Bharathidasan University , Tiruchirappalli, Tamil Nadu

Programme: M.Tech Geoinformatics
Course: Remote Sensing

Unit 3: Satellite Orbits

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Orbits

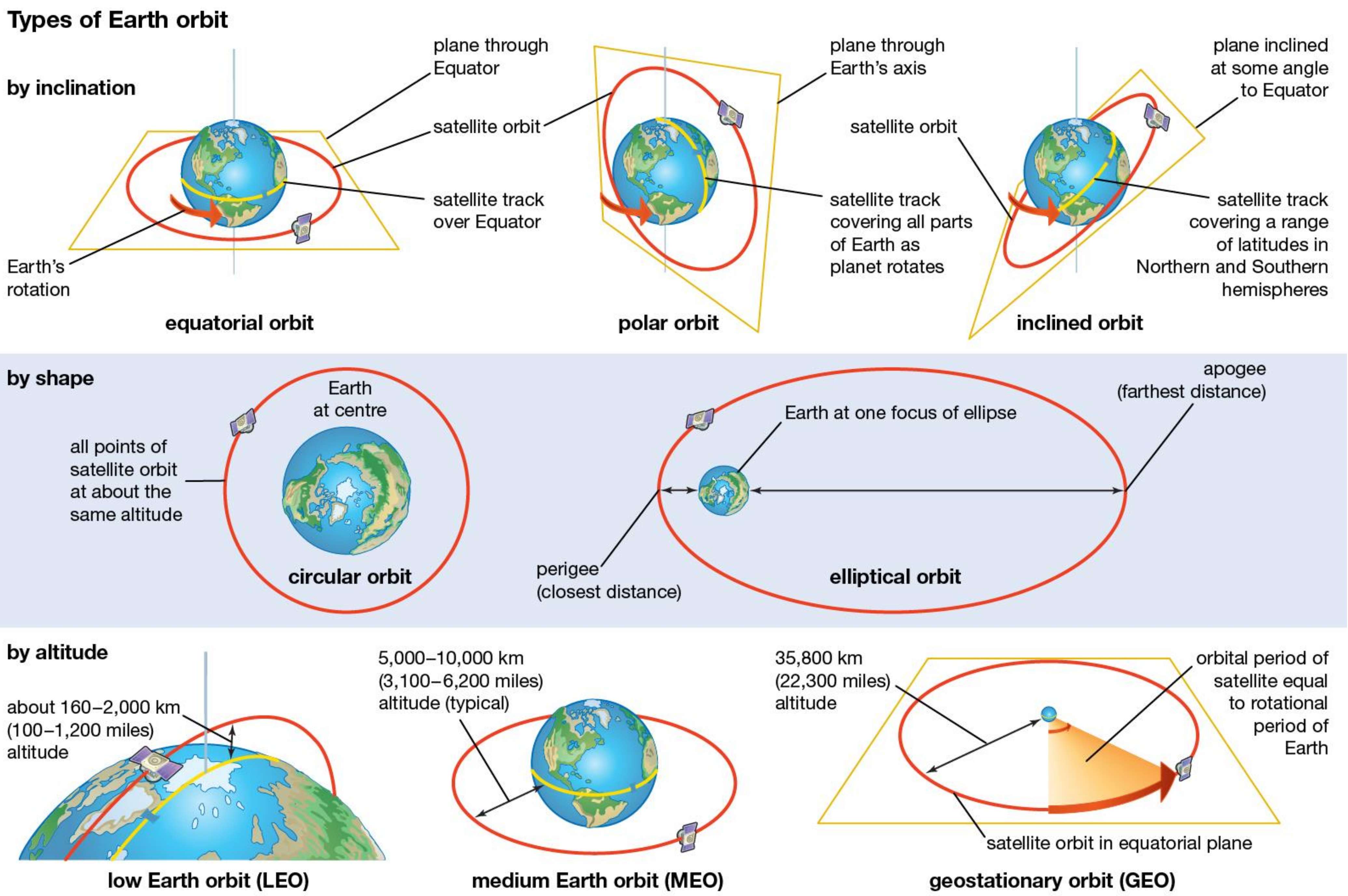
The path followed by a satellite is referred to as its orbit.

Satellite orbits are matched to the capability and objective of the sensor(s) they carry.

Orbit selection can vary in terms of altitude (*their height above the Earth's surface*) and their orientation and rotation relative to the Earth.

