# Session 1

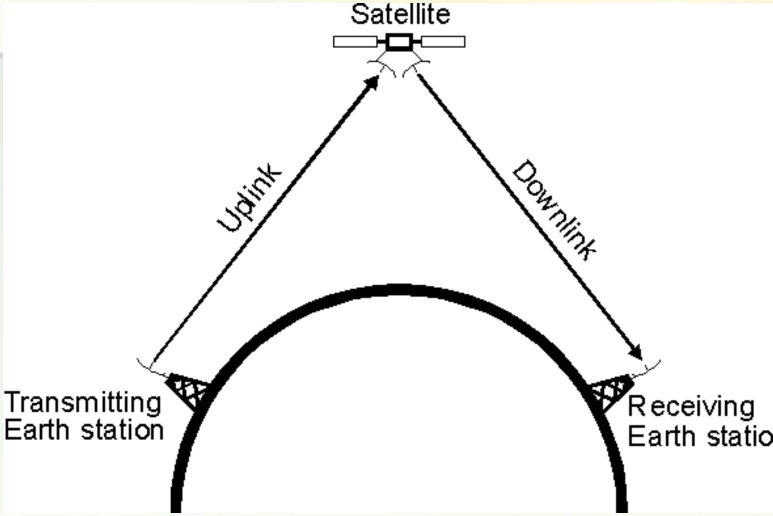
Satellite Technology and Satellite Communications Systems

# 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

## 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
- Variable (Information Rates) Data Speeds

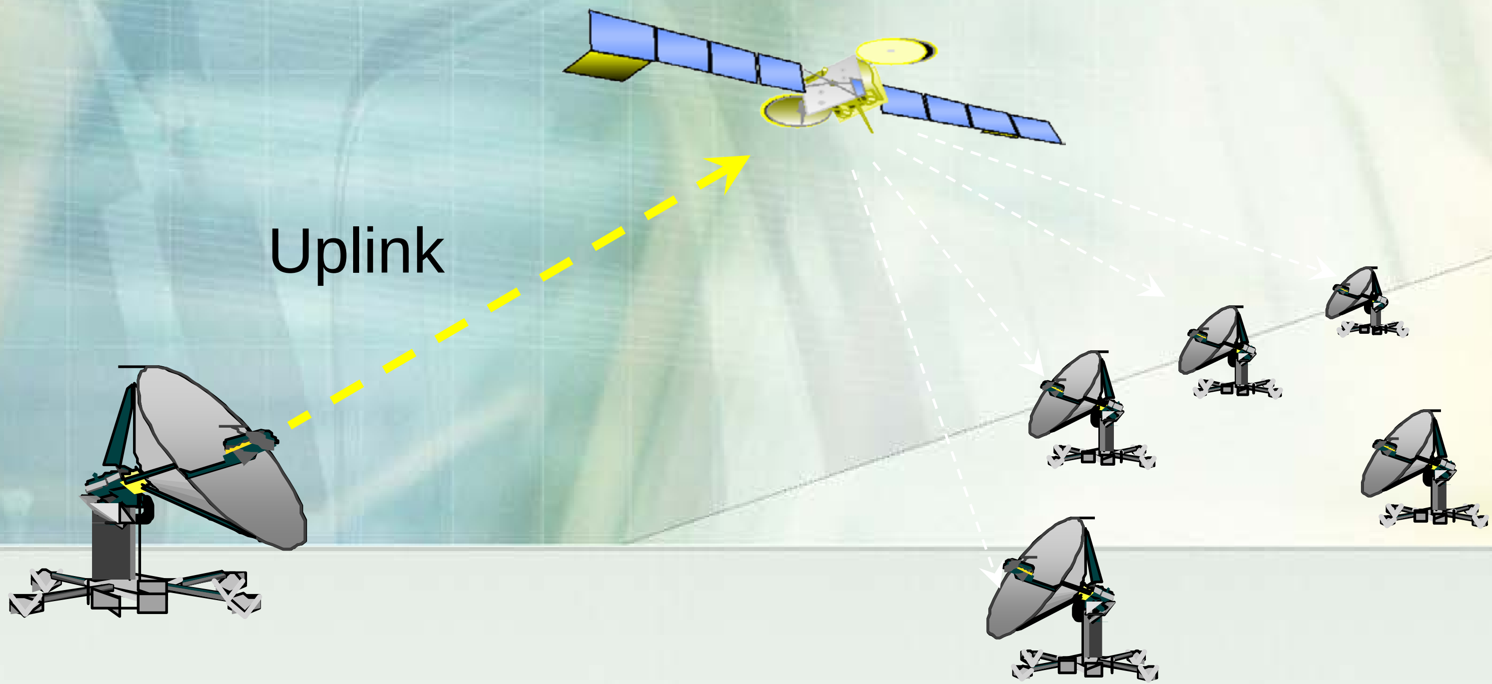
# 1- Birth of satellite communications

## Interest of satellites

Satellites are complementary to cable for the following reasons:

