ITU/ITSO Workshop

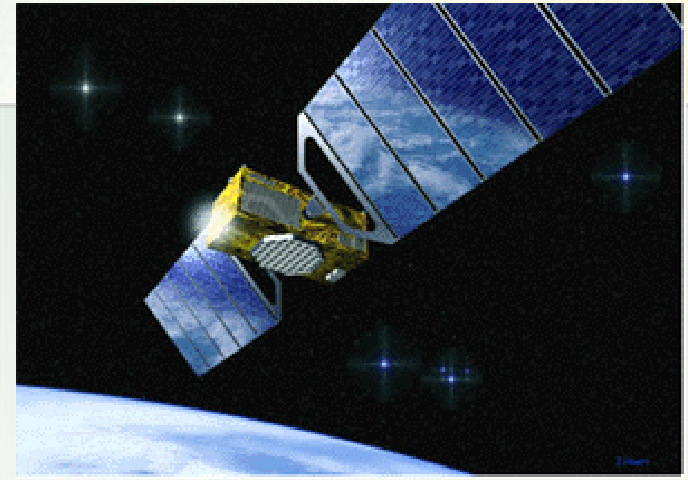
VSAT and Satellite Systems

Day 1 session 1

Basic satellite communications

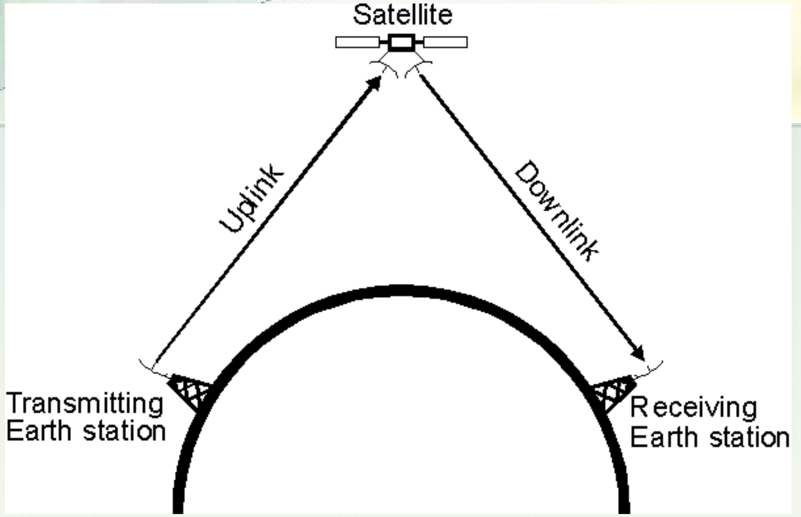
1- Birth of satellite communications

Satellites are able to fulfill a number of roles. One of the major roles is communications. A satellite enables communications to be established over large distances - well beyond the line of sight. Communications satellites may be used for many applications including provision of telephony and internet connections to remote areas of the Earth, ships, aircraft and other mobile vehicles.



1- Birth of satellite communications

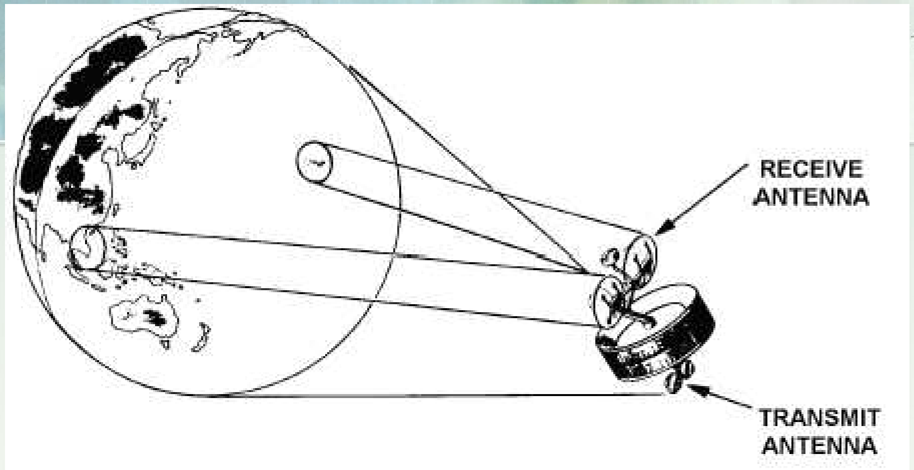
When used for communications, a satellite acts as a repeater. Its height above the Earth means that signals can be transmitted over distances that are very much greater than the line of sight. An earth station transmits the signal up to the satellite. This is called the up-link and is transmitted on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



1- Birth of satellite communications

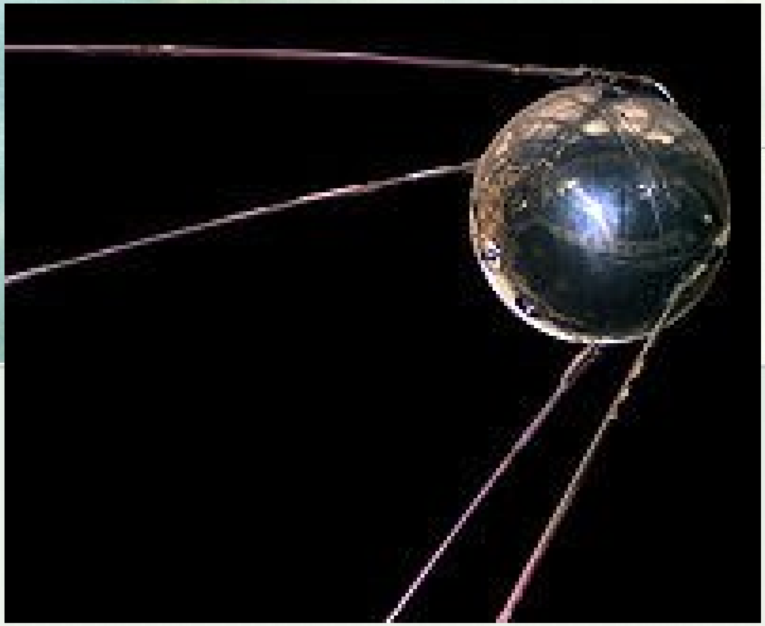
In the context of spaceflight, a **satellite** is an object that has been placed into orbit by human endeavor.

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



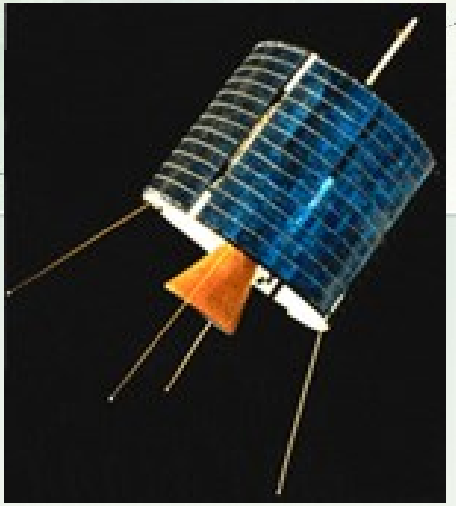
1- Birth of satellite communications

The first satellite (Sputnik 1) was launched in 1957 by Russia.



1- Birth of satellite communications

Intelsat I (nicknamed **Early Bird** from 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

- 100 satellites were launched in 2011
- 1075 satellites will be built between 2012-2021 (worth $198Bn)

1- Birth of satellite communications

Satellites Provide Some Capabilities Not EASILY Available with Terrestrial Communication Systems

- Adaptable to the needs of different customers
- Variable Information Rates
- 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

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 have 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 distant 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
- 3) There are certain satellite systems utilizing MEO which are about to be launched which will have high capacity (1.2Gb per beam), low latency (around 120 mS round trip) together with lower cost. Factors approaching 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.

