CMR
INSTITUTE OF
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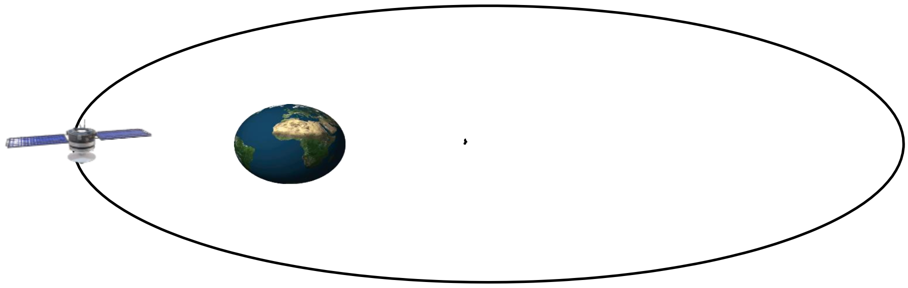
Internal Assesment Test - I

Sub:	Satellite Communication							Code:	18EC732
Date:	31/ 10/ 2023	Duration:	90 mins	Max Marks:	50	Sem:	7th	Branch:	ECE
Answer Any FIVE FULL Questions									

		Marks	OBE CO	OBE RBT
1.	Define and explain three laws of Kepler's to describe the motion of artificial satellites around the earth with neat diagrams and necessary equations	[10]	CO1	L2
2.	Define i) Orbit ii) trajectory iii) Newton's second law of motion iv) Apogee v) Argument of perigee.	[10]	CO1	L2
3.	An Earth station is located at 30 degree west longitude and 60 degree North latitude. Determine the earth stations azimuth and elevation angles with respect to geostationary satellite located at 50 degree west longitude. The orbital radius is 42,164 km. Assume the radius of the earth to be 6378 km.	[10]	CO1	L3
4	Explain with neat block diagram Earth station architecture.	[10]	CO2	L1
5.	Describe with a neat block diagram the satellite tracking system and explain any four tracking methods.	[10]	CO2	L2
6.	Explain briefly the following i) Orbital Perturbation ii) Sun Transit Outrage and Earth Eclipse of satellite	[10]	CO2	L2
7	List and explain the types of Earth stations on the basis of service provided by them and their usage.	[10]	CO2	L1
8	Explain the effect of injection velocity on satellite orbit	[10]	CO1	L3

1.

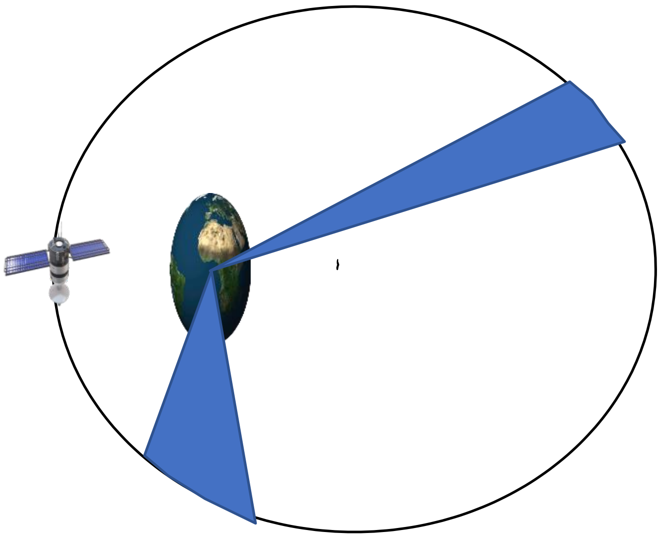
Kepler's first law states that the path followed by a satellite around the primary will be an ellipse



$$v = \sqrt{\left[\mu\left(\frac{2}{r} - \frac{1}{a}\right)\right]} \qquad e = \frac{\sqrt{a^2 - b^2}}{a}$$

For an elliptical orbit, $0 < e < 1$

Kepler's second law states that, for equal time intervals, a



satellite will sweep out equal areas in its orbital plane, focused at the barycenter

Kepler's third law states that the square of the periodic time of orbit is proportional to the cube of the mean distance between the two bodies.

