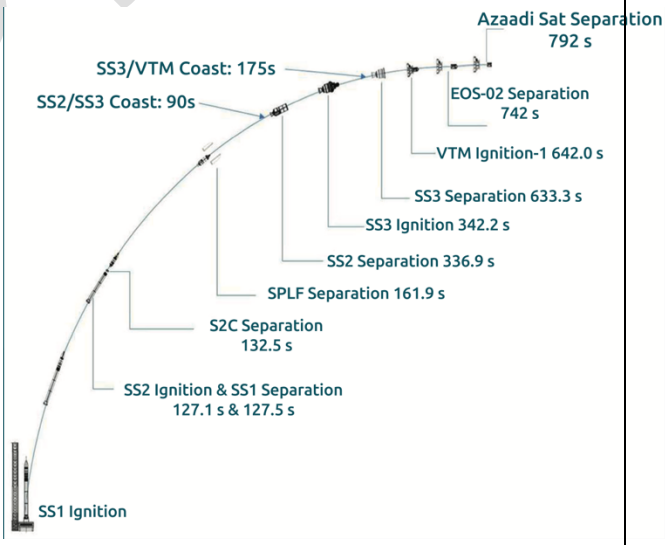
- **Steps taken by ISRO to develop RLV.**
  - In May 2016, ISRO successfully test fired its first indigenous winged reusable satellite launch vehicle.
    - In this experimental mission, the HS9 solid rocket booster carrying RLV-TD lifted off form the First Launch Pad at Satish Dhawan Centre, Sriharikota.
    - The RLV-TD re-entered the earth after reaching a height of 70 km.
    - It was a baby step towards developing reusable launch vehicle.
    - **Ultimate Aim**: Ultimate aim of the project is to put satellite into orbit around earth and then reenter the atmosphere.
  - **The final version would take another 10-15 years to get ready**.

5) LOW-COST SMALL SATELLITE LAUNCHER (SSLV)

- **Introduction**
  - The Indian SSLV (Small Satellite Launch Vehicle) is a small launch vehicle which serves small satellite launches.
  - It is the **smallest vehicle** at 110-ton mass at ISRO.
  - **Low turnaround time**: It takes only 72 hours to assemble (unlike around 70 days needed for PSLV).
  - **Low Human Resource requirement**: Only 6 people are required to do assembly (unlike 60 people for the PSLV).
  - **Cost Effective:** The overall cost of building the SSLV will only be Rs 30 crores.
  - **Capability:** Payload capacity of 500 Kg to 500 km planar orbit or 300 kg to SSPO. Using PSLV for these small satellites was an overkill.
  - It uses **three solid fuel-based stages** and a liquid fuel-based **velocity trimming module (VTM**) to place the satellite in orbit.
  - It is ideal for on-demand, quick turn-around launch of small satellites.
  - **Major technologies** developed as part of SSLV are flexible nozzle control with electro-mechanical actuators for all stages, miniaturized avionics, and a velocity trimming module in the upper stage for precise satellite injections.

- **Need**
  - The **global demand** for launch of small satellite is increasing. It is being demanded by businesses, government agencies, universities, and various research labs.

- **First Developmental Flight**
  - The maiden flight of SSLV in Aug 2022 can be considered a partial success.
    - When it came to the stage when the satellite had to be set in orbit, there was a glitch which resulted in the satellite being lost forever. ISRO announced that there was a malfunction of a sensor which resulted in placing the satellites in an elliptical orbit, rather than a circular orbit.
      - It placed the satellites into 356 km X 76 km elliptical orbit instead of 356 km circular orbit.



- **2nd Developmental Flight: SSLV-D2/ EOS-07 Mission (Feb 2023)**
  - The 2nd developmental flight of SSLV-D2 was successfully launched on Feb 10, 2023.
  - It intended to inject EOS-07, Janus-1 and AzaadiSAT-2 satellite into 450 km circular orbit, in its 15 minutes flight.
    - **EOS-07** is 156.3 kg satellite designed, developed and realized by ISRO. New experiments include mm-wave Humidity Sounder and Spectrum Monitoring payload.

- Janus-1, a 10.2 kg satellite belongs to Antaris, USA.
- **AzaadiSAT-2** is a combined effort of about 750 girl students across India guided by SpaceKids India, Chennai.

5. ISRO SATELLITES

1) BASICS

What is a satellite?

- Satellite means a smaller, space-based object moving in a loop (an orbit) around a larger object.
  - The Moon is a natural satellite of earth because gravity locks it in orbit around our planet.

2) COMMUNICATION SATELLITES

- **Introduction**
  - A communication satellite is an artificial satellite that is placed in earth's orbit for the purpose of sending and receiving communication data between a source and destination. They are basically "**space mirrors**" that can help us bounce radio, TV, Internet data, and other kinds of information from one side of earth to another.
  - It is used to provide **data communication and relaying services** for televisions, radio, telecommunication, weather and internet.
  - Communication satellites essentially overcome the problem of sending radio waves, which travel in straight lines, around our curved planet.
  - They commonly move in geo-stationary orbit.
    - Why?
  - Communication satellites can also move in highly elliptical orbit.

- **Two types of Communication Satellites – Passive and Active**

A) COMMUNICATION SATELLITES OF INDIA / ISRO

- **The Indian National Satellite System (INSAT) System** is one of the largest domestic communication satellite systems in Asia-Pacific region.
  - It was established in 1983 with the launch of INSAT 1B, it initiated a major revolution in India's communications sector and sustained the same later.
  - The system presently consists of the constellation of INSAT system consisting of around 20 operational satellites, namely INSAT-3A, 3C, 4A, 4B, 4CR, GSAT 6,7,8,9,10, 12, 14, 15, 16, 18, 19, 17, 6A, 29, **11** (largest 5850 Kg, Dec 2018), 7A (Mostly for serving air force, Dec 2018) and 31 (Feb 2019).
- INSAT system with more than 200 transponders in the C, extended C and Ku-bands provides services to telecommunication, television broadcasting, satellite newsgathering, societal application, weather forecasting, disaster warning and search and rescue operations.

B) RECENT EXAMPLES OF COMMUNICATION SATELLITES

GSAT-20

- **Why in news?**
  - ISRO's commercial arm to launch GSAT-20 Satellite on SpaceX's Falcon-9 in 2024 (Jan 2024)

- **Details about GSAT**
  - The GSAT-20 is a high throughput Ka- band satellite which will be fully owned, operated and funded by NSIL.
    a. It will offer Ka-Ka band HTS capacity with 32 beams having Pan-India coverage including A&N and Lakshadweep.
    b. The satellite weighs **4,700 kg** and offers HTS capacity of nearly **48 Gbps** and has been specifically designed to meet the demanding service needs of **remote and unconnected areas.**

3) EARTH OBSERVATION SATELLITES (PHOTOGRAPHY, IMAGING AND SCIENTIFIC SURVEYING)

- Earth Observation Satellites are specifically designed for Earth Observation from Orbit and are used for environmental monitoring, meteorology, map making etc. Most earth observation satellites carry instruments that should be operated at a relatively low altitude.

- **Earth Observation Satellites of India**
  - » Starting with IRS-1A in 1988, ISRO has launched many operational remote sensing satellites.
  - » Today, India has one of the largest constellations of remote sensing satellites in operation. Currently, earth observation satellites which are in **Sun-synchronous orbit** include
    - EOS-01, EOS-02, EOS-06 (Oceansat-3)
    - RESOURCESAT-1, 2, 2A
    - CARTOSAT-1, 2, 2A, 2B etc
    - CARTOSAT-3 (Launched in Nov 2019)
    - RISAT-1, RISAT-2, RISAT-2B (launched in May 2019 – PSLV C46), RISAT-2BR1 (launched in Dec 2019 – PSLV C-48)
    - OCEANSAT-2
    - Megha-Tropiques, SARAL and SCATSAT-1
    - **HySIS**
  - Earth Observation satellites in **Geostationary Orbit include:**
    - EOS-03 (couldn't be put in orbit due to failure of GSLV-F10)
    - INSAT-3D, INSAT 3DR
    - Kalpana & INSAT 3A
  - » Varieties of instruments have been flown onboard these satellites to provide necessary data in a diversified spatial, spectral and temporal resolutions to cater to different user requirements in the country and for global usage. The data from these satellites are used for several applications covering

agriculture, water resources, urban planning, rural development, mineral prospecting, environment, forestry, ocean resources and disaster management

4) SATELLITE NAVIGATION (SAT – NAV)

- **Why in news recently?**
  - ISRO's GSLV-F12 successfully places navigation satellite NVS-01 into intended orbit (May 2023)

A) BASICS ABOUT SATNAV

- A satellite navigation (SATNAV) system is a technology that allows users to determine their precise location, velocity, and time information anywhere on or near Earth's surface.
- It uses a network of satellite in space and provide accurate positioning data.
- Currently, there are **four global satellite-based navigation system –** the American **GPS**, the Russian **GLONASS** (GLObalnaya NAvigatsionnaya Sputnikovaya Sistema), the European **Galileo** and the Chinese BeiDou.
- India has a regional system called **NavIC** and Japan has **Quasi Zenith**.