- **Broadcast satellites:** broadcast television signals from one point to another (similar to communications 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 cm

- **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:**
  - 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)

1- Birth of satellite communications

Satellite applications

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
- Data to handhelds

GPS/Navigation

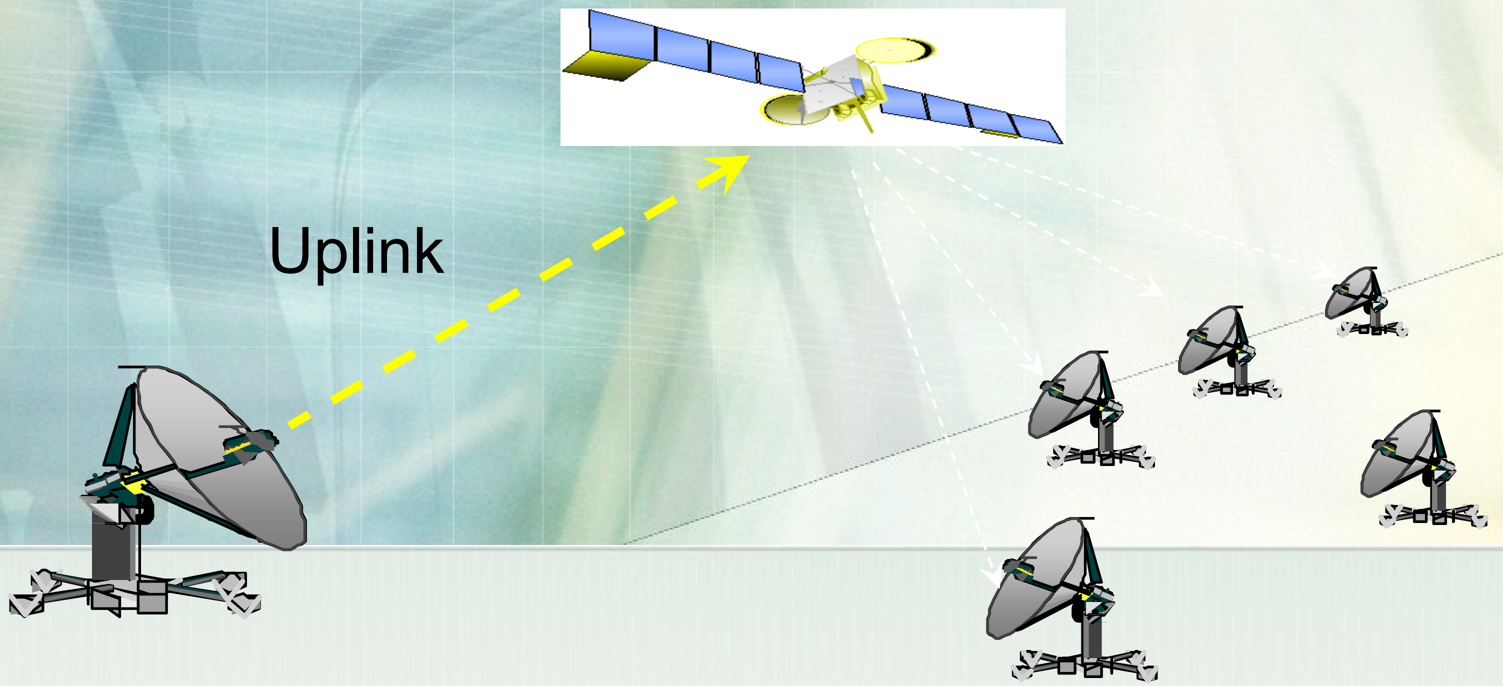
- Position Location
- Timing
- Search and Rescue
- Mapping
- Fleet Management
- Security & Database Access
- Emergency Services

Remote Sensing

- SCADA (e.g. **Pipeline Monitoring)**
- Infrastructure Planning
- Forest Fire Prevention
- Urban Planning
- Flood and Storm watches
- Air Pollution Management
- Geo-spatial Services

