Old constellations, new systems, never-ending regulation

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Short History: prehistory and science fiction

- The very first step can be considered the physical law issued in 1687 by Sir Isaac Newton,

$$F = \frac{GMm}{r^2}$$

  which actually rules how to place a satellite into space, but the actual placing took some time (about 3 centuries).
- The term satellite was referred to a smaller body (natural satellites) that revolved around a larger astronomical object. All the moons circling the planets of the solar system are satellites.
- The idea of an artificial satellite was probably first proposed by the American clergyman Edward Everett Hale in his collection 'The Brick Moon, and Other Stories', published in 1899.
- Any man made object that revolves around a larger astronomical object is called an artificial satellite.

Short History: the start of the space age

- Progresses on research area of rockets, pushed mainly by military needs raised during World War II (Von Braun), allowed to develop enough powerful carriers to put an object in the space.
- The Space Age started on October 1957, when the first artificial satellite, **Sputnik 1**, was placed in orbit by the Soviet Union.
- Sputnik 1 emitted a radio beep, but it was enough to qualify as an orbiting satellite, and the first one in space.
- From that date satellite evolution has grown exponentially and so far thousands of satellites were launched.
- They are used for **Telecommunications**, Navigation, Earth observation (including weather and military scope), deep space observation (astronomy, astrophysics) and other purposes.

Milestones of Satellite Communication (1)

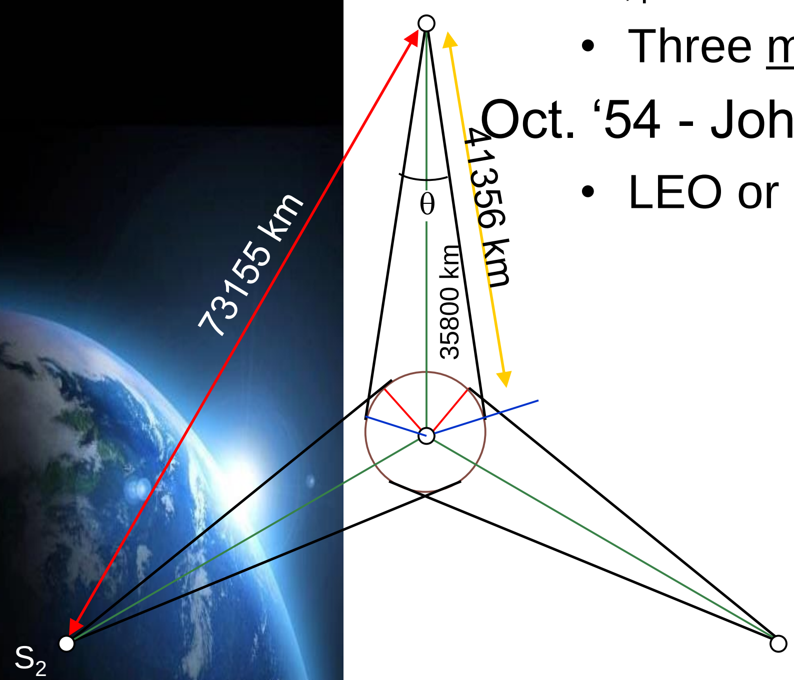
Satcom Vision and Development of Launch Technologies

Oct. '45 - Arthur CLARKE: "Extraterrestrial relays", Wireless World, p.305

- Three <u>manned</u> GEO space station

Oct. '54 - John PIERCE: "Telecommunications satellites"

- LEO or GEO satellites <u>without man</u> in space



Clarke's conception of GEO

Milestones of Satellite Communications (2)

- Oct. ‘57 - URSS: “Sputnik mission ”
  - First artificial satellite (non TLC): 85 kg in low Eart
- Jul. ‘61 - John. F. KENNEDY: “Policy statement on communications satellites”
- 20 December 1961 - The United Nations General Assembly adopts Resolution 1271, stating that global satellite communications should be made available on a non-discriminatory basis.

Birth of Satellite Communications

- Aug. ‘62 - Law in the U.S.: “Communications Satellite Act”
  - Birth of COMSAT
- Aug. ‘64 - Inter-governmental agreement : “Interim Arrangements for a Global Commercial Communications Satellite System”
  - Birth of ICSC and INTELSAT

1958-64: LEO and MEO experiments

- *Pre-recorded message transmission*
- Dec. ‘58 - SCORE (60 kg of payload launched on ATLAS at 190 km perigee - 1500 km apogee)

  Oct. ‘60 - COURIER (227 kg, 970-1200 km)

Milestones of Satellite Communications (3)

- *Passive reflection*
  Aug. ‘60 - ECHO I (76 kg, 1200-1480 km)
  Jan. ‘64 - ECHO II (248 kg, 980-1260 km)
- *Telephone and TV transmission*
  Jul. ‘62 - TELSTAR I (77 kg, 940-5640 km)
  Dec. ‘62 - RELAY I (78 kg, 1320-7430 km)
  May ‘63 - TELSTAR II (79 kg, 970-10800 km)
  Jan. ‘64 - RELAY II (78 kg, 2080-7420 km)

1963-64: GEO experiments

Jul. ‘63 - SYNCOM II (39 kg, almost GEO: i=33°)

Aug. ‘64 - SYNCOM III (66 kg)

1965: The first HEO satellite and GEO operational systems

Apr. ‘65 - MOLNIYA I (1020-39450 km, 12 hours)

Apr. ‘65 - INTELSAT I (“Early Bird”)

- Starts INTELSAT GEOs for intercontinental fixed services

1972 - FIXED CONTINENTAL SERVICES

- In the U.S. regional systems start for fixed (continental) services

Milestones of Satellite Communications (4)

Commercial services development

1976 - MARISAT

- Three satellites for <u>mobile</u> maritime communications

1982 - INMARSAT GLOBAL SYSTEMS

- Fully operational GEO global systems, for mobile maritime service

1988 - FIRST LAND MOBILE SATELLITE SYSTEM

- OMNITRACS starts to provide in North America land mobile satellite messaging and localization services

1991 - ITALSAT (ITALY)

- The first satellite using Ka band, on board processing and multibeam coverage

1992 - GEO Satellites for mobile telephony (1st war in the gulf)

1998/2000 - IRIDIUM/GLOBALSTAR

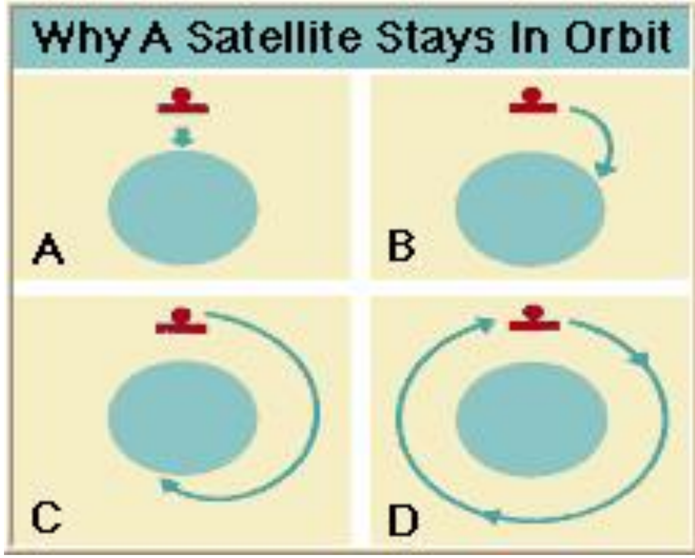
- Global mobile services with hand held terminals

2012 – KaSat (Eutelsat, first High Throughput Satellite)

ORBITS

Mechanics

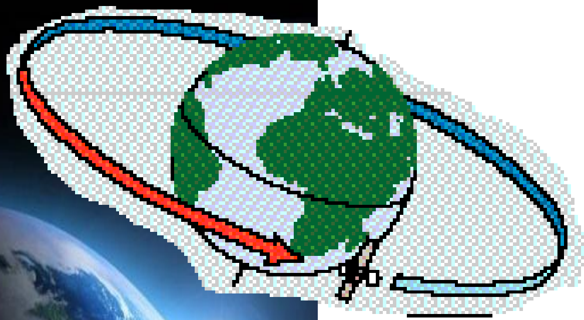
- Most satellites are lifted into orbit by multistage rockets. It is also possible to place satellites in orbit by using reusable shuttles (for low altitude orbits).
- A satellite to orbit the Earth is positioned at least 200-250 km above the Earth's surface so that atmospheric drag will not slow or damage the satellite.
- The satellite's motion is governed by the same laws that govern the motion of natural satellites and it can travel around the planet in a nearly circular orbit, as shown in the figure, or in other orbit configurations.

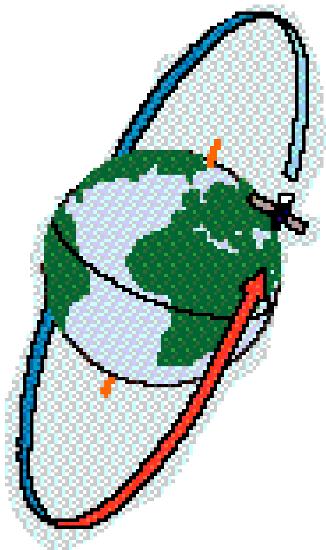


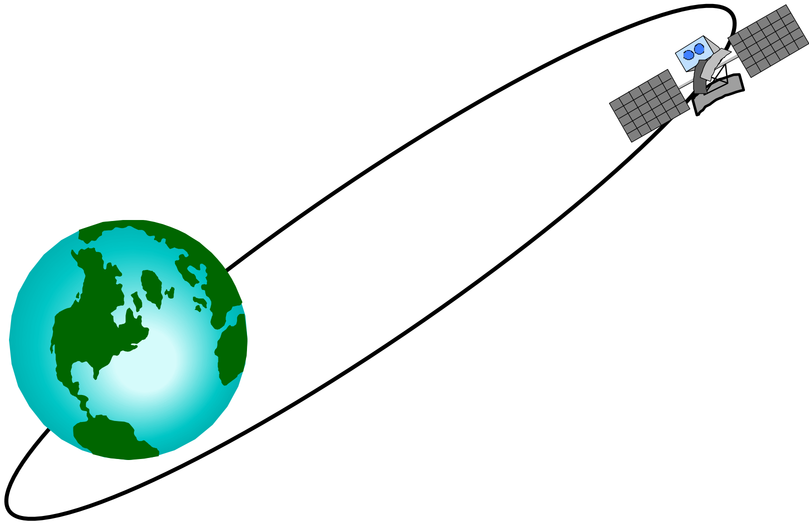
Orbit Classification

- Based on the inclination, i, over the equatorial plane:
  - Equatorial (i=0°)
  - Polar (i=90°)
  - Inclined (0° <i<90°)

- Based on eccentricity
  - Elliptical
  - Circular



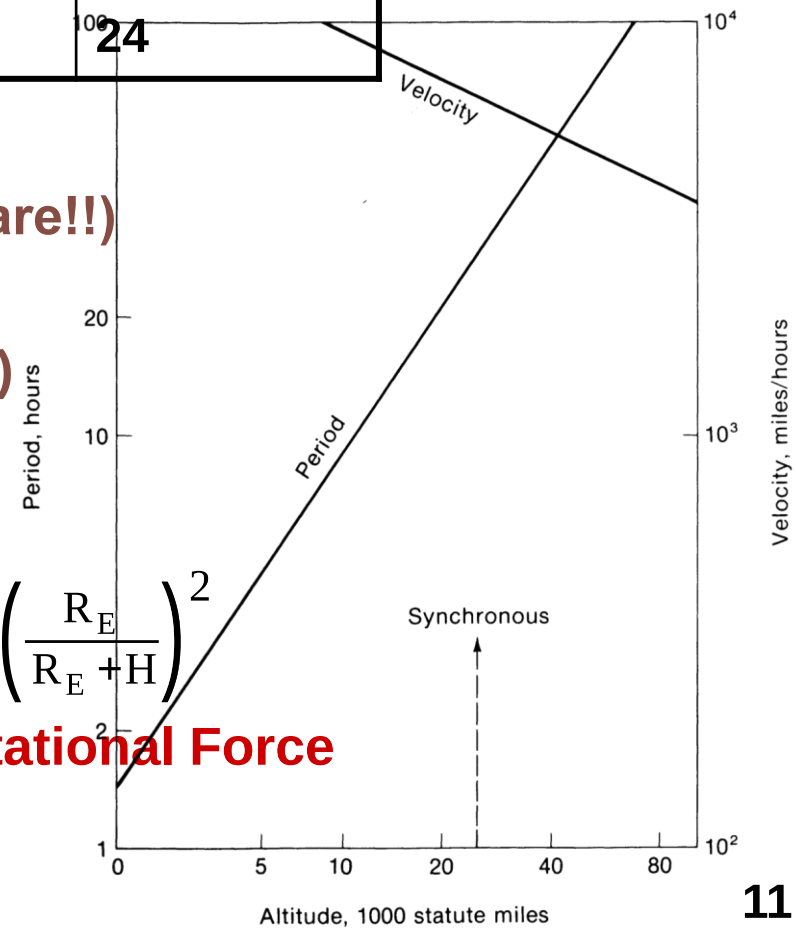




The equatorial plane is the reference to determine the inclination.