- **Methods used in SATNAV: Triangulation and Trilateration**:
- **Accuracy**: They generally provide high levels of positioning accuracy (within a few meters), depending on the quality of receiver and the number of satellites in view. However, various factors such as signal obstruction, atmospheric conditions, and receiver limitations can affect the accuracy.
- **Applications**: **Navigation purposes** -> helping users find their way while driving, hiking, or boating. It is also used in aviation, surveying, geolocation-based services, precision agriculture, and even in some outdoor recreational activities. It can be used for vehicle tracking, fleet management, precise timing etc.

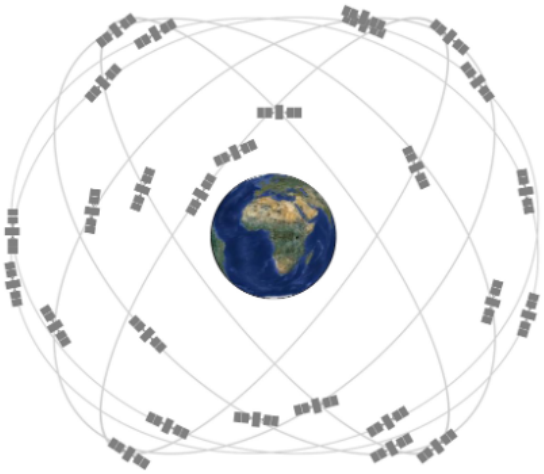
B) GLOBAL POSITIONING SYSTEM (GPS)

- The best-known satnav system, GPS, uses 24 active satellites (including backups). Day and night, 365 days a year, they whiz around earth once every 12 hours on orbital plane inclined 55 degrees to the equator.
- Wherever you are on earth, you are in sight of at least half a dozen of them, but **you need signals from 3 or 4 satellites** to determine your position with an accuracy of just a few meters.

- **How GPS Finds your location?**
  - It uses **Trilateration**

- **GPS Constellation arrangement**
  - GPS constellation fly in medium earth orbit (MEO) at an altitude of approx. 20,200 kms. Each circle orbits the earth twice a day.

» The satellites are arranged in six equally placed orbital planes surrounding the earth. Each plain contains four slots occupied by baseline satellites. This 24-slot arrangement ensures users can view at least four satellites from virtually any point on the planet.

» 

C) BEIDOU

- **Details**
  - China initiated Beidou in 1994 with first BeiDou satellite launched in 2000.
  - **Second generation BeiDou (BDS-2)** provided **coverage to Asia Pacific region** starting in 2012.
  - **Third generation BeiDou** (BDS-3) satellite deployment started in 2015. **In 2020, the system has been completed and it can now provide global services.** With this they have joined United States' GPS and Russia's GLONASS in providing global PNT services, with Europe's Galileo to follow. These are all compatible and interoperable, meaning users can draw services from all of those to improve accuracy.

- **Satellite Constellation**
  - **24 satellites in Medium Earth Orbit** (around 21,500 kms above the earth) provide the positioning, navigation, and timing (PNT) services. These satellites use rubidium and hydrogen atomic clocks for highly-accurate timing that allows precise measurement of speed and location.
  - **Satellites in geosynchronous Orbit (**including Geo-stationary orbit**)** help BeiDou provide short messaging service through which 120-character messages can be sent to other BeiDou receivers.

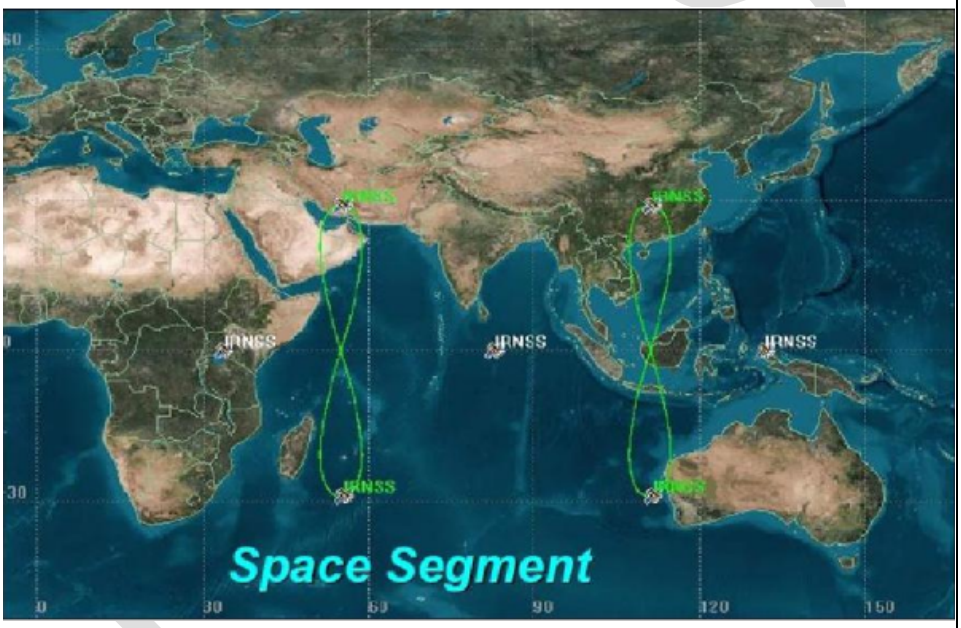
- **Plans of Expansion:**
  - In Nov 2022, China outlined plans to further expand the global reach of its home grown Beidou satellite navigation system.
    a. **Pakistan** in 2014 became the first foreign country to set up a Beidou network.
    b. **Beidou** has set up a first of three Continuously Operating Reference Stations (CORS) for its network in Thailand in 2013, to serve as a hub for ASEAN.

D) GAGAN AND GEMINI (CLASS DISCUSSION)

E) NAVIC (NAVIGATION USING INDIAN CONSTELLATION)

- Indian Regional Navigation Satellite System (IRNSS) (also called Navigation Using Indian Constellation (NAVIC)), is a regional satnav system developed by ISRO. It aims to provide reliable position, navigation and timing (PNT) services over India and its neighbourhood, upto 1500 km from its boundary. In addition it is also capable of broadcasting messages. This can be used for broadcasting safety-of-life alerts in areas with poor or no communication, particularly in Ocean.

- **Need of IRNSS** when services like GPS are easily available.
    - The access to foreign controlled global navigation satellite systems is **not guaranteed in hostile situations**, as happened to Indian military depending on American GPS during **Kargil Wa**r.



- **NAVIC provides two types of services**:
    - » **Standard Positioning Service** (Open for Civilian Use)
    - » **Restricted Services** (Encrypted one, for authorized users (military))

- **Components of IRNSS System**:

    - » Space segments consists of **7 satellites, 3 satellites in GEO stationary orbit (GEO)** and **4 satellites in GEO synchronous orbit(GSO)** with inclination of **29 degree** to the equatorial plane.
    - » All the satellites will always be visible in the Indian region.

    - » **First of the 2nd generation satellite – NVS-01** was successfully launched in May 2023
        - ISRO's **GSLV F12** (GSLV-MK-II mission)successfully places navigation satellite NVS-01 into intended orbit.
        - **About GSLV F12**:
            - » It is the 15th flight of India's GSLV and the 9th flight with indigenous cryo stage.

        - **About NVS-01**:
            - » **Heavier:** It weighs 2232 kg and has been placed in geosynchronous orbit (older IRNSS satellites weighed 1,425 kg)

» **Indigenous Atomic Clock**: For the first time, the satellite carries an indigenous atomic clock. The space qualified Rubidium atomic clock has been indigenously developed by Space Application Centre – Ahmedabad.