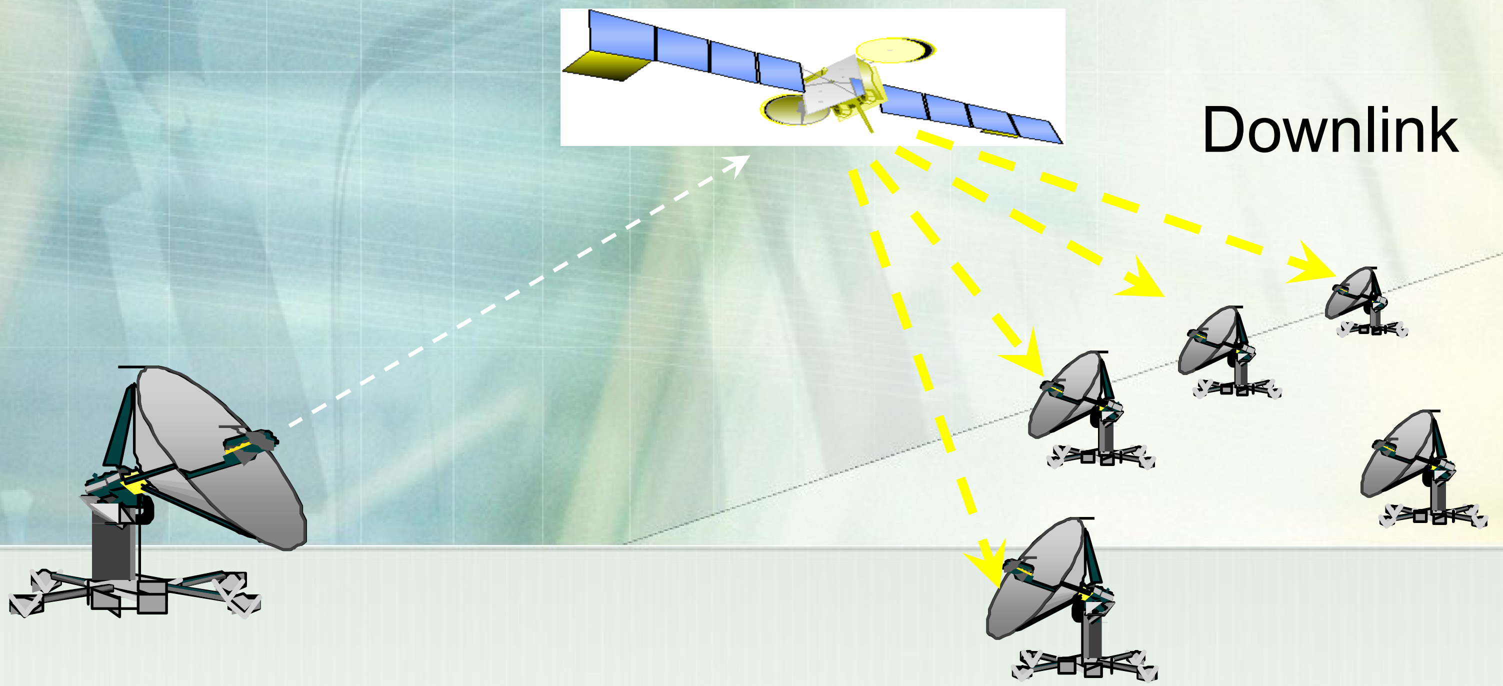
2- Communications links

Uplink



Uplink - The transfer of information to the satellite

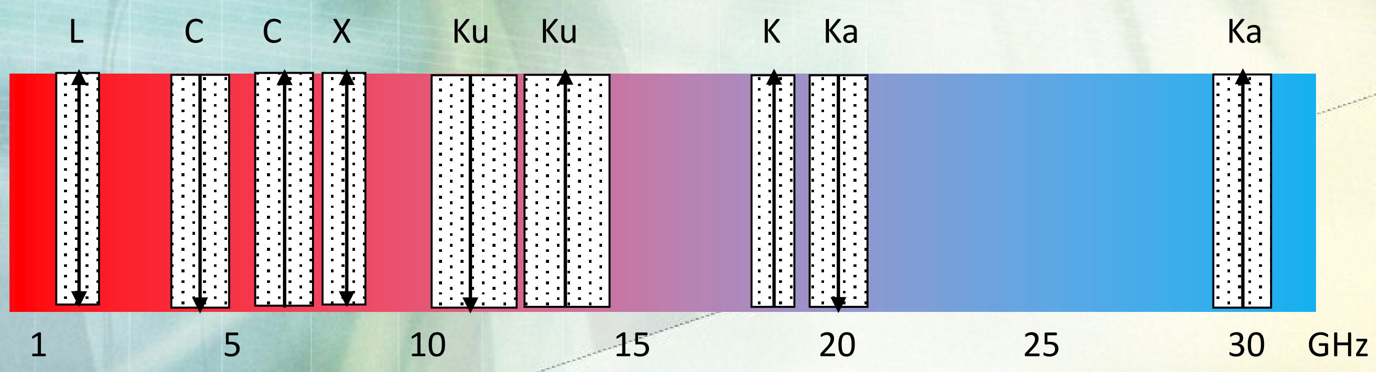
2- Communications links
Downlink



Downlink - The transfer of information from the satellite

2- Communications links

Frequency spectrum



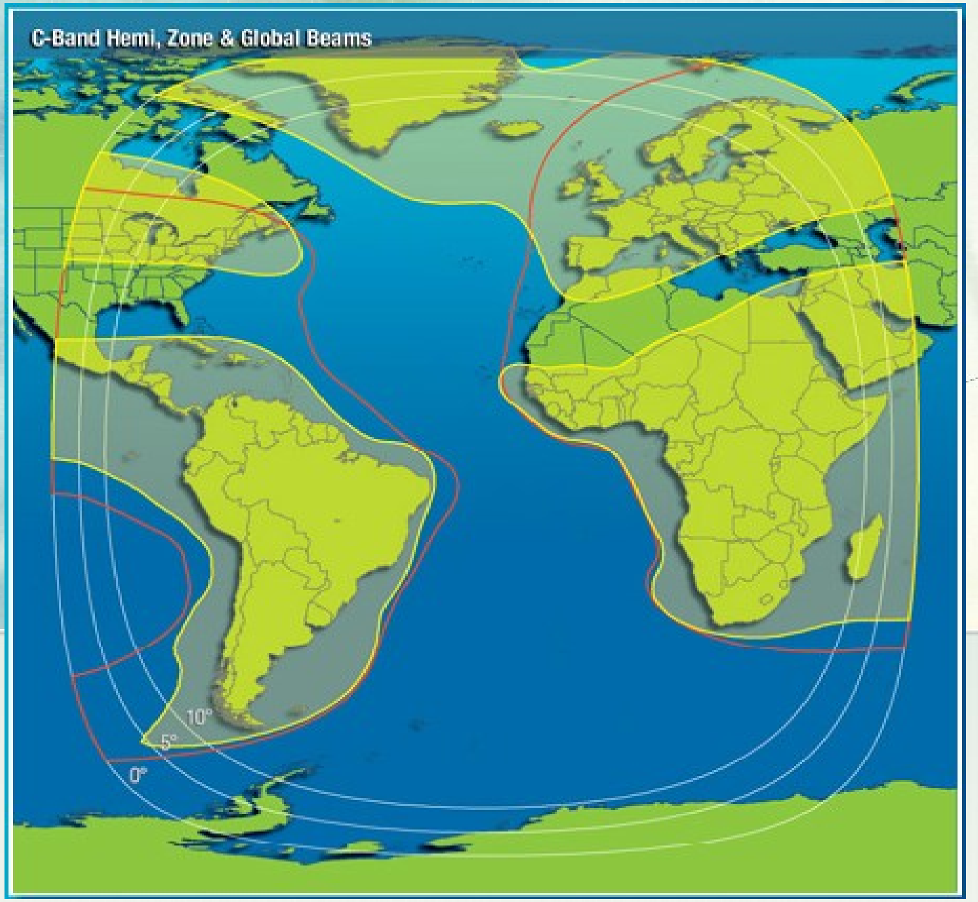
2- Communications links

Satellite bands

Band	Uplink	Downlink
C-Band	5850-7025	3400-4800
X-Band	7900-8400	7250-7750
Ku-Band (non std)	12750-13250	10700-12750
Ku-Band	13750-14500	10700-12750
DBS	17300-18400	11700-12750
K/Ka	29000-31000	19000-21000

2- Communications links

Uplinks and Downlinks



- Can be different footprints for uplink and downlink
- Sometimes different bands

3- Space segment

Payload and bus

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- Space segment

Transponder

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- Space segment
Transponder

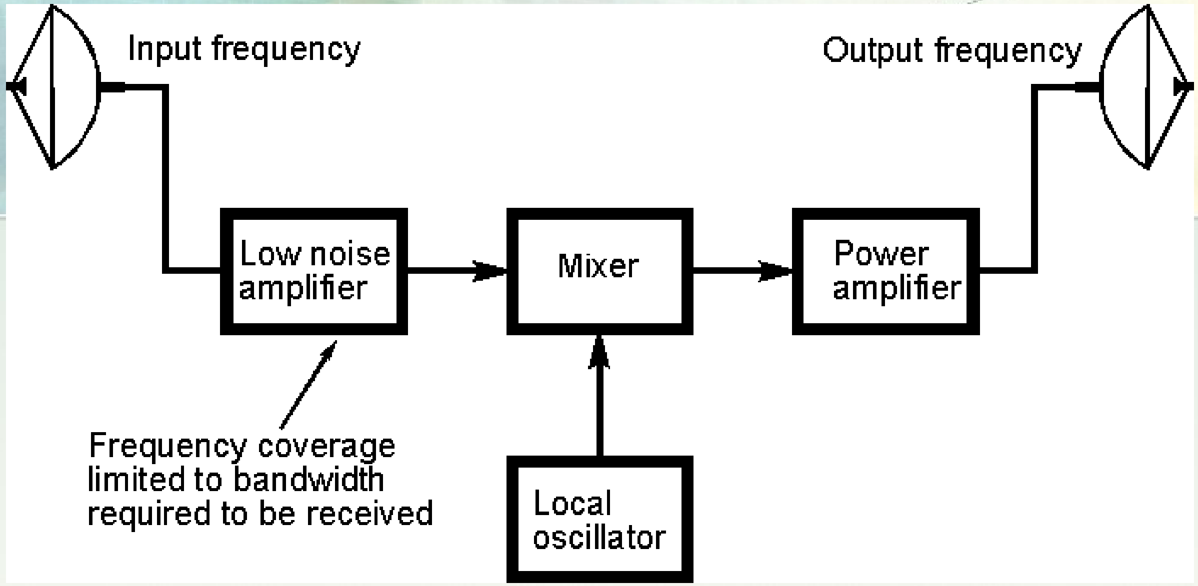
This basically consists of a low noise amplifier, a frequency changer (consisting of a mixer and local oscillator), and then a high power amplifier. The filter on the input is used to make sure that any *out of band* signals such as the transponder output are reduced to acceptable levels so that the amplifier is not overloaded.

