LEO, MEO & GEO SATELLITES

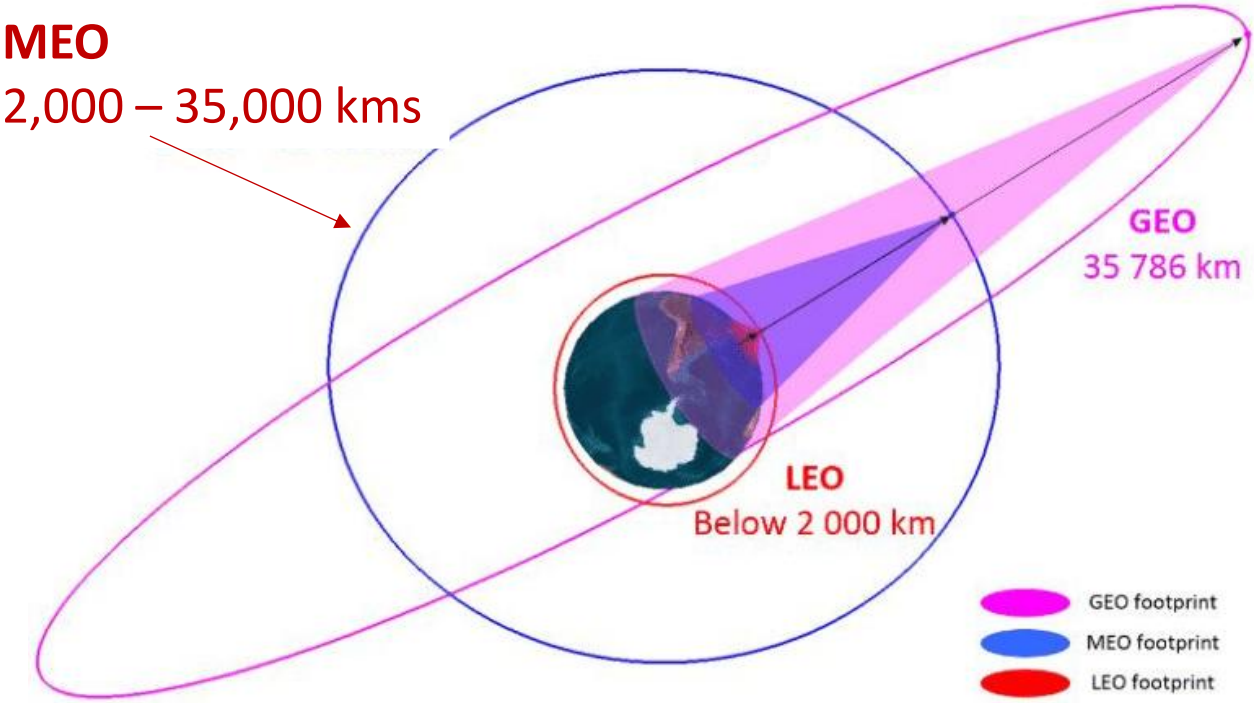
ECE 521E – RADAR & SATELLITE ENGINEERING

Monday, 21 September 2026

SATELLITE ORBITS

There are THREE different satellite orbit altitude, i.e

1. **Low earth orbit (LEO)** - located at an altitude of 5,000 - 2,000 km and circulate the Earth in the range of 90 to 120 min.
2. **Medium earth orbit (MEO)** - located at an altitude of 2,000 to 36,000 km and take around 6 h to circulate the Earth.
3. **Geostationary earth orbit (GEO)** - altitude of 35,786 km, in which they exactly match the earth rotation speed (i.e., circulate the earth once in 24 hours).