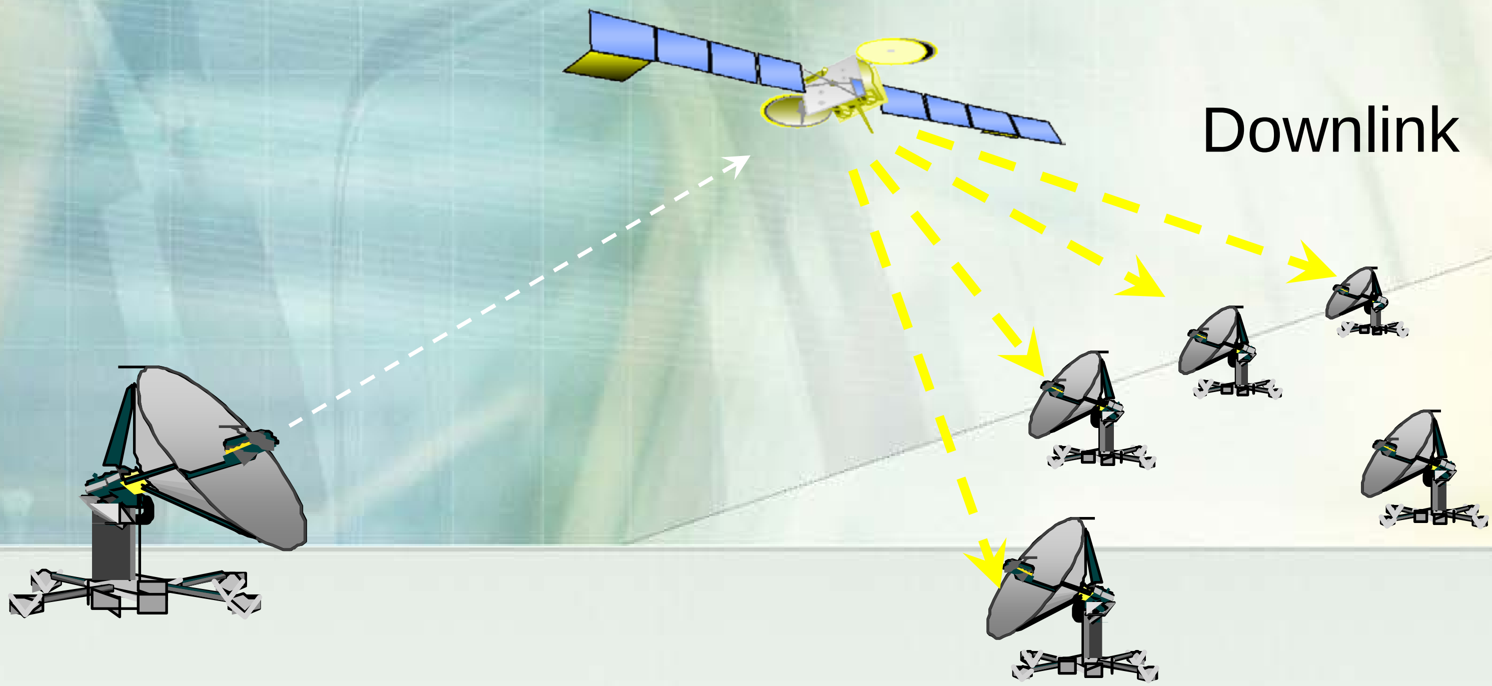
- 1) Submarine cables (and landline fibre) are subject to cuts. Satellites provide an excellent means of back-up and should always be considered in any national plan as a means of resilience and network security
- 2) Although a lot of countries are getting access to fibre, they have problems distributing 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
- 3) There are certain satellite systems utilizing MEO which are about to be launched which will have both high capacity (1.2Gb*ps* per beam) and quality (low latency of 120 ms round trip) and cost ($750 per Mb*ps* per month) factors that approach that of submarine cable.

# 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

# 3.2- The space segment

TRANSPONDER

The circuitry in the satellite that acts as the receiver, frequency changer, and transmitter is called a transponder.

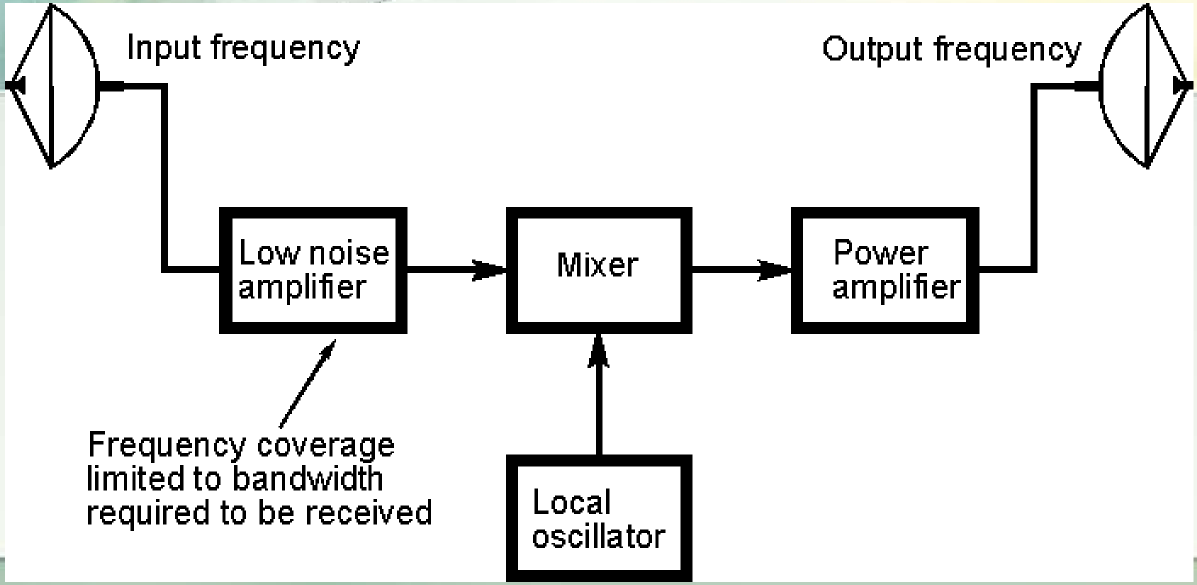
This basically consists of a low noise amplifier, a frequency changer consisting a mixer and local oscillator, and then a high power amplifier. The filter on the input is used to make sure that any out of band signals such as the transponder output are reduced to acceptable levels so that the amplifier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

