WORKSHOP
ON
SATELLITE COMMUNICATIONS

CIDADE DA PRAIA
CABO VERDE

11.10 – 15.10.2010

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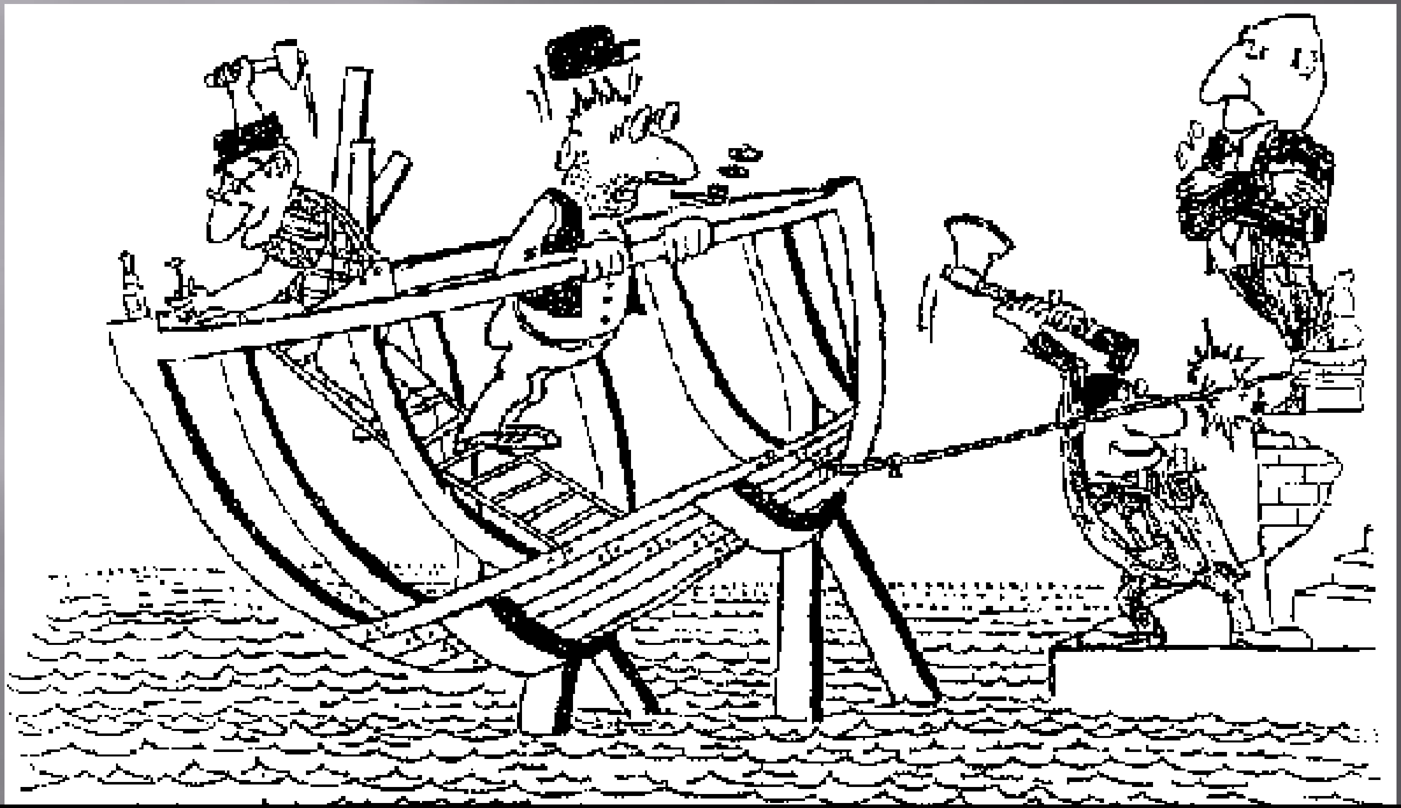
Agenda

Day 1	Satellite Technology
Day 2	Earth Station Technology
Day 3	Transmission & Networking Plan
Day 4 AM	Link Budget Analysis & Design
Day 4 PM	Vsat Installation & Maintenance
Day 5 AM	Vsat Maintenance Audit
Day 5 PM	Regulatory factors

Workshop timeframe

08h30 – Morning session
10h00 - Coffe Brake
12h00 – Lunch
13h00 – Afternoon session
14h30 – Coffe Brake
15h30 – Day End Session

Who defined this target



Prazo é prazo !

Satellite Technology

- Fundamentals
- Orbits
- Design
- Operation
- Life Cycle Management
- Telemetry, Tracking and Command (TTCM)

Fundamentals

- Early Radio Communications
- Before Intelsat
- Radio Astronomy
- Geo Satellites
- Moon reflexion
- Low orbit Satellite
- Synchronous satellite
- ………..

Early Communications

The HF spectrum saturation was a seriously limitation for the long distance development communications, particularly through the Ocean and the existing alternatives namely submarine cable solutions at least up to 1960, were very expensive.

…Such way and out of radio wave the moon reflexion – initially detected at 1946, - and latter developed through radar technics for the WWII .

….By 1957 has been tested a signal reception reflected in the moon and in 1959 concluded a well successful communication between

UK and US and US and CAN. Notwithstanding the communication has been established in poor conditions, that represented an importante goal.

…At 1954 in an internal meeting "Institute of Radio Engineers" J.R.Pearce made the presentation of an automatic plattform for the radio signal reflexion .

……In October 1957 URSS launch Sputnik I – a non stationery satellite – who transmited teleme try data for 21 days.
January 1958 USA put in orbit Explorer I who during 5 month relayed space effects and his own circuitry.

Before Intelsat

April 1960 Nasa launched the first weather satellite Tairos I in a circular orbit of 700 Km that sent 22952 photos during two months.
In 1962 the USA launched Telstar I put in an elliptical orbit, and demostrated the satellite economics and technical availability

…Finally several satelite experiments realized at worldwhile scale, have been complemented with the deployment of several Earth Stations.

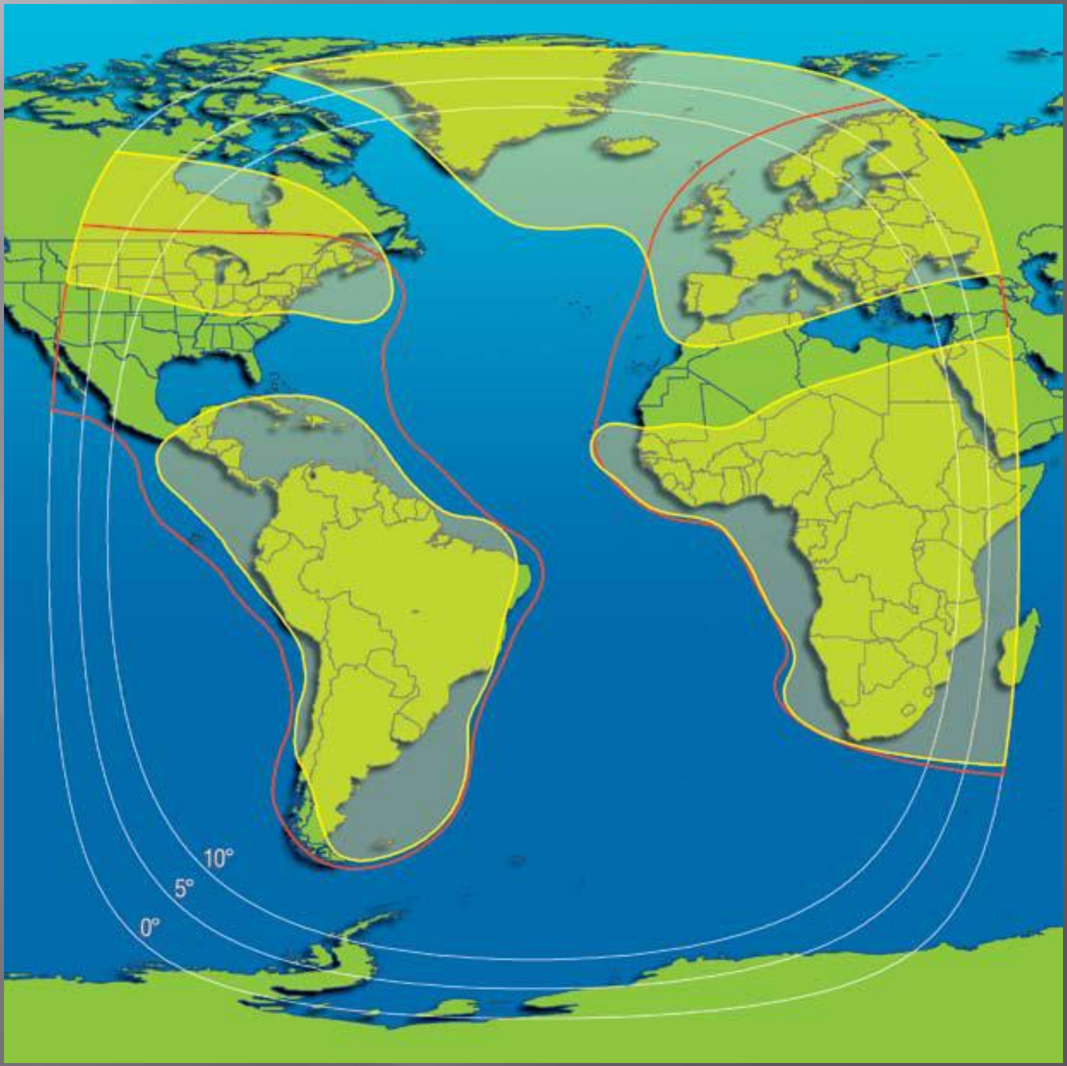
….Latter on, ICSC – Interin Consortium for the satellite Communications - leaded to the Intelsat name, and started satellite communications.

……Since Early Bird – Intelsat I satellite communications achieved a such big development through artifitial satellite and earth stations.
In 1962 has been created under the aproval of United Sates law a private corporation latter on named Comsat, who gathered several countries.
The representation od the countries through his signatories launched at 20 Agosto 1964 the International Communications consortium Intelsat.

Satellite Systems and Networks

- Types of Sat Systems
  - Intelsat
  - Inmarsat
  - Regional
  - Domestic
- Categories of Sat Communications Systems
  - Fixed Sat Services (FSS)
  - Direct Broadcast sat Services (DBSS)
  - Mobile Sat services (Maritime, Aeronautic, Land mobile)
  - Other (Meteo, Educational, Scientific, Militar)

Down link footprint IS 903 on 325,5º E



Atlantic

Global

Hemi

Zone

Downlink footprint
IS 904 on 60º E

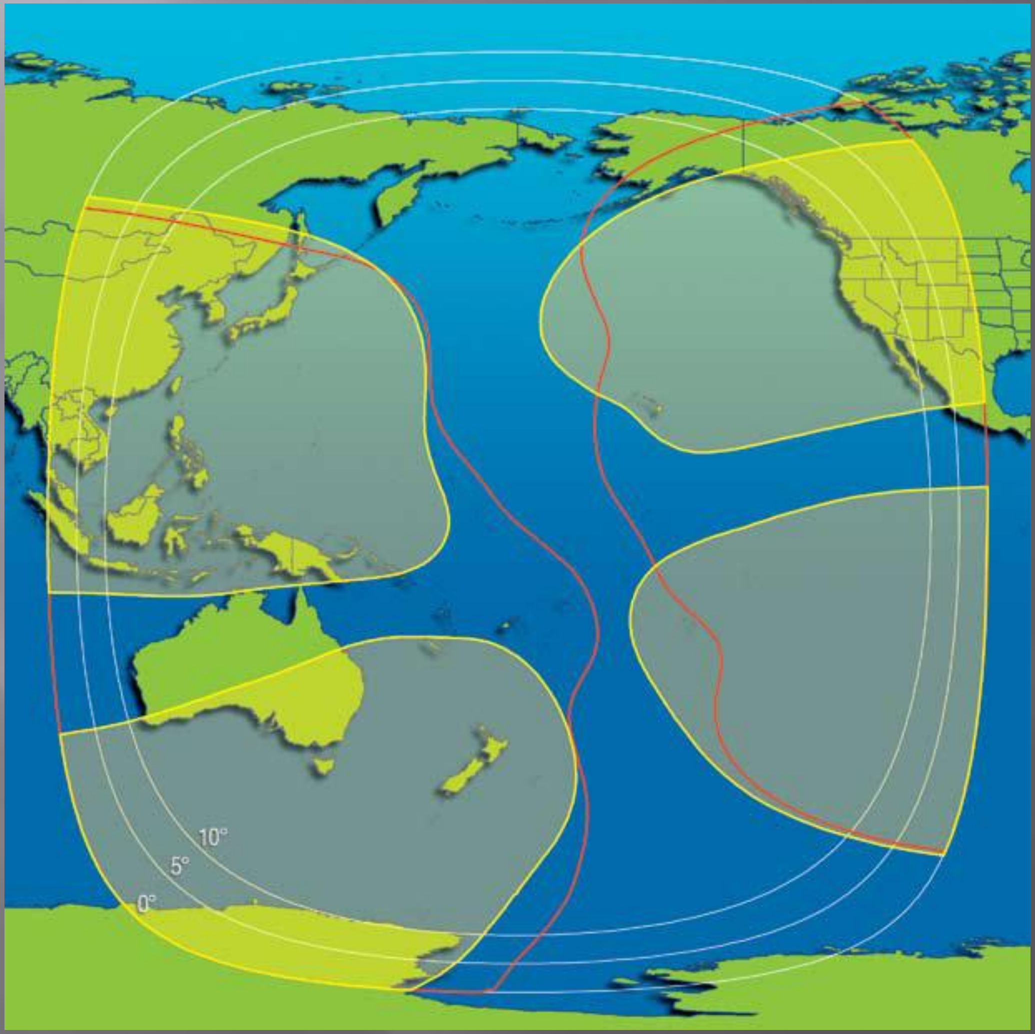
Indic

Global

Hemi

Zone

Downlink footprint IS 701 on 180º E



Pacific

Global

Hemi

Zone

Satellite Network Domestic / Regional Services

- Intelsat Satellite Networks
  - Evolutionary growth of dom / reg ntw through
    - Intelsat Lease capacity
    - Small dom ntw
    - Expanded dom ntw
    - Regional ntw
  - Domestic / Reg Ntw for:
    - Economic development projects
    - Diplomatic ntw
- Dedicated Domesmtic or Reg Sat Ntw
  - Dedicated services for national / reg services
  - ITU / Intelsat Intersystem Coordination

Vsat Networks

- Cost effective alternative to terrestrial for data, and video communications
- Shared and dedicated Vsat Sytems option
- Network flexibility
- Aplications
  - Finantial institutions (deliver time sensitive on stocks, bonds…to clients
  - Retail stores (sales, inventories, credit requests, demos and education videoconferencing)
  - Accounting payroll (centralized accounting system)
  - Videoconferencing (saving travel and cost)

Application

- Corporation
  - Retail; Oil & Gas;
  - Banking and POS
- Telephone
  - Public: Public Call Offices,
  - SME; SOHO
  - Private lines
  - Enterprise:Network infraestructures and data
- Internet
  - Final user, Kyosk
  - SME, SOHO, school
  - IP networking for corporations

Intelnet Services

- Small earth stations for 0,8 – 1,5 microteminals
- Data Broadcast / Distribution for Internacional or Domestic Services
  - Intelnet I (data distribution 9,6 and 64 Kbps)
  - Intelnet II (data collection up to 128 Kbps)
- Modulation Techniques
  - BPSK fec ½ up to 128 Kbps
  - Spread spectrum up to 9,6 Kbps
- Transponder 2-9 MHz incremental lease, preemptible or non-preemptible basis
- Terms and conditions similar to IBS on a leased basis

IBS & IDR Services

- All Digital, High quality services
- Information rates
  - IBS (64 Kbps – 8 Mbps, private services)
  - IDR (64 Kbps – 44,736 Mbps, common carrier trafic)
- Global coverage / conectivity, domestic and internacional services
- Applications
  - Voice communications
  - Data services
  - Videoconferencing
  - Audio or printed material distribution
  - ISDN applications

Digital TV Distribution

- All digital TV service for modern codec developments (15-68 Mbps)
- New services provides 15, 32, 34, 45 and 68 Mbps offerings:
  - Fully accptable quality TV
  - Better than or equivalent to CCIR FM standards
  - Ku band (Standards C, E-1, E-2, E-3)
  - C Band (Standard A, B, F-1, F-2 , F-3)
- Tariffs have minimum 1 year lease
- Video / TDMA possible

Intelsat Restoration Services

- Intelsat has been providing restoration services for submarine cable systems
- Medium capacity cable restoration
  - Requirements and tariffs to be discussed and agreed with signatories
  - Transponder lease basis on spare satellites
  - Large optical fiber cable restoration
  - Spare satellite capacity reservations
  - Reserved for emergencies and may be used by Intelsat for other services qhen needed

Satellite and Fiber Cable Comparison

Item	Fiber cable	Satellite
Connectivity	Point-to-point	Point-to-point, multipoint-to-point,broadcasting,mobile
Link characteristics: Bandwidth Time delay	 Multi-Gbs Very small	 Limited by channelized About 0,25 s round trip delay
Reliability	New emerging systems Potencial high reliability	Proven high reliability
Reconfigurability operational flexibility	Dificult Limited	Easy excellent using transport. E/S
Availability	Limited worlwide	Completely global
By-pass capacity	None.Needs PTT controlled local distribution network	Avoid local distribution network, with on-premises sat terminals
Regulatory restriction	Foreign end distribution network controlled by foreign PTT	Commercial sat foreign end ½ circuit, needs PTT coordination
Cost	Depends both on, link and distance capacity	Insensitive to distance, but depends on link capacity

Communications Satellite broadcast

- USA (NASA)
- CANADA (Royal Society do Canadá)
- JAPAN (Science & Technology Agency, MPT)
- EUROPE (European Spaces Agency)
- ……

