Day 1 course

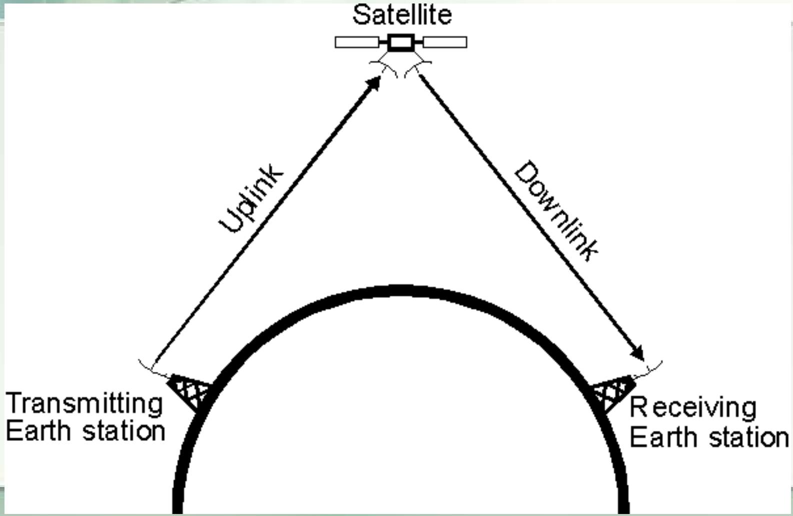
Basics of satellite communications

1- Birth of satellite communications

Satellites are able to fulfill a number of roles. One of the major roles is for satellite communications. Here the satellite enables communications to be established over large distances - well beyond the line of sight. Communications satellites may be used for many applications including relaying telephone calls, providing communications to remote areas of the Earth, TV direct to user broadcasting, providing satellite communications to ships, aircraft and other mobile vehicles, and there are many more ways in which communications satellites can be used.

1- Birth of satellite communications

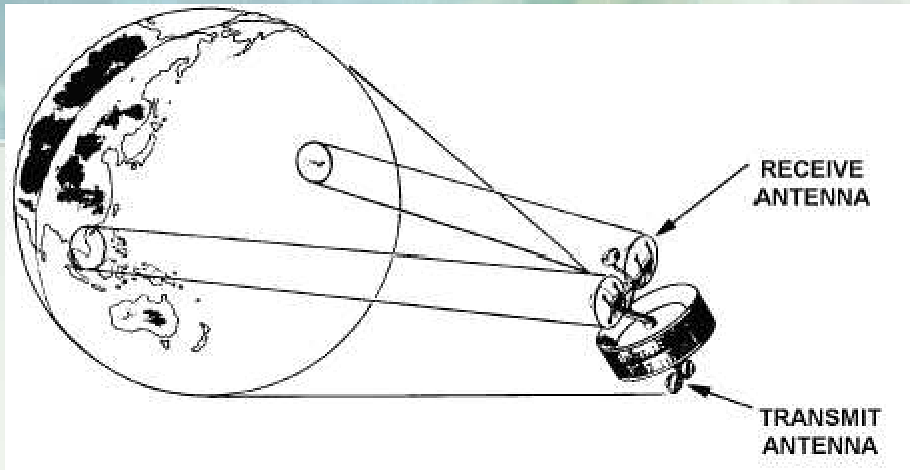
When used for communications, a satellite acts as a repeater. Its height above the Earth means that signals can be transmitted over distances that are very much greater than the line of sight. An earth station transmits the signal up to the satellite. This is called the up-link. The satellite receives the signal and retransmits it on what is termed the down link. To avoid interference, the uplink and downlink are on different frequency bands.



1- Birth of satellite communications

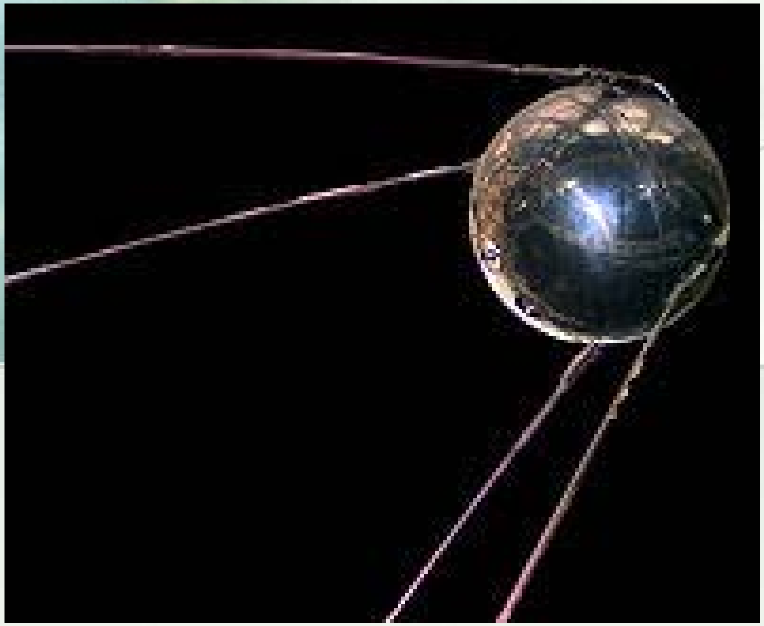
In the context of spaceflight, a **satellite** is an object which has been placed into orbit by human endeavor.

Such objects are sometimes called **artificial satellites** to distinguish them from natural satellites such as the Moon.



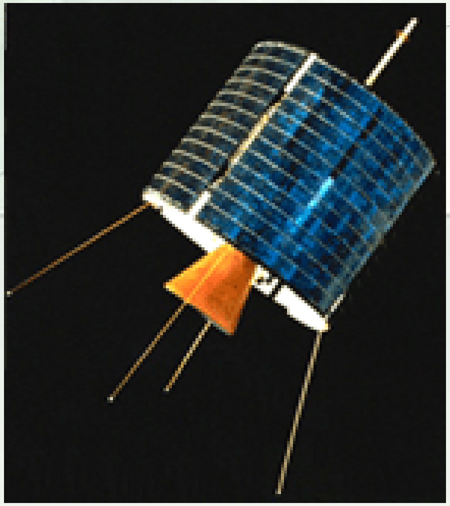
1- Birth of satellite communications

First satellite was launched in 1957 by Russia. It was Sputnik 1.



1- Birth of satellite communications

INTELSATI (nicknamed **Early Bird** for the proverb "The early bird catches the worm") was the first (commercial) communications satellite to be placed in geosynchronous orbit, on April 6, 1965.



