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Basics of Satellite Communications

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Topics Outline

- Birth of Satellite Communications
- Communication Links
- The Space Segment
- Satellite Design
- The Ground Segment
- Teleports
- Satellite Orbits
- Building and Launching Satellites
- Satellite Regulation
- Earth Station Registration
- Satellite Regulatory Organisations
- Satellite Operators
- Satellite Services
- Technology Trends

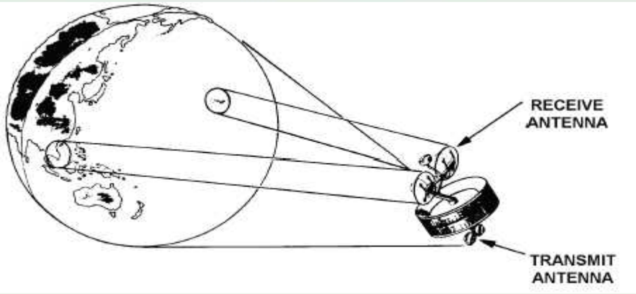
Birth of satellite communications 1/8

What is a satellite?

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

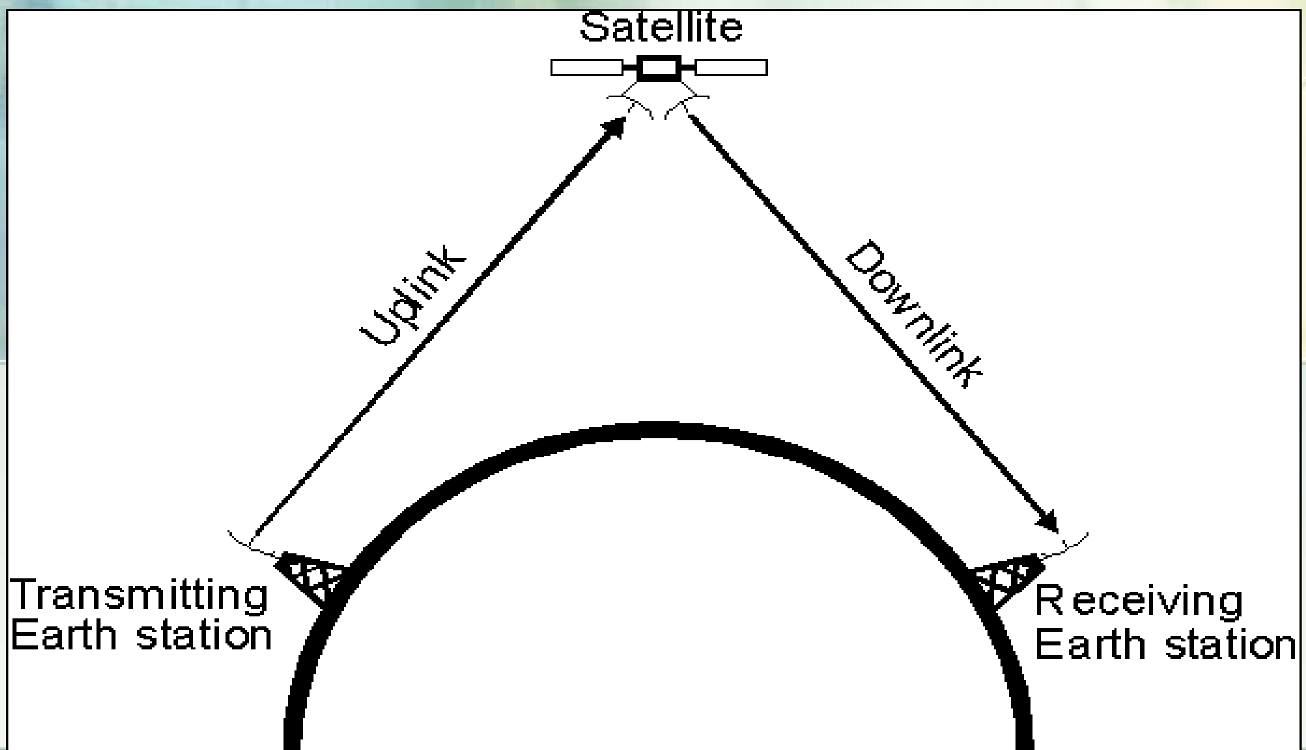
Why is the above definition not quite accurate?

- **Because we also have natural satellites such as the Moon. To be more exact, the above definition is for *artificial satellites***



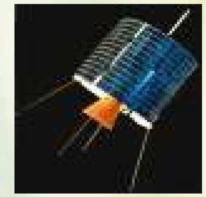
Birth of satellite communications 2/8

A communications satellite actas as a repeater



Birth of satellite communications 3/8

Frequently Asked Questions (FAQs)



1. Who invented satellites?
   - Arthur C. Clarke, who went on to be a well-read author of science fiction novels
2. When were satellites invented?
   - The first satellites were experimented with in the late 1950's and early 1960's. Intelsat's first satellite, which was called 'Early Bird', was launched on 6 April 1965. First satellite was launched in 1957 by Russia. It was Sputnik 1.
3. How big is a satellite?
   - Based on the Intelsat 9 series , before liftoff it's, about 4,500 kilograms! Without fuel, it's about 2,000 kilograms! The body is 5.6 meters, and the solar panels are 31 meters wide – more than a 10-story building!
4. How many years can a satellite last?
   - It varies by satellite type. The type of satellites that Intelsat owns can last over 20 years, but typically their work life is approximately 15 years

Birth of satellite communications 4/8

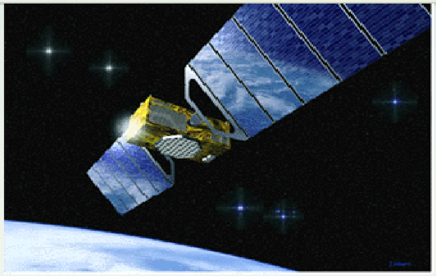
Frequently Asked Questions (Cont'd)

5. How do you fix satellites if they get broken?
   - The satellites send back 'health check' information to ground engineers all the time. Pre-developed commands are sent to the satellite to perform certain functions, such as firing a booster or changing the angle of a solar panel, so that it can repair itself.
6. How does a satellite get its power?
   - Mostly solar power collected by the solar arrays/panels There are also batteries on the satellites for the times when the satellite passes through the earths shadow. This is called eclipse.
7. How much power does it take to transmit a signal?
   - The power used to send a communications signal to the Earth from a satellite is about the same as a typical 60W light bulb, just like you have at home.
8. What kinds of people work in the satellite industry?
   - All kinds! Engineers, rocket scientists, sales people, writers, accountants and lawyers

Birth of satellite communications 5/8

Communications satellites may be used for many applications:

- relaying telephone calls
- providing communications to remote areas of the Earth,
- TV direct to user broadcasting
- providing communications to ships, aircraft and other mobile vehicles
- etc .