» **L1 signals for better use in wearable devices**: The second generation satellites have send signals in a third frequency, L1, besides the L5 and S frequency signals that the existing satellites provide. This will increase operability with other satellite based navigation systems. L1 frequency is the most commonly used in the GPS and will increase the use of NavIC in wearable devices which use low power signal frequency chip.

» **Longer Mission Life** of 12 years (earlier NavIC satellites have a mission life of 10 years).

- **Current Situation** (June 2023)
  - The receivers have now been deployed, and NavIC is in use for projects like public safety, power grid synchronization, real-time train information system, and fishermen's safety.
  - Other upcoming initiatives (such as) common alert protocol based emergency warning, time dissemination, geodetic network, unmanned aerial vehicles are in the process of adopting NavIC system.

    Some cell phone chipsets build by Qualcomm, MediaTek integrated NaviC receivers in 2019. Some example phones which are NavIC enabled include Redmi Note 9, realme 6, the OnePlus Nord etc.

5) SATELLITES TO STUDY THE SUN: ADITYA L1

- It is **India's first observatory class space based solar mission**.
- It was launched into space on 2nd Sep 2023 onboard PSLV-C57 and reached the L1 point on 6th Jan 2024, **127 days** after its launch.
- It has a mission life of **5 years** during which its payloads will **study various aspects of sun**. It serves as a **space weather station** and the data from the spacecraft will aid in making models and predicting storms in advance.
- The orbit of Aditya-L1 spacecraft is a periodic **Halo Orbit** with an **orbital period of about 178 earth days**. This halo orbit is a periodic, **three dimensional** orbit at L1 involving sun, earth and spacecraft.

- **Why study sun from space and specifically from Lagrangian point 1?**
  - **Why study sun from Space?**
    - Various types of radiations from sun are not able to reach earth due to **atmosphere of the earth and earth's magnetic field** making their study difficult from earth.
  - **Why from Lagrangian Point-1 (L1)?**
    - A Satellite placed in the **halo orbit around the Lagrangian point 1 (L1)** of the Sun-Earth system has the major advantage of **continuously viewing the Sun without any occultation/ eclipses.**

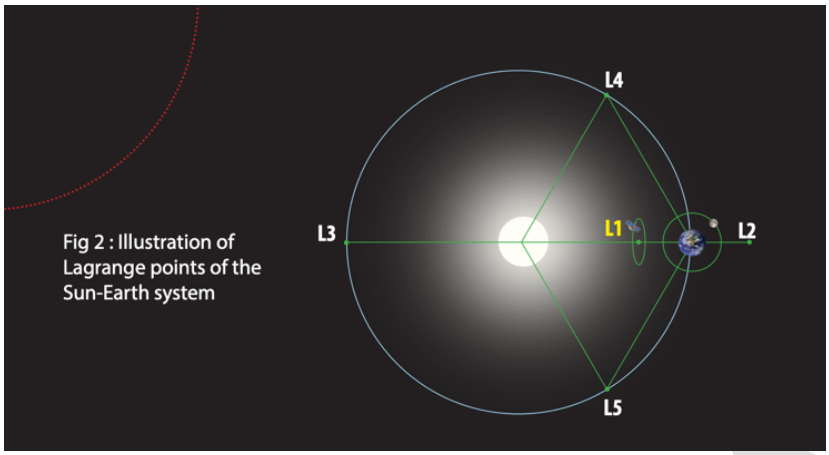
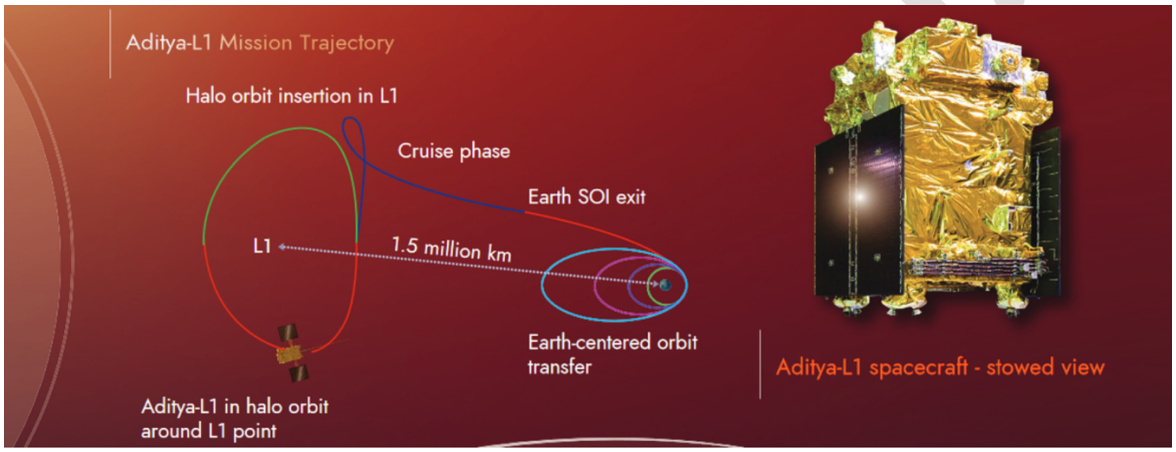


Fig 2 : Illustration of Lagrange points of the Sun-Earth system

What Trajectory ADITYA-L1 followed to reach Lagrangian Point-1: Through various orbit raising manoeuvres and cruise phase, it was placed in a halo orbit around the Lagrangian Point-1 (L1) of the Sun Earth System, which is about **1.5 million km** from the Earth.



The path Aditya-L1 will take to get to L1. | Photo Credit: ISRO

- **Major Science Objectives**:
  - Understand the **coronal heating and solar wind acceleration**; understand the initiation of **Coronal mass ejection (CME)**, flares, and near earth space weather; understand the coupling and dynamics of the solar atmosphere; understand solar wind distribution and temperature anisotropy.
- **Aditya-L1 went with 7 Payloads**:

Remote Sensing Payload:

a. **Visible Emission Line Coronagraph (VELC):** It can peek as close as **1.05 solar radii**, a region never imaged by any solar telescope. It can thus give us more information about **coronal mass ejection**.

b. **Solar Ultraviolet Imaging Telescope (SUIT):** It will observe UV radiations from different zones of the solar atmosphere. It will help us to better understand the climate variation on earth.

c. **Solar Low Energy X-Ray Spectrometer** (SoLEXS)

d. **High Energy L1 Orbiting X-Ray Spectrometer** (HEL1OS)

In-Situ Payloads:

a. **Aditya Solar Particle Experiment (ASPEX):** In-situ measurements of solar particles and ions.
b. **Plasma Analyzer Package for Aditya** (PAPA)
c. **Advanced Tri-axial High Resolution Digital Magnetometers**

With the help of e,f, and g scientists can predict probable geomagnetic storms and better understand space weather dynamics.

Understanding Lagrangian Points

- These are position in an orbital configuration of two large bodies where **a small object affected only by gravity can maintain a stable position relative to two large bodies**. The Lagrange points mark positions where the **combined gravitational pull of two large masses provides precisely the centripetal force required to orbit with them**.

- The interaction of the forces creates a point of equilibrium where a spacecraft may be "parked" to make observation.

- These points are named after Joseph-Louise Lagrange, an 18th-century mathematician.

- There are **five such points, labeled L1 to L5** all in the orbital plane of two large bodies.
  - Three of these Lagrangian points – **L1, L2, and L3 – are unstable positions** that lie along an imaginary straight line connecting the two larger bodies.
    - Because of this **instability**, an object positioned at one of the three unstable Lagrange points L1, L2, and L3 – can be easily de-orbited by even weak force and they will then drift into space. Therefore, spacecraft here will need to frequently burn fuel via its thrusters, at the various moments of displacement to adjust to orbital movement frequently.

  - The other two – **L4 and L5** – are **stable locations** that from the apexes of two imaginary equilateral triangles with the two large celestial bodies at the vertices of each triangle. Objects stay undisturbed at L4 and L5 because of a restoring force – a force acting against any displacement – that prevents them from being nudged away from the stable point. Because of this stability, this point tends to accumulate a lot of interstellar dust and asteroids called **Trojans** that zip around the points. Scientists have detected various Trojans at L4 and L5 of Sun-Jupiter System, Sun-Mars System, Sun-Neptune system etc.
    - **They are also potential Site for Space Colonies**

- **Are there other space explorers at L1**?
  - Yes, it is already home to **four robotic explorers** – NASA's Solar and Heliospheric Observatory Satellite, Deep Space Climate Observatory, Advanced Composition Explorer, and the Global Geospace Science Wind Satellite.
  - In next few years, some more observatories by USA and EU will be reaching here.