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

# 3.2- The 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 that the transmitter does not interfere with the receiver. This might result from spurious signals arising from the transmitter, or the receiver may become de-sensitised by the strong signal being received from the transmitter. The filters already mentioned are used to reduce these effects.



# 3.2- The space segment

## Satellite design (electrical power)

## 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 (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, 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.

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.

## 3.2- 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.

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.

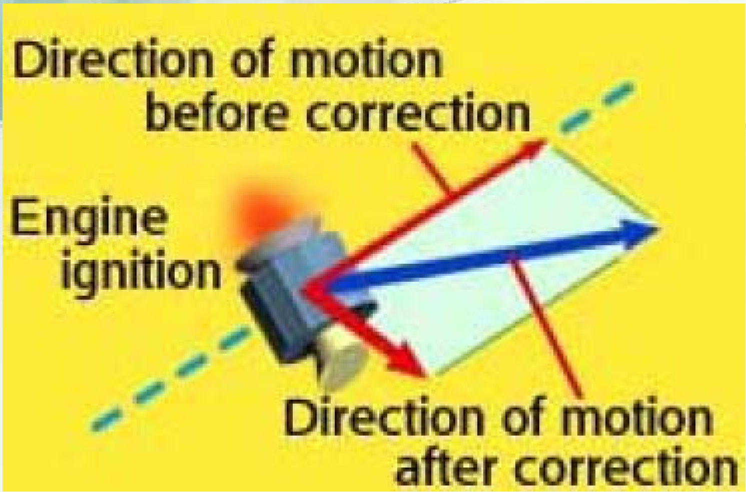
## 3.2- The space segment

## Satellite design (Orbital control)

Orbital correction is carried out by command from the TT&C earth station, which monitors the satellite position. East-west and north south station-keeping maneuvers are usually carried out using the same thrusters as are used for attitude control.

## 3.2- The space segment
## Satellite design (Orbital control)

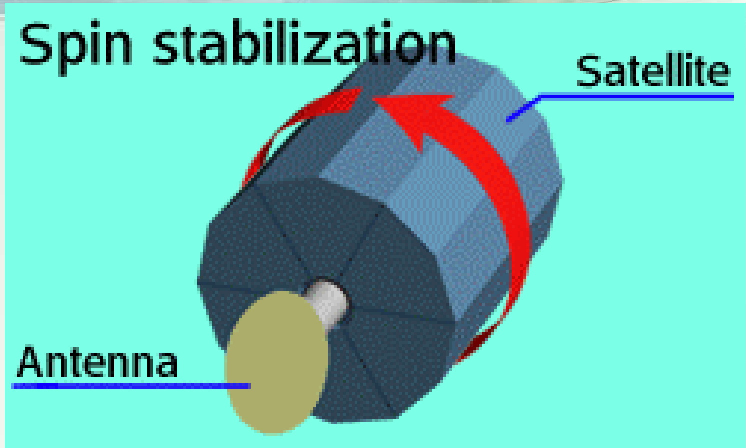
In order for a geostationary communications satellite to continue to function, it must remain stationary with respect to all the earth station antennas that are pointed at it. To correct for the orbital fluctuations that all satellites are subject to, each satellite carries a thrust subsystem to give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

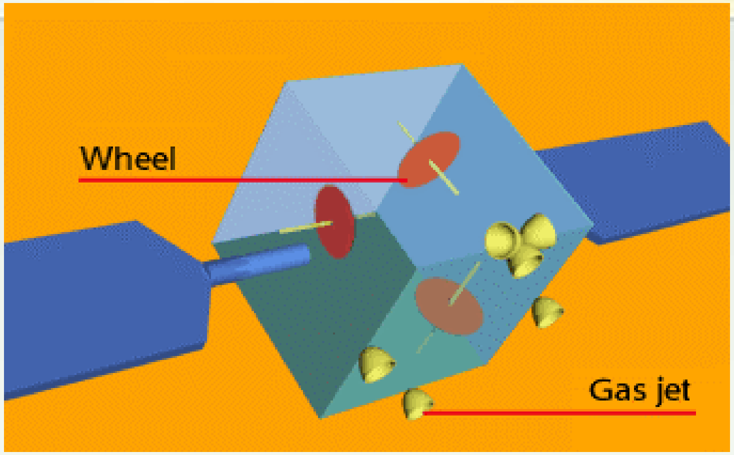


## 3.2- The space segment
## Satellite design (Orbital control)

Remaining on-station is only half the battle. Additionally, the satellite's antennas must always be aimed at the same spot on the 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



