Today's Important Topic for UPSC CSE Aspirants (Aditya L1)

Comprehensive Explanation for Questions:

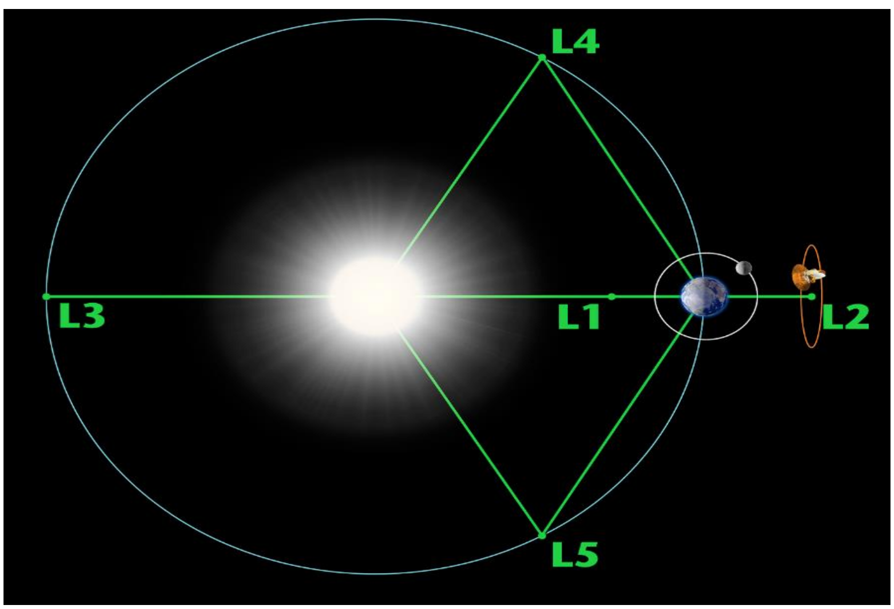
Inside Story of the News (Aditya L 1) :

- **India's first solar mission, ISRO's Aditya L1 spacecraft, named after one of the Sanskrit names of the Sun, will be launched by the PSLV-XL launch vehicle on August 26, 2023**, from the Satish Dhawan Space Centre (SDSC SHAR) in Sriharikota.
- **It will be launched into Low Earth Orbit (LEO) around 800 km from the Earth's surface.**
- The spacecraft will perform a 'Surya Namaskar' (salutation to the Sun) as it orbits around a special point called Lagrange point 1 (L1), which is about 93 million miles or 149 million kilometers away from the Sun.
- **This mission will be the first of its kind to study and research the Sun's atmosphere, its environment, and everything related to it.**
- The 1,500 kg spacecraft will carry special equipment called payloads to study different parts of the Sun's atmosphere.
- **Using the special vantage point L1, four payloads directly view the Sun, and the remaining three payloads carry out in-situ studies of particles and fields at the Lagrange point L1,** thus providing important scientific studies of the propagatory effect of solar dynamics in the interplanetary medium.
- The suits of Aditya L1 payloads are expected to provide most crucial information to understand the problem of coronal heating, coronal mass ejection, pre-flare and flare activities and their characteristics, dynamics of space weather, propagation of particle and fields etc.
- **The Aditya L1 mission will use its onboard thrusters to increase its orbital height and exit from the earth's gravitational influence, then it will cruise on a coasting path towards L1.**
- This method is adopted to have the best propulsion efficiency to conserve the propellant.
- **Once the spacecraft reaches approximately 1.5 million kilometers from Earth, it will be inserted into a halo orbit.**
- The Aditya L1 mission will always be in reduced Earth gravitational pull, as it will be in the L1 Lagrange point.
- **The L1, L2, and L3 Lagrange points are colinear, meaning that they lie along the line connecting the Earth and the Sun.**
- The L4 and L5 Lagrange points are 60 degrees apart, located 60 degrees ahead and behind the Earth in its orbit around the Sun.
- **The spacecraft shall be placed in a halo orbit around Lagrange point 1 (L1) of the Sun-Earth system, which is about 1.5 million km from the Earth.**
- **A satellite placed in the halo orbit around the L1 point has the major advantage of continuously viewing the Sun without any occultation/eclipses.**
- This will provide a greater advantage of observing solar activities and its effect on space weather in real time.