1- Birth of satellite communications

Benefits of satellites

Satellites Provide Some Capabilities Not EASILY Available with Terrestrial Communication Systems

- Adaptable to the needs of different customers
- Mobility
- Cost advantage over building land lines for a limited population
- No geographical obstructions that prohibit landlines
- Quick implementation – e.g. News Gathering
- Alternate routing or redundancy as required
- Cost is independent of distance
- Cost effective for short term requirements e.g. Sporting Events

1- Birth of satellite communications

Interest of satellites

Satellites are complementary to cable for the following reasons:

- 1) Submarine cables (and landline fibre) are subject to cuts. Satellites provide an excellent means of back-up and should always be considered in any national plan as a means of resilience and network security
- 2) Although a lot of countries are getting access to fibre, they have problems distributing that large bandwidth to centers far away from the cable landing. Microwave or landline fibre may not be cost effective in the short run or may take a long time to reach upcountry locations. The interim solution is to have a VSAT network utilizing satellites for cellular backhaul and internet trunking until terrestrial capacity on microwave or fibre can reach the remote locations
- 3) There are certain satellite systems utilizing MEO (medium Earth orbit) which are about to have both high capacity (1.2Gb*ps* per beam), quality (low latency of 120 ms round trip) and cost ($750 per Mb*ps* per month) factors that approach that of submarine cable.

1- Birth of satellite communications

Types of satellites

- **Communications satellites:** A communications satellite is a radio relay station in orbit above the earth that receives, amplifies, and redirects analog and digital signals carried on a specific radio frequency.

In addition to communications satellites, there are other types of satellites:

- **Weather satellites:** These satellites provide meteorologists with scientific data to predict weather conditions and are equipped with advanced instruments

1- Birth of satellite communications

Types of satellites

- **Earth observation satellites:** These satellites allow scientists to gather valuable data about the Earth's ecosystem

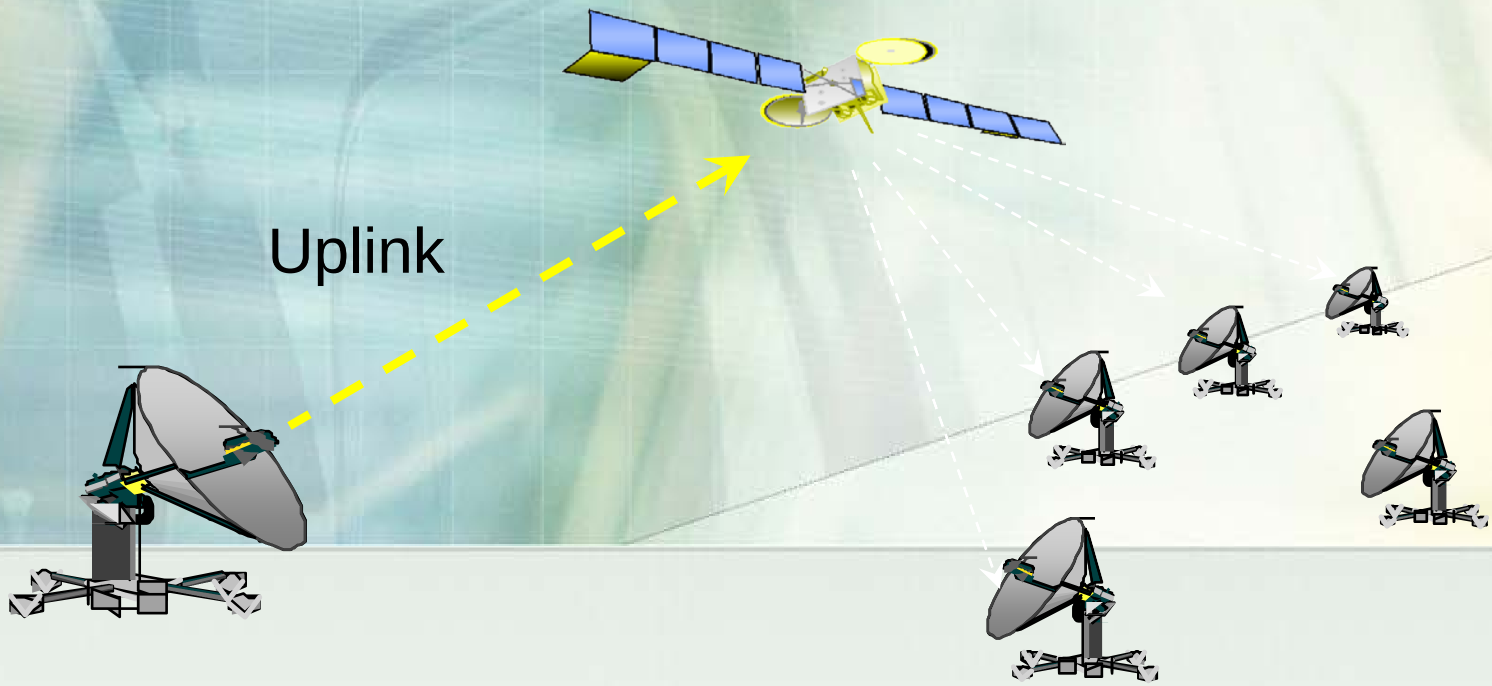
- **Navigation satellites:** Using GPS technology these satellites are able to provide a person's exact location on Earth to within a few meters

- **Broadcast satellites**: broadcast television signals from one point to another (similar to communications satellites).
- **Scientific satellites :** perform a variety of scientific missions. The Hubble Space Telescope is the most famous scientific satellite, but there are many others looking at everything from sun spots to gamma rays.

