SATELLITES IN ORBIT

ECE 514E – RADAR & SATELLITE ENGINEERING

Monday, September 8 2025

DEFINITIONS: SPACE

Space is a place free from obstacles.

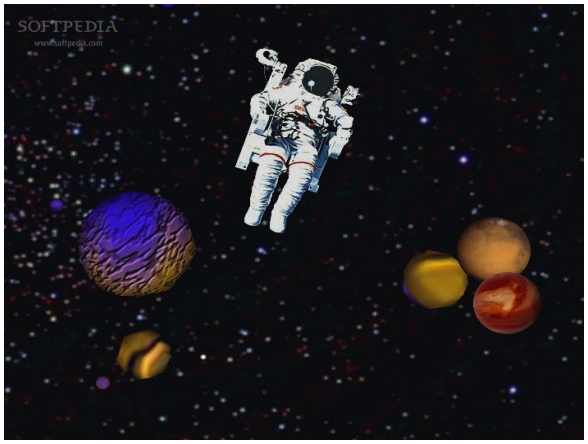
- An altitude at which an aircraft cannot fly due to the lack of aerodynamic force.

Outer Space Law Treaty

- International law to ensure that the governments of all countries have no claim of sovereignty over the space or the moon.
- Most of the members of UN involved in space activities have signed this treaty which is administered by ITU.

CLASSIFICATION OF SPACE

- **Air space.** Region below **160** km from the earth's surface which are usually subject to the jurisdiction of a particular country.
- **Outer Space:** Falls between **160** km and **42,000** km: Aerodynamic lift is ineffective and is taken over by the centrifugal force.
- **Deep space:** Regions beyond **42,000.** Not used for satellite communication.



DEFINITION OF AIR SPACE & LIMITS

1. **Airspace**, in international law, the space above a particular national territory, treated as belonging to the government controlling the territory. It does not include outer space.
2. 30 Km above the surface of earth is air space for the navigation of aeroplanes and further 160 Km is the near space for the navigation of rockets.
3. Above the near space and beyond is the outer space which is common heritage or “Res Communis” of the mankind.

AIR SPACE THEORIES – THE FUNDATIONS OF INTERNATIONAL SPACE LAW

These theories recognizes the upper extent of state jurisdiction up to extreme limit of air space in its geophysical meaning. The theory is further divided into the following into subheads;

(a) Atmosphere theory: The theory depicts that the outer space begins at the outer limit of territorial atmosphere. The territorial atmosphere is further divided into troposphere, stratosphere, ionosphere, and exosphere, although there is no proper demarcation of between the layers of the outer space.

(b) Aerodynamic lift theory: According to this theory, it is believed that the state jurisdiction should be extended to heights necessary for winged aircrafts to fly. According to the jurists in this school, the outer space begins where there is no possibility to fly winged planes.

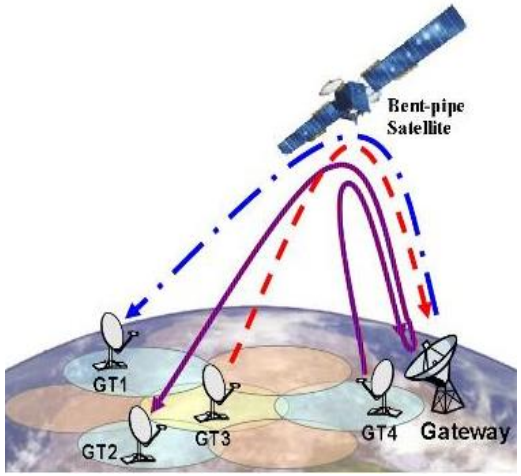
(c) Biological theory: the theory proposed that air space continues as long as there is possibility of human life to survive, and beyond that the outer space starts.

LAW OF AIR SPACE

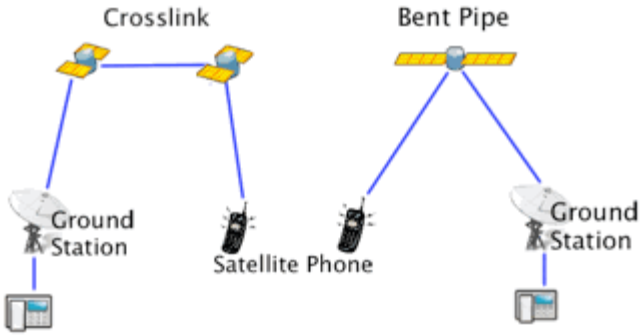
1. **Law of the air space and outer space** regulates the administration of access of air and outer space.
2. According to the law whoever violates the air space of any states violates its sovereignty.
3. **Article 2 of UN charter:** There are no treaties that give title to air space to the state below it because it is an inherent and understood right which doesn't need treaties for its recognition.

PASSIVE/ACTIVE SATELLITES

- Unlike Passive Satellites, Active Satellites employ transponders to amplify, process and retransmit signals.

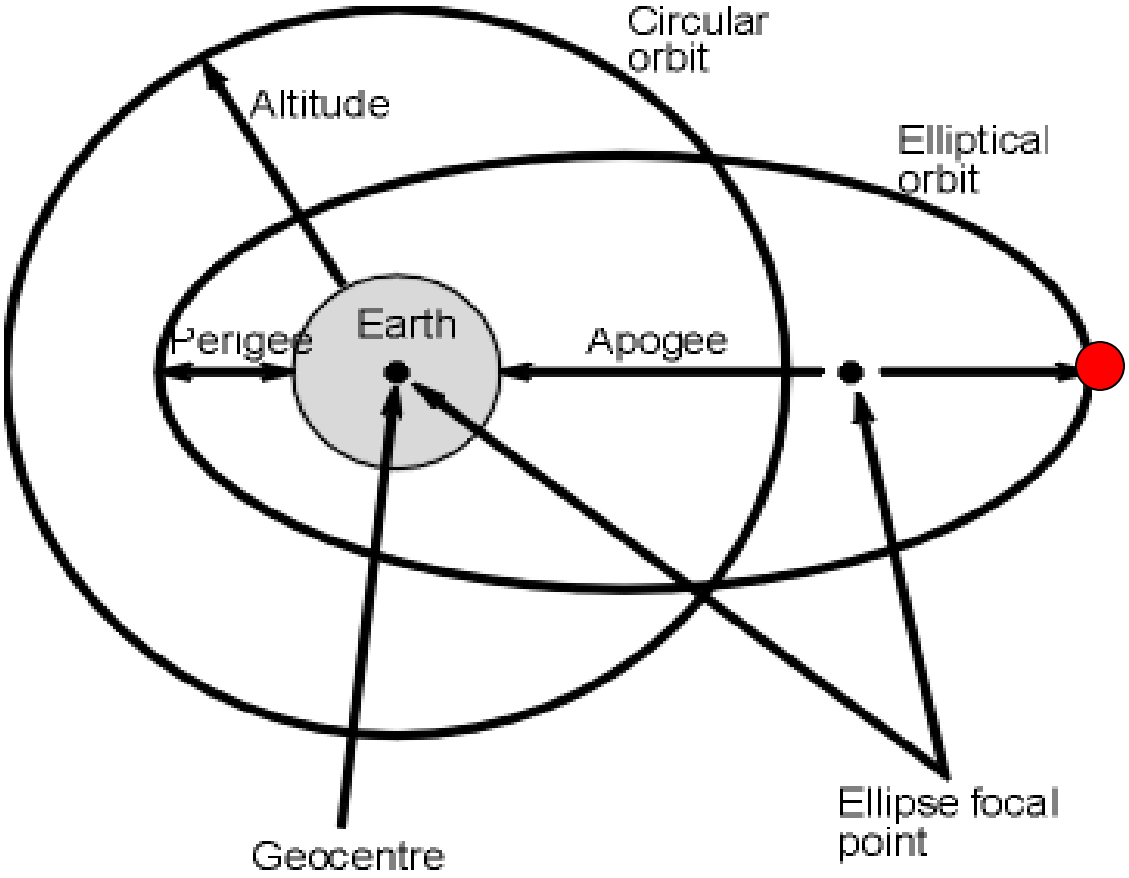


- They use **bend-pipe technology** where frequency translation and amplification take place in the transponder before the signal is beamed back to the earth.