- **The spacecraft carries seven payloads to observe the photosphere, chromosphere and the outermost layers of the Sun (the corona) using electromagnetic and particle and magnetic field detectors.**
- **Major Objectives:**
  - Study of Solar upper atmospheric (chromosphere and corona) dynamics.
  - Study of chromospheric and coronal heating, physics of the partially ionized plasma, initiation of the coronal mass ejections, and flares
  - Observe the in-situ particle and plasma environment providing data for the study of particle dynamics from the Sun.
  - Physics of solar corona and its heating mechanism.
  - Diagnostics of the coronal and coronal loops plasma: Temperature, velocity, and density.
  - Development, dynamics, and origin of CMEs.
  - Identify the sequence of processes that occur at multiple layers (chromosphere, base, and extended corona) which eventually leads to solar eruptive events.
  - Magnetic field topology and magnetic field measurements in the solar corona.
  - Drivers for space weather (origin, composition, and dynamics of solar wind.

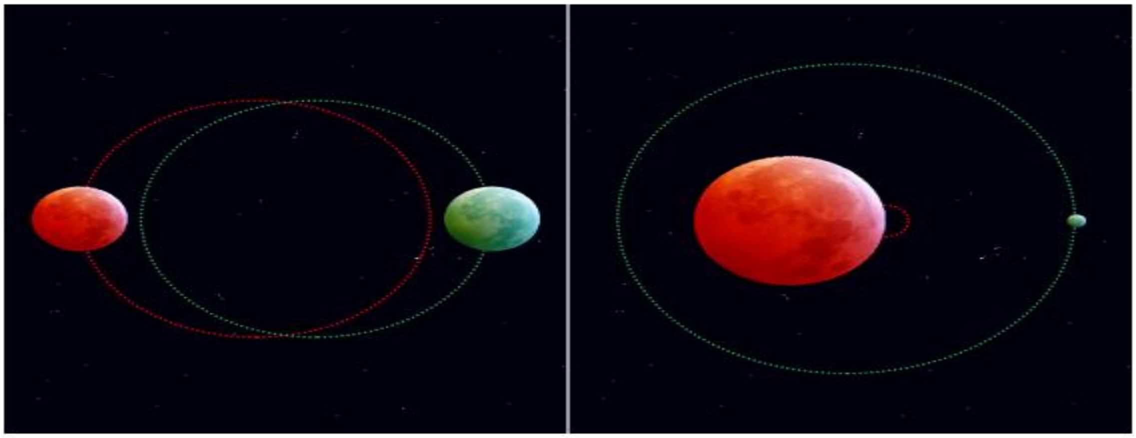
What are Lagrange Points?

- Lagrange points are positions in space where objects sent there tend to stay put.
- At Lagrange points, the gravitational pull of two large masses precisely equals the centripetal force required for a small object to move with them.



- These points in space can be used by spacecraft to reduce fuel consumption needed to remain in position.
- Lagrange Points are positions in space where the gravitational forces of a two-body system like the Sun and the Earth produce enhanced regions of attraction and repulsion.
- These can be used by spacecraft to reduce fuel consumption needed to remain in position.
- **Lagrange points are named in honor of Italian French mathematician Josephy-Louis Lagrange.**

