SR. NO.	DATE	TITLE	PAGE NO.	TEACHER'S SIGN

Satellite Communication 15EC755

Module - 1

Satellite Orbits and Trajectories

Syllabus:

Definition, Basic principles, Orbital parametes injection velocity and satellite trajectory, Types of satellite orbits, Orbital perterbations, satellite stabilization, Orbital effects on satellite performance Eclipses, Look angle Determination (Az & E).

A satellite in general is any natural or artificial body moving around a celestial body such as planets and stars.

Applications of satellites

A satellite while in orbit performs the designated role throughout its lifetime. Satellites are used for variety of applications including

- ✓ Communication GSAT, INSAT
- ✓ Weather forecasting INSAT-3D, 3D R (ISRO)
- ✓ Earth observation GISAT-1, EOS-01, 04, cartosat-3
- ✓ Navigation and scintific missions. IRNSS-1G, 1A, 1H NVS-01, GPS (US)
- ✓ Military satellites. GSAT-7, GSAT-7A

(NAVIC) - Operational Name

IRNSS - Indian Regional Navigation Satellite System

GSAT - Geosynchronous Satellite

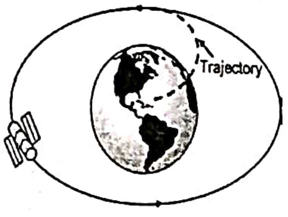
INSAT - Indian National Satellite System

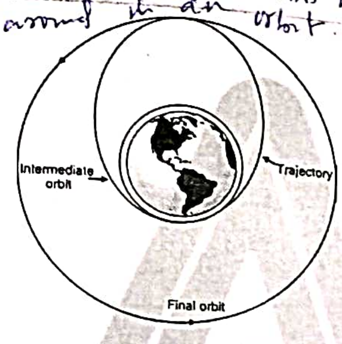
Netwon Second law - Net force is equal to mass time acceleration

Trajectory - an object moving under the action of given force.
(or)
The curved path along which Something (rocket) moves through the air or through Space.

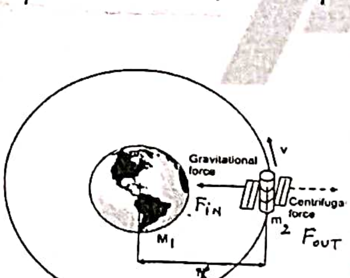
Orbit and Trajectory.

A trajectory is a path traced by a moving body, an orbit is a trajectory that is periodically repeated. The path followed by the motion of an artifical Satellite around in an orbit.





Expression for orbital period & velocity



According to Newton's law of gravitation, every particle irrespective of mass attracts every other particle with a gravitational force (F) whose magnitude is directly proportional to the product of the masses of two particles and inversely proportional to the square of the distance between them.

Mathematically,

$$F = \frac{G M_1 M_2}{r^2}$$

where M_1, M_2 are the masses of the two particles

$r \rightarrow$ distance between the two particles.

$G \rightarrow$ gravitational constant $= 6.67 \times 10^{-11} m^3/kg s^2$

According to Newton's second law of motion,

$$F = M \times a \qquad a = \text{acceleration}$$

When the satellite is in its orbit, it experiences two forces viz centripetal and centrifugal force.

if both forces on satellite are equal, then the satellite orbit Earth with uniform velocity 'v'.

$$\underbrace{\frac{G M_1 M_2}{r^2}}_{\substack{\text{Centripetal force} \\ F_{IN}}} = \underbrace{\frac{M_2 v^2}{r}}_{\substack{\text{Centrifugal force} \\ F_{OUT}}}$$

velocity with which Satellite orbits in circular

$$\therefore \quad v = \sqrt{\frac{G M_1}{r}} = \sqrt{\frac{\mu}{r}}$$

where M_1 is mass of the Earth

$\mu = G M_1 = 3.986013 \times 10^5 km^3$

μ = Earth's geocentric gravitational constant

Then, the orbital period is given by

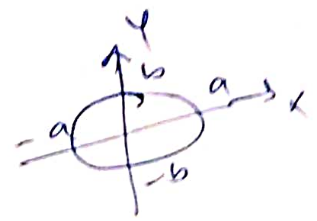
$$T = \frac{2\pi r}{v} \Rightarrow \frac{2\pi r . r^{1/2}}{\sqrt{\mu}}$$

$$T = \frac{2\pi r^{3/2}}{\sqrt{\mu}}$$

T = orbit period

The centripetal force is the forces pointing towards the center of a circle that keeps an object moving in a circular path.

The centrifugal force is the sensation that an object feels when it moves in that circular path, with that sensation



In case of elliptical orbit, the Kinetic and potential energies of a satellite at any point at a distance 'r' from the center of Earth given by

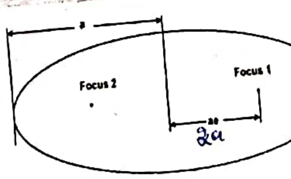
Kinetic Energy $= \frac{1}{2} M_2 v^2$

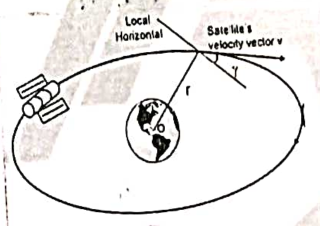
potential Energy $= -\frac{G M_1 M_2}{r}$

Sum of Kinetic and potential energies of satellite always remains constant, which is equal to

$$= -\frac{G M_1 M_2}{2a}$$

Where $M_1 \rightarrow$ mass of the Earth
$M_2 \rightarrow$ mass of the satellite
$a \rightarrow$ semimajor axis of the orbit.





$$\therefore \frac{1}{2} M_2 v^2 - \frac{G M_1 M_2}{r} = -\frac{G M_1 M_2}{2a}$$

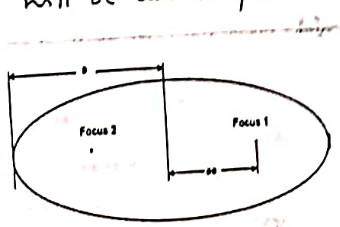
$$v^2 = G M_1 \left(\frac{2}{r} - \frac{1}{a}\right)$$

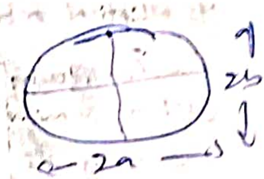
$$\therefore v = \sqrt{\mu\left(\frac{2}{r} - \frac{1}{a}\right)}$$

Kepler's Laws of planetary Motion.