Satellite communications terminology 1

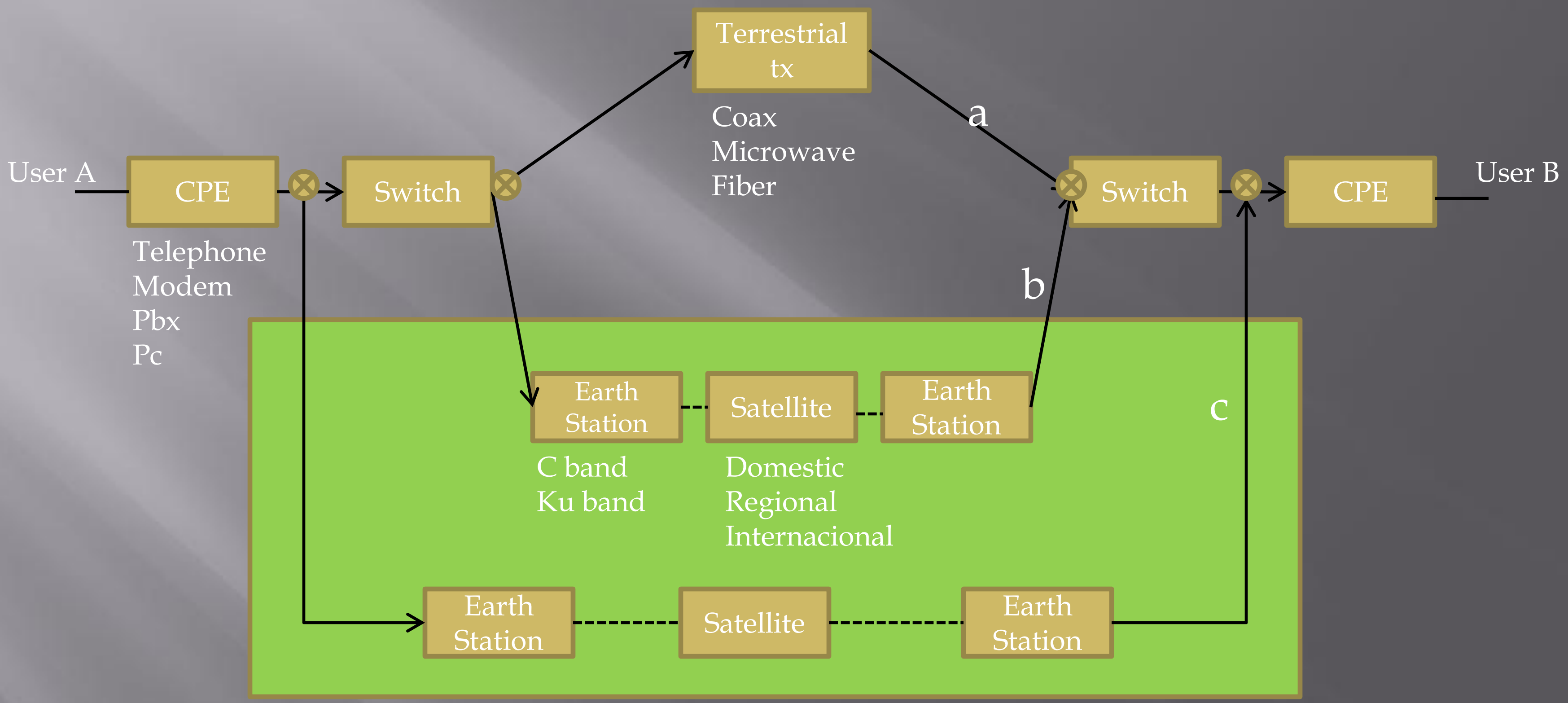
Satellite technical terms and definition are regulated in the “Radio Regulations” and agreed between the WARC (World Administrative Radio Conference) and the ITU (International Telecommunications Union) namely:

- Space radiocom Services
  - Fixed Sat Services
  - Mobile Sat Services
  - Broadcast Sat Services
  - Radionavegation Sat Services
  - Earth exploration Sat Services
  - Meteorological Sat Services
  - Amateur Sat Services
- Geostationary Sat Communications
  - Geometry relating to Sat and Earth Stations
  - Parameters on Geostationary Sat
  - Features (multiple acess, wide coverage, high quality_band,availability for mobile com, economic efficiency

Satellite communications terminology 2

- Frequencies and Sat Orbit
  - Allocation of Frequencies and their efficient utilization
  - Interference coordination
  - Efficient Utilization of sat orbit
- Signal Intensity and Signal to Noise Ratio
  - Receiving power
  - S/N ratio
- Multiple Acess
  - FDMA
  - TDMA
- Commercial Sat Communications
  - Transition in International Telecommunications
  - Business Activities of Intelsat
  - Economic Efficiency of Sat communications (balance of space and earth station costs, comparison of satellite and submarine cable systems)
  - Maritime Mobile at Communications

Satellite Systems



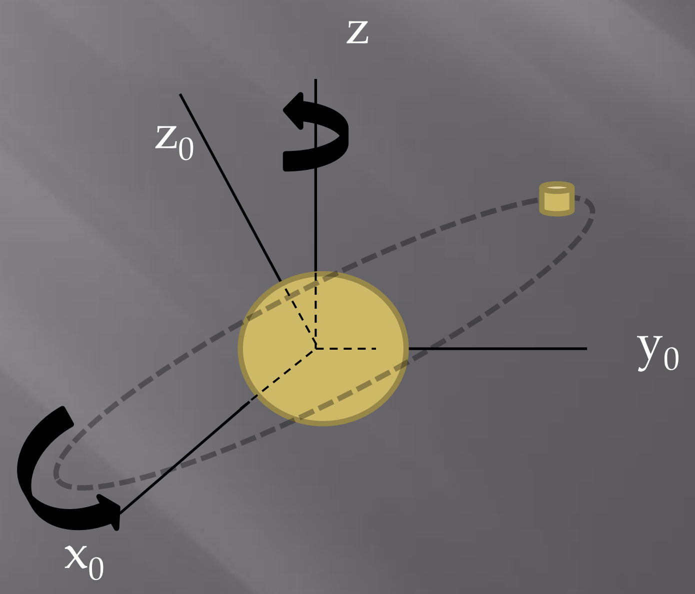
a– terrestrial only
b– terrestrial & sat
c– satellite only

Orbit Definitions

- Shynchronous Orbit
  - An orbit whose period of revolution is a multiple of earth’s orbit
- Geoshynchronous orbit
  - An orbit whose period of revolution is the same as that of of the earth’s orbit
- Geostationary orbit
  - A circular orbit whose period of revolution is equal to that of the earth’s and whose plan is in the same plan of the equator
    - The distance above the earth for a body to maintain orbit and travel the same speed as the rotating earth is 35888 Km.
    - A body orbiting at this distance above the equator apperas to be stationary to na observer on earth as the inclination with respect to the palne of equator is o^{o}

Orbit 1

Defined as the movement of a particle (or body) around the other, motivated by a central force in accordance with the Law of Universal Gravitation, which is calculated - as one of the classic problems in mechanics Background - by Newton in the XVII Century



r = Distance Earth-satellite

Orbit 2

- Gravitational force on satellite is:

  $F = - G\, M_e\, m_s \;/\; r^2$ being

  $G = 6{,}672 \times 10^{-11}$ Nm/Kg

  M_e = earth mass, m_s = sat mass

  $G\, M_e = 3{,}9861352 \times 10^5\ Km^3 / S^2$ ou C^{te} Kepler (μ)

- According 2nd Newton's law:

  $F = m_s \,.\, d^2r/dt^2$

- Or in other way $\boxed{1 / r \,.\, d^2r / dt^2 + \mu r / r^3 = 0}$

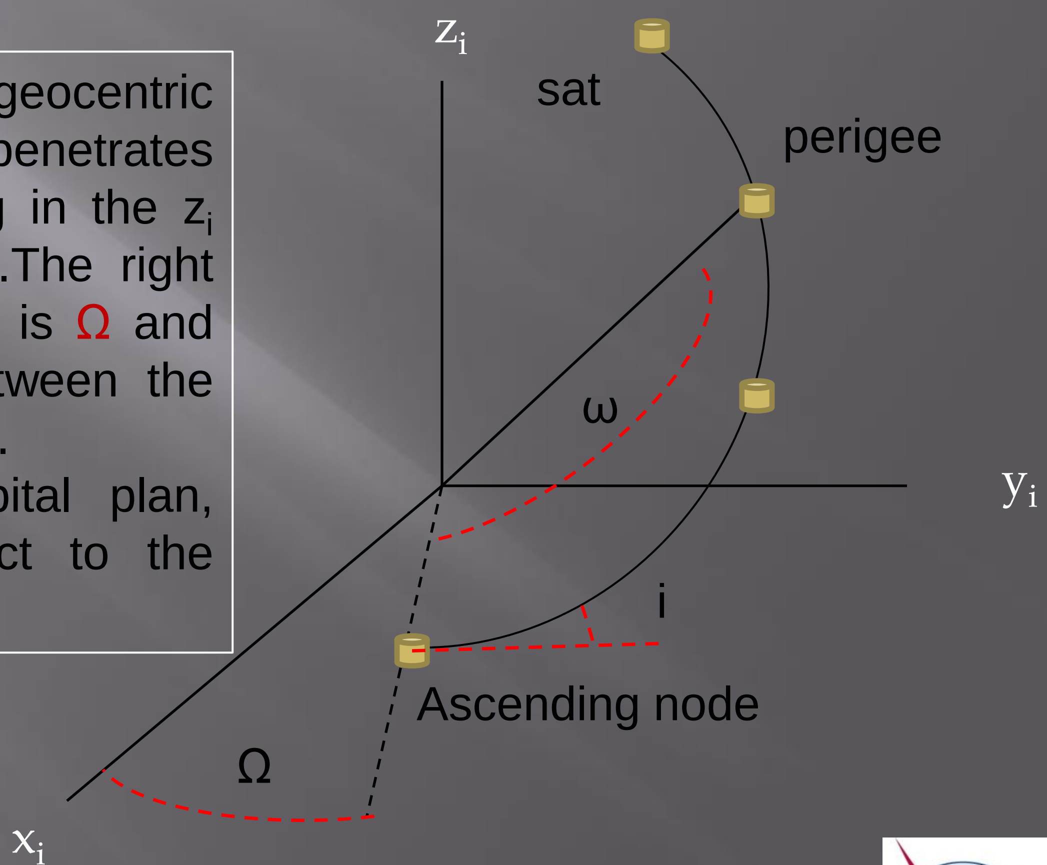
Geostationary Orbit

In conclusion:

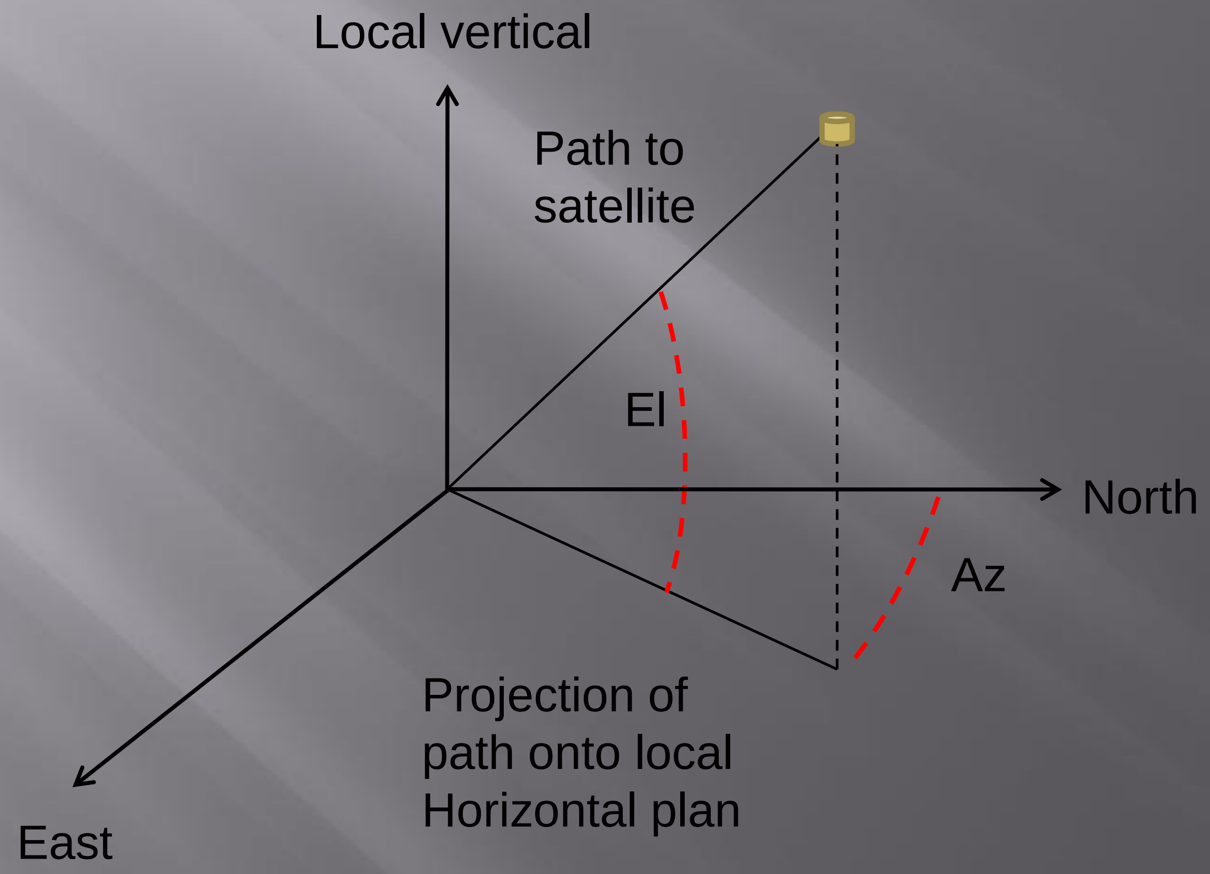
- The movement under 3 dimensions of a satellite corresponds mathematically to a plan
- The orbit is an eclipse according, 1st Keppler’s law
- In special conditions - excentricity equals 0 - the orbit will be a circle, whose center is located the earth’s center.

Orbital Elements

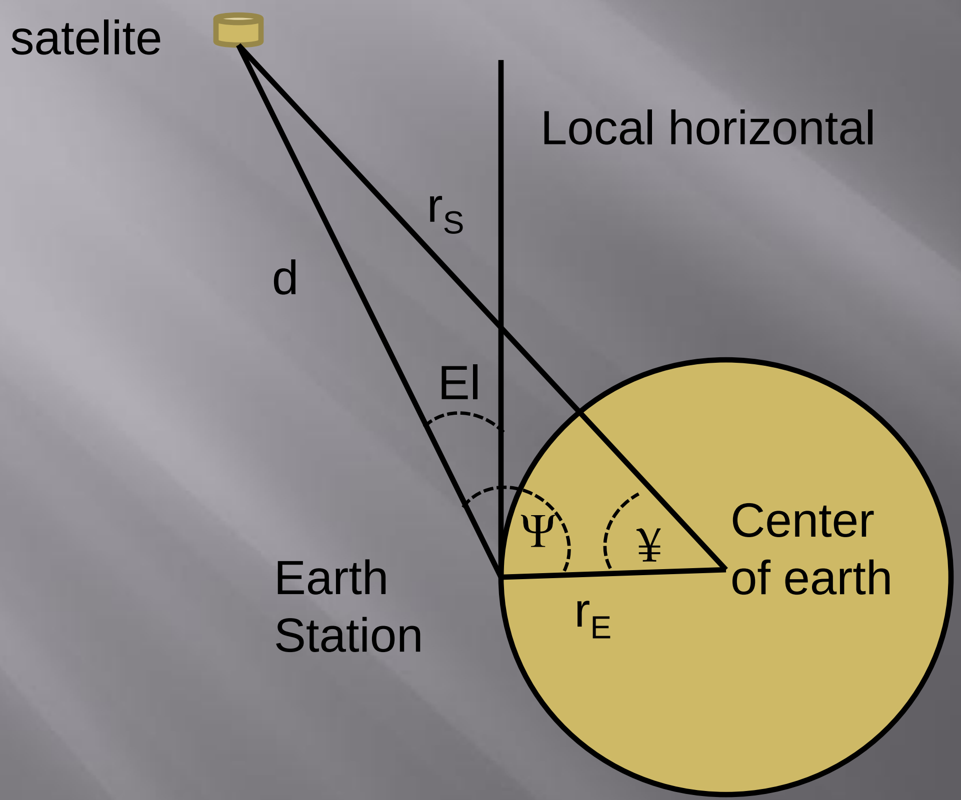
Locating the orbit in the geocentric equatorial system.The satellite penetrates the equatorial plan (while moving in the z_i direction) at the ascending node.The right ascension of the ascending node is Ω and the inclination i is the angle between the equatorial plan and the orbital plan.
Angle ω, measured in the orbital plan, locates the perigee with respect to the equatorial plan.



Look angle determination



Elevation calculation



L_E – E/S N Latitud

l_E – E/S W longitud

L_S – SS N Latitud

l_S - SS W longitud

$E_L = \Psi - 90$

Elevation Calculation

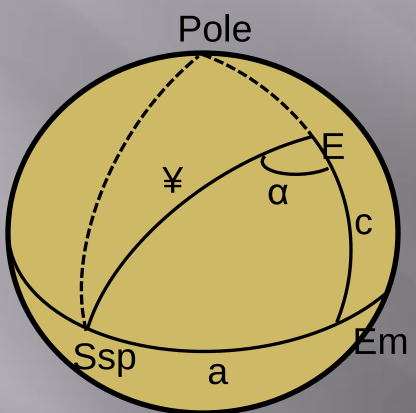
The elevation E_L:

- $\cos\ ¥ = \cos(L_E).\cos(L_S).\cos(l_S - l_E) + \sin(L_E).\sin(L_S)$
- $\cos(E_L) = \sin\ ¥ / [1 + (r_T / r_S)^2 - 2.(r_T/r_S).\cos ¥]^{1/2}$
- Or for geoshyncronous satellite
- $\cos(¥) = \cos(L_E).\cos(l_S - l_E)$
- $\cos(E_L) = \sin\ ¥ / [1{,}02274 - 0{,}301596 . \cos\ ¥]^{1/2}$

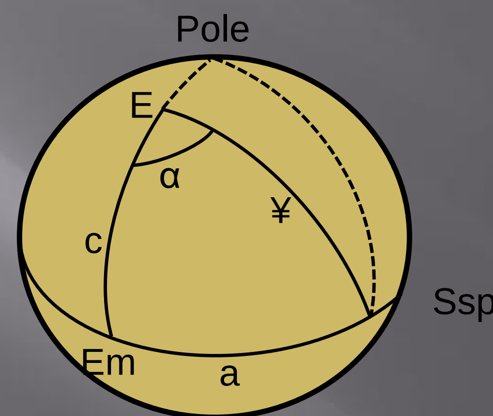
where
r_E – 6370 Km
r_S – 42242 Km

Azimuth Calculation

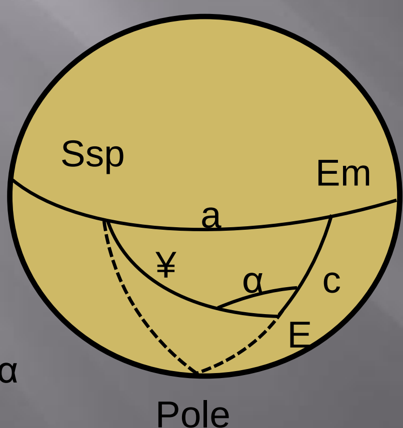
<u>Speciallization to geostationary satellite</u>