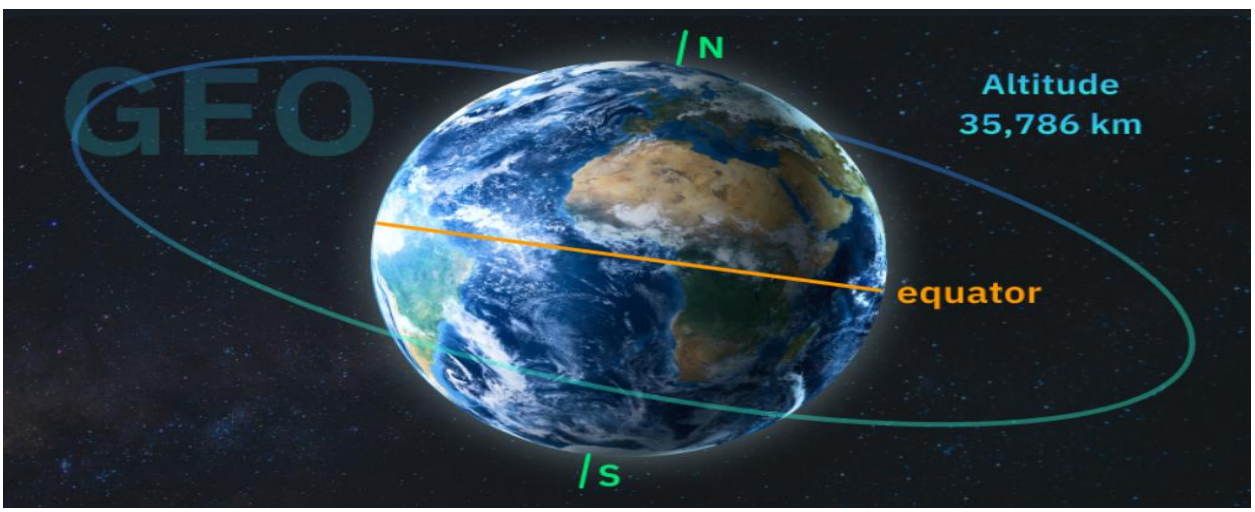
- The L1 point is one of the most important Lagrangian points, found by mathematician Joseph Louis Lagrange.
- It is located about 1.5 million kilometers inside Earth's orbit, between the Sun and the Earth.
- At these points, the gravitational forces between two objects balance out or have a neutral gravity point, making it possible for spacecraft to stay in one place without using much fuel.
- These spots are like parking spaces in space that spacecraft can use to stay in one place without using much fuel.
- It is like finding a stable spot in a river where the water flows in a way that keeps you in the same spot without paddling.
- **There are five special points where a small mass can orbit in a constant pattern with two larger masses.**
- The Lagrange Points are positions where the gravitational pull of two large masses precisely equals the centripetal force required for a small object to move with them.
- Of the five Lagrange points, three are unstable and two are stable.
- **The unstable Lagrange points – labeled L1, L2, and L3 – lie along the line connecting the two large masses.**
- **The stable ones, known as L4 and L5, form the tips of two equal-sided triangles with big masses at their corners.**
- **L4 is ahead of Earth's orbit, and L5 is behind it.**
- In the above contour plot, we see that **L4 and L5 correspond to hilltops and L1, L2 and L3 correspond to saddles (i.e., points where the potential is curving up in one direction and down in the other).**
- **The L1 point of the Earth-Sun system gives a clear view of the sun all the time, without any occultation/ eclipses and it is where the Solar and Heliospheric Observatory Satellite (SOHO) is located.**
- Aditya L1, is also known as Aditya-Lagrange Point 1. After reaching the LEO, the satellite will be maneuvred using its onboard thrusters.
- A series of earth burn elliptical orbital maneuvers are conducted to raise its orbit towards the L1 Lagrange point to surpass the earth's gravitational pull.
- The estimated time required to reach the L1 Lagrange point is around 109 days.
- Once the Aditya L1 mission reaches the L1 Lagrange point, it will be injected to a halo orbit.
- **A halo orbit is a type of orbit that allows the satellite to remain in a stable position between the Earth and the Sun.**
- The satellite will use its onboard scientific instruments to study the dynamics of the Sun's chromosphere and corona, its magnetic field, and its solar flares, solar wind etc.
- The data collected by the Aditya L1 mission will help scientists to understand better about the Sun and its impact on Earth.
- The most used L-points are **L1 and L2. These are both four times farther away from Earth than the Moon – 1.5 million km, compared to GEO's 36 000 km – but that is still only approximately 1% of the distance of Earth from the Sun.**



— Mass affects orbiting bodies

About an orbit:

- An orbit is the curved path that an object in space (such as a star, planet, moon, asteroid or spacecraft) takes around another object due to gravity.
- Gravity causes objects in space that have mass to be attracted to other nearby objects.
- If this attraction brings them together with enough momentum, they can sometimes begin to orbit each other.
- Objects of similar mass orbit each other with neither object at the centre, whilst small objects orbit around larger objects.
- In our Solar System, the Moon orbits Earth, and Earth orbits the Sun, but that does not mean the larger object remains completely still. Because of gravity, Earth is pulled slightly from its centre by the Moon (which is why tides form in our oceans) and our Sun is pulled slightly from its centre by Earth and other planets.