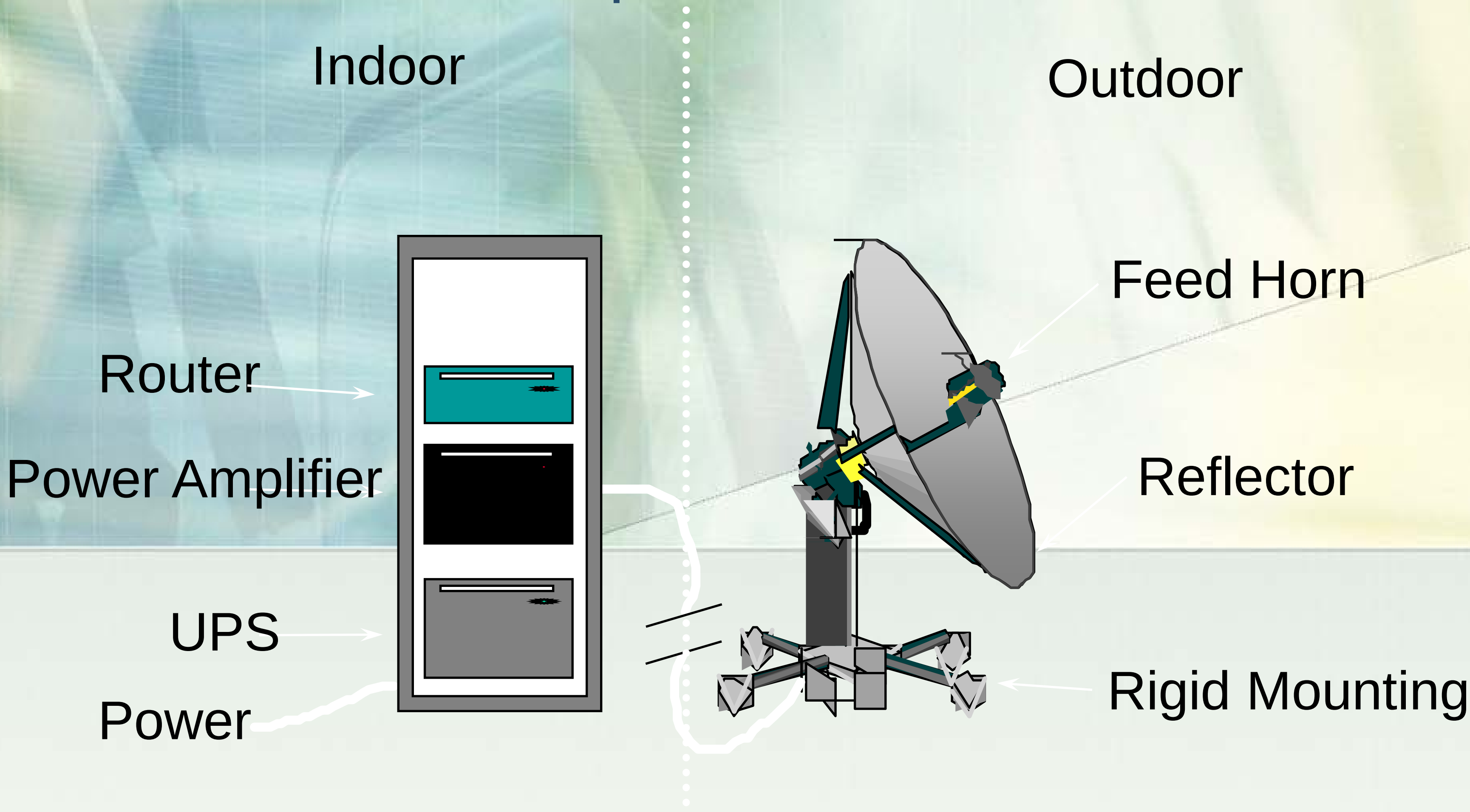



## 3.3- The ground segment

- Earth station components
- Factors governing antenna sizes
- The differences between a major earth station and a VSAT
- Permissions required to install and operate a VSAT / Earth station