$$\frac{Gm_1m_2}{r^2} = \frac{m_2v^2}{r}$$

Replacing v by ωr in the above equation gives

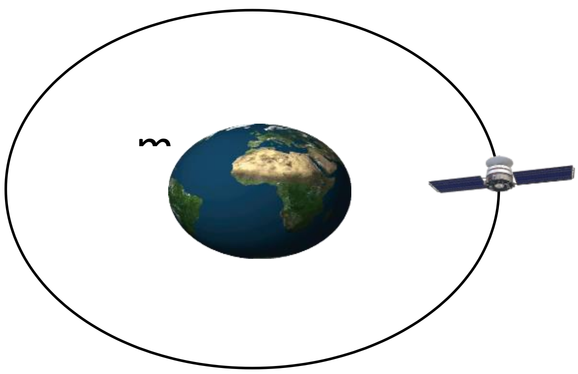
$$\frac{Gm_1m_2}{r^2} = \frac{m_2\omega^2r^2}{r} = m_2\omega^2r$$

which gives $\omega^2 = Gm_1/r^3$. Substituting $\omega = 2\pi/T$ gives

$$T^2 = \left(\frac{4\pi^2}{Gm_1}\right)r^3$$

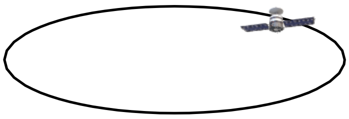
This can also be written as

$$T = \left(\frac{2\pi}{\sqrt{\mu}}\right)r^{3/2}$$



2.

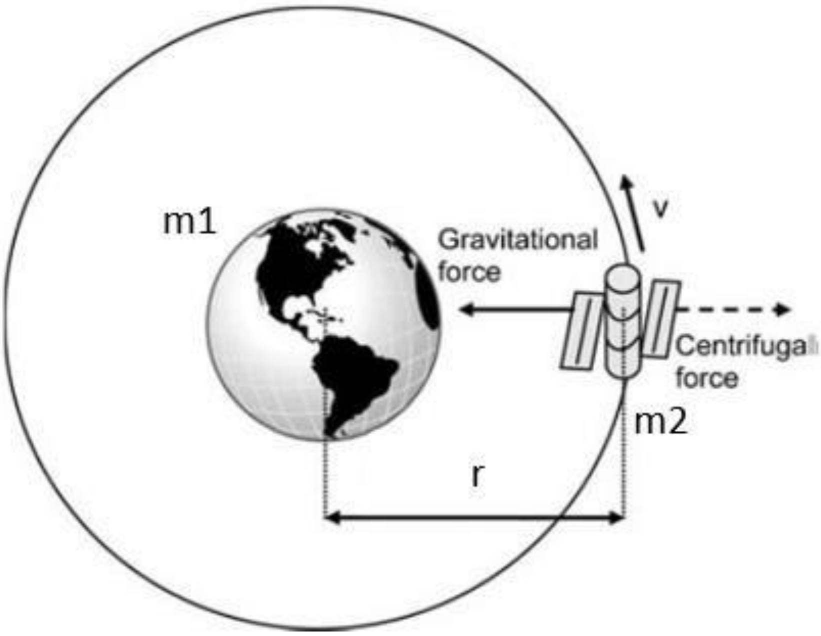
A trajectory is a path traced by a moving body, an orbit is a trajectory that is periodically repeated.An orbit is a trajectory that is periodically repeated.While the path followed by the motion of the artificial satellite around earth is an orbit.The path followed by the launch vechicle is a trajectory called the lauch trajectory.

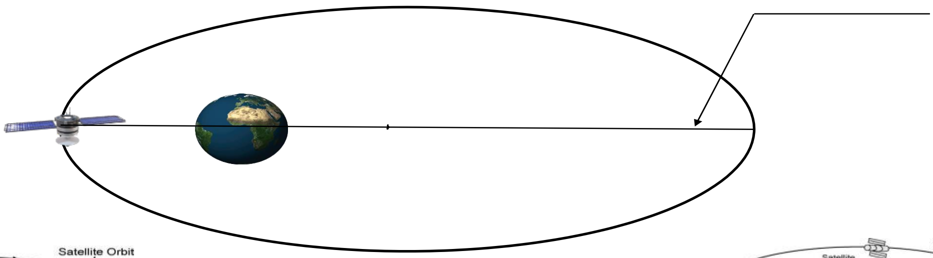


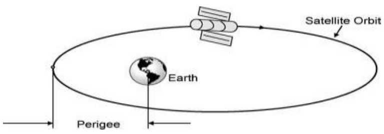
Newton's second law of motion, the force equalsthe product of mass and acceleration In the case of a satellite orbiting Earth, if the orbiting velocity is *v*, then the acceleration, called centripetal acceleration, experienced by the satellite at a distance *r* from the centre of the Earth would be