1- Birth of satellite communications
Types of satellites

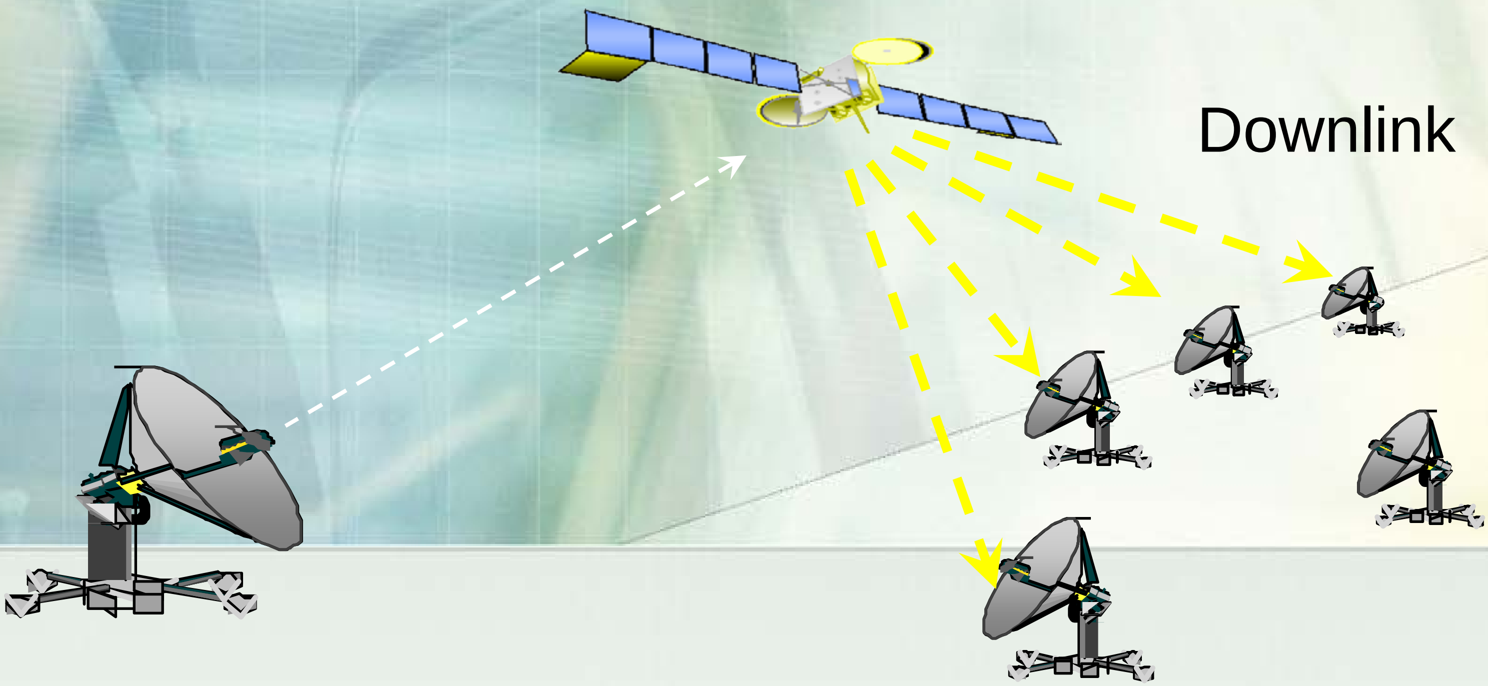
- **Military satellites:** are up there, but much of the actual application information remains secret. Intelligence-gathering possibilities using high-tech electronic and sophisticated photographic-equipment reconnaissance are endless. Applications may include:
  - Relaying encrypted communications
  - Nuclear monitoring
  - Observing enemy movements
  - Early warning of missile launches
  - Eavesdropping on terrestrial radio links
  - Radar imaging
  - Photography (using what are essentially large telescopes that take pictures of militarily interesting areas)

3.1- Communications links
Uplink



Uplink - The transfer of information to the satellite

3.1- Communications links
Downlink



Downlink - The transfer of information from the satellite

3.1- Communications links

Uplink and Downlinks

- NOTE:
  - Satellites receive at a different frequency than they transmit at
  - Different wavelengths give different radiation patterns on the antennae
  - This causes slightly different footprints for uplink and downlink
  - For marketing reasons the patterns may be different

3.2- The space segment

The equipment carried aboard the satellite also can be classified according to function.

The payload refers to the equipment used to provide the service for which the satellite has been launched.

The bus refers not only to the vehicle which carries the payload but also to the various subsystems which provide the power, attitude control, orbital control, thermal control, and command and telemetry functions required to service the payload.

3.2- The space segment

In a communications satellite, the equipment which provides the connecting link between the satellite’s transmit and receive antennas is referred to as the **transponder**.

The transponder forms one of the main sections of the payload, the other being the antenna subsystems.

3.2- The space segment

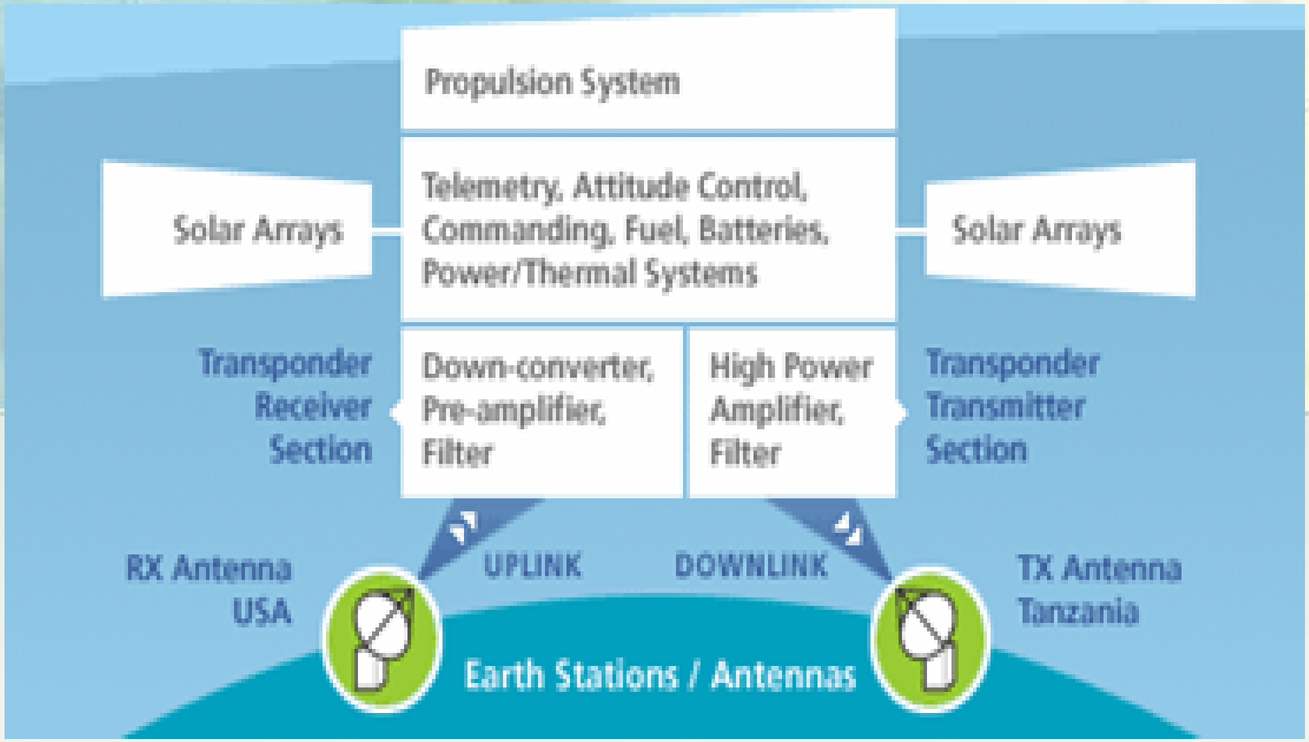
Communications data passes through a satellite using a signal path known as a transponder.