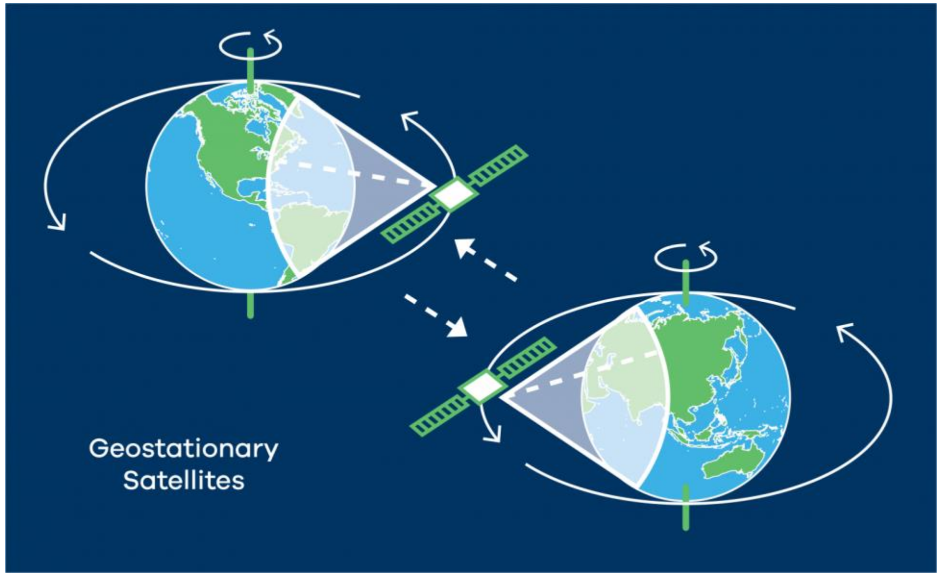
Types of Orbits

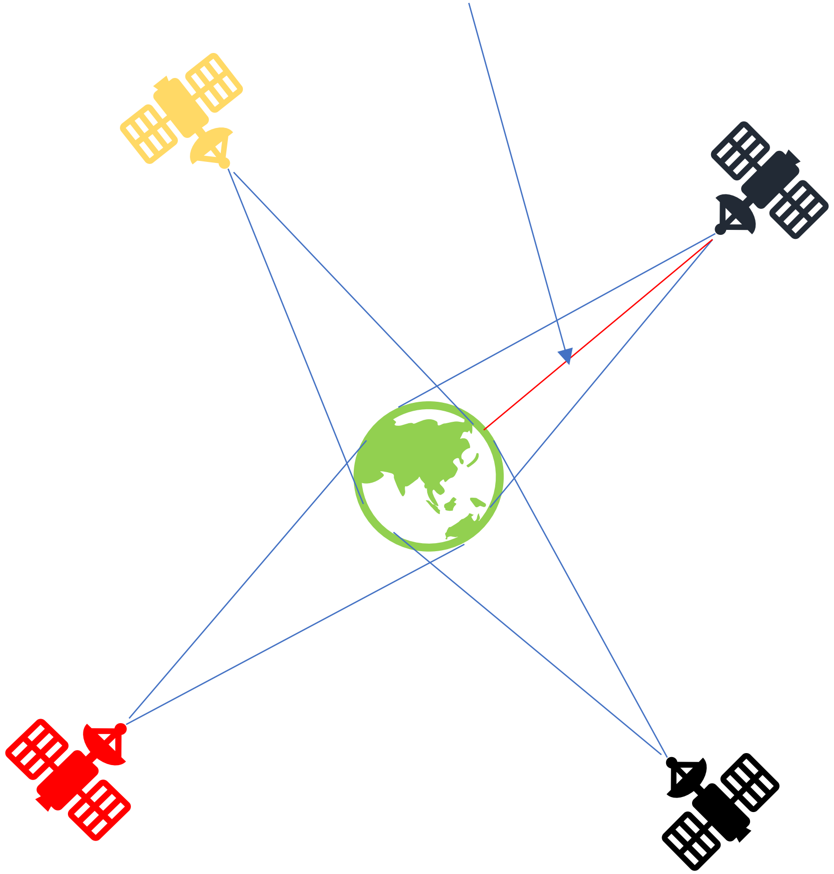
- Geostationary orbit (GEO)
- Low Earth orbit (LEO)
- Medium Earth orbit (MEO)
- Polar orbit and Sun-synchronous orbit (SSO)
- Transfer orbits & geostationary transfer orbit (GTO)
- Lagrange points (L-points)


Types of Earth orbit
by inclination
plane through Equator
satellite orbit
satellite track over Equator
Earth's rotation
equatorial orbit
plane through Earth's axis
satellite track covering all parts of Earth as planet rotates
polar orbit
satellite orbit
plane inclined at some angle to Equator
satellite track covering a range of latitudes in Northern and Southern hemispheres
inclined orbit
by shape
Earth at centre
all points of satellite orbit at about the same altitude
circular orbit
apogee (farthest distance)
Earth at one focus of ellipse
perigee (closest distance)
elliptical orbit
by altitude
about 160–2,000 km (100–1,200 miles) altitude
low Earth orbit (LEO)
5,000–10,000 km (3,100–6,200 miles) altitude (typical)
medium Earth orbit (MEO)
35,800 km (22,300 miles) altitude
orbital period of satellite equal to rotational period of Earth
satellite orbit in equatorial plane
geostationary orbit (GEO)