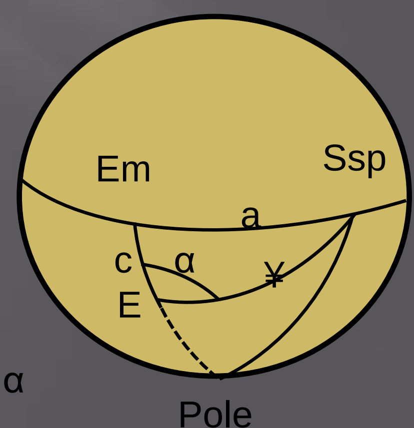
Az = 180º + α



Az = 180º - α



Az = 360º - α



Az = α

Azimuth Calculation

Being $a = |l_S - l_E|$, $c = |L_E - L_S|$

calling s ao ½ perimeter of triangle

$s = 0{,}5\ (a+c+¥)$

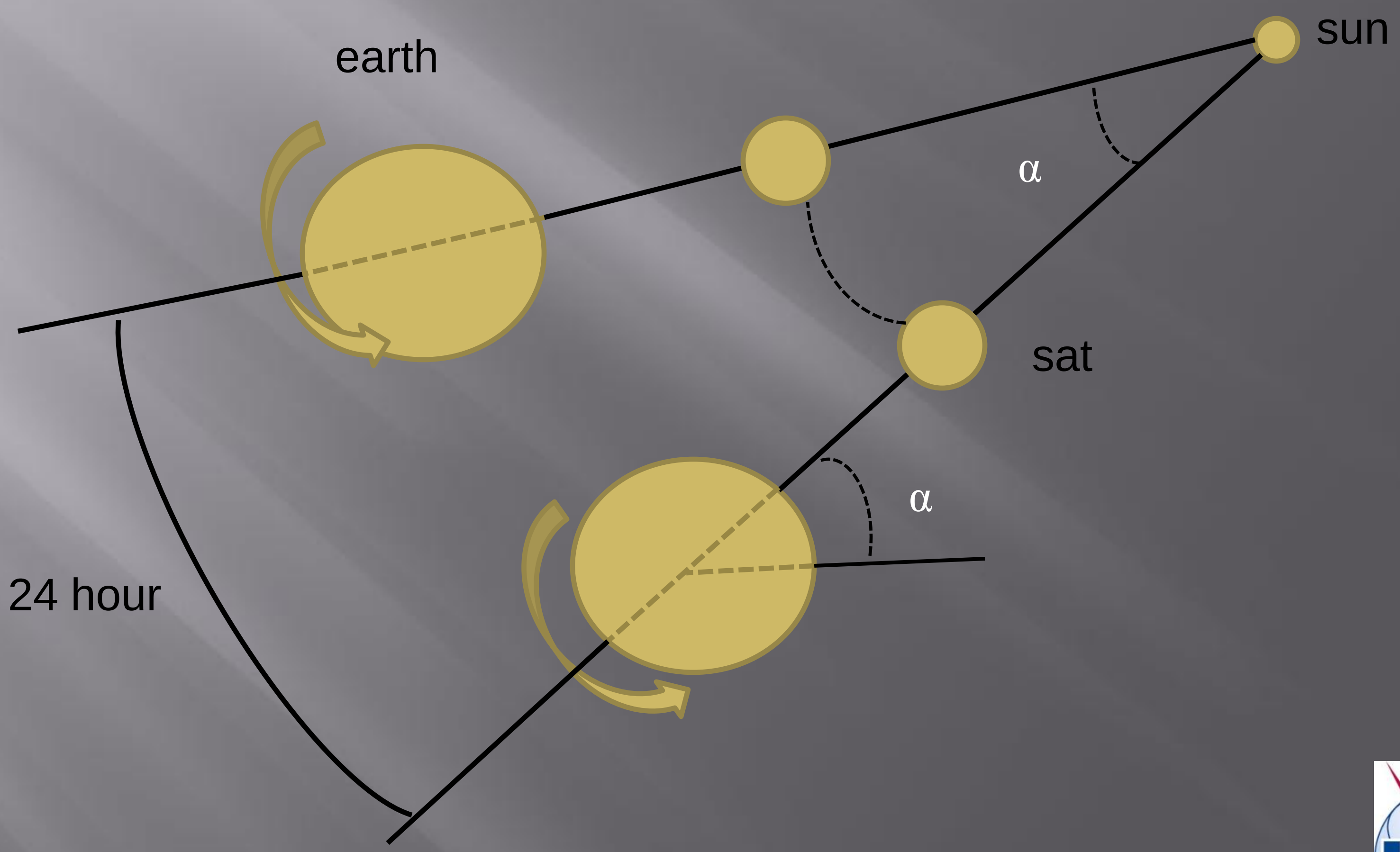
α, such as:

$\tan^2(\alpha/2) = \sin(s - ¥).\sin(s - c) / [\sin s\ .\ \sin(s - a)]$

or

$\boxed{\alpha = 2\tan^{-1}[\sin(s - ¥).\ \sin(s - |L_E|) / \sin(s)\ .\ \sin(s - |l_e - l_s|)]^{1/2}}$

Orbital period 1



Orbital period 2

- Is the virtual rotation period superior or equal to the earth rotation period e.g $\underline{360^{0} + \alpha}$, being $\underline{\alpha}$ the angle (degree) traversed by earth in his translation movement during one year :

  362 day 6 hours - equals to 360^{0}

  1 day - equals α

- Being earth angular velocity $\omega = (360^{0} + \alpha) / 24$

  or $\omega = 15{,}04107^{o}$ / hour

- The earth real rotation period,

  $T = 2\pi / \omega = 23{,}93447$ hours

Distance to Satellite

- Gravitational force on satellite is :

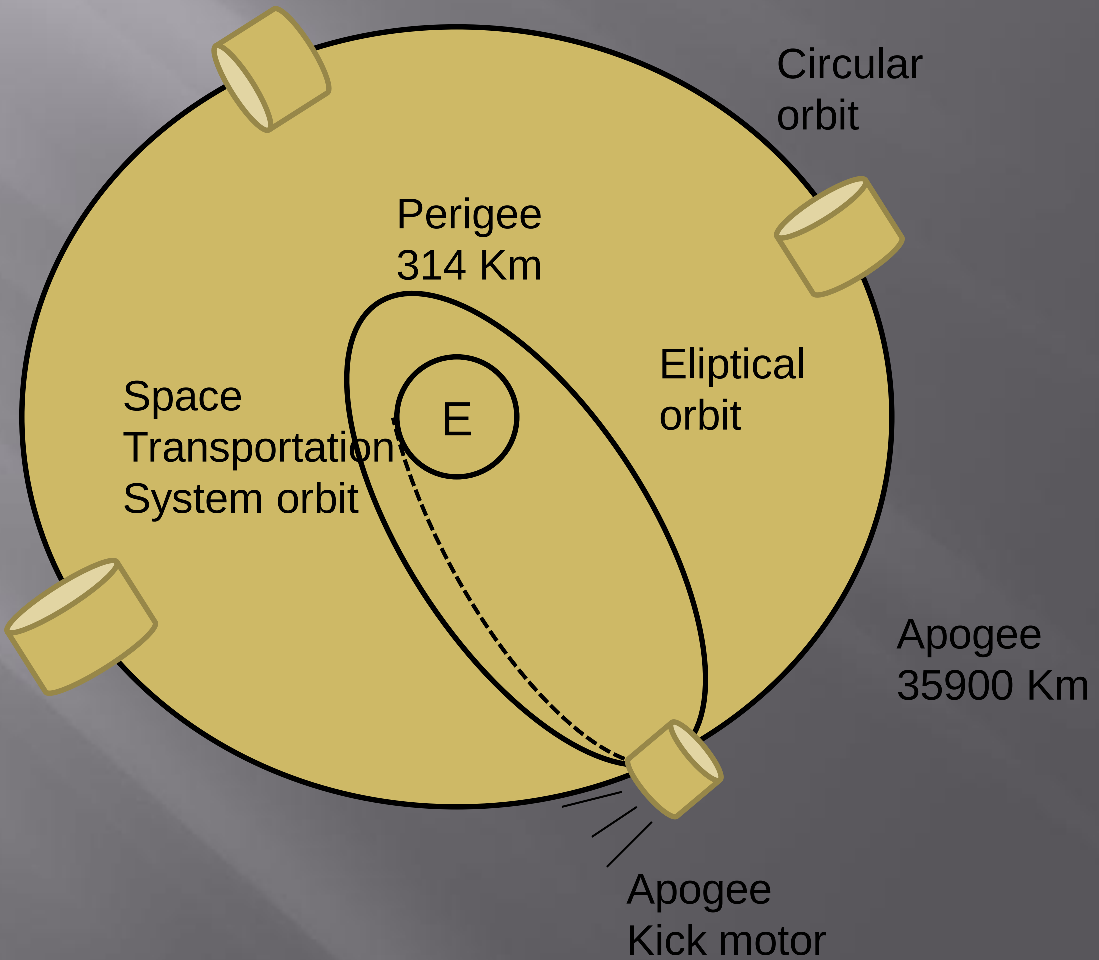
  $F_A = G\,M_T\,m\ / r^2$

  with $G\,M_T = \mu = 3{,}9861352 \times 10^5\ Km^3 / s^2$
- Other way Centrifugal force $F_C = m\,\omega^2\,r$

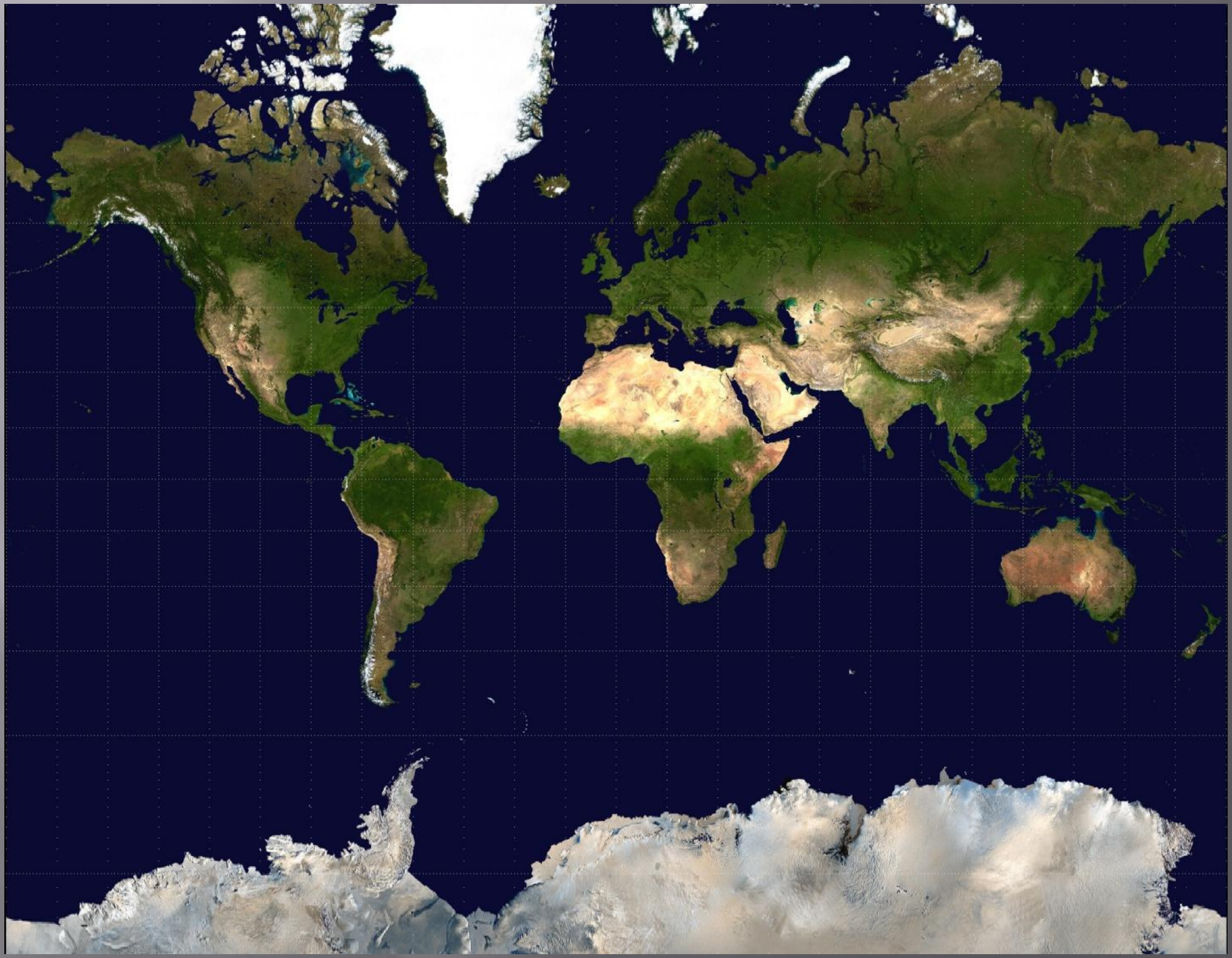
  or $r = 42164{,}6$ Km
- Being the earth's radium = 6373 Km
- Distance to satellite 42164 – 6373

  35789,6 Km

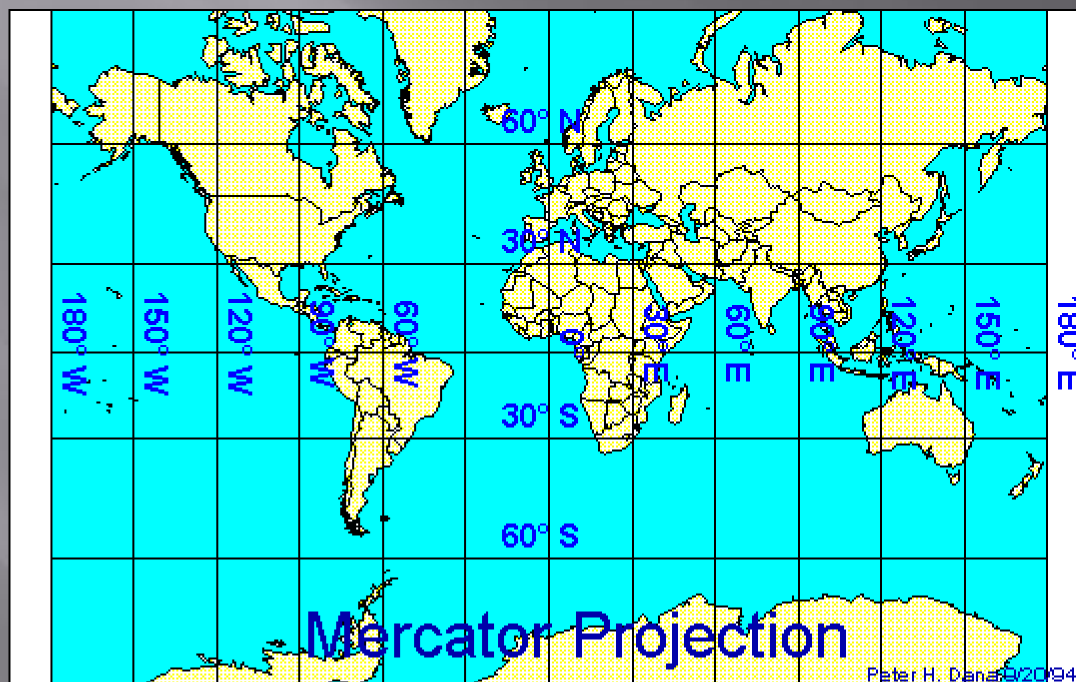
Launching Synchronous satellite



Design 1



Design 2



60° N
30° N
30° S
60° S
180° W
150° W
120° W
90° W
60° W
0°
30° E
60° E
90° E
120° E
150° E
180° E
Mercator Projection
Peter H. Dana 9/20/94

Design 3

- The design of a geostationary satellite shall follow 3 main operational considerations:
  1. Tha primary telecommunications mission which requests that the RF signal are received and transmitted at a specified power level within tha angles defined by the coverage zones on Earth;
  2. The space environment, and its efects on materials, components and sub-systems;
  3. The environment stresses during launching and lift off which vary according to the launcher used and the launch procedure.

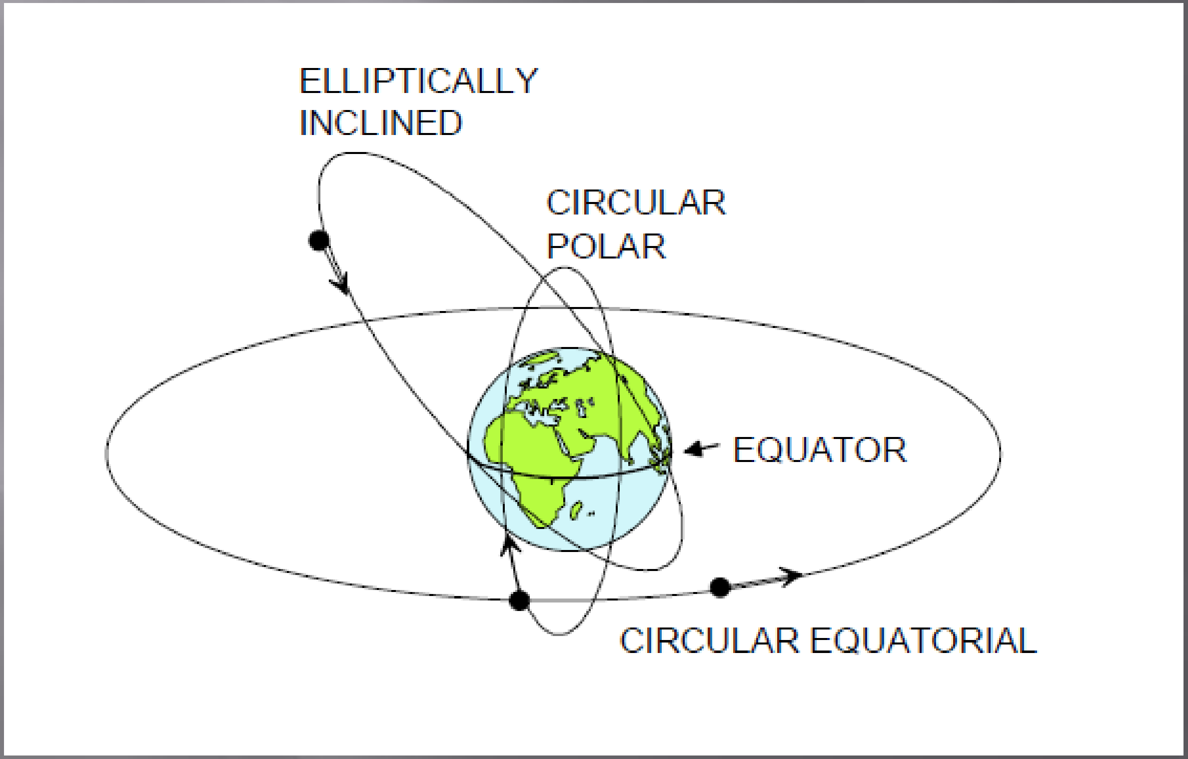
Subsystem Design

- A geostationary communications satellite can be divided into sub-systems each of which has a specific function. It is common practice to distinguish the communications sub-system or paylod (repeaters and antennas) that perform the primary mission from the *bus* or *platform* which includes all ohter sub-systems (common sub-systems) and is designed to support the communications sub-system.
- The requirements common to all satellite projects that need emphasis are:
  - Minimal massa
  - Minimal power consumption
  - High reliability