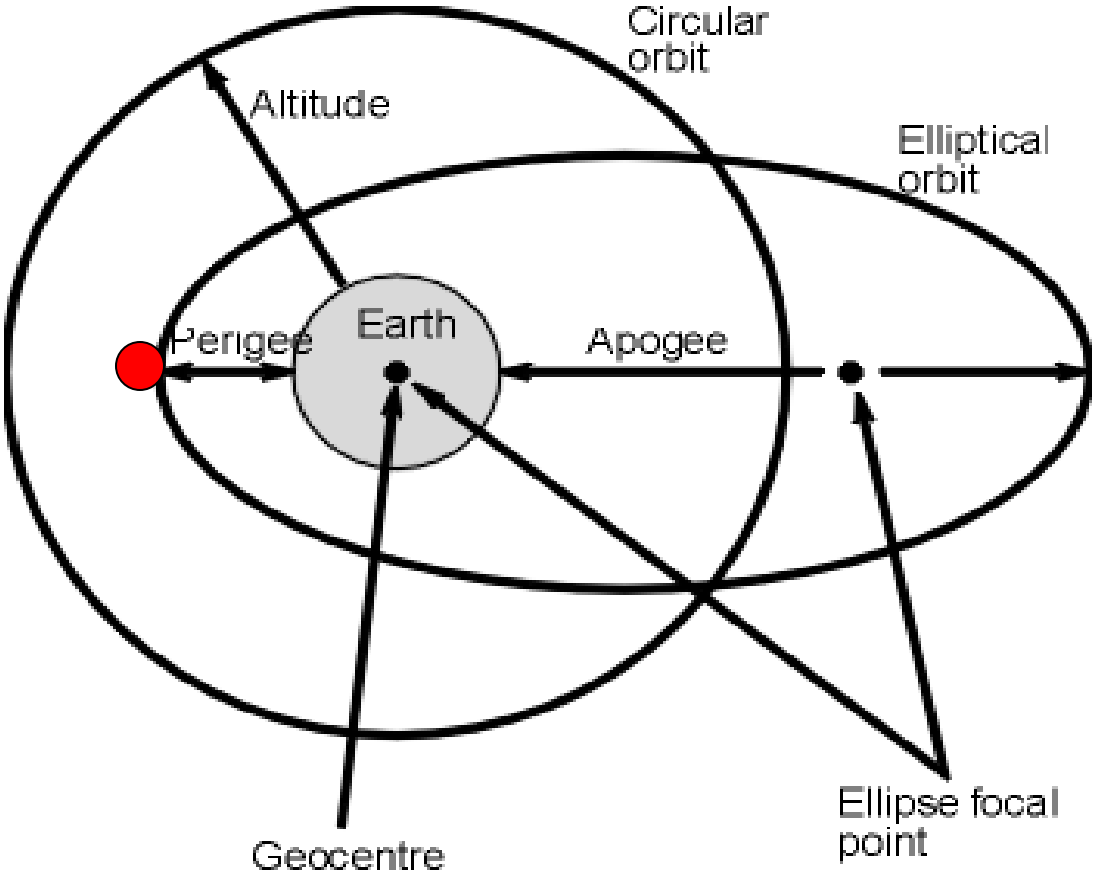
- Further, most contemporary communication satellites employ **regenerative technology** in which demodulation/demultiplexing takes place thus allowing Intersatellite Links (ISL).

SATELLITE ORBITS



1. The point in orbit when satellite is farthest from the earth or primary body is called apogee.
2. The apogee depends on the eccentricity and is equal to $a(1 + e)$, where a is the major axis of the ellipsoid and e is the eccentricity.

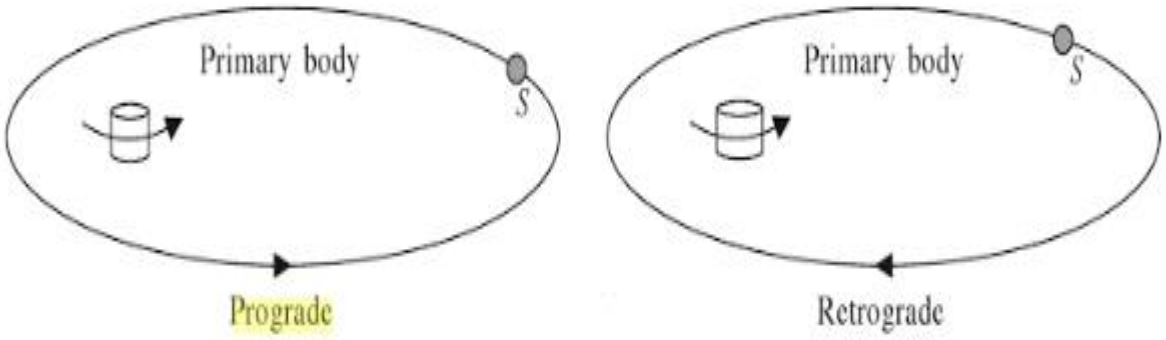
PERIGEE



1. In an elliptical orbit the distance of satellite from primary body varies.
2. The point in orbit when satellite is nearest to the earth or primary body is called perigee.
3. The perigee depends on the eccentricity and is equal to $a(1 - e)$, where a is the major axis of the ellipsoid and e is the eccentricity.

PROGRADE ORBIT

- When a man-made satellite orbits in the same direction as the direction of revolution of earth, the orbit is called prograde orbit.
- Launching of the satellite is necessarily in prograde orbit.