Geostationary orbit (GEO)

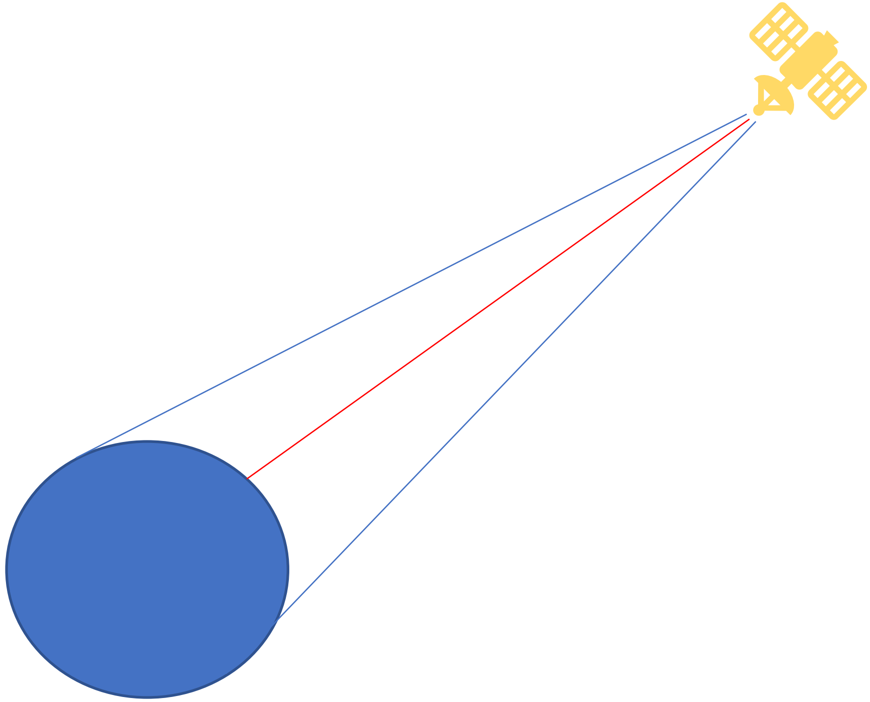
Satellites in geostationary orbit (GEO) circle Earth above the equator from west to east following Earth's rotation – taking 23 hours 56 minutes and 4 seconds – by travelling at exactly the same rate as Earth. This makes satellites in GEO appear to be 'stationary' over a fixed position. In order to perfectly match Earth's rotation, the speed of GEO satellites should be about 3 km per second at an altitude of 35 786 km. This is much farther from Earth's surface compared to many satellites.

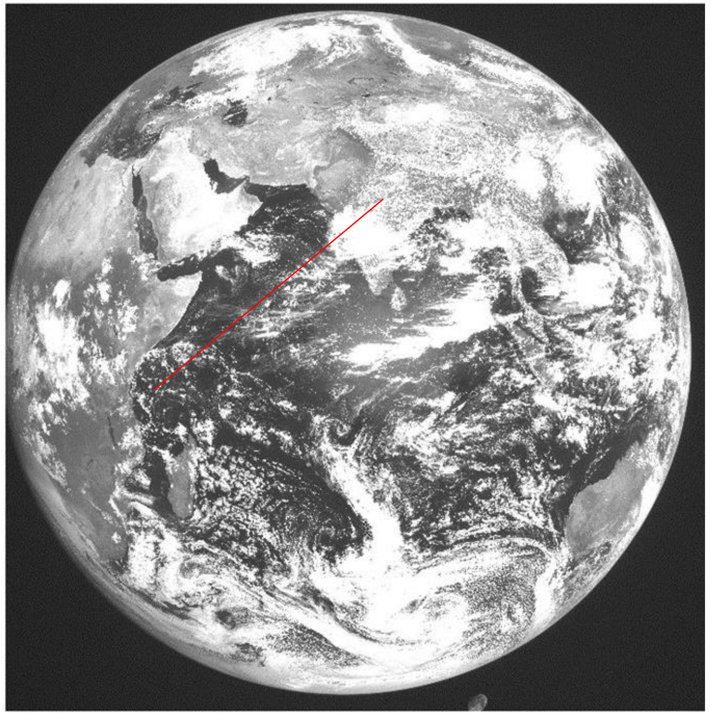




GEO is used by satellites that need to stay constantly above one particular place over Earth, such as telecommunication satellites. This way, an antenna on Earth can be fixed to always stay pointed towards that satellite without moving. It can also be used by weather monitoring satellites, because they can continually observe specific areas to see how weather trends emerge there.

