Satellite Technology (20EC81)
V-Sem, ASE&IT, A.Y: 2024-2025

Unit-I
Introduction to Satellite Systems

Presented by

Mr.M.Sivasankara Rao

Sr.Assistant Professor in ECE

Lakireddy Bali Reddy College of Engineering, Mylavaram

Contents

- Course Educational Objective and CO's.
- Syllabus and textbooks
- Introduction to satellites
- Need of space communication
- Common satellite applications and mission
- General structure of satellite communication system
- Types of spacecraft orbits
- Launch vehicles
- Satellite system and their functions

Course Educational Objective

- This course provides the knowledge on different laws associated with the motion of satellite.
- This course gives the knowledge on launching the satellite into orbit with launch vehicles.
- This course also provides the knowledge on various sub systems, structures, thermal control and applications of satellite.

Course Outcomes

At the end of the course, the student will be able to

- **CO1**: List out the operational bands, Spacecraft control mechanisms, sensors, and navigational aids for satellite applications (Remember-L1)
- **CO2**: Summarize the functions of satellite space segment, earth segment, Multiple access techniques, and satellite services. (Understand-L2)
- **CO3**: Illustrate the operational principles of satellite power system and spacecraft Control mechanism. (Understand-L2)
- **CO4**: Outline the concepts of orbital mechanics & satellite communication and its application(Understand-L2)

Syllabus and textbooks

Syllabus:

- Unit- 1: Introduction to satellite systems
- Unit- 2: Orbital Mechanics
- Unit- 3: Power system and Bus electronics
- Unit- 4: Spacecraft control
- Unit- 5: Satellite services & Applications

Textbooks:

- Trimothy Pratt, Charles Bostian, J Allnut , 'Satellite Communication', John Wiley & Sons, 2/e,2003.

Introduction to Satellites

- In the context of spaceflight, a satellite is an object that has been intentionally placed into orbit.
- These objects are called artificial satellites to distinguish them from natural satellites such as Earth's Moon.
- If the communication takes place between any two earth stations through a satellite, then it is called as satellite communication.
- In this communication, electromagnetic waves are used as carrier signals. These signals carry the information such as voice, audio, video or any other data between ground and space and vice-versa.

Introduction to Satellites

A satellite is simply any body that moves around another (usually much larger) one in a mathematically predictable path called an orbit.

In general terms, a **satellite** is a smaller object that revolves around a larger object in space. For example, moon is a natural satellite of earth.

History of satellites

Order	Country	Date of first Launch	Rocket	Satellite
1	Soviet Union	4 October 1957	Sputnik-PS	Sputnik 1
2	United States	1 February 1958	Juno I	Explorer 1
3	France	26 November 1965	Diamant-A	Astérix
4	Japan	11 February 1970	Lambda-4S	Ohsumi
5	China	24 April 1970	Long March 1	Dong Fang Hong I
6	United Kingdom	28 October 1971	Black Arrow	Prospero
7	India	1975/ 18 July 1980	SLV	Aryabhata/ Rohini D1
8	Israel	19 September 1988	Shavit	Ofeq 1
9	Iran	2 February 2009	Safir-1	Omid
10	North Korea	12 December 2012	Unha-3	Kwangmyŏngsŏng-3 Unit 2
11	South Korea	30 January 2013	Naro-1	STSAT-2C
12	New Zealand	12 November 2018	Electron	CubeSat

Need of space communication

- Daily life for a large portion of the world's population now involves sharing information via mobile phones, personal computers and other electronic communication devices.
- Space-based technologies, namely communications satellites, enable global telecommunications systems by relaying signals with voice, video and data to and from one or many locations.
- While Earth-based alternatives to space technologies are sometimes possible, space-based technology can often reduce infrastructure requirements and offer more cost effective service delivery options.
- For instance, instead of constructing a series of transmission and relay towers to broadcast television programmes to far-to-reach places, one satellite dish could be provided to a remote community to pick up broadcast signals sent from a satellite.

Need of Satellite Communication

The following two kinds of propagation are used earlier for communication up to some distance.

Ground wave propagation − Ground wave propagation is suitable for frequencies up to 30MHz. This method of communication makes use of the troposphere conditions of the earth.

Sky wave propagation − The suitable bandwidth for this type of communication is broadly between 30–40 MHz and it makes use of the ionosphere properties of the earth.

Need of Satellite Communication

The maximum hop or the station distance is limited to 1500KM only in both ground wave propagation and sky wave propagation. Satellite communication overcomes this limitation. In this method, satellites provide **communication for long distances**, which is well beyond the line of sight.

Since the satellites locate at certain height above earth, the communication takes place between any two earth stations easily via satellite. So, it overcomes the limitation of communication between two earth stations due to earth's curvature.