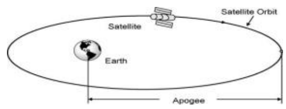
$$F_{in} = \frac{Gm_1m_2}{r^2}$$

Where $\mu = Gm_1 = 3.986\,013 \times 10^5\ \mathrm{km^3/s^2}$



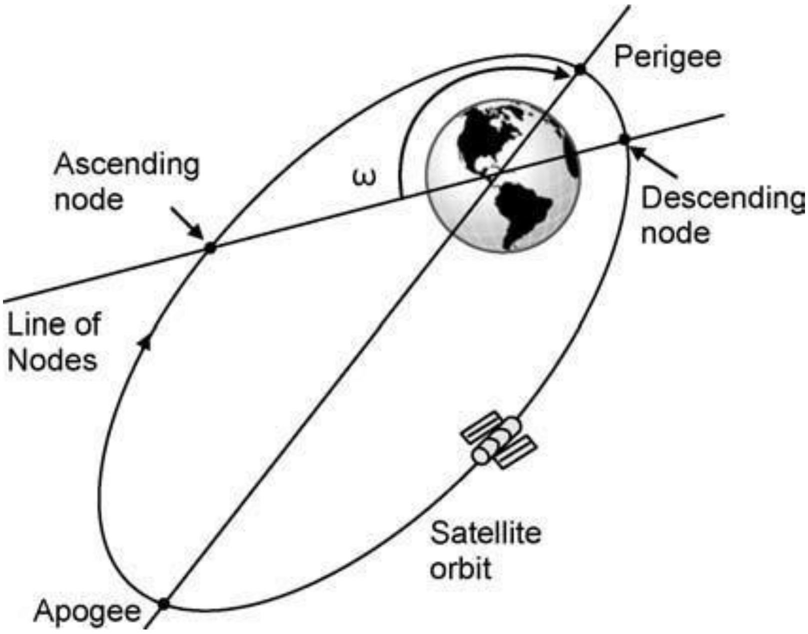






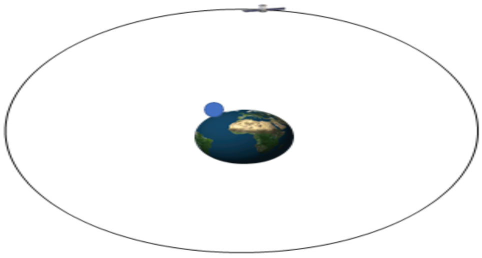
Apogee is the point on thesatellite orbit that is at thefarthest distance from the centre of the Earth.

Argument of perigee. The angle from ascending node to perigee, measured in the orbital plane at the earth's center, in the direction of satellite motion.



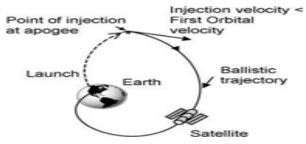
8.Injection Velocity:

Injection velocity and satellite trajectory

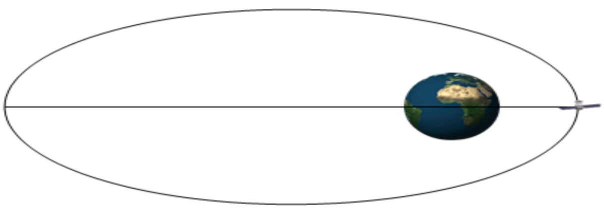


If the injection velocity happens to be less than the first cosmic velocity, the satellite follows a ballistic trajectory and falls back to Earth

In fact, in this case, the orbit is elliptical and the injection point is at the apogee and not the perigee



Injection velocity and satellite trajectory



For injection velocity greater than the first cosmic velocity and less than the second cosmic velocity, i.e.

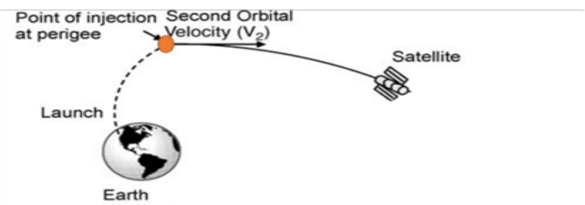
$$V > \sqrt{(\mu/r)} \quad \text{and} \quad V < \sqrt{(2\mu/r)}$$

(At this point apogee is very high , so second term can be neglected)

$$V_P = \sqrt{\left[\left(\frac{2\mu}{r}\right) - \left(\frac{2\mu}{R+r}\right)\right]}$$

the orbit is elliptical and eccentric

Injection velocity and satellite trajectory



The injection point in this case is the perigee and the apogee distance attained in the resultant elliptical orbit depends upon the injection velocity.