# 3.3- The ground segment

## Earth Station Components



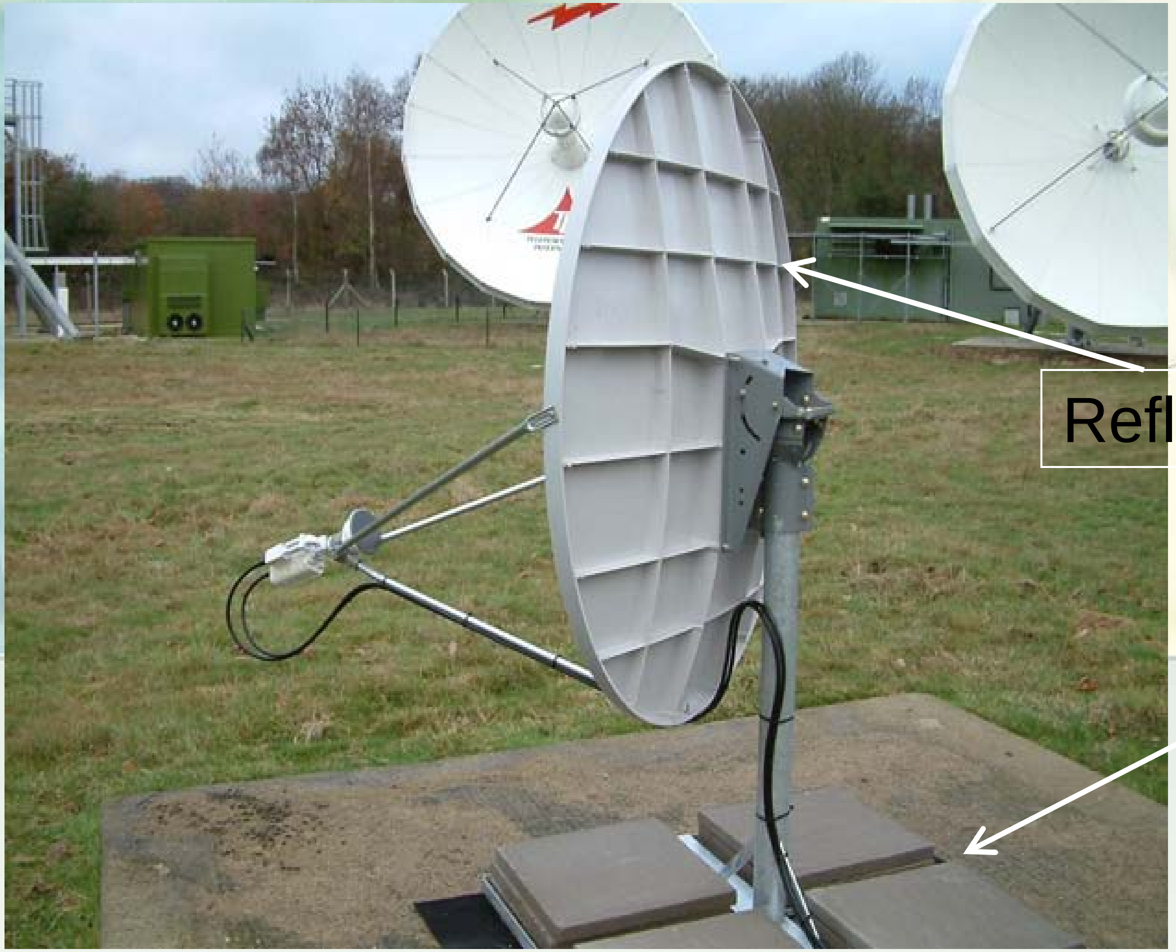

**Earth Station Components – generic simplified diagram**

# 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

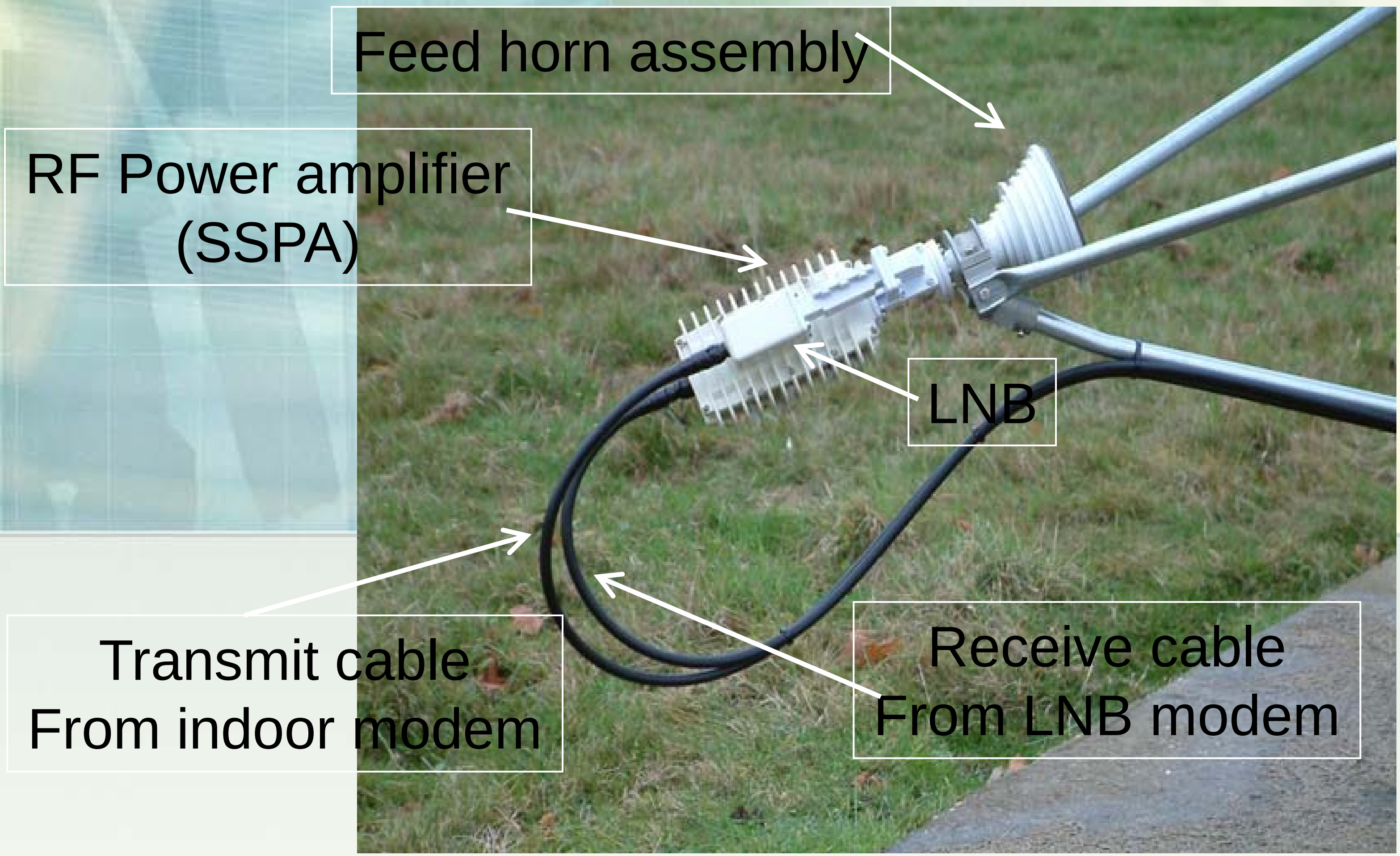
# 3.3- The ground segment
## Earth Station Components