Kepler's First Law.

The path followed by a satellite around primary will be an ellipse.



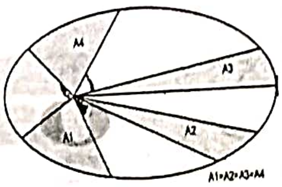


where $e = \frac{\sqrt{a^2-b^2}}{a}$ eccentricity

$v = \sqrt{\mu\left(\frac{2}{r} - \frac{1}{a}\right)}$ velocity of satellite in elliptical orbit.

Kepler's Second law:

for equal time intervals, a satellite will sweep out equal areas in its orbital plane.



Where the rate of change of swept out area is given by $\frac{dA}{dt} = \frac{\text{Angular momentum of the satellite}}{2m}$

where $m \rightarrow$ mass of the satellite.

Kinetic energy is not constant

more on the Earth's surface

less on near earth

$$v^2 = \frac{\left(-\frac{G m_1 m_2}{2a} + \frac{G m_1 m_2}{r}\right)}{\frac{1}{2} m_2} = G m_1\left(\frac{2}{r} - \frac{1}{a}\right)$$

Kepler's third law.

The square of the time period of any satellite is proportional to the cube of semi-major axis of its elliptical orbit.

Considering a circular orbit of radius 'r' (where semi-major axis = semi minor axis).
Equating the forces on the satellites,

$$\underbrace{\frac{G M_1 M_2}{r^2}}_{\text{Centripetal force}} = \underbrace{\frac{M_2 v^2}{r}}_{\text{Centrifugal force}}$$

replacing 'v' by ωr, we get

$$\frac{G M_1 \cancel{M_2}}{r^2} = \frac{m_2 \omega^2 r^2}{r} = \cancel{m_2} \omega^2 r$$

$$\Rightarrow \omega^2 = \frac{G M_1}{r^3}$$

Substituting $\omega = \frac{2\pi}{T}$, we get,

$$\left[\frac{2\pi}{T}\right]^2 = \frac{G M_1}{r^3}$$

$$T^2 = \frac{4\pi^2}{G M_1} \cdot r^3$$

$\therefore$ orbital period $T = \frac{2\pi\, r^{3/2}}{\sqrt{\mu}}$

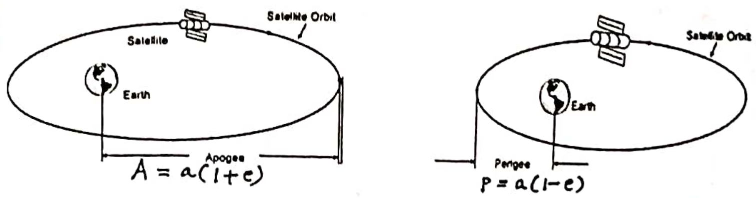
The above equation holds good for elliptical orbit, by replacing r by 'a' as

$$T = \frac{2\pi\, a^{3/2}}{\sqrt{\mu}}$$

$$T^2 = \frac{4\pi^2}{GM} a^3 = \frac{4\pi^2}{\mu} a^3$$

Orbital parameters.

Apogee: Apogee is the point on satellite orbit that is at the farthest distance from center of the Earth.

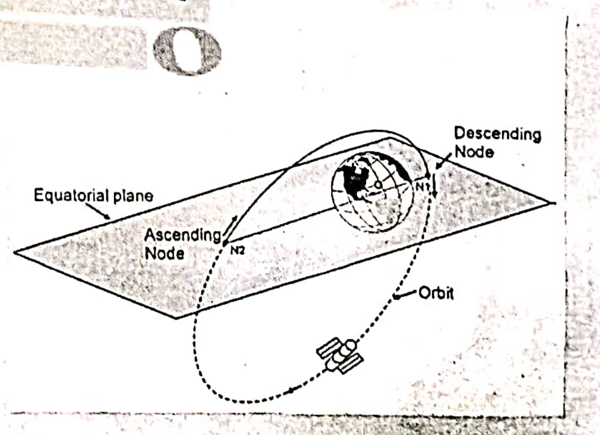


perigee: perigee is the point on orbit that is nearest to the center of the Earth.

Line of apsides: The line joining the perigee and apogee through the center of the Earth.

Ascending Node: The point where the orbit crosses the equatorial plane of Earth going from South to North (N_2).

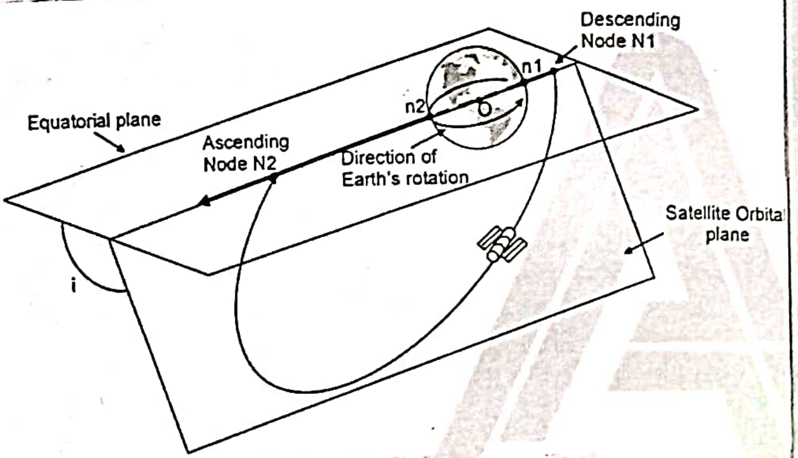
Descending Node: The point where the orbit crosses the equatorial plane of Earth going from North to South (N_1)



The Right Ascension of the Ascending node (RAAN) is the longitude of the point where the Spacecraft crosses the equatorial plane moving from South to North.

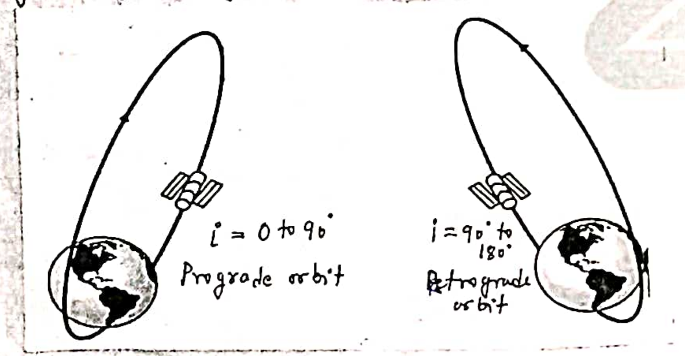
Line of Nodes: The line joining ascending and descending nodes through the center of Earth.