Similarly the output from the amplifiers is filtered to make sure that spurious signals are reduced to acceptable levels.

Some modern satellites demodulate the signals and the route them internally for retransmission.

3- Space segment
Transponder

In view of the fact that the receiver and transmitter are operating at the same time and in close proximity, care has to be taken in the design of the satellite or the receiver may become de-sensitised by the strong signal being received from the transmitter.



3- Space segment

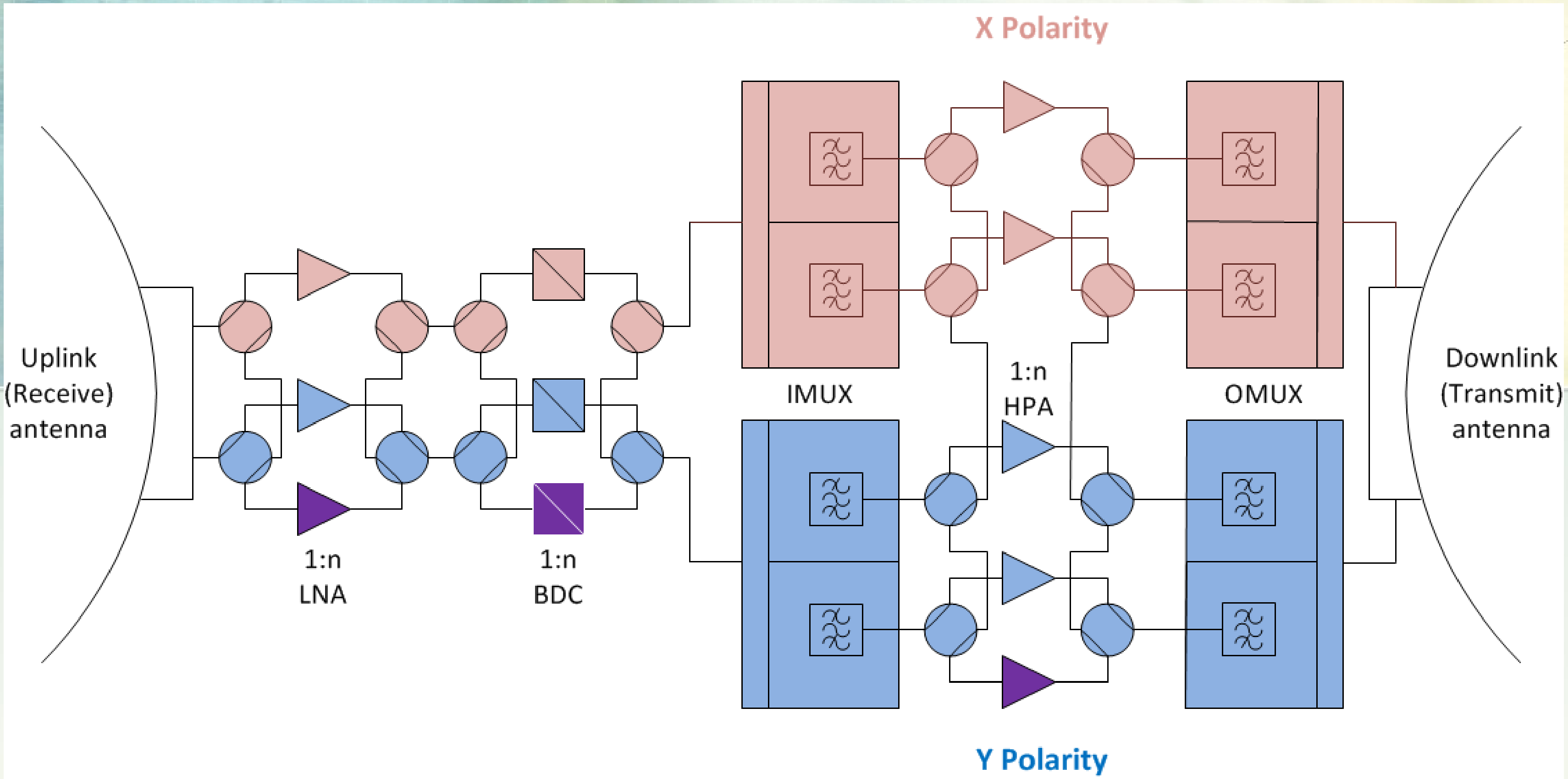
Transponder

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

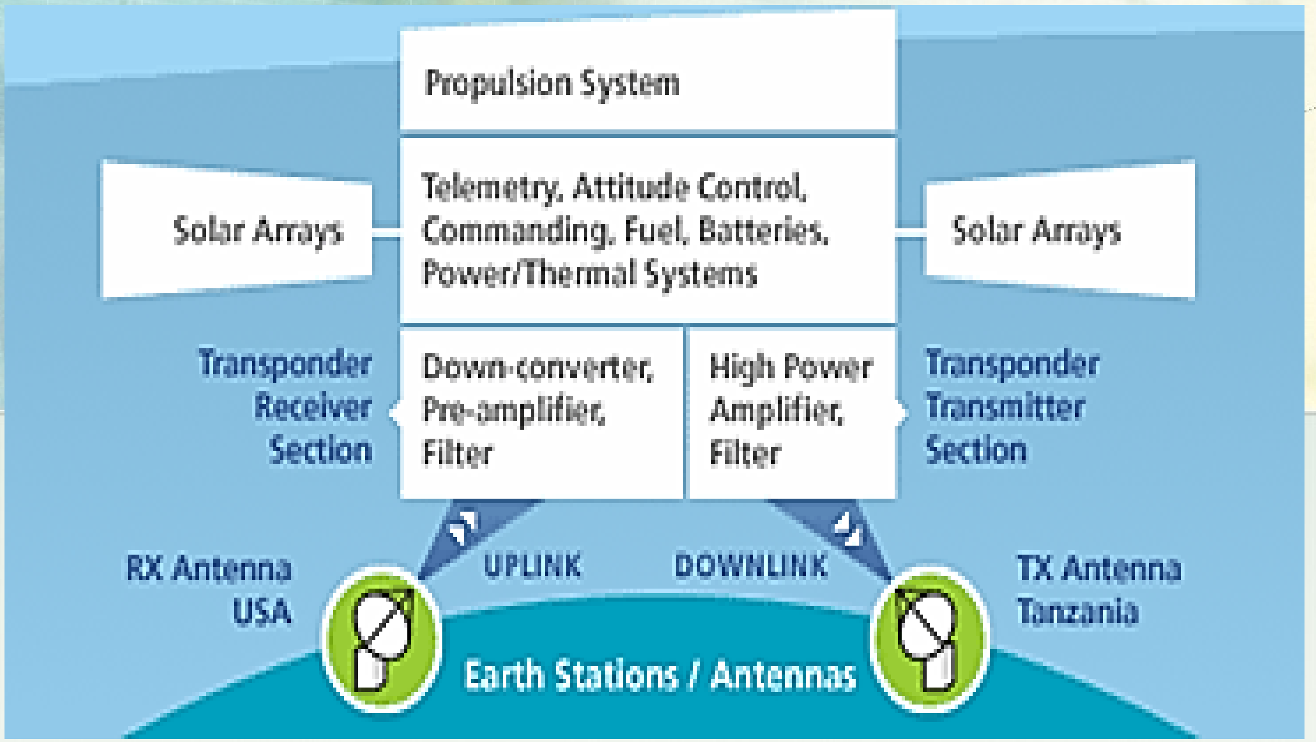
With this immense capacity, today's communication satellites are an ideal medium for transmitting and receiving almost any kind of content - from simple voice or data to the most complex and bandwidth-intensive video, audio and Internet content.