the velocity v at any other point

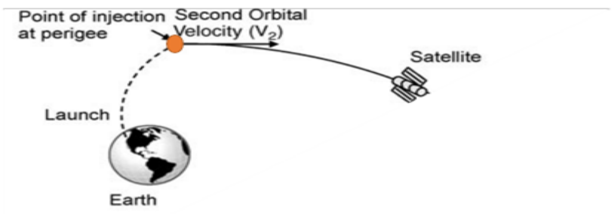
$$V_p = \sqrt{\left[(2\mu/r) - \left(\frac{2\mu}{R+r}\right)\right]}$$

When the injection velocity equals $\sqrt{(2\mu/r)}$

the apogee distance R becomes infinite and the orbit takes the shape of a parabola and the orbit eccentricity is 1

This is the second cosmic velocity V_2. At this velocity, the satellite escapes Earth's gravitational pull.

Injection velocity and satellite trajectory



The injection point in this case is the perigee and the apogee distance attained in the resultant elliptical orbit depends upon the injection velocity.

the velocity *v* at any other point

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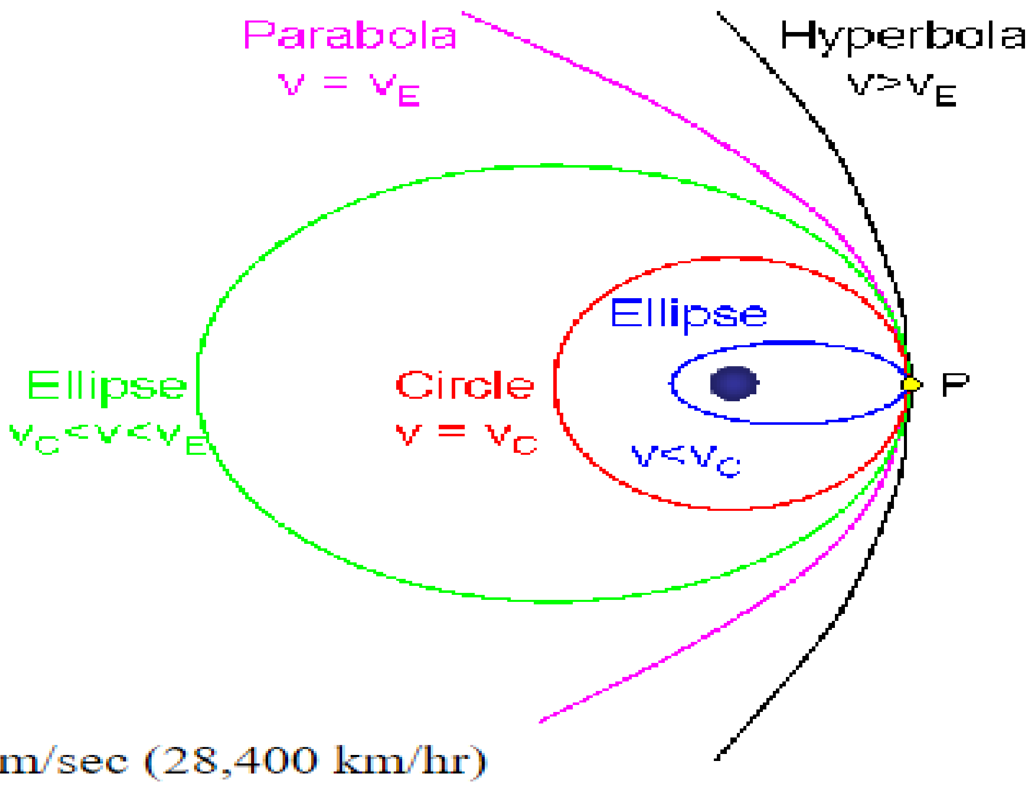
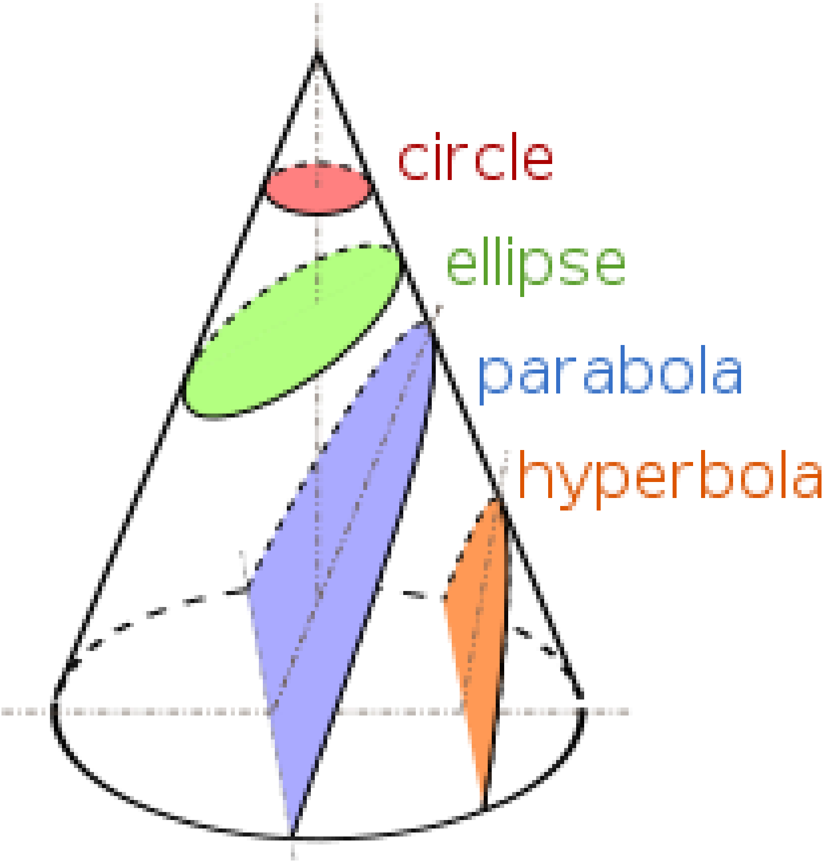