Circular Orbits

Orbit type	Altitude (km)	Period (h)
LEO	500-1700	1.5-2
MEO	5000-10000-20000	3.3-6-12
GEO	35800	24



m = satellite mass (don't care!!)

g_0 = 9.81 m/s^2

R_E = 6378 km (Earth radius)

H = orbital height

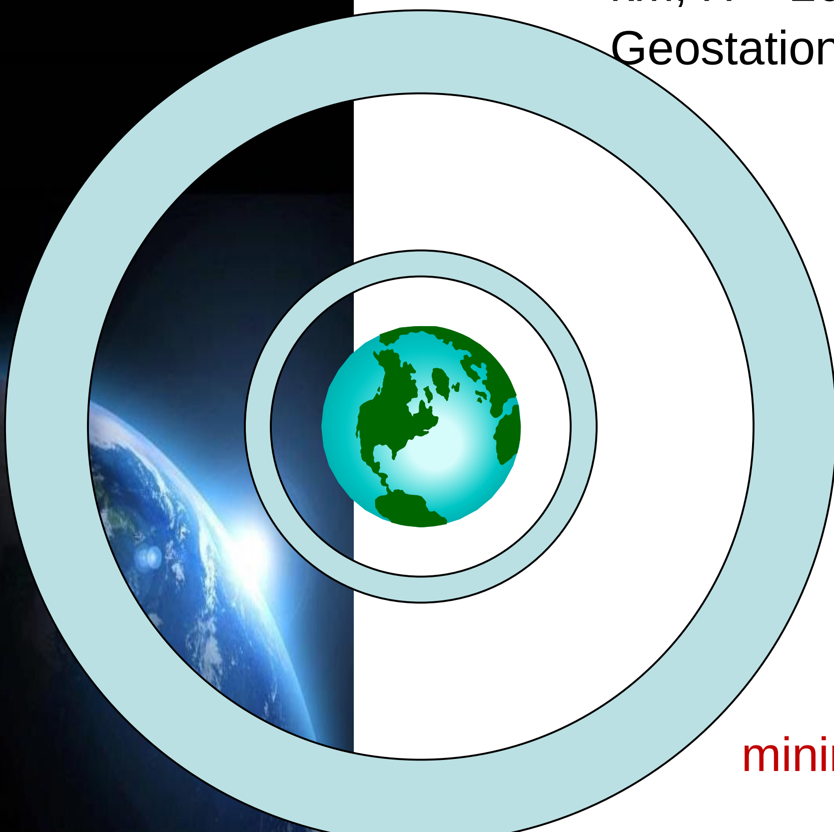
T = orbital period

$$m(R_E + H)\left(\frac{2\pi}{T}\right)^2 = mg_0\left(\frac{R_E}{R_E + H}\right)^2$$

Centrifugal Force = Gravitational Force

Circular Orbits (2)

- Based on the circular orbit altitude, H, over the Earth surface:
  - Low-altitude Earth Orbits (LEO): 500 km < H < 1700 km
  - Medium-altitude Earth Orbits (MEO): 5000 km < H < 10000 km; H > 20000 km
  - Geostationary Earth Orbit (GEO): H = 35800 km



When locating a satellite we need to avoid:

- *Atmosphere* still dense at H < 250 km thus creating atmospheric drag that can damage the mechanical parts
- *Van Allen Belts* composed of ionized particles which can damage electronic devices
  - Internal belt H ≈ 1700-5000 km
  - External belt H ≈ 10000-20000 km

The orbit altitude (height) is always referred to the subsatellite point that is the minimum distance between the user and the satellite

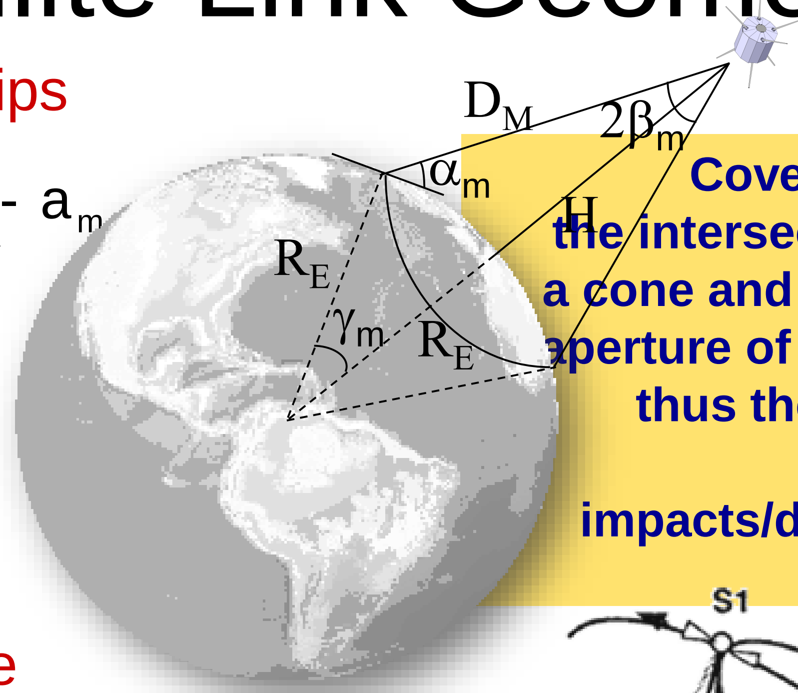
Satellite Link Geometry

Main relationships

1) $\gamma_M = \arccos\left(\frac{R_E}{R_E + H}\cos(\alpha_m)\right) - \alpha_m$

2) $\beta_M = \frac{\pi}{2} - (\alpha_m + \gamma_M)$

3) $\frac{D_M}{R_E} = \frac{\sin(\gamma_M)}{\sin(\beta_M)}$



Coverage given by the intersection between a cone and a sphere. The aperture of the cone (and thus the coverage) is arbitrary and impacts/depends on α_m

H is the satellite altitude

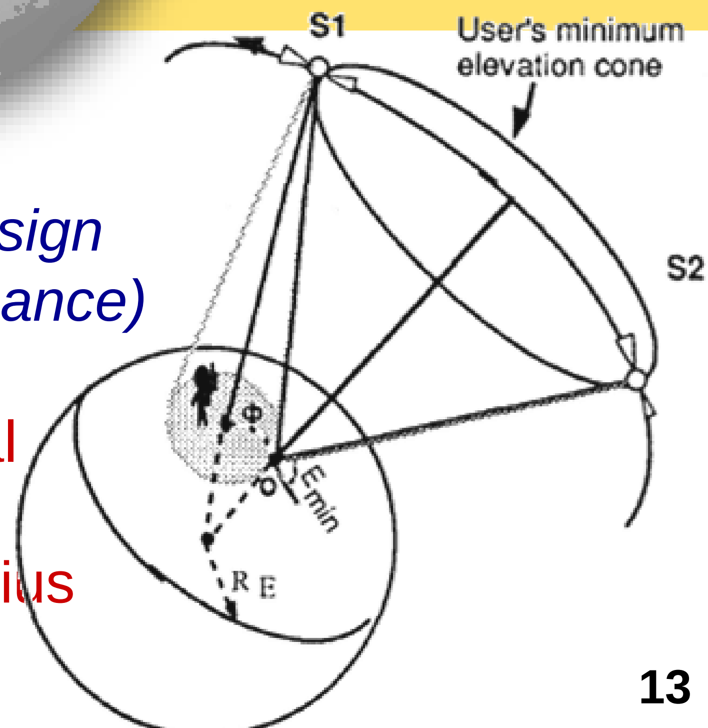
$2\cdot\beta_M$ is the maximum nadir angle

α_m is the minimum elevation angle *(design parameter related to system performance)*

$2\cdot\gamma_M$ is the maximum subtended angle

D_M is the maximum satellite-to-terminal distance (edge of coverage)

R_E = 6378 km is the average Earth radius



Constellations Features

- Coverage
  - the concept of coverage is relative to the target service area
  - Fully deployed constellation for real time services (e.g.: voice) with full Earth (or regional) coverage
  - Sparse constellations suitable for non real time data services
  - To reduce the constellation size and to optimize **offered traffic/coverage**, polar regions (lat. >70°) may not be covered
  - Main parameters for communications services: D_M, α_m
- Altitude, H
  - Such to avoid Van Allen Belts and atmospheric drag
- Maximum distance D_M
  - Impact propagation delay (unavoidable)
    - Subjective perceived quality
    - Protocol performance
  - and free space losses
- Minimum elevation angle, α_m
  - Angle under which the terminal “sees” the satellite at the edge of coverage. Influences:
    - constellation size,
    - visibility of satellites,
    - area of service.
  - Small α_m reduces constellation size, increases probability of obstruction (due to orography, etc.) and atmospheric supplementary attenuation

Lower Bound on the Number of Satellites

$$S' = 2\pi R_E^2 (1 - \cos(\gamma'))$$

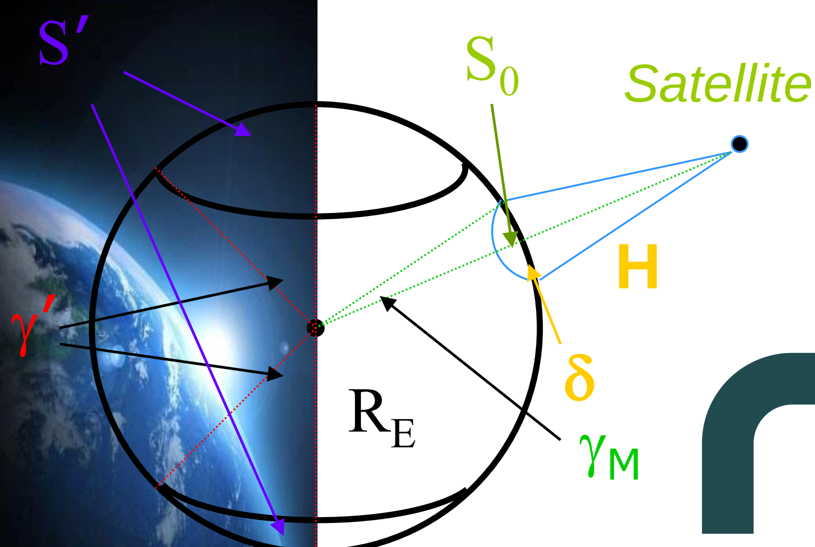
Earth's area — Pole's area

$$S_{tot} = S - 2 \cdot S' = 4\pi R_E^2 \cos(\gamma')$$

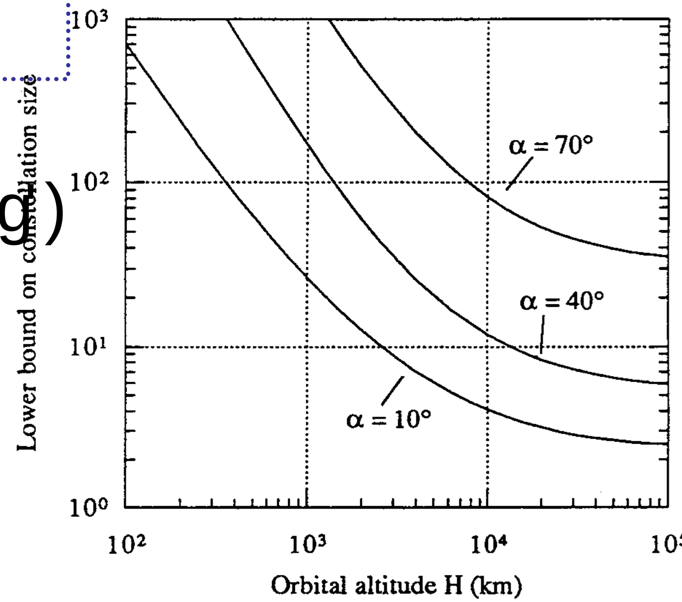
Area to be covered (service area)

$$S_0 = 2\pi R_E d$$ Single satellite coverage area

where δ is earth's spherical segment deepness



Circular orbits



Lower bound on the constellation size for global coverage (polar regions excluded) with minimum elevation angle as a parameter.

$$n_{sat} > \frac{S_{tot}}{S_0} = \frac{2 \cdot \cos(\gamma')}{1 - \cos(\gamma_m)}$$

where $\gamma_M = f(\alpha_m, H)$ and $\gamma' = 20°$

Very rough, approximate (but less than we can think) but very quick to have an idea in a few minutes at no cost before undertaking a significantly demanding endeavor.