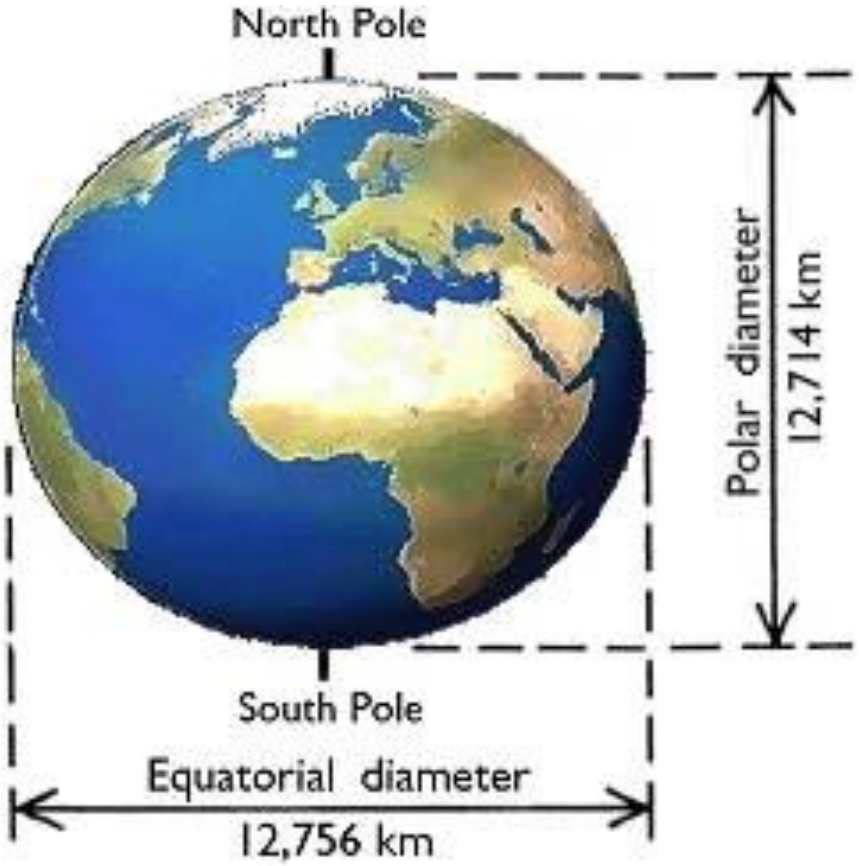


SOME IMPORTANT FACTS (1)

- Diameter of sun = 1,391,4 000 Km
- Diameter of Jupiter = 139,822 km
- Diameter of Saturn = 116,464 km
- Diameter of Uranus = 50,724 km
- Diameter of Neptune = 49,244 km
- Diameter of Earth = 12,732 Km
- Diameter of Venus = 12,104 km
- Diameter of Mars = 6,779 Km
- Diameter of Mercury = 4,879 km

Jupiter's mass one-thousandth that of the Sun, but two-and-a-half times that of all the other planets in the Solar System combined.

SOME IMPORTANT FACTS (2)



1. What is the speed of a stationery object on the earth's surface along the equator?

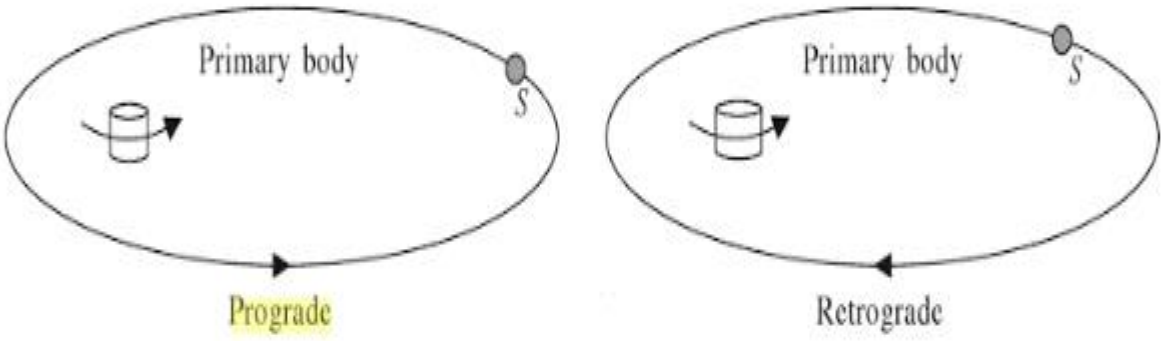
2. What is the speed of a stationery object on the earth's surface at the north pole?

RETROGRADE ORBITS

1. When a man-made satellite orbits in the opposite direction than that of the direction of revolution of earth, the orbit is called retrograde orbit.

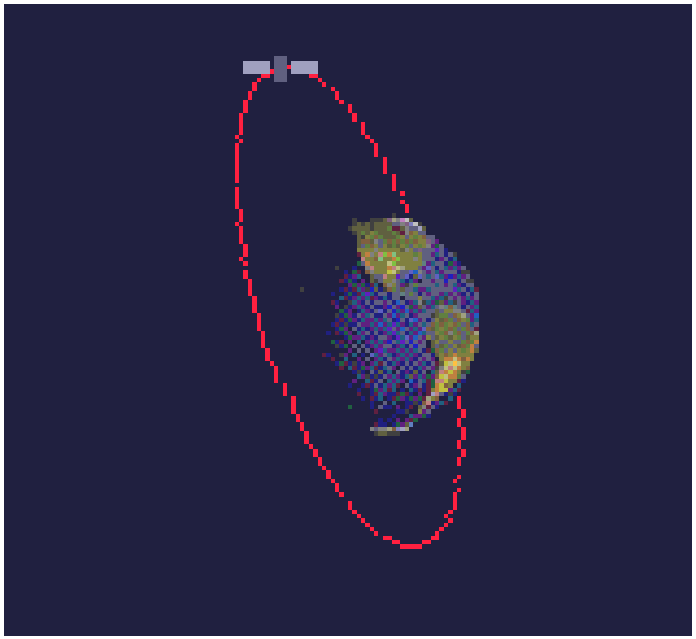
2. Retrograde orbits are more expensive to launch than prograde orbits because the rocket has to burn more fuel to overcome the initial rotation imposed on the satellite because Earth's rotation.

3. Sun-synchronous satellites are launched in retrograde orbits



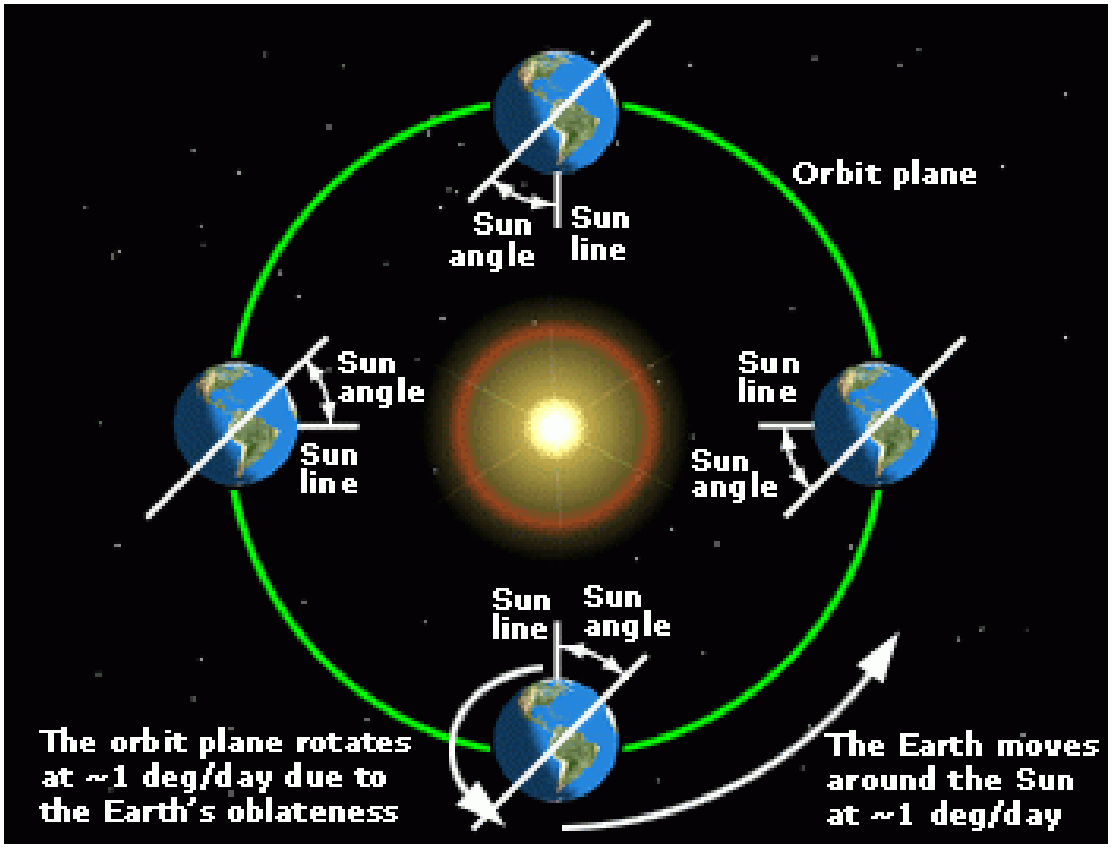
SUN-SYNCHRONOUS SATELLITES (1)

