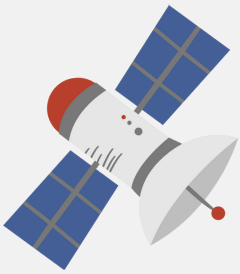
FUNDAMENTALS OF SATELLITE COMMUNICATION SYSTEMS

VOLUME 1

NOR ASILAH BINTI SURIP
TS SYAMSUL BAHRI BIN MOHAMAD



FUNDAMENTALS OF SATELLITE COMMUNICATION SYSTEMS

Volume #1

EDITORIAL BOARD

First Edition
First Print 2023

Nor Asilah Binti Surip
Ts Syamsul Bahri Bin Mohamad

Published by:
Politeknik Merlimau,
Kementerian Pendidikan Tinggi,
77300 Merlimau, Melaka
Tel: 06-263 6687
Fax: 06-2636678
https://pmm.mypolycc.edu.my/

Cataloguing-in-Publication Data

Perpustakaan Negara Malaysia

A catalogue record for this book is available from the National Library of Malaysia

eISBN 978-967-2762-79-9

PREFACE

In the name of Allah, and with His grace and blessings, this book was successfully published with His permission. This book is written to accompany a reference book for students taking the course of Satellite Communication Systems, particularly Polytechnic students and others interested in Satellite Systems.

Thousands of satellites have been launched into Earth's orbit since the first man-made satellite was launched in 1957. Depending on the needs of a country, the satellite sent has a specific purpose and function. This book is intended to assist readers in better understanding satellite systems, particularly communication satellite systems.

Finally, many thanks to everyone who contributed significantly, provided ideas, and encouraged the publication of this book.

Thank You
Nor Asilah Surip
2023

Acknowledgments

I would like to thank everyone who supported me with the Fundamentals of Satellite Communication Systems book. Throughout the project, I am grateful for their encouragement, guidance, invaluable constructive criticism, and friendly advice. I am grateful to them for sharing their honest and illuminating perspectives on a variety of issues related to this work. Thank you for supporting me in all of my endeavors and inspiring me to finish this book.

Nor Asilah

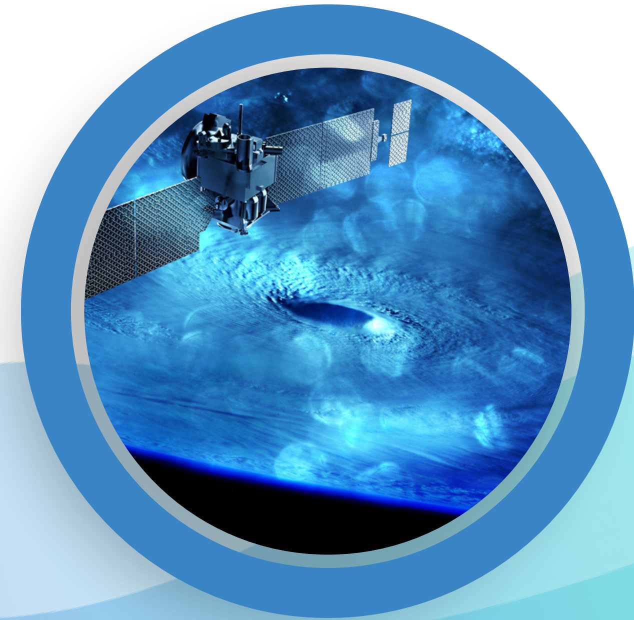
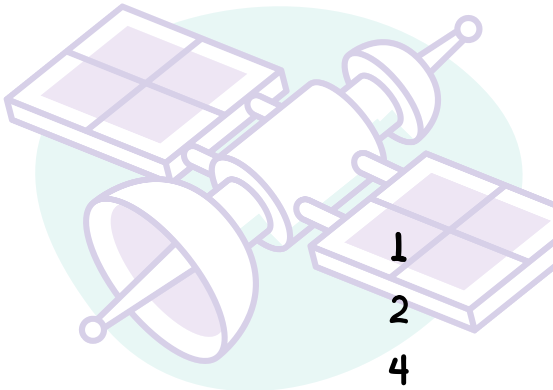


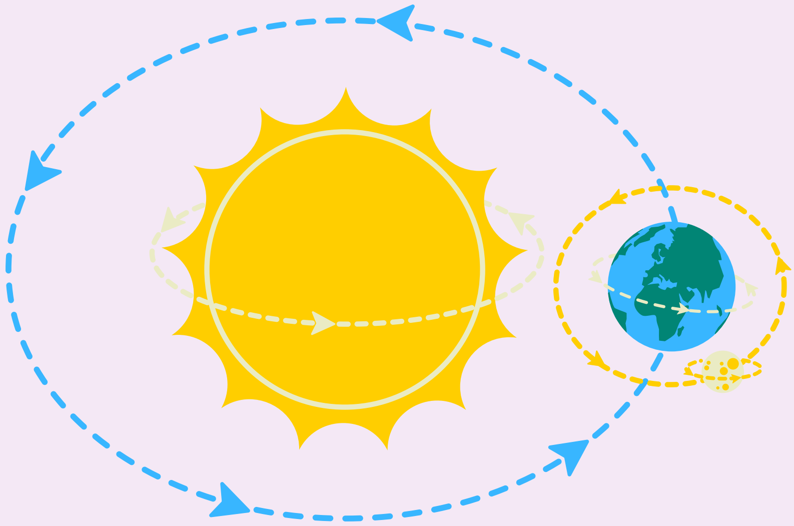
TABLE OF CONTENT



TOPIC 1

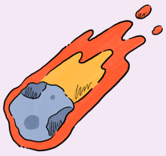
INTRODUCTION TO SATELLITE SYSTEMS

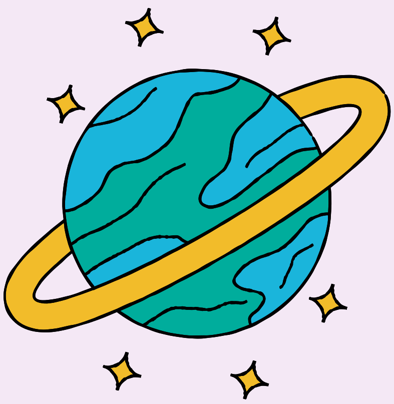
1.1 What Is a Satellite?



A moon, planet, or device circling a star or planet is called a satellite. The largest and oldest satellite of Earth is the moon. It controls the tides and gives the earth reflecting light, among other things.

Two examples of natural satellites are the moon and Earth. The moon orbits the Earth, whereas the Earth orbits the sun, which reveals the reason. Thus, a satellite is a metaphor for all the celestial bodies that envelop Earth, including the moon and meteorites.

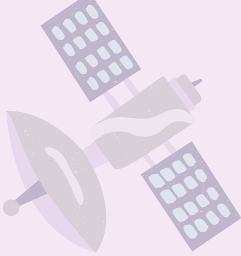




Satellites act as a camera because some of them take pictures of the planet. It will help meteorologists predict weather and track hurricanes.

Some satellites take pictures of other planets, the sun, black holes, dark matter, or faraway galaxies. The pictures will help scientists to understand the solar system.

A satellite is a machine that is sent into space and orbits Earth or another planet in space.

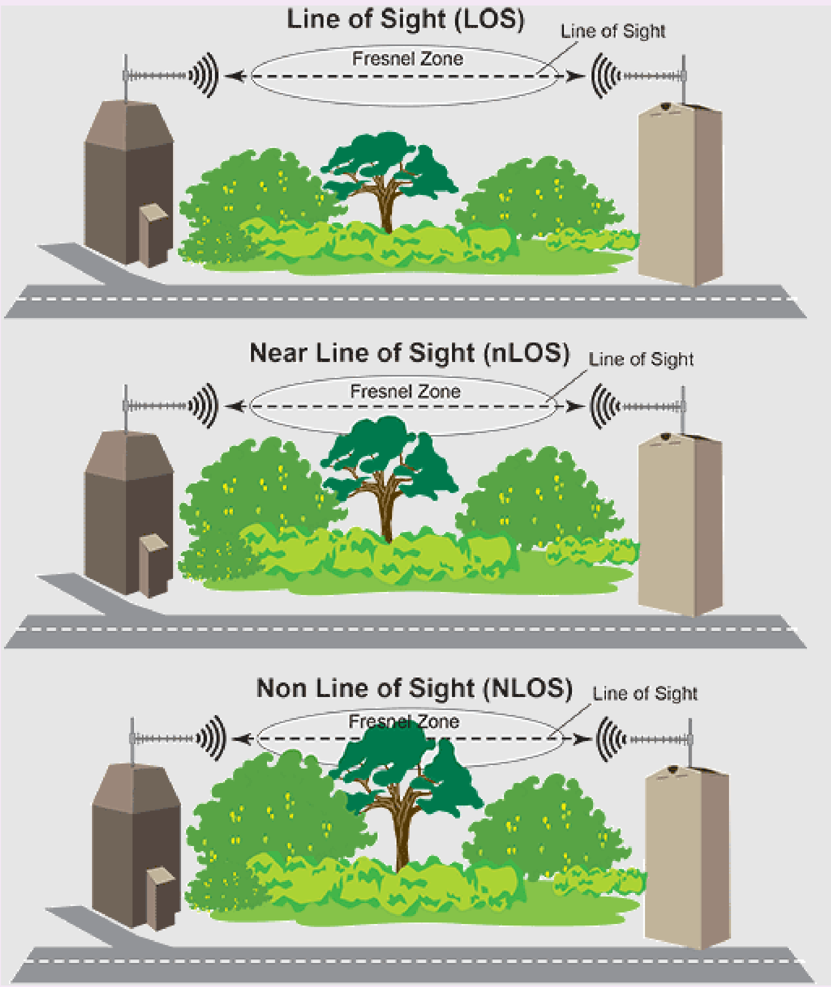


1.2 Why Are Satellites Important?

Satellites can collect more data quickly, than instruments on the ground because they have the ability to see large areas of Earth .

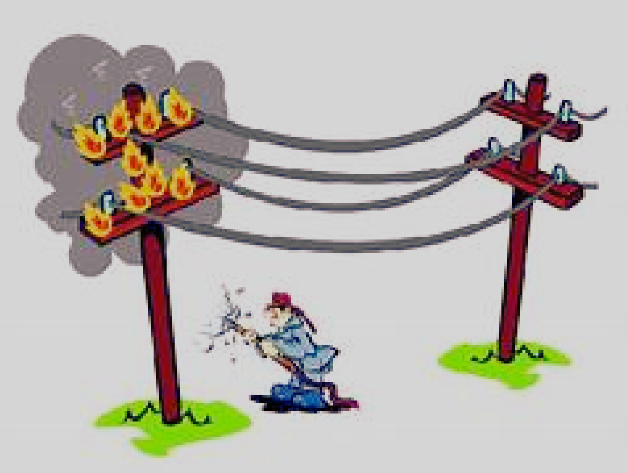
Satellites can also look deeper into space than terrestrial observatories. This is due to the fact that satellites fly over clouds, dust, and molecules in the atmosphere, which can obscure views from the ground.