Geostationary orbit

Features:

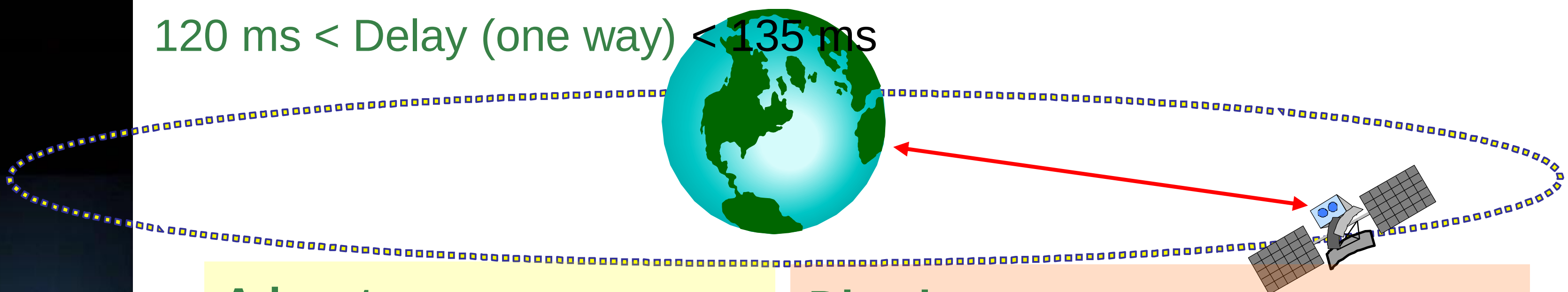
Coplanar with the equator

H = 35800 km over the sub-satellite point

Satellite in *practically* fixed position with respect to the Earth surface

Satellite position identified only by the longitude relative to Greenwich

120 ms < Delay (one way) < 135 ms



Advantages

Large coverage

No tracking (actually not critical, often not required)

Fixed delay

Fixed geometry

A few satellites for global coverage

Disadvantages

No coverage over $\pm$ 70° lat (at poles)

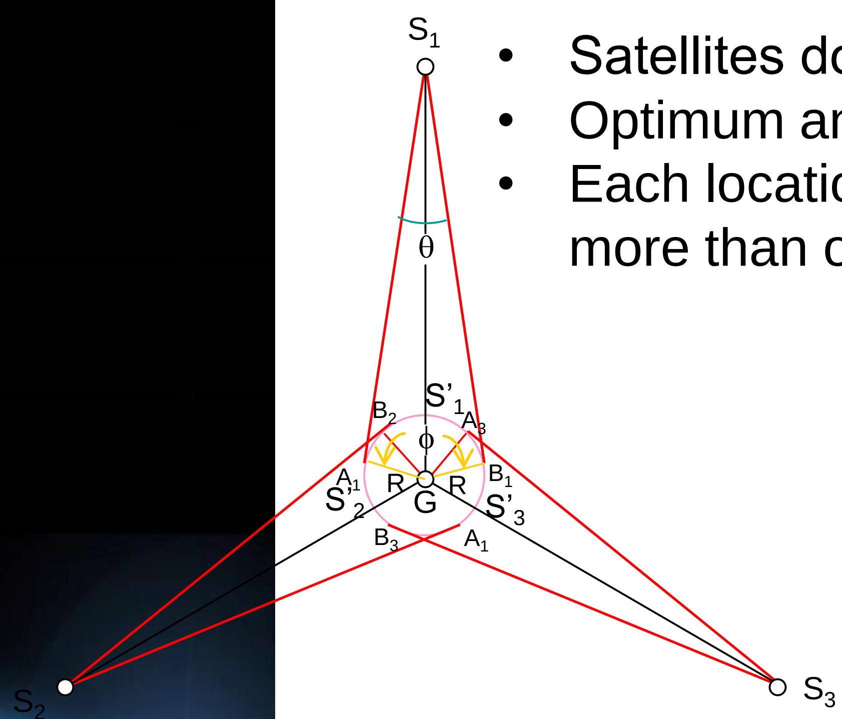
Low elevation angle at high latitudes

High power

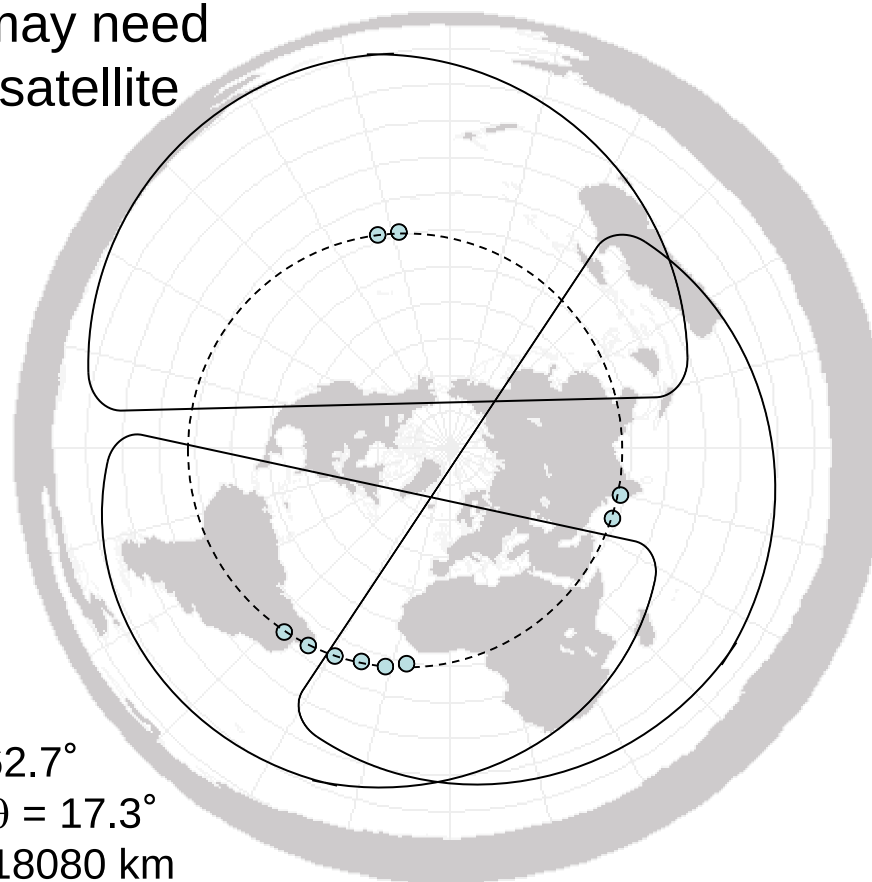
High delay

Big satellite

GEOs: Earth coverage by three positions



- Satellites don't cover poles
- Optimum angular spacing may not be 120°
- Each location may need more than one satellite



Earth's radius: $R = GA = GB = 6378$ km

Overlap angle on Earth: $A_1GB_2 = 42.7°$

Earth's circumference = 40004 km

Angle illuminated on Earth: $A_1GB_1 = \phi = 162.7°$

Look angle from satellite for global beam: $\theta = 17.3°$

Arc length illuminated on Earth: $A_1S'_1B_1 = 18080$ km

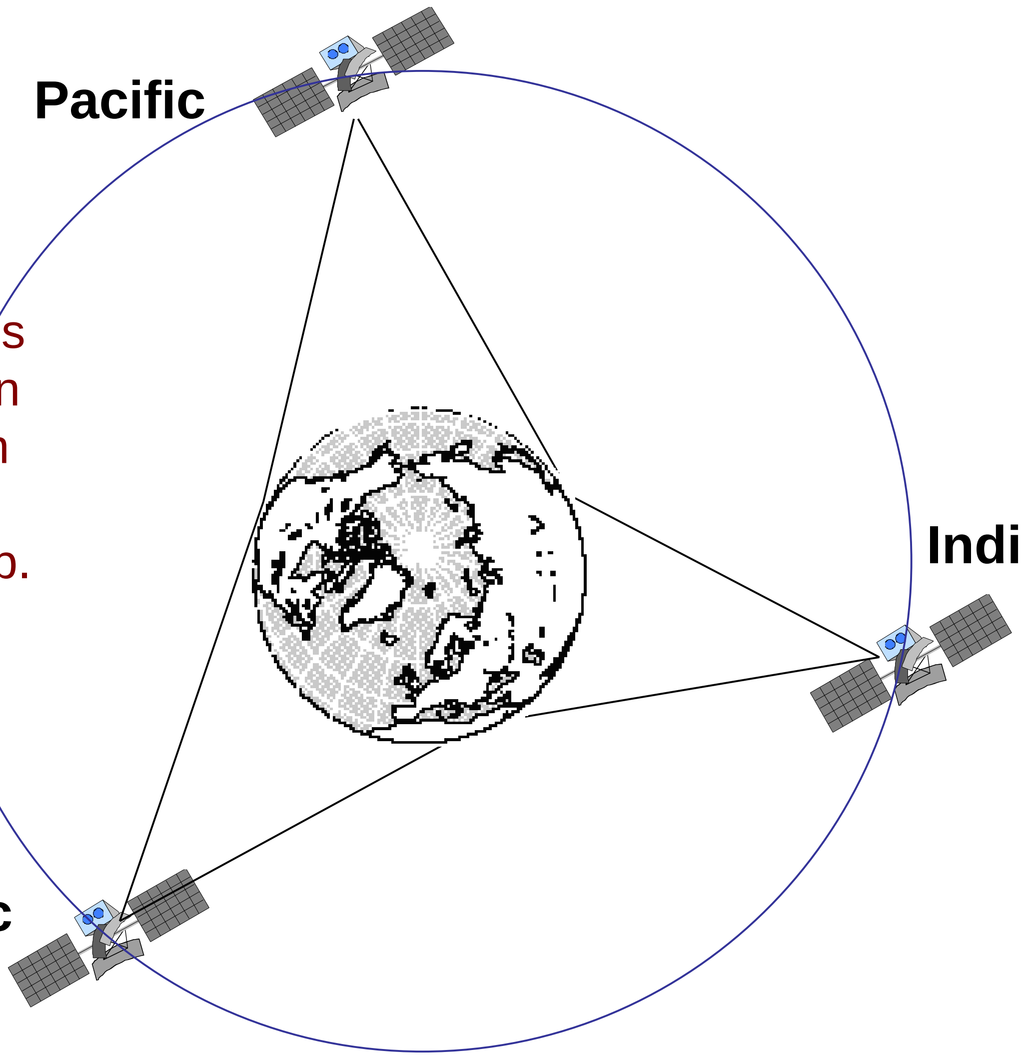
Satellite to Earth centre: $S_1G = S_2G = S_3G = 42238$ km

Satellite to Earth min distance: $S_1S'_1 = S_2S'_2 = S_3S'_3 = 35800$ km

Satellite to Earth max distance: $S_1A_1 = S_1B_1 = S_2A_2 = S_2B_2 = S_3A_3 = S_3B_3 = 41747$ km

GEO coverage strategy 1: ocean regions

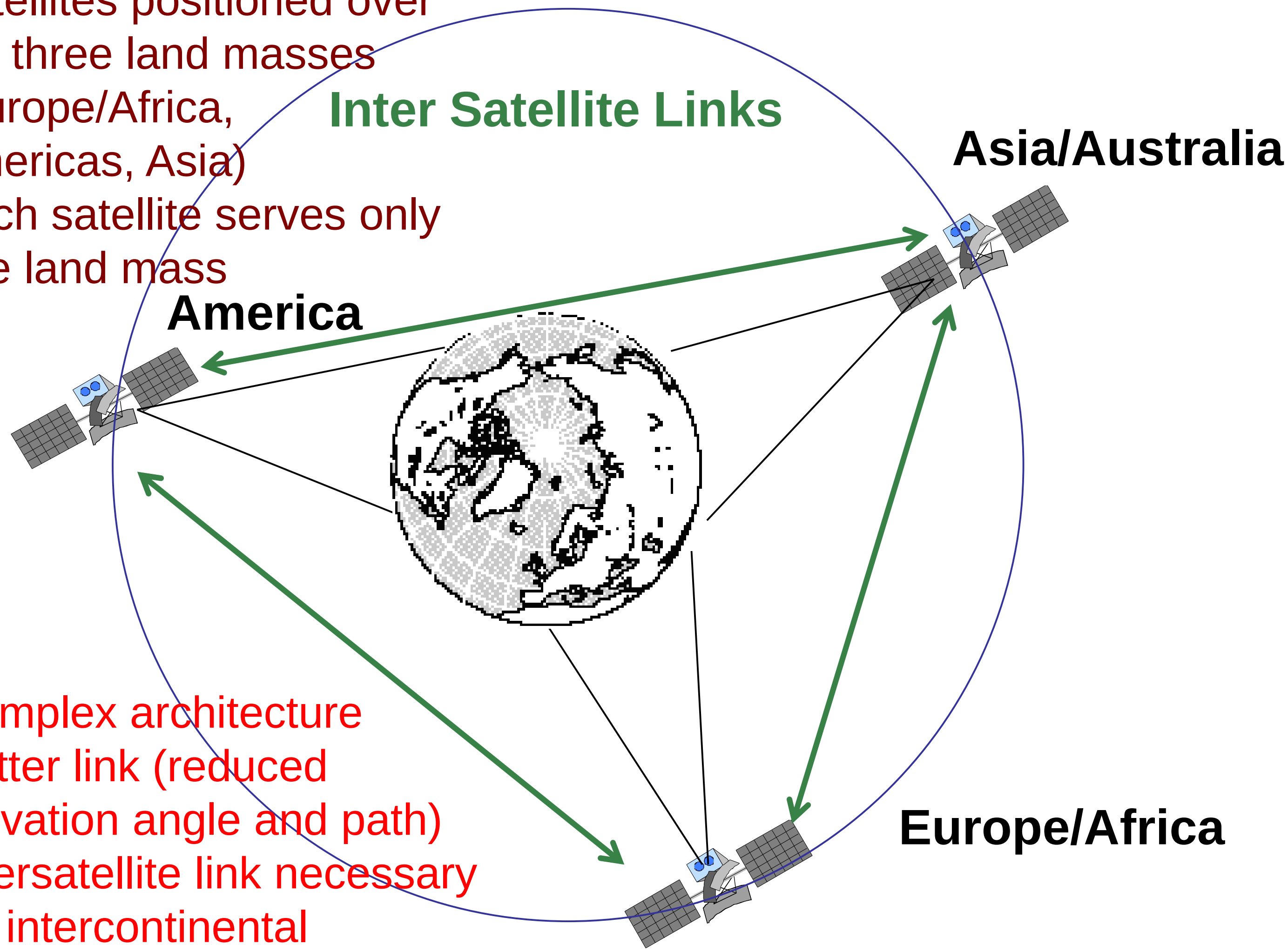
- Satellites positioned over the three oceans
- Land masses on the same ocean are connected through one hop. Double hop for very far points.