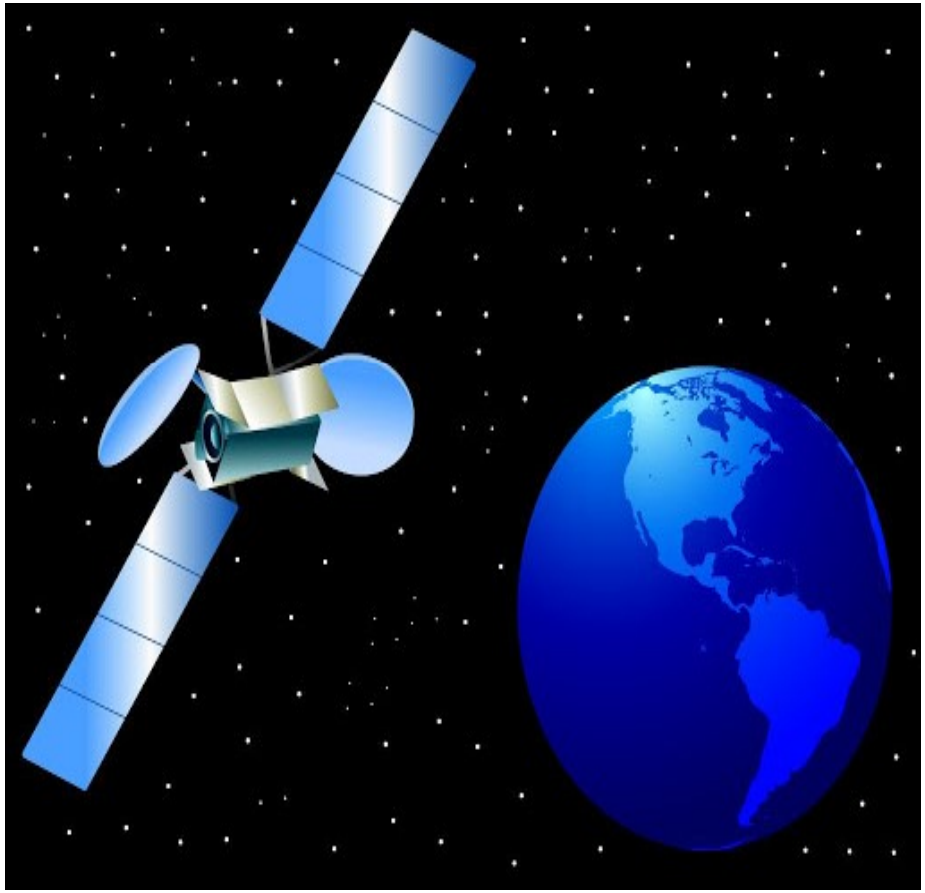
How satellite works

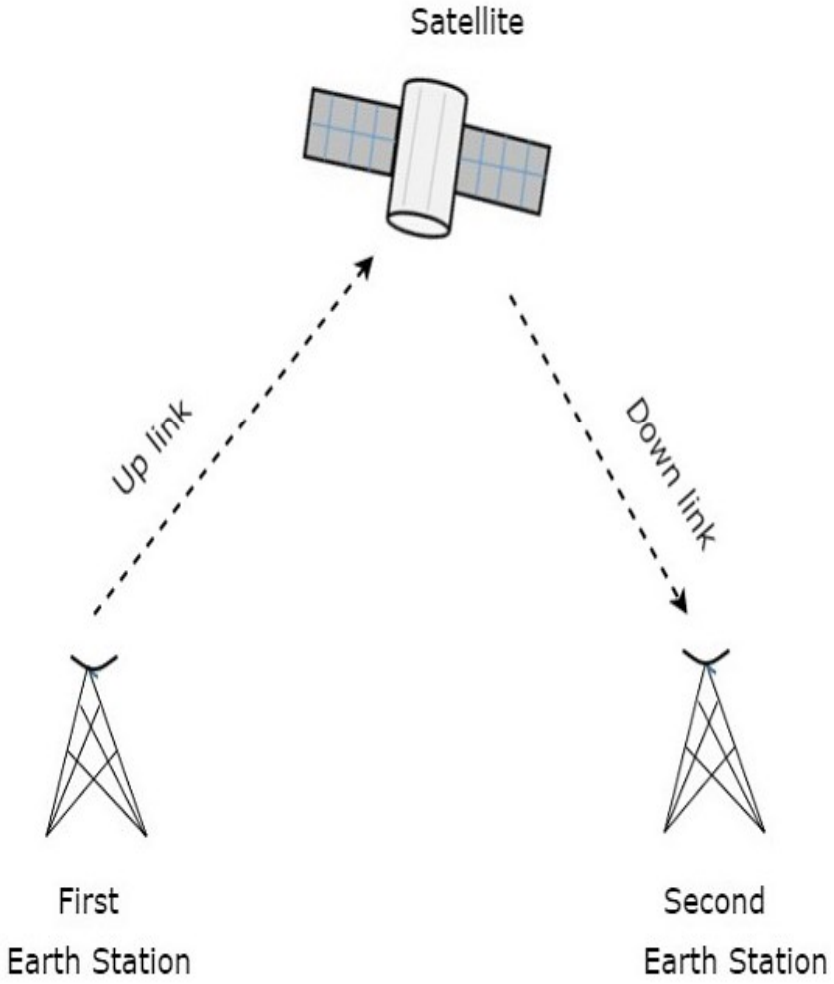
A **satellite** is a body that moves around another body in a particular path. A communication satellite is nothing but a microwave repeater station in space. It is helpful in telecommunications, radio and television along with internet applications.

A **repeater** is a circuit, which increases the strength of the received signal and then transmits it. But this repeater works as a **transponder**. That means, it changes the frequency band of the transmitted signal from the received one.

The frequency with which, the signal is sent into the space is called as **Uplink frequency**. Similarly, the frequency with which, the signal is sent by the transponder is called as **Downlink frequency**. The following figure illustrates this concept clearly.

How satellite works





Satellite services

- **Fixed Service Satellites (FSS)**
  - Example: telephone system, Sat to Cable
- **Broadcast Service Satellites (BSS)**
  - Example: Satellite Television/Radio Also called Direct Broadcast Service (DBS).
  - In Europe called DTH
- **Mobile Service Satellites (MSS)**
  - Include land mobile, maritime mobile, and aeronautical mobile.
- **Navigational satellite services** i.e. GPS
- **Meteorological satellite services** i.e. Weather and rescue service

Satellite frequency bands

Frequency Band Spectrum	Frequency Range (in GHz)	Satellite Service Type	Applications
L-band	1.518-1.675 GHz	MSS (Mobile Satellite Service)	Civilian mobile communication services and global positioning systems (GPS). For instance, Inmarsat use the frequency range to facilitate communication across various mediums such as air, water, and land, as well as for weather radar systems.
S-band	1.97 - 2.69 GHz	MSS (Mobile Satellite Service)	Satellite TV, mobile broadband services, radio broadcasting, and in-flight connectivity For instance, communication between the International Space Station (ISS) and the space shuttle.
C-band	3.4GHz - 7.025 GHz	FSS (Fixed Satellite Service)	Data services, unprocessed satellite feeds, and networks for satellite TV For Example: Telstar satellites use the frequency range for facilitating transportation operations.
X-band	7.25 - 8.44 GHz	FSS (Fixed Satellite Service)	Military operations, pulsed radar systems, synthetic operational and wave radars, weather monitoring, air traffic control, maritime traffic regulation, defense surveillance, and the detection of vehicle speeds.
Ku-band	10.7 - 14.5 GHz	FSS (Fixed Satellite Service), BSS (Broadband Satellite Service)	Fixed satellite television data services.
Ka-band	17.3 - 30 GHz	FSS (Fixed Satellite Service), BSS (Broadband Satellite Service)	Two-way broadband services for both mobile and fixed applications, fixed satellite television services, and the deployment of close-range targeting radars within military systems.
Q/V -band	37.5 - 51.4 GHz	MSS (Mobile Satellite Service), BSS (Broadband Satellite Service)	High-speed broadband services (fixed and mobile) and in-flight connectivity.

Pros and Cons of Satellite Communication

The following are the **advantages** of using satellite communication:

The area of coverage is more than that of terrestrial systems

Each and every corner of the earth can be covered

Transmission cost is independent of coverage area

More bandwidth and broadcasting possibilities

Pros and Cons of Satellite Communication

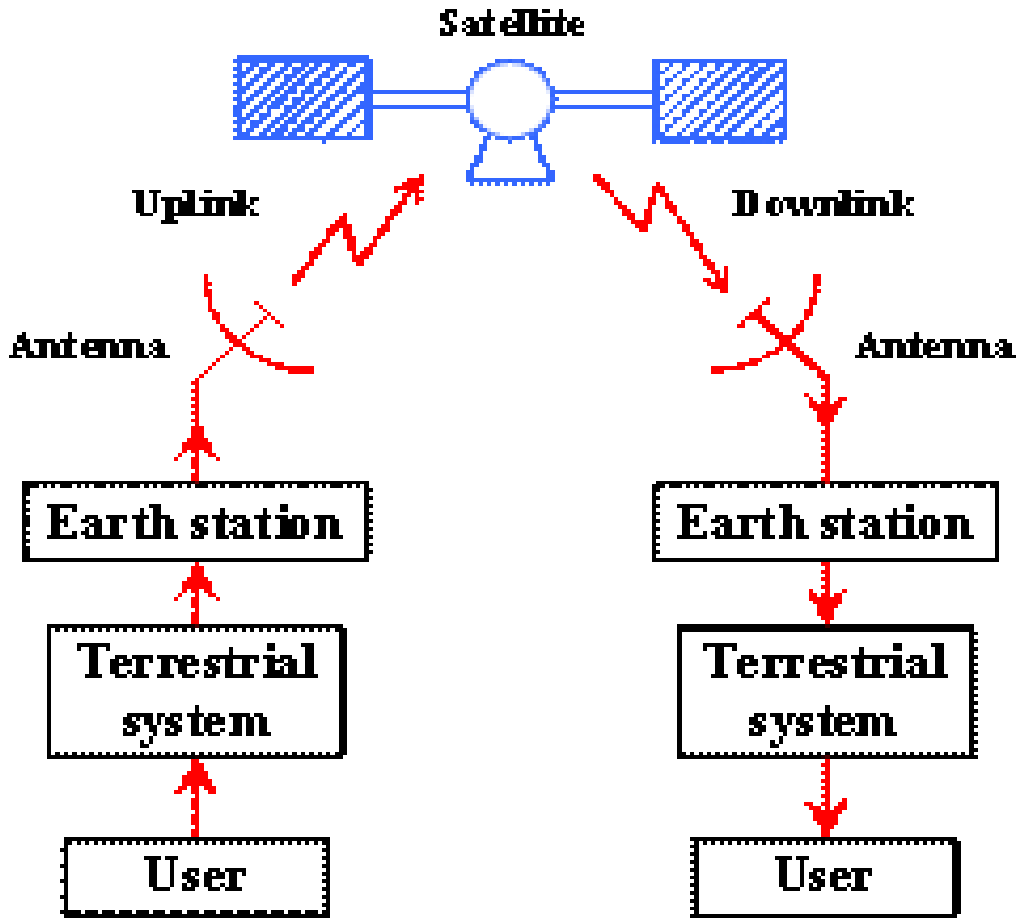
Following are the **disadvantages** of using satellite communication −