3- Space segment

Payload



Diagrammatic Representation of a Satellite



3- Space segment
Electrical power

Electrical power is derived from PV solar panels with batteries providing the power when the spacecraft is in ECLIPSE (not in view of the sun)

Modern communications satellites have about solar cells mounted on extendable arms , providing about 14kW of power.

3- Space segment

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.

Altitude 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 and solar winds.

3- Space segment

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.

Infrared sensors, referred to as *horizon detectors*, are used to detect the rim of the earth against the background of space. With the use of four such sensors, one for each quadrant, the center of the earth can be readily established as a reference point.

Any shift in orientation is detected by one or other of the sensors, and a corresponding control signal is generated which activates a restoring torque.

3- Space segment
Orbital control

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

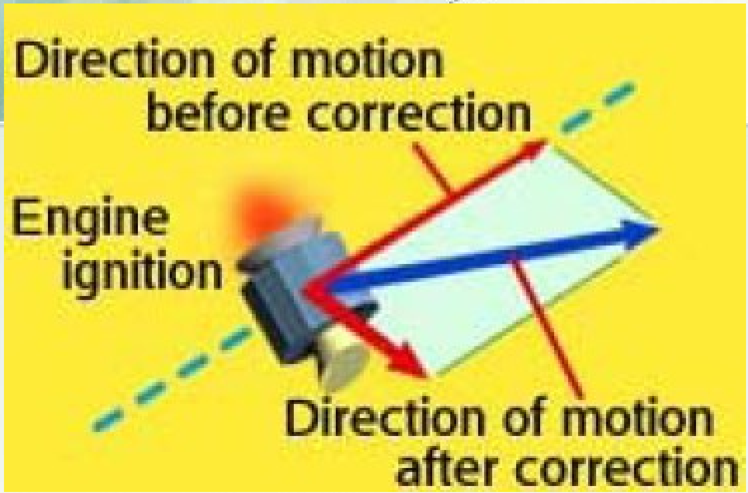
The equatorial ellipticity of the earth causes geostationary satellites to drift slowly along the orbit, to one of two stable points, at 75°E and 105°W.

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.

This results in the satellite drifting back through its nominal station position, coming to a stop, and recommencing the drift along the orbit until the jets are pulsed once again.

3- Space segment
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."

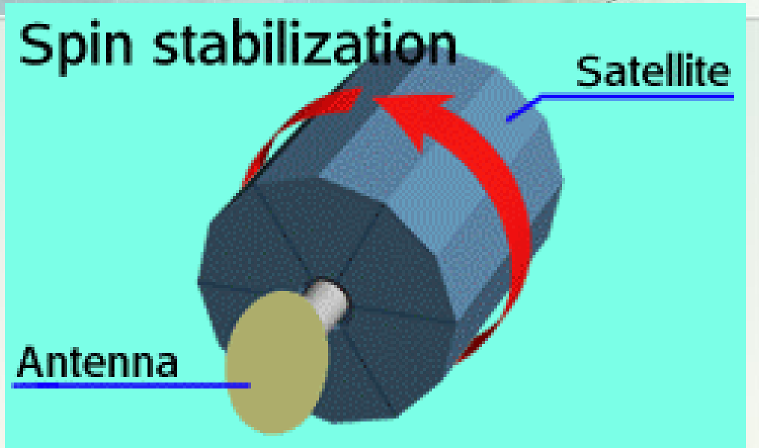


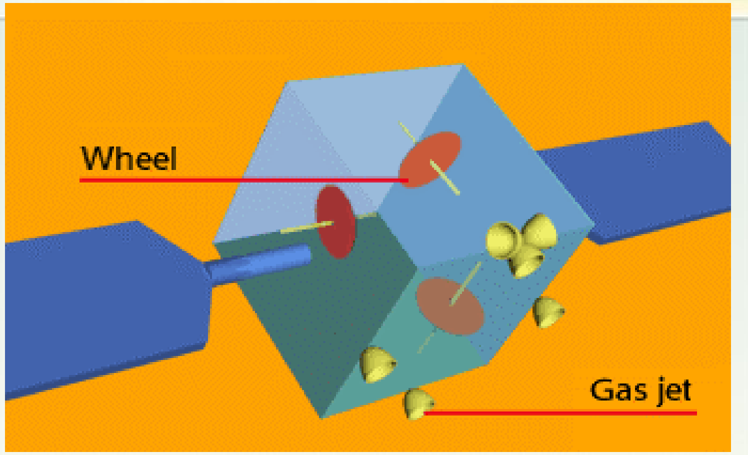
3- Space segment

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 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- Space segment
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.