Typically satellites have between 24 and 72 transponders. A single transponder is capable of handling up to 155 million bits of information per second.

With this immense capacity, today's communication satellites are an ideal medium for transmitting and receiving almost any kind of content - from simple voice or data to the most complex and bandwidth-intensive video, audio and Internet content.

3.2- The space segment

Diagrammatic Representation of a Satellite



3.2- The space segment
Satellite design (electrical power)

Early communications satellites were severely limited by the lack of suitable power sources. This severely limited the output power of the satellite transmitter.

The only source of power available within early weight restrictions was a very inefficient panel of solar cells without battery backup.

A major disadvantage of this type of power source is that the satellite has no power when it is in ECLIPSE (not in view of the Sun). For continuous communications, this outage is unacceptable.

3.2- The space segment

Satellite design (electrical power)

A combination of solar cells and storage batteries is a better prime power source. This is a practical choice, even though the result is far from an ideal power source.

About ten percent of the energy of the sunlight that strikes the solar cells is converted to electrical power. This low rate is sometimes decreased even further.

3.2- The space segment

Satellite design (electrical power)

Early satellites had over 8,500 solar cells mounted on the surface of the satellite, which supplied about 42 watts of power. No battery backup was provided in these satellites.

Newer communications satellites have about 32,000 solar cells mounted on the surface of the satellite, and they supply about 520 watts. A nickel cadmium battery is used for backup power during eclipses.

Nuclear power sources have been used in space for special purposes, but their use stops there. Technology has not progressed sufficiently for nuclear power sources to be used as a power source.

3.2- The space segment

Satellite design (electrical power)

3.2- The space segment
Satellite design (Attitude control)

The *attitude* of a satellite refers to its orientation in space. Much of the equipment carried aboard a satellite is there for the purpose of controlling its attitude.

Attitude control is necessary, for example, to ensure that directional antennas point in the proper directions. In the case of earth environmental satellites, the earth-sensing instruments must cover the required regions of the Earth, which also requires attitude control.

A number of forces, referred to as *disturbance torques,* can alter the attitude, some examples being the gravitational fields of the Earth and the Moon, solar radiation, and meteorite impacts.

3.2- The space segment
Satellite design (Attitude control)

Attitude control must not be confused with *station keeping,* which is the term used for maintaining a satellite in its correct orbital position, although the two are closely related.

3.2- The space segment

Satellite design (Orbital control)

In addition to having its attitude controlled, it is important that a geostationary satellite be kept in its correct orbital slot.

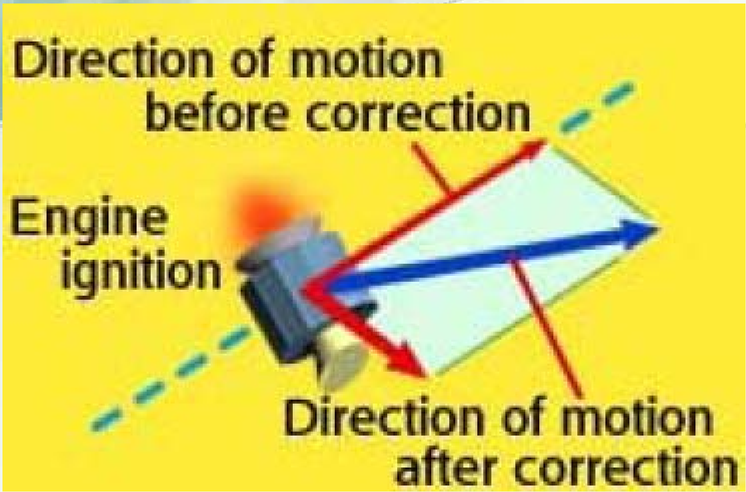
The equatorial ellipticity of the earth causes geostationary satellites to drift slowly along the orbit, to one of two stable points, at 75°E and 105°W.

To counter this drift, an oppositely directed velocity component is imparted to the satellite by means of jets, which are pulsed once every 2 or 3 weeks.

3.2- The space segment

Satellite design (Orbital control)

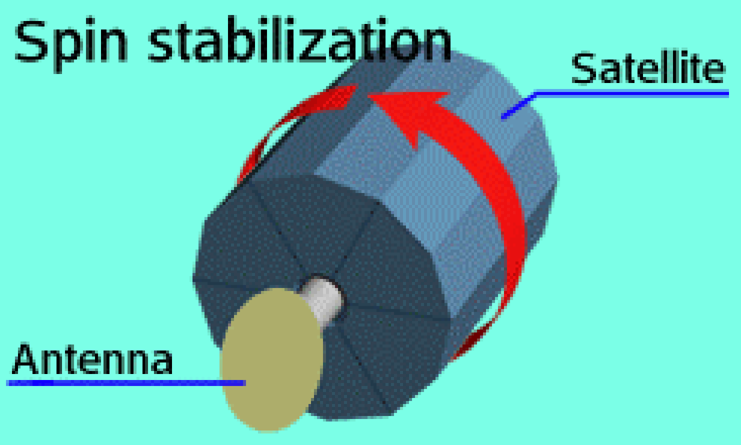
In order for a geostationary communications satellite to continue to function, it must remain stationary with respect to all the earth station antennas that are pointed at it. To correct for the orbital fluctuations that all satellites are subject to, each satellite carries a thrust subsystem to give it an occasional nudge to keep it "On Station."