Inclination: It is the angle that the orbital plane of satellite makes with the earth's equatorial plane.



It is measured from ascending node to the the orbit from the equatorial plane.

Prograde & Retrograde orbit.



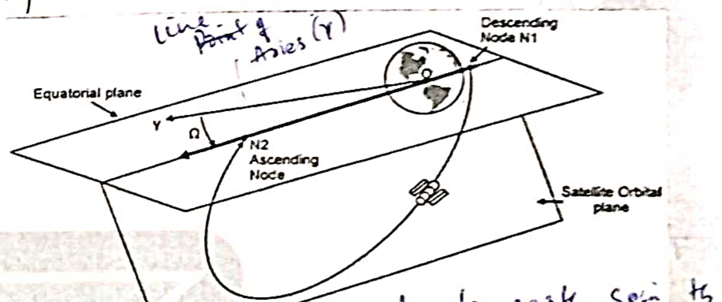
Prograde – All planets, Sun, earth, moon, rotate in prograde i.e 'Anti clock wise direction'

retrograde – clock wise direction

An orbit in which satellite moves in the same direction as earth's rotation known as Prograde orbit.

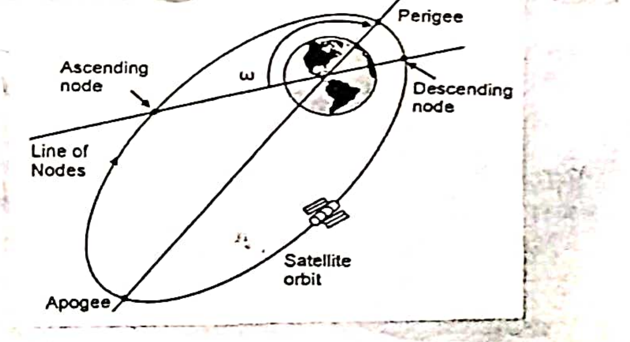
An orbit in which satellite moves in a direction counter to earth's rotation is retrograde orbit.

Right Ascension of Ascending Node: (Ω)
This is the angle made by line of nodes with respect to the direction of the vernal equinox.(Υ).



due to earth spin the point of Ascending node is not fixed.

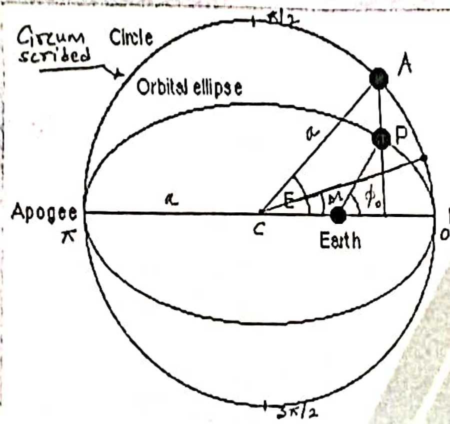
Argument of perigee: (ω)
This parameter defines the location of major axis of satellite orbit. It is measured between the line join the perigee and center of the earth and line of nodes from ascending to descending nodes in the same direction as that of satellite orbit.



Vernal equinox occurs the Sun crosses the equator going from south to north & an imaginary line of point i.e point of Aries is called line of Aries (Υ)

True Anomaly - is the angle from the perigee to the satellite position measured at the earth's center.

True anomaly, Mean Anomaly & Eccentric anomaly.



True anomaly (ϕ_0): is the angle from perigee to the satellite position, measured at the center of the earth.

Mean anomaly (M): is the arc length (radians) that satellite would have traversed since the perigee passage if it is moving on a circumscribed circle of mean angular velocity η.

$M = E - e\sin E$.

Eccentric anomaly (E): Angle made by drawing vertical line from position of satellite intersects circumscribed circle at A.

refer: www.youtube.com/watch?v=cf9jh44kL20

Injection Velocity and Resulting Satellite trajectories

The horizontal velocity with which a satellite is injected into space by the launch vehicle with the intention of imparting a specific trajectory to the satellite has a direct bearing on the satellite trajectory.

The general expression for the velocity of a satellite at the perigee point (v_p), assuming an elliptical orbit is given by

$$v_p = \sqrt{\mu\left(\frac{1}{P} - \frac{2}{A+P}\right)}$$

Where A is the Apogee distance

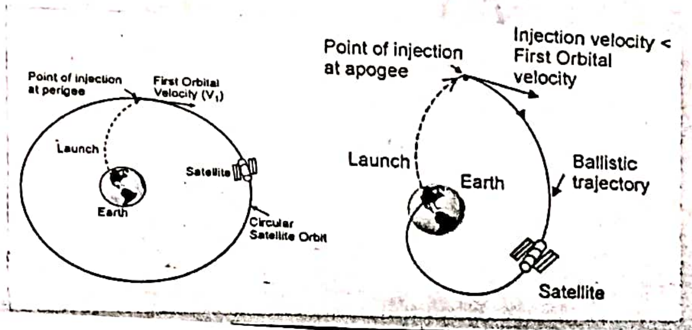
P is the perigee distance

$\mu = GM$ = Kepler's constant.

first cosmic velocity v_1 is one at which apogee and perigee distances are equal, $A = P$ and orbit is circular. Then the above expression reduces to

$$v_1 = \sqrt{\frac{\mu}{P}}$$

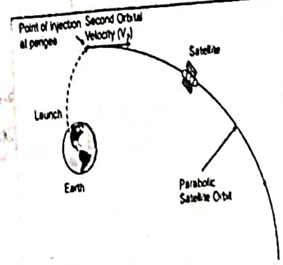
If the injection velocity < first cosmic velocity, the satellite follows a ballistic trajectory and falls back to Earth.



Mean anomaly (M) = an average value of the angular position of the satellite with reference to the perigee. for a circular orbit, 'M' gives the angular position of the satellite in the orbit. For elliptical orbit, the position is much more difficult to calculate.

Cosmic velocity is the minimum speed directed in the necessary directions to escape the gravitational attraction of a cosmic body such as star, planet or a galaxy

...or injection velocity > first cosmic velocity and ...s than second cosmic velocity, ie $v > \sqrt{\frac{\mu}{p}}$ and $< \sqrt{\frac{2\mu}{p}}$, the orbit is elliptical and eccentric. ($0<e<1$).