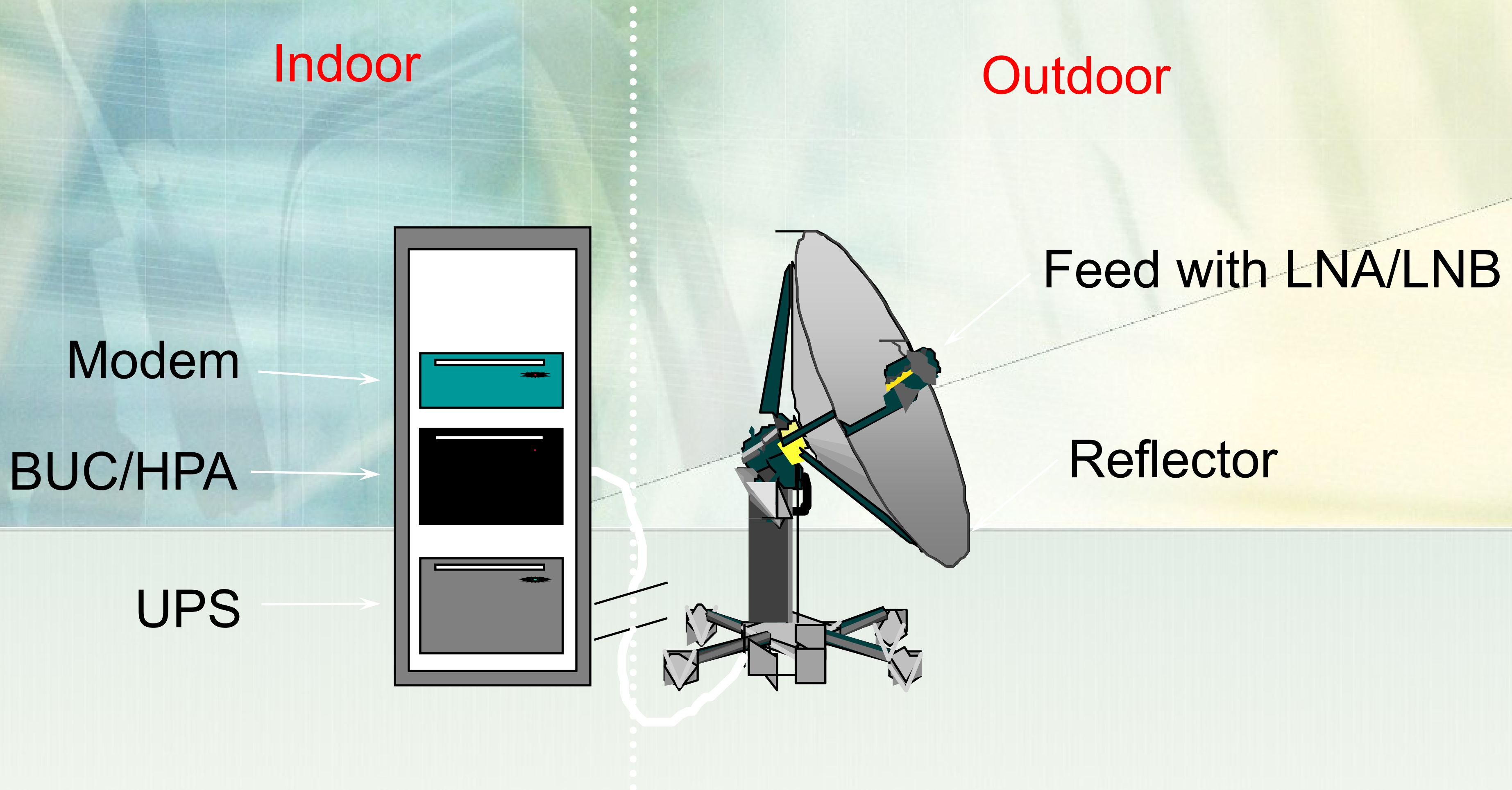
3- Space segment

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.

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.

4- Ground segment
Components



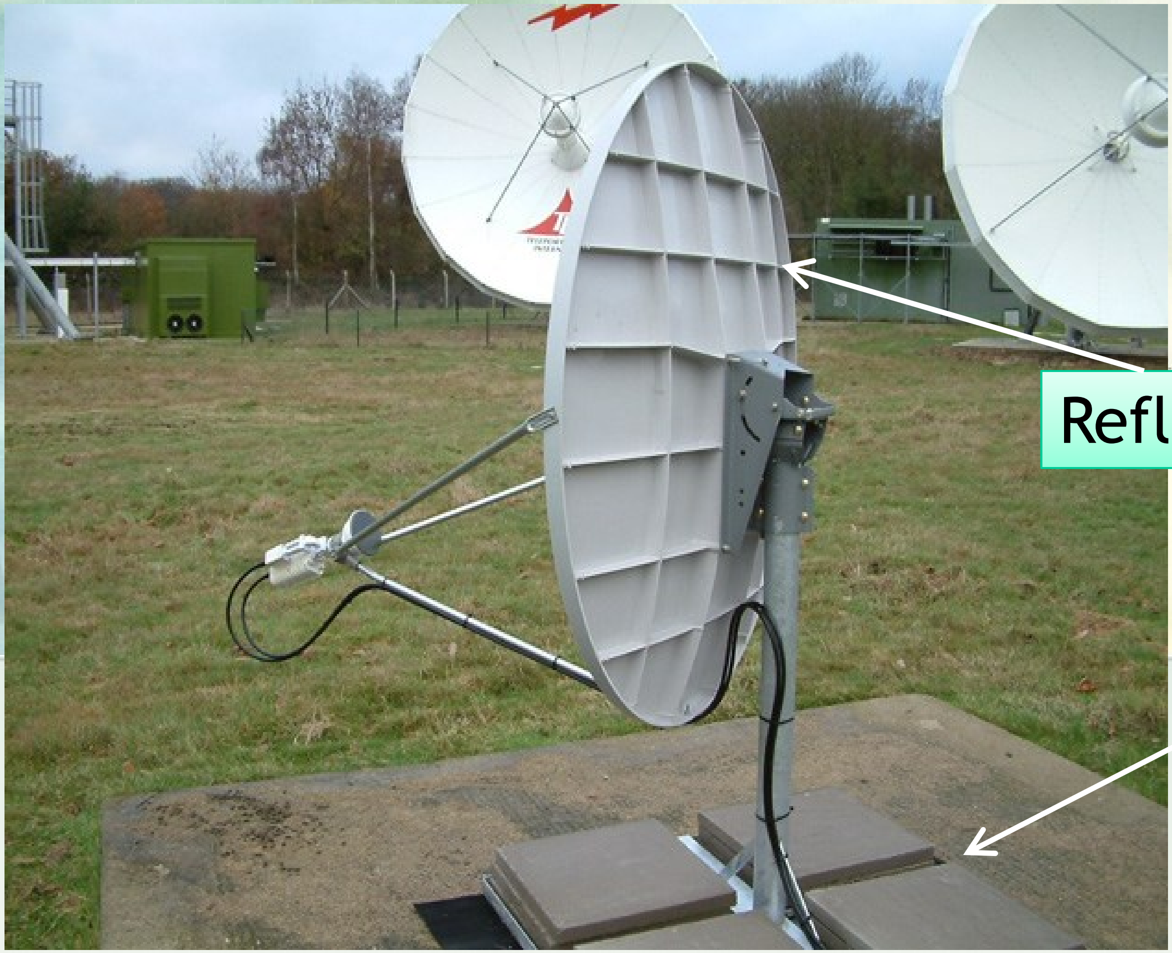
4- Ground segment
Components

- UPS / Power – Un-interruptible Power Supply – protected ac power supply
- Modem – Adds Forward Error Correction (FEC) to the data and modulates an IF signal (and performs reverse function on receive)
- Block Up Converter (BUC) – Converts the IF signal from the modem to the final transmit frequency
- High Power Amplifier (HPA) –Boosts the microwave signal to a suitable level for onward transmission to the satellite

4- Ground segment
Components

- Mount – Used to hold the antenna stable under all weather conditions
- Reflector -Focuses receive signal into the feed horn and focuses the transmission signal from the feed horn towards the satellite
- Feed horn –Connects receive signals into the LNB and radiates transmit signals to the reflector
- Low Noise Amplifier (LNA) – Receives and amplifies the signal from the satellite
- Low Noise Block converter (LNB) – Receives and amplifies the signal from the satellite then downconverts it to L-band (950-2150 MHz)