v_C = 7.9 km/sec (28,400 km/hr)

v_E = 11.2 km/sec (40,300 km/hr)



This is evident from the generalized expression for the velocity of the satellite in elliptical orbitsaccording to which

$$V_p = \text{velocity at the perigee point}$$
$$= \sqrt{\left[(2\mu)\left(\frac{1}{r} - \frac{1}{R+r}\right)\right]}$$

6.Orbital preturbations:

Orbital perturbations

The Keplerian orbit described so far is 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 the gravitational pull of the earth

In practice, other forces which can be significant are the

gravitational forces of the sun and the moon and atmospheric drag.

The gravitational pulls of sun and moon have negligible effect on low-orbiting satellites, but they do affect satellites in the geostationary orbit

Atmospheric drag, on the other hand, has negligible effect on geostationary satellites but does affect low orbiting earth satellites below about 1000 km.

Due to these factors, the satellite orbit tends to drift and its orientation also changes and hence the true orbit of the satellite is different from that defined using Kepler's laws.

Orbital perturbations

Effects of a nonspherical earth

As the perturbed orbit is not an ellipse anymore, the satellite does not return to the same point in space after one revolution

The time elapsed between the successive perigee passages is referred to as anomalistic period.

The anomalistic period t_A is given by equation

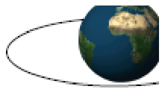
$$t_A = \frac{2\pi}{\omega_{\text{mod}}}$$

where

$$\omega_{\text{mod}} = \omega_0 \left[1 + \frac{K(1 - 1.5 \sin^2 i)}{a^2(1 - e^2)^{3/2}} \right]$$

ω_0 is the angular velocity for spherical Earth, $K = 66\ 063.1704 \text{km}^2$, a is the semi-major axis,e is the eccentricity

$$\omega_0 = \sqrt{\frac{\mu}{a^3}}$$



it is known that the earth is not perfectly spherical, there being an equatorial bulge and a flattening at the poles, a shape described as an *oblate spheroid*

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

The first of these, known as *regression of the nodes*, is where the nodes appear to slide along the equator

The second effect is rotation of apsides in the orbital plane

regression of the nodes :The line of nodes, which is in the equatorial plane, rotates about the center of the earth. Thus , the right ascension of the ascending node, Ω shifts its position

If the orbit is prograde , the nodes slide westward, and if retrograde, they slide eastward

As seen from the ascending node, a satellite in prograde orbit moves eastward, and in a retrograde orbit, westward. The nodes therefore move in a direction opposite to the direction of satellite motion, hence the term *regression of the nodes*

The rate of regression of the nodes $$\frac{d\Omega}{dt} = -K\cos i$$

rotation of apsides in the orbital plane $$\frac{d\omega}{dt} = K(2 - 2.5\sin^2 i)$$