TV signals weren't transmitted very far before satellites. Broadcasting transmissions can only travel in straight lines. As a result, instead of following Earth's curve, they would promptly disappear into space.



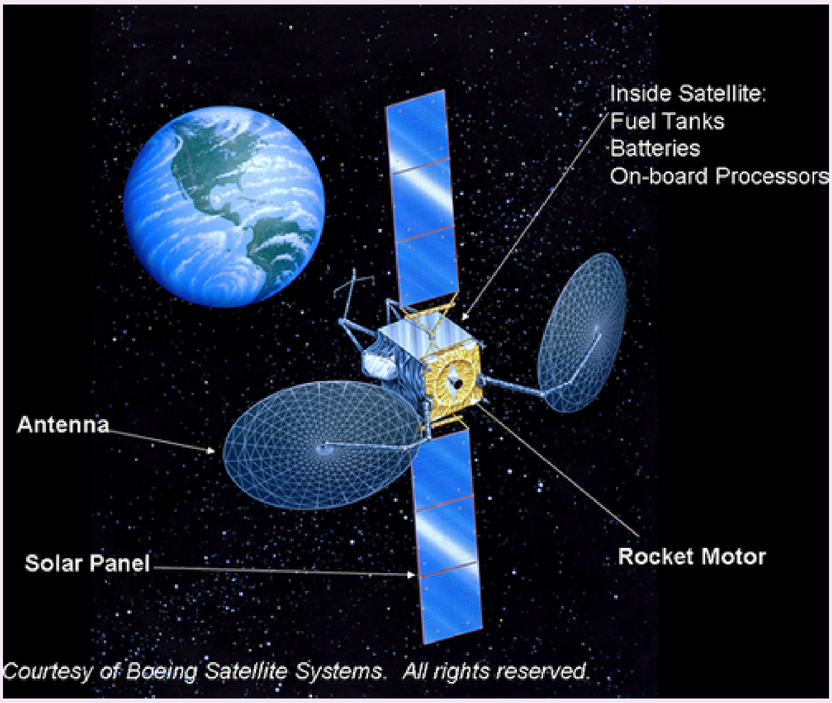
Obstacles such as mountains, trees or towering buildings can cause the signals to be blocked.

Communication calls to faraway places were also problematic. The installation of telephone wires over long distances or underwater is challenging and expensive to do.



Using satellites, TV signals, and phone calls are sent upward to a satellite. A satellite can then send them back down to various locations on Earth almost instantly.

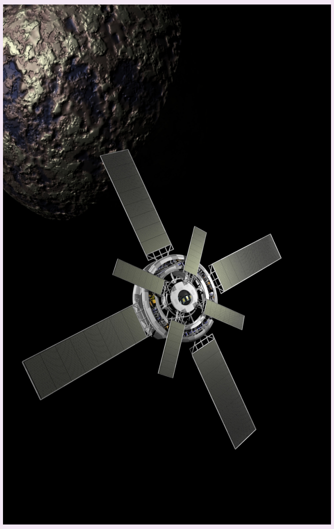
1.3 What Are the Parts of a Satellite?

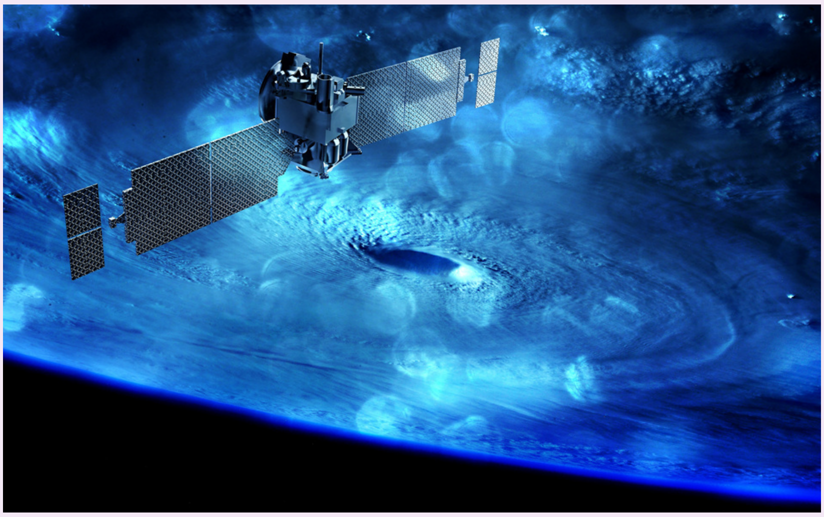


Satellites come in a variety of forms and sizes. Most, however, include at least two components: an antenna and a power source.

The antenna transmits and receives data, typically to and from Earth. A solar panel or a battery can be used as the power source. Solar panels generate electricity by converting sunlight.

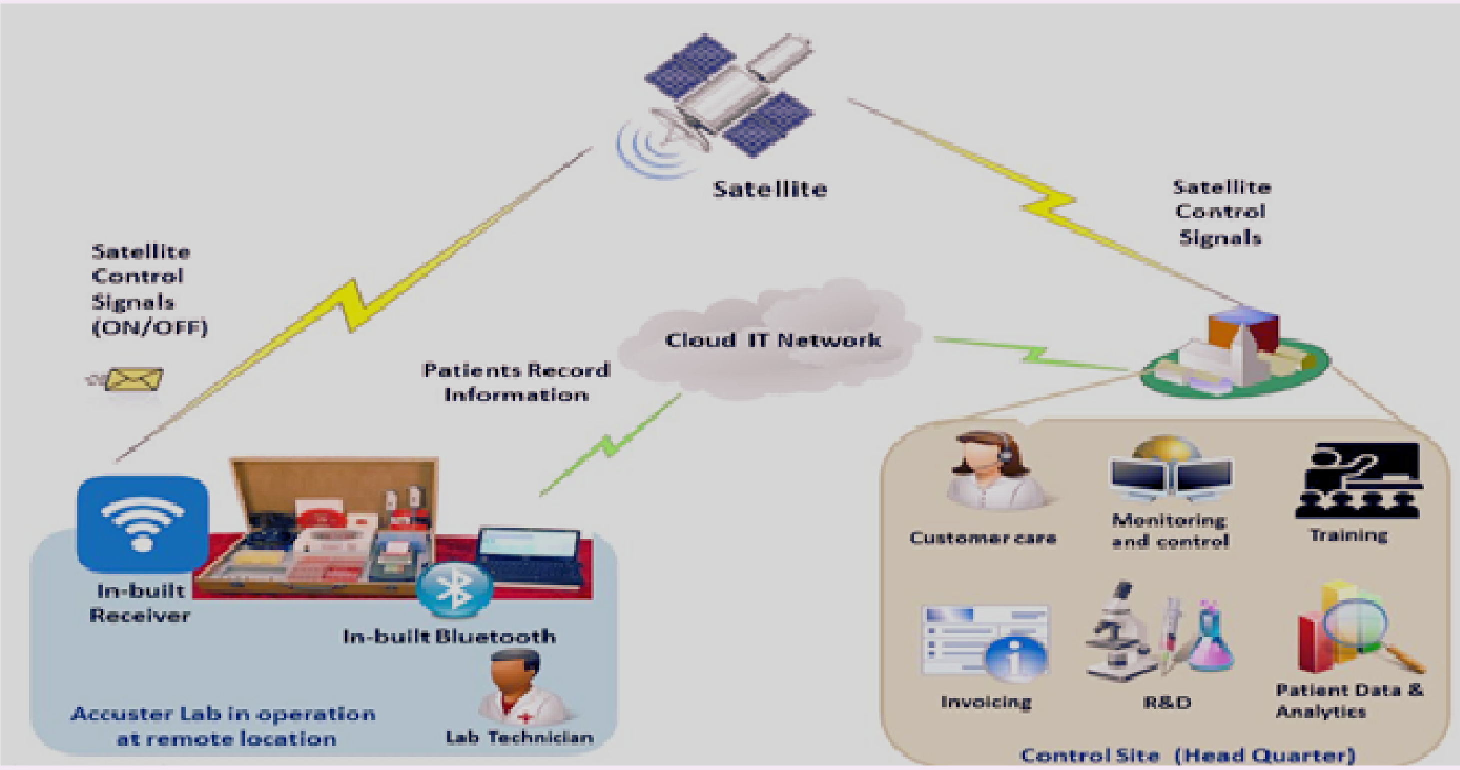
Many satellites are equipped with cameras and scientific equipment. These devices sometimes point toward Earth to gather information regarding its land, air, and ocean. At times, they turn toward space to gather information from the solar system and universe.





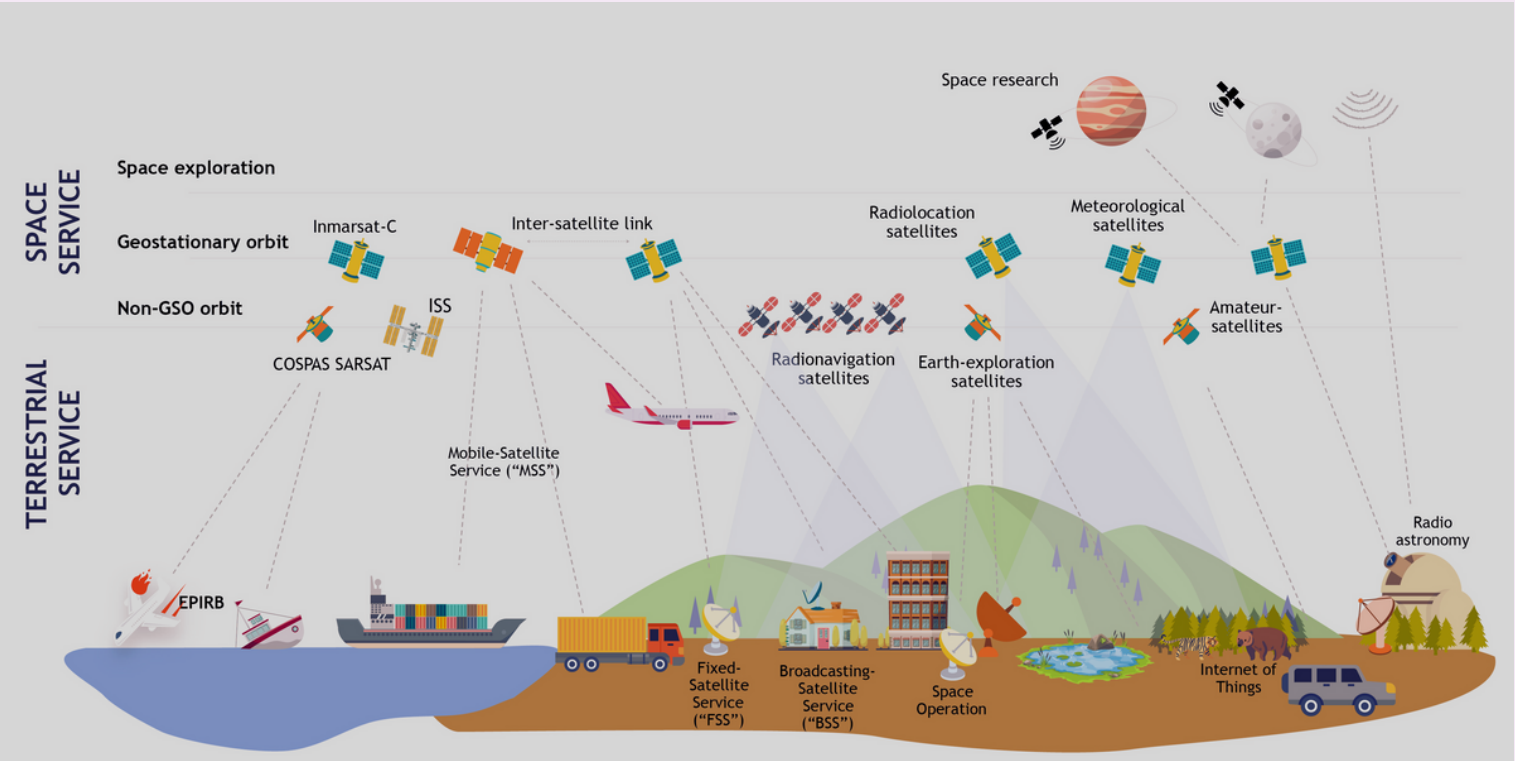
1.4 Why Satellites Don't Crash Onto Each Other?