Birth of satellite communications 6/8

Benefits of Satellites

- Adaptable to customer requirements
- Mobility
- Cost advantage
- Not affected by geographical obstructions
- Quick implementation
- Alternate routing (backup) or redundancy
- Cost is independent of distance
- Cost effective for short term requirements

Birth of satellite communications 7/8

Satellites are complementary to cable for the following reasons:

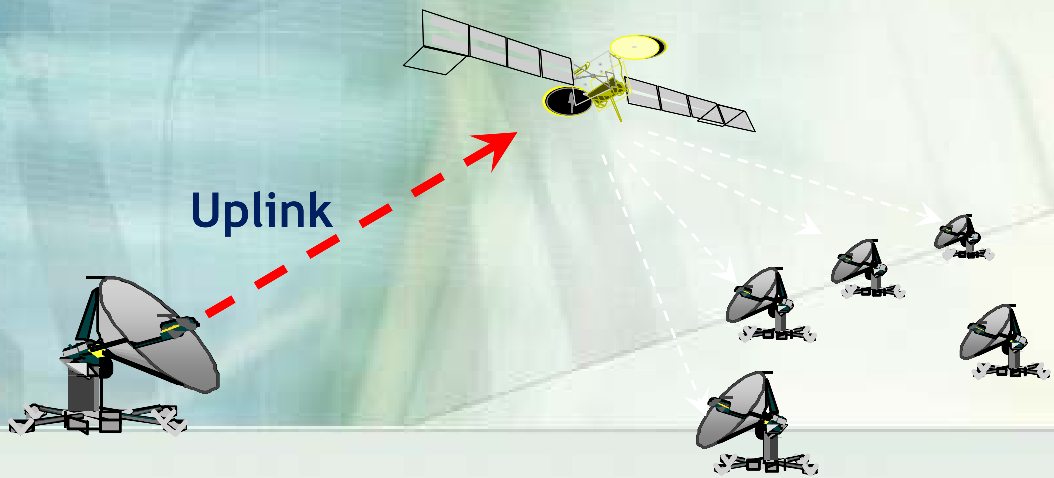
- Submarine cables (and landline fibre) are subject to cuts
- Interim solutions for cellular backhaul and internet trunking
- Satellite systems utilizing MEO (Medium Earth orbit) have both high capacity and high quality.

Birth of satellite communications 8/8

Types of satellites

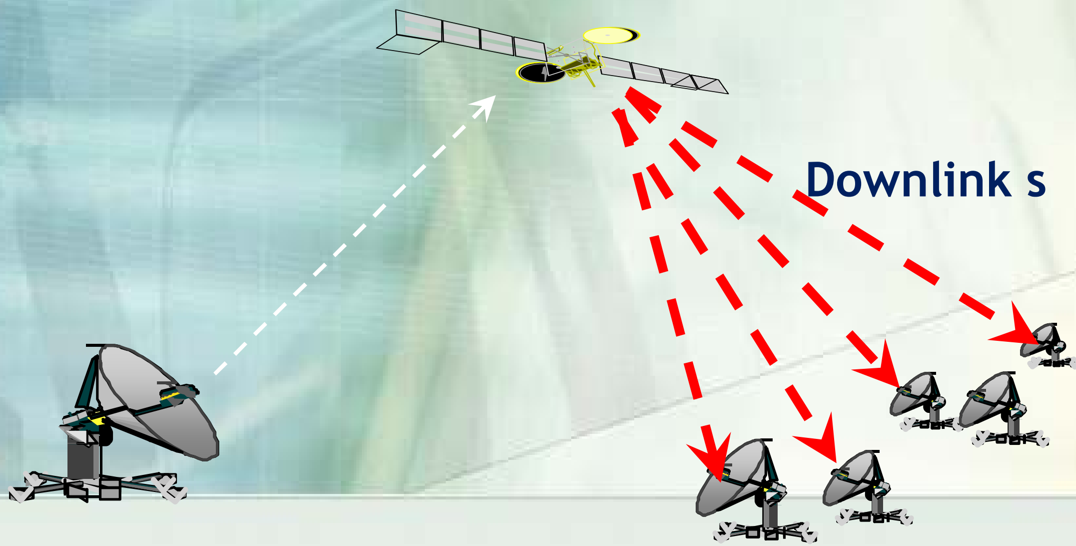
- Communications satellites
- Weather satellites
  - provide meteorologists with scientific data to predict weather conditions and are equipped with advanced instruments
- Earth observation satellites
- Navigation satellites
  - using GPS technology, these satellites are able to provide a person's exact location on Earth to within a few meters
- Broadcast satellites
  - broadcast television and radio signals from one point to another (similar to communications satellites).
- Scientific satellites
  - perform a variety of scientific missions e.g. The Hubble Space Telescope
- Military satellites

Communication Links 1/4



Uplink - The transmission of signals to the satellite

Communication Links 2/4



Downlink - The transmission of information from the satellite. Many Earth Stations can be covered by one satellite footprint

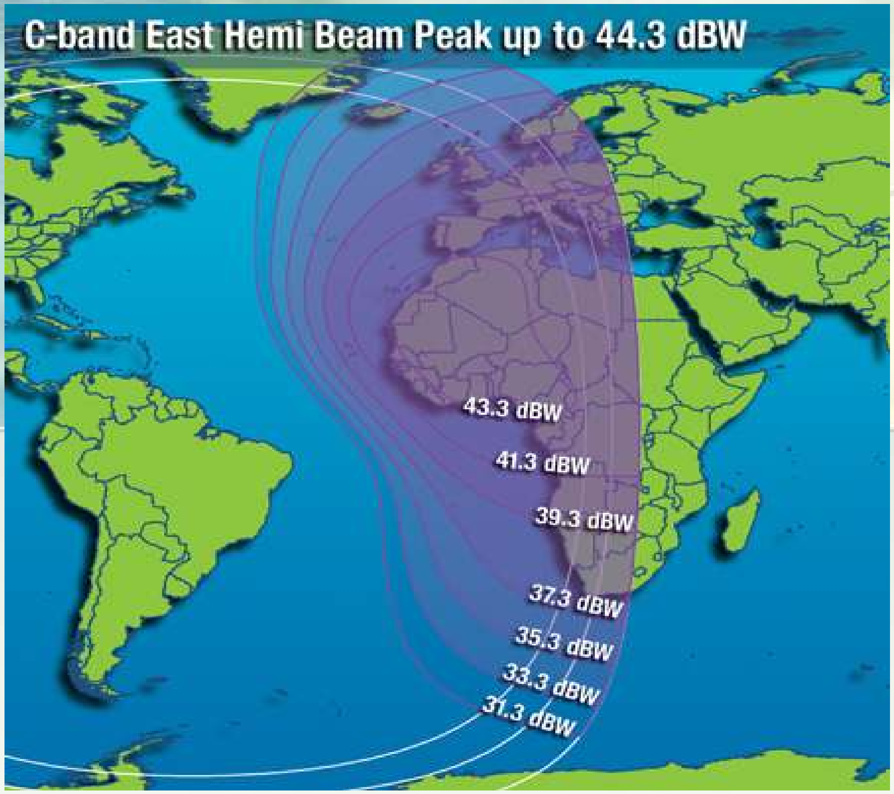
Communication Links 3/4

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

Communication Links 4/4

A satellite "footprint"



Satellite frequency bands

– **L-band**	(1.5 – 1.7 GHz)	**Mobile Satellite Services (MSS)**
– **S-band:**	(2.0 – 2.7 GHz)	**MSS, Digital Audio Radio Services (DARS)**
– **C-band**	(3.4 – 7.1 GHz)	**Fixed Satellite Services (FSS)**
– **X-Band**	(7.25 – 8.4 GHz)	**Military/Satellite Imagery**
– **Ku-band**	(10.7–14.5 GHz)	**FSS, Broadcast Satellite Services (BSS)**
– **Ka-band**	(17.7 - 21.2GHz and 27.5 – 31 GHz)	**FSS Broadband and inter-satellite links**