Satellites in GEO cover a large range of Earth so as few as three equally-spaced satellites can provide near global coverage. This is because when a satellite is this far from Earth, it can cover large sections at once





INSAT-3DR IMAGER

15th Sep 2016, 11:30 hr, IST Visible Band

Low Earth Orbit (LEO)

A low Earth orbit (LEO) is, as the name suggests, an orbit that is relatively close to Earth's surface. It is normally at an altitude of less than 1000 km but could be as low as 160 km above Earth – which is low compared to other orbits, but still very far above Earth's surface.

By comparison, most commercial aeroplanes do not fly at altitudes much greater than approximately 14 km, so even the lowest LEO is more than ten times higher than that.

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.

LEO’s close proximity to Earth makes it useful for several reasons. It is the orbit most commonly used for satellite imaging, as being near the surface allows it to take images of higher resolution. 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. Satellites in this orbit travel at a speed of around 7.8 km per second; at this speed, a satellite takes approximately 90 minutes to circle Earth, meaning the ISS travels around Earth about 16 times a day.

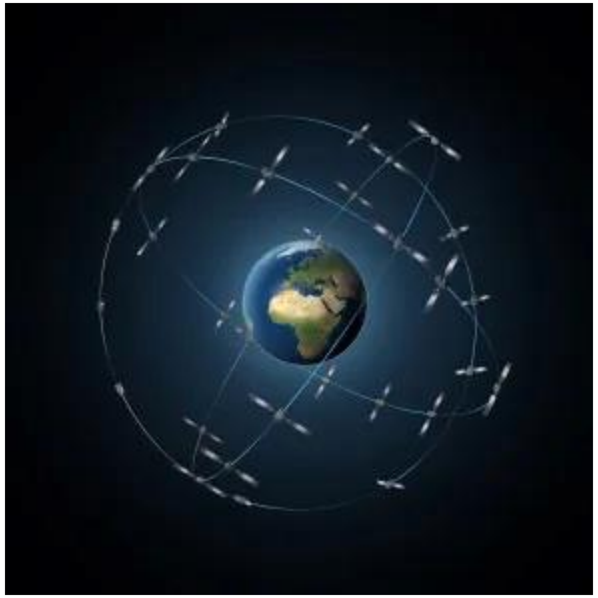
However, individual LEO satellites are less useful for tasks such as telecommunication, because they move so fast across the sky and therefore require a lot of effort to track from ground stations.

Instead, communications satellites in LEO often work as part of a large combination or constellation, of multiple satellites to give constant coverage. In order 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. This lets them cover large areas of Earth simultaneously by working together

	Low Earth Orbit (LEO)-satellite systems classification			
	Voice and other narrowband communications	Broadband communications	Low-power long-range IoT applications	Earth Observation (EO) and Synthetic Aperture Radar (SAR) satellites
Main characte-ristics	Medium-size constellations Oldest LEO constellations Typically in L and S bands (1-4GHz)	Large-size constellations Typically multiple orbits per constellation High carrier frequencies: typically in Ka and Ku bands (17-20 GHz) or in mmWave bands (30-90 GHz)	Medium-to-large size constellations Small-sized satellites (e.g., nano-satellites) fast to deploy Typically one orbit per constellation	Small-to-medium size constellations Many use low carrier frequencies: typically in VHF/UHF (100-400 MHz) Some also in X bands (8-10 GHz)
Examples	Globalstar (US) Gonets (Russia) Iridium (US)	Amazon Kuiper (US) Hongyan and Hongyun (China) OneWeb (UK) PointView (US) Samsung (South Korea) Skynet (India) Starlink/SpaceX (US) Telesat (Canada)	Astrocast (Switzerland) Hiber (Netherlands) Kepler comm (Canada) Myriota (Australia)	BlackSky global (US) Capella Space (US) Iceye (Finland and Poland) RapidEye (Germany) Synspective (Japan) Urthecast (Canada) Ursa and HawkEyre 360 (US)

Medium Earth orbit (MEO)

Medium Earth orbit comprises a wide range of orbits anywhere between LEO and GEO. It is similar to LEO in that it also does not need to take specific paths around Earth, and it is used by a variety of satellites with many different applications. It is very commonly used by navigation satellites