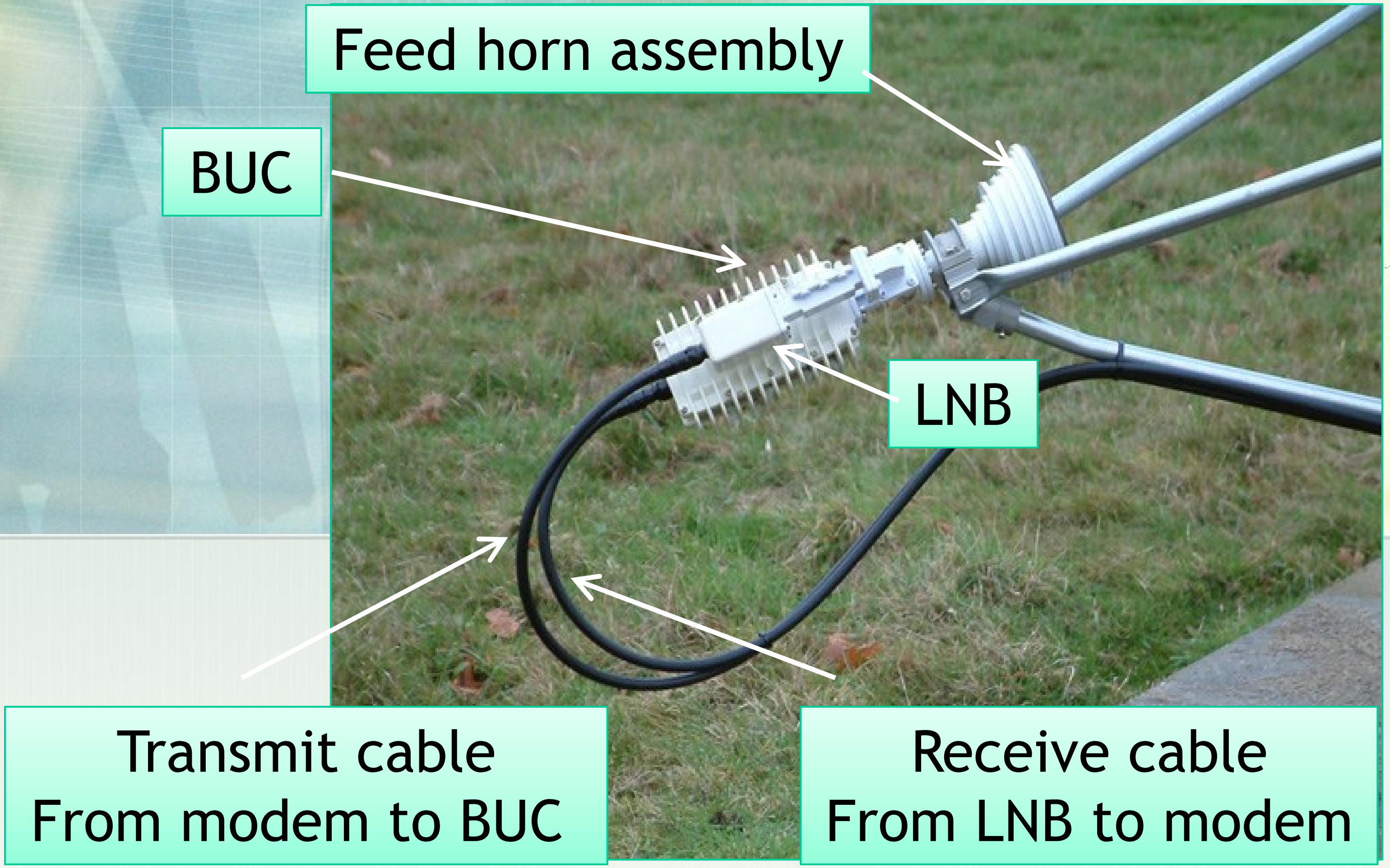
4- Ground segment
Components



Reflector

Ground Mount with weights

4- Ground segment
Components



4- Ground segment

VSAT vs Major Earth Station

- 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 ranges from 3.7M to 16M+
- Basically same components in each
- Supports multiple services
- All components redundant
- Can transmit and receive in both polarisations
- Usually configured with large RF power amplifiers
- Always connected to protected Power supplies
- Usually connected to multiple terrestrial paths

4- Ground segment
Large antenna

Pros

- Less co-satellite interference
- Improved G/T (receive sensitivity)
- Reduced space segment costs
- Smaller HPA

Cons

- Narrow beamwidth requires more accurate pointing
- Planning consent
- Civil engineering

4- Ground segment
Large antenna

4- Ground segment
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
- Preferably to more than a single fibre supplier

4- Ground segment
Teleport

4- Ground segment

Permission to install and operate

- 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?

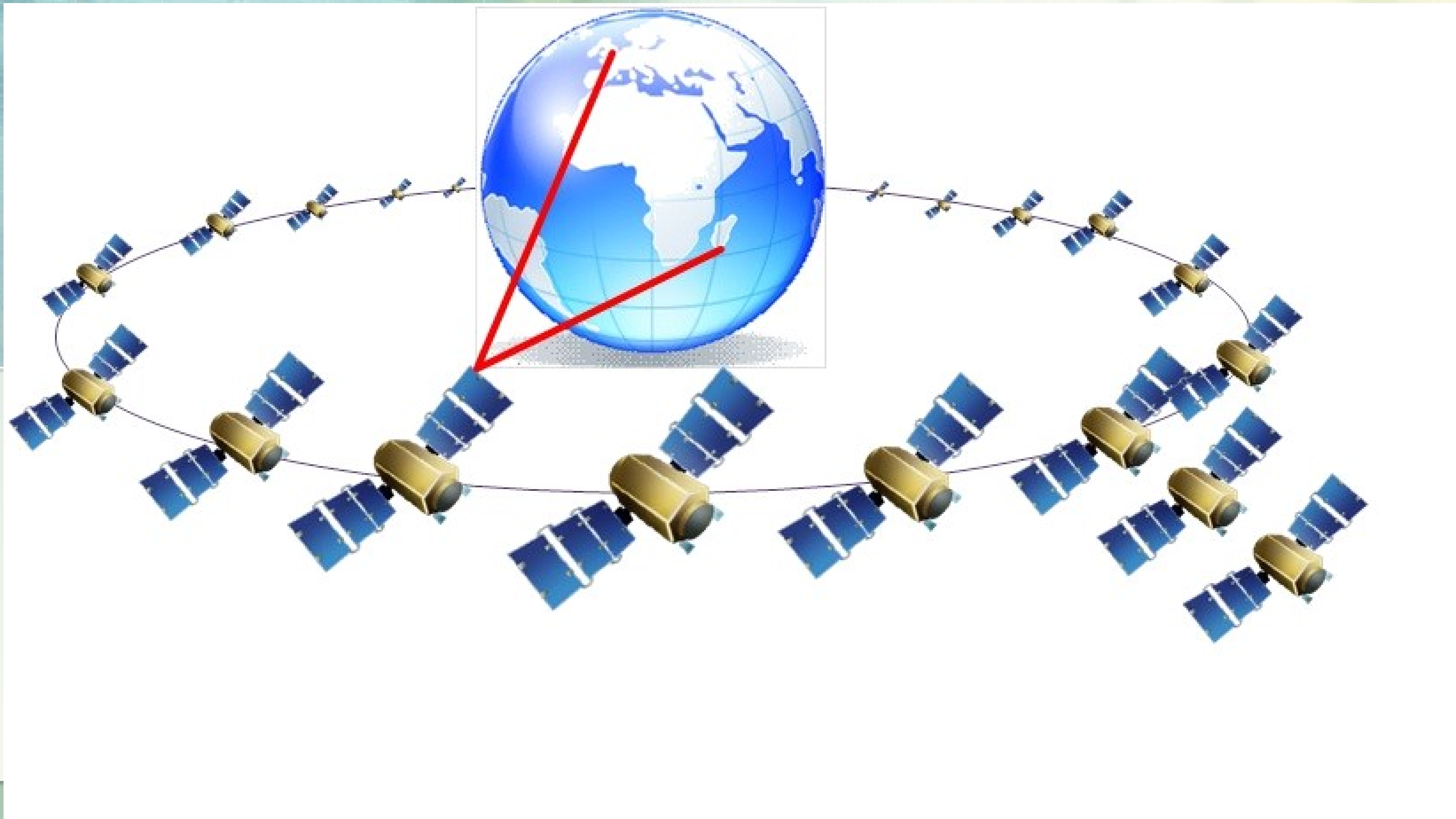
5- Satellite orbits

Geosynchronous Orbit (GEO)

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 trip around the globe. 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.