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
  - ✓ Link budget requirement
  - ✓ Cost factors
    - – Larger antenna may be less than the cost of a lease with a smaller antenna

## 3.3- The ground segment

Factors governing Reflector sizes (2)

- Receiving:
  - ✓Antenna Gain dictated by the Link Budget
  - ✓Large earth station can receive a weaker signal than the equivalent small antenna
  - ✓Cost implications with the Link Budget
  - ✓Planning permission

    e.g. Europe 0.9M is the minimum size

## 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+ weighing 20 T or mo re costing $1M+
- Basically same components in each
- 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

# 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- Orbital positions and radio interferences

## LICENSING

The ITU Member States have established a legal regime, which is codified through the ITU Constitution and Convention, including the Radio Regulations. These instruments contain the main principles and lay down the specific regulations governing the following major elements:

- frequency spectrum allocations to different categories of radio communication services;
- rights and obligations of Member administrations in obtaining access to the spectrum/orbit resources;
- international recognition of these rights by recording frequency assignments and, as appropriate, orbital positions used or intended to be used in the Master International Frequency Register.

# 5- Orbital positions and radio interferences

## LICENSING

The above regulations are based on the main principles of efficient use of and equitable access to the spectrum/orbit resources laid down in No. 196 of the ITU Constitution (Article 44), which stipulates that *"In using frequency bands for radio services, Members shall bear in mind that radio frequencies and the geostationary-satellite orbit are limited natural resources and that they must be used rationally, efficiently and economically, in conformity with the provisions of the Radio Regulations, so that countries or groups of countries may have equitable access to both, taking into account the special needs of the developing countries and the geographical situation of particular countries".*

# 5- Orbital positions and radio interferences

EARTH STATION AND VSAT REGISTRATION

The ITU controls frequency allocations, permitted power levels and modes of operation. These restrictions are intended primarily to prevent interference between all types of systems employing radio communications and to protect some telecommunications services, such as emergency services.

In addition to that, many governments currently impose restrictions and regulations on service providers and users. These national regulations are specific to each particular country.

## 5- Orbital positions and radio interferences

EARTH STATION AND VSAT REGISTRATION

Due to the increasing uptake of sophisticated telecommunications systems, that are sold and used in all countries, the licensing regime for end-user equipment (such as VSAT terminals) is becoming simpler and less costly.

You will find the procedures and regulations that rule the installation and operation of VSAT terminals in regulatory agencies in the countries or on ITU web site.

# 5- Orbital positions and radio interferences

## EARTH STATION AND VSAT REGISTRATION

A licence is required by the national telecommunications authority of a country where any earth station as a part of a network, be it the hub, a control station or a VSAT, is planned to be installed and operated.

The concern reflected here is to ensure compatibility between radio networks by avoiding harmful interference between different systems.

By doing so, any licensed operator within a certain frequency band is recognized as not causing unacceptable interference to others, and is protected from interference caused by others.

In the past, national telecommunication authorities have required licensing of individual VSAT terminals in addition to requiring a network operator's license. Then, the US Federal Communication Commission (FCC) implemented with success a *blanket licensing* approach for VSATs operated within the US.

# 5- Orbital positions and radio interferences

EARTH STATION AND VSAT REGISTRATION

With blanket licensing, VSATs are configured based upon technical criteria (power level, frequency, etc.) to eliminate the risk of interference, so a single license can be issued covering a large number of VSAT terminals.