- Simplest architecture
- Worst link (low elevation angle, long path)

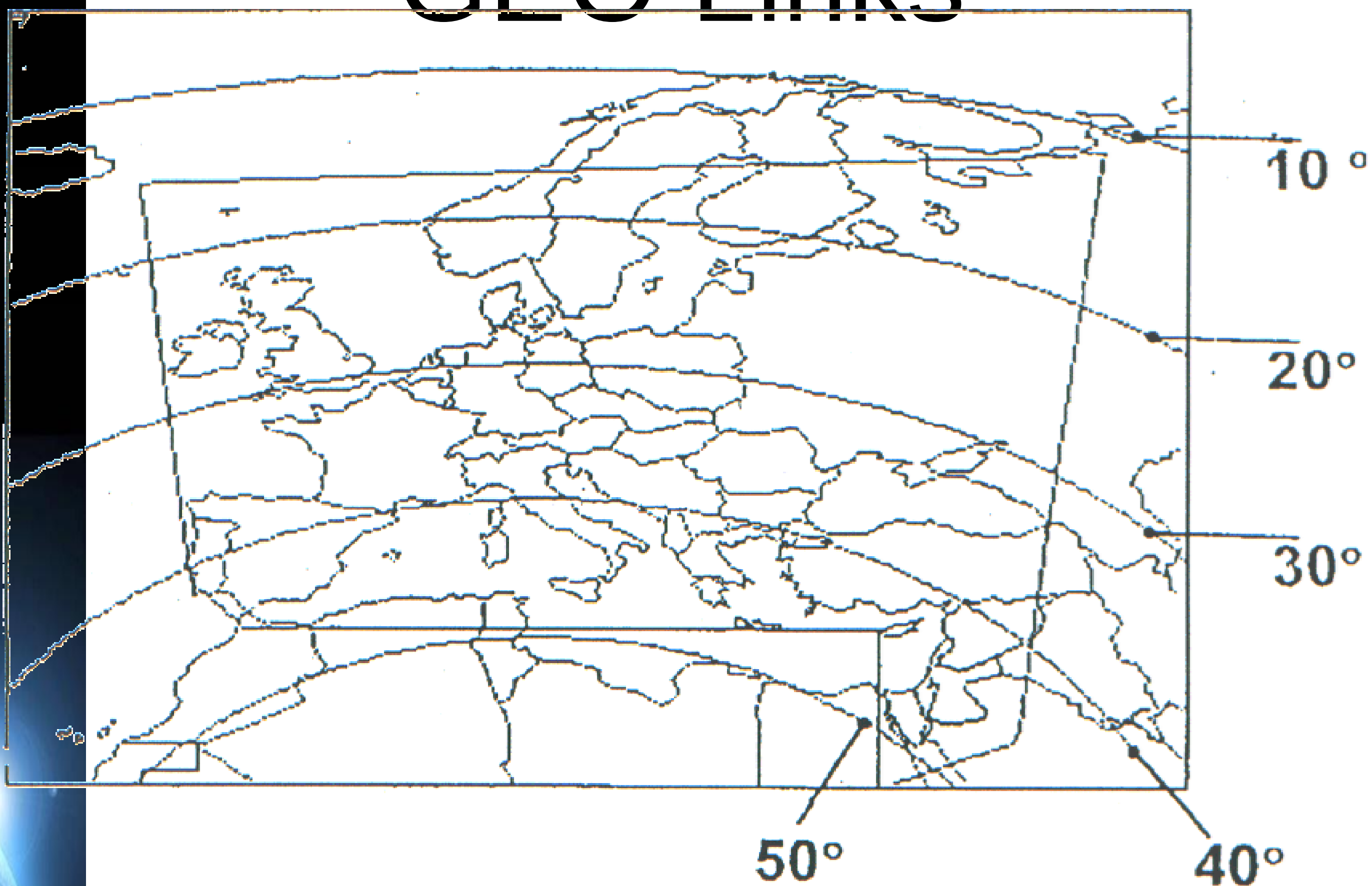
GEO coverage strategy 2: land masses

- Satellites positioned over the three land masses (Europe/Africa, Americas, Asia)
- Each satellite serves only one land mass



- Complex architecture
- Better link (reduced elevation angle and path)
- Intersatellite link necessary for intercontinental connection

Geometrical Characteristics for GEO Links



Elevation angle to point a GEO satellite positioned over central Europe

Characteristics of LEO orbits

- 500 km < H < 1700 km
- Includes polar, equatorial and inclined circular orbits and elliptical orbits with small eccentricity or a combination

Advantages

Spectrum efficiency (small cells ➔ ➔ frequency reuse)

Limited free space losses

Limited propagation delay

High elevation angle even at high latitudes

Cost of in orbit injection per satellite

Disadvantages

Large number of satellite for full coverage

Frequent handovers

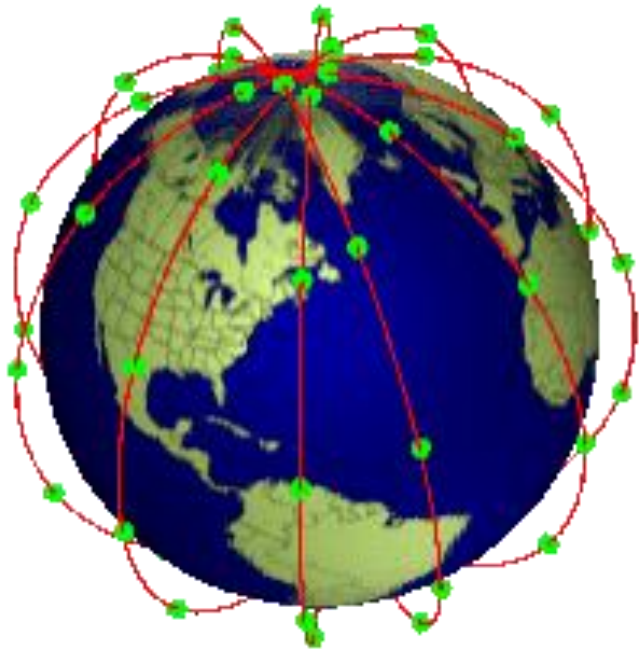
Variable delay (low variance)

Variable elevation angle (high variance)

Doppler effect

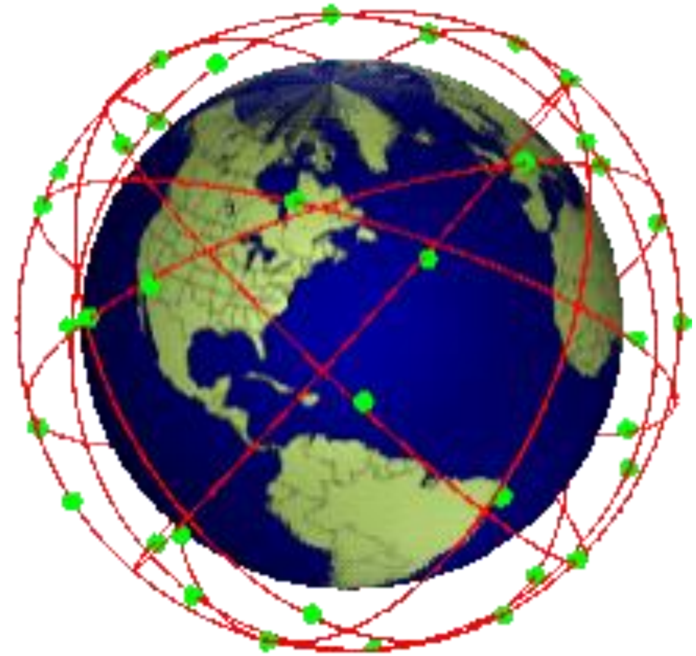
Tracking at ground

Examples of LEO constellations



Polar constellation

Easier interplane-satellite links because satellites can be phased

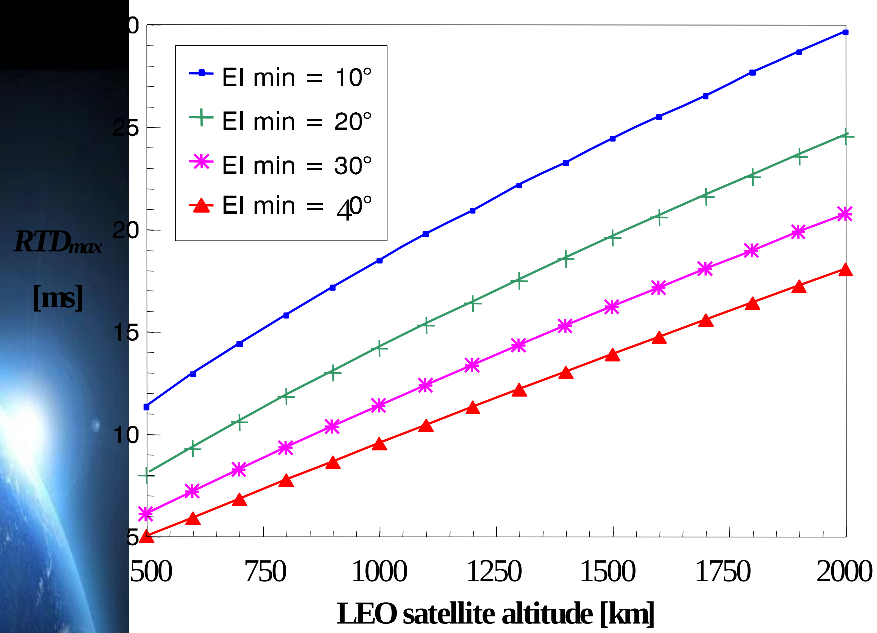


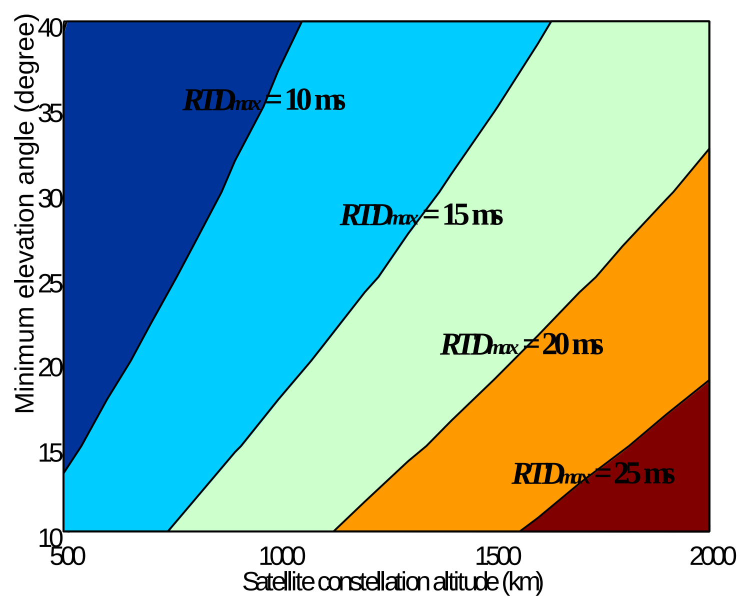
Inclined constellation

Optimized to better cover latitudes around the value of orbit inclination angle

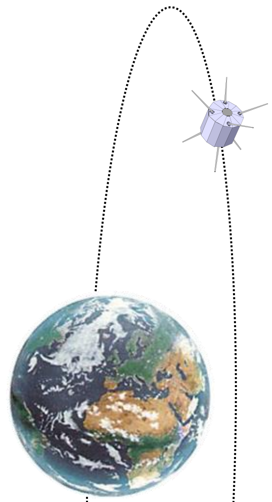
Round Trip Delay

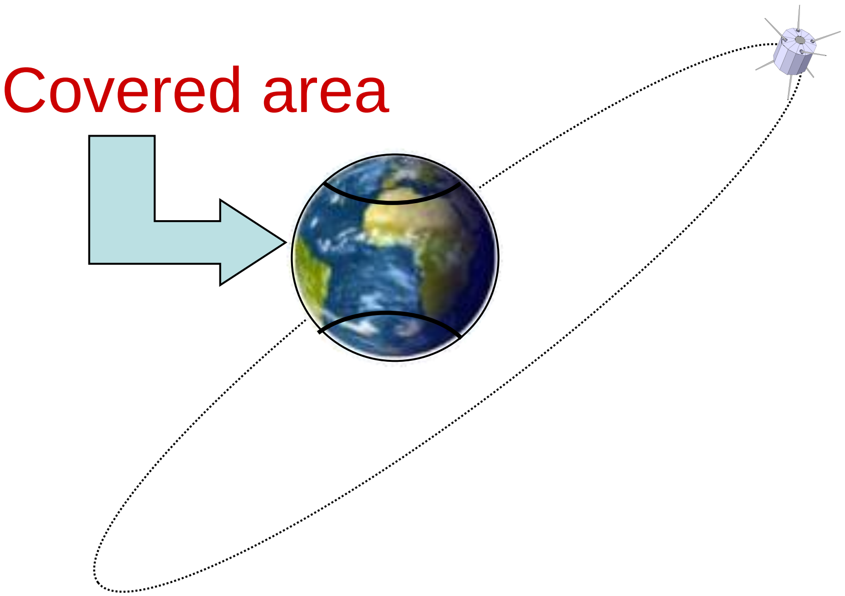
Round Trip propagation Delay (RTD) depends on the satellite altitude and the minimum elevation angle (*mask angle*). A given RTD value can be obtained with several combinations of minimum elevation angle and satellite constellation altitude.