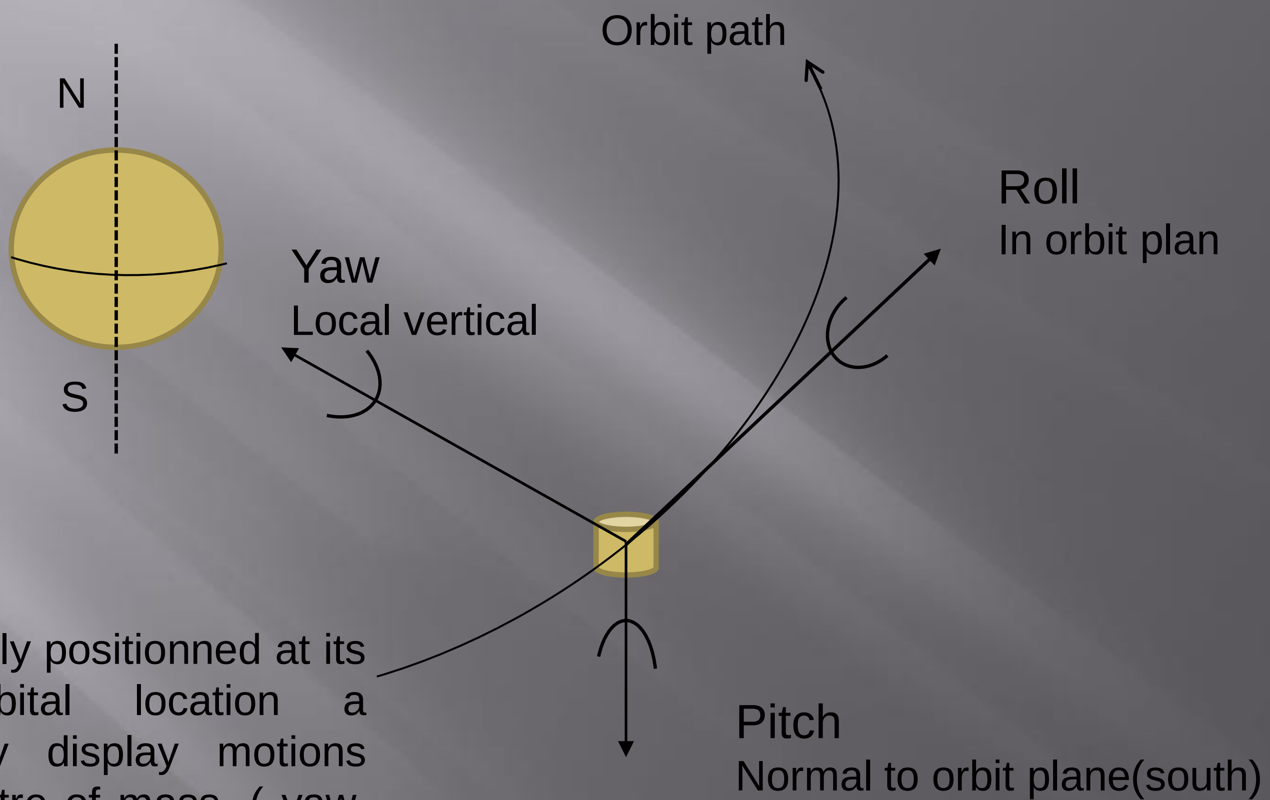
Satellite sub-systems

Subsystem	Function	Main characterístics
Attitude and orbit (AOCS)	Attitude stabilization and orbit stabilization	Accuracy
Propulsion	Provides velocity increments and torques	Specific impulse Mass of propellent
Telemetry tracking and command (TTCM)	Exchange of house-keeping data with control centre	Number of channels Security of communications
Thermal control	Temperature regularion	Heat dissipation capability
Structure	Support equipments	Stifiness
Electric power supply	Provides electric energy at various voltage levels	Power voltage regulation
Antennas	Receive and transmit RF signals	Coverage and gain
Repeaters	Amplify sgnlas and change frequency	Noise figure, linearity, [illegible] RF power

Position and orbit 1



Position and orbit 2



When correctly positionned at its nominal orbital location a satellite may display motions about its centre of mass. (yaw, pitch and roll).
The satellite attitude is determined by the angles that the satellite body make with this reference axis

Position and orbit 3

- Sensors for detection of attitude
  - Sun sensors
  - Horizon sensors
  - Stellar sensors
  - Inertial sensors
  - Radiofrequency sensors
  - Laser sensors
- Actuators for attitude control
  - Momentum devices
  - Thrusters
  - Magnetics coils
  - Solar sails

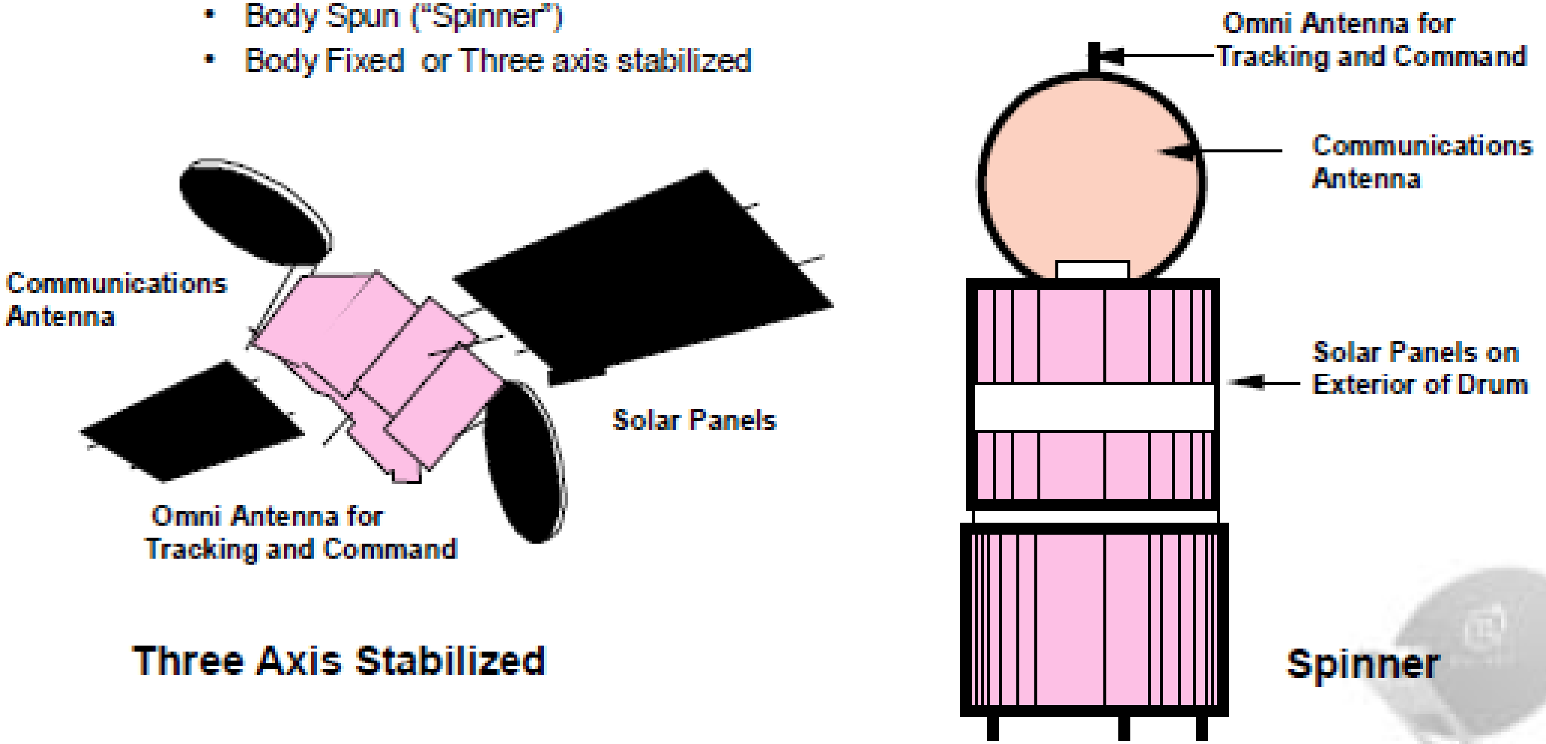
Position and orbit 4

- Attitude control techniques
  - Stabilization by gravitational gradient (LEO)
  - Spin stabilization (transfer orbital phase)*
  - Dual spin satbilization (spot beams satellite)
  - Three axis stabilization

* achieved by rotation of geo sat body between 30 and 120 rpm, creating na ennertial stifiness which maintains the sat axis perpendicular to equatorial plane

Position and orbit 5

- **Two basic types of communication satellites:**
  - Body Spun ("Spinner")
  - Body Fixed or Three axis stabilized



Position and orbit 6

- Station Keeping
  - Determination of position
    - Angle measurement (achieved by varying the ground antenna pointing and searching maximum recpetion gain or using monopulse techniques)
    - Range measurement (through phase shift between transmited and received signals)
  - North - South station keeping (…as the luni-solar atraction reflects in a change of inclination, annual velocity ioncrement must be applied)
  - East - West station keeping (due to asphericity of the earth's gravity)

Position and orbit 7

Satellite station keeping

Gravitational effects of the sun and the moon, the radiation pressure of the sun, the earth's magnetic field and other forces cause perturbations in the orbit of a satellite.

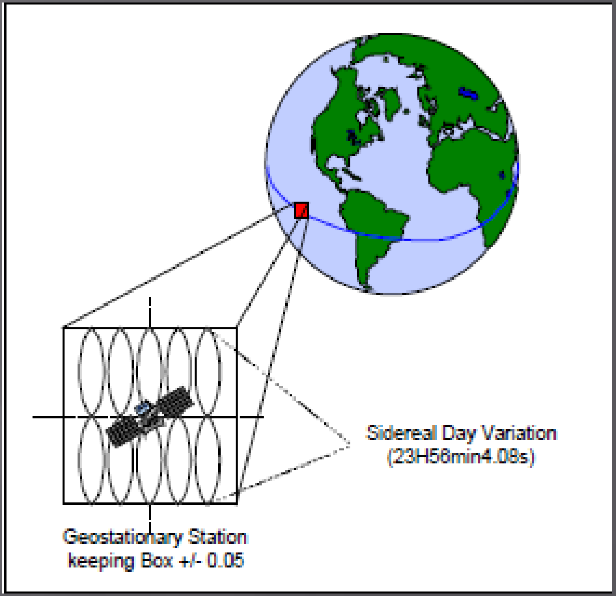
Satellite must contain fuel to correct for these perturbations and hence the life of a satellite is determined by how well the on-board fuel is managed by the satellite operator.

Hydrazine fuel is used and thrusters are mounted on the body of the satellite which are fired as required to maintain a specific tolerance.

Approximately 20 to 40% of the dry mass of a satellite is allocated for station keeping fuel.

Typically, a +/- 0.05 degree station keeping box wrt North-South and West-East is maintained by satellite operator.

Majority of fuel used for N-S station keeping corrections.



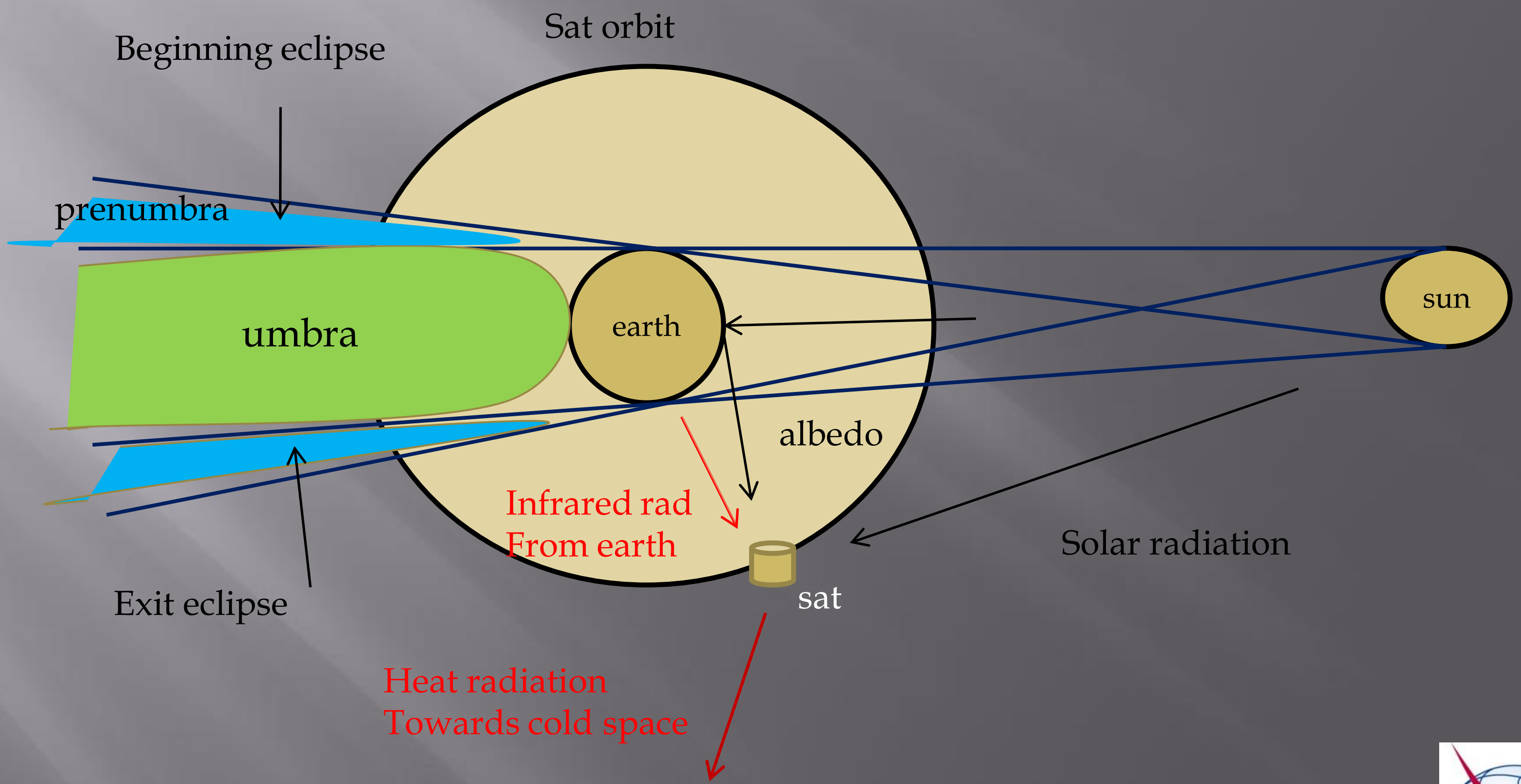
Propulsion sub-system

- Aims generating forces:
  - Low thrust actuators devoted to atittude and orbit corrections which provide na annual velocity increment of the order 50 m/s and boosts from 10^{-3} N up to 20 N, and can operate from several hundreds to several thousants of hours made up of many short operating cycles , a lon life about seven to tem years for communications satellite;
  - High thrust motors (400N up to 50KN) named apogee kick motor, which provides the velocity increment required for the geostationary satellite orbit injection at the transfer orbit apogee (about 1500 m/s);
  - Very high thrust which provides the velocity increment required to inject the satellite into the trasnfer orbit (about 2430 m/s)
  - Chemical (0,5 N até 10KN)
  - Electric (2 e 10 mN)

Telemetry Tracking Command

- Transmit house-kiping informationand status of the satellite to the ground control station;
- Provide angular and range measurements to permit locallization of the satellite
- Receive command signlas from the ground control station to initiate attitude and station keeping manoeuvres and operations of the on-board equipments
- The frequencies generally used are either VHF (148 to 149,9 UL or 136 to 138 MHz DL) or S band (2025 to 2120 MHz UL or 2200 to 2300MHz DL)

Thermal Control



Thermal Control 1

- Required to maintain equipments and structure of the satellite within specified temperature ranges.This must be ensured whether the equipments are operating or not;
- Is designed considering the diferent requirements of the operational and transfer orbit phases, which involve diferent attitudes and orbits and diferent status of the apogee motor ;
- Acceptable temperature ranges, e.g

Batteries	0 º C a +20 º C
Solar Cells	-100 º C a +50 º C
Electronic equipment	-10 º C a +60 º C
Propeller Tanks	+10 º C a +50 º C
Infrared sensors	-20 º C a +45 º C

Thermal Control 2

- Passive thermal control
  - Based on the absorptance α and emittance ε of the surface finish, and the ratio α / ε is of prime importance in determining the surface mean temperature when exposed to the sun (white paint, aluminium paint, black paint, polished metal surface)
- Active thermal control
  - Heat pipes ensuring adiabatic transfer of heat from heat sources to radiators by successive vaporization and condensation of a fluid at the two extremities of a pipe
  - Hinged flaps and multiple blade louvres mechanisms arranged to expose or to cover radiator areas
  - Electrical heaters activated either by thermostats or telecommand

Structure

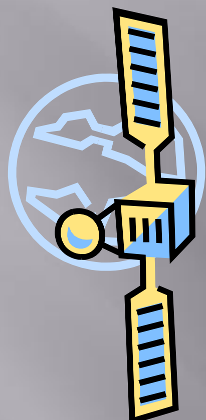
Structural materials must have resistance to deformation and be lightweight.This are confliting requirements.Current techniques allow about 6 % of the satellite's total mass only to be used for its structure (aluminium, magensium alloys, honeycomb panels, bonded assemblies and carbon fibre reinforced plastic materials for solar panels, antenna towers)

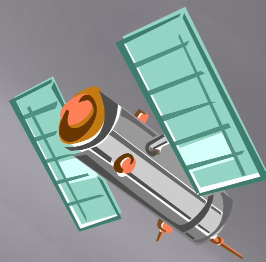
- Support the on-board equipment especially during the launch phases where the machanical stresses are higher
- Ensure correct positionnng of the equipment (alignement of sensors, thrust axes of thrusters, axes of antennas…)
- Allow the various separations and deployments
- Avoid electrical charge accumulation

Power Supply

- Primary energy source
  - Solar panel and cells (requiring sun sensors, electronics for measurement and control , a servo motor and a bearing and power transfer assembly)
- Secondary energy sources
  - Electrochemical accumulators:
    - Sufficient Lifetime whitch depends on the depth of discharge and temperature
    - Hight specific energy in Wh / Kg
  - N_i-C_d, A_g-C_d, N_i-H_2, A_g-H_2)
- Power conditioning and protection circuits
  - Unregulated (simpler, lower mass, however equipments subjected to variations in voltage) and regulated (not subjected to variation voltages , but costly to the masss budget and outout power, and less reliability)
- Spin stabilized satellite (specific power unit~ *9,7 W / Kg)* body fixed satellite (specific power unit ~ 19 W/Kg)

Solar Arrays evolution

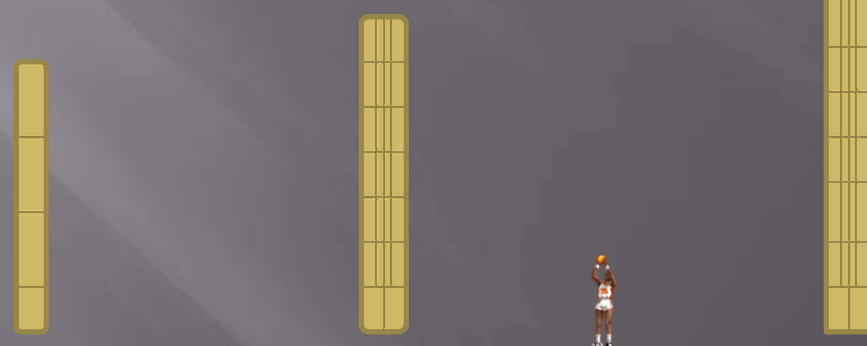




Ultra light pannel
4,7 KW
Lifetime 7-15 Y

Light pannel
2 KW
Lifetime
7 Y

Intelsat V



1 m

Antenna 1
(in the satellite)

The approach to the design and sizeing of satellite antennas is related directly with the desired coverage no satélite, but also related with the stress of mechanical effects - torques - on the structure on the satellite.