About HALO Orbits: A halo orbit is a, three dimensional orbit near the L1, L2, or L3 Lagrangian point in the three body problem of orbital mechanics. Although the Lagrange point is just a point in empty space, its peculiar characteristics is that it can be orbited.

6. OTHER IMPORTANT PROJECTS OF ISRO

1) PROJECT NETRA

- It is **an EWS in space to detect debris and other hazard**s to satellite. It will also provide warning against missile and space attack against India's assets.
- It will consist of many observational facilities, connected radars, telescopes, data processing units, control centers etc.
- **Initially**, it will be launched for **LEO satellites** which inhabits remote sensing satellites. **Eventually,** NETRA will also have the capability to capture **GEO**, where communication satellites mostly reside.
    - **Does India not have any collision avoidance detection mechanism now?**
- Even now, India does collision avoidance maneuvers on our satellites. But for this it depends on data from **NORAD (**North American Aerospace Defense Command**)** and others available in the public domain.

- **NOTE:** NORAD is an initiative of USA and Canada and shares selective debris data with many countries

2) MISSION SHAKTI

- An ASAT tested by India.

3) GAGANYAAN

4) XPOSAT (X-RAY POLARIMETER SATELLITE)

- **Why in news?**
    - ISRO launched the XPoSat, in a two-part mission, onboard a PSLV C58 flight on 1st Jan 2024.

- **More Details**
    - XPoSat is a specialized science mission that will study the **polarization of X-Rays** in space.
        - The **mechanization of polarization of radiation gives away the nature of its source,** including the strength and distribution of the magnetic field and the nature of radiation around it.

    - XPoSAT carries two scientific payloads in a **low earth orbit**:
        - The **Primary Payload** (POLIX) (**Polarimeter Instrument of X-Rays)** will measure the polarimetry parameters (degree and angle of polarization) in **medium X-ray range of 8-30 Kilo electron volt (KeV) photons** of astronomical origin.

- **The POLIX** payload is developed by the Raman Research Institute (RRI), Bangalore, with support from ISRO centres.
- The **XSPECT (X-Ray Spectroscopy and Timing)**: It will study X-rays of energy 0.8-15 KeV and changes in continuous X-Ray emissions.
  - The **XSPECT** payload is developed by the UR Rao Satellite Centre (URSC), ISRO.
- Together (POLIX and XSPECT), they are expected to shed light on intense X-ray sources such as pulsars and blackholes.

- **Need**:
  - **Better understanding of the universe**:
    - **So far**, astronomers have largely used and depended on spectroscopic, imaging and timing-based data obtained from either ground-based telescopes or satellite based missions. **Polarization** based study was done either in the optical or radio bands.
    - **XPOSAT** will be game changer and will facilitate X-Ray polarization measurement possible from bright source, that too in the medium energy band (8-30 KeV) – which **has never been attempted before**.
    - It is thus an **excellent diagnostic tool to understand the emission processes** from astronomical sources.
    - In space, X-Rays get polarized by multiple factors - for e.g. when X-rays are subjected to strong magnetic field or due to interactions with material present around black holes. So, by studying this polarization, scientists can understand the key characteristics of the **source**.

- **International Trend in Space-Based X-Ray Polarimetry**
  - Internationally, space-based x-ray polarimetry is gaining importance.
    - The **Imaging X-Ray Polarimetry Explorer** (IXPE) mission, launched in 2021, represents NASA's inaugural space-based endeavor, focused on scrutinizing X-Ray Polarization across various celestial bodies.
    - **Note:** XPoSAT energy range of 8-30 keV for polarization measurement is complimentary to IXPE energy range of 2-8 KeV (soft X-Ray band). Therefore, XPoSat and IXPE spacecrafts will collectively probe different emission mechanisms and physics for bright X-Ray sources. Their coordinated observation will provide a wide window in the energy range of **2-30 KeV** for polarimetric observations for bright X-Ray sources.

  - **Note**: India's ASTROSAT – India's first astronomy-based space mission launched in Sep 2015 – performed timing and broadband spectroscopy of X-Ray sources but no polarization studies were performed.

- **Which sources will be observed?**

- The XPoSat team has identified several tens of sources radiating X-Rays. XPoSat will observe two kinds of sources – **Persistent Sources** (targeted known source) and **transient sources** (pulsars, active galactic nuclei, magnetars)

- **Other Facts about XPOSAT**:
  - Launched on Jan 1, 2024
  - Precise Circular Orbit of 650 km, inclination of 6 degrees.
  - It is only the **second space-based experiment, to study X-ray polarization**, and at higher x-ray energies than the other, **NASA's Imaging X-Ray Polarimetry explorer**.
  - The instrument is totally indigenous in design and fabrication.

A) UNDERSTANDING POLARIZATION – CLASS DISCUSSION

B) UNDERSTANDING POLARIZED GLASSES

Polarized glasses cut the hazardous glare off the flat surfaces such as water, glass, and asphalt. When the polarized axis is vertical, all light that has been polarized through reflection and is now traveling horizontally (such as glare off of water or a windshield), will be blocked by the filter.

Polarized glasses are special materials which allow only vertically altering electric fields, and helps to decrease the glare from ground reflection, which consist of mostly horizontal polarization. Reflection polarizes the randomly varying sunlight into a single direction. Scattering of sunlight by air molecules also has a similar effect.

5) NASA-ISRO SYNTHETIC APERTURE RADAR (NISAR) IMAGING SATELLITE

- **Introduction:**
  - NASA-ISRO SAR (NISAR) is a LEO observatory being jointly developed by NASA and ISRO. It will map the entire globe in 12 days and provide spatially and temporally consistent data.
  - It carries **L** and **S** dual band SAR, which works with sweep SAR technique to achieve large swath with high resolution data.
  - Once launched, it will be **world's most expensive earth-imaging satellite** till date costing around $1.5 billion.

- **Collaboration**
  - NISAR is considered the first big collaboration between ISRO and NASA, certainly on RADAR but just in general as well.
    - S-Band SAR is being built by ISRO and L-band by NASA
    - The satellite will be launched from India using **GSLV-MK-2**.
    - **Uses:** NISAR will provide an unprecedented, detailed view of the earth by using Advanced RADAR imaging. It is designed to observe and take measurements of some of the planet's most complex process, including ecosystem disturbances, ice-sheet collapse, and natural hazards such as earthquakes, tsunamis, volcanoes, and landslides. The satellite thus will be used for:

- Mapping and monitoring of natural resources
- Estimating agricultural biomass over full duration of crop cycle.
- Assessing soil moisture
- Monitoring of floods and oil slicks
- Monitoring coastal erosion, coastline changes, and variation in the wind.

- **Target**: The target launch readiness date is January 2024.

7. NASA'S INTERPLANETARY MISSION

1) MARS ORBITER MISSION

- **Details**

  - Mars Mission (MOM), also called Mangalyaan is spacecraft orbiting MARS **since 24 September 2014**.
  - It was launched on 5 November 2013 by the Indian Space Research Organization (ISRO).
  - It is India's first interplanetary mission and ISRO has become the fourth space agency to reach Mars, after the Soviet space program, NASA, and the European Space Agency.
  - It is the first Asian nation to reach Mars orbit, and the first nation in the world to do so in its first attempt.

- **What is MOM doing?**
  - It has been looking for signs of atmospheric methane while studying surface features - just like NASA's MAVEN Mission. Methane is considered a **biomarker**: a substance whose presence indicates the current or historical presence of life.
  - MOM is also exploring and observing Mars surface features, morphology, minerology, and the Martian atmosphere.

- **Mars Orbiter Mission – 2** (Mangalyaan – 2) is expected to be launched in the year 2024. It will consist of an orbiter and may also include a lander and rover.

2) VENUS: SHUKRAYAAN-1

Why in news?

- India to launch Shukrayaan Venus Mission in 2024 after pandemic delays

Details

- Shukrayaan-1 is a **proposed orbiter to Venus by ISRO** to study the surface and atmosphere of Venus. It will be first mission to Venus by ISRO.
- ISRO has been soliciting ideas for instruments for a Venus-mission since at least 2018.
- **Earlier,** ISRO was aiming for a mid-2023, but pandemic related delays have pushed the target to Dec 2024.