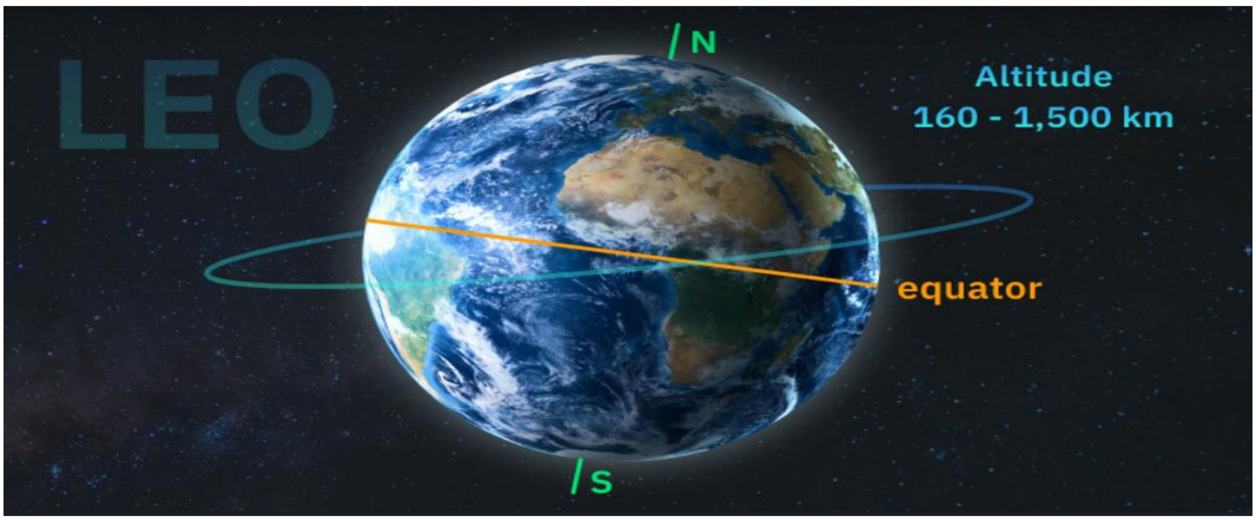


Types of orbits:

Geostationary orbit (GEO):

- Spacecraft in geostationary Earth orbit is positioned 35,786 kilometers above Earth's surface, precisely over the equator.
- Three evenly spaced machines in GEO can give nearly worldwide coverage thanks to the huge area they cover on Earth.

- Objects in GEO appear motionless from the ground because their orbital period is identical to Earth's rotation — 23 hours, 56 minutes, and 4 seconds.
- This allows a terrestrial antenna to always point toward the same device in space.
- That's why this type of satellite is perfect for always-on communication services like TV and phones.
- Also, this type can be used in meteorology to keep an eye on the weather in particular regions and track the development of local patterns.
- The downside of GEO type of spacecraft for real-time communication is the longer signal delay caused by their great distance from Earth.
- This makes satellites in GEO appear to be 'stationary' over a fixed position.