1. Gravitational torque

These effects may cause the satellite to rotate about its centre of mass unless the axis of smaller inertia of the satellite is aligned with the earth local vertical, and depend on the distance of gravitational centre of earth to the satellite centre. This torque which may be used to stabilize satellite placed in a low orbit is rather ineficient for the stabilization of geostationary satellites

Antenna 2

2. Operational (automatic or manned) torques to

- Antenna pointing
- Solar panels pointing
- Station keeping manoeuvres
- Or consequence of propellent tanks emptiness

In conclusion the geostationary satellite is subject to perturbations which cause it to drift away from his nominal position and which create attitude perturbing torques. The drift in lattitude is the most significant, and results from the luni-solar attraction ,due to a variation in the inclination of the orbital plane of about 1º / y .The drift in longitude is basically due to the asymmetry of the terrestrial potential and depends on nominal situation of the satellite relative to 2 equilibrium points e.g 105º long W and 76º long E

Antenna 3

We come to the need to the satellite stabilization through the well known *gyroscópic* effect due to its capability of keep stiffness to torques tending to disturb the orientation of rotational axis.

Spin stabilization is achieved by rotation of the geostationary satellite body between 30 and 120 rpm creating na internal stiffness which maintains the satellite axis perpendicular to the equatorial plane.
Hence this simple technique benefits from the properties of a gyroscope, but has the inconveniente of either accepting a toroidal pattern antenna (and therefore low gain), or imposing the use of a de-spun antenna or communication payload which requires specific technology.

Antenna 4

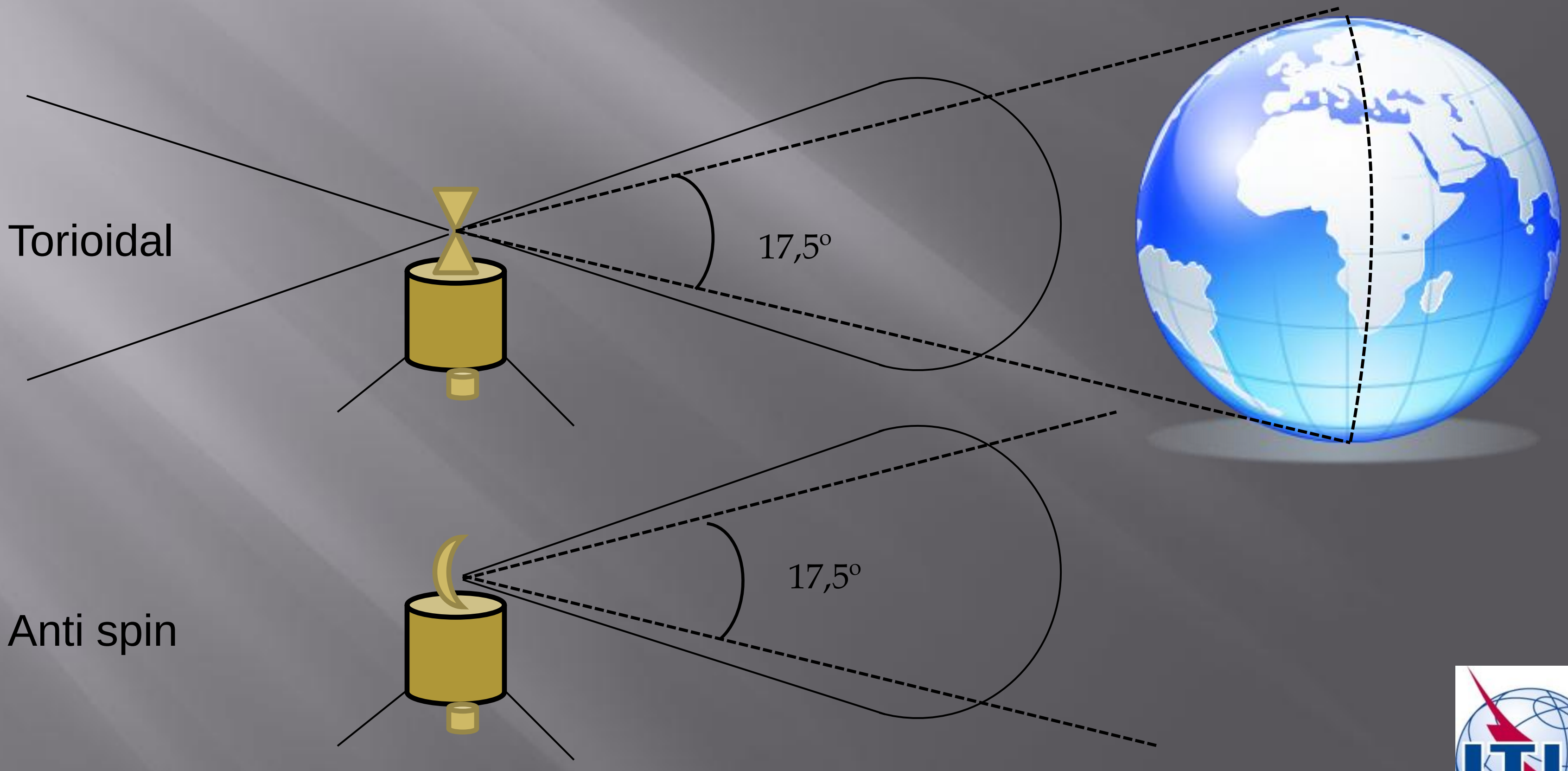
Depending on the satellite stabilization, hence :

- Rotating antenna platfform (spin satbilized sat)
  - Wired antenas (monopole, dipole TTCM, UHF e VHF)
  - Toroidal antenna
  - *Electronically De-spun antenna*
- Stabilized antenna platform (dual spin or body stab. sat)
  - *Horn* antenna
  - Double reflector antenna
  - Multibeam reflector antennas

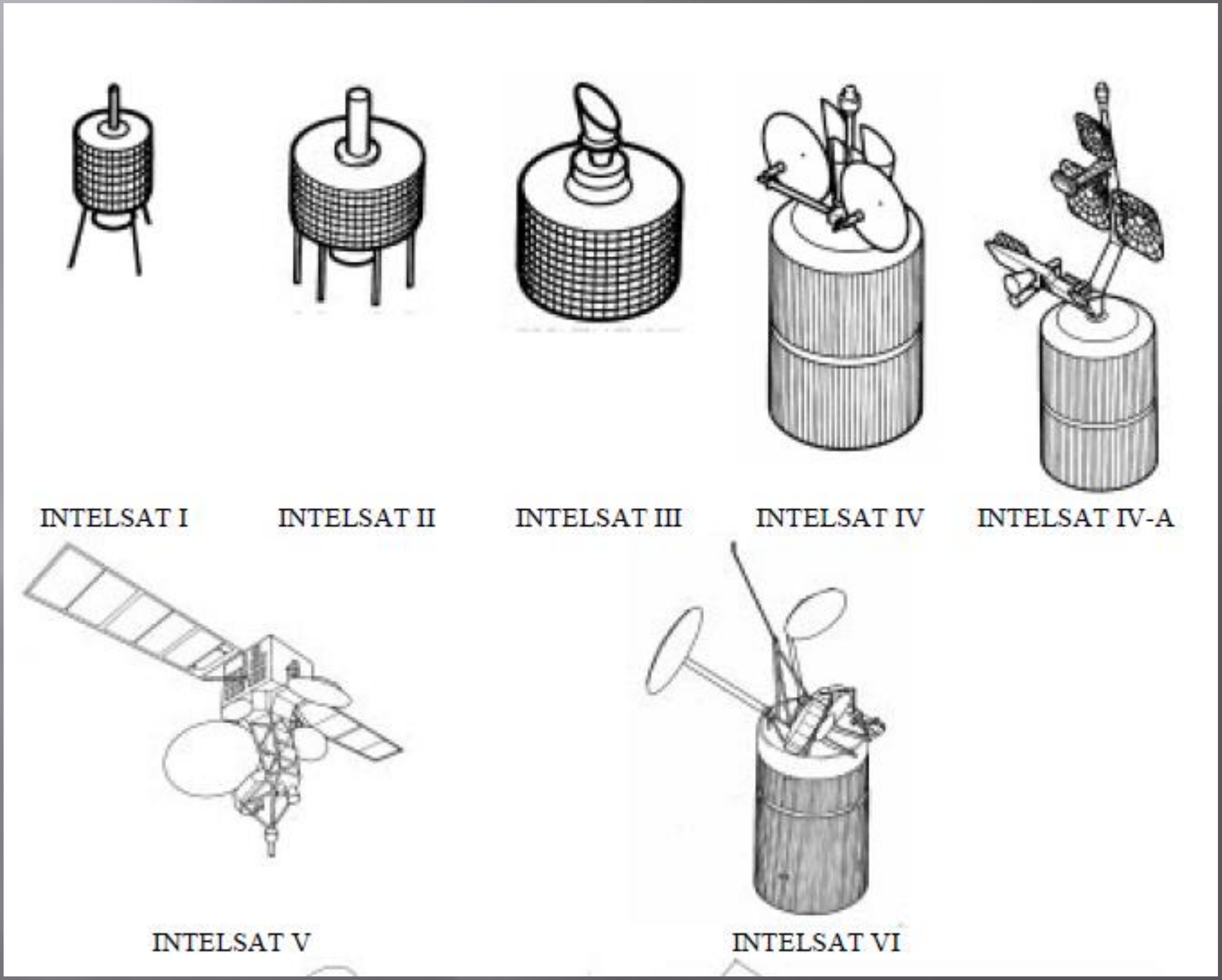
and with the coverage footprints

- Global, Hemi, Zone beams
- Spot beam
- Shaped, Multiple beam

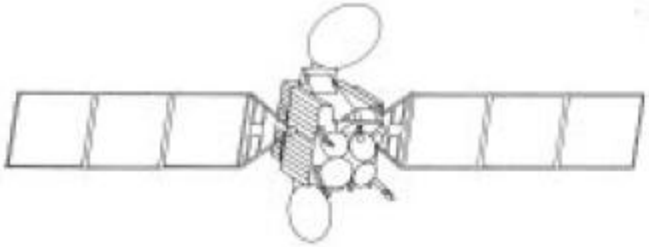
Antenna 5



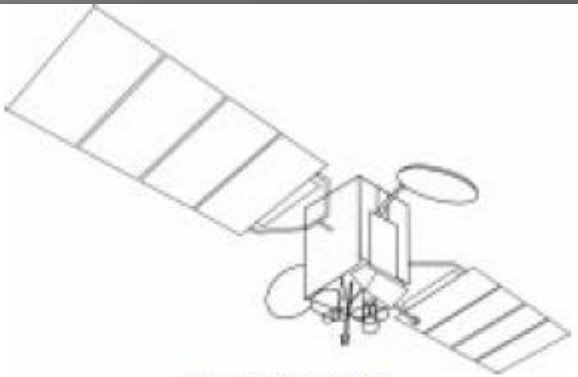
Antenna 6


INTELSAT I
INTELSAT II
INTELSAT III
INTELSAT IV
INTELSAT IV-A
INTELSAT V
INTELSAT VI

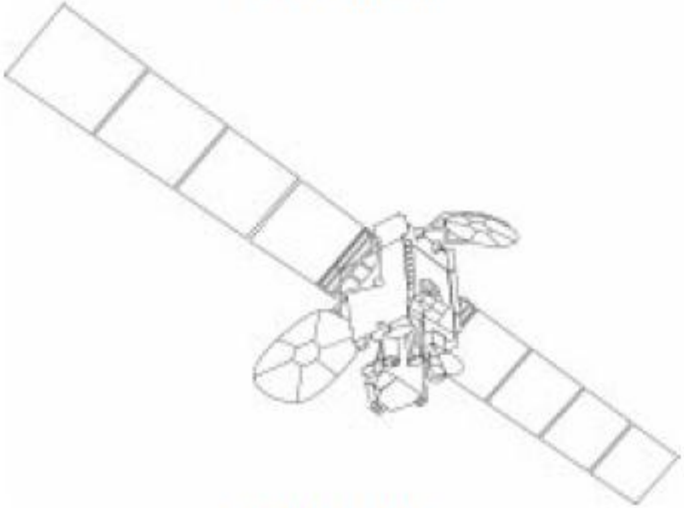
Antenna 7



INTELSAT VII



INTELSAT VIII

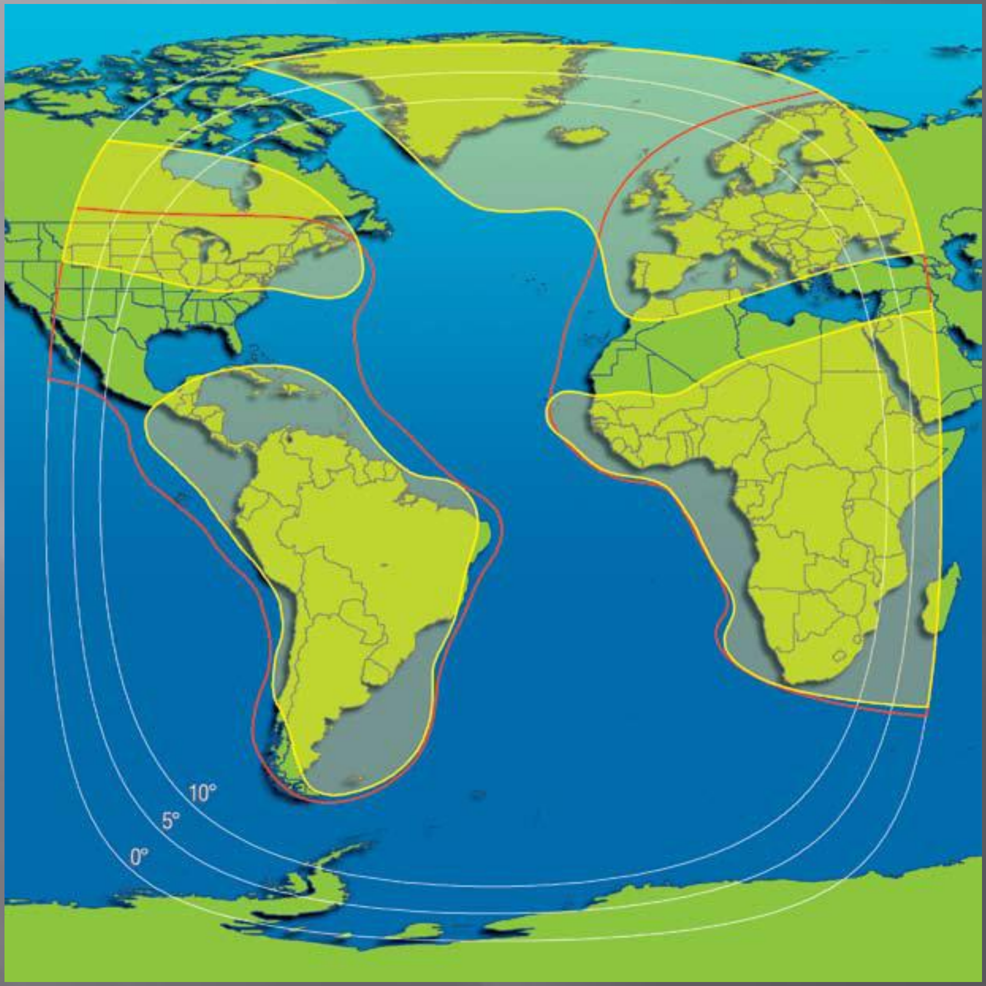


INTELSAT IX

Antenna 8

INTELSAT Satellite Series	TOTAL RF BW (MHz)	RF BAND	PRIME POWER (Watts)	WEIGHT (Kg).	STABILI-ZATION TYPE	Design LIFE (years)	NEW FEATURE
I	50	C	45	45	SPIN	1.5	First satellite for international telephony services
II	125	C	75	45	SPIN	3	Telephony plus TV capacity.
III	450	C	120	300	SPIN	5	The first global satellite system.
IV	480	C	460	720	SPIN	7	SCPC service and the RF band divided into 36 MHz transponders.
IV-A	800	C	595	795	SPIN	7	Frequency reuse by spatial isolation
V	2200	C and Ku	175	970	3-AXES	7	Frequency reuse by polarization isolation, Ku-band package and cross-strapped operation.
V-A	2250	C and Ku	1475	970	3-AXES	7	Frequency reuse for global beams and steerable spot beams
VI	3300	C and Ku	2100	1800	SPIN	10	SS-TDMA operation and Solid State Power Amplifiers (SSPAs) as output amplifiers in some beams.
VII	2432	C and Ku	4000	1437	3-AXES	10.9	SSPAs in all C-band transponders; switchable transponder and enhanced U/L connectivity in Zone Beams; 12 GHz D/L capability; enhanced Ku-Spot 2 coverage for POR
VII-A	3160	C and Ku	5000	1823	3-AXES	10.9	Linearized Traveling Wave Tube Amplifiers (LTWTAs) and paralleled LTWTAs in Ku-band for a high power mode; Ku- to C-band connectivity
VIII	2550	C and Ku	5100	1587	3-AXES	10	Polarization reversal option in Ku-band; TV Broadcast mode in Zone Beams for a West Quasi-Hemi coverage; flexible transponder activation for 6 out of 10 Channels in Ku-band
APR	396	Extended C	2200	1118	3-AXES	12	Linear polarization, extended C-band, higher EIRP
IX	3456	C and Ku	8085	1900	3-AXES	13	Selectable split uplink in Global Channel 12 for SNG; selectable split uplink in Hemi Channel 9 for DAMA. Flexible transponder activation for 12 out of 16 channels in Ku-band. Equipped with an overdrive control for Ku-band transponders.