Blanket licensing has since gained interest among national telecommunications authorities all over the world, as a result of equipment manufacturers complying with the recommendations issued by international standardization bodies, such as the International Telecommunication Union (ITU) and the European Telecommunications Standard Institute (ETSI). Relevant documentation from these bodies is available at http://www.itu.int/home/index.html and http://www.etsi.org/.

# 5- Orbital positions and radio interferences

## EARTH STATION AND VSAT REGISTRATION

A licence usually entails the payment of a licence fee, which is most often in two parts: a one-time fee for the licensing work and an annual charge per station.

The licensing procedure is simpler when the network is national, as only one telecom authority is involved.

For transborder networks, licences must be obtained from the different national authorities where the relevant earth stations are planned to be installed and operated, and rules often differ from one country to another. To facilitate the access to these rules, telecommunications authorities around the world have begun posting data related to their nations’ VSAT regulatory conditions on the World Wide Web.

# 5- Orbital positions and radio interferences

## INTERFERENCE BETWEEN C-BAND AND WIMAX

The "extended" C band frequencies (3.4 to 3.7 GHz) have already been identified by several national administrations for use by new services like Broadband Wireless Access (BWA) and WiMax.

In addition, other administrations are looking to deploy these new terrestrial services in the "standard" C band frequencies (3.7 to 4.2 GHz). In countries where WiMax services have been introduced, there have been significant in-band and out-of-band interference issues and services interruptions for satellite ground stations and their related services.

Where some other interferences may occur, it is important to do electromagnetic survey before installation and make sure to have a valid license.

# 6- Radio regulations

There are many actors in the satellite communications :

- Satellite Service Providers (O3b, Rascom, Intelsat, Gilat, Astrasat,…)
- VSAT Installers (Libercom, skytel,…)
- Regulators (FCC, ARCE,…)

# 6- Radio regulations

**Among the regulations agencies you have :**

- **International regulators (ITU)**
- **Continental regulators associations (CITEL, APT, ATRN)**
- **Regional regulators (Regulatel, Comtelca, ARTAO, TRASA …)**
- **National regulators (FCC, NTIA,…)**
- **International Organizations (INTELSAT, ITSO, GVF,…)**

**ITU is an international organization within the UnitedNations system. As well as responsibility for Telecommunications matters, they are also responsible for global regulations for all radio uses• The ITU is based in Geneva, Switzerland.**

# 6- Radio regulations

**Continental and Regional Regulators associations**

**The ITU Radio Regulations form a framework for Radio Regulations, but are not sufficient for complete Regulation•**

**Almost all countries / territories fall within a Regional Regulatory group**

– *IRG for Europe*

– *CITEL across the Americas*

– *APT across Asia Pacific Region*

– *Arab States*

**These groups often provide more detailed regulation, specific to the needs of the Region.**

# 6- Radio regulations

**Continental and Regional Regulators associations**

**The continental and regional associations have different degree of maturity and competencies.**

They can rarely impose their decisions to their members, despite a consensual decision making, some of them can advance or even facilitate the adoption of common positions including during regional international meetings of the International Union of Telecommunications (ITU) or the World Trade Organization (WTO)