» **Note:** This launch opportunity comes only in 19 months due to orbital configuration and period of Earth and Venus. So, after Dec 2024, the next opportunity will be available in mid-2026.

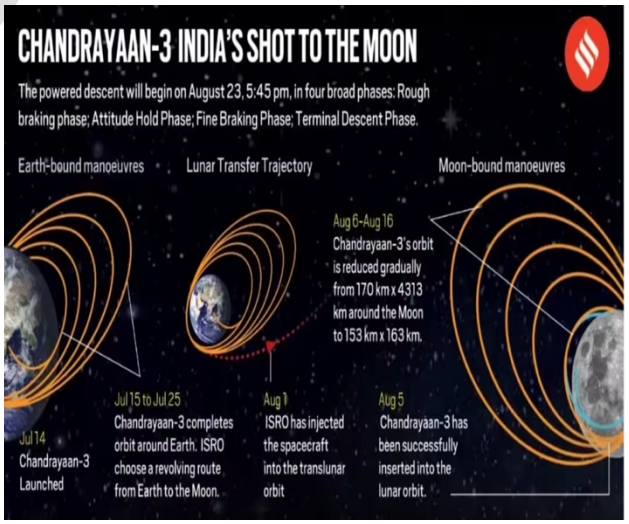
- It will be launched with the help of GSLV MK-II or GSLV MK-III.

- **Venus Missions in the Past**
  - » **Dozens of missions** have flown to Venus since the 1960s, but only a few in recent years.
    - **ESA's Venus Express** orbited the Venus between 2006 – 2014.
    - **Japan's Akatsuki** spacecraft entered orbit in 2015 after a previous unsuccessful attempt.
    - Several aircrafts are also performing **flybys** of Venus in the near future, including **NASA's Parker Solar Probe** for Solar Observation, and **Europe's BEPIColombo** en route to Mercury.

3) CHANDRAYAAN 3.0 (LVM3-M4) MISSION

- **Why in news?**
  - Chandrayaan-3 becomes the first to land near Moon's south pole (Aug 2023)
- **Details**
  - Chandrayaan -3 is the third Moon Mission of ISRO that was launched in July 2023 perched on GSLV-MK-3 heavy lift vehicle. It is a follow-on mission to Chandrayaan-2 and demonstrated **end-to-end capability in safe landing and roving in lunar surface** when it landed on the south pole of Moon on 23rd Aug 2023.
  - With this, India has become the **fourth** country in the world after USA, Russia and China to successfully land on Moon.

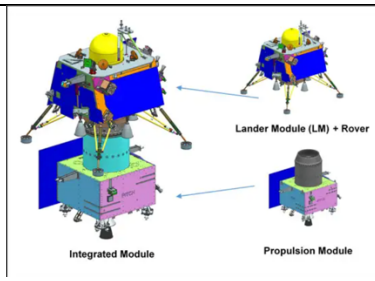
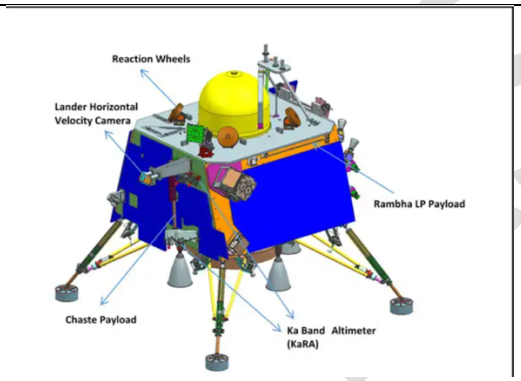
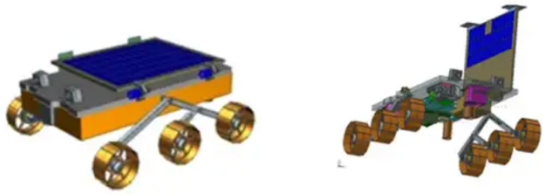
A) UNDERSTANDING THE DIFFERENT PHASES AND PATH TAKEN BY CHANDRAYAAN



- LVM-3 launched the Chandrayaan-3 in an elliptical parking orbit of 170 X 36500 km.
- Chandrayaan was launched on 14th July 2023. The whole process took 42 days, with the landing taking place on Aug 23.

B) COMPONENTS OF CHANDRAYAAN 3.0:

- It consists of a **Propulsion Module (PM), Lander Module** (LM), and a **Rover** with an objective of developing and demonstrating new technologies required for inter-planetary mission. **Note**: It doesn't have an orbiter module.

Propulsion Module (PM) PM carried the LM from launch vehicle injection till final lunar 100 km circular orbit and separated LM from PM. This propulsion module has Spectro-Polarimetry of Habitable Planet Earth (**SHAPE**) payload to study the spectral and Polari metric measurements of Earth from the lunar orbit.	
The Lander (Vikram) had the capability to soft land at a specified lunar site and deploy rover. It happened on 23rd Aug 2023. It remained **stationary** on the surface and carries four payloads which would record the chemical, thermal, and seismic instruments of the moon's surface. **Lander Payloads:** Lander module has four payloads (Chaste, RAMBHA, ILSA and LRA) **Chandra Surface Thermophysical Experiment (ChaSTE):** To carry out the measurements of thermal properties of lunar surface near polar region. **Instrument for Lunar Seismic Activity** (ILSA) for measuring the seismicity around the landing site and delineating the structure of the lunar crust and mantle.	 **RAMBHA- LP (Radio Anatomy of Moon Bound Hypersensitive ionosphere and atmosphere) - RAMBHA:** To measure the near surface plasma (ions and electrons) density and its changes with time. A passive **Laser Retroreflector Array** (LRA) from NASA is accommodated for lunar laser ranging studies. It acts as a target for lasers for very accurate measurements for future missions.
Rover (Pragyaan) is a 6 wheeled robotic vehicle. **Life**: One lunar day (14 earth day) **Payload**: Laser Induced breakdown Spectrometer **(LIBS):** It will determine the chemical and mineral composition of the lunar surface. Alpha Particle X-Ray Spectrometer **(APXS)**: It will determine the composition of elements such as magnesium, aluminium, silicon, potassium, calcium, titanium and iron in the lunar soil and rocks.	

C) LANDING WAS THE MOST COMPLICATED PART HERE:

- Landing is the **most complicated part** of the mission. The Lander and Rover get ejected at a speed of around 6,000 km/hr and have to be slowed down to roughly 3 km/hr before it lands. Since

moon doesn't have atmosphere, parachute kind of mechanism can't be used. Here, **thrusters** had to be fired in opposite direction to slow down the lander.

D) WHERE DID LANDER LAND?

- It landed at around 70-degree S near the southern pole of the moon.
- **Why?**
    a. The site was selected as there are several craters here that are permanent in shade and cane be reservoir of frozen water which is key to the future space mission.

E) ROVER:

Within a few hours of landing, ISRO also released a 26-kg rover from the lander module, which slided on the ramp to reach the moon's surface. The six wheeled rover, which is carrying two instruments and moves very slowly, is expected to crawl on the surface for 14 days, conducting chemical and elemental analysis of lunar soil and rocks.

E) COMPARING CHANDRAYAAN-1, CHANDRAYAAN-2 AND CHANDRAYAAN-3

	Chandrayaan-1	**Chandrayaan-2**	**Chandrayaan-3**
Year	2008	2019	2023
Rocket Used	PSLV	LVM-3	LVM-3
Payloads	Orbiter + Impactor Module (for crash landing)	Orbiter + Lander (Vikram) + Rover (Pragyan)	Lander + Rover
Successful	Yes	Partially Yes (Lander failed)	Yes
	Perhaps the most important discovery of Chandrayaan-1 was the **discovery of water and hydroxyl (OH) molecules** in the Moon's thin atmosphere (exosphere) as well on the lunar surface. **Buried Lava Tubes**: The terrain mapping camera and hyperspectral imager on board Chandrayaan-1 detected an underground **lava** tube, which, scientists believe, can provide a safe environment for human habitation in the future. It can protect against hazardous radiation, small meteoric impacts, extreme temperature and dust storms on the surface.	It helped in separately identifying the water and hydroxyl molecules, and mapping water features across the moon for the first time.	