Footprint – Global, Hemi, Zona

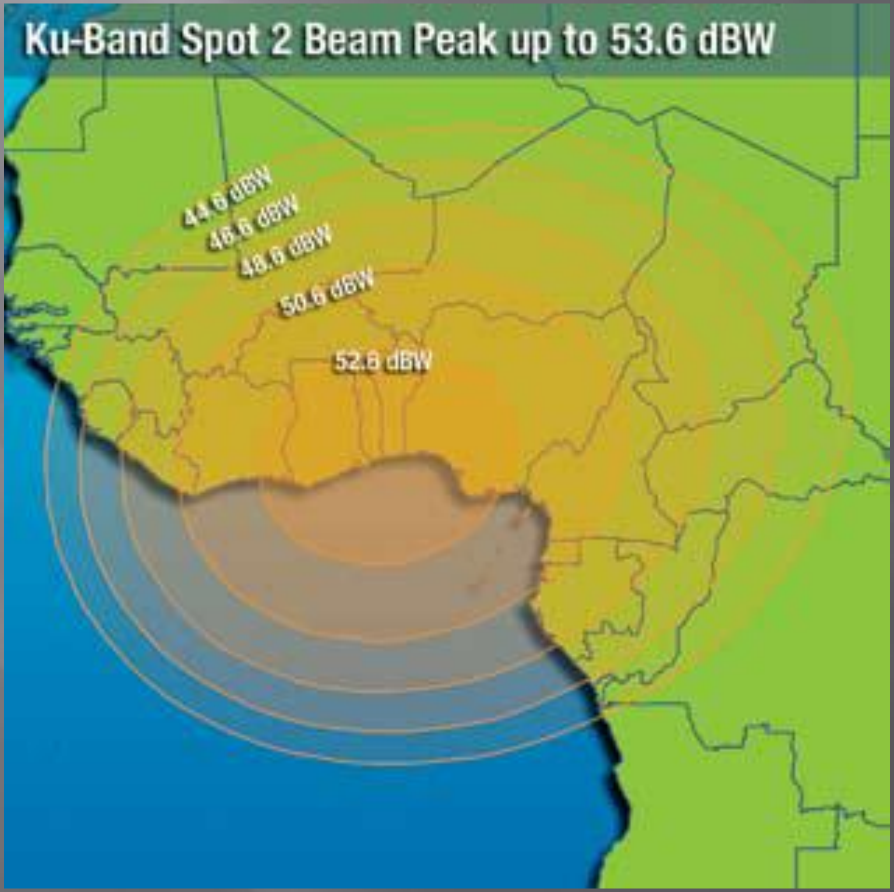


Global

Zona

Hemi

Footprint - Spot



Transponder 1

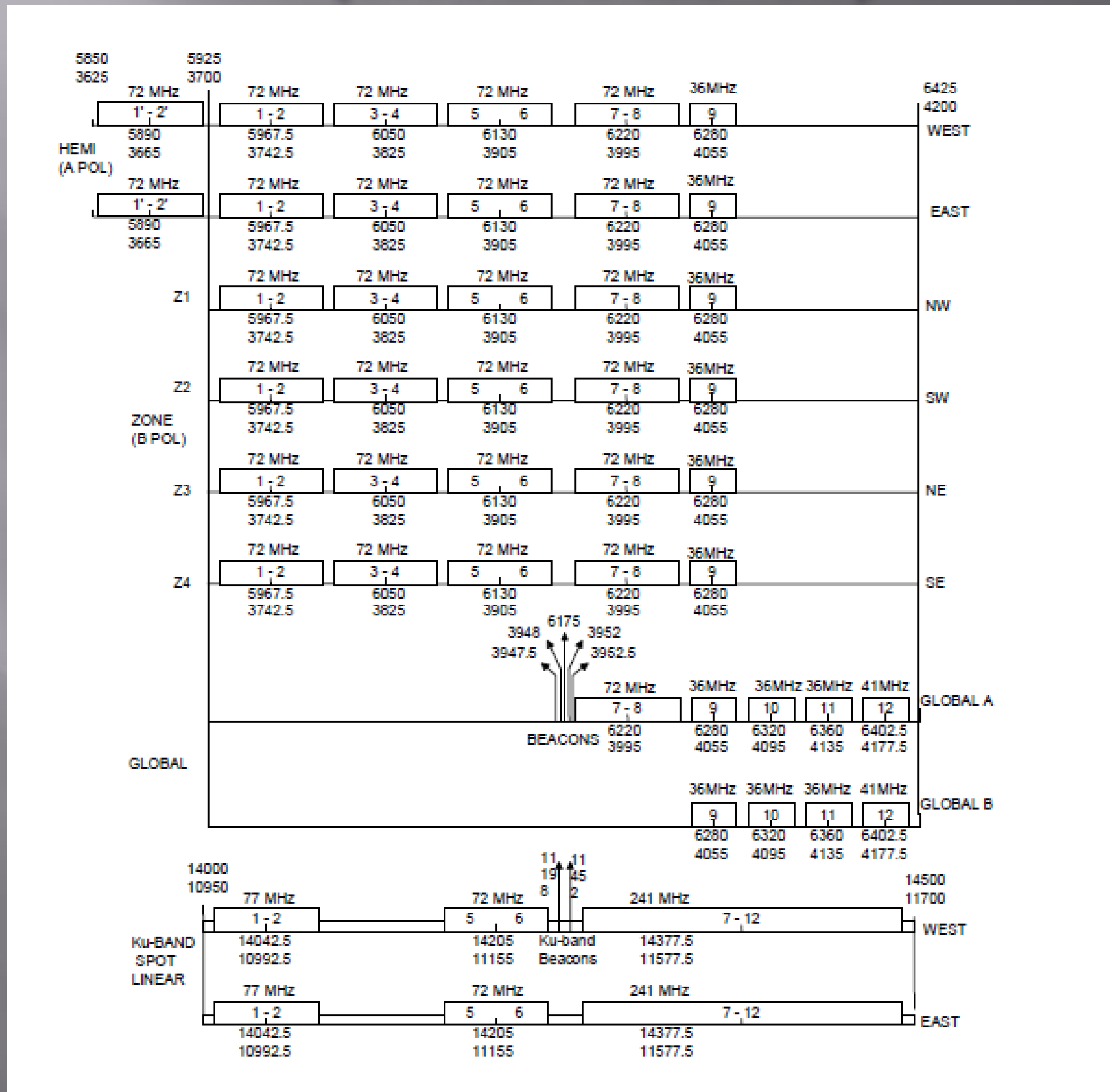
Electronic devices that:

- Amplifly signal received form earth at very low level, to signal output to be sent to earth from -100 dBW to 10 dBW what means 110 dB of gain;
- Convert the frequency , which avoids interference between the powerful transmitted signal and the weak incoming signal.
- And in some particular cases (regenerative repeater) also provides on-board detection of the received signal prior to baseband processing and remodulation for down link transmission.

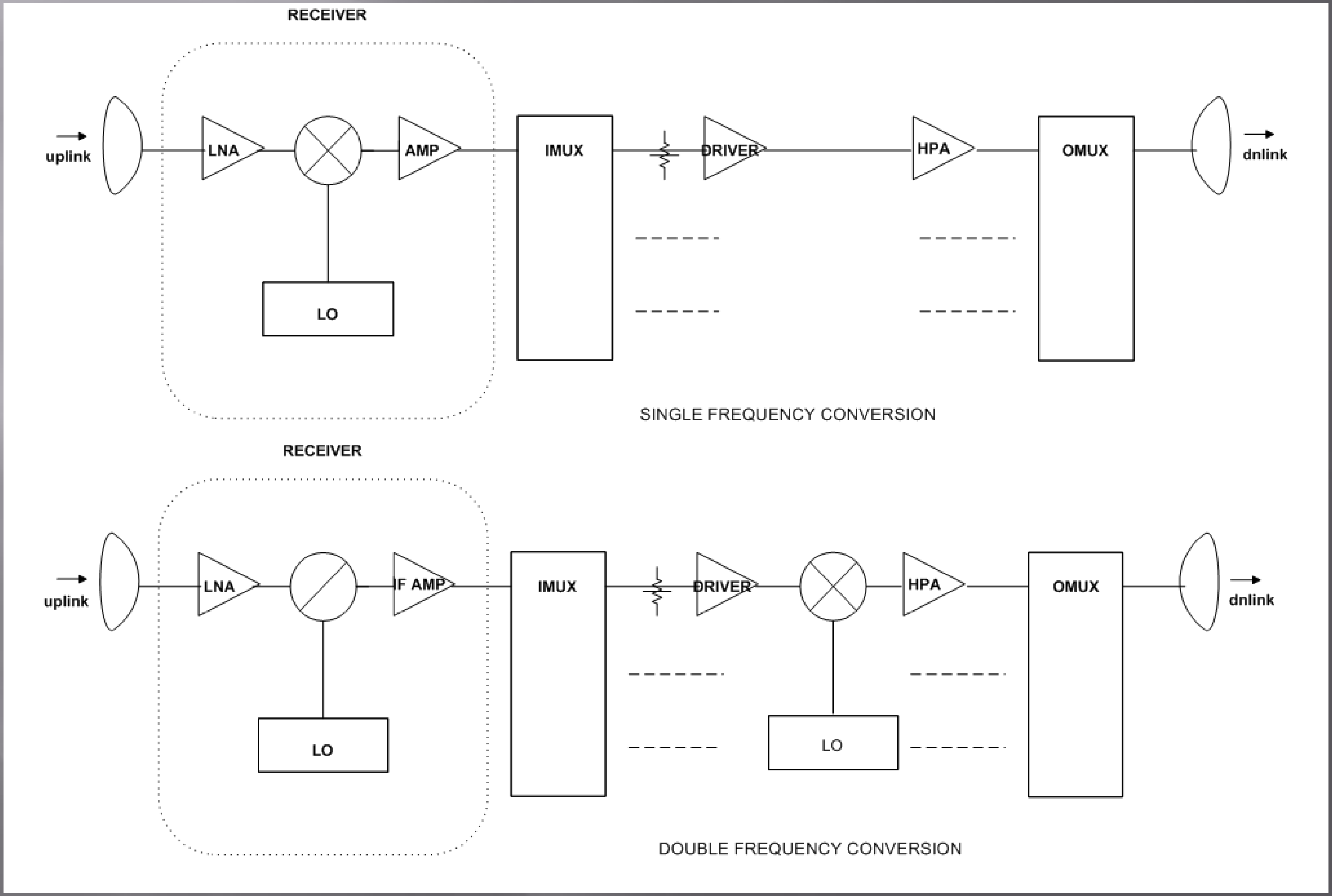
Transponder 2

The basic building block of any satellite communications package is the transponder.This device receives the uplink carriers, amplifies them, convert them to the correct downlink frequency band and transmit them via a high power amplifier back to earth.
In the early satellite a few transponder - Intelsat I and II employed 1 or 2 250 MHz - and those used had a relative low output power (1 or 2 W). As the demand for circuits grow the design of communications package changed to offer more transponder. Each covering a small portion of the available band thus providing better linearity and a higher output power capability.
Intelsat IV contained 12, 40 MHz transponder (36 MHz usable and 4 MHz guard band) what means 480 MHz useful and 20 MHz for flight beacon.
To achieve the optimization of the frequencies used, cecome common the use or spatial frequnecy reuse, and frequency polarization reuse, in su way the initial 500 MHz bandwith become 2500 MHz.

Transponder frequency plan (Intelsat VI)



Transponder architecture



Transponder components 1

- Low Noise Amplifiers
- Down converter
- Post converter amplifier
- Input and output multiplexers
- Switch matrix (multibeam sat)
- Channel power amplifier
  - Driver
  - Output stage
  - Multi carrier operation
  - HPA (TWTA)
- Regeneration repeater

Transponder components 2

The overall performance of communications payload is closely related to the characteristics of repeater.For instance the receiver G/T of satellite depends on the receiver inout amplifier noise figure.

The downlink frequency stability depends on that of the local oscilattor.Out of band signals are generated by the repeater non linearities and are sensitive to filter characterisitcs.The EIRP of satellite depeends on the saturated power of HPA and the loss of output devices (filters, feeders etc)

- Low Noise Amplifiers
  - Basically the low noise amplifier (preamplifier) conditions the repeater global noise figure .High gain 5 to 20 dB, and NF of 3 dB (6GHz), 4dB (14GHz) 8dB (30 GHz)
- Down Converter
  - Includes mixer, filter, local oscillator.Typically mixer conversion loss is 5 to 7 dB.

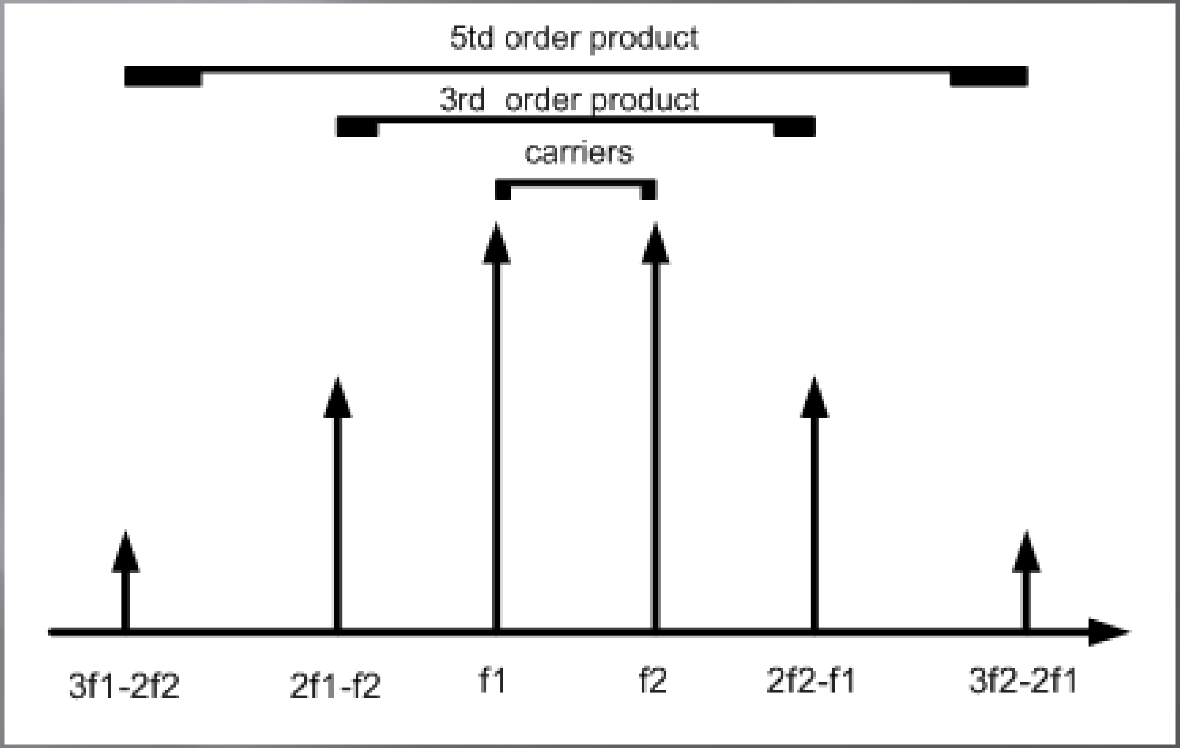
Transponder components 3

- Post conversion amplifier
  - After frequency conversion hjgh gain amplifier is necessary to bring signals to a hjgh level for the input of transmitter power stages
- Input & output multiplexer
  - Determine the inout and output of the channelized part of the repeater, making use of high Q's band pass filter which impose the transponder bandwith.:
    - IMUX splits into separate channels the total bandwith, through circulators and a set of bandpass filters.
    - *OMUX* combines the channels after power amplification. Tight requirements are imposed concerning the insersion of the OMUX as any power loss reduces the satellite EIRP and generates heat.

Transponder components 4

- Switch matrix
  - With multibeam satellite switches are required to modify the beam interconnectivity.Switches operated through ground command allow fora semi-fixed interconnection scheme .Rapid switches (several times switch within a millisecond) implies:
    - Solid state switches
    - On board control
- Channel power amplifier
  - Comprises one or several stages of power amplification (driver) and the output stage.
  - Power amplifiers are not linear and non-limear operation generates undesirable signals as intermodulation products, e.g when a non-linear amplifier is driven by two equal power carriers at frequencies f_1 and f_2 (next slide) the products of third and fifth order are significants, or $2f_2$-f_1 and $2f_1$-f_2 and also $3f_2$-$2f_1$ and $3f_3$-$2f_1$