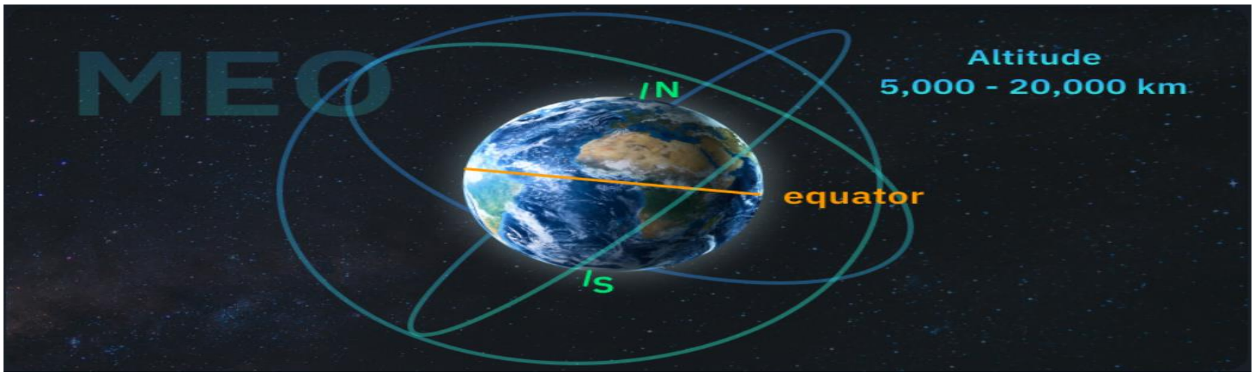
- GEO is used by satellites that need to stay constantly above one particular place over Earth, such as telecommunication satellites.

Low Earth orbit (LEO):

- Low Earth Orbit satellites are moving at an altitude of roughly 160–1,500 kilometers above the Earth's surface.
- They have a short orbital period, between 90 and 120 minutes, meaning they can travel around the planet up to 16 times a day.
- This makes them particularly well-suited to all types of remote sensing, high-resolution earth observation, and scientific research, as data can be acquired and transmitted rapidly.
- All the types of satellites in LEO can vary the angle of their plane relative to the Earth's surface.
- A low Earth type of orbit is very common, as it provides more potential paths for spacecraft to take.
- However, because of their proximity to the Earth, they have a smaller coverage area than other satellite types.
- Often, groups of LEO spacecraft, known as satellite constellations, are launched together to form some type of net encircling the Earth.
- This lets them cover huge areas simultaneously by working together.
- Unlike satellites in GEO that must always orbit along Earth's equator, LEO satellites do not always have to follow a particular path around Earth in the same way – their plane can be tilted. This

means there are more available routes for satellites in LEO, which is one of the reasons why LEO is a very commonly used orbit.

- It is also the orbit used for the International Space Station (ISS), as it is easier for astronauts to travel to and from it at a shorter distance.
- However, individual LEO satellites are less useful for tasks such as telecommunication, because they move so fast across the sky and therefore require a lot of effort to track from ground stations.
- Instead, communications satellites in LEO often work as part of a large combination or constellation, of multiple satellites to give constant coverage.



- To increase coverage, sometimes constellations like this, consisting of several of the same or similar satellites, are launched together to create a 'net' around Earth.

Medium Earth orbit (MEO):