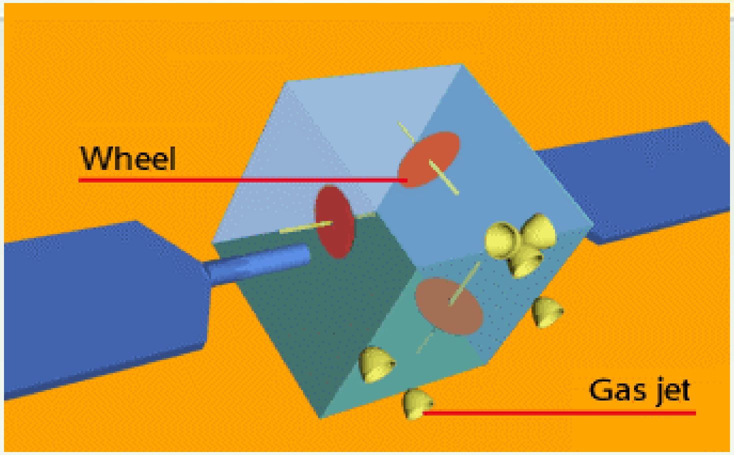


3.2- The space segment
Satellite design (Orbital control)

Remaining on-station is only half the battle. Additionally, the satellite's antennas must always be aimed at the same spot on the Earth’s surface. This requires gyroscopic stabilization of the satellite body. This is accomplished with gyroscopes in one of two configurations:

- Spin stabilization, in which the entire satellite body is spun (antennas are de-spun), or
- Internal gyroscopes





3.2- The space segment

Satellite design (Thermal control)

Satellites are subject to large thermal gradients, receiving the sun's radiation on one side while the other side faces into space.

In addition, thermal radiation from the earth and the earth's albedo, which is the fraction of the radiation falling on earth which is reflected, can be significant for low-altitude earth-orbiting satellites, although it is negligible for geostationary satellites.

Equipment in the satellite also generates heat which has to be removed. The most important consideration is that the satellite's equipment should operate as nearly as possible in a stable temperature environment.

3.2- The space segment

Satellite design (Thermal control)

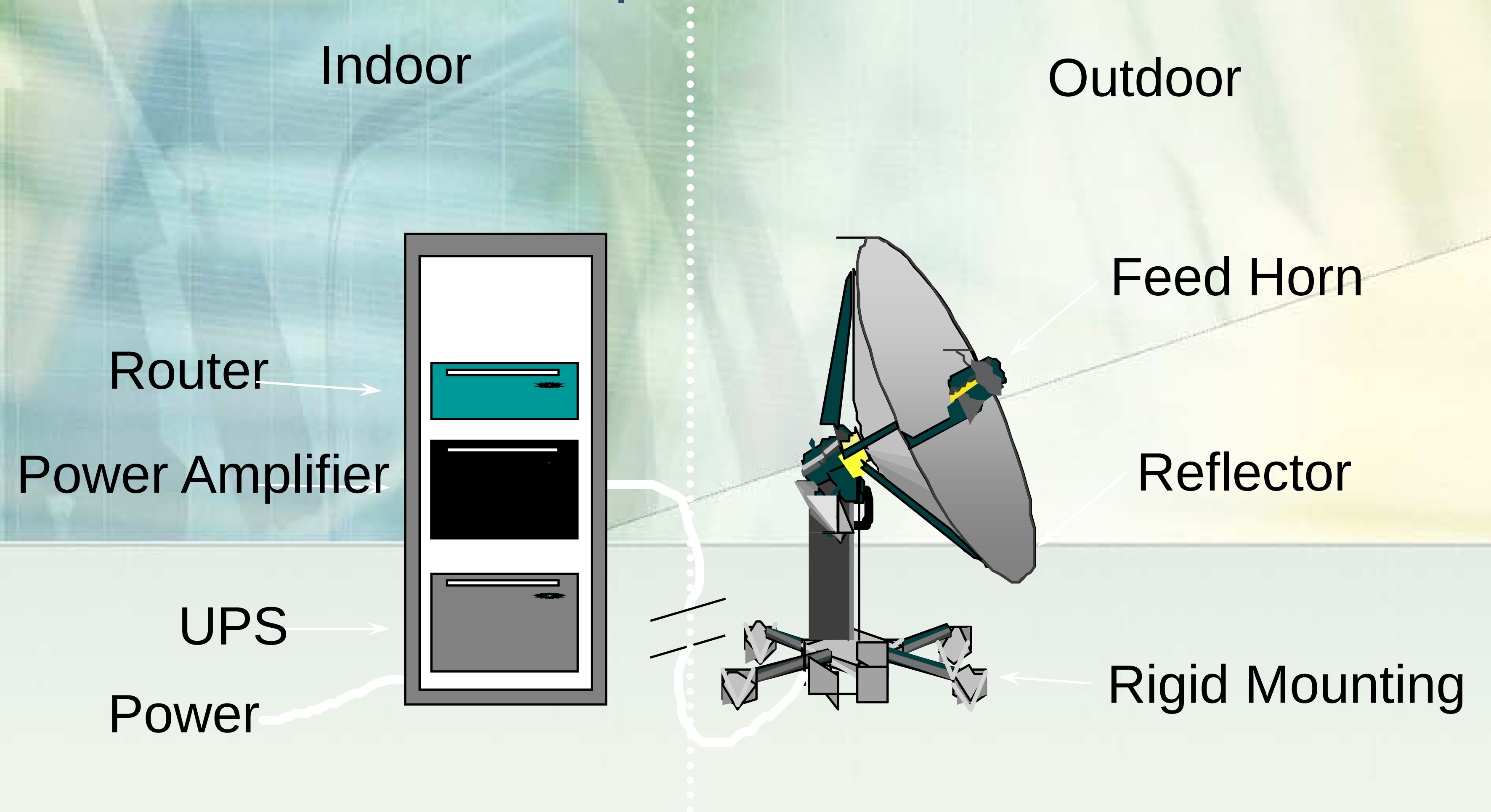
In order to maintain constant temperature conditions, heaters may be switched on (usually on command from ground) to make up for the heat reduction which occurs when transponders are switched off.

In INTELSAT VI, heaters are used to maintain propulsion thrusters and line temperatures.