Source: Satellite Industry Association (USA), 2012

The Satellite Communication System

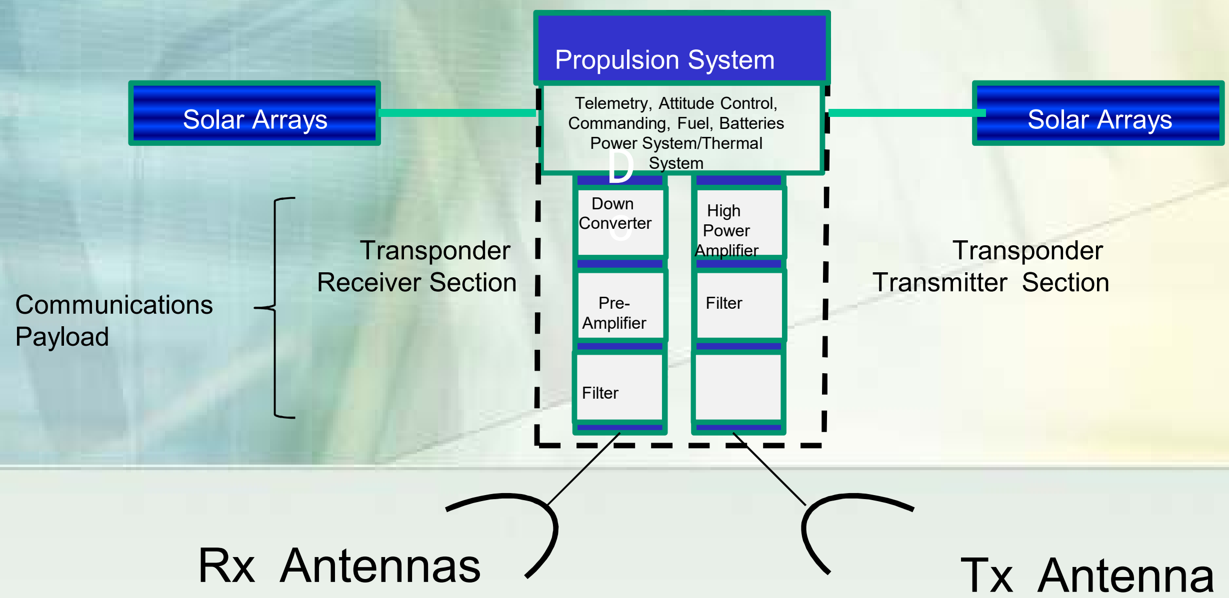
- space segment
- ground segment
- transmission medium (99% “free space”)

The Space Segment 1/4

A telecommunications satellite comprises of:

- A platform (or bus): propulsion system, fuel tanks, batteries, solar panels, attitude and orbit control functions, etc. It is usually standardized by the manufacturer.
- **A payload: the equipment used to provide the service for which the satellite has been launched. Its is customized for a given mission**

The Space Segment 2/4



Block Diagram of a Communications Satellite

The Space Segment 3/4

The Transponder

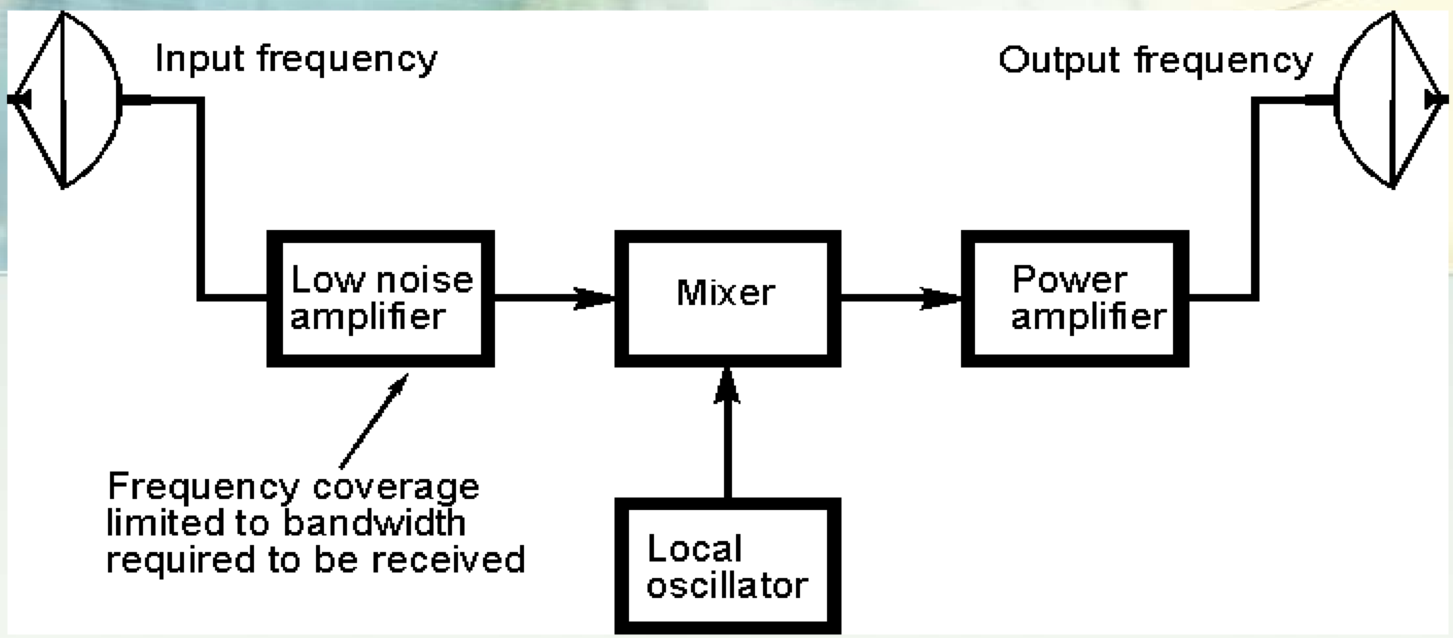
This is the equipment which provides the connecting link between the satellite's transmit and receive antennas. It forms one of the main sections of the payload, the other being the antenna subsystems.

Satellite Transponder Capacity

Typically satellites have between 24 and 72 transponders. A transponder bandwidth is typically 36 MHz, 54 MHz or 72 MHz

The Space Segment 4/4

A closer look at the Transponder



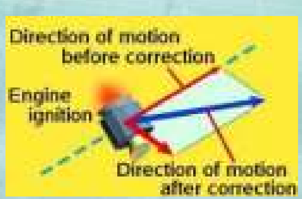
Satellite Design$_{1/2}$

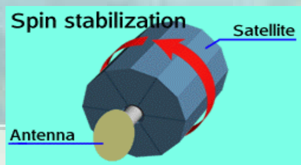
Key aspects of Satellite Design

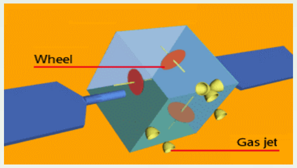
- Electrical Power
- Station Keeping
- Attitude Control
- Orbital Control
- Thermal Control

Satellite Design$_{2/2}$

Orbital Control







- Necessary keep the satellite stationary with respect to all the earth station antennas that are pointed at it.

- Each satellite carries a thrust subsystem to give it an occasional nudge to keep it "on station."