- Launching of satellites into orbits is a costly process.
- Propagation delay of satellite systems is more than that of conventional terrestrial systems.
- Difficult to provide repairing activities if any problem occurs in a satellite system.
- Free space loss is more
- There can be congestion of frequencies.

Satellite applications

- Atmosphere and Weather Broadcasting
- Radio and TV broadcasting
- Military satellites
- Satellites for Navigation
- Global telephone backbones
- Global mobile communication
- Connections for remote or developing areas

General structure of satellite communication system



Spacecraft orbits

The path followed by a satellite is referred to as its orbit. An object in orbit is called a satellite.

A satellite can be natural, like the moon or it can be human-made, like the space station.

The moon goes in orbit around Earth.
Satellite orbits are matched to the capability and objective of the sensor(s) they carry.

Orbit selection can vary in terms of altitude,orientation and rotation relative to the Earth.

Orbits

Various orbits are possible depending on the inclination of the orbital plane with the plane containing the earth's equator.

Based on the height parameter the orbits can be classified as

1 HEO

2 MEO

3 LEO

Types of spacecraft orbits

STELLITE ORBIT NAME	ORBIT	SATELLITE ORBIT ALTITUDE (KM ABOVE EARTH'S SURFACE)	APPLICATION
Low Earth Orbit	LEO	200 - 1200	Satellite phones, Navstar or Global Positioning (GPS) system
Medium Earth Orbit	MEO	1200 - 35790	High-speed telephone signals
Geosynchronous Orbit	GSO	35790	Satellite Television
Geostationary Orbit	GEO	35790	Direct broadcast television

Orbits & Satellites

How many geostationary satellites are required to completely cover the entire earth?
Three Geo synchronous satellites
Answer: Three Geo synchronous **satellites are required** to **cover the entire** geographical area that are placed at 120 degree (120*3=360)

How many minimum number of satellites are required for the global communication?

Since four **satellites** must be visible from any point on the planet and the **satellites** are arranged into six orbital planes, the **minimum number of satellites needed** to provide full coverage at any location on Earth is 24.

Earth Orbit Satellites

Following are the three important **types of Earth Orbit satellites** −

- Geosynchronous Earth Orbit Satellites
- Medium Earth Orbit Satellites
- Low Earth Orbit Satellites

Now, let us discuss about each type of earth orbit satellites one by one.

Geosynchronous Earth OrbitSatellites:

A Geo-synchronous Earth Orbit **(GEO) Satellite** is one, which is placed at an altitude of **22,300** miles above the Earth. This orbit is synchronized with a side real day (i.e., 23 hours 56 minutes). This orbit can have inclination and eccentricity.

The same geo-synchronous orbit, if it is circular and in the plane of equator, then it is called as **Geostationary orbit**. These Satellites are placed at 35,900kms (same as Geosynchronous) above the Earth's Equator and they keep on rotating with respect to earth's direction (west to east).

Earth Orbit Satellites

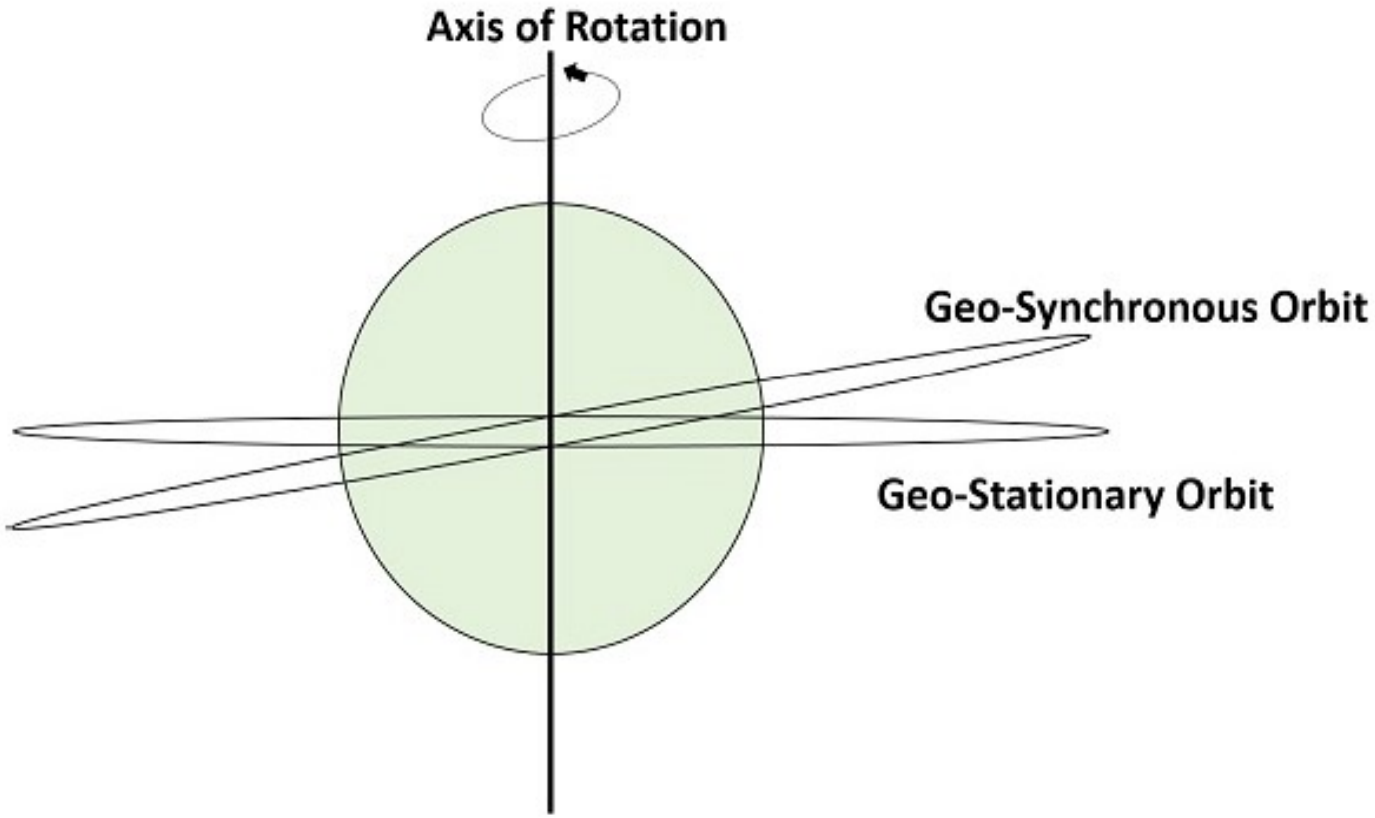
The satellites present in these orbits have the angular velocity same as that of earth. Hence, these satellites are considered as **stationary** with respect to earth since, these are in synchronous with the Earth's rotation.