3.3- The ground segment

- Earth station components
- Factors governing antenna sizes
- The differences between a major earth station and a VSAT

3.3- The ground segment
Earth Station Components



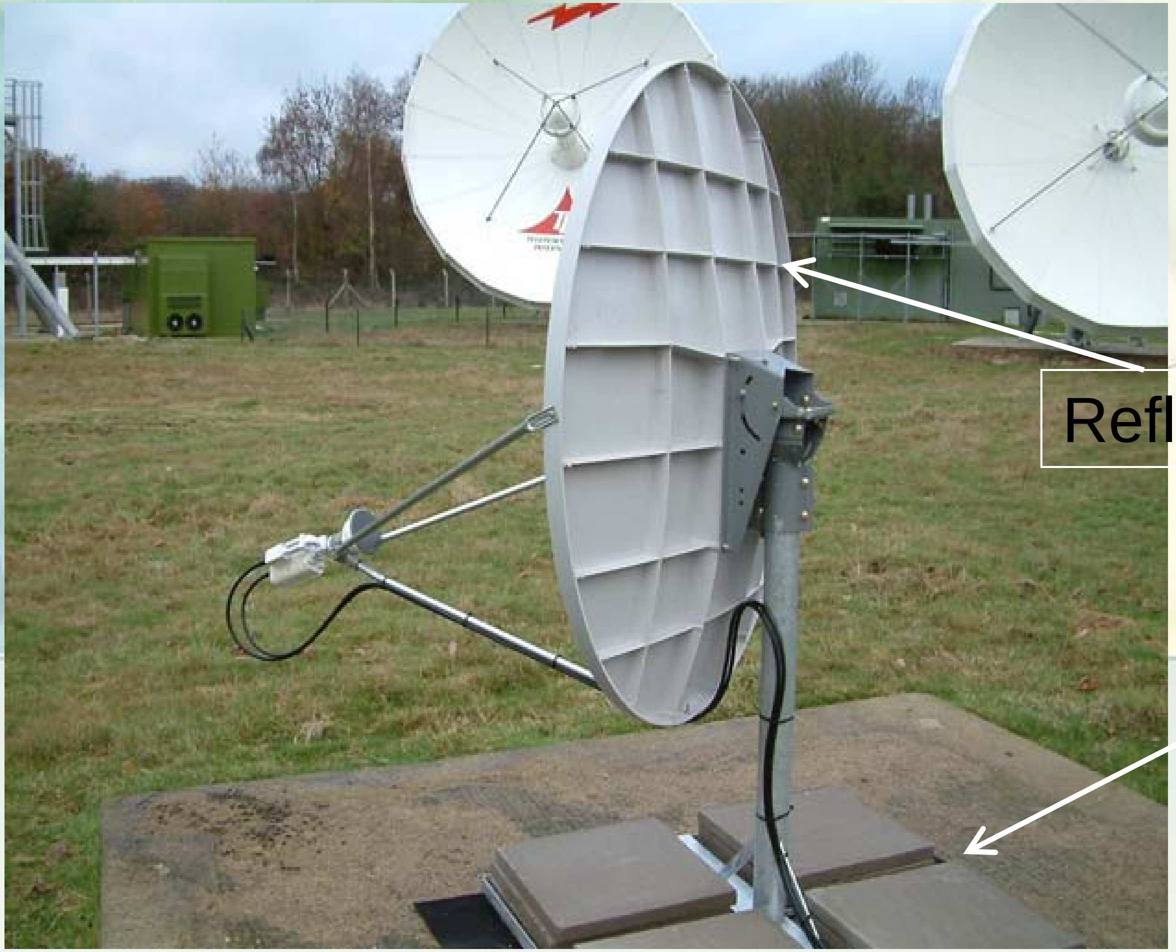
Earth Station Components – generic simplified diagram

3.3- The ground segment

Earth Station Components

- Reflector – Physical reflecting piece – focuses signal into the LNB assembly and / or focuses the transmission signal towards the satellite
- Feed horn – Device to accept the focussed RF signals into the LNB or conversely to output the RF signal to the satellite
- Power amplifier – Device that accepts a signal from the modem and boosts it to a suitable level for onward transmission to the satellite
- LNA,B or C – Low Noise Amplifier – Receives the signal from the satellite,
- Modem – Converts a data signal to one suitable for transmission to the satellite
- UPS / Power – Un-interruptible Power Supply - Power input to the devices
- Rigid Mounting – Some form of mounting to hold the antenna assembly vertical and pointed correctly under most normal condition