The Ground Segment 1/6

Topic Outline

- Ground Earth Station (GES) 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

The Ground Segment 2/6

GES Components- simplified list

1. Reflector

   – Physical reflecting piece – focuses signal into the LNB assembly and / or focuses the transmission signal towards the satellite

2. Feed horn

   – Device to accept the focussed RF signals into the LNB or conversely to output the RF signal to the satellite

3. Power amplifier

   Device that accepts a signal from the modem and boosts it to a suitable level for onward transmission to the satellite

4. LNA,B or C - Low Noise Amplifier

   Receives the signal from the satellite,

The Ground Segment 3/6

GES Components- simplified list (Cont'd)

5. Modem

   Converts a data signal to one suitable for transmission to the satellite

6. Up Converter

   – Converts the modulated signals from RF to RF frequency

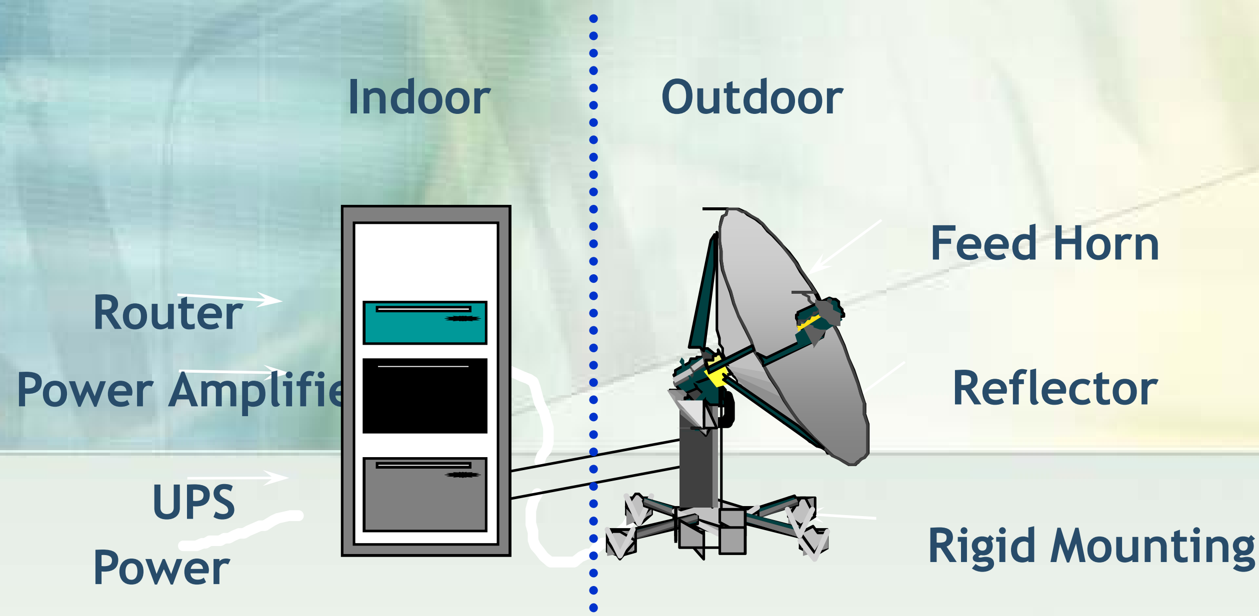
7. Down Converter

   – Converts the modulated signals from RF to RF frequency

8. Mounting

   – Some form of mounting to hold the antenna assembly vertical and pointed correctly under most normal condition