International organizations control and track satellites in space. Collisions are uncommon since satellites are launched into orbits designed to prevent colliding with other spacecraft. However, orbits may change over time. And as more satellites are deployed into orbit, the probability of a crash increases.



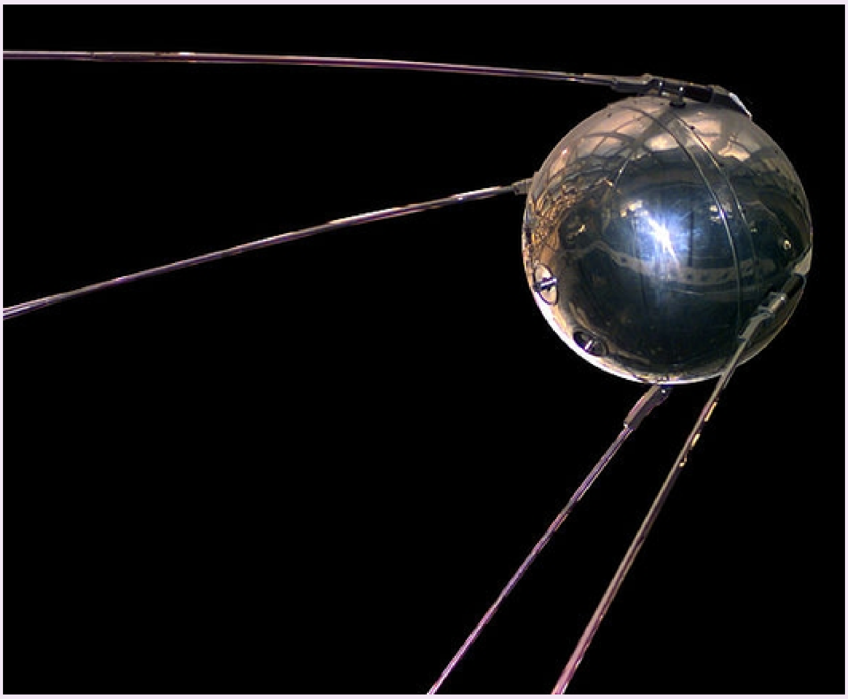
1.5 What Are the Applications of Satellites?

There are numerous uses for satellites, such as satellite TV, satellite radio, satellite phones, live satellite mapping, tracking, navigation, satellite weather, and satellite images, and many more.



1.6 What Was the First Satellite in Space?

The Soviet Union was the first to launch a satellite into space. The satellite was launched in 1957 and was called Sputnik 1.

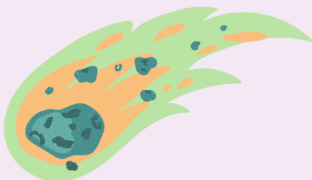


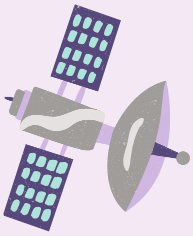
The satellite Sputnik 1

CHAPTER SUMMARY

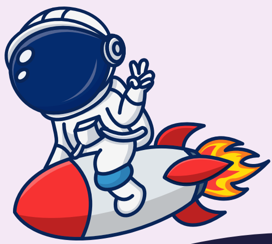
Satellites have allowed us to see large areas of Earth at one time. This ability means satellites can collect more data, more quickly, than instruments on the ground.

A satellite is an expression that represents all the objects that surround the Earth. Among these objects are the moon, meteors and other celestial bodies.





Satellites come in a variety of forms and sizes. Most, however, include at least two components: an antenna and a power source.



There are numerous uses for satellites, such as satellite TV, satellite radio, satellite phones, live satellite mapping, tracking, navigation, satellite weather, and satellite images, and many more

Satellites in space are controlled and kept track by international organizations.

Simple Exercises

1. What Is a Satellite?

2. What are satellites used for?

3. What Is an Orbit?

4. What is a space station?

5. What is a communication satellite?

Answer

1

Anything that orbits a planet or star is called a satellite.

2

The main roles of satellites are for communication, navigation and observation

3

An object in space, either a star, planet, moon, asteroid, or spacecraft, follows a curved route around another object as a consequence of gravity. This is referred to as an orbit.

4

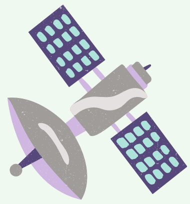
A space station is a spacecraft that supports a human crew in orbit for an extended period

5

Satellites are used to receive, amplify and retransmit data to earth stations

TOPIC 2

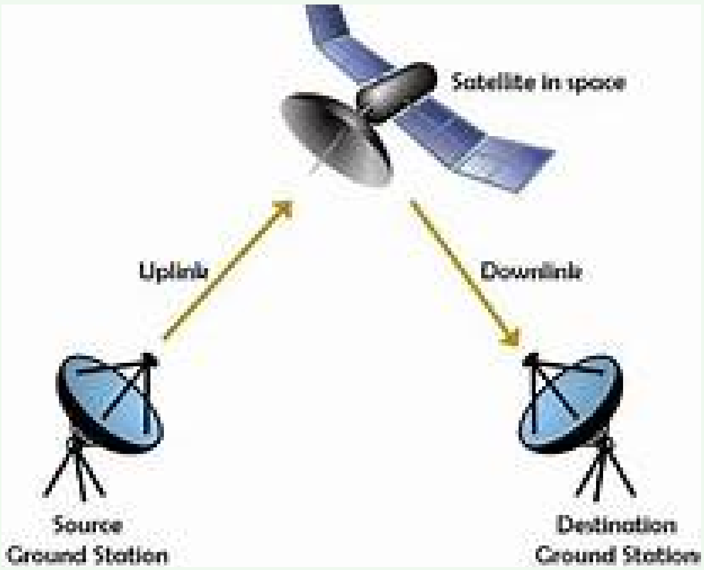
SATELLITE COMMUNICATION SYSTEM

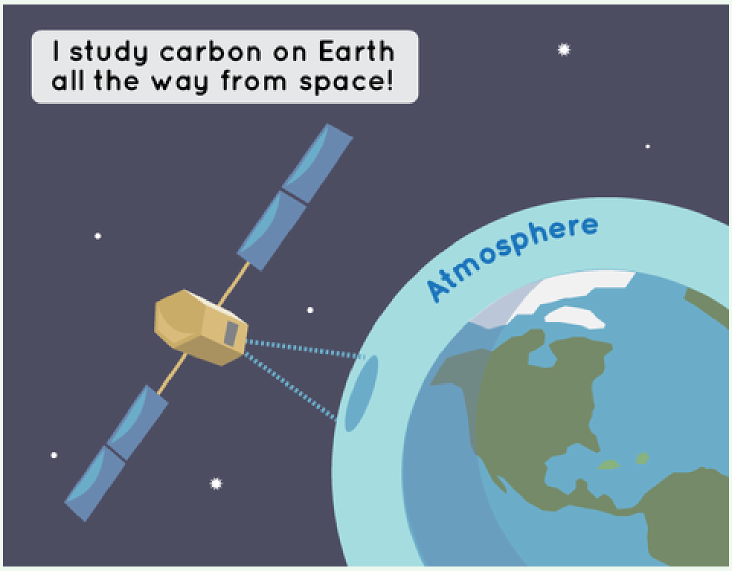


2.1 Communication Satellite

A communications satellite is an artificial satellite that relays and amplifies radio telecommunication signals via a transponder.

It creates a communication channel between a source transmitter and a receiver at different locations on Earth.