When the injection velocity $= \sqrt{\frac{2\mu}{p}}$, the apogee distance becomes infinite and the orbit takes the shape of parabola. This velocity is known as second cosmic velocity V_2.

At this velocity, the satellite escapes from earth's gravitational pull.

if injection velocity $> V_2$, the trajectory is hyperbolic and $e>1$.

If the injection velocity is increased further, a stage is reached where the satellite succeeds in escaping from the solar system.

Types of Satellite orbits

The satellite orbits can be classified on the basis of

1. orientation of orbital plane
2. eccentricity
3. Distance from Earth

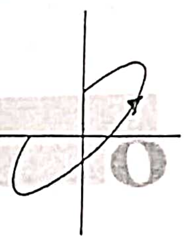
1. based on orientation of orbital plane.

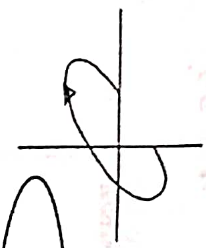
Equatorial orbit
inclination angle $i = 0°$

Polar orbit
Inclination $i = 90°$

Prograde orbit
Inclination angle $0°$ to $90°$

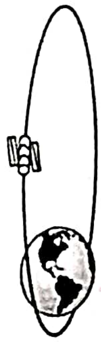
Retrograde orbit
inclination $i = 90°$ to 180





2. based on eccentricity

circular orbit



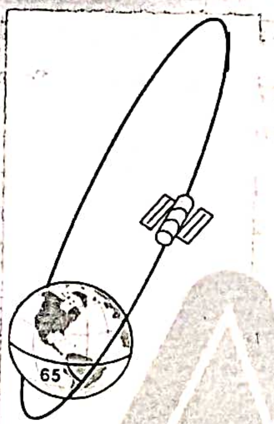
elliptical orbit.

Eccentricity means a measure of how much the deviation of the curve has occurred from the circularity of the given shape.

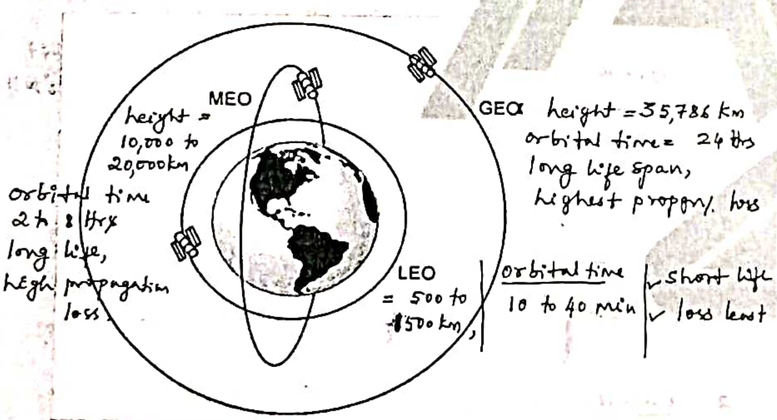
$E<1$ = ellipse $E=0$ - curve is circular. $=1 \Rightarrow$ parabol
$E>1$ = hyperbola.

Molniya orbit

- ✓ Highly eccentric,
- ✓ inclination $I = 65°$
- ✓ elliptical orbit to covers higher latitudes.
- ✓ $e = 0.75$ with $h_p = 400km$, $h_a = 40{,}000km$
- ✓ 12 hours orbit time, satellite spends about 8 hours above a particular high northern latitude station before diving to a low perigee.



3: based on distance from Earth.



Orbital Perturbation.

The Keplerian orbit described ideal in the sense that it assumes that the earth is a uniform spherical mass and that the only force acting is the centrifugal force resulting from satellite motion balancing gravitational pull of the earth.

The other forces significant are the gravitational pulls of sun and moon and atmospheric drag.

effect of a nonspherical earth.

. for a spherical earth of uniform mass, Kepler's third law given by

$$\boxed{n_0 = \sqrt{\frac{\mu}{a^3}}}$$

where n_0 = mean motion
a = length of the semi major axis

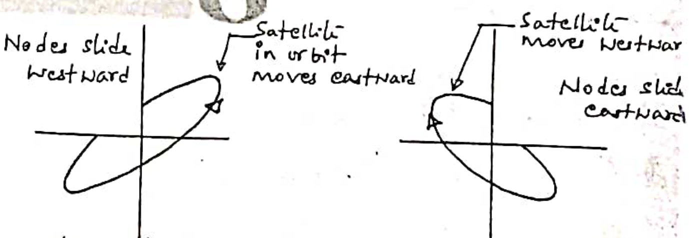
The anomalistic period is given by

$$\boxed{P_A = \frac{2\pi}{n}}$$ seconds.

where n is in radian/second

The oblateness of the earth also produces two rotations of the orbital plane.

→ regression of the nodes
→ rotation of line of apsides.



The nodes moves in a direction opposite to direction of satellite motion, Hence the name regression of the nodes.

Anomalistic Period.

P_A:- earth perigee passage

The Time between consecutive passage of the satellite through the perigee position

Anomalistic period (P_A)

if consider of the earth is non uniform mass the earth is not perfectly spherical, there being an equatorial bulge & flattening at the poles, a shape described as a Oblate Spheroid for polar orbit ($i = 90^\circ$) regression is Zero.

The factor K given by

$$\boxed{K = \frac{n K_1}{a^2(1-e^2)^2}}$$

where n = mean motion
a = semimajor axis
e = eccentricity
$K_1 = 66063.1704 \text{ km}^2$

Then rate of change of Ω is given by

$$\boxed{\frac{d\Omega}{dt} = -K \cos i}$$

if $i > 90^\circ$, regression is eastward and the orbit is retrograde
$i < 90^\circ$, regression is westward and the orbit is prograde.

The other effect produced by equatorial bulge is rotation of line of apsides given by

$$\boxed{\frac{d\omega}{dt} = K(2 - 2.5\sin^2 i)}$$

When $i = 63.435^\circ$, no rotation takes place.

Regression of nodes ($\Delta\omega$)

Rotation of apsides caused by earth oblateness is similar to regression of nodes.