The **advantage** of Geostationary orbit is that no need to track the antennas in order to find the position of satellites.

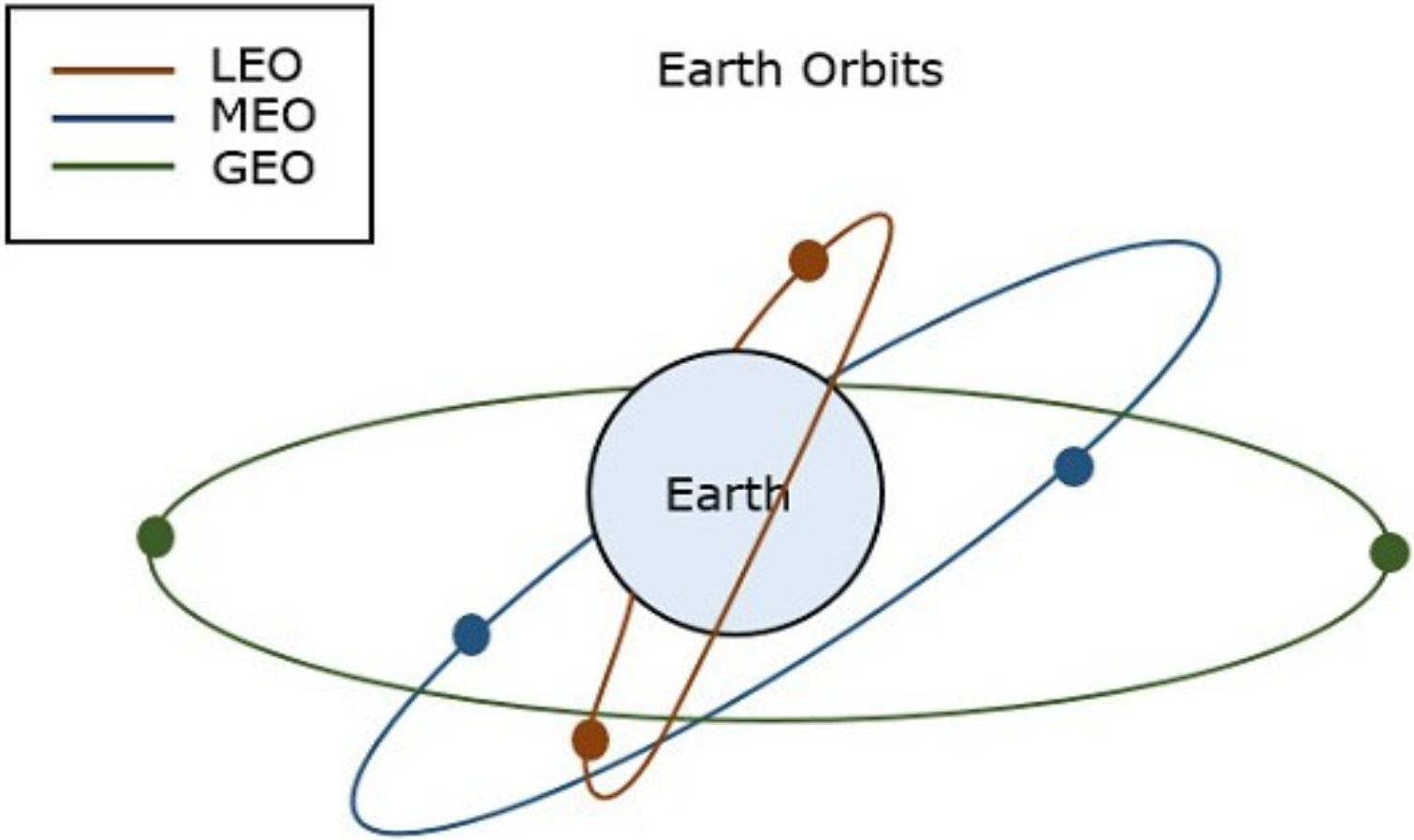
Geostationary Earth Orbit Satellites are used for weather forecasting, satellite TV, satellite radio and other types of global communications.

The following figure shows the difference between Geo-synchronous and Geo-stationary orbits. The axis of rotation indicates the movement of Earth.

Geosynchronous Earth Orbit Satellites



Earth Orbit Satellites



Types of satellite orbits

- The satellite orbits can be classified on the basis of:

1. Orientation of the orbital plane

i. Equatorial orbit

ii. Polar orbit

iii. Prograde orbit

iv. Retrograde orbit

2. Eccentricity

i. Elliptical orbit

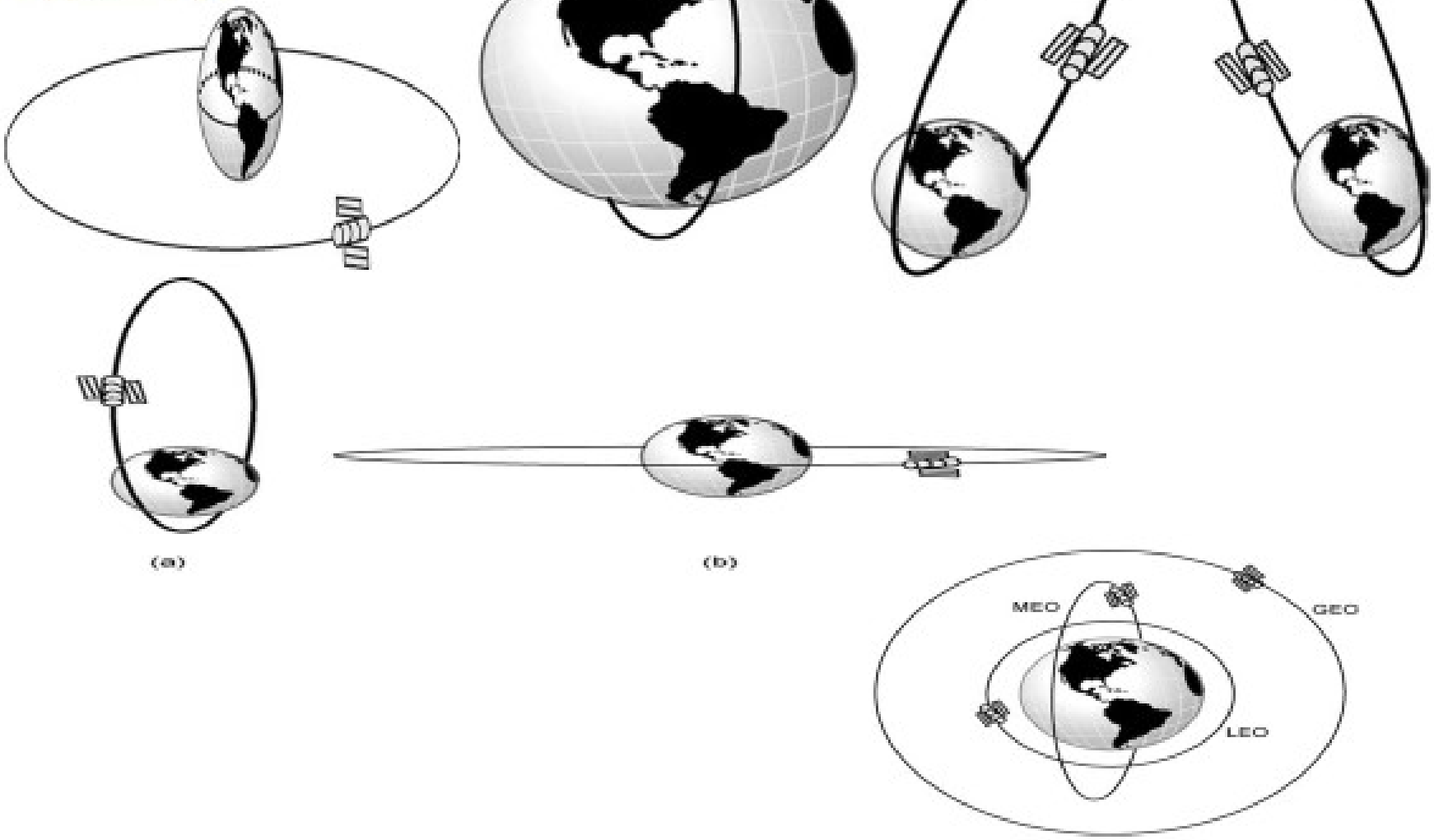
ii. Circular orbit

3. Distance from Earth

i. LEO

ii. MEO

iii. GEO (GSO)


(a)
(b)
MEO
GEO
LEO

Types of orbits-LEO,MEO,GEO

Orbit Type	*Mission*	*Altitude*	*Period*	*Tilt*[a]	*Shape*
LEO					
• Polar sun-synchronous	Remote sensing/ weather	~150–900 km	~98–104 min	~98°	circular
• Inclined nonpolar	International Space Station	~340 km	~91 min	~51.6°	circular
• Polar non–sun-synchronous	Earth observing, scientific	~450–600 km	~90–101 min	~80–94°	circular
MEO					
• Semisynchronous	Navigation, communications, space environment	~20,100 km	~12 hours	~55°	circular
GEO					
• Geosynchronous • Geostationary	Communication, early warning, nuclear detection, weather	~35,786 km	~24 hours (23h 56m 04s)	~0°	circular
HEO					
• Molniya	Communications	Varies from ~495 km to ~39,587 km	~12 hours (11h 58m)	63.4°	long ellipse

Satellite launching process

The process of placing the satellite in a proper orbit is known as the **launching process**. During this process, from the earth stations, we can control the operation of satellites. Mainly, there are four stages in launching a satellite.

- **First Stage** − The first stage of launch vehicle contains rockets and fuel for lifting the satellite along with launch vehicle from ground.
- **Second Stage** − The second stage of launch vehicle contains smaller rockets. These are ignited after completion of first stage. They have their own fuel tanks in order to send the satellite into space.

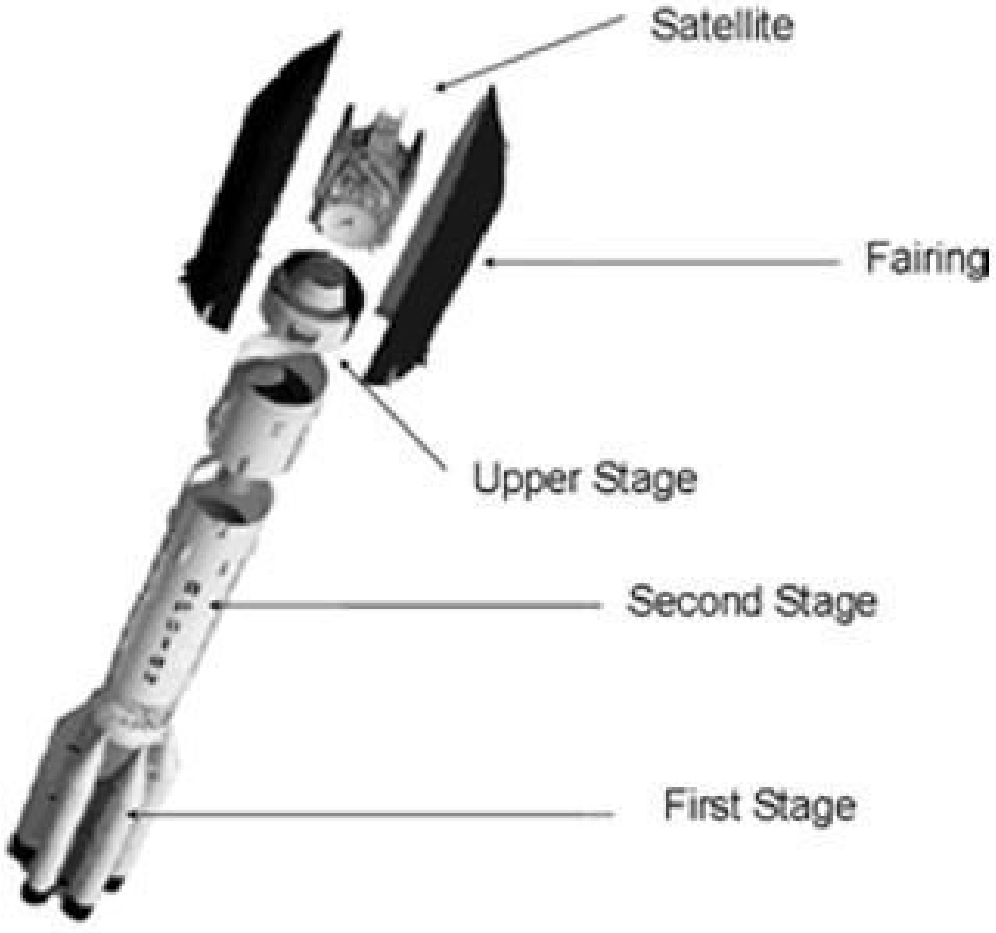
Satellite launching process

- **Third Stage** − The third (upper) stage of the launch vehicle is connected to the satellite fairing. This fairing is a metal shield, which contains the satellite and it protects the satellite.

- **Fourth Stage** − The satellite gets separated from the upper stage of the launch vehicle, when it has been reached to out of Earth's atmosphere. Then, the satellite will go to a “transfer orbit”. This orbit sends the satellite higher into space. When the satellite reached the desired height of the orbit, its subsystems like solar panels and communication antennas get unfurled. Then the satellite takes its position in orbit with other satellites.

- Now, the satellite is ready to provide services.

Satellite launching process




ISRO
INDIA
SDSC SHAR

Types of launch vehicles

Types of satellite launch vehicles

- Expendable Launch Vehicles (ELV)- get destroyed after leaving the satellites in space.
- Reusable Launch Vehicles (RLV)- will return back to earth after leaving the satellite in space.
- India has two operational launchers: Polar Satellite Launch Vehicle (PSLV) and Geosynchronous Satellite Launch Vehicle (GSLV)

Satellite Launch vehicles

- A satellite is sent into space on top of a rocket. When a satellite is put into space, we say that it is "launched."
- The rocket that is used to launch a satellite is called a "**launch vehicle**."
- This satellite launching needs the earth stations in order to operate the satellite operation.
- A **launch vehicle** or **carrier rocket** is a rocket-propelled vehicle used to carry a payload from Earth's surface to space, usually to Earth orbit or beyond.