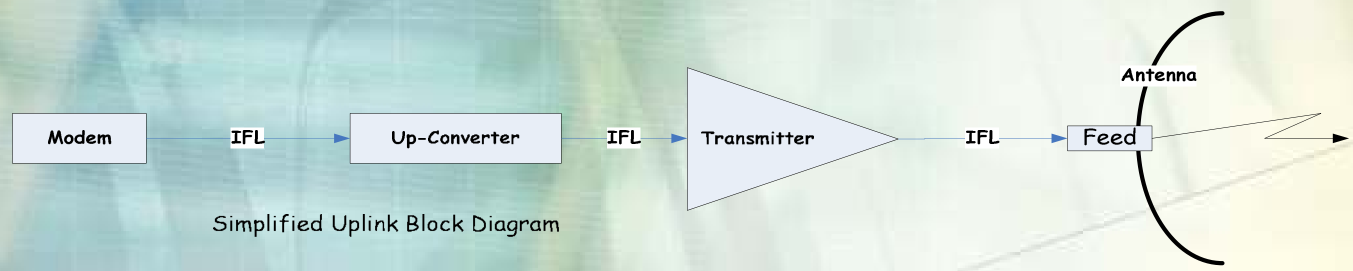
The Ground Segment $_{4/6}$



GES Components - generic simplified diagram

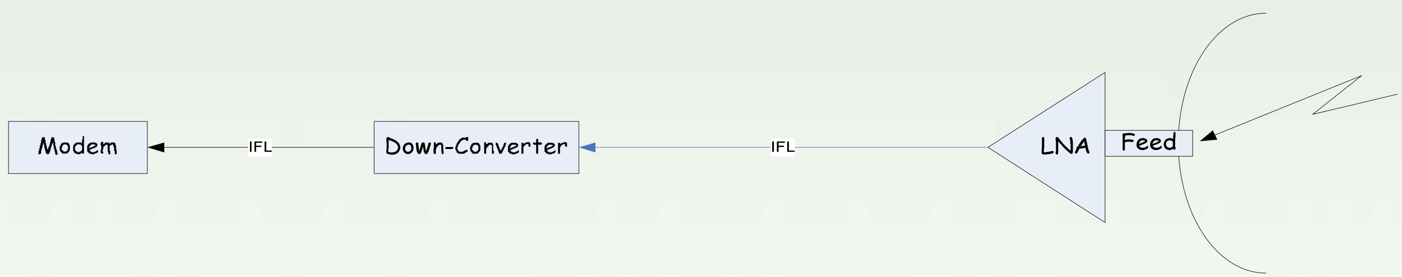
The Ground Segment 5/6

Uplink Block Diagram

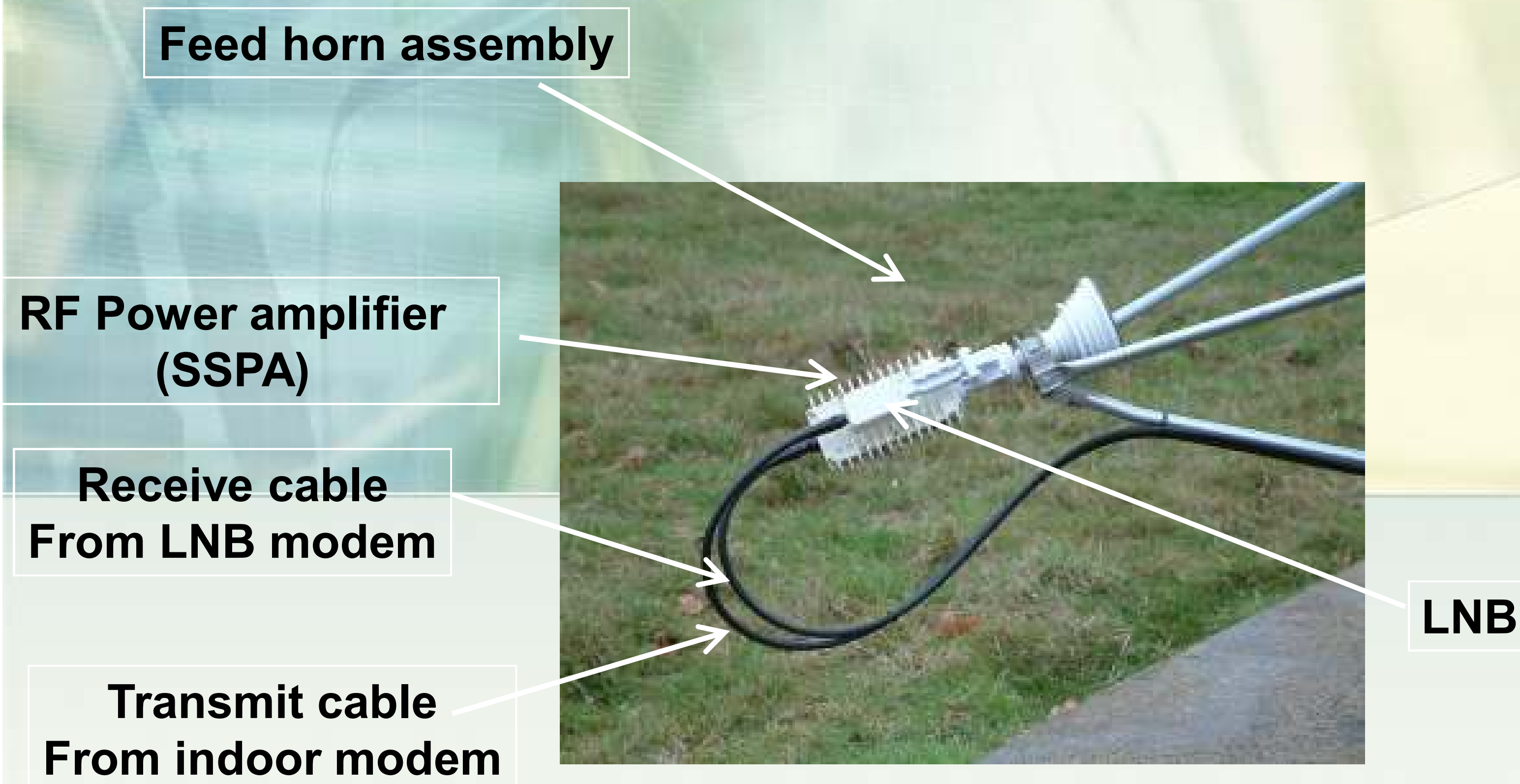


Simplified Uplink Block Diagram

Downlink Block Diagram



The Ground Segment 6/6



VSAT components

Factors Governing GES Reflector Sizes

Technical Factors

- Large earth stations have smaller beam width therefore point more accurately
- Large antennas results in less RF signal wastage
- Large antennas have less co-satellite interference
- Link Budget requirement

Cost Factors

- A Larger antenna may be less than the cost of a lease with a smaller antenna

Regulatory Factors

- Planning permission the Government or Local Authority may limit the minimum or maximum antenna size (e.g. for EM safety or aesthetics)

Major Earth Station and VSATs 1/3

VSAT – **V**ery **S**mall **A**perture **T**erminal:

- 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 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

Major Earth Station and VSAT $_{2/3}$

Reflector

Ground Mount with weights

Picture of a VSAT

Major Earth Station and VSAT 3/3

Large earth station antennas

What is 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

A typical Teleport

Permissions required to install & operate a VSAT / Earth station

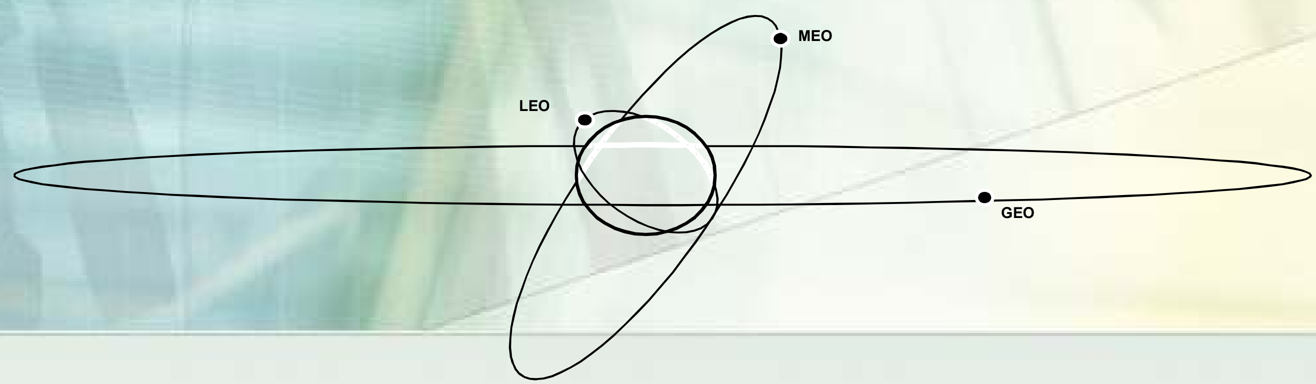
Just because it can work does not necessarily mean you may go out install and operate!

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

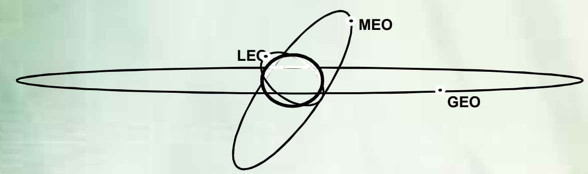
  Will the landlord permit your activity?
- Regulatory authority

  Does the law allow you to build and operate?

Satellite Orbits 1/6

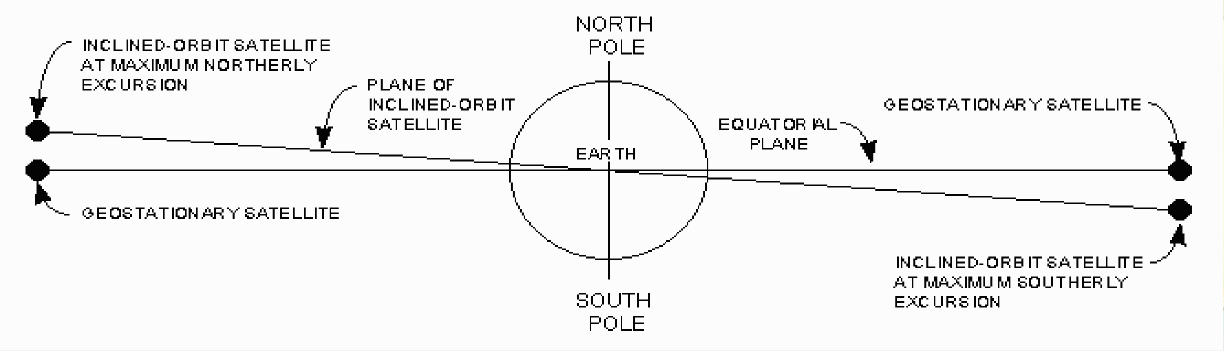


Satellite Orbits 2/6



Type	LEO	MEO	GEO
Description	Low Earth Orbit Equatorial or polar orbit	Medium Earth Orbit Equatorial or Polar orbit	Geostationary Earth Orbit Equatorial orbit
Height	100-500 miles	6000-12000 miles	22,282 miles
Signal Visibility / orbit	15 min	2-4 hrs	24 hrs
Advantages	Lower launch costs Short round trip signal delay Small path loss	Moderate launch cost Small round trip delays	Covers as much as 42.2% of the earth's surface Ease of tracking No problems due to doppler
Disadvantages	Tracking antenna required Short life, 5-8 years Encounters radiation belts	Tracking antenna required Larger delays Greater path loss than LEO's	Large round trip delays Weaker signals on Earth