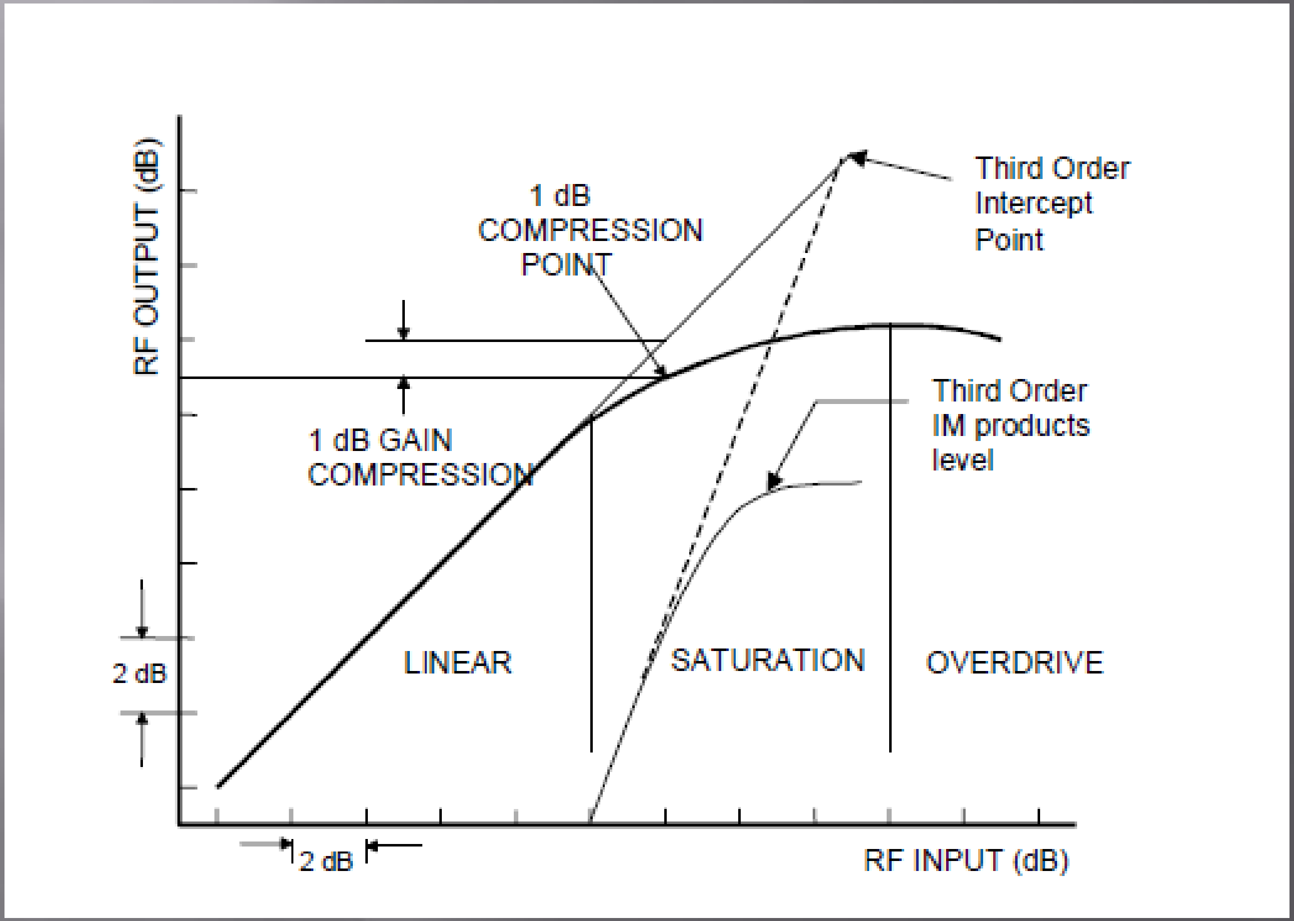
Non linearity effects



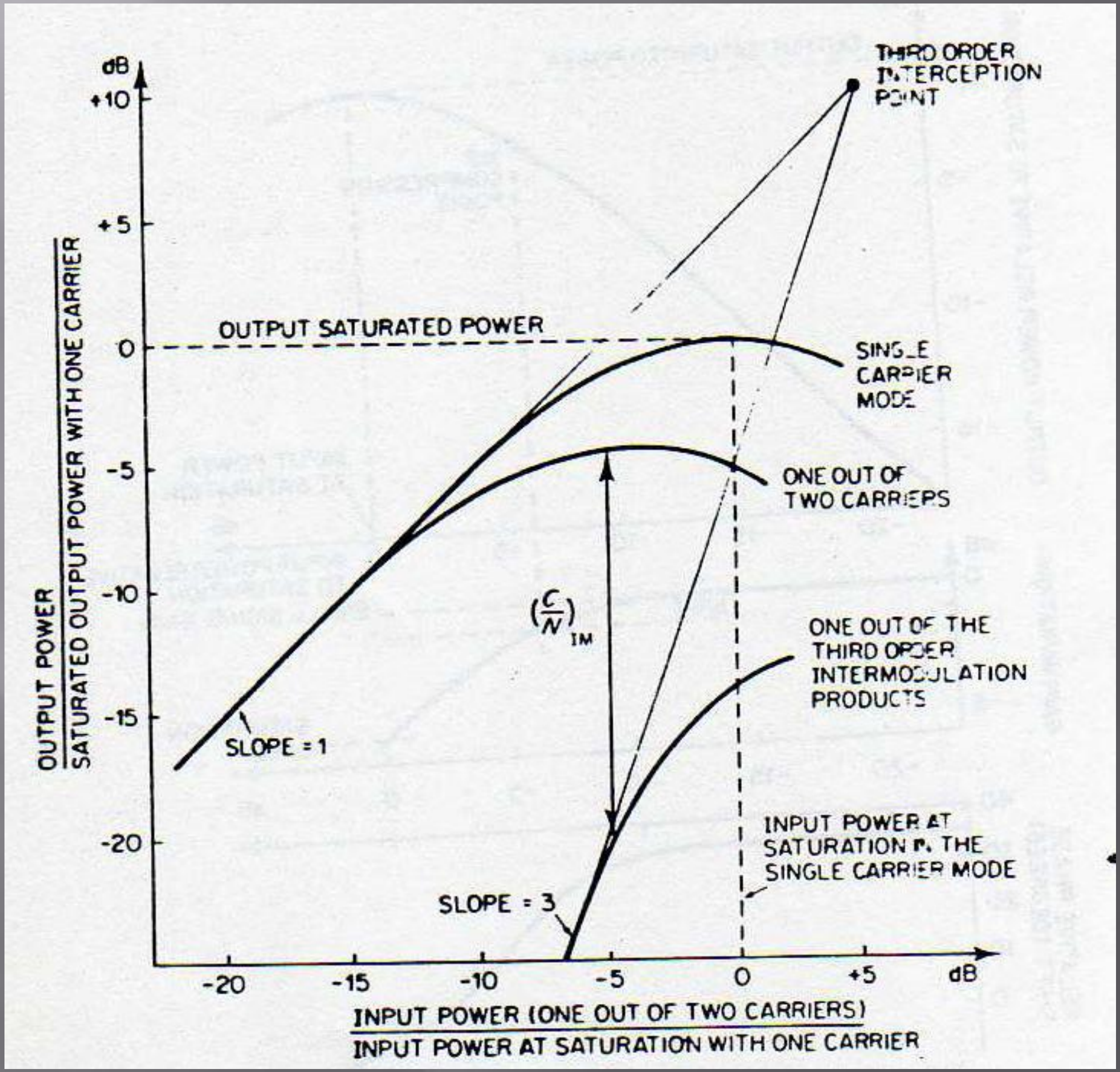
Transponder components 5

- Driver is a narrowband amplifier which amplifies signlas at the IMUX output to the power level required to drive the output stage.
- Output Stage as well as the HPA, refers the common situation where output power gain and phase shit in terms of input power are achieved. The variations in phase shift of the output carrier when the input power varies, turns into phase modulation when the input carrier is amplitude modulated or what is caled AM / PM conversion showed in the following slides, respectively for monocarrier and multicarrier situation
- Nowadays output stages are implemnted mostly with travellling wave tubes (TWT) but solid state power (SSPA) is being the winner, because are lighter in weight more linear and offer a significant improvement in reliability, meaning improved linearity increased transponder capacity.

Mono-Carrier Output



Multicarrier



TWT 1

The RF wave's electric field traveling in the slow-wave structure penetrates into the electron beam region, and causes some electrons to accelerate and some others to decelerate producing a periodic velocity modulation approximately in phase with the RF electric field.

The electron bunches thus formed tend to concentrate ahead of the accelerating field and behind the decelerating ones. Because the average velocity of the electron beam is slightly greater than that of the RF wave, the bunches will tend to move "back" into regions where the RF field will decelerate the electrons. As the electrons lose velocity, the energy lost by the electrons is transferred to the RF energy in the RF wave.This transfer of energy registers a constant gain in the amplitude of the RF wave per unit of length.

. The wave traveling from input to output will be amplified, and the wave traveling from output to input will not be amplifie d.

…/…

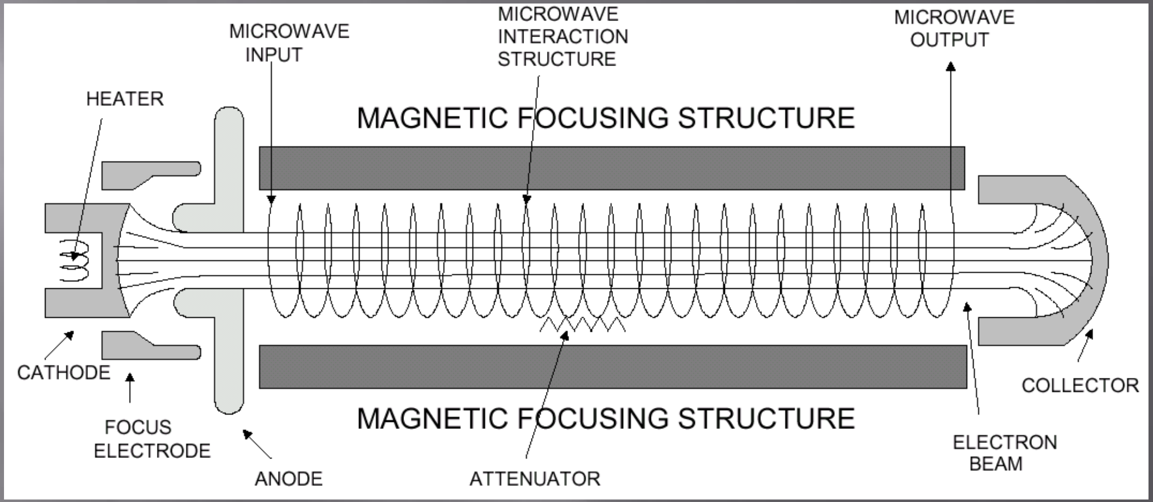
TWT 2

…/…

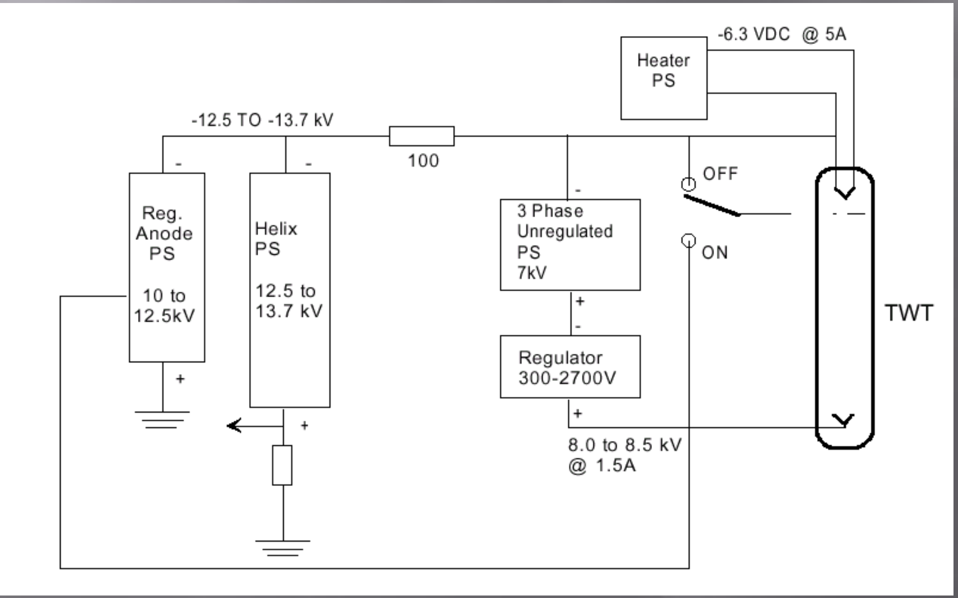
However, in the presence of the inevitable reflections at the output and input couplers, some RF energy could be reflected back towards the input along the helix, and upon reflection from the input coupler, this signal will represent RF feedback. All practical TWTAs have sufficient gain for this feedback mechanism to result in self-oscillation. It is fairly simple to interrupt this feedback path by placing RF attenuation on one or more of the helix support rods. The attenuation is formed by placing a carefully controlled pattern of a resistive material on the rods prior to their installation into the helix structure.

Pyrolytic graphite (carbon) and titanium carbide are the most commonly used substances. The density of this attenuation pattern is selected to provide a very low reflection of RF energy so that any energy reflected from the output of the TWTA is absorbed in the attenuation.

TWT 3

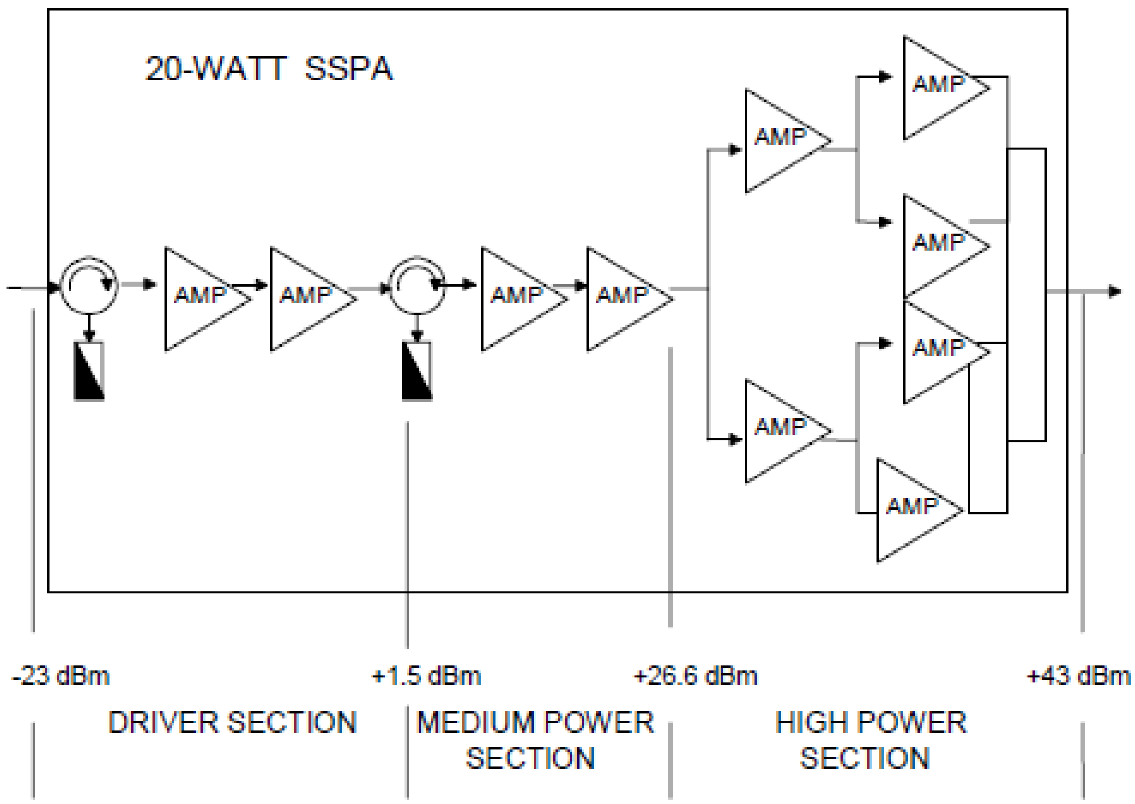


MICROWAVE INPUT
MICROWAVE INTERACTION STRUCTURE
MICROWAVE OUTPUT
HEATER
MAGNETIC FOCUSING STRUCTURE
CATHODE
FOCUS ELECTRODE
ANODE
MAGNETIC FOCUSING STRUCTURE
ATTENUATOR
COLLECTOR
ELECTRON BEAM



-6.3 VDC @ 5A
Heater PS
-12.5 TO -13.7 kV
100
Reg. Anode PS
10 to 12.5kV
Helix PS
12.5 to 13.7 kV
3 Phase Unregulated PS 7kV
Regulator 300-2700V
8.0 to 8.5 kV @ 1.5A
OFF
ON
TWT

SSPA Stage



20-WATT SSPA
AMP
-23 dBm
+1.5 dBm
+26.6 dBm
+43 dBm
DRIVER SECTION
MEDIUM POWER SECTION
HIGH POWER SECTION

Transponder components 6

Regeneration Repeater

- On-board regeneration in a digital satellite communications system is na attractive and rapid developing option for future SS/TDMA systems.
- An SS/TDMA system with on-board regeneration performs the required switching at baseband instead of microwave frequencies
- Compared with a conventional one a regeneratice repeater has in addition a demodulator, remodulator and a baseband switch matrix replaces the microwave switch matrix

Operation

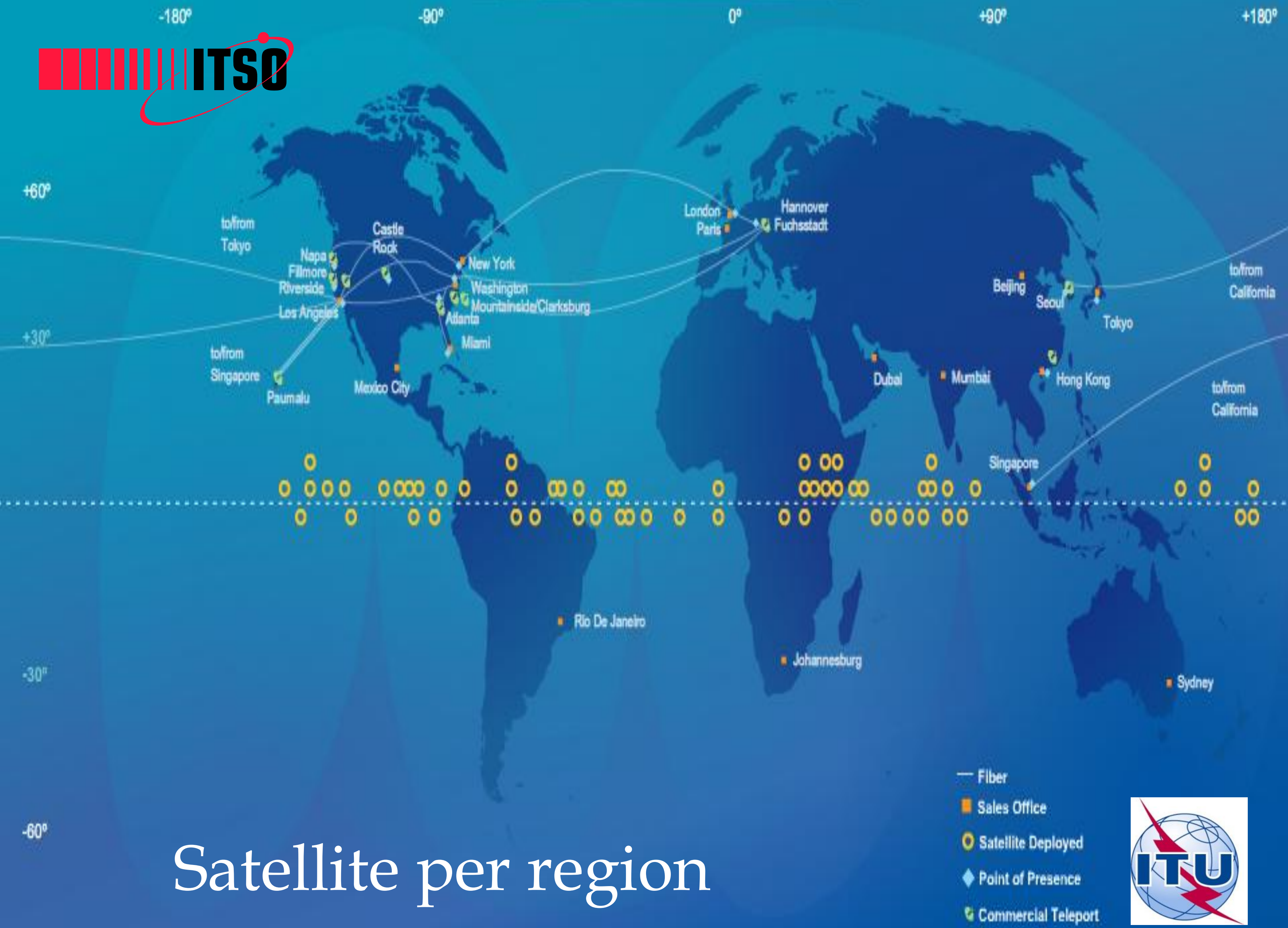
Operation

Satellite operations (SatOps) are conducted to:

- Verify and maintain satellite health
- Reconfigure and command the spacecraft
- Detect, identify and resolve anomalies
- Perform launch and early orbit operations.