LEO orbit coverage



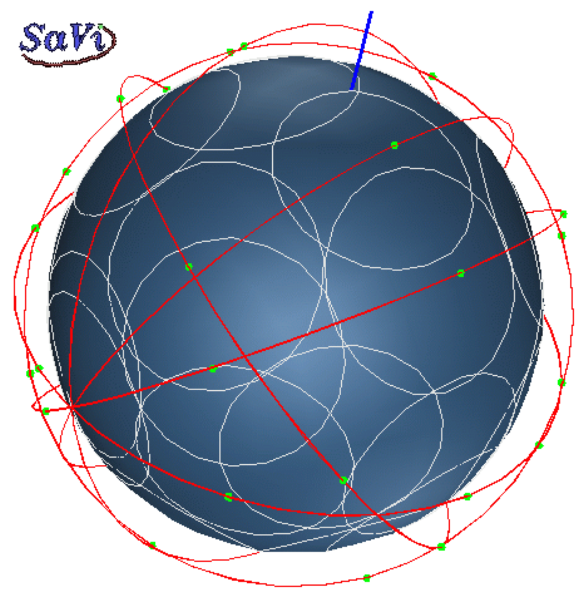


Satellite in polar orbit spans all the earth surface.

Sun-synchronous orbits: Satellite always in front of the sun (less severe requirements for batteries on board, coverage always with light, good for Earth observation).

Satellite in inclined orbit spans all the Earth surface between two parallels depending on orbit inclination and beamwidth.

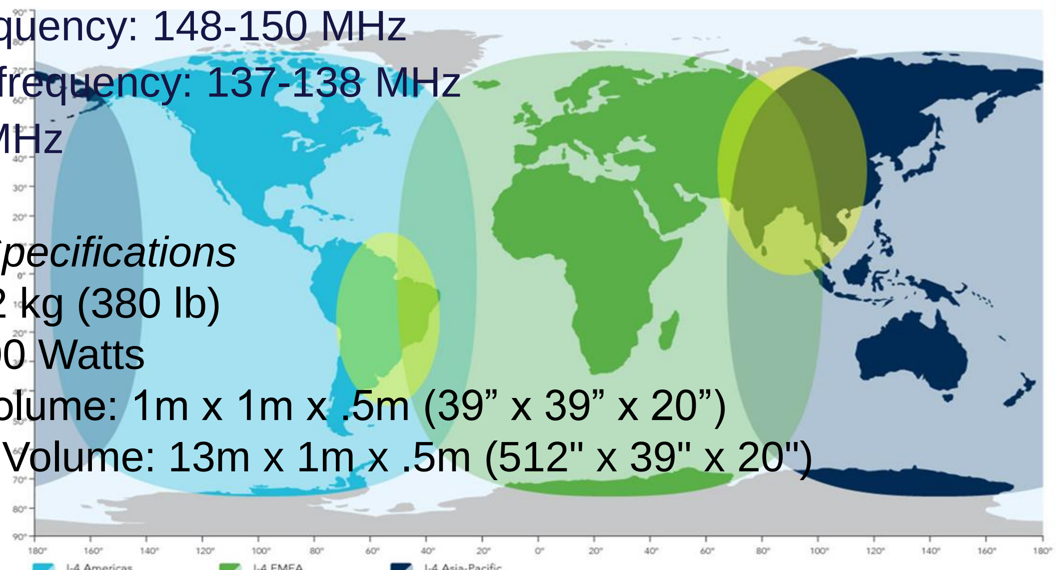
Orbcomm



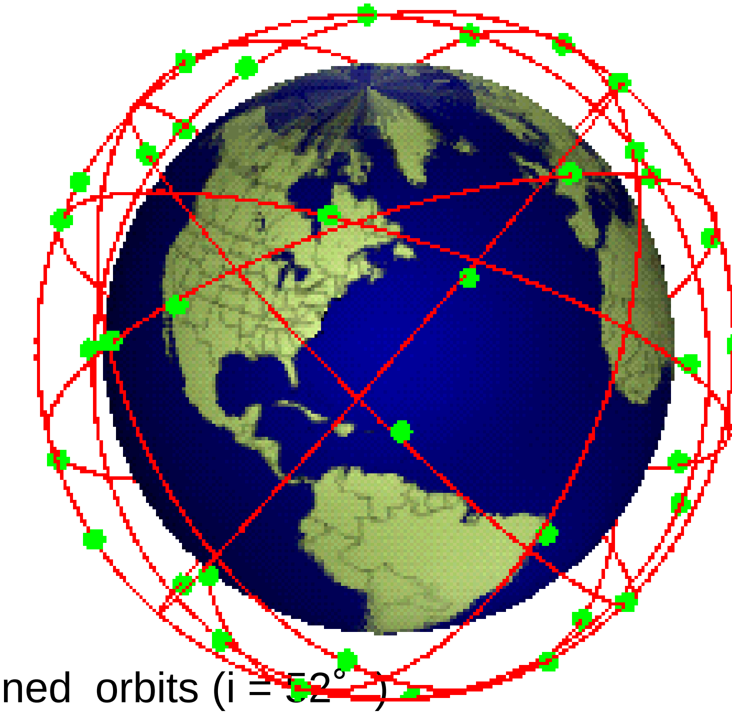
- Company: Orbcomm International
- Market: global (M2M)
- Implementation: operational
- Constellation: 31 satellites in 7 orbits
- Altitude: 825 km
- Antenna: linear (whip), single beam
- Com

Uplink frequency: 148-150 MHz
Downlink frequency: 137-138 MHz
and 400 MHz

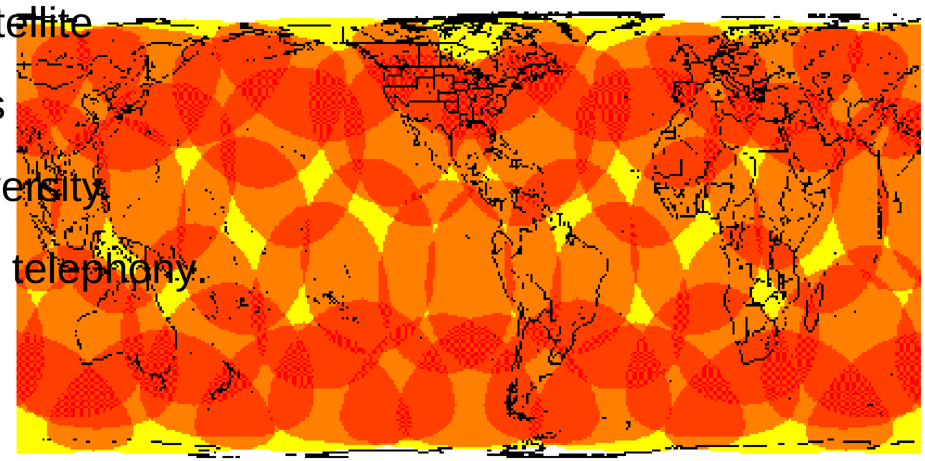
Satellite Specifications
Mass: 172 kg (380 lb)
Power: 400 Watts
Stowed Volume: 1m x 1m x .5m (39” x 39” x 20”)
Deployed Volume: 13m x 1m x .5m (512" x 39" x 20")



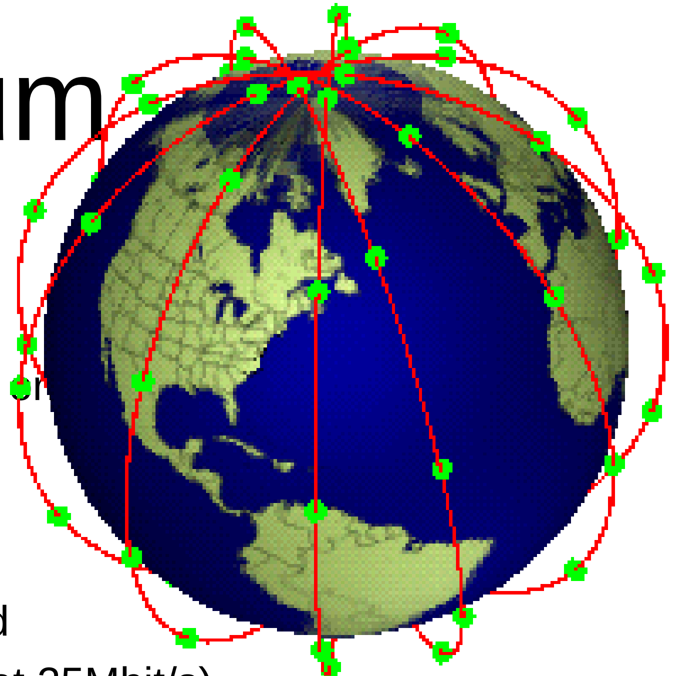
Globalstar



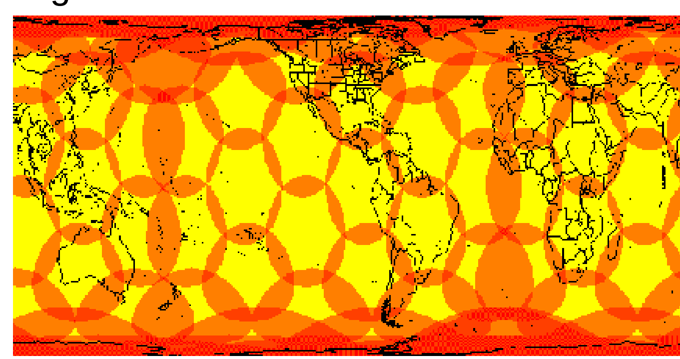
- Company: Globalstar
- Market: global (voice)
- Implementation: operational
- Altitude: 1414 km
- Constellation: 48 satellites in 8 inclined orbits (i = 52°)
- Communications: CDMA (based on the IS-95 standard)
- Antenna: 16 beams per satellite
- Frequency: L and S bands
- Other features: satellite diversity
- Services: fixed and cellular telephony.



Iridium

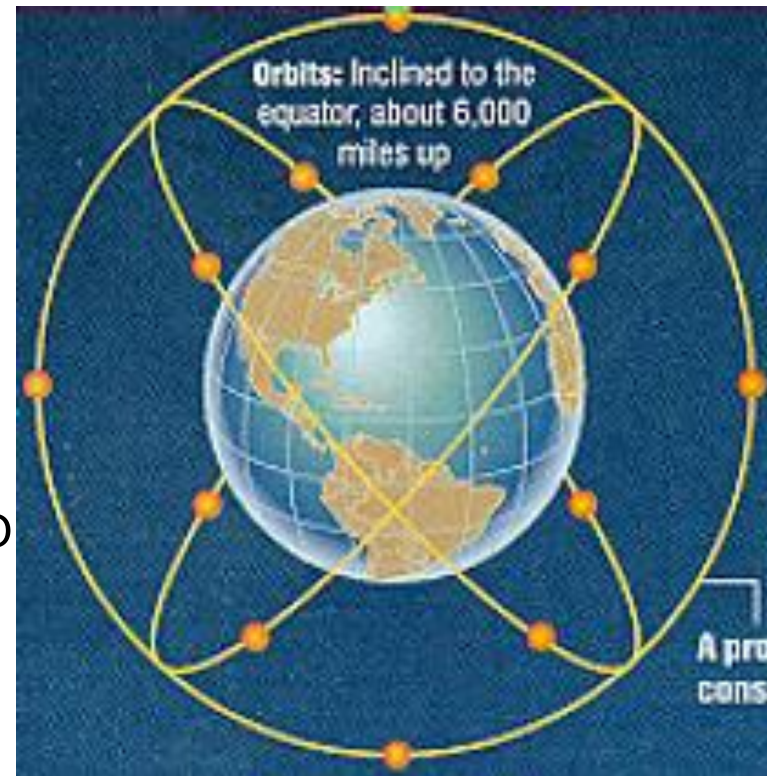


- Company: Iridium
- Market: global (voice)
- Implementation: operational
- Constellation: 66 satellites in 11 polar or
period100'28
- Altitude : 780 km
- Antenna: 48 beams per satellite
- Communications: TDMA-TDD, L band
- Other features: inter-satellite links (4 at 25Mbit/s), on-board processing
- SATELLITE
  - SPOT BEAMS 3x16 per satellite for high signal quality and spectrum efficiency
  - STABILIZATION 3 axis
  - SATELLITE WEIGHT 689 kg.
  - LINK MARGIN 16 db (average)
- First to be proposed and operational
- Operational