5- Satellite orbits

Geosynchronous Orbit (GEO)



5- Satellite orbits

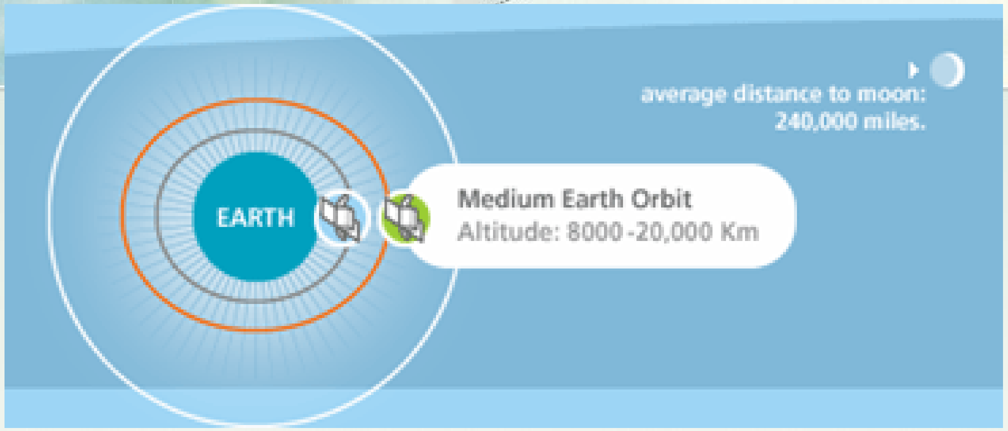
Geosynchronous Orbit (GEO)

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

5- Satellite orbits

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

- These orbits can be used 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



5- Satellite orbits

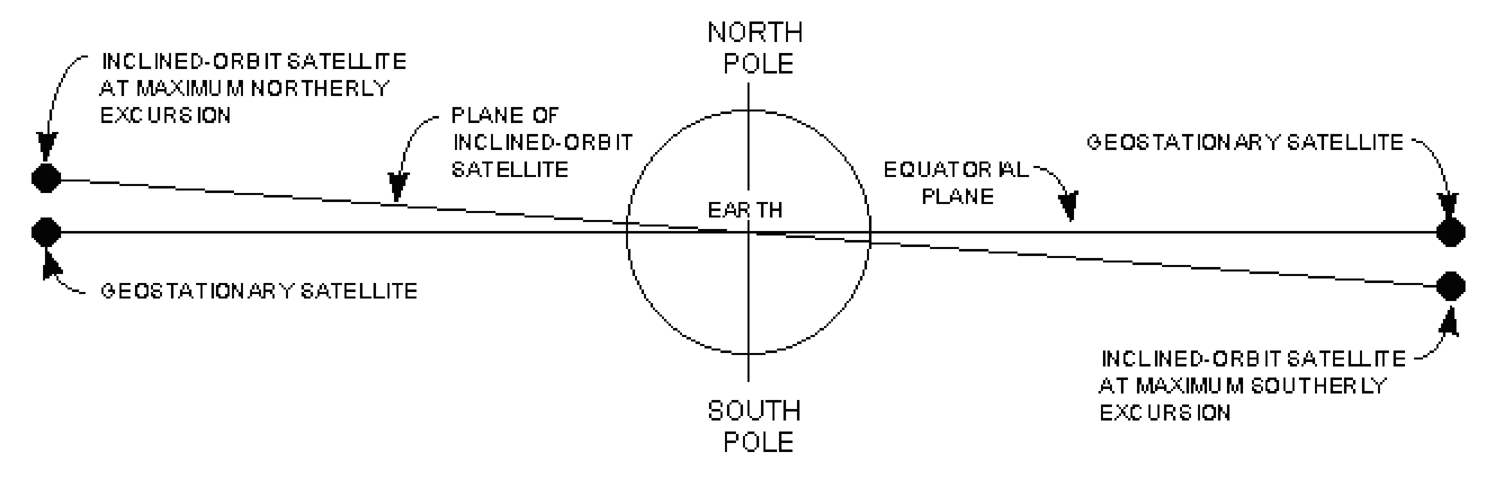
Low Earth Orbit (LEO): 500-2,000 km above the earth

- 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

5- 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.



5- Satellite orbits

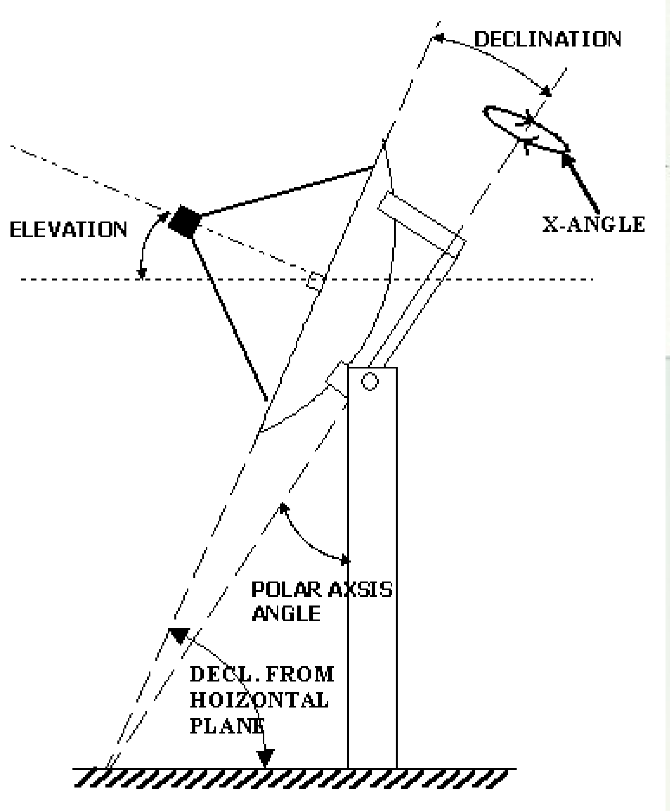
Inclined orbits

With some old satellites the lifetime can be prolonged to around 15 years by saving fuel for orbital north/south maneuvers which result the satellite drifting in the Latitude. In the extreme some satellites is 15 degrees inclined which means they moves inside a +/-15 degree box not a +/-0.03 degree box.

5- 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.



5- Satellite orbits

Inclined orbits (Implications for earth station inclination tracking)

- To avoid loss of service, the earth stations need to track the satellite following the daily sinusoidal movements.
- If you are located on the same longitude as the satellite the north-south daily movement will be up and down.
- If you are on the equator then all the satellites are in a straight line across the sky from east to west, via directly overhead and North-south movement of all these satellites will be a sideways movement.
- Anywhere else and you have daily diagonal movements to contend with, which means using two motors for an azimuth-elevation mount or a declination only motor on a polar mount dish.

5- Satellite orbits

Inclined orbits (Implications for earth station inclination tracking)

Due to the problems with tracking and the uncertainty of operation of old satellites that have exceeded their regular life, the prices charged for satellite transponder capacity are lower.

6- Satellite Systems

Purchasing capacity

- Satellite operators supply capacity as a lease in terms of bandwidth (MHz). The user can occupy the lease within the limits of a contracted “Power Equivalent Bandwidth” (PEB).
- A lease will be on a given transponder (or transponders) covering a specific footprint.
- Some transponders can be inter-connected to permit links between differing footprints.
- An alternative method of purchasing capacity is “throughput” from an IP Hub.
- Leases can be for any duration although long term leases tend to be more cost effective.

6- Satellite Systems

Satellite Operators

- Today there over 30 satellite operators in the world some having fleets of over 50 satellites
- Most large operators have the ability to transfer traffic to another satellite should there be a catastrophic failure
- Many large operators offer a choice of bands on a given satellite
- Many operators also own Teleports and provide hosting and facilities management for clients
- Some larger operators have Hubs and sell Internet capacity
- Many operators assist with identifying sources of interference
- Most operators have passed their antenna type approvals to third party approvals organisations