Denoting the epoch time by t_0,

the right ascension of the ascending node by Ω_0, and the argument of perigee by ω_0 at epoch

gives the new values for Ω and ω at time t as

$$\Omega = \Omega_0 + \frac{d\Omega}{dt}(t - t_0)$$

$$\omega = \omega_0 + \frac{d\omega}{dt}(t - t_0)$$

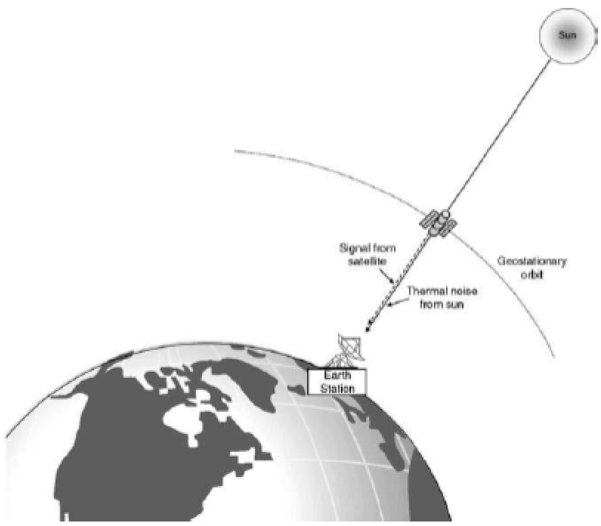
Sun Transit Outrage

There are times when the satellite passes directly between the un and the Earth

The Earth station antenna will receive signals from the satellite as well as the microwave radiation emitted by the sun (the sun is a source of radiation with an equivalent temperature varying between 6000K to 11000K).

This might cause temporary outrage if the magnitude of the solar radiation exceeds the fade margin of the receiver.

The traffic of the satellite may be shifted to other satellites during such periods.



Telemetry, tracking and command (TT&C) subsystem

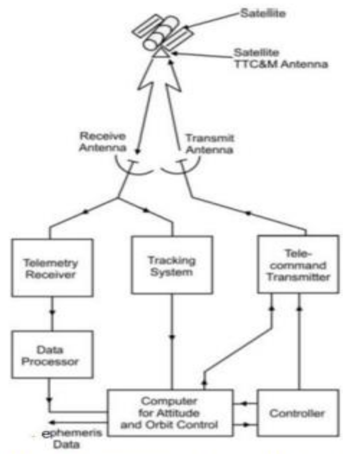
The tracking part of the subsystem determines the position of the spacecraft and follows its travel using angle, range and velocity information.

The telemetry part gathers information on the health of various subsystems of the satellite. It encodes this information and then transmits the same towards the Earth control centre.

The command element receives and executes remote control commands from the control centre on Earth to effect changes to the platform functions, configuration, position and velocity.

TTC functions

1. Continuously monitoring and reporting spacecraft health
2. Control orbit and attitude of the satellite
3. Monitoring command actions
4. Switch on and off the communication systems
5. Control of payload



Scientific **ephemerides** often contain further useful **data** about the moon, planet, asteroid, or comet beyond the pure coordinates in the sky

Attitude and orbit control subsystem

Altitude and Orbit Control **(AOC)** subsystem capable of placing the satellite into the right orbit, whenever there is deviation observed from the respective orbit.

AOC subsystem is very helpful in order to make the satellite antennas always pointing towards earth.

AOC subsystem consists of **two parts**.

- •Attitude Control Subsystem
- •Orbit Control Subsystem

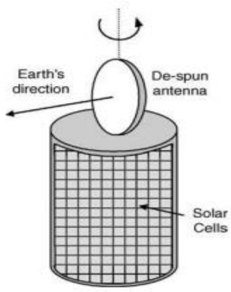
Attitude Control Subsystem

Altitude control subsystem takes care of the orientation of satellite in its respective orbit. Following are the two methods to make the satellite that is present in an orbit as stable.

Spin stabilization
Three axes method

spin stabilization

the entire spacecraft rotates around its own vertical axis, spinning like a top.
This keeps the spacecraft's orientation in space under control.
The advantage of spin stabilization is that it is a very simple way to keep the spacecraft pointed in a certain direction.
In a spin-stabilized satellite, the satellite body is spun at a rate between 30 and 100 rpm about an axis perpendicular to the orbital plane



Intelsat-1 to Intelsat-4, Intelsat-6 and TIROS-1

There are two types of spinning configurations employed in spin-stabilized satellites.

These include the

simple spinner configuration
the dual spinner configuration.

In the simple spinner configuration, the satellite payload and other subsystems are placed in the spinning section, while the antenna and the feed are placed in the de-spun platform.