Characteristics of MEO orbits

- H ≈ 5000-10000-20000 km
- Trade off between LEO and GEO
- Propagation delay and free space losses between LEO and GEO
- Lower number of satellites than LEO
- Higher elevation angle than LEO
- Lower Doppler effect than LEO
- Handover



Example

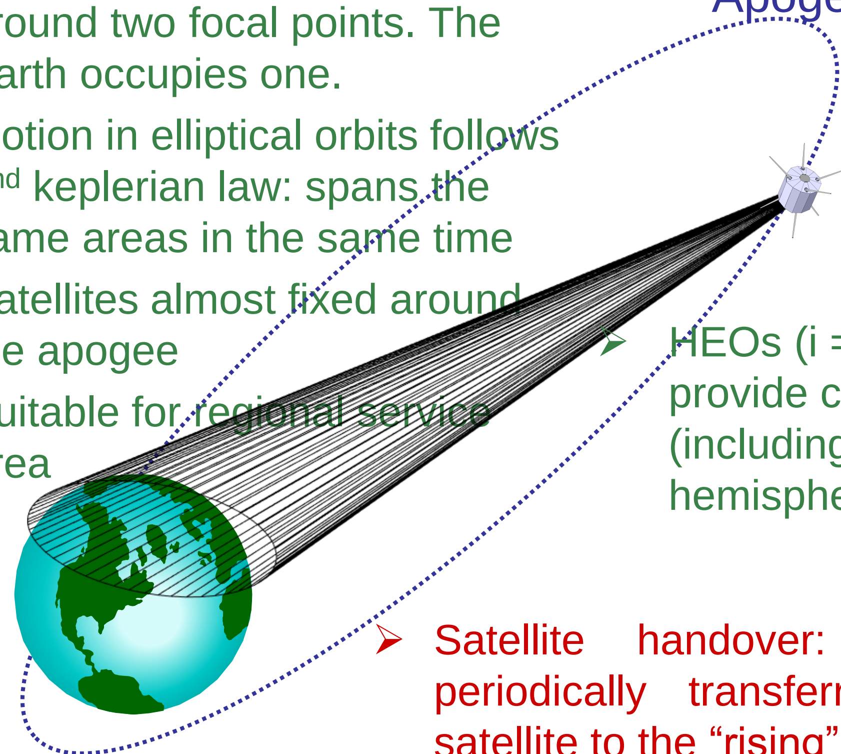
High data rate, Medium Earth Orbit: O3B (Over 3 billion)

- Ka-band beams of 700 km diameter: steerable around the globe, each delivering up to 1.6 Gbit/s (800 Mbit/s x2) 84 Gbit/s per 8 sat constell.
- Transponder bandwidth: 216 MHz (2 x 216MHz per beam)
- High Bandwidth Scalable Options from 100 Mbit/s to 1.2 Gbit/s
- Initial constellation of 12 MEO (8,062 km altitude) satellites rotate the globe approximately four times a day (3560 min period)
- 10 beams per region (7 regions) totaling 70 remote beams per 8 satellite constellation
- Roundtrip latency of less then 150 ms enabling
  - Crystal clear voice and HD video
  - Ultra-fast response time
  - Use of cloud based applications

- Continuous coverage: when one satellite leaves, another satellite takes over without transmission interruption
- Each beam is connected to a high throughput teleport, with multiple layers of redundancy, ensuring operators a reliable, high speed service
- Service model oriented to operators

Highly Elliptical Orbits (HEOs)

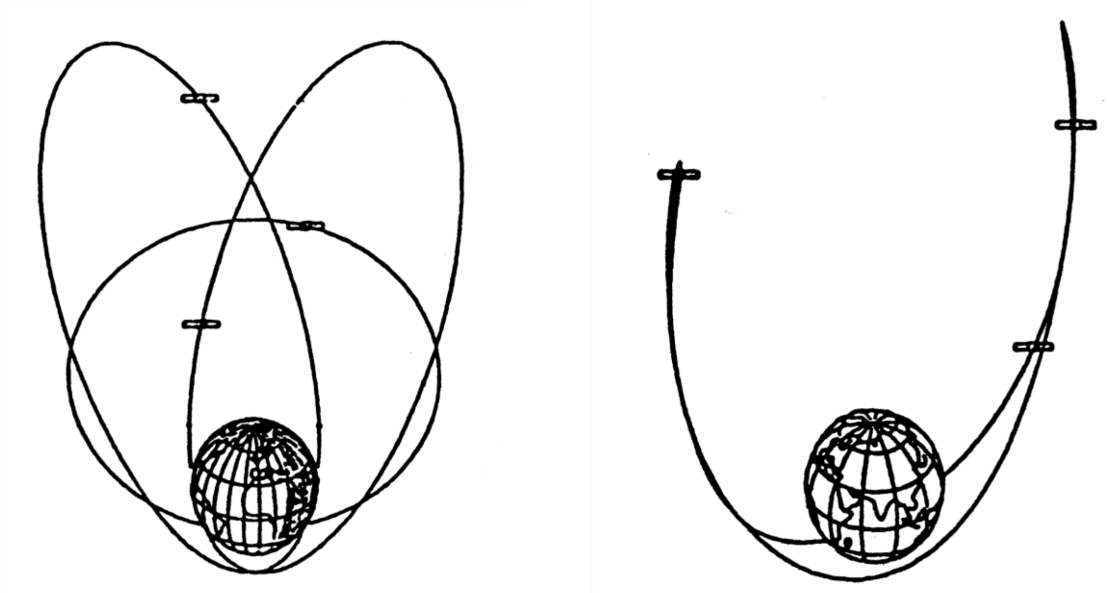
- The orbit describes an ellipse around two focal points. The Earth occupies one.
- Motion in elliptical orbits follows 2^{nd} keplerian law: spans the same areas in the same time
- Satellites almost fixed around the apogee
- Suitable for regional service area



- Due to relative motion earth satellite, Doppler effect and zoom effect
- HEOs (i = 63.4°) are suitable to provide coverage at high latitudes (including North Pole in the northern hemisphere)
- Satellite handover: all traffic must be periodically transferred from the “setting” satellite to the “rising” satellite
- Due to very high apogee, the satellite is very slow along a large arc

Depending on selected orbit (e.g. Molniya, Tundra, etc.) two or three satellites are sufficient for continuous time coverage of the service area.

HEO Satellites Mechanics



Fixed observer **Earth-fixed observer**

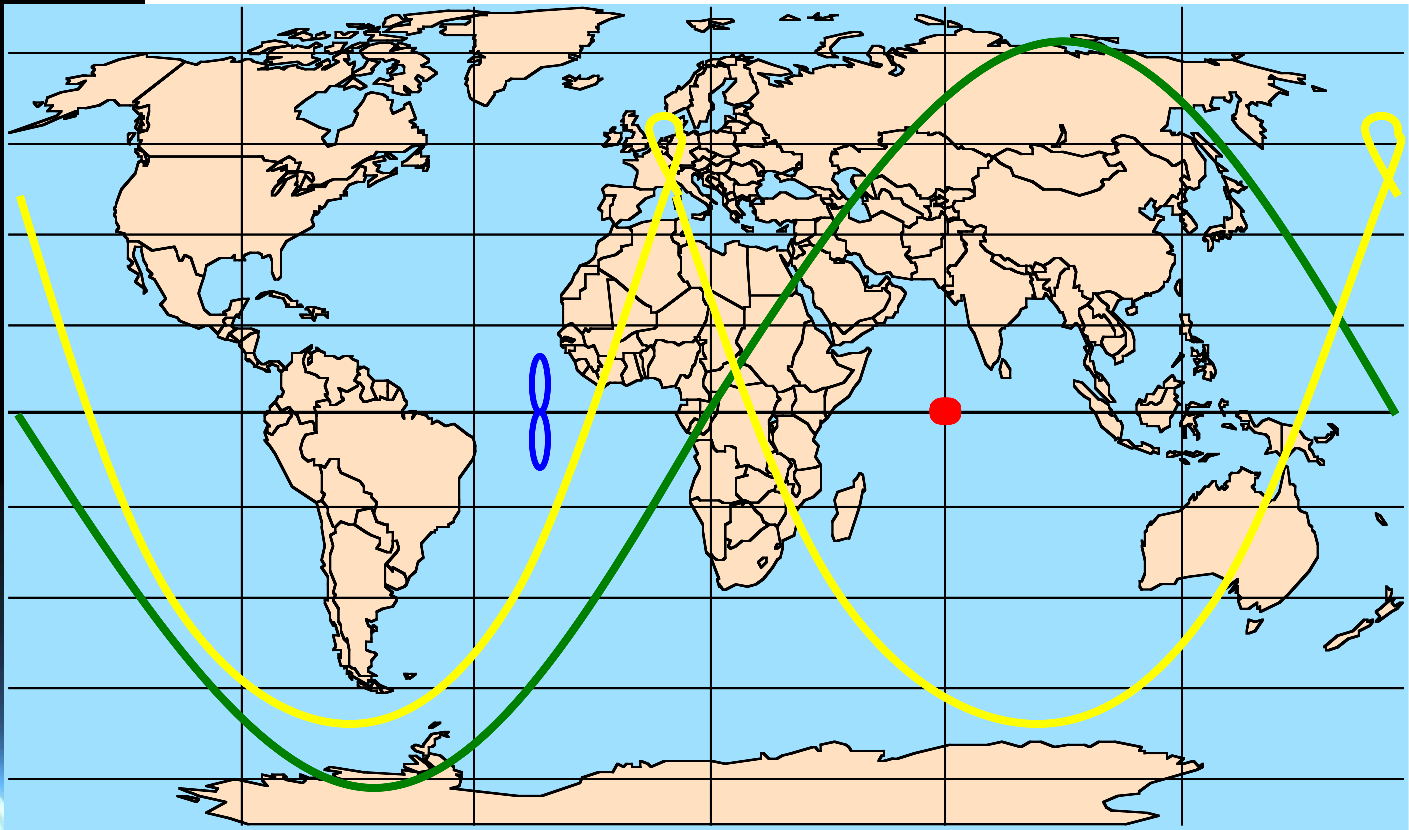
Accounting for the Earth rotation the tree satellites appear as if they were on a single track

- Advantages vs. GEO: higher elevation angle at high latitudes
- Comparable with GEO: Delay, Free Space Losses
- Disadvantages vs. GEO: larger number of satellites for the same coverage, tracking (but slow)

HEO orbits characteristics

Orbit	*Eccentricity*	*Apogee (km)*	*Perigee (km)*	*Handover (km)*	*Period (h)*	*Visibility (h)*	*Number of satellites*
Molniya	0.7	39500	1200	23500	12	8	3
Loopus	0.713	39100	1250	23500	12	8	3
Tundra	0.269	47100	24500	43300	24	8	3
Supertundra	0.423	53600	18000	42600	24	12	2

Subsatellite Tracks



LEO	GEO (perfectly stabilized)
HEO	Geosynchronous (imperfectly GEO)

Hybrid constellations

- In real systems only one type of orbits is utilized for each system
- Different orbits can be jointly utilized
- Different constellations can cooperate to provide service
- Example: joint use of GEO and LEO

Data Relay configuration: rationale

- The GEO service areas, usually dedicated to multiregional coverage
- LEO constellations can complement coverage over the areas where GEOs:
  - are completely absent (poles)
  - could perform not at their best (high latitudes, mountain regions, shaded zones)
  - may not be economically convenient (deserts, oceans).
- LEO constellation could support also the terrestrial systems
  - it can provide the necessary communication infrastructure for those service areas where
    - the deployment of terrestrial infrastructures could have a very high cost compared with the served population (polar zones, deserts)
    - could be practically impossible to set up (oceans, oil platforms)
- Adding just one or a few low cost LEO satellite to the classical GEO architecture the total coverage and capacity can greatly increase.
- Adding a full LEO constellation creates an alternative point of access.
- Modularity in setting up and deploying the constellation can be cost-effective approach.