1. In a sun-synchronous orbit, the satellite passes over the same part of the Earth at roughly the same local time each day.
2. This can make communication and various forms of data collection very convenient.
3. For example, a satellite in a sun-synchronous orbit could observe the cloud cover of Nairobi at noon everyday.



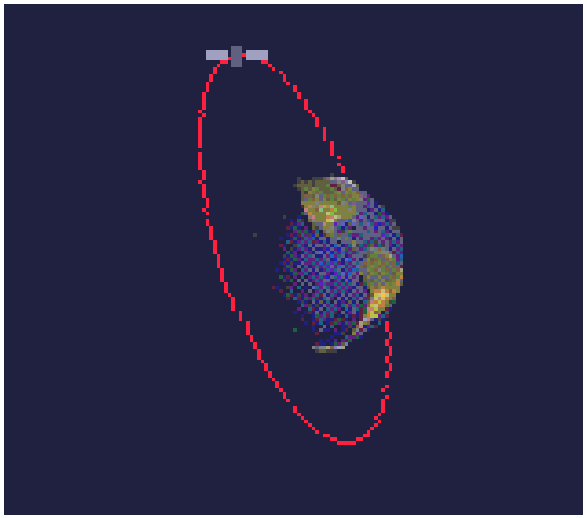
SUN-SYNCHRONOUS SATELLITES (1)

- The satellite is placed in a way so that the angle between the orbital plane and the line joining Earth and the sun remains constant.



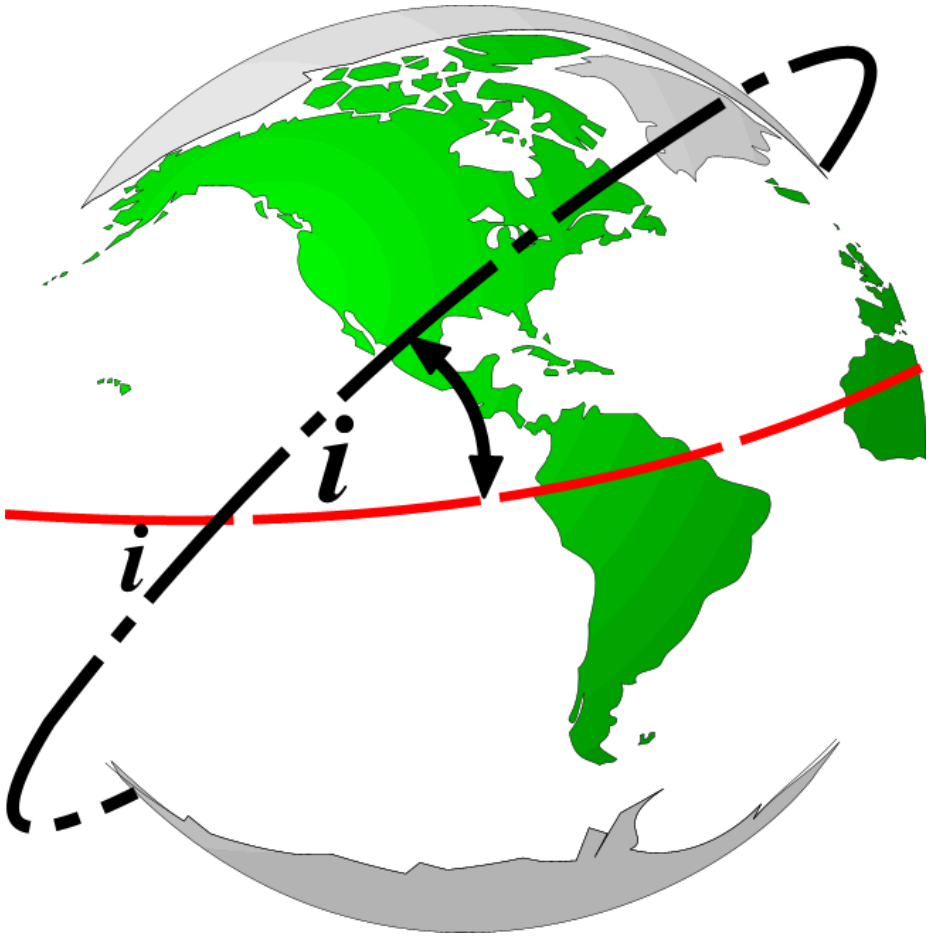
DAWN-TO-DUSK ORBIT

1. Down –to Dusk satellite trails the Earth's shadow.
2. When the sun shines on one side of the Earth, it casts a shadow on the opposite side of the Earth, i.e night-time.
3. Because the satellite never moves into this shadow, the sun's light is always on it (sort of like perpetual daytime).
4. Since the satellite is close to the shadow, the part of the Earth the satellite is always at sunset or sunrise.



5. This allows the satellite to always have its solar panels in sunshine.
6. Radarsat is an example of a satellite in a low sun-synchronous orbit

INCLINATION ANGLE



- The angle between orbital plane and earth's equatorial plane is called angle of inclination.

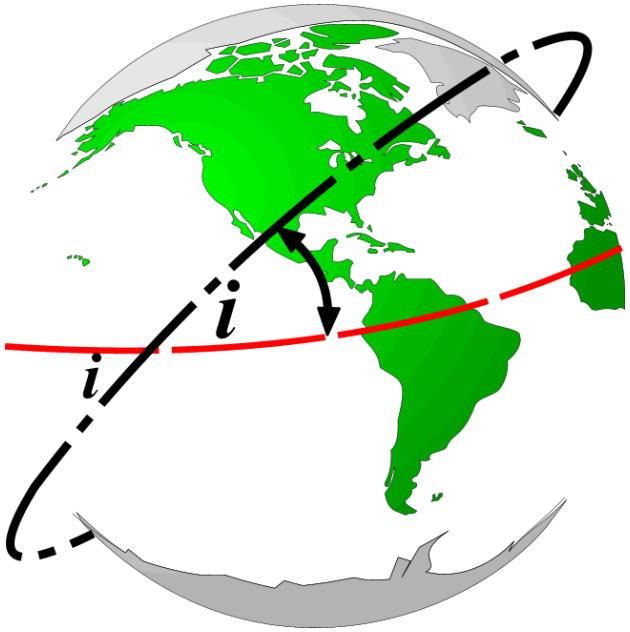
INCLINATION ANGLE

1. An inclination angle of 0 degrees occurs when satellite moving in the direction of rotation of the Earth in a plane parallel to the equator.