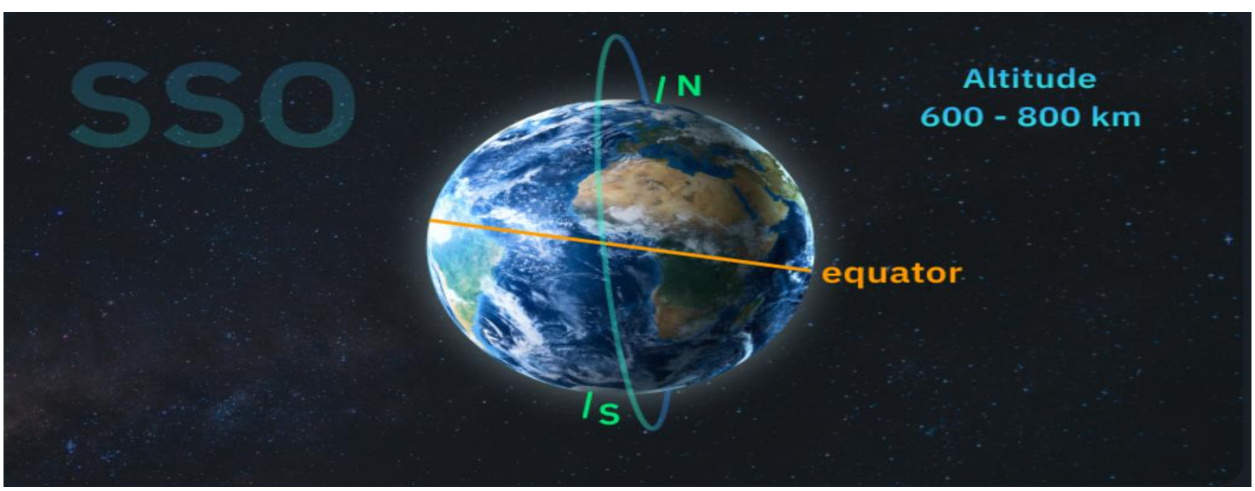
- A Medium Earth type of orbit is located between low Earth and geostationary orbits, typically at an altitude of about 5,000 to 20,000 kilometers.
- Positioning and navigation services, like GPS, extensively use MEO type of satellites.
- Recently, high-throughput satellite (HTS) MEO constellations have been put into operation to enable low-latency data communication to service providers, commercial and government organizations.
- With their longer orbital period (usually between 2 and 12 hours), this type of satellite offers a happy medium between coverage area and data transmission rates.
- Compared to low Earth orbit spacecraft, MEO ones require fewer devices to give worldwide coverage, but their time delay is longer, and their signals are weaker.
- Medium Earth orbit comprises a wide range of orbits anywhere between LEO and GEO.
- It is very commonly used by navigation satellites.
- Galileo powers navigation communications across Europe, and is used for many types of navigation, from tracking large jumbo jets to getting directions to your smartphone.
- Galileo uses a constellation of multiple satellites to provide coverage across large parts of the world all at once.

Polar orbit and Sun-synchronous orbit (SSO):

- The Sun-synchronous orbit type of satellites goes from north to south across the polar regions at an altitude of 600 to 800 km above the Earth.
- The orbital inclination and altitude of SSO spacecraft are calibrated so that they always cross any given location at precisely the same local solar time.
- Thus, the lighting conditions are consistent for imaging, making this type of satellite ideal for earth observation and environmental monitoring.
- This also implies that SSO's current and historical satellite images are well-suited for change detection.
- Scientists use these image sequences to learn about the development of weather patterns, forecast cyclones, monitor, and prevent wildfires and floods, and gather information on long-term issues like deforestation and coastline changes.
- But because of their lower orbital altitude, SSO type of spacecraft can only cover a smaller region at once and need more machines to do so continuously.
- Satellites in polar orbits usually travel past Earth from north to south rather than from west to east, passing roughly over Earth's poles.
- Satellites in a polar orbit do not have to pass the North and South Pole precisely; even a deviation within 20 to 30 degrees is still classed as a polar orbit.
- Polar orbits are a type of low Earth orbit, as they are at low altitudes between 200 to 1000 km.
- Sun-synchronous orbit (SSO) is a particular kind of polar orbit.
- Often, satellites in SSO are synchronized so that they are in constant dawn or dusk – this is because by constantly riding a sunset or sunrise, they will never have the Sun at an angle where the Earth shadows them.
- A satellite in a Sun-synchronous orbit would usually be at an altitude of between 600 to 800 km. At 800 km, it will be travelling at a speed of approximately 7.5 km per second.

Transfer orbits and geostationary transfer orbits (GTO):