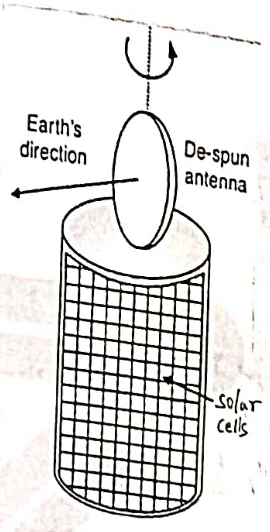
The phenomenon is caused by a higher acceleration near the equator & a resulting overshoot at periapsis. This only occurs in elliptical orbits.

Satellite stabilization.

Commonly employed techniques for satellite attitude control includes

1. spin stabilization
2. 3-axis or body stabilization.

1. spin stabilization.



Spin stabilized satellites are generally cylindrical in shape. Here the satellite body is spun at a rate between 30 and 100 rpm about an axis perpendicular to orbital plane.

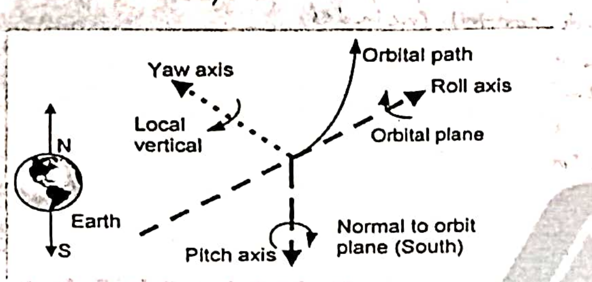
The rotation of satellite body offers inertial stiffness to prevent satellite from drifting.

Spinning types

Simple spinner
- The satellite payload & other subsystems are placed in spinning section.
- The antenna and the feed are placed in de-spun platform. (moves opposite to the satellite spinning)

dual spinner
- entire payload and antenna, feed is placed on de-spun platform
- other subsystem are located on spinning platform.

2. 3-axis or body stabilization.



The stabilization achived by controlling the movement of satellite along 3-axis that is
Yaw axis
pitch axis
roll axis.

The system uses reaction wheels or momentum wheels to correct the orbit pertrubations.

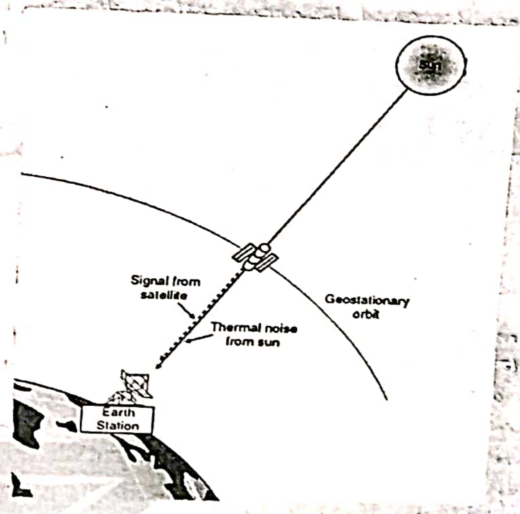
The satellite body is generally box shaped for body stabilization.

station keeping.

it is a process of maintaining satellite orbit against different factors that cause temporal drift.

- In spin stabilized satellites North-south station keeping maintained by firing thrusters parallel to spin axis. in continuous mode.
- East-west station keeping maintained by firing thrusters perpendiculars to spin-axis.
- In body stabilization firing thrusters in east-west or north-south direction in continuous mode

Sun transit outrage.



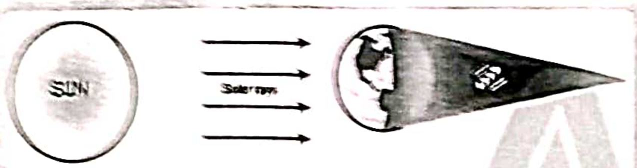
There are times when the satellite passes direct between the Sun and the Earth. The Earth station antenna receive signals from satellite as well as microwave radiation emitted by sun. This might cause temporary blanking the communication signal if solar radiation magnitude exceeds the fade margin of the receiver. This phenomenon of blanking satellite signal by hot sun is Sun transit outrage.

The traffic of satellite may be shifted to other satellite during sun transit outrage.

Eclipses

An eclipse is said to occur when the sunlight fails to reach the satellite solar panel due to an obstruction from celestial body.

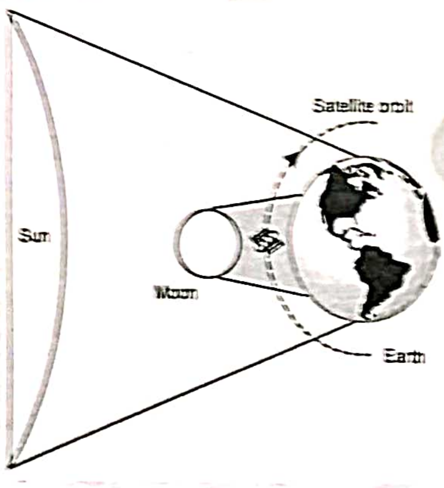
Solar eclipse.



The major and most frequent source of eclipse is due to the satellite coming in the shadow of earth, known as solar eclipse.

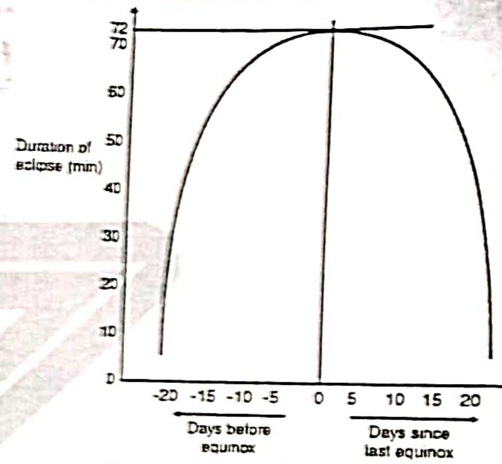
During equinoxes in March and September, the satellite, the Earth and the Sun are aligned at midnight as per local time and satellite spends 72 minutes in total darkness.

Lunar Eclipse

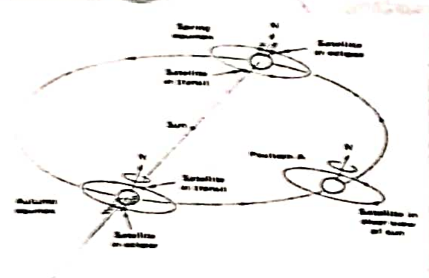


Another type of eclipse known as Lunar eclipse, when Moon's shadow passes across the satellite. This is less common phenomenon occur once in 29 years.