SUMMARY OF FEATURES OF THE GEO ORBIT

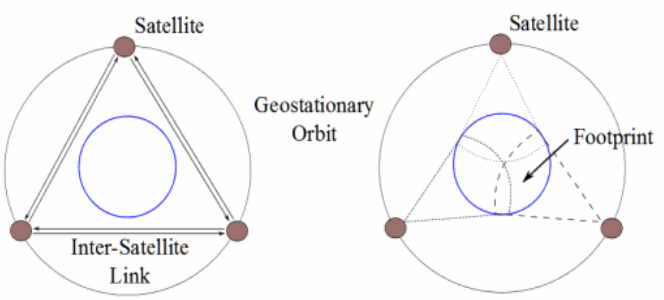
Following are the features of GEO orbit.

1. **Orbit period:** 24 hours
2. **Orbit height from Earth:** 35,786 km
3. **Life of satellite in the orbit:** Long
4. **Propagation loss in the orbit:** Highest
5. **Number of satellites to cover entire regions on Earth:** 3

ADVANTAGES OF GEOSTATIONARY ORBIT

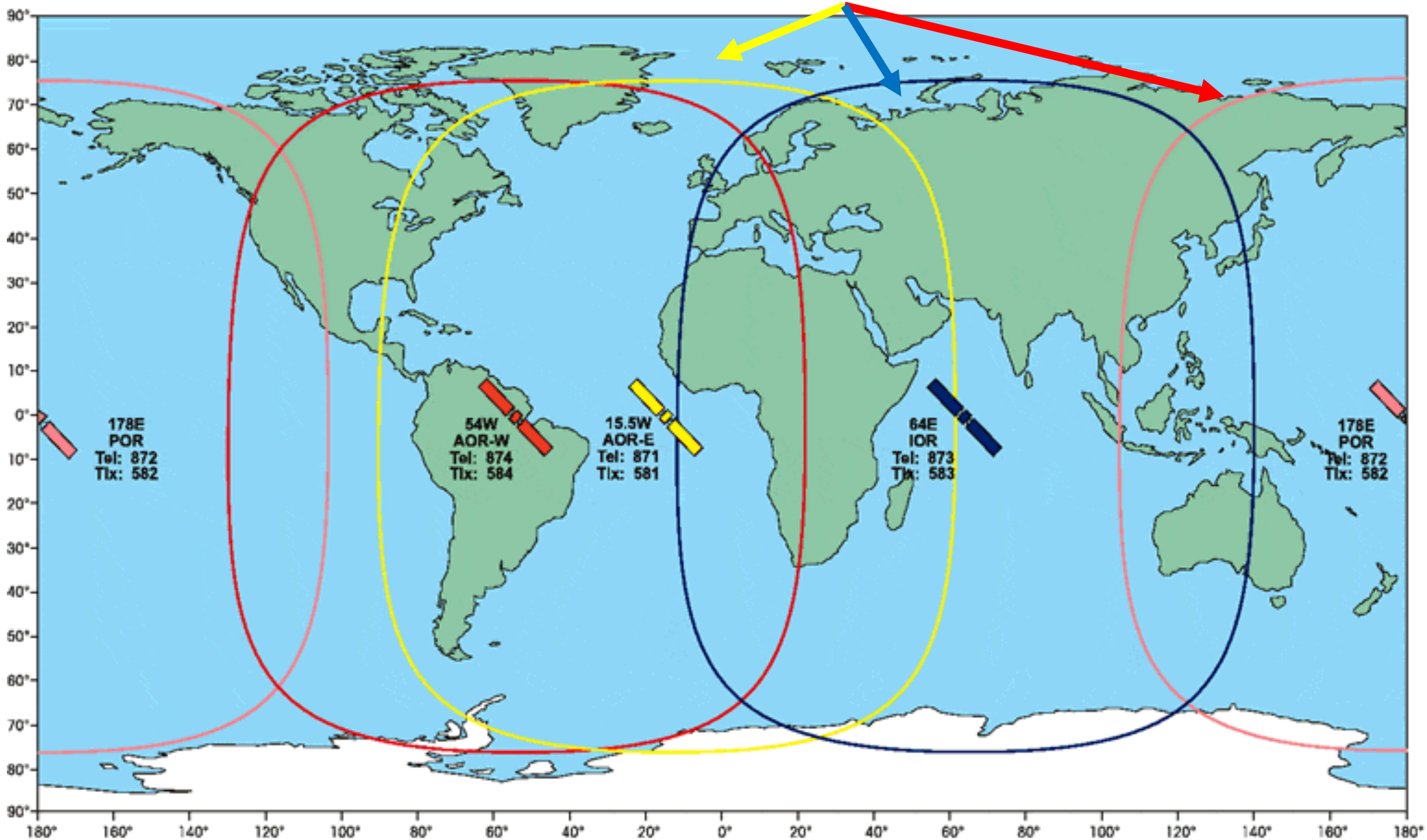
The following are the advantages of GEO orbit:

1. As it is at greater height, it covers larger geographical area. Hence only 3 satellites are required to cover the entire Earth.
2. Satellites are visible for 24 hours continuously from single fixed location on the Earth.
3. Ground station tracking is not required as it is continuously visible from earth all the time from fixed location.
4. Less number of satellites are needed to cover the entire earth. Total three satellites are sufficient for the job.
5. There is very little doppler shift and hence less complex receivers can be used for the satellite communication.
6. Inter-satellite handoff is not needed.
7. It is ideal for broadcasting and multi-point signal distribution applications.





Coverage areas for the 4 satellites



DISADVANTAGES OF GEOSTATIONARY ORBIT

The disadvantages of GEO orbit are as follows:

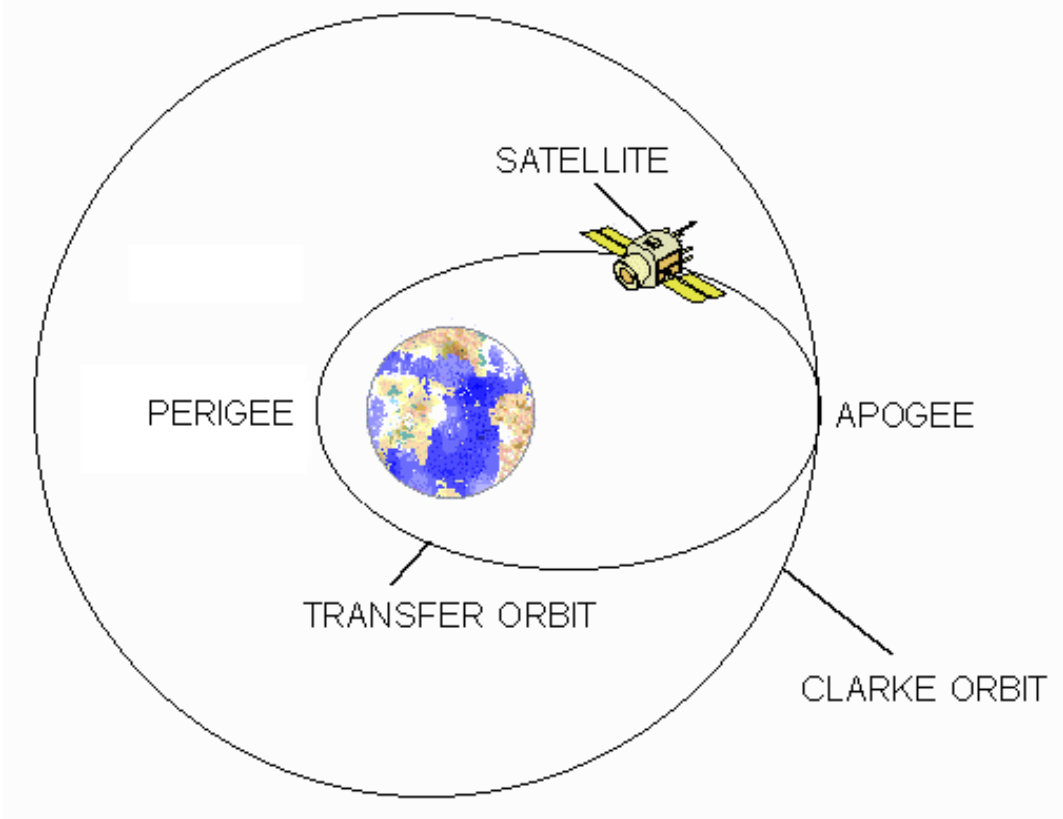
1. It is not suitable for applications requiring time critical applications such as real time voice or video. The signal requires considerable time to travel from Earth to satellite and vice versa. The signal travel delay is about 120ms in one direction. The distance of 35,786 Km gives 126 ms latency with $3x10^8$ m/sec speed of the signal.
2. Since GEO orbit is located above the equator, it is difficult to it is difficult to use the near the polar region due to the very low inclination angle.
3. Due to longer transmission distance, the received signal is very weak. This requires better LNA (Low Noise Amplifier) and also advanced signal processing algorithms in the satellite modem. This increases cost of the ground terminals.
4. It provides poor coverage at higher latitude places usually greater than 77 degrees.