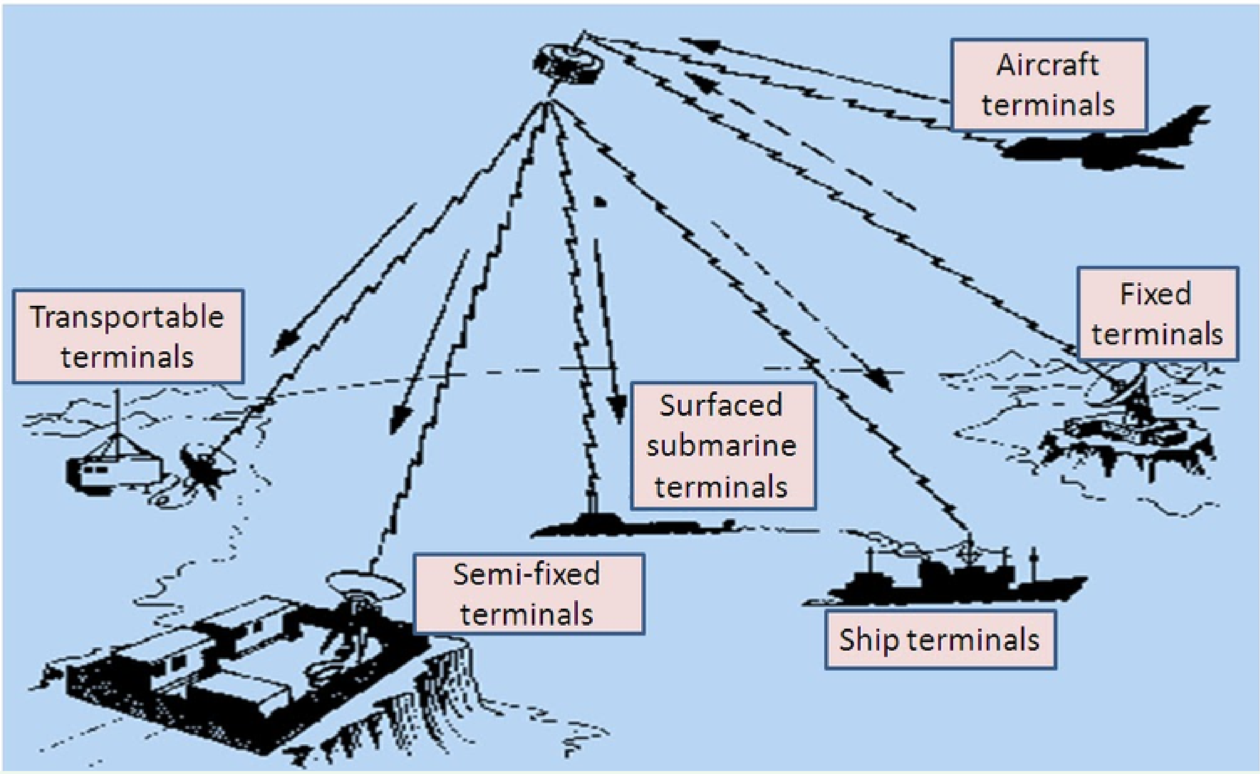




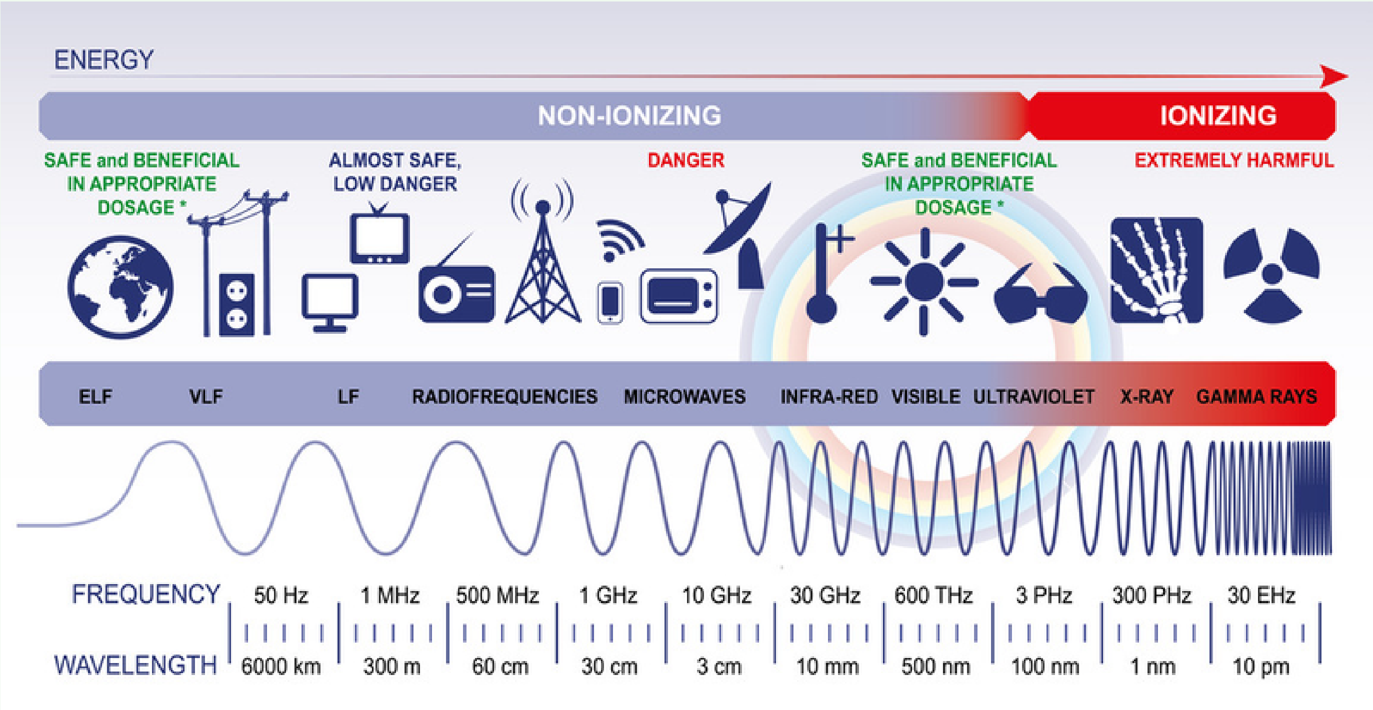
Three types of communication services that satellites provide are telecommunications, broadcasting, and data communications.

Communications satellites are used for television, telephone, radio, internet, and military applications.

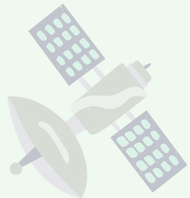
Satellite communications system



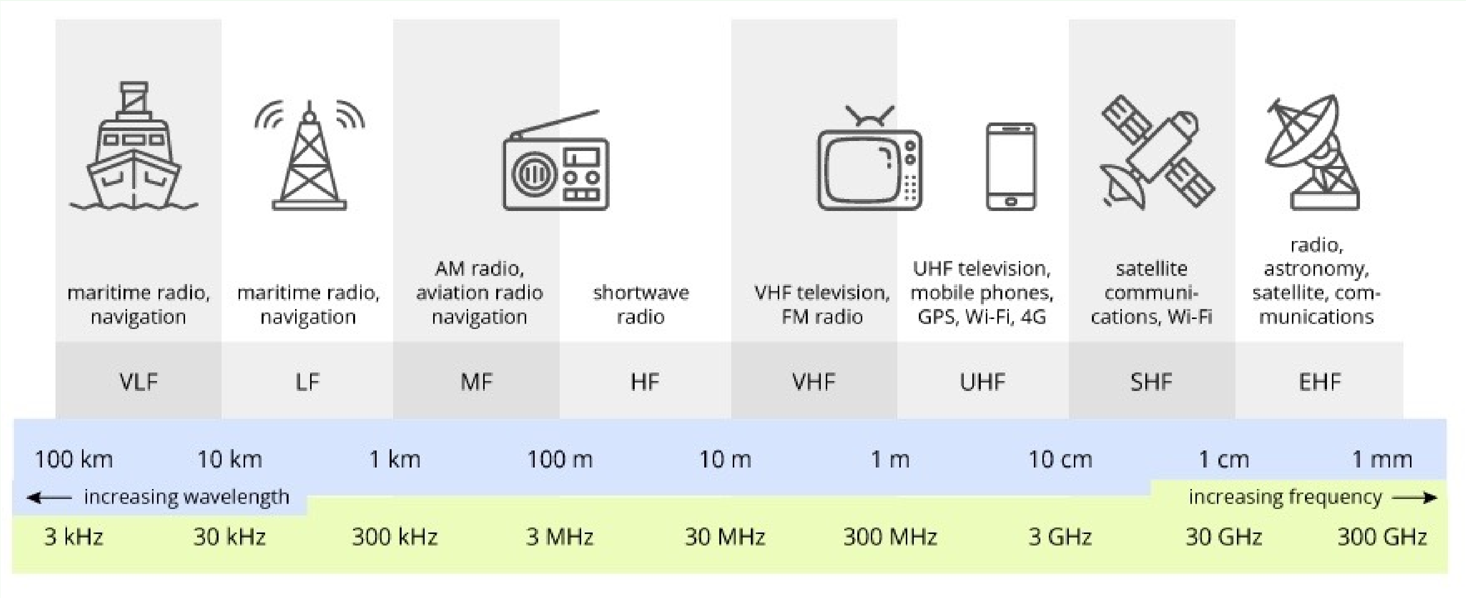
2.2 Satellite Frequency Allocation



- International Telecommunication Union (ITU) coordinates the distribution of satellite frequencies and the utilization of band spectrum.
- By sharing or reusing frequencies, satellite operators can boost capacity without really expanding the bandwidth of their spectrum.
- Satellite communication systems use frequencies that exist in the electromagnetic spectrum to provide data (uplink) to the satellite in orbit. Data is transmitted downlink from the satellite to the ground station.



In addition to telephone service, metrological services, mapping, astronomy, and weather forecasting all make use of satellite communication systems. Satellite communication uses certain ranges of frequencies from the electromagnetic spectrum.

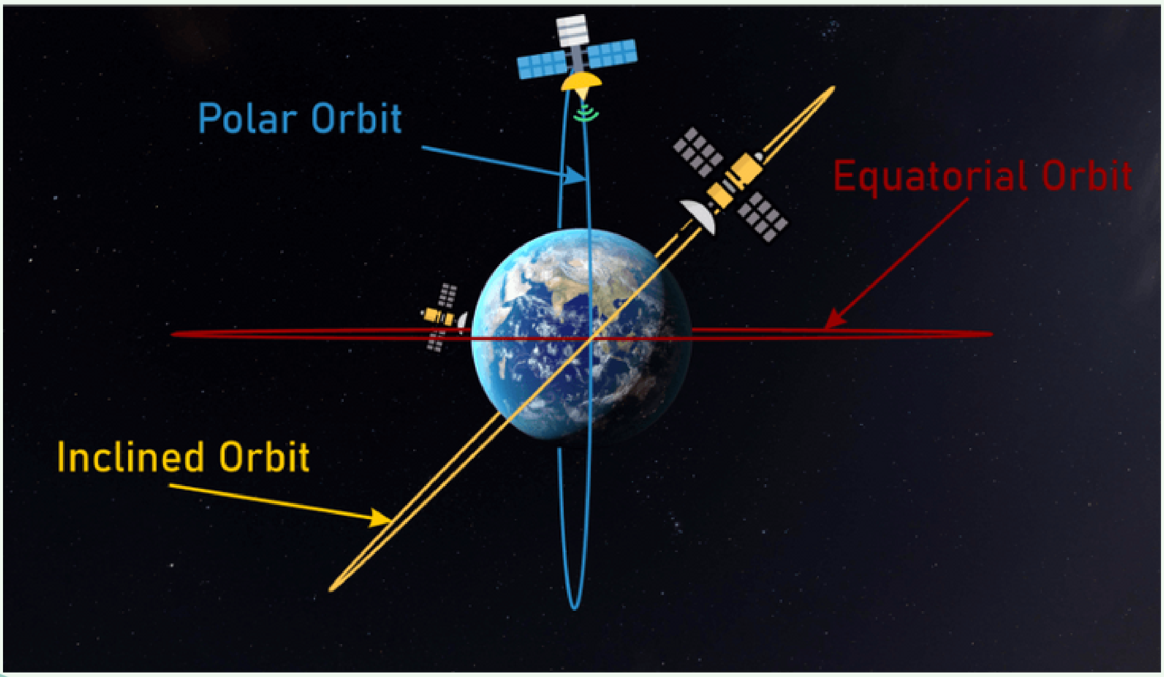


Name	Uplink (Transmit to satellite)	Downlink (Receive from satellite)
C-band	5.8 – 6.725 GHz	3.4 – 4.2 GHz
X-band	7.9 – 8.4 GHz	7.25 – 7.75 GHz
Ku-band	14.0 – 14.5 GHz	10.7 – 12.75 GHz
Ka-band	27.5 – 31.0 GHz	18.3 -18.8 GHz or 19.7 – 20.2 GHz

2.3 Classification of Satellite Orbit

A spacecraft, planet, moon, asteroid, or star that circles another object in space due to gravity is said to be in an orbit.

a. An Orbit by Inclination



i. Equatorial orbit:

An equatorial orbit is one in which the satellite orbits slightly above the equator on a mostly spherical track. It is inclined at zero degrees.

ii. Inclined orbit:

Apart from those that cross the centre or the hemispheres directly, all trajectories are skewed. A zero to 180 degree inclination angle is possible.