Types of launch vehicles

SLV-3

Height : 22.7m
Lift-off weight : 17 t
Propulsion : All Solid
Payload mass : 40 kg
Orbit : Low Earth Orbit

ASLV

Height : 23.5m
Lift-off weight : 39 t
Propulsion : All Solid
Payload mass : 150 kg
Orbit : Low Earth Orbit

PSLV-XL

Height : 44m
Lift-off weight : 320 t
Propulsion : Solid & Liquid
Payload mass : 1860 kg
Orbit : 475 km Sun Synchronous Polar Orbit (1300 kg in Geosynchronous Transfer Orbit)

GSLV Mk II

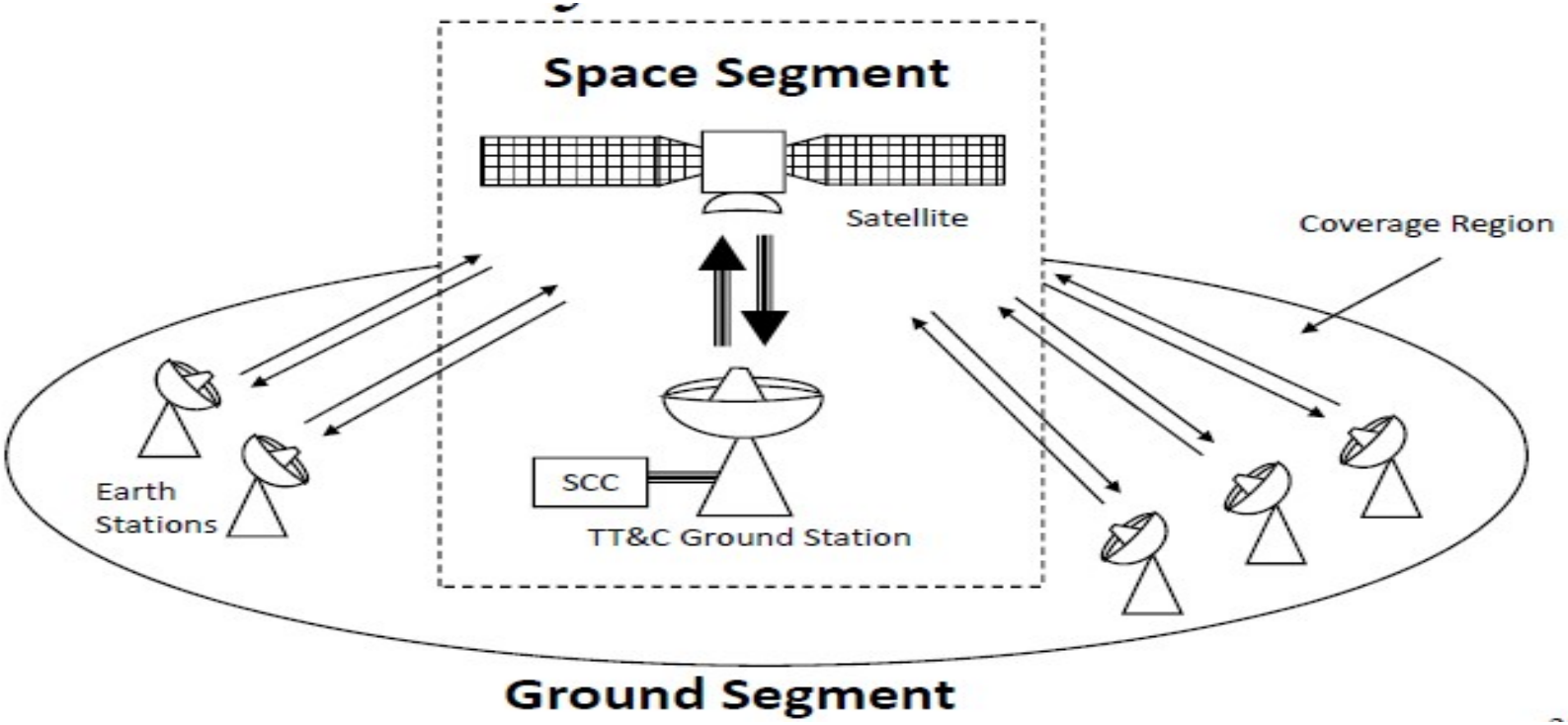
Height : 49m
Lift-off weight : 414 t
Propulsion : Solid, Liquid & Cryogenic
Payload mass : 2200 kg
Orbit : Geosynchronous Transfer Orbit

GSLV Mk III

Height : 43.43 m
Lift-off weight : 640 t
Propulsion : Solid, Liquid & Cryogenic
Payload mass : 4000 kg
Orbit : Geosynchronous Transfer Orbit

Satellite Communications system

Satellite Communications system are categorized into space segment and ground



Satellite sub systems

Space Segment Subsystems

The subsystems present in space segment are called as space segment subsystems. Following are the **space segment subsystems**.

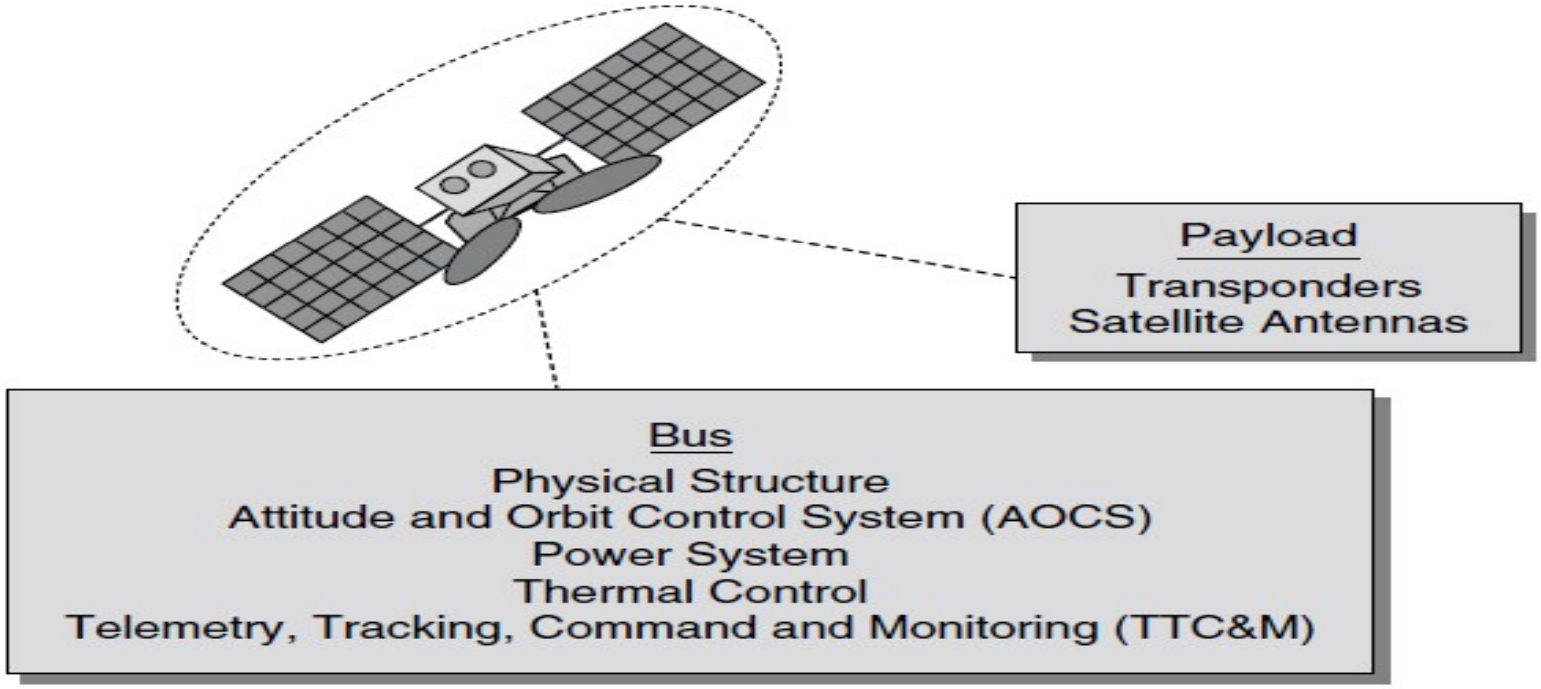
- AOC Subsystem
- TTCM Subsystem
- Power and Antenna Subsystems
- Transponders