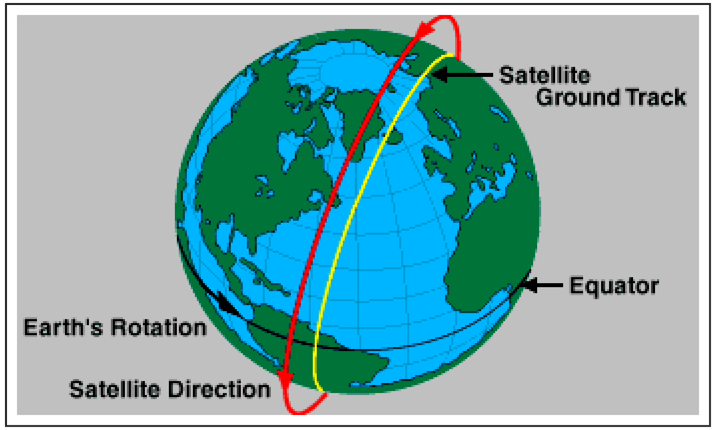


Polar & Sun-synchronous orbit (SSO)

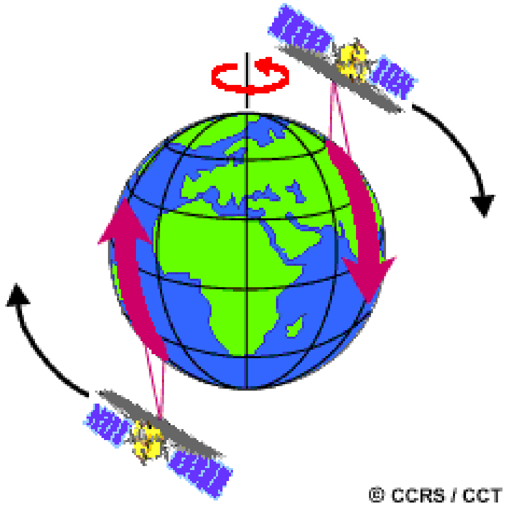
Satellites in polar orbits usually travel past Earth from north to south rather than from west to east, passing roughly over Earth's poles.

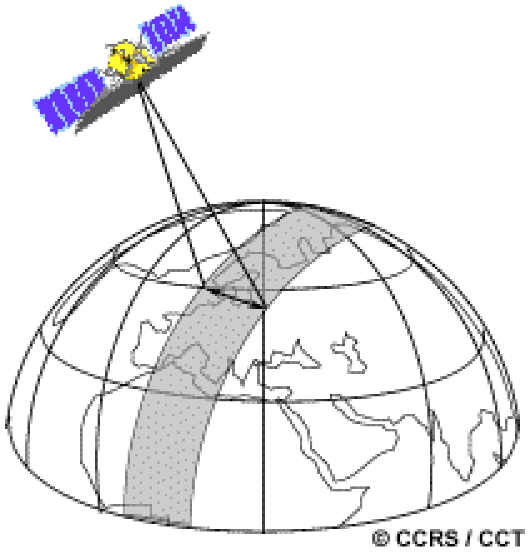
Satellites in a polar orbit do not have to pass the North and South Pole precisely; even a deviation within 20 to 30 degrees is still classed as a polar orbit. Polar orbits are a type of low Earth orbit, as they are at low altitudes between 200 to 1000 km.

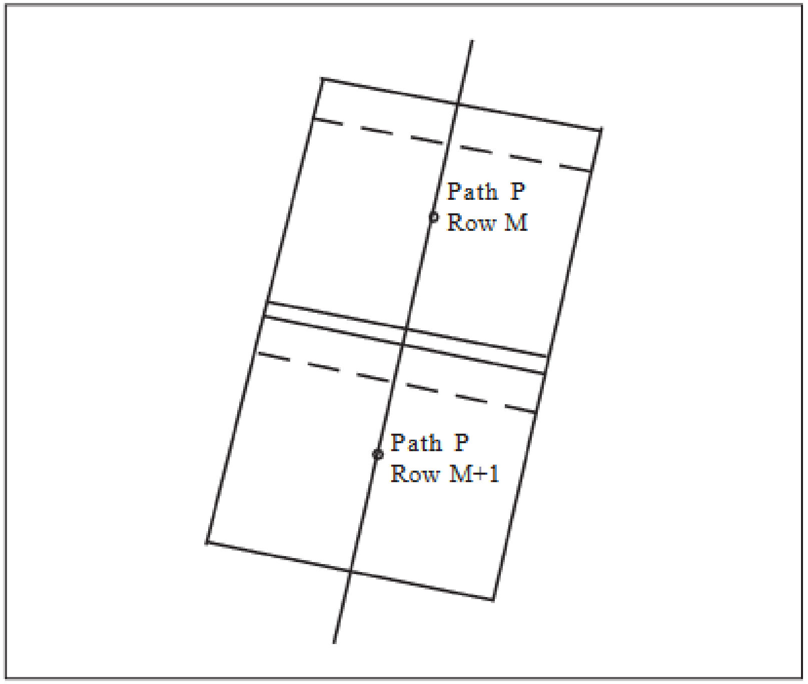
Sun-synchronous orbit (SSO) is a particular kind of polar orbit. Satellites in SSO, travelling over the polar regions, are synchronous with the Sun. This means they are synchronised to always be in the same 'fixed' position relative to the Sun. This means that the satellite always visits the same spot at the same local time – for example, passing the city of Paris every day at noon exactly.