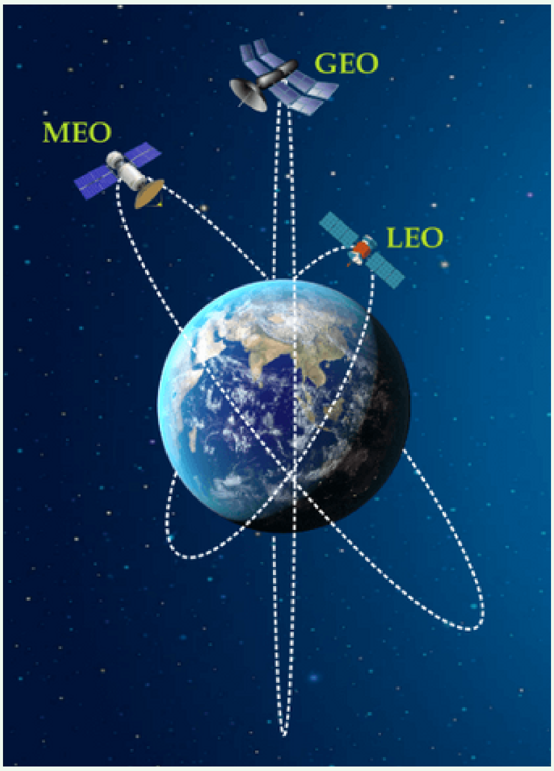
iii. Polar orbit:

A satellite that spins in an orbital configuration that is perpendicular to the equatorial plane and crosses both the North and South poles is said to be in a polar orbit. Satellites in polar orbit travel at low altitudes near the surface of the Earth, passing over and near the North and South poles. A spacecraft in a polar orbit has an angle of almost ninety degrees.

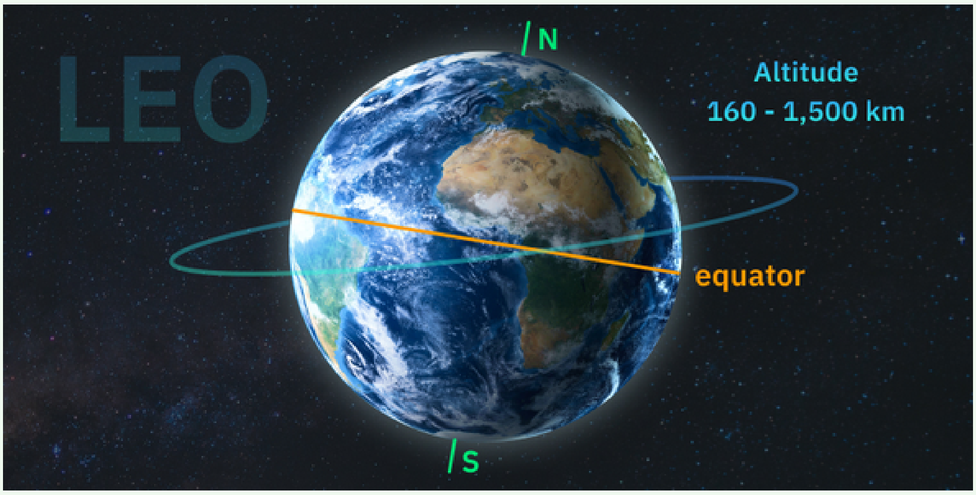
b. An Orbit by Distance from Earth

Satellites usually are classified based on their orbital altitude (distance from the Earth's surface). It will directly affect their coverage and speed around the planet.

The 3 main types of satellites based on their orbits are Low Earth orbit (LEO), Medium Earth orbit (MEO) and Geostationary orbit (GEO)



i. Low Earth Orbit (LEO)



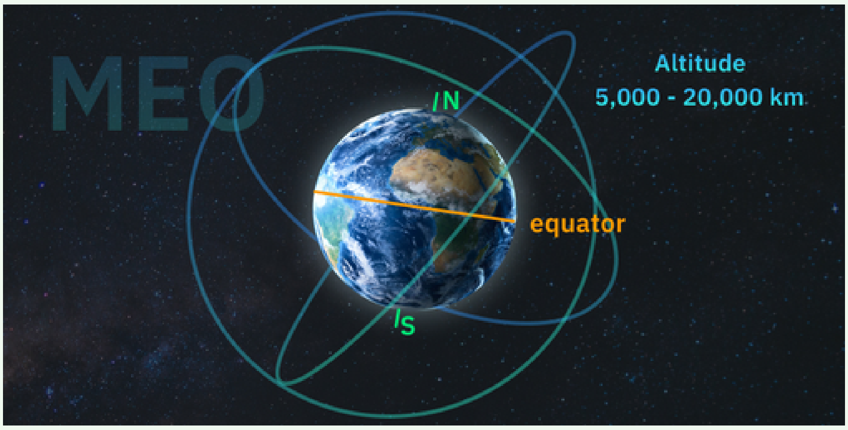
Low Earth Orbit (LEO) satellites travel at an altitude of approximately 160–1,500 kilometers above the Earth's surface.

LEO satellites must travel at high speeds to avoid being pulled back into the atmosphere by gravity.

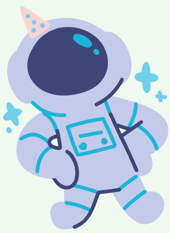
LEO has a short orbital period of 90 to 120 minutes, so it will allow them to travel around the planet up to 16 times per day.

As a result, LEO is well-suited to all types of remote sensing, high-resolution earth observation, and scientific research. So that the data can be acquired and transmitted quickly.

ii. Medium Earth Orbit (MEO)

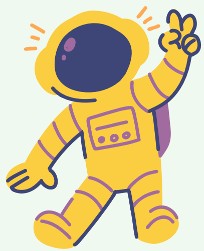


Medium Earth Orbit travels at an altitude of 5,000 to 20,000 kilometers. lies between low Earth and geostationary orbits.

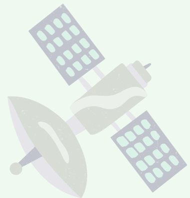


MEO satellites are widely used in positioning and navigation services such as GPS..

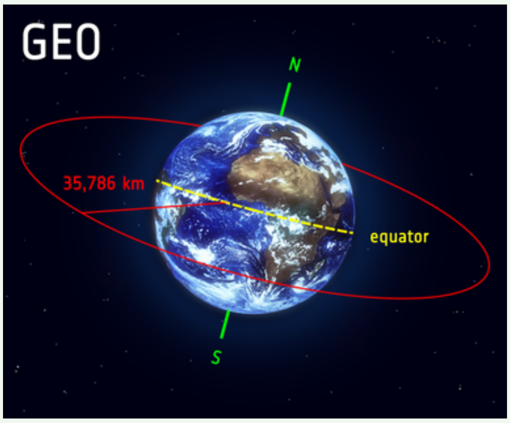
MEO has a longer orbital period (usually between 2 and 12 hours). It provides an ideal compromise between coverage area and data transmission rate.s



Apart from the fact that MEO spacecraft require fewer devices to provide global coverage than low Earth orbit spacecraft, the signals are weaker and the time delay is longer.

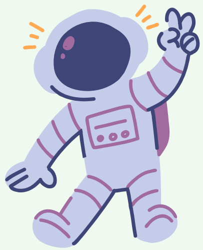


iii. Geostationary Orbit (GEO)



Geostationary Earth-orbiting is 35,786 kilometers above the Earth's surface.

Due to the size and distance, only three GEO satellites are required to provide full communications coverage.

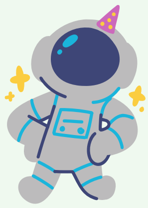


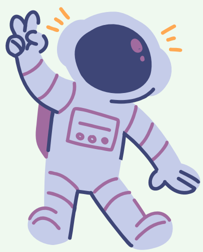
Objects in GEO appear motionless from the ground because their orbital period corresponds to the rotation of the Earth — 24 hours.

GEO allows a terrestrial antenna to always point toward the same device in space. This makes it suitable for communication services such as Televisions and phones, as well as meteorology for observing the weather in specific regions and tracking the development of local patterns..

Advantages of GEO Satellite

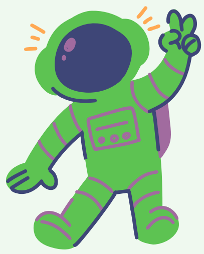
The distance between a GEO satellite and the Earth allows it to cover a large area, nearly a fourth of the Earth's surface.





These characteristics make it ideal for satellite broadcasting and other multipoint applications.

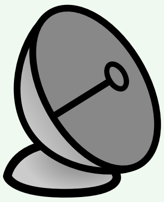
GEO satellites provide a 24-hour view of a specific area.



The geosynchronous orbit is ideal for communications. The reason for this is that the ground-based antennas must be aimed at the satellite. It can function effectively without the need for costly tracking equipment.