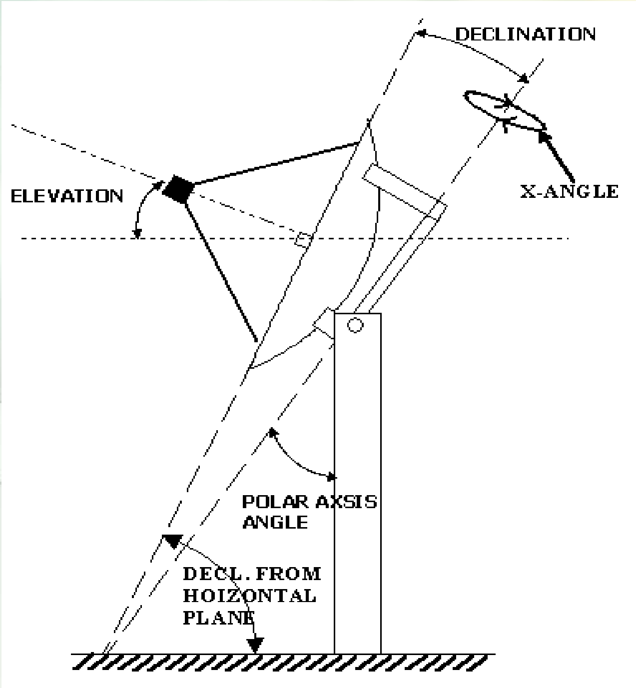
Satellite Orbits 3/6



Satellite Orbits 4/6

Inclined Orbits: Implications for earth station tracking:

Stations must have tracking systems so that their pointing is adjusted to aim at the satellite all during the day.

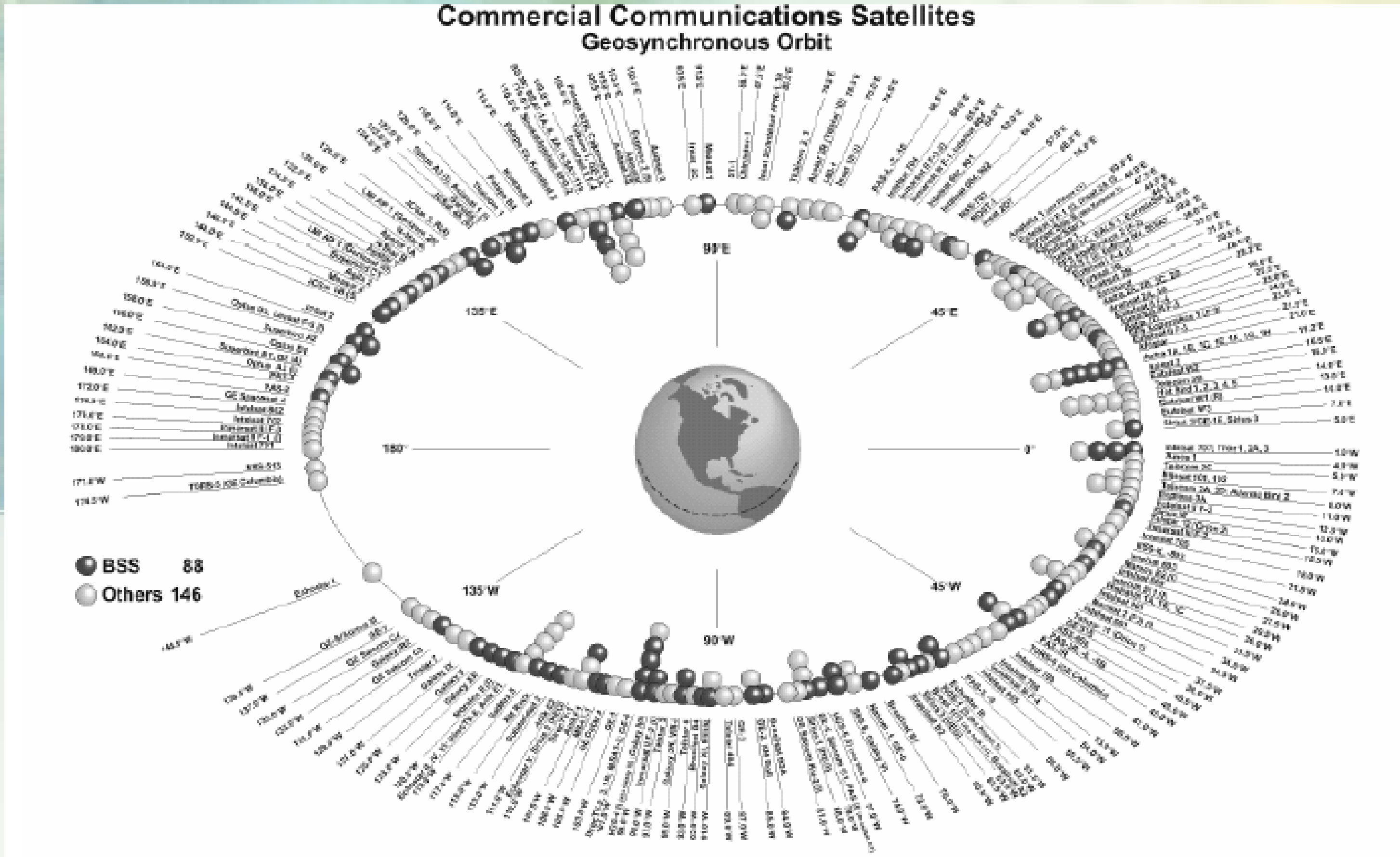


Satellite Orbits 5/6

Orbital Slot Registration

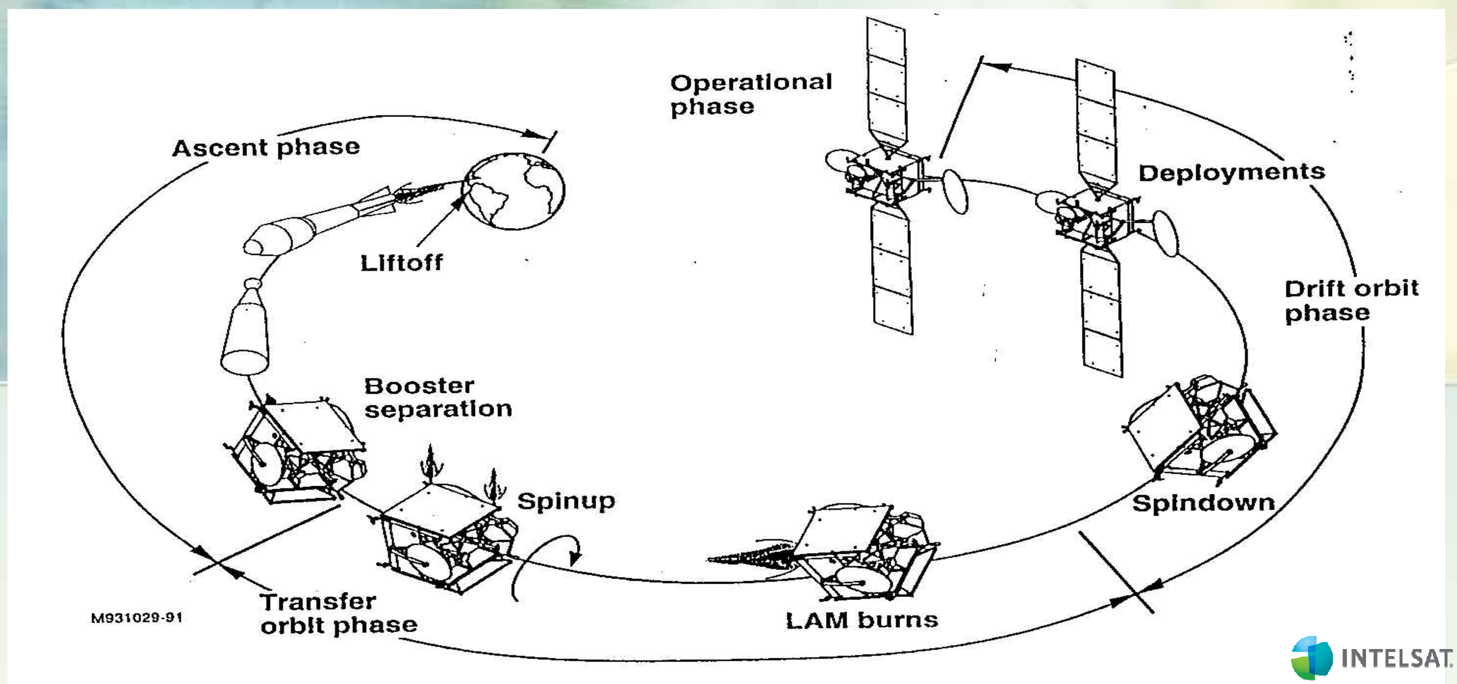
- The ITU Member States have established a legal regime, which is codified through the ITU Constitution and Convention, including the Radio Regulations
- All countries, including lesser developed countries, have an equal right to orbital slots.
- At conferences in 1985 and 1988, the ITU did give all countries the rights to an orbital slot directly over their territory,