Duration of eclipse increases from 0 to 72 min for starting 21 days before the equinox and then decreases from 72 to 0 during 21 days following the equinox.



During the period of eclipse, satellite is depleted of its electrical capacity as the sunlight fail to reach it. The high power satellites shut down for all but essential services.



Look angles of Satellite.

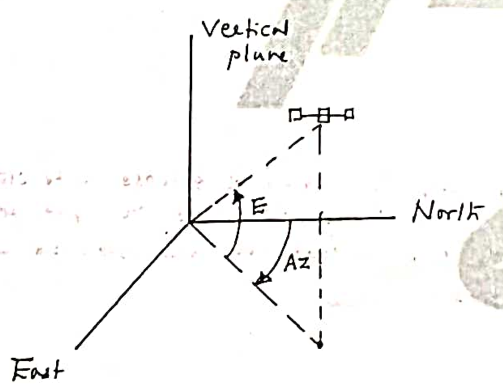
Look angle of a satellite refers to the co-ordinates to which an Earth station must be pointed in order to communicate with satellite and expressed in terms of Azimuth and Elevation angle.

Azimuth:

The angle measured Eastward (clockwise) from geographic North to the projection of satellite path on the horizontal plane at Earth station.

Elevation:

The angle measured upward from local horizontal at Earth station to satellite path.



$\theta_1 > 0$ $\theta_L - \theta_S < 0$ $\boxed{A_Z = 180 - A}$	$\theta_1 > 0$ $\theta_L - \theta_S > 0$ $\boxed{A_Z = 180 + A^{\circ}}$
$\theta_1 < 0$ $\theta_L - \theta_S < 0$ $\boxed{A_Z = A}$	$\theta_1 < 0$ $\theta_L - \theta_S > 0$ $\boxed{A_Z = 360^{\circ} - A}$

where $\theta_1 \rightarrow$ Latitude of Earth station
$\theta_L \rightarrow$ longitude of Earth Station
$\theta_S \rightarrow$ longitude of satellite

Where

$$A = \tan^{-1}\left[\frac{\tan|\theta_S - \theta_L|}{\sin\theta_1}\right]$$

Elevation E

$$E = \tan^{-1}\left[\frac{r - R\cos\theta_1 \cos|\theta_S - \theta_L|}{R\sin\{\cos^{-1}(\cos\theta_1 \cos|\theta_S - \theta_L|)\}}\right] - \cos^{-1}(\cos\theta_1 \cdot \cos|\theta_S - \theta_L|)$$

where $r \rightarrow$ orbital radius
$R \rightarrow$ Earth's radius

BASIC CONCEPTS OF SATELLITE COMMUNICATIONS

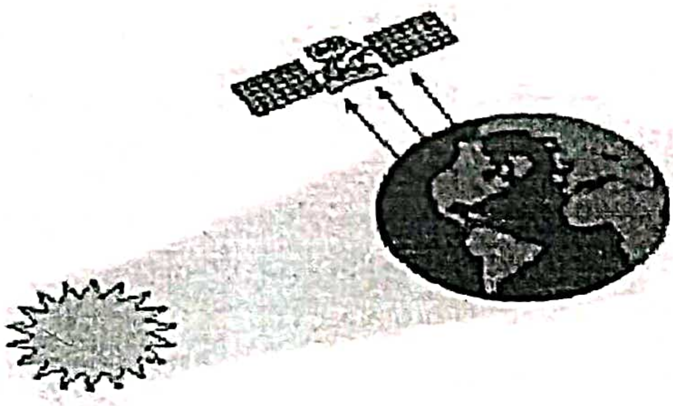
A communication satellite is an orbiting artificial earth satellite that receives a communications signal from a transmitting ground station, amplifies and possibly processes it, then transmits it back to the earth for reception by one or more receiving ground stations.

Communications information neither originates nor terminates at the satellite itself. The satellite is an active transmission relay, similar in function to relay towers used in terrestrial microwave communications.

Today's communications satellites offer extensive capabilities in applications involving data, voice, and video, with services provided to fixed, broadcast, mobile, personal communications, and private networks users.

Passive Satellites:

- A satellite that only reflects signals from one Earth station to another or from several Earth stations to several others.
- It reflects the incident electromagnetic radiation without any modification or amplification.
- It can't generate power, they simply reflect the incident power.
- The first artificial passive satellite Echo-I of NASA was launched in August 1960.

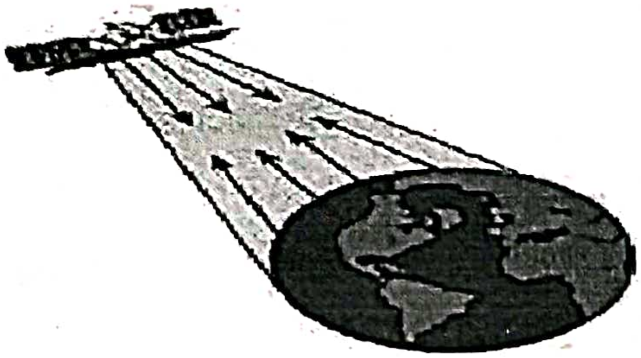


Disadvantages:

- Earth Stations required high power to transmit signals.
- Large Earth Stations with tracking facilities were expensive.
- A global system would have required a large number of passive satellites accessed randomly by different users.
- Control of satellites not possible from ground.
- The large attenuation of the signal while traveling the large distance between the transmitter and the receiver via the satellite was one of the most serious problems.

Active Satellites:

- In active satellites, it amplifies or modifies and retransmits the signal received from the earth.
- Satellites which can transmit power are called active satellite.
- Have several advantages over the passive satellites.
- Require lower power earth station.
- Not open to random use.
- Directly controlled by operators from ground.