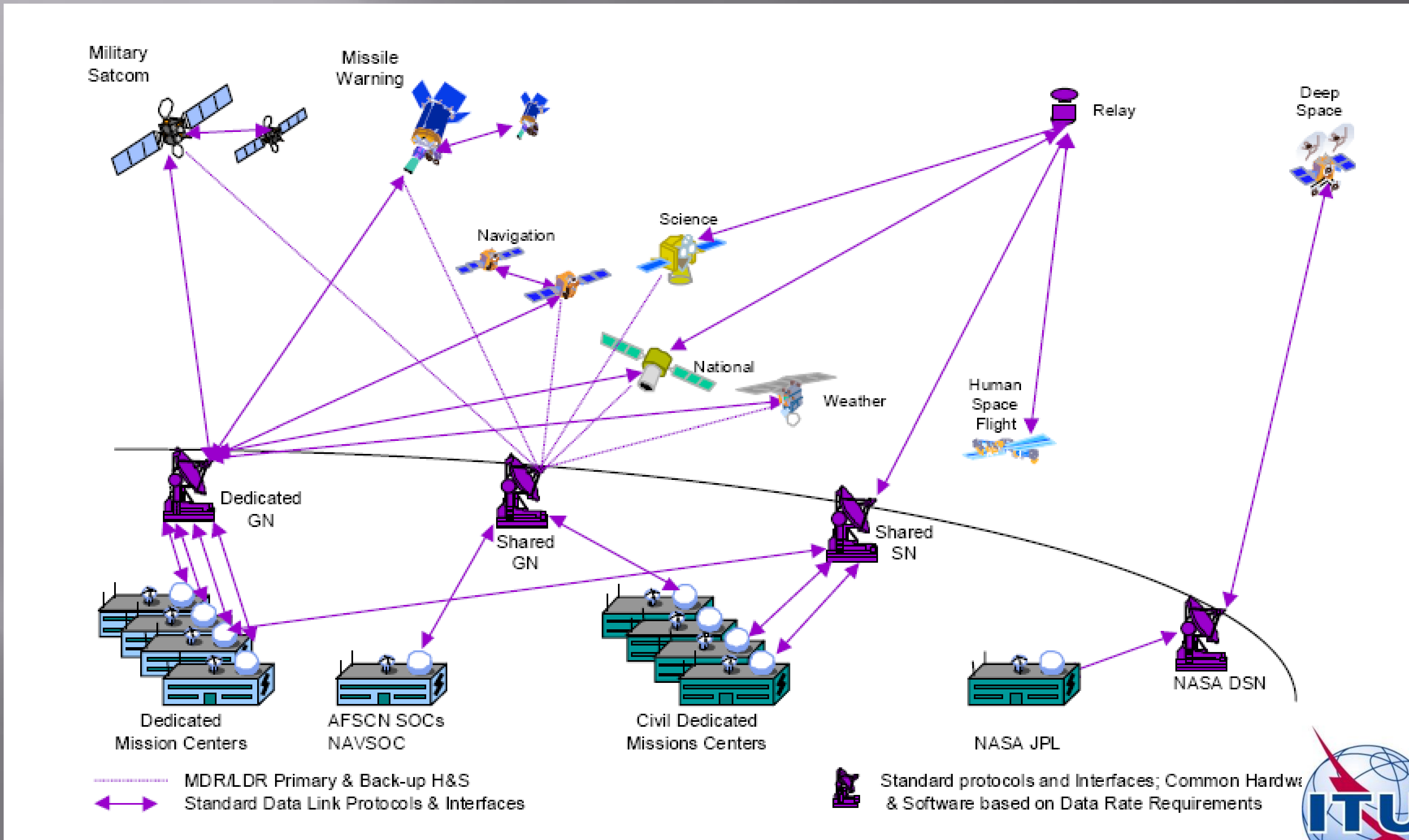
Additionally, any systems required to maintain the spacecraft operations that are not payload-specific are considered in this area.

Traditionally, the three basic functions of SatOps are telemetry monitoring, tracking, and commanding (TT&C). Satellite operational activities and their prior planning are typically labor-intensive.



Satellite per region

Operation scheme New vision



LifeCycle management 1

LifeCycle is specified as the probability of survival , e.g. the probability of at the end of a defined period the satellite service keep the same performance as in the launching.

Example for communications satellite:

- All the transponder after 5 year shall accomplish minimum as 70 % of all original specifications or
- All TWT of 20 W shall continue operational afetr 2 year, 18 minimum, after 3 year and 16 minimum afetr 7 years

In most recent satellite satellite are designed to achieve a life cycle of 13 year

LifeCycle Management 2

Factors which influence satellite lifecycle:

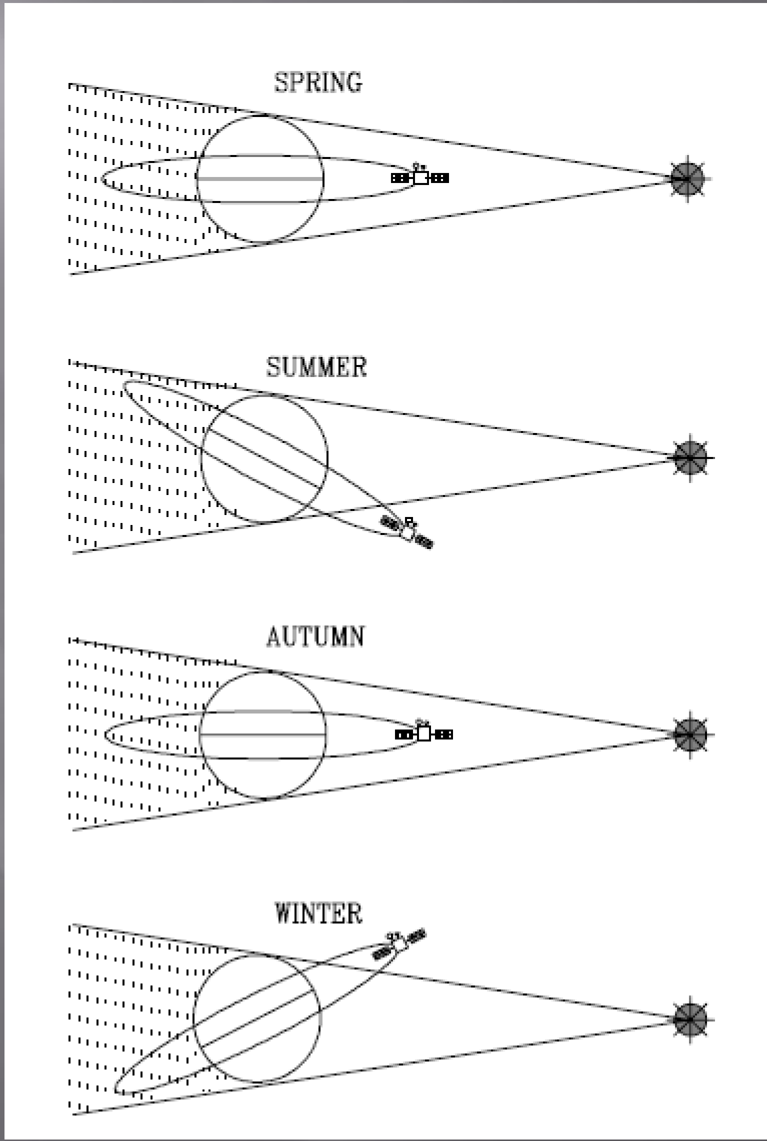
- Fuell quantity
  - N-S corrections (sun and moon atraction)
  - E-W corrections (earth roughness , satellite velocity and distance)
  - Satellite *drifting* up to 3º, in the end of life through ascending / descending movement each 24 hours, according typical format of an "8"
- TWT durability
- Batteries durability
  - Assuming output power from solar panels is 100 % (*BOL*) in the spring equinox, falls to 88% in the summer solstice, 99% in the Autumn equinox and 94% in the Winter solstice

Fuell Budget

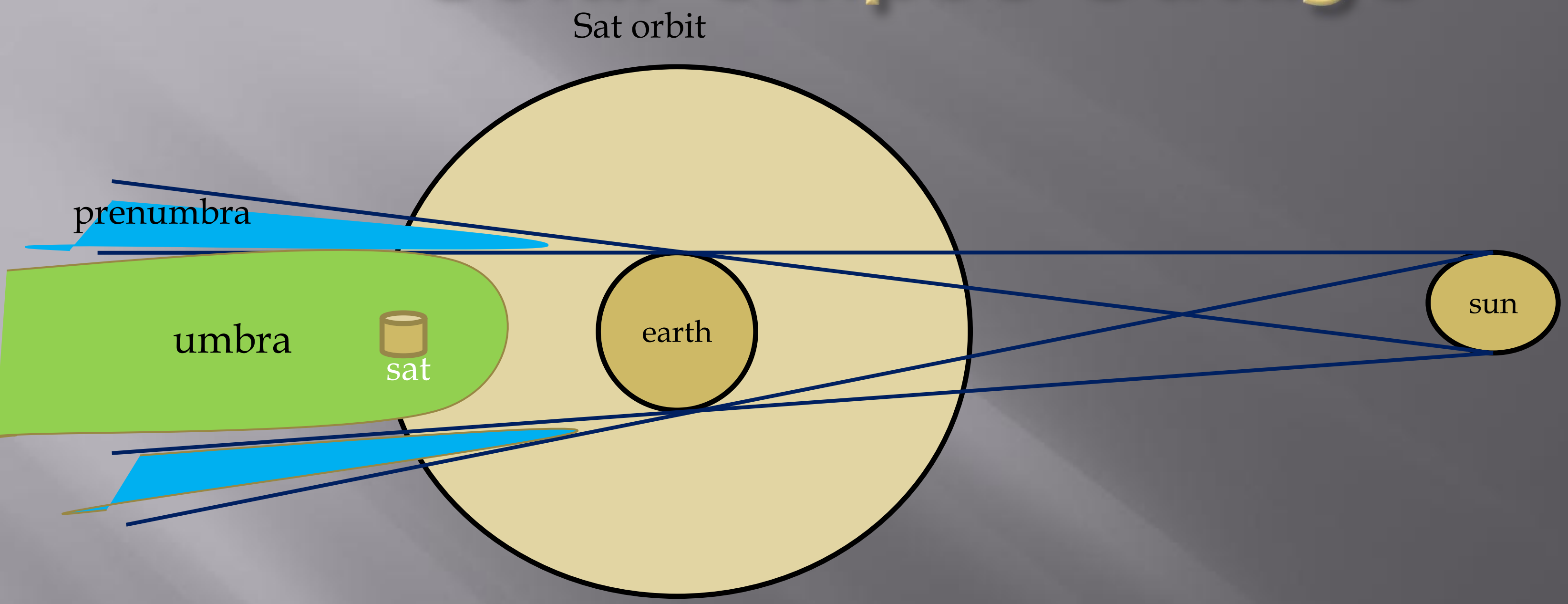
Maneauvre	**weight (Kg)**
Spin up	1,5
Rotation maintenance	4,3
Reorientation	1,2
Apogee motor correction	28,5
Spin down	1,4
N-S maintenance direction	106
E-W maintenance direction	11,7
Global position maintenance	12,3
Tottal	166,9

Intelsat V

Equinoxes

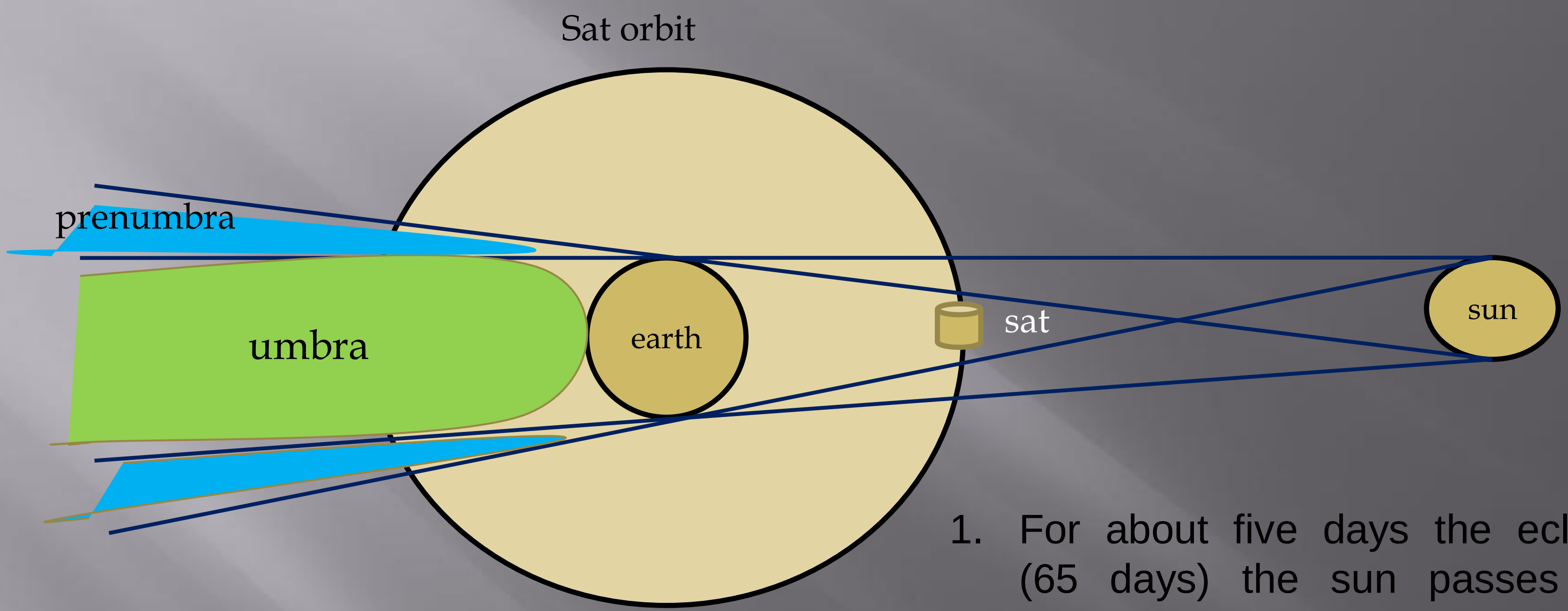


Solar eclipse Outage



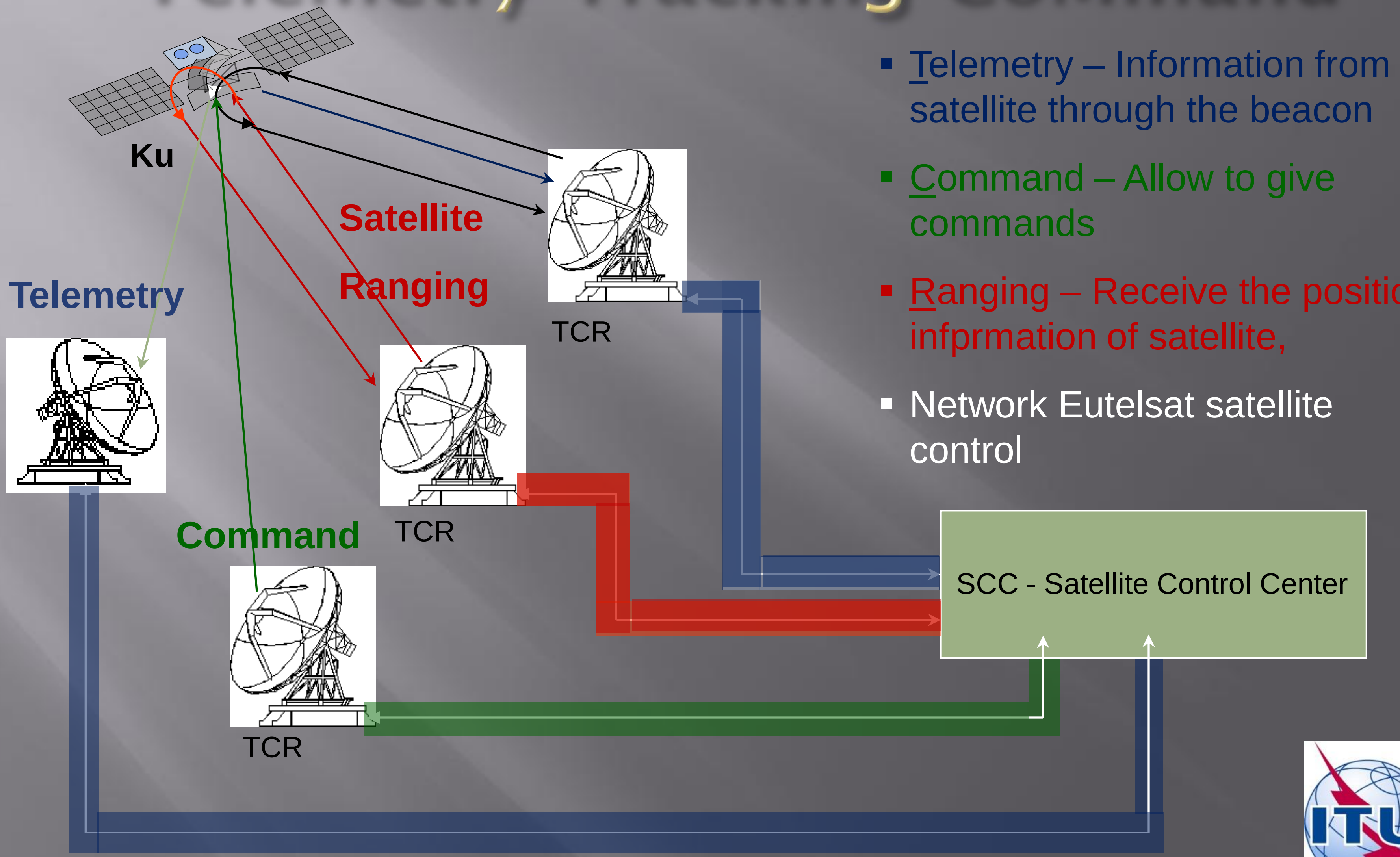
1. Satellite experience a solar eclipse two times a year- vernal and autumn equinoxes - for about 6 weeks aeach year
2. Satellites are in the earth's shadow for a few minutes to as much 65 minutes on the day of the equinoxe.
3. During eclipse there is no solar power, and batteries are needed. Also no solar warming, and thermal equilibrium needs batteries

Solar interference Outage



1. For about five days the eclipse season (65 days) the sun passes behind the satellite with respect to the earth station
2. The background noises builds up as this event unfolds for period about 10 minutes.
3. The service may be unavailale due to lower C / N for this period
4. Tracking mode is turned off to prevent earth station from tracking the sun which at this time is a strong source of energy

Telemetry Tracking CoMmand



- Telemetry – Information from satellite through the beacon
- Command – Allow to give commands
- Ranging – Receive the position infprmation of satellite,
- Network Eutelsat satellite control

Neither all presentations are successful

End 1st day

Enthusiasm ??