Earth Segment Subsystems

The subsystems present in the ground segment have the ability to access the satellite repeater in order to provide the communication between the users. **Earth segment** is also called as ground segment.

Earth segment performs mainly two functions. Those are transmission of a signal to the satellite and reception of signal from the satellite. **Earth stations** are the major subsystems that are present in earth segment.

Space segment



Elements of Satellite Communications Systems

Two major elements of Satellite Communications Systems are

- Space Segment
- Ground Segment

The Space Segment includes

- Satellite
- Means for launching satellite
- Satellite control centre for station keeping of the satellite

The functions of the ground segment are to transmit the signal to the satellite and receive the signal from the satellite. The ground segment consists of

- Earth Stations
- Rear Ward Communication links
- User terminals and interfaces
- Network control centre

Subsystems of a satellite

Major subsystems of a satellite are:

- Satellite Bus Subsystems & Satellite Payloads

Satellite Bus subsystems:

- Mechanical structure
- Attitude and orbit control system
- Propulsion System
- Electrical Power System
- Tracking Telemetry and Command System
- Thermal Control System

Satellite Bus subsystems

- Since the communications capacity earns revenue, the satellite must carry as many communications channels as possible. However, the large communications channel capacity requires large electrical power from large solar arrays and battery, resulting in large mass and volume. Putting a heavy satellite in geosynchronous orbit being very expensive, it is logical to keep the size and mass of the satellite small. Lightweight material optimally designed to carry the load and withstand vibration & large temperature cycles are selected for the structure of the satellite.
- Attitude and orbit control system maintains the orbital location of the satellite and controls the attitude of the satellite by using different sensors and firing small thrusters located in different sides of the satellite.
- Liquid fuel and oxidizer are carried in the satellite as part of the propulsion system for firing the thrusters in order to maintain the satellite attitude and orbit. The amount of fuel and oxidizer carried by the satellite also determines the effective life of the satellite.

Satellite Bus subsystems

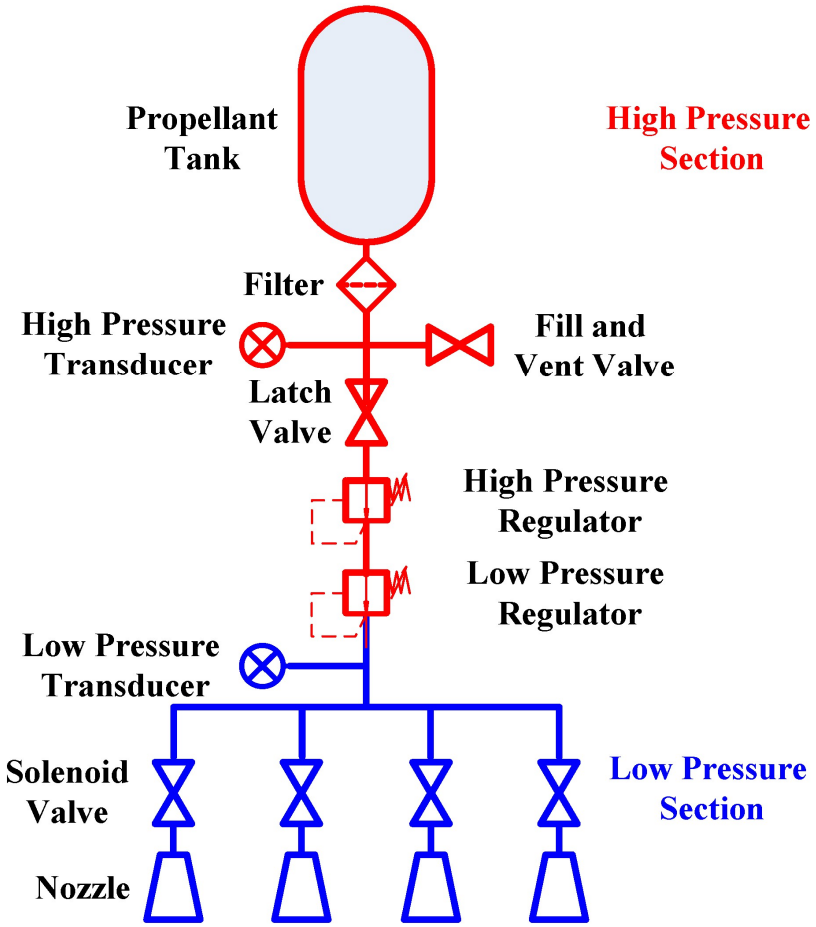
- The electrical power in the satellite is derived mainly from the solar cells. The power is used by the communications payloads and also by all other electrical subsystems in the satellite for house keeping. Rechargeable battery is used for supplying electrical power during ellipse of the satellite.
- Telemetry, Tracking and Command system of the satellite works along with its counterparts located in the satellite control earth station. The telemetry system collects data from sensors on board the satellite and sends these data via telemetry link to the satellite control centre which monitors the health of the satellite. Tracking and ranging system located in the earth station provides the information related to the range and location of the satellite in its orbit. The command system is used for switching on/off of different subsystems in the satellite based on the telemetry and tracking data.
- The thermal control system maintains the temperature of different parts of the satellite within the operating temperature limits and thus protects the satellite subsystems from the extreme temperature conditions of the outer space.