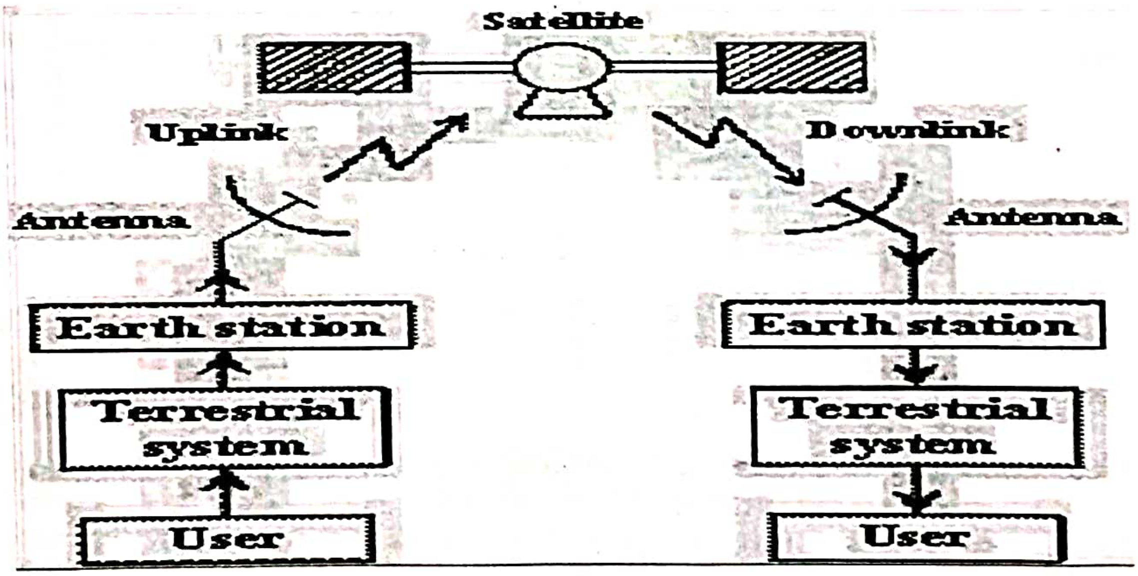


Disadvantages:

- Requirement of larger and powerful rockets to launch heavier satellites in orbit.
- Requirement of on-board power supply.
- Interruption of service due to failure of electronics components.

Two major elements of Satellite Communications Systems are:

The satellite communications portion is broken down into two areas or segments: **the space segment and the ground (or earth) segment.**



General architecture of Satellite Communication

Space Segment:

The elements of the space segment of a communications satellite system are shown in Figure. The space segment includes the satellite (or satellites) in orbit in the system, and the ground station that provides the operational control of the satellite(s) in orbit.

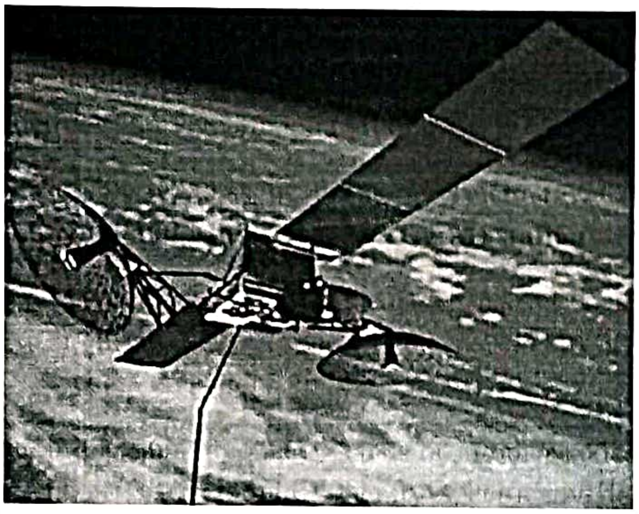
– measurement through signal of location – comm b/w satellite & earth station

The ground station is variously referred to as the **Tracking, Telemetry, Command (TT&C) or the Tracking, Telemetry, Command and Monitoring (TTC&M) station.**

from the ground station

The TTC&M station provides essential spacecraft management and control functions to keep the satellite operating safely in orbit. The TTC&M links between the spacecraft and the ground are usually separate from the user communications links.

TTC&M links may operate in the same frequency bands or in other bands. TTC&M is most often accomplished through a separate earth terminal facility specifically designed for the complex operations required to maintain a spacecraft in orbit.



Ground segment:

The ground segment of the communications satellite system consists of the earth surface area based terminals that utilize the communications capabilities of the Space Segment. TTC&M ground stations are not included in the ground segment.

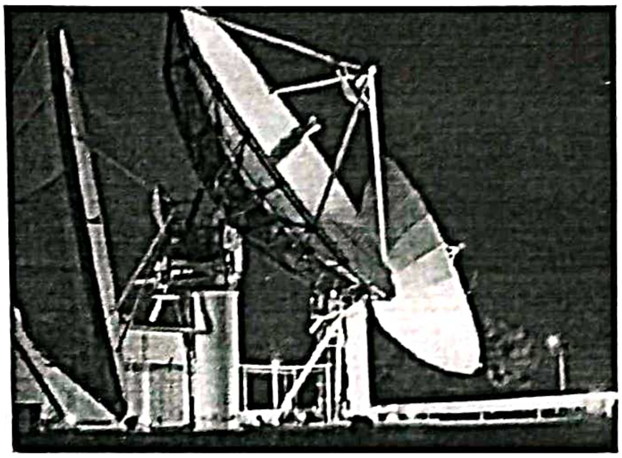
The ground segment terminals consist of three basic types:

- fixed (in-place) terminals;
- transportable terminals;
- mobile terminals.

Fixed terminals are designed to access the satellite while **fixed in-place on the ground**. They may be providing different types of services, but they are defined by the fact that they are not moving while communicating with the satellite. Examples of fixed terminals are small terminals used in private networks (VSATs), or terminals mounted on residence buildings used to receive broadcast satellite signals.

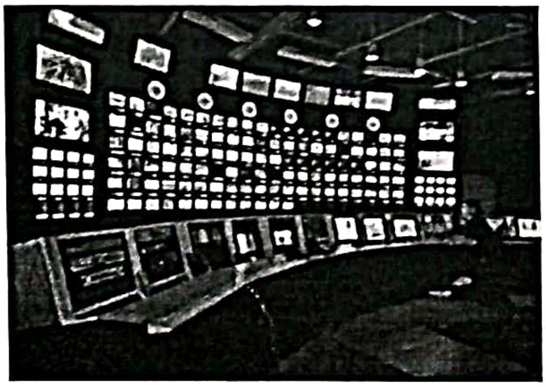
Transportable terminals are designed to be movable, but once on location remain fixed during transmissions to the satellite. Examples of the transportable terminal are satellite news gathering (SGN) trucks, which move to locations, stop in place, and then deploy an antenna to establish links to the satellite.