3.3- The ground segment
Earth Station Components

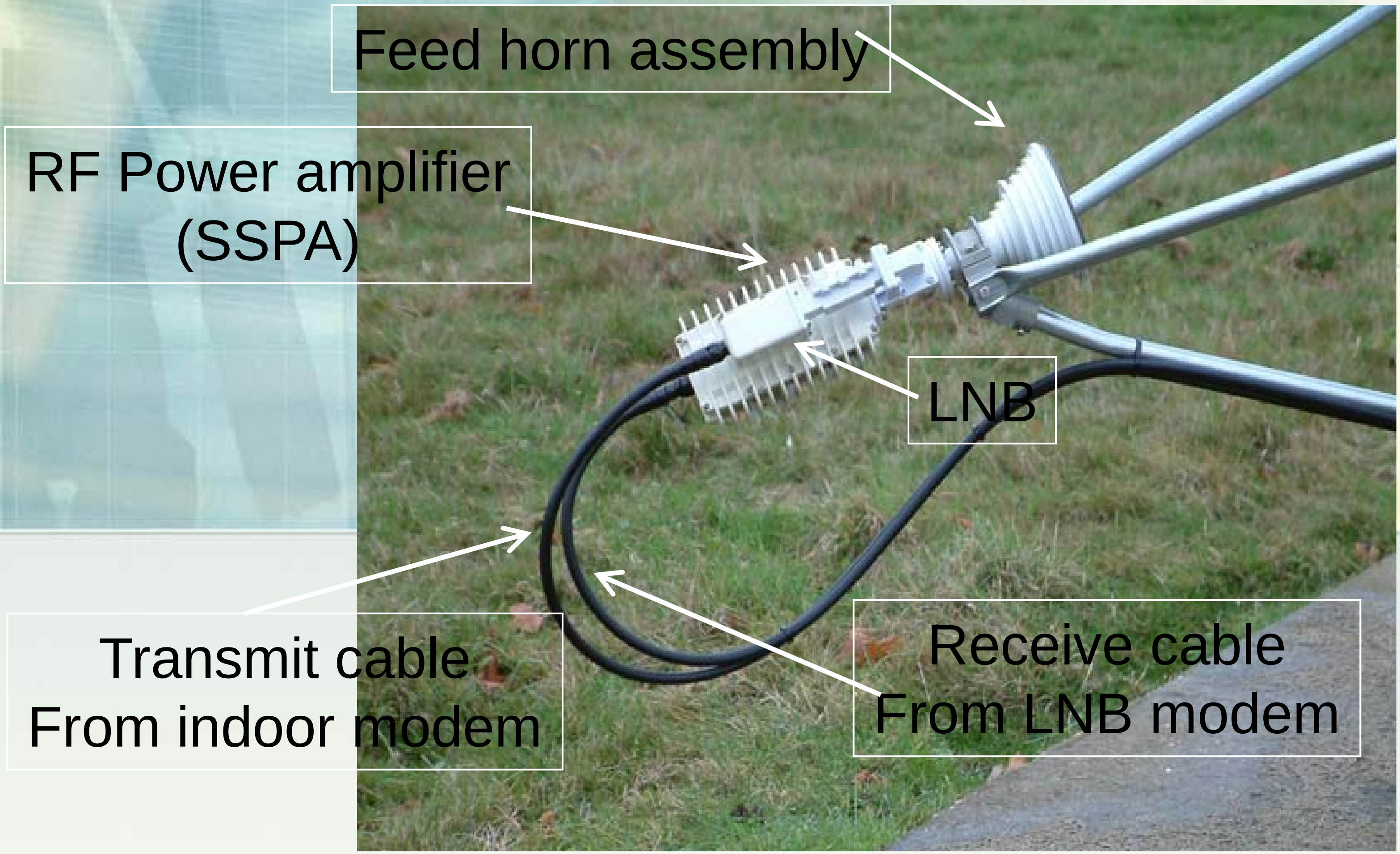


Reflector

Ground Mount with weights

3.3- The ground segment

Earth Station Components



3.3- The ground segment

Factors governing Reflector sizes

Why install a large antenna when a small one would do the job?

- Transmission:
  - ✓Large earth stations have smaller BEAM Width's therefore point more accurately
  - ✓ Less RF signal wastage
  - ✓ Less co-satellite interference
  - ✓ Cost factors
    - Larger antenna may be less than the cost of a lease with a smaller antenna

3.3- The ground segment

The differences between a Major Earth Station and a VSAT

- VSAT – Very Small Aperture Terminal
- A VSAT is typically a small earth station 0.7M to 3.7M
- Usually operates a single service or application

- Major Earth Station
- Typically A Major Earth station is sized from 3.7M to 16M+ and costing $1M+
- Basically same components in each station
- Supports multiple services
- All components redundant
- Can transmit and receive in multiple polarisations
- Usually configured with large RF power amplifiers
- Always connected to suitable Power supplies
- Usually connected to multiple terrestrial paths

3.3- The ground segment

The differences between a Major Earth Station and a VSAT

3.3- The ground segment

Permissions required to install & operate a VSAT / Earth station

- Just because it can work does not necessarily mean you may go out install and operate!

- Planning permission
  - ✓ Local Authority building departments
  - ✓ Zoning issues
- Landlord's permission

  Will the landlord permit your activity?
- Regulatory authority

  Does the law allow you to build and operate?

3.3- The ground segment

A Typical Teleport

Typical services provided by a teleport :

- Multiple large earth stations
- Well specified antennas
- Good power systems
- Ample Rack space for ancillary equipment
- 24X7 staff on-site to maintain systems
- Quality support and technical staff to assist with design, install and operation
- Good terrestrial connectivity

3.3- The ground segment
A Typical Teleport

4- Satellite orbits

Geosynchronous Orbit (GEO): 35,786 km above the earth

Orbiting at the height of 22,282 miles above the equator (35,786 km), the satellite travels in the same direction and at the same speed as the Earth's rotation on its axis, taking 24 hours to complete a full circle in its orbit. Thus, as long as a satellite is positioned over the Equator in an assigned orbital location, it will appear to be "stationary" with respect to a specific location on the Earth.

4- Satellite orbits

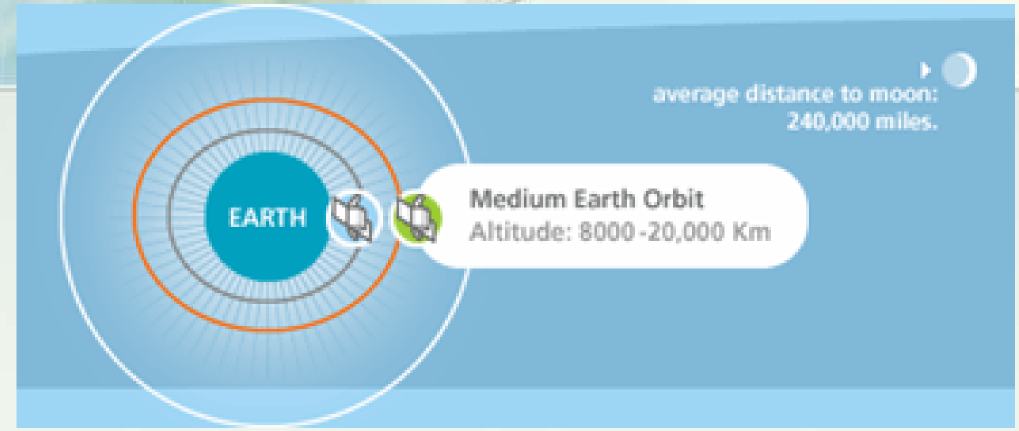
Geosynchronous Orbit (GEO): 35,786 km above the earth

A single geostationary satellite can view approximately one third of the Earth's surface. If three satellites are placed at the proper longitude, the height of this orbit allows almost all of the Earth's surface to be covered by the satellites.