Data Relay Architecture

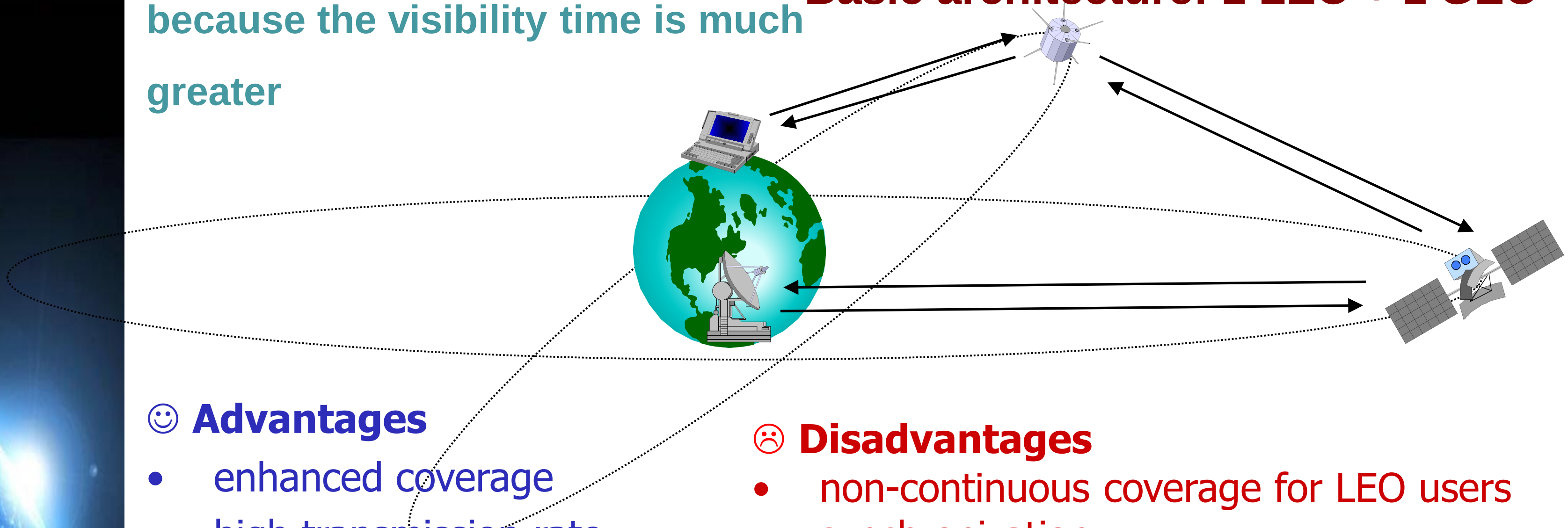
User connected to LEO satellite which is connected to a GEO satellite

Visibility LEO-GEO greatly increased with respect to a ground station

Due to short distance (Earth-LEO) high data rates are achievable

No matter if the link LEO-GEO is slower because the visibility time is much greater

Basic architecture: 1 LEO + 1 GEO



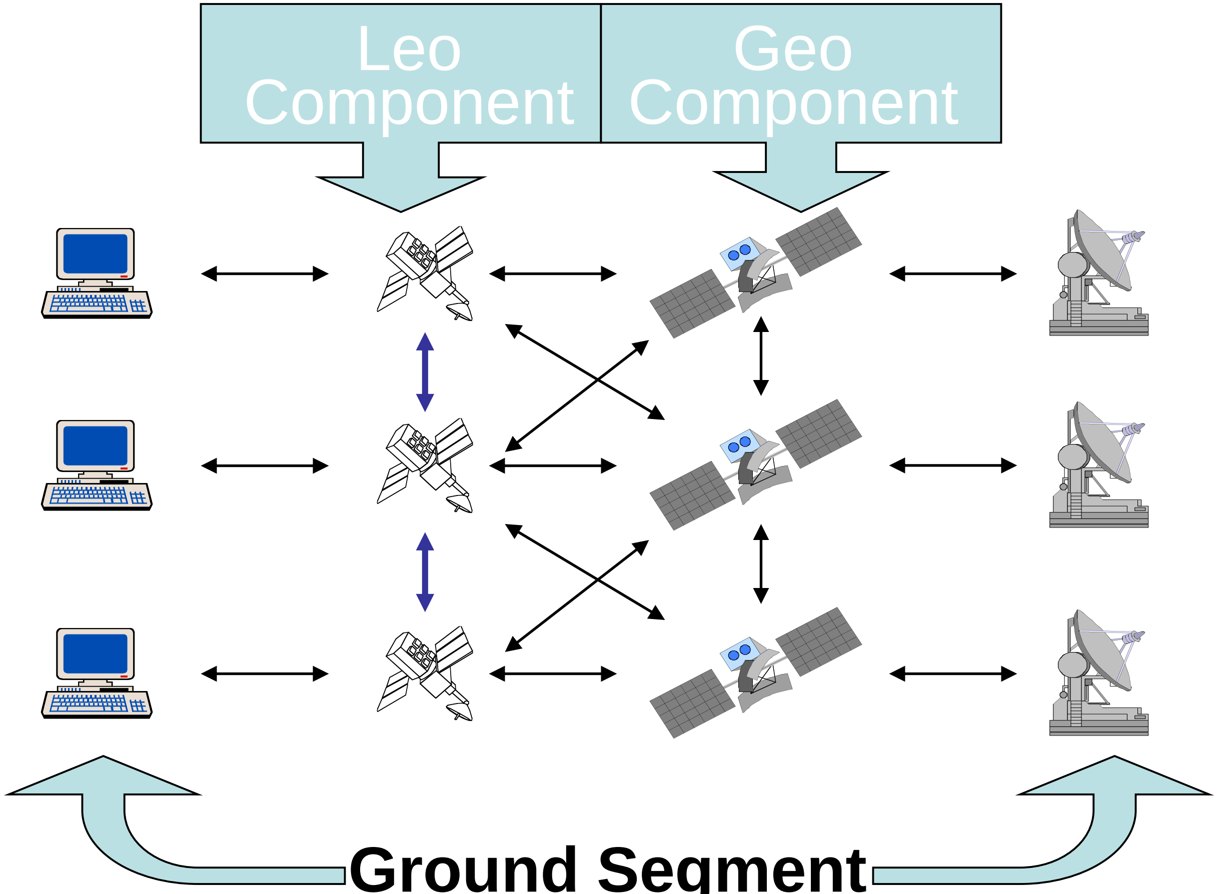
☺ **Advantages**

- enhanced coverage
- high transmission rate
- modularity

☹ **Disadvantages**

- non-continuous coverage for LEO users
- synchronization
- tracking from earth and on board

Final Architecture

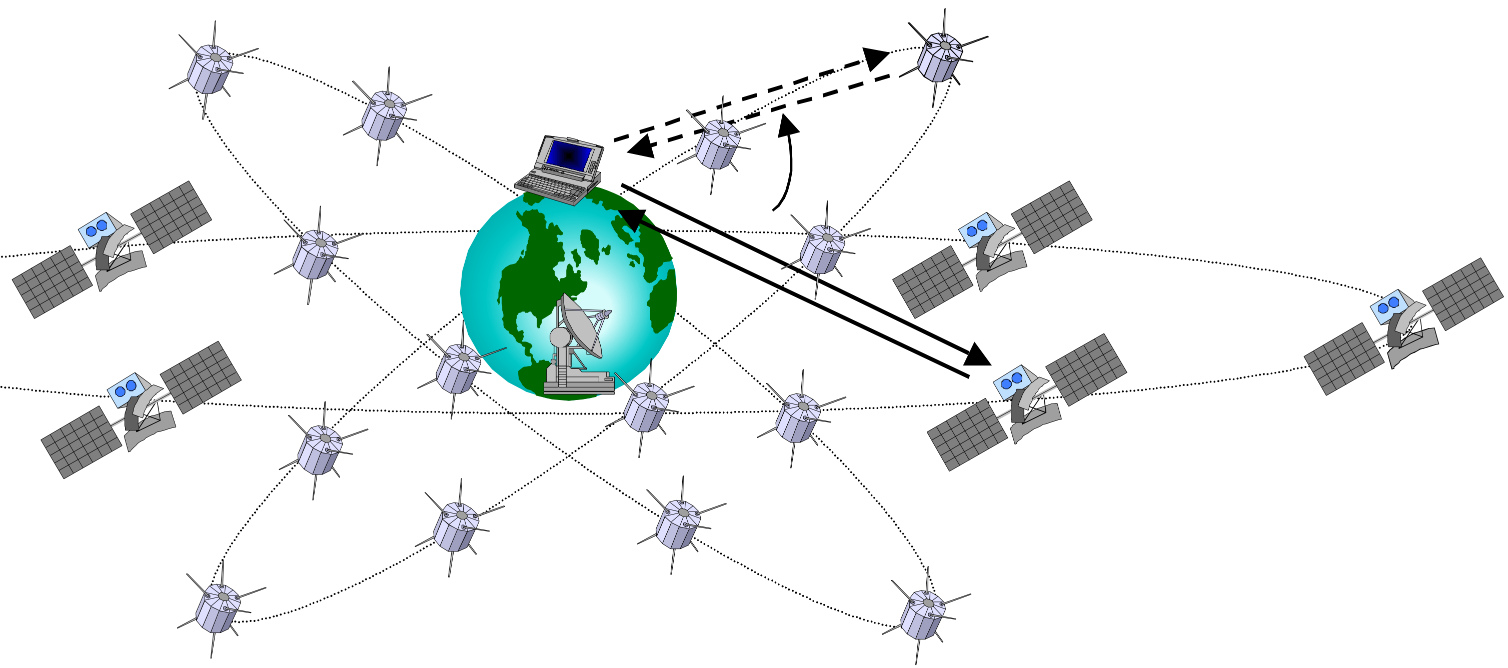


Services and Applications

- No-real time services
  - File transfer
- Applications
  - Email
  - FTP
  - Web browsing
  - Data retrivial

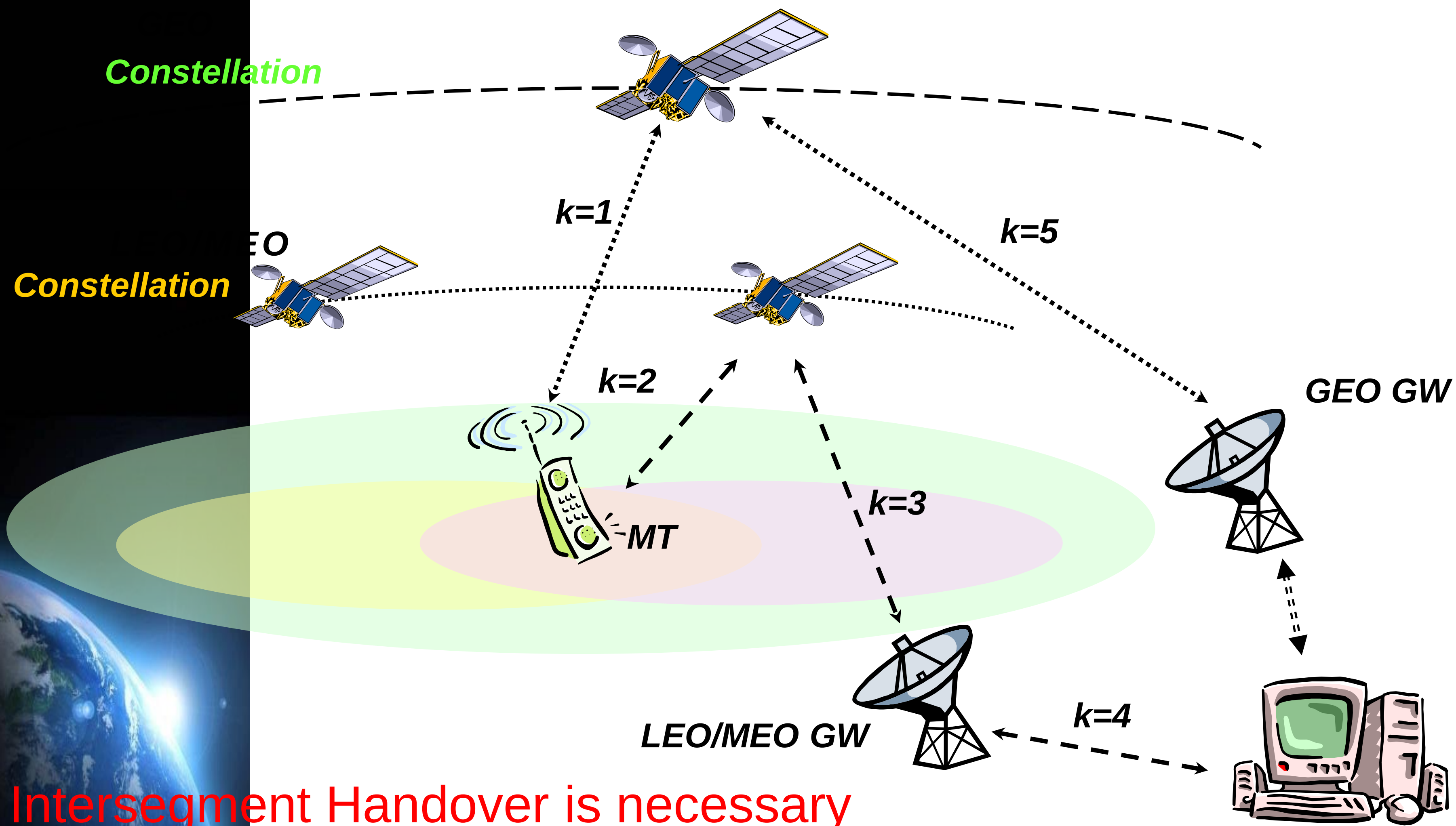
Alternative point of access architecture

- The two constellations are used alternatively on the basis of the best cost/performance ratio