2. Orbit with an inclination angle greater than 0 degrees and less than 90 degrees is a prograde orbit.

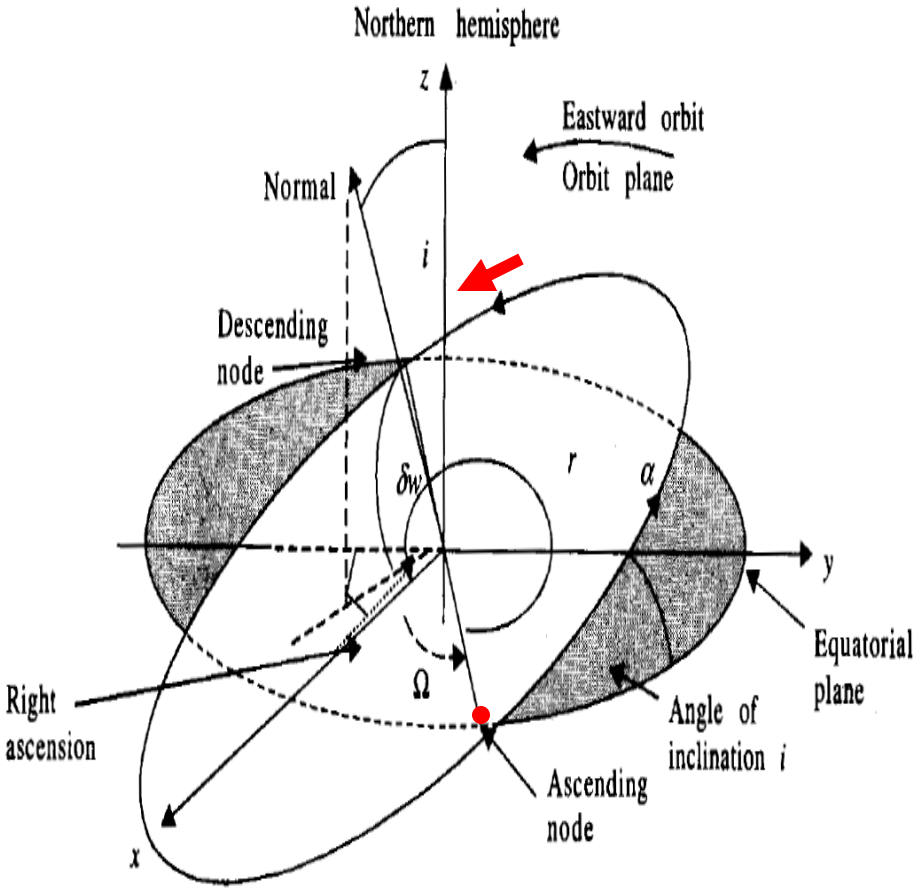
3. Orbit with an inclination angle of 90 degrees is a polar orbit.

4. Orbit with an inclination angle greater than 90 degrees is a retrograde orbit.



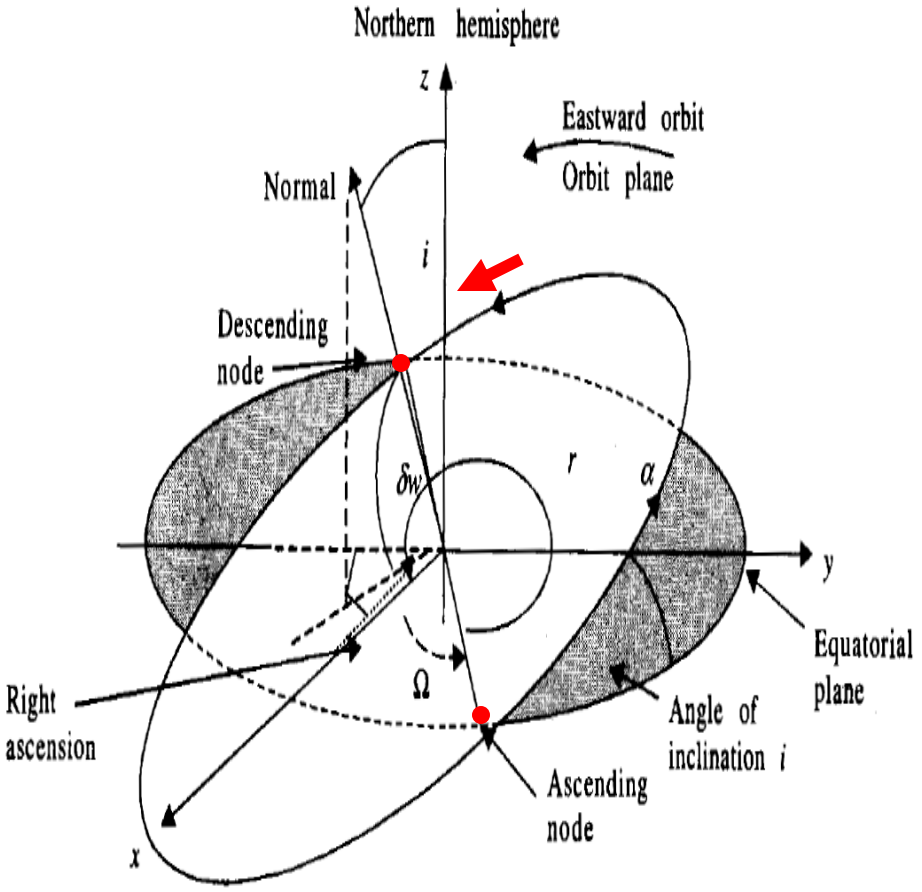
ASCENDING NODE

1. A polar satellite crosses the equatorial plane twice, once while going from south to north and once travelling from north to south.
2. The point of intersection of orbit path with the equatorial plane while travelling from south to north is called **ascending node.**

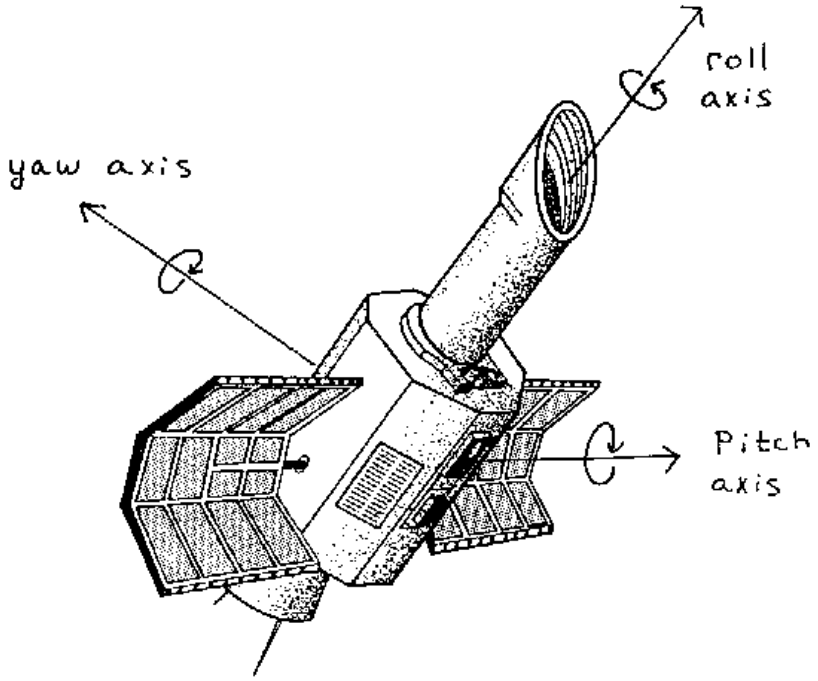


DESCENDING NODE

1. A polar satellite crosses the equatorial plane twice, once while going from south to north and once travelling from north to south.
2. The point of intersection of orbit path with the equatorial plane while travelling from north to south is called **descending node**.