4- Satellite orbits

Medium Earth Orbit (MEO): 8,000-20,000 km above the earth

- These orbits are primarily reserved for communications satellites that cover the North and South Pole
- Unlike the circular orbit of the geostationary satellites, MEO's are placed in an elliptical (oval-shaped) orbit

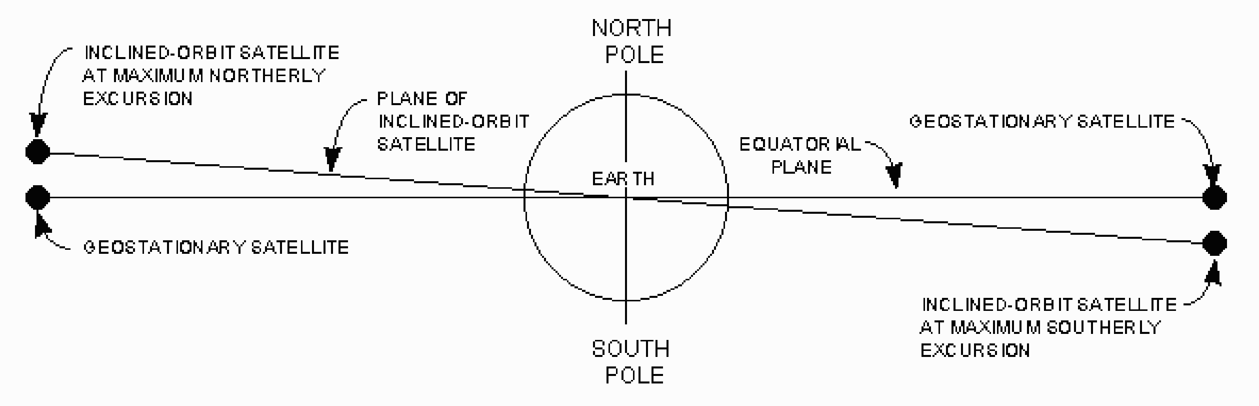


4- Satellite orbits

Low Earth Orbit (LEO): 500-2,000 km above the earth

- These orbits are much closer to the Earth, requiring satellites to travel at a very high speed in order to avoid being pulled out of orbit by Earth's gravity
- At LEO, a satellite can circle the Earth in approximately one and a half hours

4- Satellite orbits



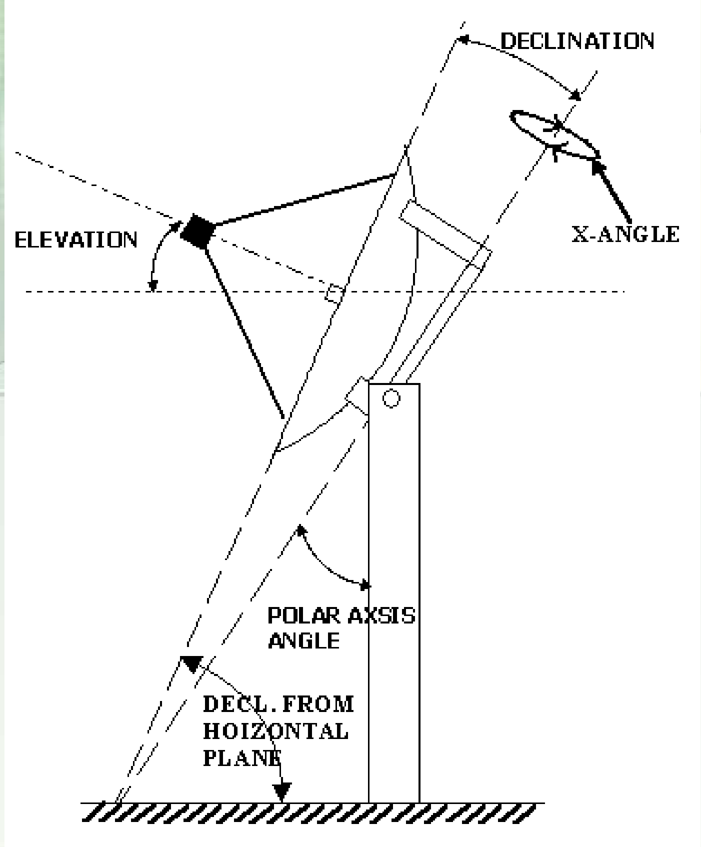
Inclined orbits

Once a satellite has been placed accurately into its geostationary orbit position it gradually starts to drift north-south on a daily basis due to the influence of the sun and moon. There is a gradual increase in the inclination of the orbit. If left alone, a satellite that has initial zero inclination will have its inclination increase at the rate of 0.8 deg per year.

4- Satellite orbits

Inclined orbits (Implications for earth station inclination tracking)

During the inclined orbit years earth stations must have tracking systems so that their pointing is adjusted to aim at the satellite all during the day.



4- Satellite orbits

GEO vs. MEO vs. LEO

- Most communications satellites in use today for commercial purposes are placed in the geostationary orbit, because of the following advantages:

✓ One satellite can cover almost 1/3 of Earth's surface, offering a reach far more extensive than what any terrestrial network can achieve

✓ Communications require the use of fixed antennas. Since geosynchronous satellites remain stationary over the same orbital location, users can point their satellite dishes in the right direction, without costly tracking activities, making communications reliable and secure

✓ GEO satellites are proven, reliable and secure - with a lifespan of 10-15 years

5- Services

The Commercial Satellite Industry

Voice/Video/Data Communications

- Rural Telephony
- News Gathering/Distribution
- Internet Trunking
- Corporate VSAT Networks
- Tele-Medicine
- Distance-Learning
- Mobile Telephony
- Videoconferencing
- Business Television
- Broadcast and Cable Relay
- VOIP & Multi-media over IP

Direct-To-Consumer

- Broadband IP
- DTH/DBS Television
- Digital Audio Radio
- Interactive Entertainment & Games
- Video & Data to handhelds

GPS/Navigation

- Position Location
- Timing
- Search and Rescue
- Mapping
- Fleet Management
- Security & Database Access
- Emergency Services

Remote Sensing

- Pipeline Monitoring
- Infrastructure Planning
- Forest Fire Prevention
- Urban Planning
- Flood and Storm watches
- Air Pollution Management
- Geo-spatial Services

6- Satellite lifecycle management

In principle, geostationary satellites occupy a fixed position in space and consequently the ground-based antennas do not need to be constantly redirected to follow the satellite’s movements.

The fact that the orientation of ground-based antennas is fixed is a major advantage of the geostationary satellite orbit used by satellite broadcasters.

In practice however, the satellite wanders slightly around its nominal orbital position under the gravitational influence of bodies such as the Sun and the Moon, as well as other influences such as Sun radiation pressure and Earth asymmetry.

7- Satellite lifecycle management

It is therefore necessary to take corrective actions in order to keep the satellite within acceptable margins from its ideal position. This is achieved by activating the so-called ‘thrusters’ that are mounted on the body of the satellite as part of its propulsion system.

As long as the satellite has enough fuel left to operate its thrusters, it can be kept in the correct position. Typically this is 10 – 15 years. As soon as the satellite is out of fuel, it will drift out of control and into space, which brings an end to its operational life.

End of Day 1 course

Satellite Technology: Satellites fundamentals, Orbits, Satellite design, Operation, Life Cycle Management.