LAUNCHING OF A SATELLITE INTO A GEOSYCHRONOUS ORBIT

1. Satellites are launched into geosynchronous orbits (Clarke orbit) using the Hohman Transfer principle.

2. **Hohmann Transfer** is an orbital manoeuvre that transfers a satellite or spacecraft from one orbit to another.

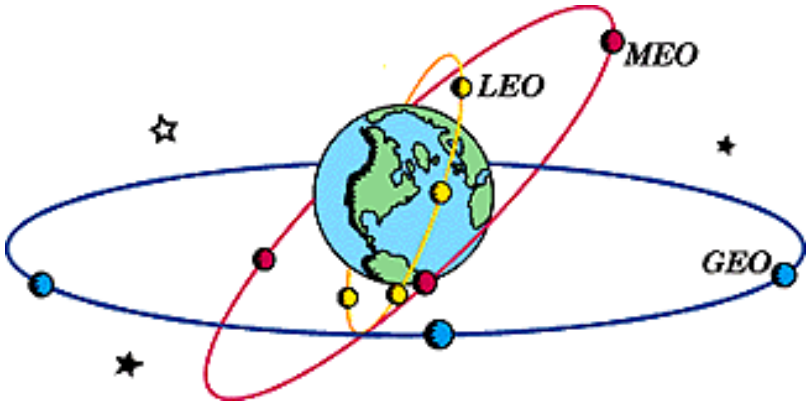
3. The orbit was proposed by a German scientist in 1925 and is the most fuel-efficient way to get from one circular orbit to another circular orbit.



FEATURES OF THE LEO ORBIT

The LEO orbit has got the following features:

1. **Orbit height from Earth:** 500 to 1,500 Km
2. **Orbit period:** 10 to 40 minutes
3. **Life of satellite in the orbit:** Short
4. **Propagation loss:** Least
5. **Number of satellites to cover entire regions on Earth:** 40 to 80.



LARGE OPERATORS OF SATELLITES IN LEO ORBITS

1. **Starlink:** As of September 2024, there are 6,426 Starlink satellites in orbit, of which 6,371 are working (confirm with a satellite tracking website, e.g. http:/www.n2yo.com or satellitemap.space).
2. **Oneweb:** As of September 2024, there are 648 oneweb satellites in orbit

ADVANTAGES OF LEO ORBIT

The advantages of LEO orbit are as follows:

(a) As it is near to the earth, provides better signal strength. Hence less power (about 1 watt) is needed for transmission.

(b) It has least propagation delay (about 10ms) compared to other orbits due to closeness to the Earth. Due to lower latency, it can be used for real-time time critical applications.

(c) It eliminates need for bulky receiver equipment due to higher C/N signal ratio.

(d) Uses low-cost user terminals.

(e) Better frequency reuse can be achieved due to smaller footprints.

(f) It provides high elevation for polar regions of the Earth. Hence better global coverage can be achieved.