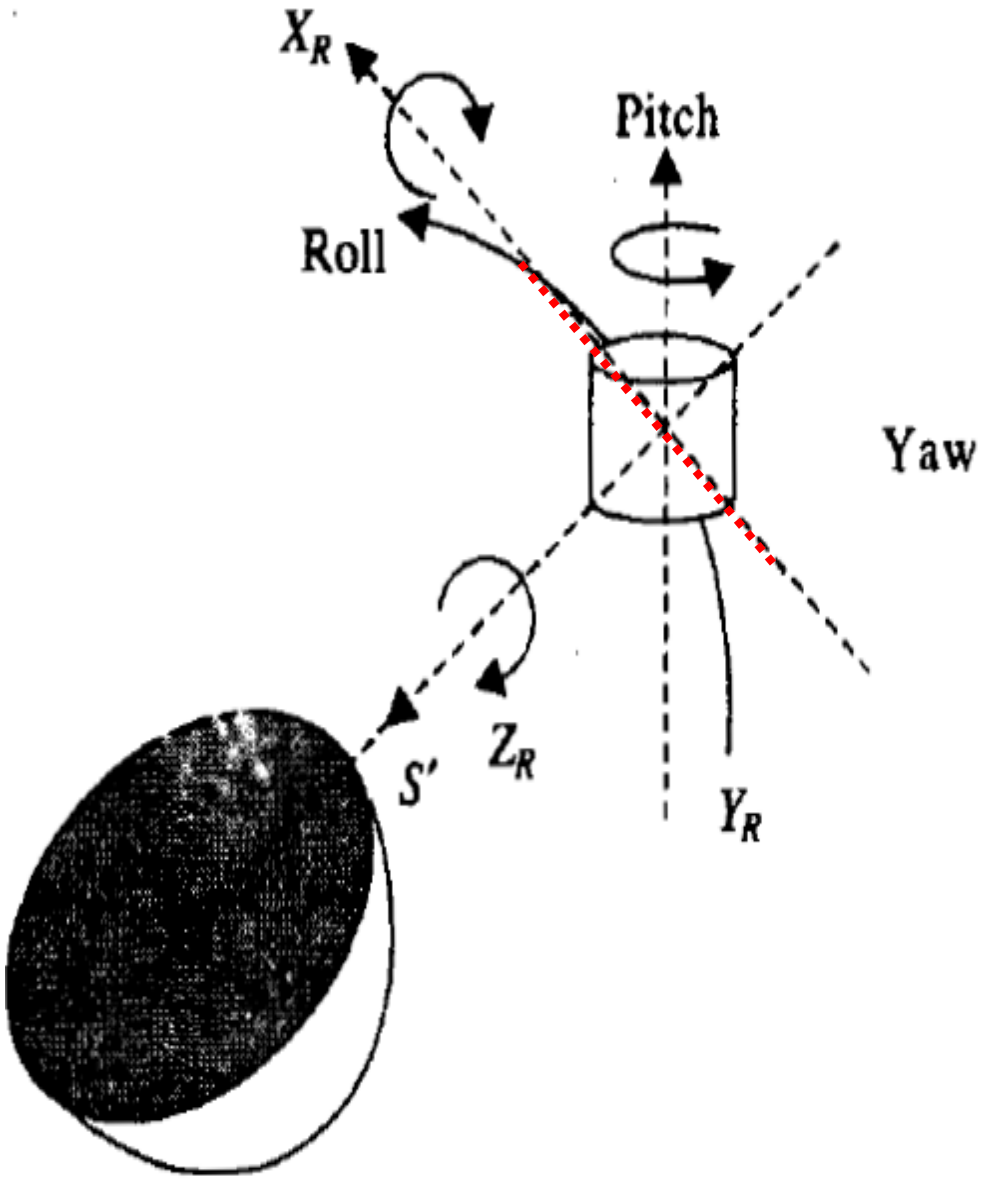
SATELLITE AXES



- The satellite being in space, to keep the spacecraft in proper position it is necessary to define the axes that control the spacecraft.
- The three axes of control are roll, pitch and yaw

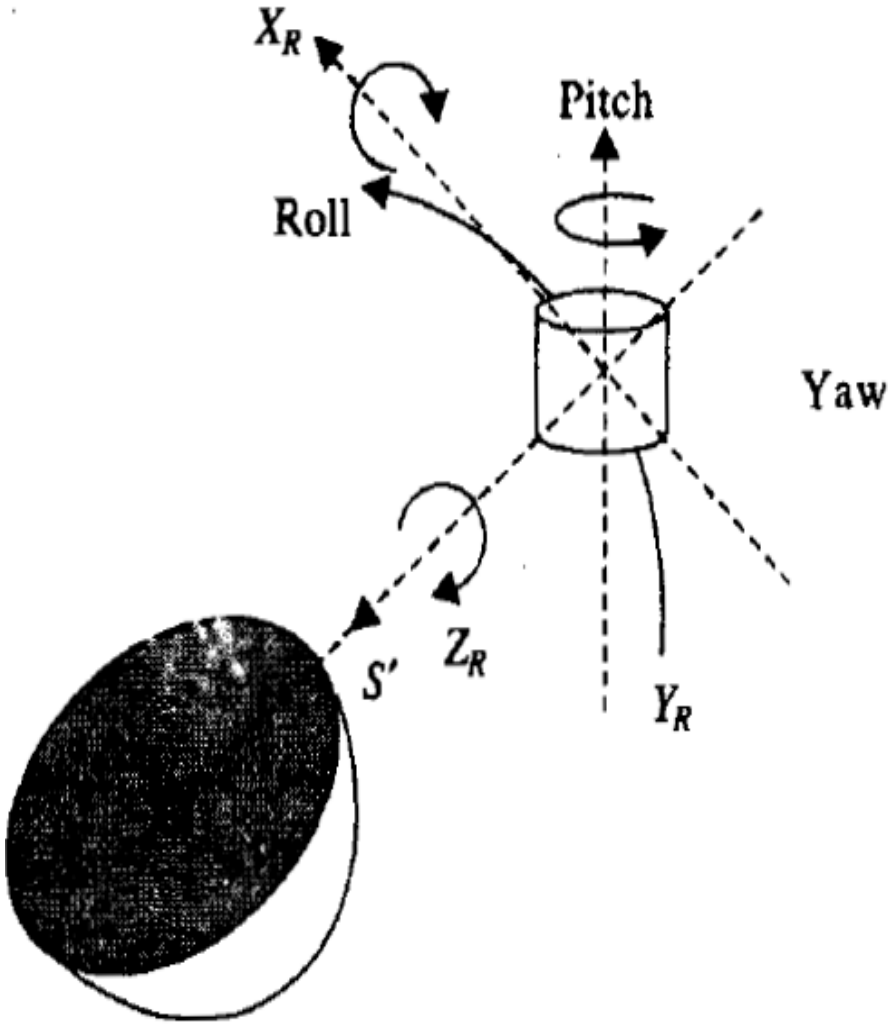
SATELLITE AXES: ROLL

- The tangent along the orbit path is called the roll axis.
- Around the roll axis the satellite can either tilt towards north or south.
- **A** tilt towards north is said to be **positive roll** while a tilt towards south is called **negative roll**.