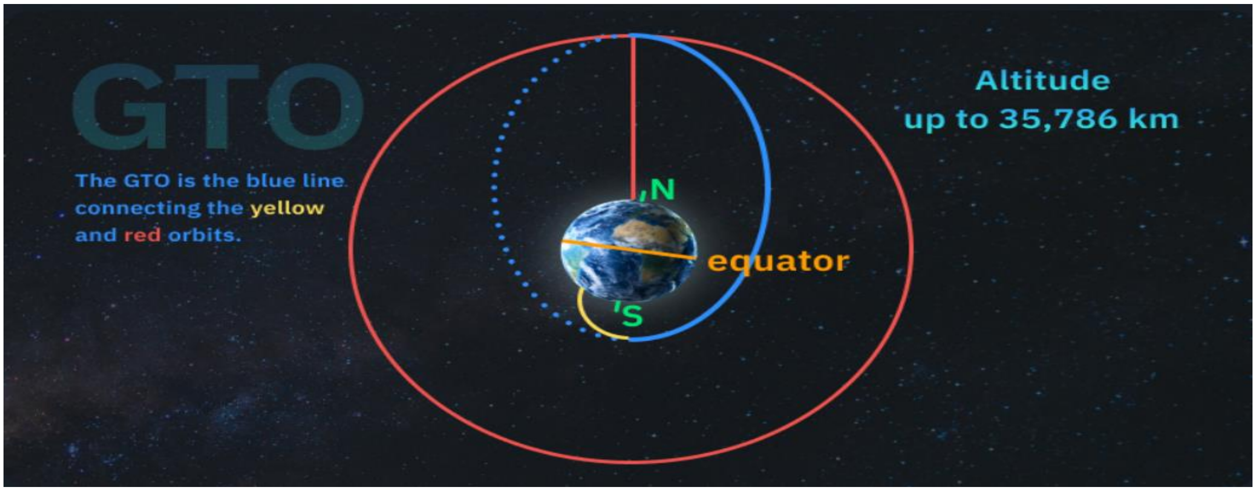
- The most frequent type of satellite transfer orbit is a geostationary one utilized to migrate from a transition orbit to GEO.
- Spacecraft are not always placed directly into their ultimate orbit when propelled from Earth into space by launch vehicles.
- Rockets carrying payload to GEO drop it off at transfer orbits, which are halfway points on the path to its final position.
- Then a satellite's engine fires to reach its destination orbit and adjusts its inclination.
- This shortcut allows the machine to reach geostationary orbit with minimal resources.



- Other, less common orbit types include the highly elliptical orbit (HEO), polar orbit, and Lagrange point (L-point).
- The objectives and tasks of the spacecraft will dictate the orbital type chosen.
- Because of this, there should be more thought given to satellite types by applications.
- Orbits have different eccentricities – a measure of how circular (round) or elliptical (squashed) an orbit is. In a perfectly round orbit, the satellite is always at the same distance from the Earth's surface – but on a highly eccentric orbit, the path looks like an ellipse.
- On a highly eccentric orbit like this, the satellite can quickly go from being very far to very near Earth's surface depending on where the satellite is on the orbit.
- At the target destination, the rocket releases the payload which sets it off on an elliptical orbit, following the blue line which sends the payload farther away from Earth.
- The point farthest away from the Earth on the blue elliptical orbit is called the apogee and the point closest is called the perigee.
- When the payload reaches the apogee at the GEO altitude of 35 786 km, it fires its engines in such a way that it enters onto the circular GEO orbit and stays there, shown by the red line in the diagram.
- So, specifically, the GTO is the blue path from the yellow orbit to the red orbit.

Do You Know about it ?

- Objects in GSO have an orbital speed that matches the Earth's rotation, yielding a consistent position over a single longitude.
- GEO is a kind of GSO.
- It matches the planet's rotation, but GEO objects only orbit Earth's equator, and from the ground perspective, they appear in a fixed position in the sky.
- GSO and GEO are used for telecommunications and Earth observation.
- LEO is commonly used for communication and remote sensing satellite systems, as well as the International Space Station (ISS) and Hubble Space Telescope.
- MEO is commonly used for navigation systems, including the U.S. Global Positioning System (GPS).



Source : https://www.theweek.in/news/sci-tech/2023/07/21/what-makes-aditya-l1-mission-to-sun-by-isro-special.html

; https://www.isro.gov.in/Aditya_L1.html

; https://www.esa.int/Science_Exploration/Space_Science/L1_the_first_Lagrangian_Point#:~:text=The%20L1%20point%20is%20perhaps,the%20Sun%20and%20the%20Earth.

; https://solarsystem.nasa.gov/resources/754/what-is-a-lagrange-point/

& https://eos.com/blog/types-of-satellites/