Mobile terminals are designed to communicate with the satellite while in motion. They are further defined as land mobile, aeronautical mobile, or maritime mobile, depending on their locations on or near the earth surface.



Satellite Control Centre function:

- Tracking of the satellite
- Receiving data
- Eclipse management of satellite
- Commanding the Satellite for station keeping.
- Determining Orbital parameters from Tracking and Ranging data
- Switching ON/OFF of different subsystems as per the operational requirements



Advantages Of Satellite Communication

- Universal: Satellite communications are available virtually everywhere.
- Versatile: Satellites can support all of today's communications needs.
- Reliable: Satellite is a proven medium for supporting a company's communications needs.
- Seamless: Satellite's inherent strength as a broadcast medium makes it perfect.
- Fast: Since satellite networks can be set up quickly, companies can be fast-to-market with new services.
- Flexible
- Expandable
- High Quality
- Quick Provision of Services
- Mobile and Emergency Communication
- Suitable for both Digital and Analog Transmission

Orbit: The path a Satellite follows around a planet is defined as an orbit.

Satellite orbits in terms of the orbital height:

According to distance from earth:

- Geosynchronous Earth Orbit (GEO)
- Medium Earth Orbit (MEO)
- Low Earth Orbit (LEO)

Geostationary or geosynchronous earth orbit (GEO) → circular orbit

GEO satellites are synchronous with respect to earth. Looking from a fixed point from Earth, these satellites appear to be stationary. These satellites are placed in the space in such a way that only three satellites are sufficient to provide connection throughout the surface of the Earth (that is; their footprint is covering almost 1/3rd of the Earth). The orbit of these satellites is circular. Lifetime expectancy of these satellites is 15 years.

There are three conditions which lead to geostationary satellites.

1) The satellite should be placed 35,786 kms (approximated to 36,000 kms) above the surface of the earth.

2) These satellites must travel in the rotational speed of earth, and in the direction of motion of earth, that is eastward.

3) The inclination of satellite with respect to earth must be 0^0

→ orbit is synchronous with the earth rotation i.e GeoSynchronous
(rotation with ~~space~~ same speed)

→ coverage 40% of planet

Geostationary satellite in practical is termed as geosynchronous as there are multiple factors which make these satellites shift from the ideal geostationary condition.

1) Gravitational pull of sun and moon makes these satellites deviate from their orbit. Over the period of time, they go through a drag. (Earth's gravitational force has no effect on these satellites due to their distance from the surface of the Earth.)

→ outward force from the mass in rotating

2) These satellites experience the centrifugal force due to the rotation of Earth, making them deviate from their orbit.

3) The non-circular shape of the earth leads to continuous adjustment of speed of satellite from the earth station.

These satellites are used for TV and radio broadcast, weather forecast and also, these satellites are operating as backbones for the telephone networks.

Advantages Of GEO

- Minimal Doppler shift
- These factors make it ideal for satellite broadcast and other multipoint applications
- GEO satellites have a 24 hour view of a particular area.
- A GEO satellite's distance from earth gives it a large coverage area, almost a fourth of the earth's surface.

Disadvantages Of GEO

- The transmit power needed is relatively high which causes problems for battery powered devices.
- These satellites cannot be used for small mobile phones.
- The biggest problem for voice and also data communication is the high latency as without having any handovers.
- Transferring a GEO into orbit is very expensive.

Medium Earth Orbit (MEO) satellites:

MEOs can be positioned somewhere between LEOs and GEOs, both in terms of their orbit and due to their advantages and disadvantages.

- required to cover a globe for 24 hours a day

Using orbits 10000 to around 20,000 km, the system only requires a dozen satellites which is more than a GEO system, but much less than a LEO system. These satellites move more slowly relative to the earth's rotation allowing a simpler system design (satellite periods are about six hours). Depending on the inclination, a MEO can cover larger populations, so requiring fewer handovers.

→ These orbits are primarily reserved for comm satellite that cover the North & South Pole

→ MEOs are placed in an elliptical orbit

Used for GPS, Navigation purpose

Indian Regional Navigation Satellite System (IRNSS)

(US) GPS & Russia's Glonass

Galileo – European

Japan, China

7 satellite

11,000 km

Advantages Of MEO

- A MEO satellite's longer duration of visibility and wider footprint means fewer satellites are needed in a MEO network than a LEO network.

Disadvantages Of MEO

- A MEO satellite's distance gives it a longer time delay and weaker signal than a LEO satellite, though not as bad as a GEO satellite.

Low Earth Orbit (LEO) satellites:

These satellites are placed 500-1500 kms above the surface of the earth. As LEOs circulate on a lower orbit, hence they exhibit a much shorter period that is 95 to 120 minutes.

LEO systems try to ensure a high elevation for every spot on earth to provide a high quality communication link. Each LEO satellite will only be visible from the earth for around ten minutes.

Using advanced compression schemes, transmission rates of about 2,400 bit/s can be enough for voice communication. LEOs even provide this bandwidth for mobile terminals with Omni-directional antennas using low transmit power in the range of 1W.

The delay for packets delivered via a LEO is relatively low (approx 10 ms). The delay is comparable to long-distance wired connections (about 5–10 ms). Smaller footprints of LEOs allow for better frequency reuse, similar to the concepts used for cellular networks. LEOs can provide a much higher elevation in Polar Regions and so better global coverage.

These satellites are mainly used in remote sensing, providing mobile communication services (due to lower latency). Subdivision: Little, Big & Mega (super) LEOs

Advantages Of LEO

- A LEO satellite's proximity to earth compared to a GEO satellite gives it a better signal strength and less of a time delay, which makes it better for point to point communication.
- A LEO satellite's smaller area of coverage, less waste of bandwidth.

Little LEO appl

- 0.8 GHz Range, Small low cost, Vehicle tracking, environmental monitoring & two-way data communication. Used for short narrow band Applications

Disadvantages Of LEO

- A network of LEO satellites is needed, which can be costly.
- LEO satellites have to compensate for Doppler shifts cause by their relative movement.
- Atmospheric drag effects to LEO satellites, causing gradual orbital deterioration.

Shorter life span of 5 to 8 years
Space Debris

Big LEO Applications
- 2 GHz above range
- → offer global service
- → high speed, high bandwidth data comm & video conference.
- → carry voice & high speed data services
- → data comm & real time voice delivery

Mega (super) LEO Applications
20 - 30 GHz Range → Handles broadband data
→ optimized for packet switched data rather than voice