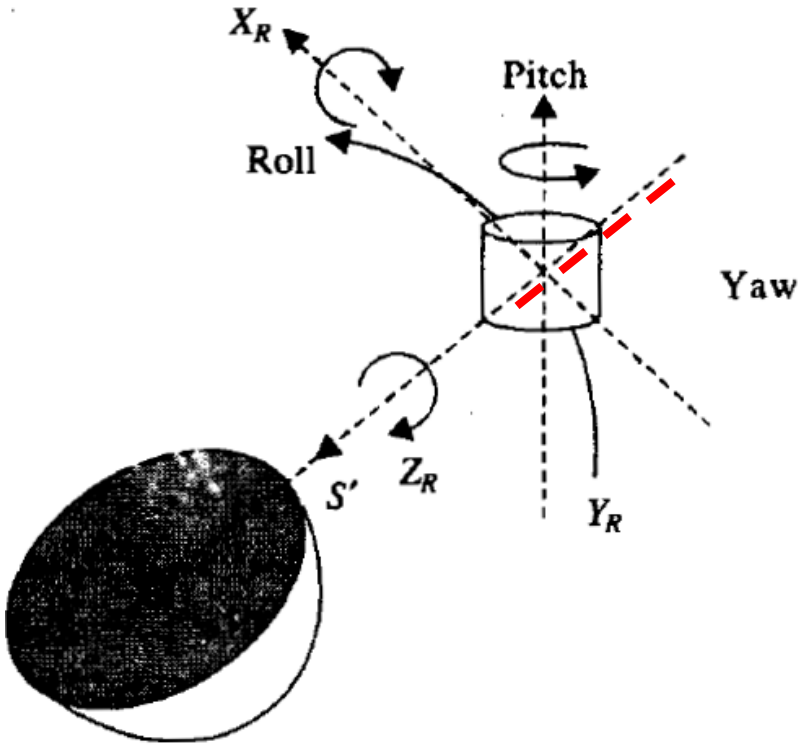
SATELLITE AXES: PITCH

1. The axis of satellite perpendicular to the orbit path is called pitch axis.
2. A satellite rotates around the pitch axis.
3. The pitch rotation can be either eastwards called positive pitch or westwards called negative pitch.
4. The Earth's pitch axis is polar axis.



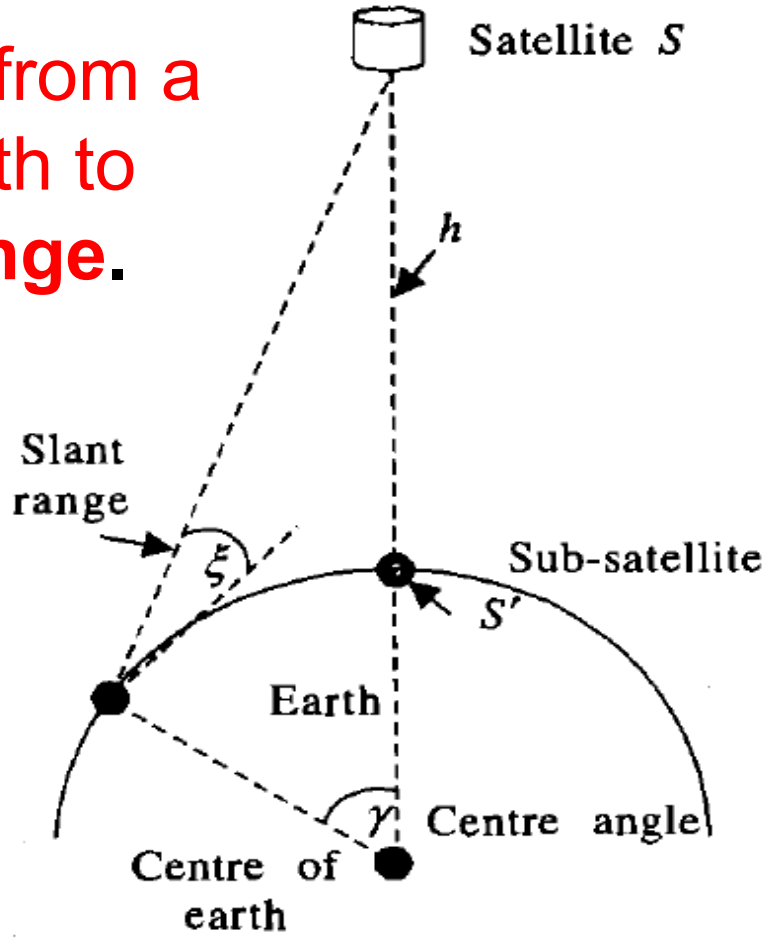
SATELLITE AXES: YAW

1. Yaw is the axis, which is directed towards the centre of the earth.
2. Along this axis the satellite can either rotate clockwise or anticlockwise.
3. A clockwise rotation is positive yaw and anticlockwise rotation is negative yaw .



SLANT RANGE

- The line of sight distance from a particular point on the earth to satellite is called **slant range.**