D) CHANDRAYAAN 3 PROPULSION MODULE RETRACES STEPS TO EARTH ORBIT: WHY IT MATTERS? (DEC 2023)

- **What happened?**
  - Scientists have brought the propulsion module (PM) of Chandrayaan 3 mission back into earth orbit.
  - This was **not part of original mission plan**. It utilized the logistics advantage of near perfect mission, especially the availability of more than 100 Kg of fuel.
  - **How was this achieved?**
    - ISRO performed maneuver to raise the orbit of the PM around the moon (from 150 km to 5,112 kms)
    - Second maneuver targeted an earth orbit of 1.8 lakh X 3.8 lakh km.

- **Significance:**
  - This experiment prepares ISRO for future missions, especially the ambitious **Lunar Sample Return Mission**.
    - Through this ISRO has been able to understand what is involved in the "planning and execution of trajectory and maneuvers to return from Moon to Earth"

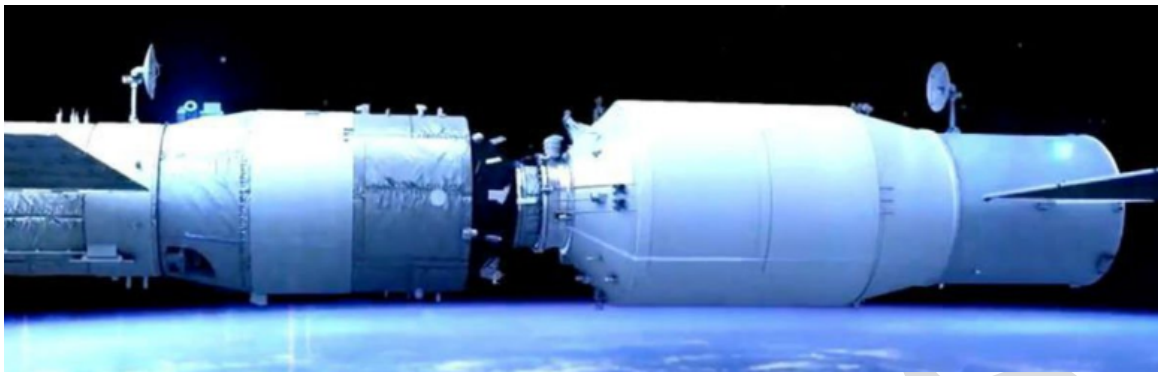
E) SIGNIFICANCE OF GOING TO MOON:

- It underlined **India's rise as a space and technology powerhouse**. It will also strengthen **India's soft power** in the global community.
- Since moon is the closest cosmic body to Earth, the plans to explore rest of the universe starts with exploration of the moon. Moon can also act as a promising test bed to demonstrate technologies required for future deep-space missions.
- It would further help "stimulate the advancement of technology, promote global alliances and inspire a future generation of explorers and scientists."
- **Resources**: Recent increase in interest in Moon is primarily due to possibility of important minerals being found on Moon.

8. OTHER IMPORTANT PROJECTS OF ISRO

1) INDIA'S OWN SPACE STATION: PLANS

- **What advancements will India need to achieve to have its space Stations?**
  - All the **Gaganyaan requirements** (Space suits, Training facilities for astronauts, Crew Escape Module, making GSLV Human rated, developing a habitable module etc)
  - **Larger bigger rocket** by upgrading the capabilities of GSLV-MK-III (it is right now capable of carrying on 10 tonnes to LEO)
  - Developing ability to perform **space docking.** ISRO has revealed its plan to carry out a space docking experiment, **Spadex**.



8. INTERNATIONAL COLLABORATION IN NEWS

1) ISRO – NORWAY

- **Why in news?**
  - Norwegian Ambassador Han Jacob Frydenlund's visit to ISRO's headquarters (June 2023)

- In June 2023, Norwegian Ambassador Frydenlund, accompanied by officials of Kongsberg Satellite service (KSAT), called on ISRO Chairman S. Somanath in Bengaluru, ISRO. The meeting concluded with a mutual agreement on the importance of maintaining a continued partnership and fostering increased engagements between India and Norway.

- It also offered an occasion to recall the '**Svalbard mission'** of 1997.

A) SVALBARD MISSION OF 1997

- On Nov 20, 1997, a Rohini RH-300 Mk-II sounding rocket rose to the skies from Svalbard, Norway, operationalizing a new rocket launching range.
- ISRO bagged the Norway mission after its commercial arm Antrix Corporation won a global tender floated by the Norwegian space agency.
- The RH-300 MK-II was given a new name by the NSC (Norwegian Space Centre): **Isbjorn-1**, which translates literally as 'Polar Bear-1'.

9. IMPORTANT TELESCOPES IN NEWS RECENTLY

1) VARIOUS TELESCOPES AT DEVASTHAL

- Devasthal observatory is located at Aryabhatta Research Institute of Observational Science (ARIES) in **Nainital.** It is located at the height of 2,450 metres in Himalayas. It is considered as one of the best sites for astronomical observations. This facility is the result of collaborative work between astronomers from ARIES, Institute of Astrophysics and Geophysics, Liege University, Belgium; the Canadian Astronomical Institutes from Vancouver, University of British Columbia; etc.

- **Telescopes at Devasthal:**
  - **Devasthal Optical Telescope (DOT)** is a custom-built instrument of great complexity. It has the distinction of being the **largest telescope in India for study of celestial objects at optical wavelength**. It is a national facility installed at Devasthal in the district of Nainital, India. It was commissioned in 2016 and is being mantained and operated by ARIES (Aryabhata Research Institute of Observational Sciences)
  - **Devasthal Fast Optical Telescope** (DFOT): It was commissioned in 2010.

  - **The International Liquid Mirror Telescope** (ILMT) is the only liquid mirror telescope operational anywhere in the world. It will also hold the unique tag of being the maiden liquid-telescope globally to be designed exclusively for astronomical purposes. It is the third telescope operating from Devasthal after DOT and DFOT.
    - The telescope was designed and built at the Advanced Mechanical and Optical Systems Corporation and the Centre Spatial de Liege, Belgium. The major instrumentation funding was jointly provided by Canada and Belgium while India will be responsible for the operations and upkeep of the telescope.
    - Unlike the conventional telescopes that can be steered to track specific stellar source objects, the ILMT will be stationary. It will basically carryout observations and imaging at the Zenith, that is, of the overhead sky. This is a survey telescope having high potential for discovering newer objects.
    - ILMT will operate every night for five years and carry out daily imaging except during June – Aug monsoon months, a precaution to protect the instruments from humid conditions.

- **What is liquid mirror telescope?**
  - LMTs are telescopes with mirrors made with a reflective liquid. The most common liquid is mercury, but other liquid will also work including (low melting alloys of gallium).
  - The liquid is rotated at a constant speed around a vertical axis, which causes the surface of liquid to assume a paraboloidal shape. This parabolic reflector can serve as the primary mirror of a reflecting telescope.
  - **Advantages:**
    - Low-cost alternative to conventional large telescopes.
  - **Limitations:** It can only be used as zenith telescopes (i.e. for looking straight up), so it is not suitable for investigation where the telescope needs to be continuously moved.

2) INDIA'S FIRST DARK SKY RESERVE

- **What is a Dark Sky Reserve?**
  - A Dark Sky Reserve is a designation given to a place that has policies in place to ensure that a tract of land or region has minimal artificial interference.

- **The International Dark Sky Association** (IDSA) is a **US based non-profit** that designates places as International Dark Sky Places, Parks, Sanctuaries, and Reserves, depending on the criteria they meet. Several such reserves exist in the world. **Between 2001 and Jan 2022**, there have been **195 sites** recognized as **International Dark Sky Places** globally. But, so far, no such reserve is in India.
- These reserves "consist of a **core area** meeting minimum criteria for sky quality and natural darkness, and a **peripheral area** that supports dark sky preservation in the core".

- **How does a site become a 'Dark Sky Reserve'?**
  - Individuals or groups can **nominate a site** for certification to the **IDSA**. There are five designated categories, namely International Dark Sky parks, communities, reserves, sanctuaries, and Urban Night Sky Places.
  - The certification process is similar to that of a site being awarded the **UNESCO World Heritage Site tag** or getting recognized as a Biosphere Reserve.
  - **Note:** India is still in the process of filing its nomination to IDSA.