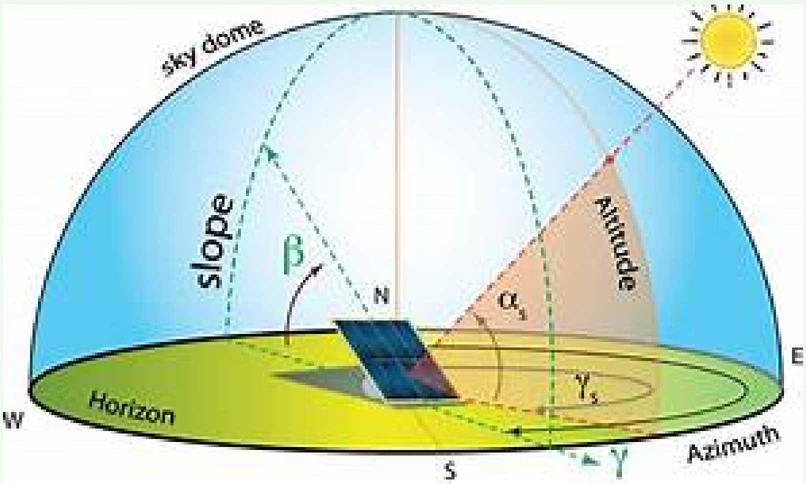
2.4 Look Angle of a Satellite

Two types of Look Angle are Azimuth Angle and Elevation Angle



Azimuth Angle

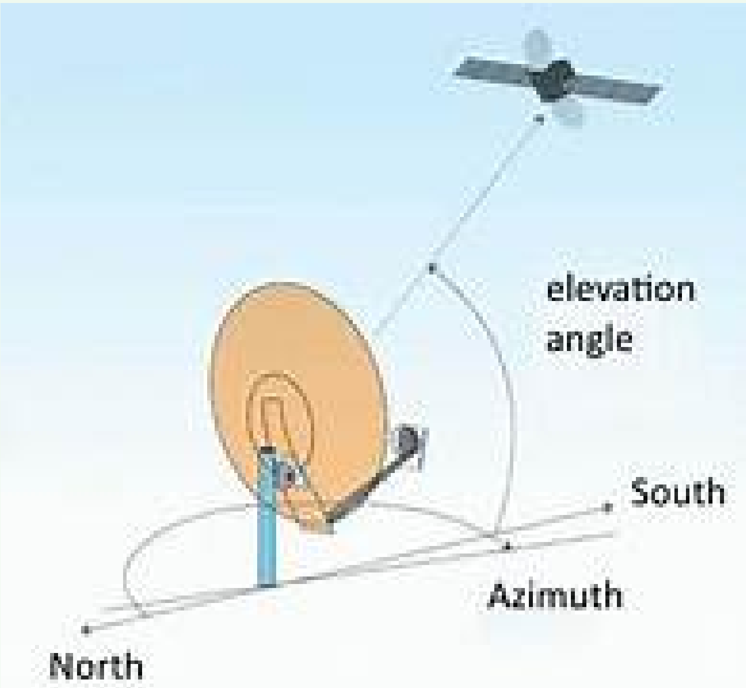
The definition of azimuth is an antenna's horizontal pointing angle, ranging from 0 to 360°.



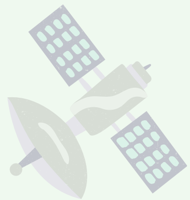
It is measured in degrees from true north, or the north pole, which is used as a reference, in a clockwise manner.

ELEVATION ANGLE

The angle formed by the horizontal plane and the antenna's pointing direction is known as the angle of elevation.

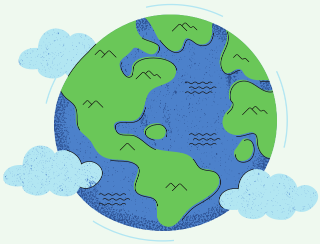


The larger the distance a wave must travel through the earth's atmosphere, the smaller the angle of elevation.



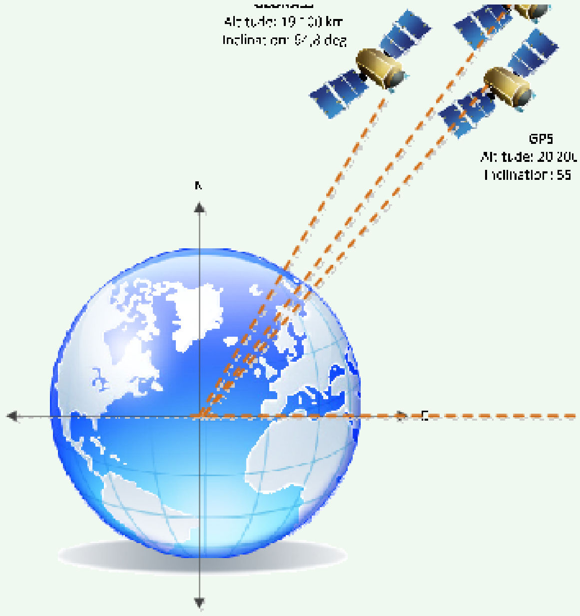
2.5 Earth Coverage Area (Foot Print)

Earth coverage, sometimes referred to as footprint, is the total surface area of the planet that a particular satellite may be able to cover.



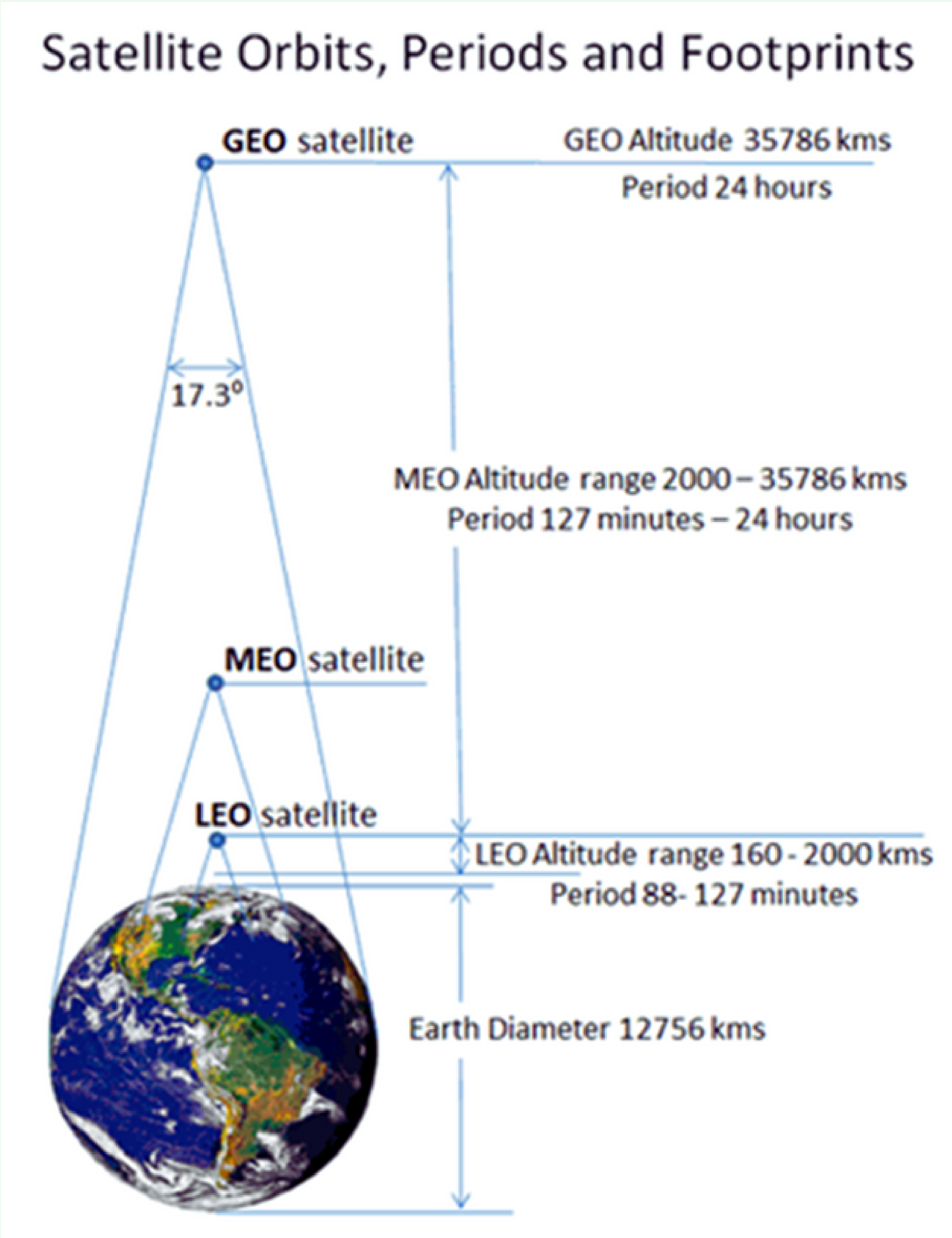
The coverage area increases as the satellite rises above the earth's surface.

Because of earth rotation, the angular velocity decreases and the ground track's displacement towards the west increases with satellite altitude.



2.6 Satellite Altitude

The altitude of a satellite is the distance between the Earth's surface and the satellite



CHAPTER SUMMARY

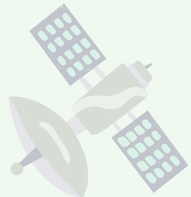
A communications satellite is a man-made satellite that uses a transponder to relay and amplify radio communications signal.

The orbital altitude of a satellite, or its distance from the Earth's surface, is typically used to classify them. This has an immediate impact on the satellite's coverage and orbital velocity.

Satellites are classified into three categories based on their orbits: Low Earth orbit (LEO), Medium Earth orbit (MEO), and Geostationary orbit (GEO).

An orbit is referred to as a planet, spacecraft, asteroid, moon, or star that circles another object in space due to gravity.

The surface area of the earth that can be covered by a given satellite, also known as its footprint.



Simple Exercises

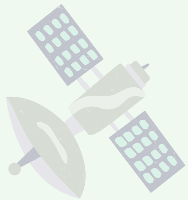
1. Name 3 types of satellite orbits.

2. List 3 applications of satellite communications.

3. What is a GEO satellite?

4. Define look angles.

5. State 3 advantages of satellite communications.



Answer

1

3 types of satellite orbit are LEO, MEO and GEO

2

phone, television, radio, and internet transmissions.