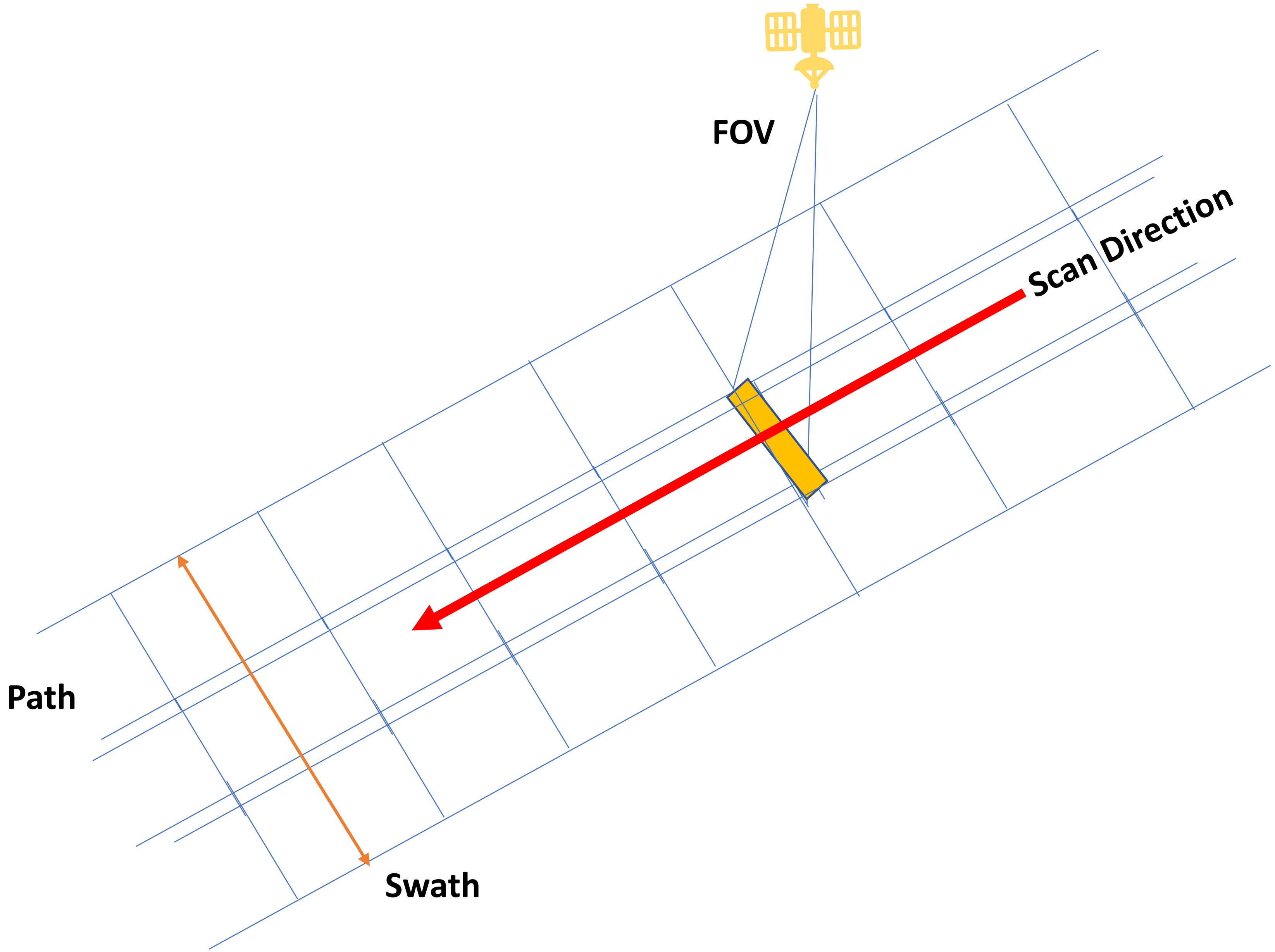
A near-polar sun synchronous orbit



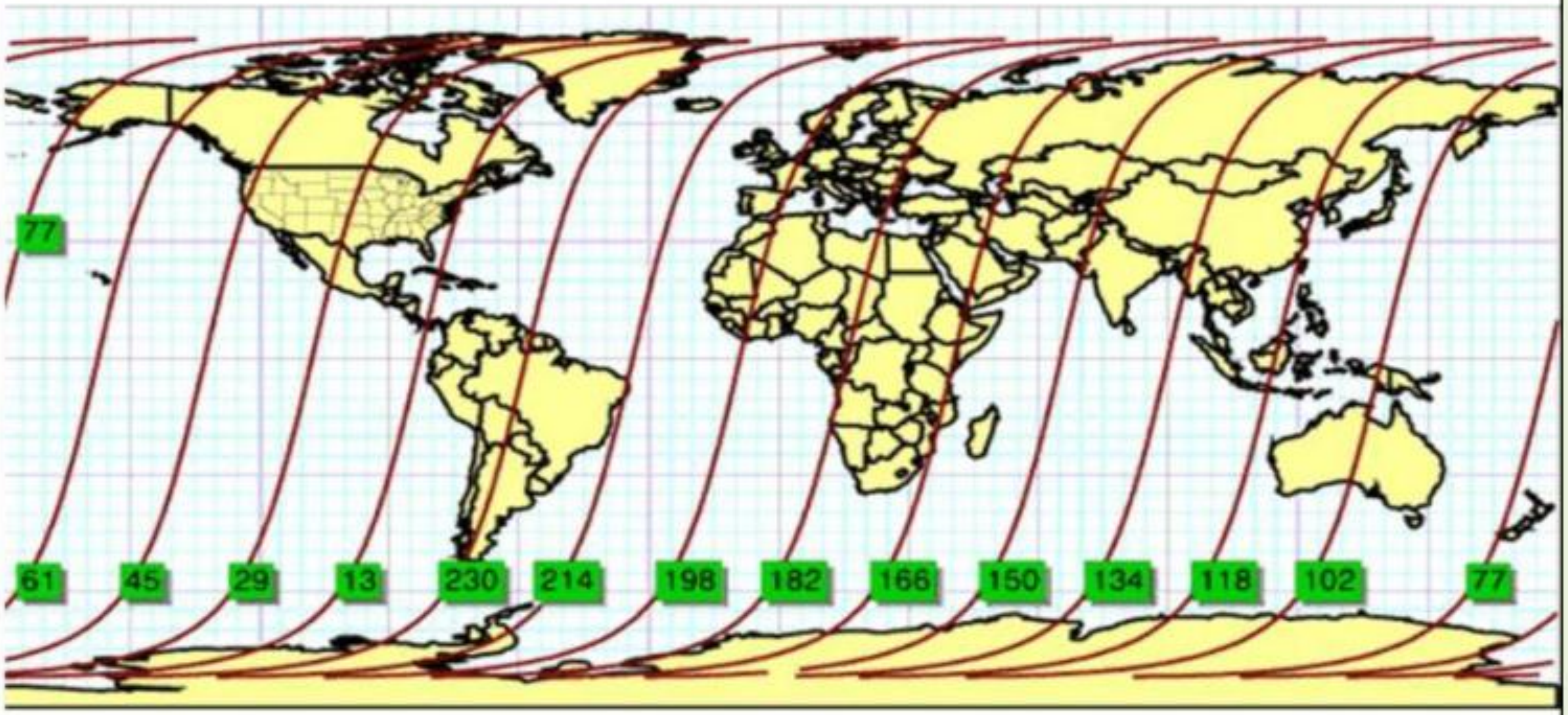




Concept of a SAT product.


FOV
Scan Direction
Path
Swath

Sun-synchronous satellites: 700-900 km altitude, rotates at circa 81-82 degree angle to equator: captures imagery approx the same time each day (10am +/- 30 minutes) -



This means that the satellite will always observe a point on the Earth as if constantly at the same time of the day, which serves a number of applications; for example, it means that scientists and those who use the satellite images can compare how somewhere changes over time.

This is because, if you want to monitor an area by taking a series of images of a certain place across many days, weeks, months, or even years, then it would not be very helpful to compare somewhere at midnight and then at midday – you need to take each picture as similarly as the previous picture as possible.

Therefore, scientists use image series like these to investigate how weather patterns emerge, to help predict weather or storms; when monitoring emergencies like forest fires or flooding; or to accumulate data on long-term problems like deforestation or rising sea levels.