DISADVANTAGES OF LEO ORBIT

The disadvantages of LEO orbit are as follows:

(a) As it is at lesser distance above the Earth, it covers less region of the earth. Hence large number of satellites are needed for global coverage. Consequently, the installation of LEO based system is expensive.

(b) Requires complex processing due to handoffs. LEO satellites move constantly and hence service is being handed off by each satellite to the next one in a constellation.

(c) Need for regular maintenance of satellites to keep them on track in the LEO orbit. Effects of the earth (gravitational and atmospheric) are more and hence will cause gradual orbital dis-orientation of the satellites.

(d) There is less time available for testing and troubleshooting activities. It is only visible for 15 to 20 minutes from particular area of the Earth.

(e) Efficiency to serve populated region is less compare to GEO satellites.

(f) Ground station is very complex as it requires to handle frequent handoffs between LEO satellites.

(g) The complete deployment of LEO constellation is essential to start the service to the customers. Hence it requires more time to provide the satellite service & mass adoption by the users compare to GEO.

(h) LEO satellites have shorter life span (about 5 to 8 years) compare to GEO satellites.

FEATURES OF THE MEO ORBIT

The MEO orbit has got the following features:

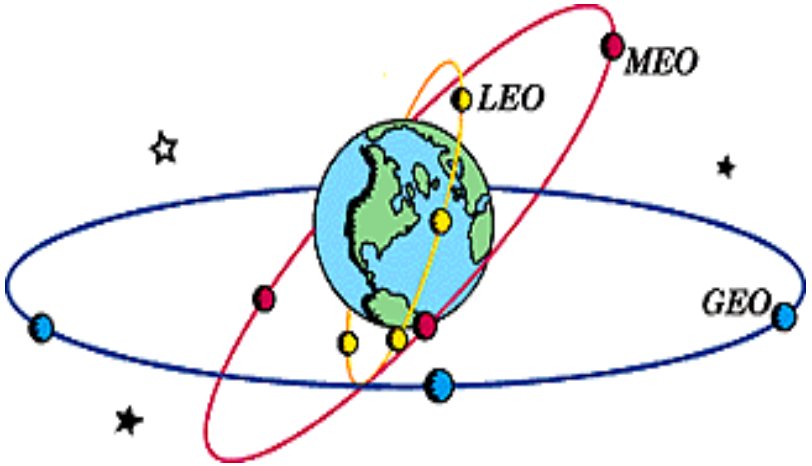
(a) **Orbit height from Earth:** 5000 to 35,860 Km

(b) **Orbit period:** 2 to 8 hours

(c) **Life of satellite in the orbit:** Longer than LEO

(d) **Propagation loss in the orbit:** Medium to High

(e) **Number of satellites to cover entire regions on Earth:** 8 to 20



ADVANTAGES OF MEO ORBIT

The advantages of Satellites launched in MEO orbit are:

1. Less number of satellites are needed to cover entire area of the Earth compared to LEO since MEO satellites are launched at higher altitude compare to LEO satellites.
2. Time delay from earth to satellite and vice versa is less (about 40 ms) compare to GEO satellites (about 126 ms) since MEO satellites are launched at lesser height compare to GEO satellites.
3. MEO system is cheaper compare to GEO.

DISADVANTAGES OF MEO ORBIT

(a) **Signals weaker** when they reach earth from MEO compare to LEO. This is due to higher altitude of MEO in comparison to LEO. Hence more transmit power is needed to overcome pathloss and other attenuating atmosphere.

(b) **Satellites are require tracking** from the Earth due to their period. It is visible for only 2 to 8 hours from earth.