Satellite Payloads

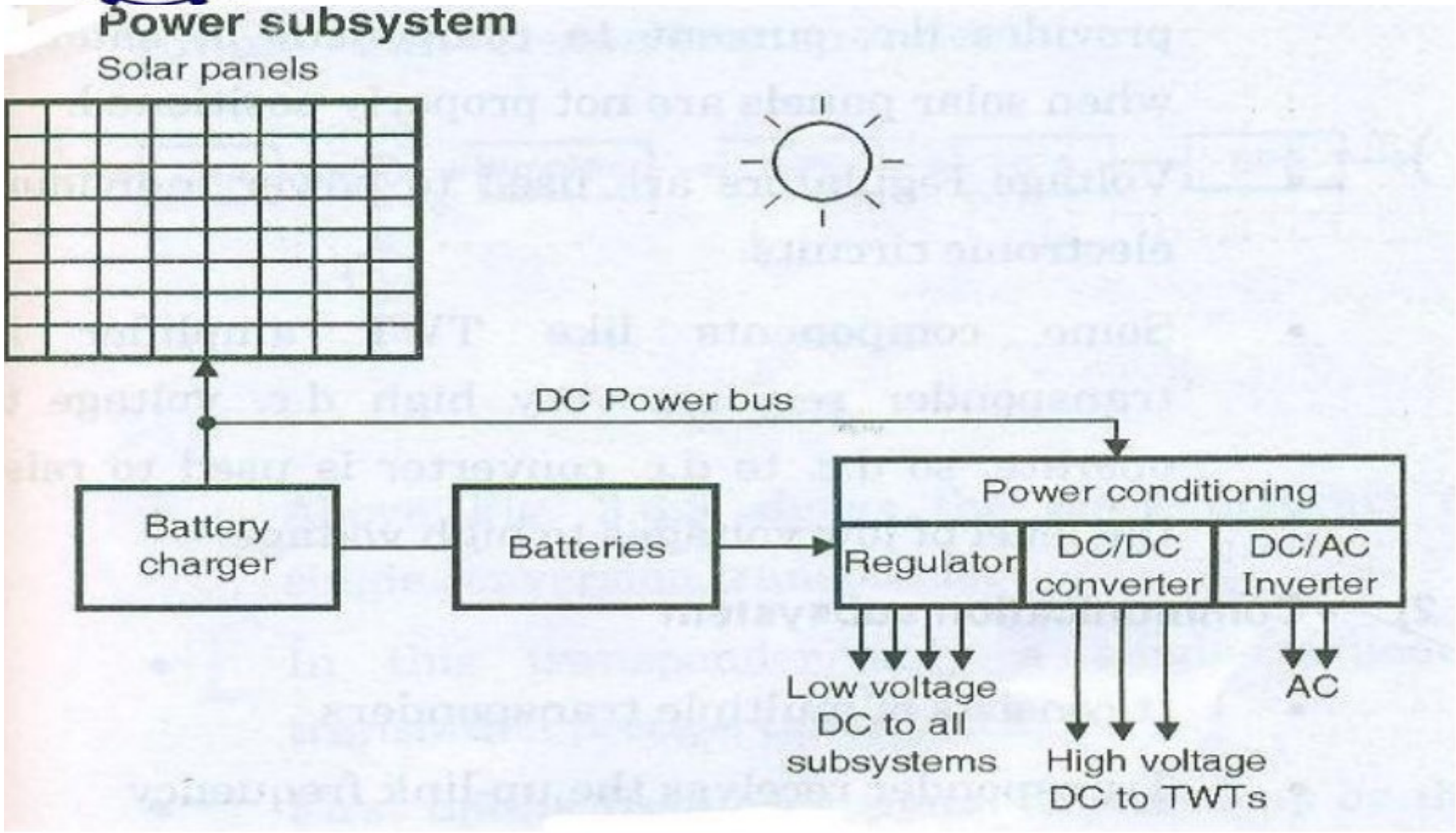
Satellite Payloads

- Communication transponders
- Communication Antennas
- The communications subsystems are the major elements of a communication satellite and the rest of the space craft is there solely to support it. Quite often it is only a small part of the mass and volume of the satellite. The communications subsystem consists of one or more antennas and communications receiver - transmitter units known as transponders.
- The actual reception and retransmission of the signals are however, accomplished by the antennas on board the satellite. The communications antennas on board the satellite maintain the link with the ground segment and the communications transponder. The size and shape of the communications antenna depend on the coverage requirements and the antenna system can be tailor made to meet the specific coverage requirements of the system

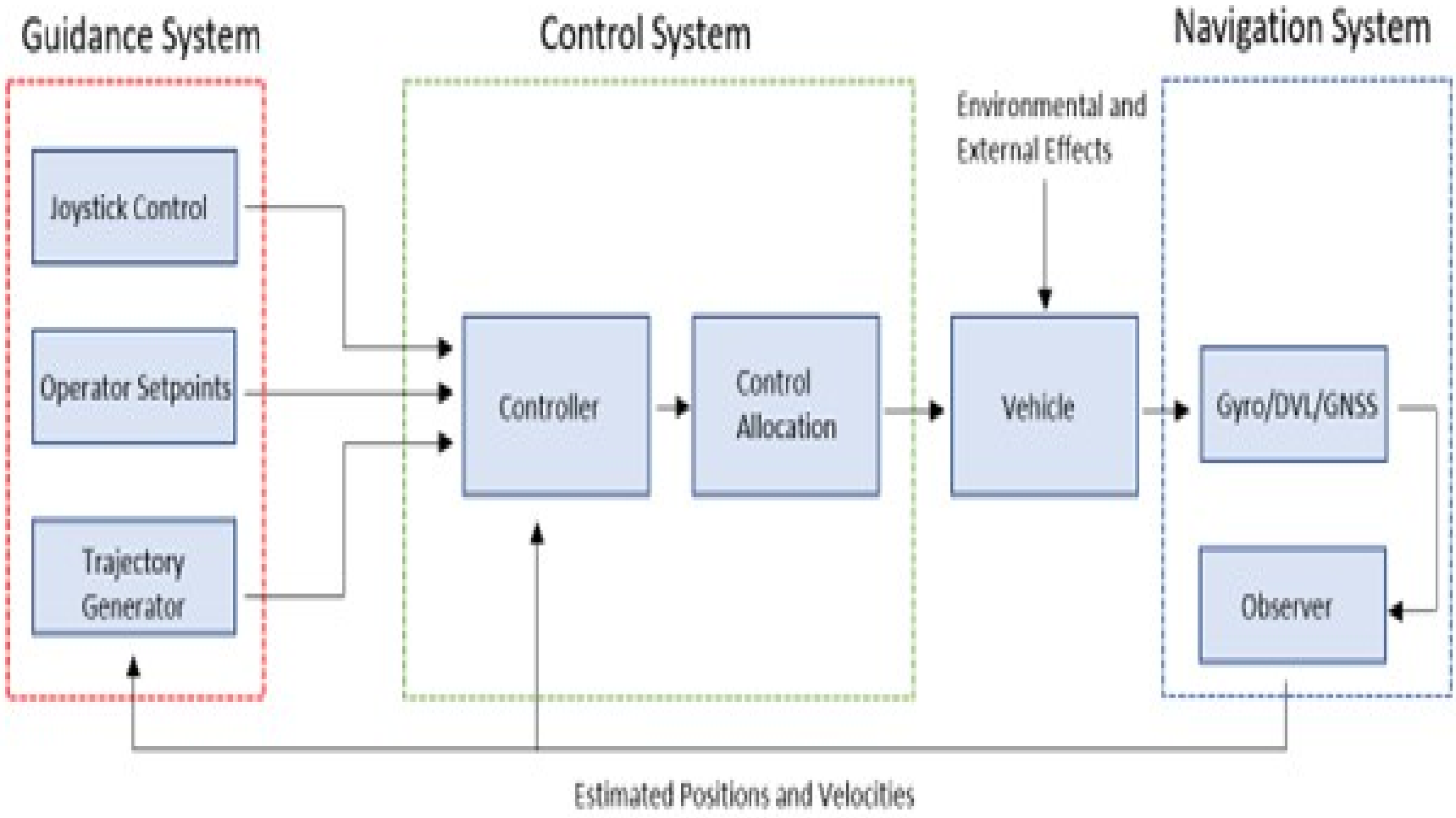
Satellite Propulsion system



Power Subsystem



Guidance Control subsystem




LAKIREDDY BALIREDDY COLLEGE OF ENGINEERING
MYLAVARAM
TRUTH ALWAYS TRIUMPHS
HARD WORK PAYS

Thank You