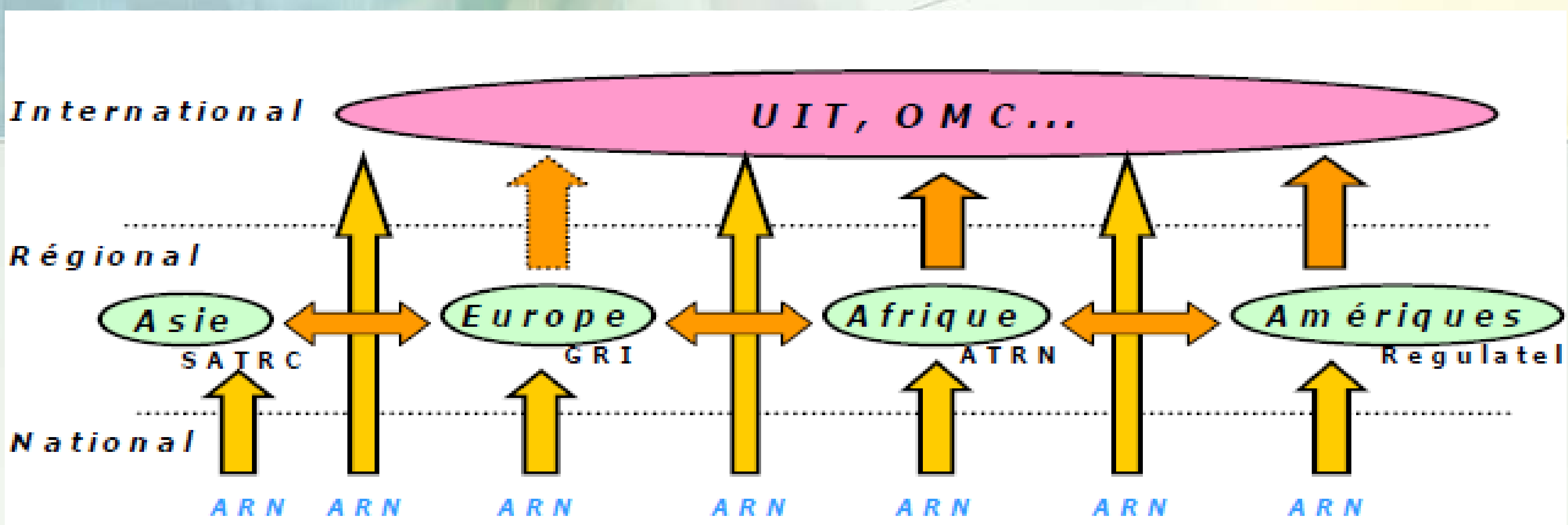
# 6- Radio regulations

## *National Regulation*

**Ultimately the responsibility for licensing falls to a National Regulatory Authority (a Government department), e.g.**

– *Ofcom in the United Kingdom*

– *FCC & NTIA in the USA*



# 6- Radio regulations

ITSO

ITSO is the continuation of INTELSAT, the intergovernmental organization established by treaty in 1973.On July 18, 2001, the satellite fleet, customer contracts and other operational assets were transferred to Intelsat Ltd, a new private company now registered in Luxembourg and various amendments to the ITSO Agreement took effect.

Under the ITSO Agreement, as amended , ITSO's primary role was that of supervising and monitoring Intelsat's provision of public telecommunications satellite services as specified in the Public Services Agreement(PSA) entered into between ITSO and Intelsat. In addition, the Director General , on behalf of the Organization, must consider all issues related to the Common Heritage. ITSO currently has 150 Member State."

## 6- Radio regulations

ITSO

The **International Telecommunications Satellite Organization** is an intergovernmental organization charged with overseeing the public service obligations of Intelsat.

GVF

Global VSAT Forum is an association of key companies involved in the business of delivering advanced digital fixed satellite systems and services.

# 6- Radio regulations

## Satellite Operators

**Intelsat, Ltd.** is a communications satellite services provider. Originally formed as **International Telecommunications Satellite Organization** (**INTELSAT**), it was an intergovernmental consortium owning and managing a constellation of communications satellites providing international broadcast services. As of March 2011, Intelsat owns and operates a fleet of 52 communications satellites.

**Eutelsat S.A.** is a French-based satellite provider. Providing coverage over the entire European continent, as well as the Middle East, Africa, India and significant parts of Asia and the Americas, it is one of the world's three leading satellite operators in terms of revenues.

# 6- Radio regulations

## Satellite Operators

**O3b is building a next-generation network that combines the reach of satellite with the speed of fiber.**

## Higher capacity

O3b’s satellite transponders have on average three to four times the capacity of those offered by GEO satellite systems. This translates into three to four times more bandwidth – and a fiber-like experience for customers.

## Greater coverage

Satellite technology can deliver Internet connectivity to any location on the planet. O3b’s next-generation satellite network will reach consumers, businesses and other organisations in more than 150 countries across Asia, Africa, Latin America and the Middle East.

# 6- Radio regulations

## Satellite Operators

## Lower latency

O3b's unique network of Medium Earth Orbit (MEO) satellites virtually eliminates the delay caused by standard Geosynchronous (GEO) satellites.

Round-trip data transmission time is reduced from well over 500 milliseconds to approximately 100 milliseconds seconds.

This creates a web experience significantly closer to terrestrial systems such as DSL or Optical Fiber.

# 6- Radio regulations

## International Organization

The **International Mobile Satellite Organization (IMSO)** is the intergovernmental organization that oversees certain public satellite safety and security communication services provided via the Inmarsat satellites. These public services include:

services for maritime safety within the Global Maritime Distress and Safety System (GMDSS) established by the International Maritime Organization (IMO)

- distress alerting
- search and rescue co-ordinating communications
- maritime safety information (MSI) broadcasts
- general communications

# 6- Radio regulations

## International Organization

The **International Mobile Satellite Organization (IMSO)**

- aeronautical safety AMS(R)S services through compliance with the Standards and Recommended Practices (SARPs) established by the International Civil Aviation Organization (ICAO)

IMSO also acts as the International LRIT Coordinator, appointed by IMO to coordinate the establishment and operation of the international system for the Long Range Identification and Tracking of Ships (LRIT) worldwide.

# 7- 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

# 8- Technology trends

- Market trends for capacity
- – continues to grow despite fibre deployment
- Potential shortage of capacity in some areas for certain types of capacity due to heavy cut backs in launches
- Bandwidth’s are ever increasing on a per link basis

# 8- Technology trends

User demands

- Smaller terminals
- High throughput
- Enhanced capability
- Constellations
- Responsive space
- Lower costs - $1000 now and lower!
- Easier access to space segment
- Easier licensing regimes
- Open standards

# 8- Technology trends

- Open Standards
- All agree
- Satellite Operators
- Network Operators
- Equipment manufacturers
- End-users

- Yes – but which one is the best one or is it a multitude of answers and solutions?

# 8- Technology trends

- Global usage and coordination
- Ka / Ku/ C Band
- Interference issues
- Global Regional frequency coordination

# End of Session 1

Satellite Technology and Satellite Communications Systems