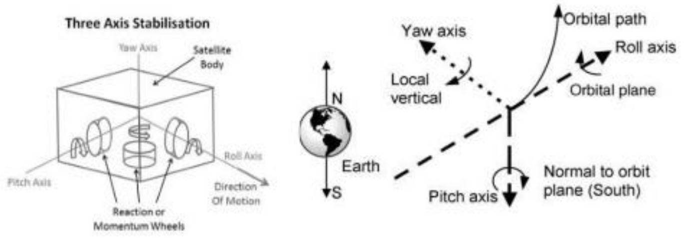
In the dual spinner configuration, the entire payload along with the antenna and the feed is placed on the de-spun platform and the other subsystems are located on the spinning body.

Three-axis or Body Stabilization

In the case of three-axis stabilization, also known as body stabilization, the stabilization is achieved by controlling the movement of the satellite along the three axes, yaw, pitch and roll

The system uses reaction wheels or momentum wheels to Correct orbit perturbation.

Roll axis is considered in the direction in which the satellite moves in orbital plane.
Yaw axis is considered in the direction towards earth.
Pitch axis is considered in the direction, which is perpendicular to orbital plane.



Intelsat-5, Intelsat-7, Intelsat-8, GOES-8, GOES-9, TIROS-N and the INSAT series

Orbit Control Subsystem

Orbit control subsystem is useful in order to bring the satellite into its correct orbit, whenever the satellite gets deviates from its orbit.

The TTC subsystem present at earth station monitors the position of satellite and there is any change in satellite orbit, then it sends a signal regarding the correction to Orbit control subsystem.

Then, it will resolve that issue by bringing the satellite into the correct orbit.

7.

An Earth station is a terrestrial terminal station mainly located on the Earth's surface

Earth stations are generally categorized on the basis of type of services or functions provided by them

types based on service provided by the Earth station	Earth stations types based on their usage
1. Fixed Satellite Service (FSS) Earth Stations 2. Broadcast Satellite Service (BSS) Earth Stations 3. Mobile Satellite Service (MSS) Earth Stations	1. Single function stations 2. Gateway stations 3. Teleports

Comparison of Earth stations

Fixed Satellite Service (FSS) Earth Station	Broadcast Satellite Service (BSS) Earth Stations	Mobile Satellite Service (MSS) Earth Stations
large Earth stations (G/T~=40 dB/K) medium Earth stations (G/T~=30 dB/K), small Earth stations (G/T~=25 dB/K), very small terminals with transmit/receive functions (G/T~=20 dB/K) Very small terminals with receive only functions (G/T~=12 dB/K) The service involves telephony, data communications and radio and television broadcast feeds. FSS satellites operate in either the C band or the Ku band FSS operates at lower power levels require a much larger dish FSS satellite transponders use linear polarization	• large Earth stations (G/T~=15 dB/K) • small Earth stations (G/T~=8 dB/K) • large Earth stations used for community reception • small Earth stations used for individual reception.(DBS)	• large Earth stations (G/T~=−4 dB/K), • medium Earth stations (G/T~=−12 dB/K) • small Earth stations (G/T~=−24 dB/K). • Satellite phone is the most commonly used mobile satellite service

Single Function Stations	Gateway Stations	Teleports
• Single function stations are characterized by a single type of link to a satellite or a satellite constellation. These stations may be • transmit-only, • receive-only or both. Some common examples are- • television receive-only (TVRO) terminals used for TV reception by an individual • satellite radio terminals • receive-only terminals used at a television broadcast • two-way VSAT terminals • Handheld satellite telephone terminals	• Gateway stations serve as an interface between the satellites and the terrestrial networks and also serve as transit points between satellites. • These stations are connected to terrestrial networks by various transmission technologies, both wired such as coaxial cables, optical fibers etc. and wireless such as microwave towers. • In gateway stations, signal processing is the major activity as gateway station receives a large variety of terrestrial signals at any given time. • These include telephone signals, television signals, and data streams and so on and to be converted into standard format before sending to intended satellite.	• Teleport is a type of gateway station operated by firms that are usually not a part of a specific satellite system • Teleports helps when line of sight is missing due to the close proximity of another tall building or some other obstacle or site is located in crowded place . • Teleports are usually located on the outskirts of the city and the connectivity from the subscriber company to the teleport station is usually provided through a hub (hub in turn is connected to the teleport through a fiber-optic or a microwave link)

3.