Satellite Orbits 6/6



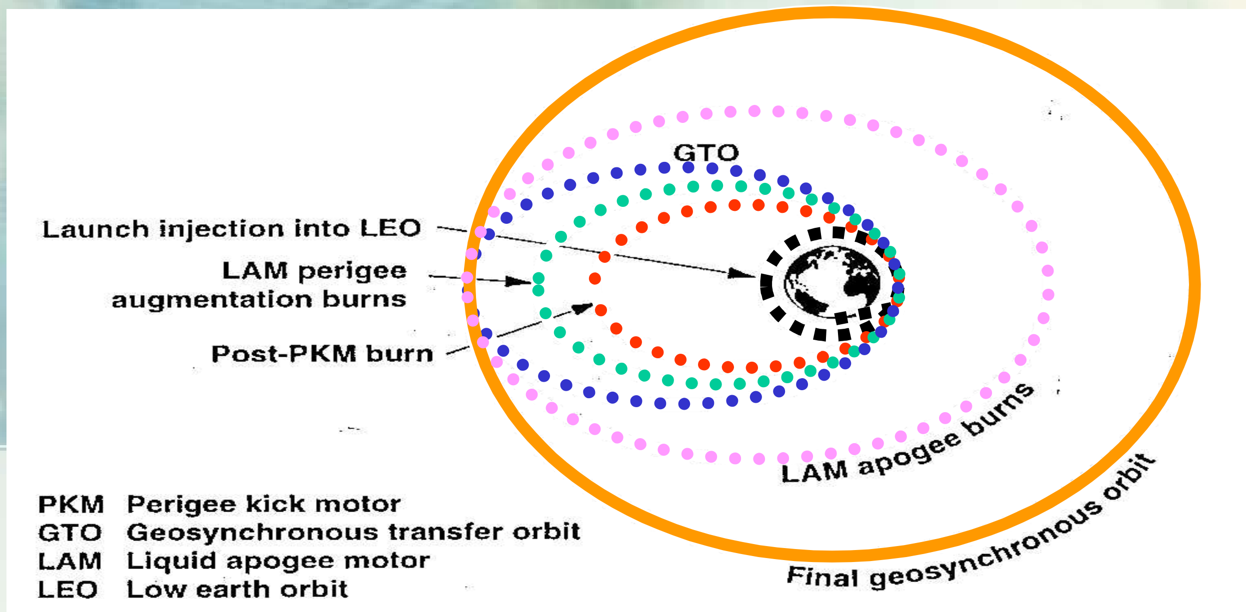
Building and launching a telecommunications satellite 1/4

GEO Satellite Launch



Multiple “burns” to achieve GEO orbit

Building and launching a telecommunications satellite 2/4



Generic Transfer Orbit Profile

Building and launching a telecommunications satellite 3/4

- It takes about 3 years to get a GEO telecom satellite built and launched.
- Satellite payloads are customized for a given mission.
- Satellites are heavily tested on the ground in facilities that reproduce the space environment:
  - Mechanical, Thermal, Noise and RF tests
- Typical cost of a satellite is $150-$250 million
  - Some satellites can cost as much as $500 million.
  - Not including launch services ($55-$100 million) and insurance

Building and launching a telecommunications satellite 4/4

- As most satellite operators are for profit businesses, this investment must be recovered from sale of services over the satellite's lifetime.
- The services may be sold directly to communication service providers or through satellite service providers.

Levels of satellite regulation

1. Global: The Radio Regulations of the ITU done by the WRCs + (Rules of Procedure done by the RRB)
2. Regional: Regional (continental) agreements, guidelines and/or regulations, e.g. EU Decision No 626/2008/EC on the selection and authorisation of systems providing mobile satellite services (MSS).
3. Sub-regional: Sub-regional agreements, guidelines and/or regulations e.g. the 2015 SADC decision on Sharing of the Ka band (26.5 – 40GHz). Fixed service and Satellite service.
4. National: National regulations
5. (State/County: Limited scope regulations e.g. earth station licensing)

Earth Station and VSAT Registration 1/4

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.

Earth Station and VSAT Registration 2/4

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.

Earth Station and VSAT Registration 3/4

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 Standards Institute (ETSI).

Earth Station and VSAT Registration 4/4

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 national authorities of the different countries where the relevant earth stations are planned to be installed and operated, and rules often differ from one country to another.

Orbital positions and radio interferences

Control of Interference

ALLOCATION

Frequency separation of stations of different services

REGULATORY_PROTECTION

e.g. No. 22.2: Non-GSO to protect GSO (FSS and BSS)

POWER_LIMITS

PFD to protect TERR services / EIRP to protect SPACE services / EPFD to protect GSO from Non-GSO

COORDINATION

between Administrations to ensure interference-free operations conditions

Satellite regulatory organisations 1/2

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.

Radio regulatory organisations 2/2

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 of the Organization 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 149 Member States."

Some International/Regional Satellite Operators

Iridium

ITU Satellite radiocommunications services classifications$_{1/2}$

1. Aeronautical mobile-satellite (OR) service
2. Aeronautical mobile-satellite (R) service
3. Aeronautical mobile-satellite service
4. Aeronautical radionavigation-satellite service
5. Amateur-satellite service
6. Broadcasting-satellite service
7. Earth exploration-satellite service
8. Fixed-satellite service
9. Inter-satellite service
10. Land mobile-satellite service

ITU Satellite radiocommunications services classifications$_{2/2}$

11. Maritime mobile-satellite service
12. Maritime radionavigation-satellite service
13. Meteorological-satellite service
14. Mobile-satellite service
15. Radiodetermination-satellite service
16. radiolocation-satellite service
17. Radionavigation-satellite service
18. Space operation service
19. Space research service
20. Standard freq. and time signal-satellite service

Industry Satellite Services Products 1/2

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

Industry Satellite Services Products 1/2

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

Technology trends 1/11

- Satellite capacity continues to grow despite fibre deployment
- Potential shortage of capacity in some areas for certain types of capacity due to heavy cutbacks in launches
- Bandwidth is ever increasing on a per link basis

Technology trends 2/11

Addressing the bottom line through the use of the latest technologies

- DVB-S2 and DVB-S2x
- Adaptive Coding and Modulation
- Carrier Cancellation Technology (CCT) or "C^{n}C"
- Lower Roll off factors
- Multi-demodulator Hub Cards

INTELSAT
Envision. Connect. Transform.