3

GEO is a circular orbit travel at 36000 km above Earth's equator

4

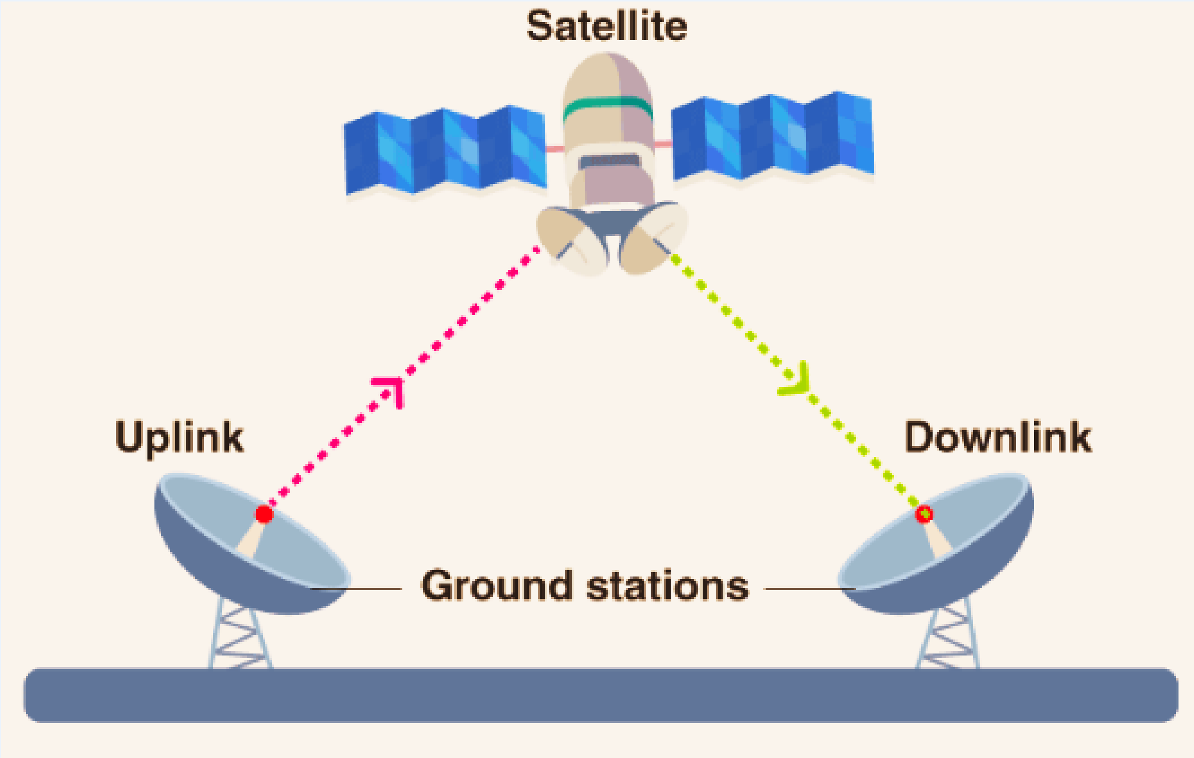
The coordinates to which an earth station must be pointed to communicate with a satellite are called look angles.

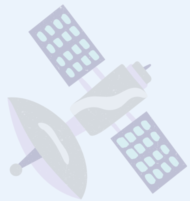
5

- Lots of bandwidth
- Greater connectivity than terrestrial systems
- Every region of the earth can be accessed via satellite communication.

TOPIC 3

THE ELEMENTS OF SATELLITE SYSTEM



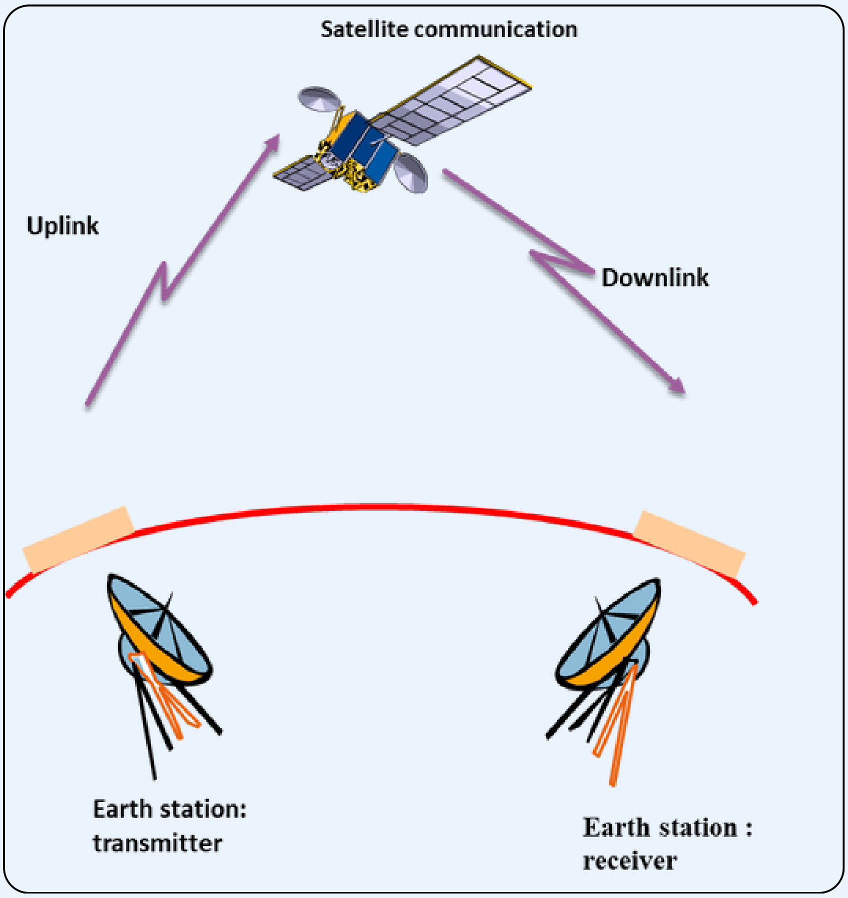


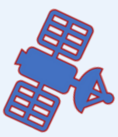
3.1 Satellite System

Satellite Systems are divided into two sections : Space segment and Earth Segmen

Space Segment

Earth Segment





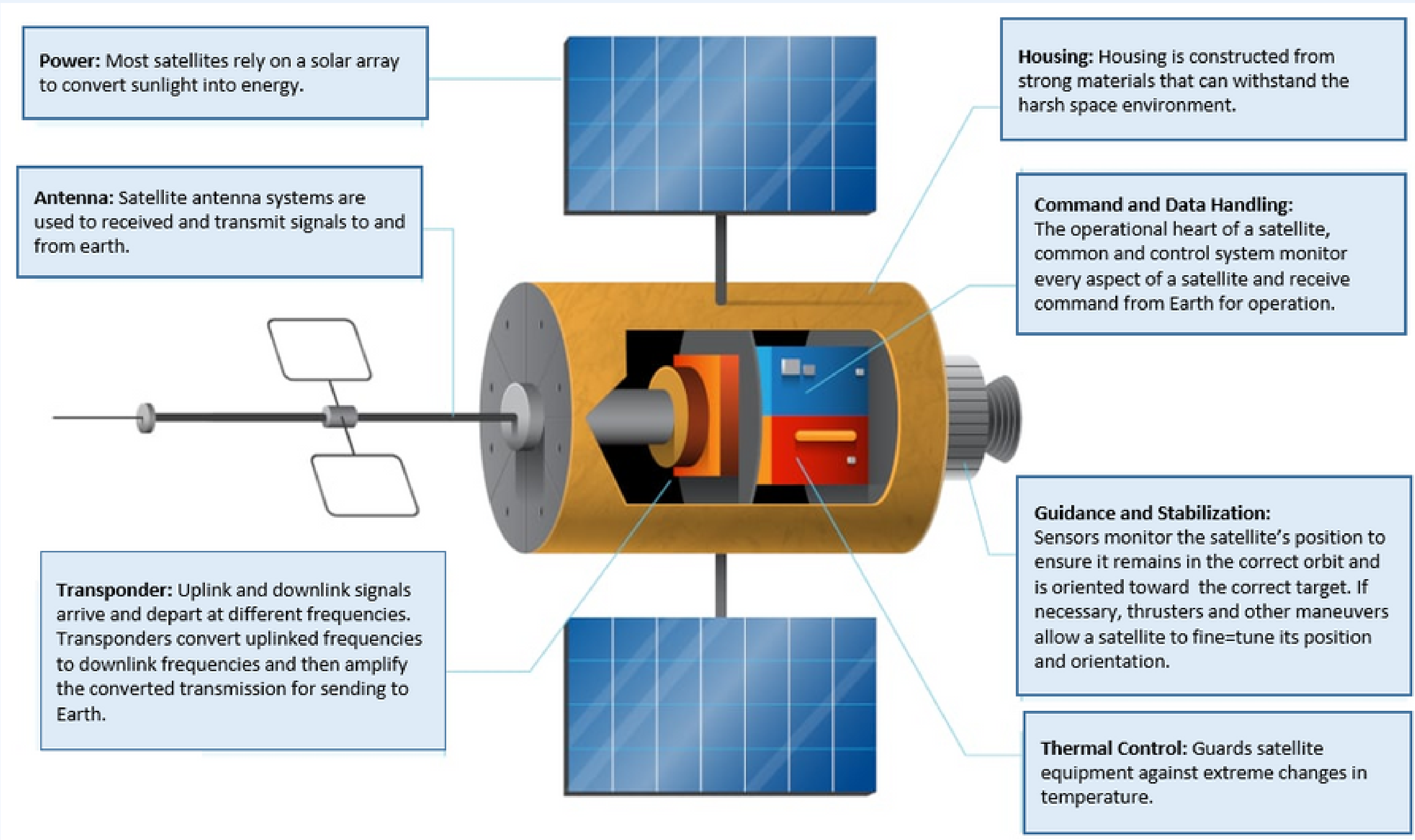
- The satellites in the space segment function to receive, amplify, and retransmit the signals back to earth.

- The uplink transmitter station in the Earth segment transmits signals to the satellite. The downlink receiving station is responsible for receiving satellite signals.

3.2 Elements of Satellite System

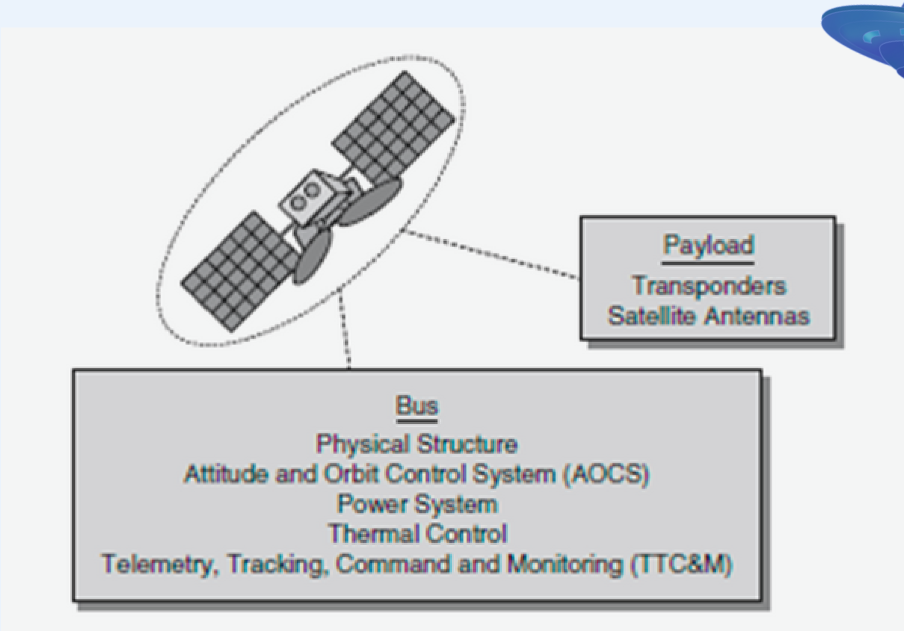
There are 7 elements contained in the Satellite System:

1. Power
2. Antenna
3. Transponder
4. Housing
5. Command and Data Handling
6. Guidance and stabilization
7. Thermal Control



3.3 Satellite Sub-System

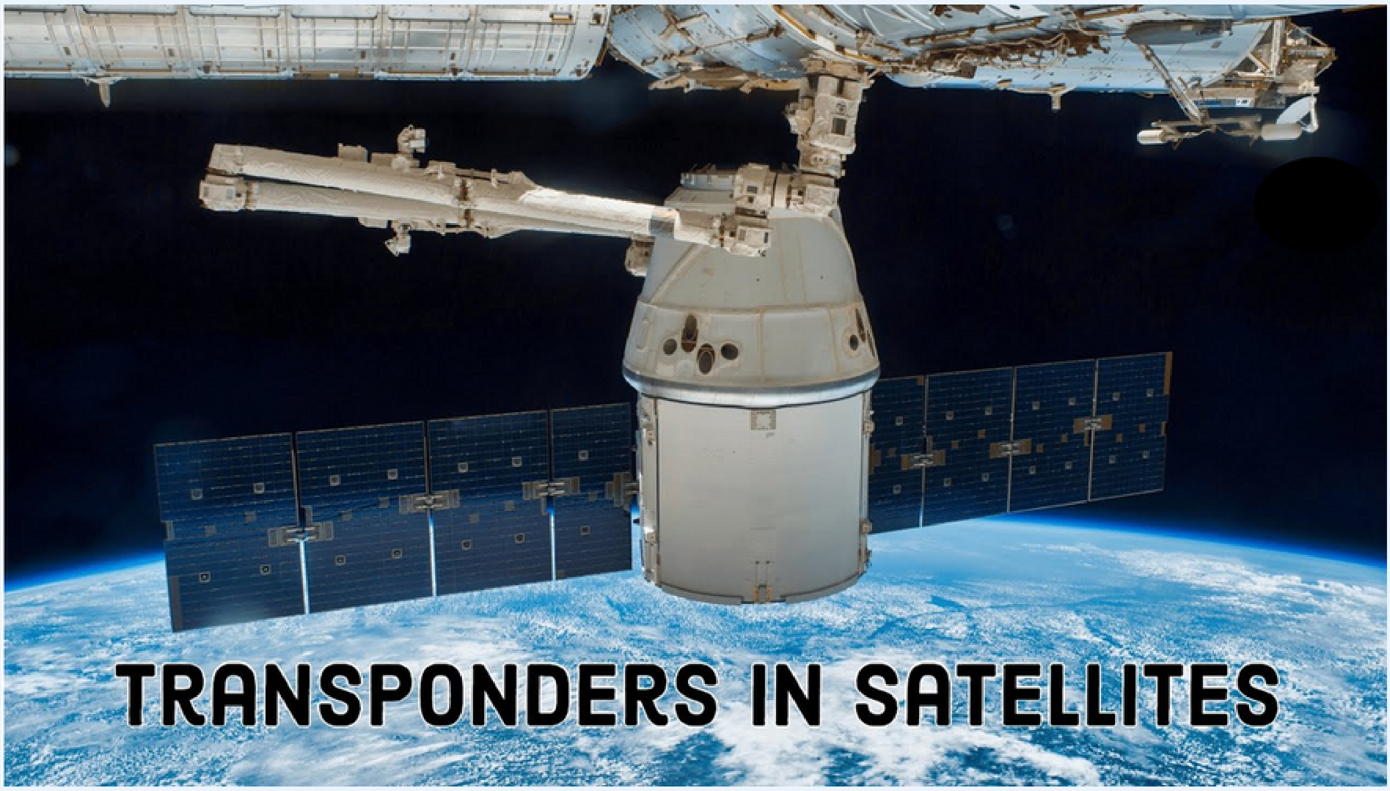
A satellite system is comprised of the spacecraft (bus) and payload(s).



The primary part of a communications satellite is the payload. It consists of transponders and antennas. The payload subsystem's primary functions are as follows:

i. Gather the signal transmitted by the earth station. In addition, try to capture as little interference as possible.
ii. To increase the strength of the received signal.
iii. Changing the frequency of the signal from the uplink to the downlink (such as changing it from 14 to 11 GHz).
iv. To supply the necessary power for downlink transmission.

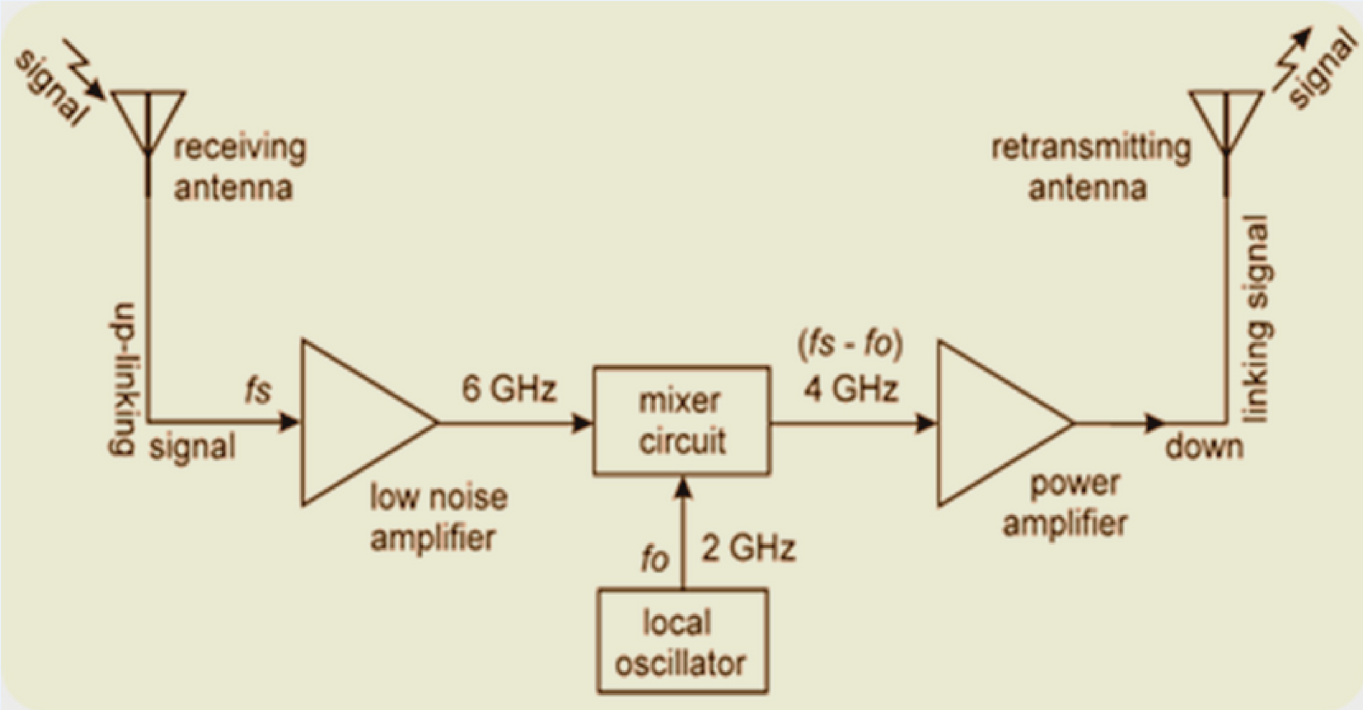
Transponder



An uplinked signal is received, amplified, modulated, and retransmitted by a circuit aboard a satellite called a satellite transponder.

A satellite can have a large number of transponders (a communication satellite, for example, has at least 12 transponders), each of which operates on a distinct frequency and offers a variety of services.

BLOCK DIAGRAM OF TRANSPONDER



Receiving antenna: receive up link signal from earth station → LNA: choose and amplified uplink signal → Local oscillator: to produce LO, 2 GHz.

→ Mixer: combine the uplink signal and local oscillator to produce down link signal → HPA (power amplifier): amplified down-link signal → Retransmitting antenna: transmitt down link signal to earth station

→ Up linking signal and down linking signal : as carrier signal from satellite in any information or data

CHAPTER SUMMARY

Satellites receive, amplify, and retransmit signals back to Earth in the space segment.

The uplink transmitter station in the Earth segment transmits signals to the satellite. The downlink receiving station is responsible for receiving satellite signals.

The payload subsystem's primary functions are as follows:

i. Gather the signal transmitted by the earth station. In addition, try to capture as little interference as possible.

ii. To increase the strength of the received signal.

iii. Changing the frequency of the signal from the uplink to the downlink (such as changing it from 14 to 11 GHz).

iv. To supply the necessary power for downlink transmission.

Satellites in orbit are managed and controlled by international organizations.

Simple Exercises

1. What is the uplink signal?

2. What powers a Spacecraft?

3. What is the main function of the payload system?

4. State the function of Mixer in Satellite Transponder

5. Define satellite transponder.

Answer

1

The link where the earth station is transmitting the radio wave towards the satellite

2

A spacecraft generally gets its energy from Sun and batteries

3

Function of Payload:
i. Gather the signal transmitted by the earth station. In addition, try to capture as little interference as possible.
ii. To increase the strength of the received signal.
iii. Changing the frequency of the signal from the uplink to the downlink (such as changing it from 14 to 11 GHz).
iv. To supply the necessary power for downlink transmission.

4

Mixer: combine the uplink signal and local oscillator to produce down link signal

5

A satellite transponder receives, modulates, amplifies and re-transmits an uplinked signal.

References

a. Louis J. Ippolito Jr. (2017). Satellite Communications Systems Engineering: Atmospheric Effects, Satellite Link Design and System Performance. 2nd Edition. West Sussex, UK: Wiley

b. Anil K. Maini, Varsha Agrawal. (2014). Satellite Technology: Principles and Applications. 3rd Edition. John Wiley & Sons Ltd

c. Annapurna Das, Sisir. K. Das (2014). Microwave Engineering.3rd Edition. Mc Graw Hill Education

d. Ali R. Ebadi (2013). Communication Satellite Fundamentals. From Design To Launch and Operation. Oxford University Press.

e. W. Tomasi (2011), Advanced Electronic Communications Systems. Prentice Hall

FUNDAMENTALS OF SATELLITE COMMUNICATION SYSTEMS

VOLUME 1

This book is intended as a reference for students enrolled in the Satellite Communication Systems course, as well as for others interested in learning about the fundamentals of satellite systems, particularly communication satellite systems.

This book begins with an introduction to the satellite system and progresses through several topics such as the relevance of satellites, how they are utilized, satellite communication systems, orbit types, satellite look angles, earth coverage, satellite elements, and satellite sub-systems.

This book also includes chapter summaries at the end of each chapter for rapid review and practice problems to enhance students' knowledge and understanding of the satellite system.

e ISBN 978-967-2762-79-9

9 789672 762799

POLITEKNIK MERLIMAU

(online)