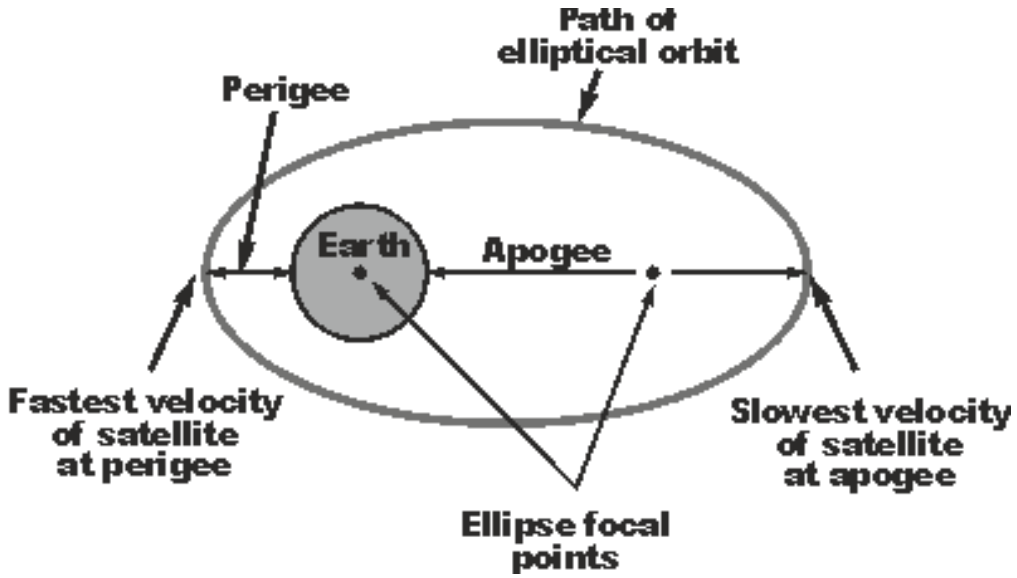
(c) **MEO satellite system** is more expensive compare to LEO.

(d) More MEO satellites are needed for continuous global coverage compared with GEO.

HIGHLY ELLIPTICAL ORBITS (HEOs)

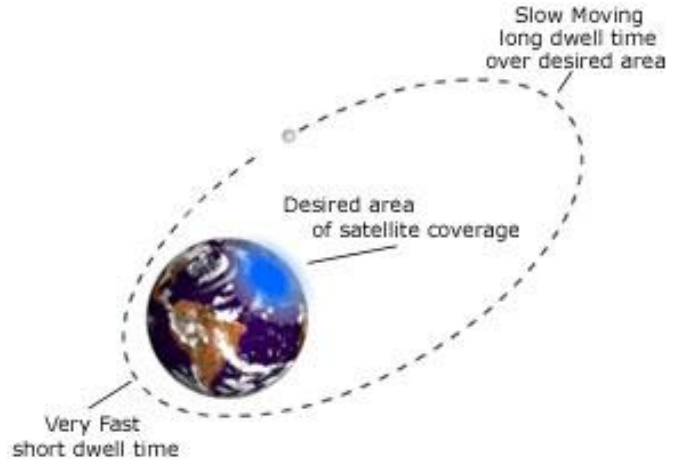
- **Highly elliptical orbit (HEO)** follows the curve of an ellipse as shwon

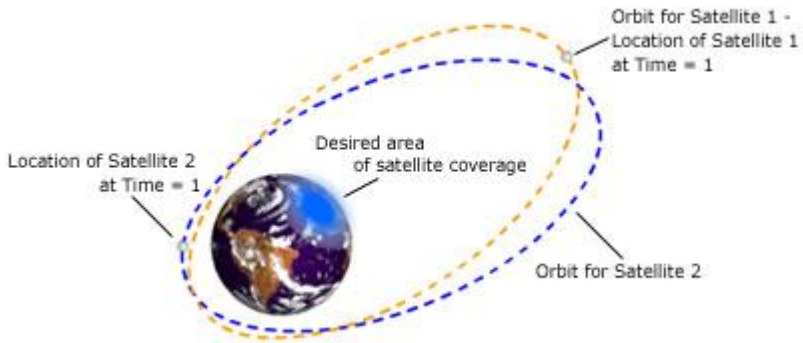
- A key features of an elliptical orbit is that the satellite in an elliptical orbit moves much faster when it is close to Earth than when it is further away (recall Kepler's 2nd Law).