Solution:

Since the Earth station is in the northern hemisphere and is located towards east of the satellite, the **azimuth angle A** is given by (180° + A'), where A' can be computed from

$$A' = \tan^{-1}\left(\frac{\tan|\theta_s - \theta_L|}{\sin\theta_l}\right)$$

where

θ_s = satellite longitude = 50°W
θ_L = Earth station longitude = 30°W
θ_l = Earth station latitude = 60°N

Therefore

$$A' = \tan^{-1}\left(\frac{\tan 20°}{\sin 60°}\right) = \tan^{-1}\left(\frac{0.364}{0.866}\right) = \tan^{-1}(0.42) = 22.8°$$

and

$$A = 180° + 22.8° = 202.8°$$

The Earth station elevation angle is given by

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

where

r = Satellite orbital radius
R = Earth's radius

Substituting the values of various parameters gives

$$E = \tan^{-1}\left[\frac{42\,164 - 6378\ \cos 60^\circ \cos 20^\circ}{6378\sin\{\cos^{-1}(\cos 60^\circ \cos 20^\circ)\}}\right] - \cos^{-1}(\cos 60^\circ \cos 20^\circ)$$

$$= \tan^{-1}\left[\frac{42\,164 - 2998}{6378\sin(\cos^{-1} 0.47)}\right] - \cos^{-1} 0.47$$

$$= \tan^{-1}\left(\frac{39\,166}{5631}\right) - 62^\circ$$

$$= 81.8^\circ - 62^\circ = 19.8^\circ$$

Therefore,

$$\text{Azimuth} = 202.8^\circ \text{ and Elevation} = 19.8^\circ$$

7.

Earth Station Architecture

The major components of an Earth station include

- the RF section,
- the baseband equipment and
- the terrestrial interface.
- support facilities

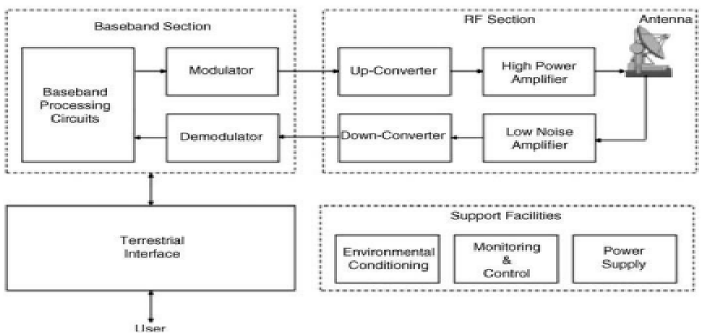
The RF section as mainly consists of

in the up-link channel (from ES to satellite)

- antenna subsystem,
- high power amplifier (HPA)
- the up-converter

in the down-link channel(from satellite to ES)

- antenna subsystem,
- low noise amplifier (LNA)
- down-converter



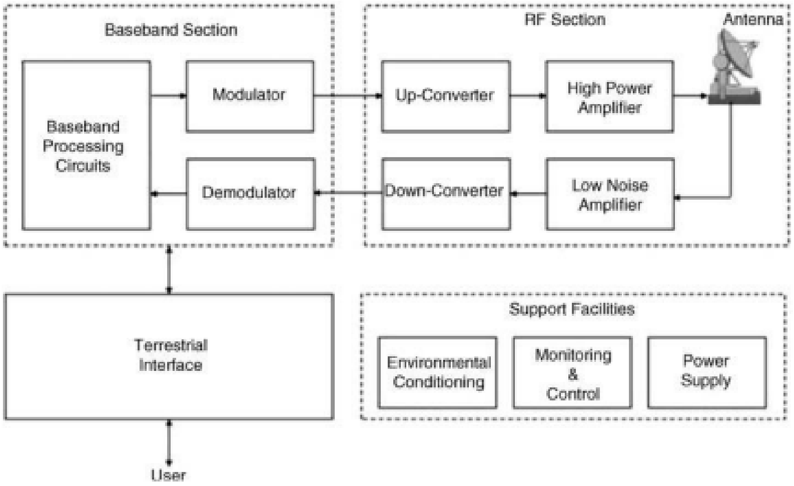
The job of up-converter in the up-link channel is to up-convert the baseband signal to the desired frequency.

The upconverted signal is then amplified to the desired level before it is fed to the feed system for subsequent transmission to the intended satellite

Similarly, a low noise amplifier amplifies the weak signals received by the antenna.

The amplified signal is then down converted to the intermediate frequency level before it is fed to the modem in the baseband section

The antenna feed system provides the necessary aperture illumination, introduces the desired polarization and also provides isolation between the transmitted and the received signals by connecting HPA output and LNA input to the cross-polarized ports of the feed.



ıe baseband section performs the ɔdulation/demodulation function with the specific ˌuipment required depending upon the modulation ːhnique and the multiple access method employed.

ıe baseband section input/output is connected to the rrestrial network through a suitable interface known as rrestrial interface.

'he terrestrial network could be a fiber optic cable nk or a microwave link or even a combination of the ʋo.