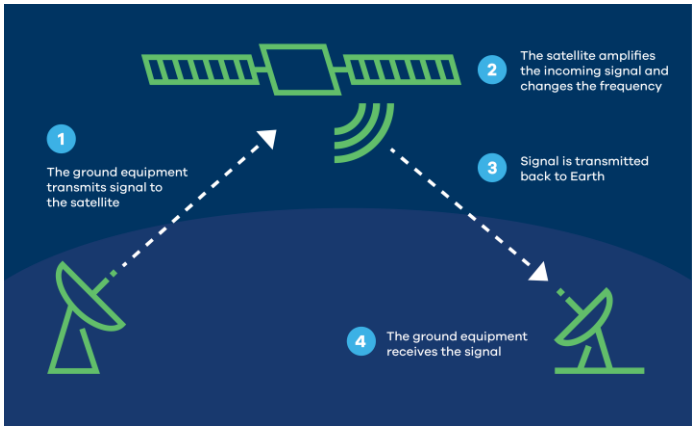
SATELLITE SERVICES

There are five categories of satellite services, i.e

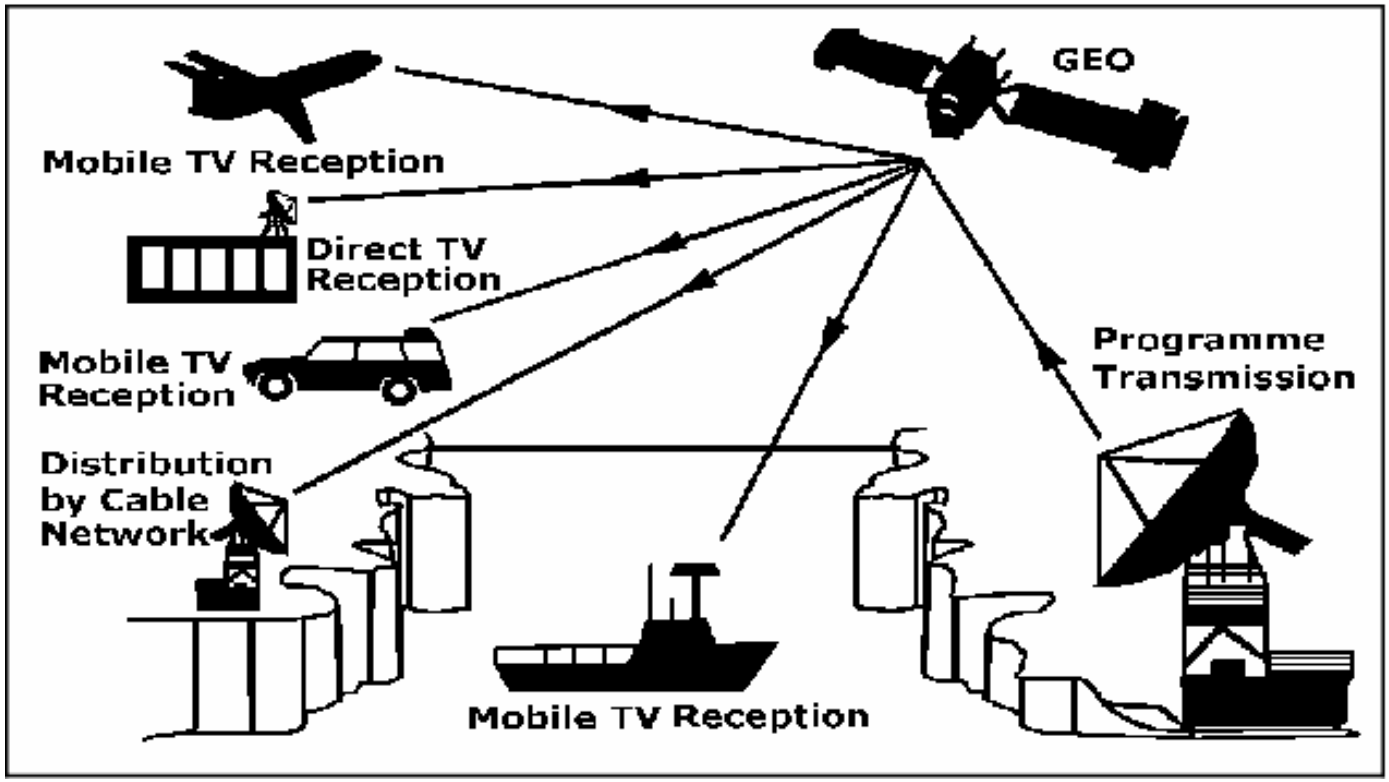
1. Fixed satellite services (FSS)
2. Broadcast Satellite Services (FSS)
3. Mobile Satellite Services (MSS)
4. Navigational Satellite Services (NSS)
5. Weather Satellite Services (WSS)

FIXED SATELLITE SERVICE (FSS)

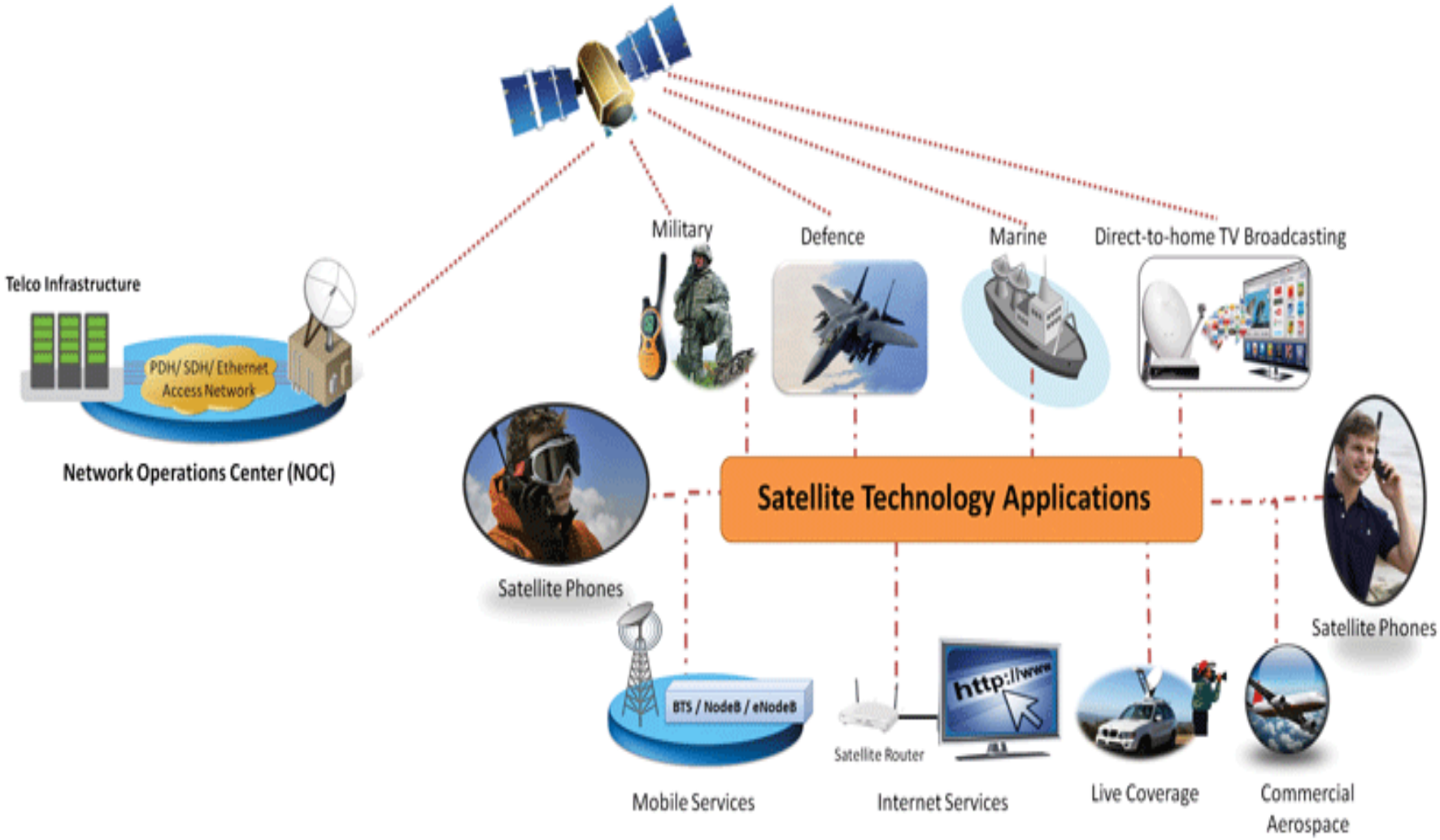
- **Fixed Satellite Service (FSS)** is radiocommunication service between fixed earth stations and a satellite.
- This service may include satellite-to-satellite links, which may also be operated in the inter-satellite service; the fixed-satellite service may also include feeder links for other space radiocommunication services.



MOBILE SATELLITE SERVICE (MSS)



SATELLITE TECHNOLOGY APPLICATIONS



SATELLITE-BASED MOBILE COMMUNICATION SYSTEM