HIGHLY ELLIPTICAL ORBITS (HEOs) DWELLING TIME

- HEO satellite spend most of its time near apogee (the furthest point in its orbit) where it moves very slowly according to Keplers 2nd law.
- Thus it can be above home base most of the time, taking a break once each orbit to speed around the other side.
- HEO satellite has long dwell time over one area, but at certain times when the satellite is on the high-speed portion of the orbit, there is no coverage over the desired area.
- To solve this problem we could have two satellites on similar orbits, but timed to be on opposite sides of the orbit at any given time. In this way, there will always be one satellite over the desired coverage area at all times.





ADVANTAGES OF HEOs

Advantages of HEOs are as follows:

1. HEOs can be used to provide coverage over any point on the globe. It is not limited to equatorial orbits like the geostationary orbit which lacks high latitude and polar coverage.
2. With two satellites in any orbit, they are able to provide continuous coverage to a region.

As a result it ability to provide high latitude and polar coverage, countries such as Russia which need coverage over polar and near polar areas make significant use of highly elliptical orbits.

DISADVANTAGES OF HEOs

- The main disadvantage is that the satellite position from a point on the Earth does not remain the same.

HISTORY OF THE USE OF SATELLITE ORBITS

1. **In the beginning**, communication satellites were placed in low-earth orbits (LEO).
2. There was also the **Russian Molniya system** based on HEOs in which the satellite only operates around the apogee,and was switched off elsewhere.
3. Then came the realization of Arthur C. Clarke's dream (expressed in 1945) of a single satellite in the equatorial orbit that would revolve around the planet once in 24 hours.
4. This led to the launch of the first GEO communication satellite, **Intelsat 1 (Early bird) in 196**4.
5. **Interest in LEO and MEO satellites** was revived in the 1990's with the advent of satellite telephony and global navigation systems.

MILESTONES IN SATELLITE COMMUNICATION (1)

- **1957:** Launch of Sputnik I by Russia.
- **1962:** The world's first active communications satellite, Telstar 1, was launched. This satellite was built by Telesat's predecessors at AT&T and Bell Laboratories.
- **1964:** Agreements were signed which created the International Telecommunications Satellite Organization (INTELSAT).
- **1965:** Launch of first geostationary satellite, Early bird by Intelsat. Early bird provided almost 10 times the capacity of the submarine telephone cables at almost 1/10th the price.
- **1972:** Telesat Canada launched the first domestic communications satellite, ANIK, to serve the vast Canadian continental area.
- 1972: The East African Community builds the Longonot Earth Station and the PANAFTEL Microwave Radio System.
- **In the mid-1970s** several satellites were built using three-axis stabilization. They were more complex than the spinners, but they provided more despun surface to mount antennas and they made it possible to deploy very large solar arrays.

MILESTONES IN SATELLITE COMMUNICATION (2)

- **1976:** COMSAT launched a new kind of satellite, MARISAT, to provide mobile services to the United States Navy and other maritime customers.
- **1979:** the UN International Maritime Organization sponsored the establishment of the International Maritime Satellite Organization (INMARSAT) in a manner similar to INTELSAT.
- **1998: Iridium satellite telephone system launched.** The first Iridium call was made by Vice President of the United States Al Gore to his wife.
- **On 15th April 2023**, Kenya launched its first satellite named TAIFA-1.

Further Reading:

KENYA'S FIRST SATELLITE TAIFA-1 LAUNCHES TO SPACE AFTER THREE ATTEMPTS (nacosti.go.ke)



RECOMMENDED TRAINING VIDEOS

(c) Introduction to Satellite Communication Tutorial by TutorVista
(b) Satellite Communication Lecture - IIT
(c) How do we communicate with space?
(d) GOES-R Solar Array Deployment Test at Lockheed Martin
(e) Origami in Space: BYU-designed solar arrays inspired by origami

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