- **Who is developing India's first Dark Sky Reserve?**
  - The **Ladakh UT administration** is leading the efforts to establish the country's first Dark Sky Reserve. The Department of Science and Technology (DST) and experts from Indian Institute of Astrophysics (IIA), Bengaluru, are providing scientific and technological support in developing this first of its kind facility. The formal decision to set up this Dark Sky Reserve was made through a MoU signed between officials from the **IIA, Bengaluru, the Ladakh UT and the Ladakh Autonomous Hill Development Counci**l in June 2022.
  - It will be situated at a height of 4,500 metres above sea level, **the Hanle Dark Sky Reserve** (HDSR) will come up within the **Changthang WLS**.
  - The IIA **already manages the Indian Astronomical Observatory (IAO) complex at Hanle, Ladakh**. Here scientists have been carrying out astronomical observations using the existing gamma ray, an infrared and an optical telescope to study exoplanets, galaxies, and stars through the pristine skies of Hanle.
  - **For Dark Sky Reserv**e, in the pilot phase, IIA has procured ten small and easy to handle telescopes and light reflecting shields. IIA's scientific and outreach experts will identify locals and train them to use these telescopes. This will include basic sky gazing, identification of constellations, and locating the pole star, among others. These telescopes will be **installed at the homestays,** which is a popular option for tourist accommodation in Ladakh.

- **Why was Ladakh chosen for the project?**
  - It is a unique cold desert located about 3,000 metres above sea level with high mountainous terrains. Very cold temperature and long and harsh winter makes the UT very inhabitable. This **aridity, limited vegetation, high elevation, and large area with sparse populations** – all make it the **perfect setting for long-term astronomical observatories and dark sky places**.

- **Promotion of Astronomy Tourism** in an environment friendly and sustainable manner is one of the primary objectives of the proposed reserve. Scientific methods would be used here to keep light pollution under control.

A) THE INDIAN ASTRONOMICAL OBSERVATORY (IAO)

- The Indian Astronomical Observatory, the **high-altitude station of IIA**, is situated to the north of Western Himalayas, at an altitude of 4,500 meters above mean sea level.
- It is located atop Mt. **Saraswati** in the **Nilamkhul Plain in the Hanle Valley in Changthang**, it is a dry, cold desert with sparse human population and has the **Hanle monastery as its nearest neighbours**.
- The cloudless sky and low atmospheric water vapor make it one of the best sites in the world for optical, infrared, sub-millimeter, and millimeter wavelengths.
- **Prominent Telescopes located at the Hanle Observatory:**
  - The Himalayan Chandra Telescope
  - High Energy Gamma Ray Telescope (HAGAR)
  - The Major Atmospheric Cherenkov Experiment Telescope (MACE)
  - Growth-India

10. SPACE INFRASTRUCTURE IN INDIA

- **Background**:
  - Space activities in India began with the establishment of the **Indian National Committee for Space Research (INCOSPAR)** in 1962. In the same year, work on establishment of Thumba Equatorial Rocket Launching Station (TERLS) near Thiruvananthapuram was also started.

  - **ISRO** was formed on 15th Aug 1969, and superseded INCOSPAR with an expanded role. In 1972, **Space Commission** and **Department of Space (DOS)** were constituted by the GoI, and ISRO was brought under DOS.
    - **ISRO** is the space agency of India. It is involved in science, engineering, and technology to harvest the benefits of our space for India and mankind. It has established major space systems for communication, television broadcasting, and remote sensing. It has also developed satellite launch vehicles like PSLV, GSLV, LVM-3 etc. It also contributes to science and science education in the country. It has launched Indian's NAVIC, Chandrayaan, MOM-1, Aditya-L1 and several other incredible missions.
    - **Space Commission** formulates the policies and oversees the implementation of the Indian Space Program to promote development and application of space science and technology for the socio-economic benefit of the country.
    - **DOS** implements these programs through ISRO and other associated organizations:

- **The Major establishments of DOS and their area of activities are:**

A) VIKRAM SARABHAI SPACE CENTRE (VSSC):

- Located in Thiruvananthapuram, it is responsible for design and development of **launch vehicle (rocket) technology**. Its major programs include, PSLV, GSLV, LVM-3, RLV, Rohini Sounding Rockets etc.

B) UR RAO SATELLITE CENTRE (URSC)

- Located in Bengaluru, it is the lead centre for design and development of **satellites** including communication, navigation and remote sensing satellites. These satellites provide applications in the areas of telecommunication, television broadcasting, VSAT services, tele-medicines, tele-education, navigation, weather forecasting, disaster warning etc.

C) SATISH DHAWAN SPACE CENTRE (SDSC)-SHAR

- It is the '**Spaceport of India**'. It is the backbone of the ISRO in providing **launch base infrastructure** for the Indian Space Program.
- It is located at Sriharikota, Andhra Pradesh.

D) LIQUID PROPULSION SYSTEMS CENTRE (LPSC)

- It is the lead centre of ISRO for the design, development, and realization of advanced **propulsion systems for launch vehicles**.
- It is primarily responsible for developing and deploying **earth storable, cryogenic, semi-cryogenic, and electric propulsion systems for ISRO's launch vehicles and satellites**.
- Its activities are spread across **its two campuses**, namely, LPSC, Valiamala, Thiruvananthapuram, and LPSC, Bengaluru.

E) SPACE APPLICATION CENTRE (SAC)

- Located in Ahemedabad, it's a major R&D centre of ISRO.
- It develops space borne and air-borne **instruments and payloads** and their applications for national development and societal benefits.
- For e.g., the **communication transponders** developed at this centre for the INSAT and GSAT series of satellites are used by the government and private sector for VSAT, DTH, Internet, broadcasting etc.
- It also designs and develops **optical and microwave sensors** for satellites, signal and image processing software, GIS software, and many applications for Earth Observation Program of ISRO.

F) HUMAN SPACE FLIGHT CENTRE (HSFC)

- Set up in 2019, it is the lead centre for ISRO's Human Spaceflight program.

- It undertakes multidisciplinary R&D activities in new domains of human science and technology while conforming to high standards of reliability and human safety.
- It is currently focused on **Gaganyaan mission** and is working on end-to-end mission planning, development of orbital module, life support systems, selection and training of astronauts etc.
- It is currently operating from ISRO-HQ campus, Bengaluru.

G) NATIONAL REMOTE SENSING CENTRE

- It is responsible for **establishment of ground centres for receiving satellite data**, generation of data products, aerial remote sensing data acquisition, dissemination to the users, development of techniques for remote sensing applications including disaster management support, geospatial services etc.

H) ISRO PROPULSION COMPLEX (IPRC)

- Located in Mahendragiri, it is responsible for assembly, integration and testing of liquid propulsion systems for operational and developmental launch vehicles.
- It is also responsible for qualification, testing and acceptance of liquid engines, cryogenic engines, spacecraft engines etc.

I) ISRO TELEMETRY, TRACKING AND COMMAND NETWORK (ISTRAC)

- It is responsible for providing telemetry, tracking and command (TTC), and mission control services to major launch vehicle, laboratory for electro-Optics Systems (LEOS) and Interplanetary Spacecraft missions of ISRO.
- It is also responsible for operating the complex ground segment of NaVIC.

J) MASTER CONTROL FACILITY (MCF)

- It is responsible for **on-orbit Operations (OOP)** and **Launch & Early Orbit Phase (LEOP)** operations of geostationary/geosynchronous & IRNSS class of spacecrafts of ISRO.
- It is located at Hassan in Karnataka.

K) ISRO INTERTIAL SYSTEMS UNIT (IISU)

- Located in Thiruvananthapuram, it is responsible for design and development of inertial systems for launch vehicles and satellites. These include mechanical and optical gyros, Altitude reference systems, accelerometer packages etc.

L) LABORATORY FOR ELECTRO OPTICS SYSTEMS (LEOS)

- Located in Bengaluru it is responsible for design, development and production of altitude sensors, high resolution imaging optics, and special purpose science instruments for several spacecrafts.

M) INDIAN INSTITUTE OF REMOTE SENSING (IIRS)

- IIRS, Dehradun, is a premier institute with primary aim to build capacity in Remote Sensing and Geoinformatics and their applications through education and training programs at the postgraduate levels.

N) DEVELOPMENT AND EDUCATIONAL COMMUNICATION UNIT (DECU)

- Located in Ahemedabad, it is responsible for implementation of satellite-based societal applications in the country.
- It is involved in the system definition, planning, implementation, and social research & evaluation of such applications.

O) NATIONAL ATMOSPHERIC RESEARCH LABORATORY

- Located in Gadanki near Tirupati, it is an autonomous organization engaged in **cutting edge research in atmospheric and space sciences** with the vision of developing capability to predict the behaviour of the earth's atmosphere through observations and modelling.