Often, satellites in SSO are synchronised 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 orbit (GTO)

Transfer orbits are a special kind of orbit used to get from one orbit to another. When satellites are launched from Earth and carried to space

The satellites are not always placed directly on their final orbit. Often, the satellites are instead placed on a transfer orbit: an orbit where, by using relatively little energy from built-in motors, the satellite or spacecraft can move from one orbit to another

https://global.jaxa.jp/projects/rockets/h2a/upgrade.html

1.Ignite the second stage engine (second time) at the perigee to increase speed.
2.Long space flight ("long coast") for about four hours without separating the second stage and a payload.
3.Ignite the second stage engine for the third time at the apogee to increase speed, and separate the payload to inject it into the upgraded geostationary transfer orbit (upgraded GTO).
4.The payload increases its speed at the apogee and enters into the geostationary orbit

Lagrange points (L)

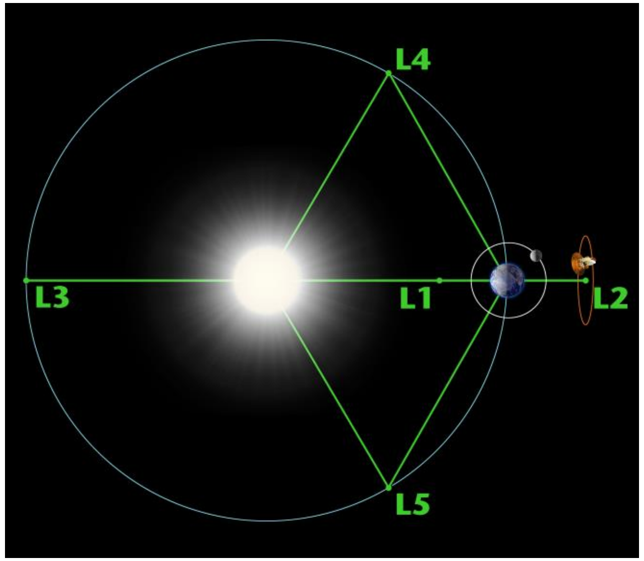
Lagrange points are positions in space where objects sent there tend to stay put. At Lagrange points, the gravitational pull of two large masses precisely equals the centripetal force required for a small object to move with them. These points in space can be used by spacecraft to reduce fuel consumption needed to remain in position

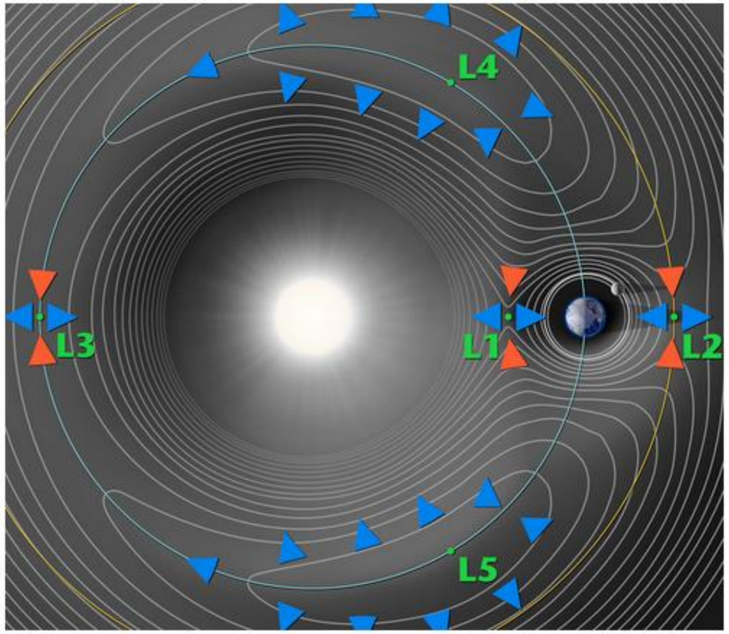
For example, for space-based observatories and telescopes whose mission is to photograph deep, dark space, being next to Earth is hugely detrimental because Earth naturally emits visible light and infrared radiation that will prevent the telescope from detecting any faint lights like distant galaxies. Photographing dark space with a telescope next to our glowing Earth would be as hopeless as trying to take pictures of stars from Earth in broad daylight.

Lagrange points, or L-points, allow for orbits that are much, much farther away (over a million kilometres) and do not orbit Earth directly. **These are specific points far out in space where the gravitational fields of Earth and the Sun combine in such a way that spacecraft that orbit them remain stable and can thus be 'anchored' relative to Earth.**

If a spacecraft was launched to other points in space very distant from Earth, they would naturally fall into an orbit around the Sun, and those spacecraft would soon end up far from Earth, making communication difficult. Instead, spacecraft launched to these special L-points stay fixed, and remain close to Earth with minimal effort without going into a different orbit.

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





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

REFERENCE

https://www.esa.int/Enabling_Support/Space_Transportation/Types_of_orbits#GEO

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

https://bhuvan.nrsc.gov.in/bhuvan/PDF/Resourcesat-1_Handbook.pdf

THANK YOU