Technology trends 3/11

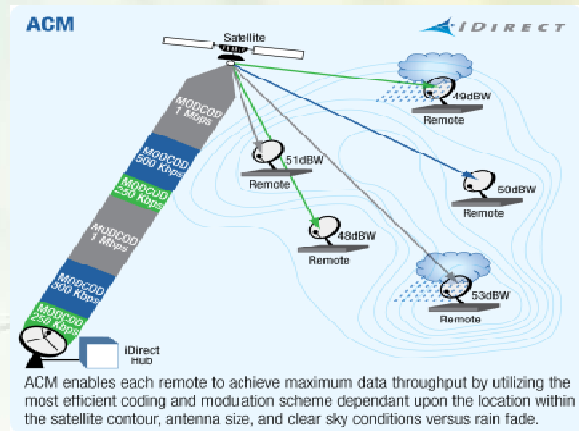
DVB-S2 & Extensions: A new standard enables true convergence

- Excellent spectral efficiency:
  - Up to 40% bandwidth saving compared to DVB-S
  - Up to 2dB better than Turbo Codes
  - HDTV enabler
- Unlike DVB-S, DVB-S2 is optimised for MPEG *and* IP
- Allows for DTH and DTT distribution in single carrier

Technology trends 4/11

Adaptive Coding & Modulation

- Higher throughput for the same amount of resources
- When rain fade issues arise, the modulation can adjust so as to ensure the remote stays in the network
- Allows lower per Mbps price points to be achieved, leading to more competitive prices in the market



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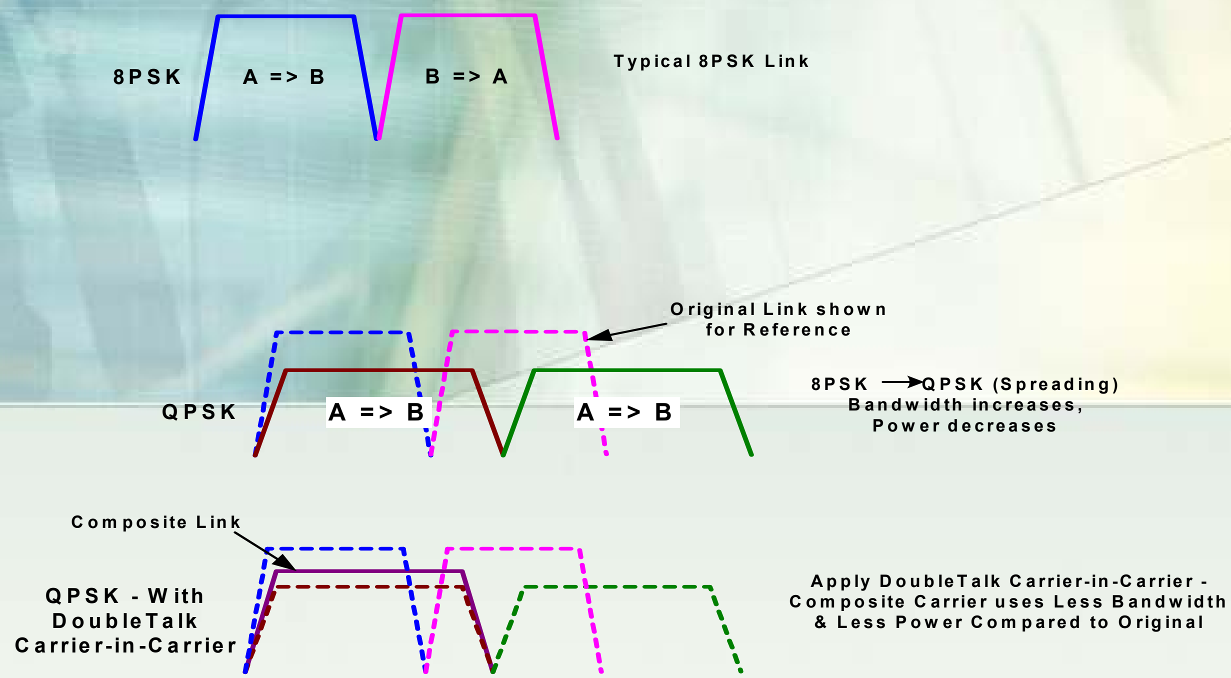
Maximum achievable data throughput by utilizing the most efficient coding and modulation scheme at any moment in time, depending on location within the satellite contour, antenna size and atmospheric conditions

Technology trends 5/11

Carrier Cancellation Technology



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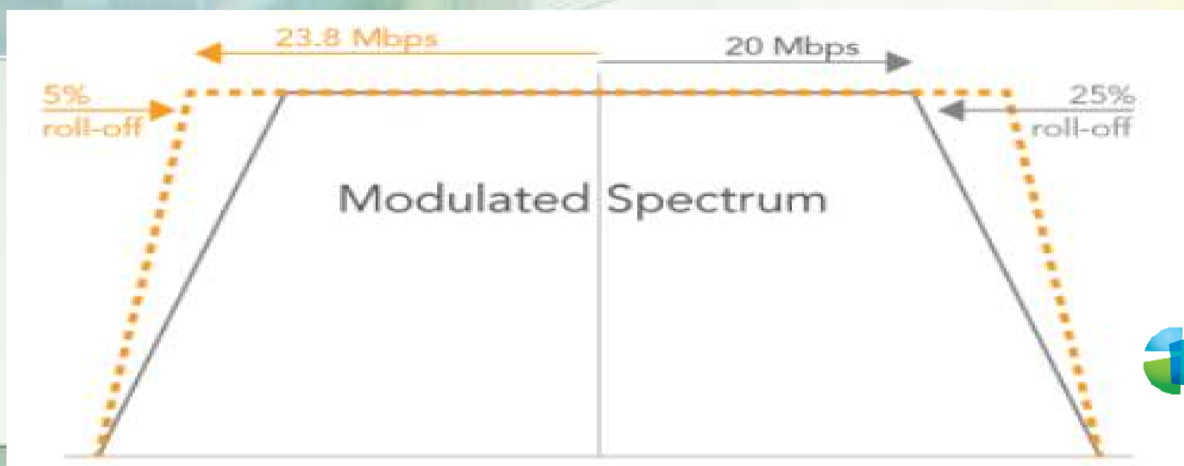
Technology trends 6/11

Roll Off

- Allocated BW directly proportional to Symbol rate X Roll off
- Typical roll off – 35%
- Most recent roll off available 5%
- Drives efficiency



INTELSAT
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Technology trends 7/11

Multi-Demodulator Cards: Multiple inbound carriers in one return card

- **Reduces cost of equipment – fewer cards and less chassis space**
- **Potential to pay as you grow with existing hardware (only software required)**
- **Ease of manageability**
- **Far more common today across various platforms**

Technology trends 8/11

Combination of Features: Equipment Vendors are integrating options to their products

- DVB-S2 with ACM
  - Satellite equipment vendors (eg. HNS, iDirect, Shiron)
- Carrier in Carrier
  - Comtech EFData CDM-625/CDM-625A
  - Viasat/iDirect PCMA
- DVB-S2, Carrier in Carrier with ACM
  - Comtech EFData CDM-750
- Hub demodulator card
  - iDirect, Comtech, etc

INTELSAT
Envision. Connect. Transform.

Technology trends 9/11

User demands

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

Technology trends 10/11

Open Standards?

- Industry Players (Satellite Operators, Network Operators, Equipment manufacturers and End-Users) agree that Open Standards are good for everyone
- But which one is the best one or is it a multitude of answers and solutions?

Technology trends 11/11

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

END