P) NORTHEASTERN-SPACE APPLICATIONS CENTRE (NE-SAC)

- It is an autonomous organization under DOS and Northeastern Council (NEC). It has the mandate of providing **space-based governance and development** by taking up projects in the fields of natural resource management, infrastructure planning, healthcare, education, emergency communication etc.
- It also conducts training and capacity building in the field of geospatial technology and UAV based remote sensing applications.

Q) INDIAN INSTITUTE OF SPACE SCIENCE AND TECHNOLOGY

- Established in 2007 at Thiruvananthapuram, it is Asia's first Space University. It aims to provide **high quality education** in Space S&T to meet the demands of the Indian Space Program. It offers undergraduate, postgraduate, doctoral and post-doctoral programs.

R) ANTRIX CORPORATION LIMITED (ACL)

- It is a GoI company under the administrative control of DOS.
- It is engaged in providing space sector products and services worldwide ranging from supply of hardware and software, earth observation and scientific missions, transponder lease services, launch services etc.

11.IMPORTANT PERSONALITIES

A) DR VIKRAM SARABHAI (12TH AUG 1919 – 30TH DEC 1971)

- Vikram Sarabhai, **father of Indian Space Program**, was born on 12th of Aug,1919 in Ahmedabad.

- **Key contributions**
  - He was a great institution builder and established or helped to establish a large number of institutions in diverse fields. He established **Physical Research Laboratory (PRL)** in 1947. PRL was the cradle of space sciences in India. PRL had a modest beginning at his residence, the RETREAT, with research in cosmic rays. It was formally established at M.G. Science Institute, Ahemedabad, on 11th Nov 1947
  - He played an important role in establishment of a number of institutions including IIM Ahemedabad.
  - The **establishment of ISRO** was one of his greatest achievements. He successfully convinced the government of the importance of space program after the Russian Sputnik launch.
    - He was the first chair of Indian National Committee for Space Research (INCOSPAR) which was predecessor to ISRO (established in its current form in 1969).
    - He also contributed in the setting up of Thumba Equatorial Rocket Launching Station at Thiruvananthapuram, with its inaugural flight in 1963.
  - He was also chairperson of Atomic Energy Commission.
- **Recognition**
  - **i)** He received Shanti Swarup Bhatnagar Medal in 1962
  - **ii)** Was awarded Padma Vibhushan (posthumously) in 1972. Earlier was awarded Padma Bhushan in 1966.
- **Other Key Positions held:**
  - **i)** President of the Physics Section, Indian Science Congress (1962)
  - **ii)** President of General Conference of the I.A.E.A, Vienna (1970)

B) S SOMNATH

- Sreedhar Panicker Somanath is the current chairperson of the ISRO. Earlier he has served as the chairperson of Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram and Director of Liquid Propulsion Systems Centre (LPSC), Thiruvananthapuram.
- He was associated with the PSLV project during its Initial days. He was also the project director of the GSLV-MK-III launch vehicle in from 2010 to 2014.

12. COMMERCIALIZATION AND PRIVATIZATION IN SPACE SECTOR

A) PRARAMBH MISSION

- **Why in news?**

- Launch of Vikram-S (i.e., Vikram Suborbital) rocket by Skyroot Aerospace is being hailed as an important milestone in India's outer space journey (Nov 2022)

- **Details:**
  - **Skyroot Aerospace**, an Indian private sector space enterprise, created history by launching India's first privately developed rocket **Vikram-S**.
  - **Vikram-S** is a single stage rocket. It is India's first privately developed cryogenic hypergolic-liquid and solid fuel-based rocket engine. It was developed using advanced composite and 3-D printing technologies.
  - It carried three customer payloads in a sub-orbital flight. It was launched from the sounding rocket complex of the ISRO's Satish Dhawan Space Centre in Sriharikota, Andhra Pradesh
  - The rocket reached a peak-altitude of 89.5 kms and has met all flight parameters.
  - **More About Skyroot:**
    - It is a relatively new entity that was set up in 2018. In 2020, after government announced opening up of space sector for private entities, it became the first startup to sign an MoU with ISRO to launch a rocket.
    - It is producing a series of Vikram Satellite, named after Dr Vikram Sarabhai. The goal is to launch small satellites using this rocket.
  - **Future Plans of SkyRoot:**
    - **Vikram-1** is being developed to carry 480 kg payload to Low inclination Orbit.
    - **Vikram-2** which will follow Vikram-1, will carry 595 kg to low inclination orbit.
    - **Vikram-3** will carry 815 kg to Low inclination orbit.
    - Skyrocket also says that the rockets will be able to undertake multi-orbit insertion ans inter-planetary missions as well as offer "customized, dedicated and ride share options covering a wide spectrum of small satellite customers needs".

2) NEW INSTITUTIONS

B) NEW SPACE INDIA LIMITED (NSIL)

- NSIL is a **wholly owned government of India undertaking/CPSE**, under the administrative control of Department of Space (DOS). It was established in March 2019 to **commercially utilize the R&D work of ISRO Centers** and other constituent units of DOS.

- **Roles and Functions:**
  - **i. Small Satellite technology transfer to Industry**, wherein NSIL will obtain license from ISRO/DOS and **sub-license it to industry**.
  - **ii.** Manufacture of SSLVs in collaboration with Private sector.
  - **iii.** Productionization of PSLV through Indian Industry.
  - **iv.** Productionization and marketing of space-based products and services, including launch and applications
  - **v.** Transfer of technology developed by ISRO Centres and constituent units of DOS

vi. Marketing spin-off technologies and product/services, both in India and abroad.
vii. Any other subject which GoI deems fit.

- **As part of the space sector reforms announced by GOI in June 2020**, NSIL was mandated to **build, launch, own and operate satellites** in "Demand-driven mode" to meet the service needs of the user.
- The **launch of Brazil's Amazonia-1 satellite** in March 2021, was the first dedicated communication mission of NewSpace India Limited. Earlier launches facilitated by NSIL were piggybacked with ISRO's primary satellites.
    i. Launch of GSAT-24 in June 2022 was the first demand driven satellite mission undertaken by NSIL. The capacity onboard the satellite was fully secured by **TataPlay**.
    ii. **Presently (Jan 2024) NSIL owns and operates 11 communication satellites in India**.
    iii. On similar lines, in 2024, NSIL will be undertaking the GSAT-20 satellite mission to offer cost-effective Ka-Ka band HTS capacity primarily for meeting the Broadband. The bulk of the capacity onboard GSAT-20 have already been secured by Indian Service Providers.

- **Significance of NSIL:**
    i. Meet the ever-increasing demands of Indian Space Program.
    ii. Commercially exploit the emerging global space sector.
    iii. Spur the growth of Indian Industries in the space sector and enable Indian industries to scale up manufacturing and production base.

B) IN-SPACE (INDIAN NATIONAL SPACE PROMOTION AND AUTHORIZATION CENTRE)

- It is an independent nodal agency under Department of Space (DoS). It was set up in 2020 to boost commercialization of Indian Space Activities and encourage private sector participation.

- It will permit and oversee the following activities of **non-Government Private Entities** (NGPEs):
    - Building of launch vehicles and satellites and providing space-based service as per the definition of space activities.
    - Sharing ISRO infrastructure/premise etc.
    - Establishment of temporary facilities within the premise of ISRO
    - Establishment of **new space infrastructure and facilities**, by NGPEs, in pursuance of space activities based on safety norms and other statutory guidelines and necessary clearance.
    - Building of Spacecrafts by NGPEs for registration as Indian satellites and all associated infrastructure
    - Using of spacecraft data and rolling out of space based services and all other associated infrastructure for the same.
- It will **draw up integrated launch manifest** – considering the needs of ISRO, NSIL, and NGPEs based on priorities and readiness.
- It will **draw up suitable mechanism for promotion, handholding, infra-sharing** etc. to encourage participation of NGPEs.
- The **decision of IN-SPACe** shall be final and binding on all stakeholders including ISRO, NSIL etc. NGPEs will not be required to seek separate permission from ISRO.

- **Structure of In-SPACe** – It has a Chairman, technical experts for space activities, safety experts, experts from academia and industries, legal and strategic experts from other departments, members from PMO and MEA of GoI.
- **Monitoring and Promotion Directorate of IN-SPACe** will have the oversight of the activities as per IN-SPACe decisions and shall report back to IN-SPACe for corrective actions and resolutions if any.