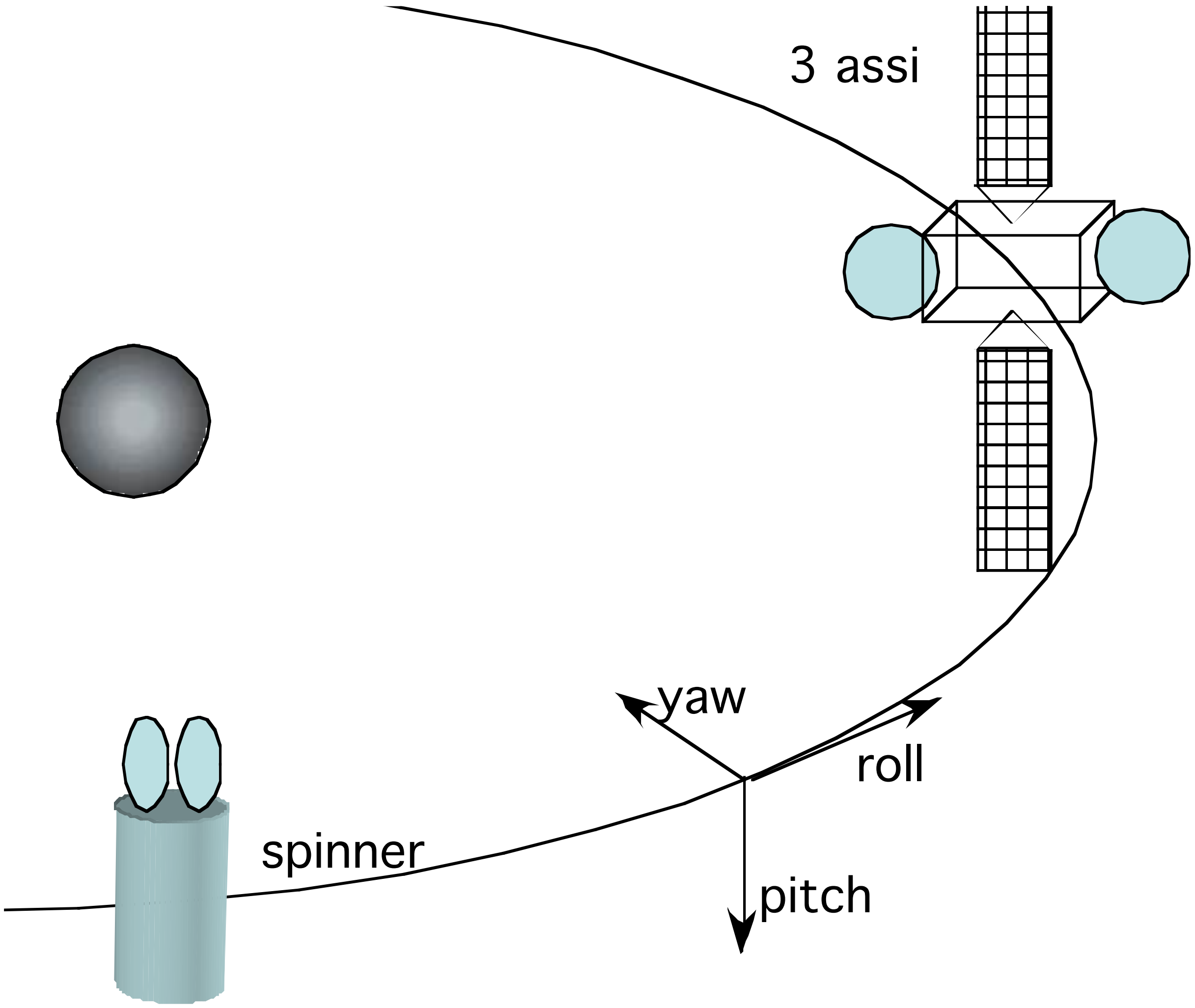
Full LEO constellation needed

Handover



Intersegment Handover is necessary

Stabilization



Satellite classification in terms of weight

category	mass range (kg)
large satellite	> 1,000
medium-sized satellite	500-1,000
minisatellite	100-500
microsatellite	10-100
nanosatellite	1-10
picosatellite	0.1-1
femtosatellite	< 0.1

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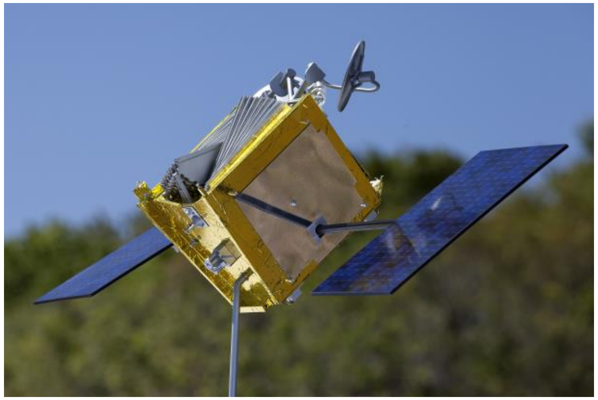
LEOSAT

- 108 satellites in polar orbits
- H = 1440 km
- Optical intersatellite link
- On board processing
- Ka band
- Flat panel antennas
- Each satellite in the LeoSat constellation supports:
  - 10 Ka-band steerable user antennas, each of which is capable of providing customer terminals with between 50 Mbit/s and 1.6 Gbit/s of symmetrical data connectivity
  - Two steerable gateway antennas, capable of an aggregated throughput of up to 10 Gbit/s (which can also be used for customer traffic when not over a gateway)
  - 4 optical inter-satellite links
- 2019 Launch of two Early Birds offering GigaByte Store and Forward Services
- 2021 Start of launch of the constellation offering real-time, point-to-point connectivity with coverage growing from the Poles to the Equator on completion
- 2022 Full Worldwide Service Availability

OneWeb



- 648 satellites
- 2.1 Gbit/s
- Electric propulsion
- User terminal antenna phased array 36x16 cm^2
- 50 Mbit/s downlink
- Ku band
- H = 1200 km
- 74 satellites already launched
- Despite the bankruptcy process in the end of May 2020, OneWeb filed an application to FCC for increasing the number of satellites to 48000.
- UK available to fund the project

Starlink

- 12000 satellites
- 538 already launched
- 1440 to start service
- H = 550 km
- Ku band
- User terminal 19-inch phased array antenna, easy installing

Telesat

- 300 satellites (current plan)
- 1600 satellites (future plan)
- H =
- Ka band
- Polar and inclined orbits
- Gbit/s per user, Terabit/s total capacity
- Intersatellite link
- On board processing

Kuiper (Amazon)

- 3236 satellites
- 578 satellites to launch service
- H =

REGULATION & STANDARDIZATION

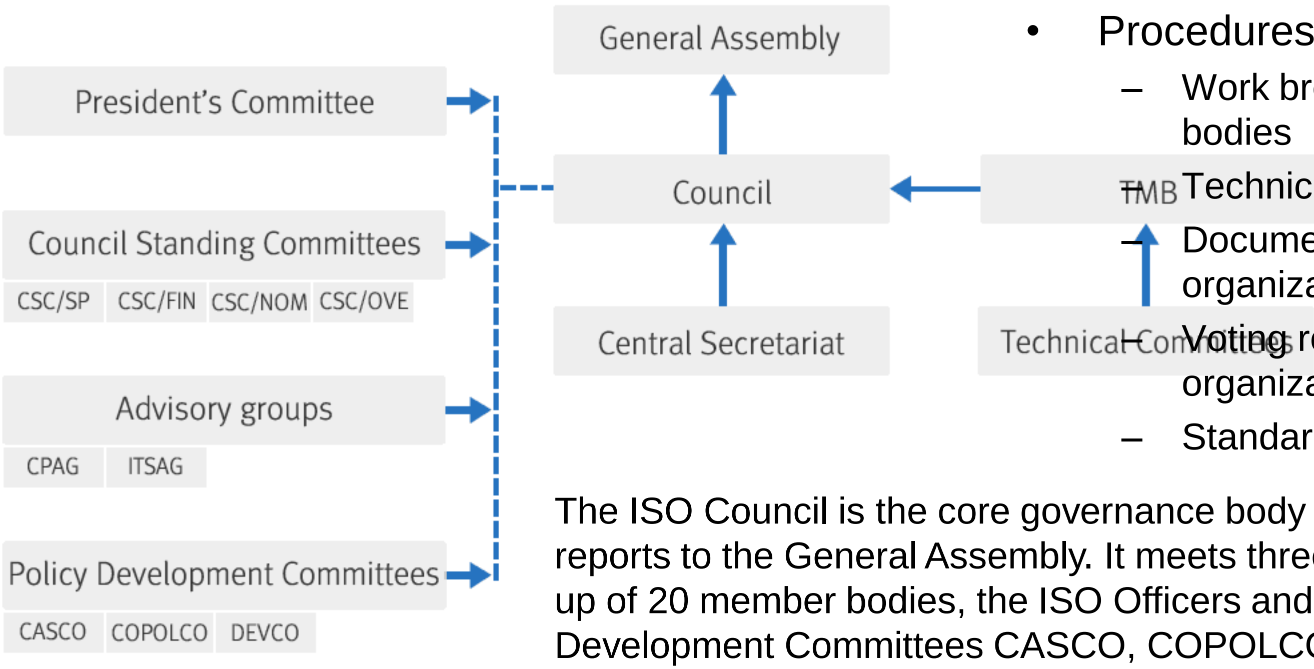
Standardization bodies and fora

- ISO (International Organization for Standardization)
- ETSI (European Telecommunication Standard Institute)
  - DVB (Digital Video Broadcasting)
  - DVB RCS (DVB Return Channel on Satellite)
- DVB (Digital Video Broadcasting)
- IETF (Internet Engineering Task Force)
- ITU (International Telecommunication Union)
- 3GPP (3rd Generation Partnership Program)
- FCC (Federal Communication Committee)
- IEEE (International Electronics and Electrical Engineering)
- CEPT (Conference Europeen Post et Telecommunication)
- GSC (Global Standards Collaboration)
- AIS (Alliance for the Information Society)
- MMAC (Multimedia Mobile Access Communication Systems)

ISO MISSION

- ISO (International Organization for Standardization) is the world's largest developer and publisher of International Standards.
- ISO is a network of the national standards institutes of 164 countries, one member per country, with a Central Secretariat in Geneva, Switzerland, that coordinates the system.
- ISO is a non-governmental organization that forms a bridge between the public and private sectors. Many of its member institutes are part of the governmental structure of their countries, or are mandated by their government. Other members have their roots uniquely in the private sector, having been set up by national partnerships of industry associations.
- Therefore, ISO enables a consensus to be reached on solutions that meet both the requirements of business and the broader needs of society.

ISO Governance Structure



- Procedures
  - Work brought by National standards bodies
  - Technical committees develop drafts
  - Documents approved by ISO members organizations
  - Voting restricted, one vote per member organization
  - Standards issued by ISO

The ISO Council is the core governance body of the Organization and reports to the General Assembly. It meets three times a year and is made up of 20 member bodies, the ISO Officers and the Chairs of the Policy Development Committees CASCO, COPOLCO and DEVCO.

The Council has direct responsibility over a number of bodies reporting to Council:
The President's Committee advises Council on matters decided by Council. Membership to the Council is open to all member bodies and rotates to make sure it is representative of the member community.
Council Standing Committees address matters related to finance (CSC/FIN), strategy and policy (CSC/SP), nominations for governance positions (CSC/NOM), and oversight of the Organization's governance practices (CSC/OVE). Advisory Groups provide advice on matters related to ISO's commercial policy (CPAG) and Information Technology (ITSAG).
CASCO - provides guidance on conformity assessment / COPOLCO - provides guidance on consumer issues
DEVCO - provides guidance on matters related to developing countries

ETSI mission

- Founded in 1988, not-for-profit organization, 800 members, 67 countries (5 continents),
  - Manufacturers
  - Network operators
  - National Administrations
  - Service/content providers
  - Universities and Research bodies
  - User groups
  - Consultancies
- It is officially recognized by the European Commission as a European Standards Organization.
- Produces globally-applicable standards for Information and Communications Technologies (ICT), including fixed, mobile, radio, converged, broadcast and internet technologies.
- By adhering to these standards, manufacturers and service providers can claim ‘presumption of conformity’ with the essential requirements of a directive (by self-declaration) rather than having to go through costly type approval processes in different Members States.

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ETSI Role

- GSP: Global Standards Producer
  - ETSI creates standards intended to meet global needs in ICT (global applicability of technical specifications)
- ESO: European Standards Organization
  - ETSI produces Harmonized Standards in all areas of telecommunications & ICT used to access European market
- SPO: Service Providing Organization
  - Interopolis: interoperability engineering
  - Forapolis: forum management
  - Plugtests events, home of TTCN-3
- Documents
  - EN European Standards
  - ES ETSI Standard
  - TS Technical Specification
  - EG ETSI Guide
  - TR Technical Report
  - SR Special Report

Type of committees

- **Technical Committee (TC)** – addressing a number of standardization activities in a specific technology area.
- **ETSI Project (EP)** – similar to a Technical Committee but established to meet particular market sector needs rather than centered around a basic technology. ETSI Projects last for a fixed period of time.
- **ETSI Partnership Project** – established when there is a need to co-operate with other organizations to achieve a standardization goal. There are currently two Partnership Projects: the Third Generation Partnership Project
(3GPPTM) and one M2M.
- **Industry Specification Group (ISG)** – operating alongside our traditional standards-making mechanisms and focusing on a very specific activity. ISGs are self-contained, decide their own work programme and approve their own specifications. They offer quick and easy alternative to creation of industry fora.
- **Special Committee (SC)** – like TCs, addressing a number of standardization activities in a specific technology area but SCs tend to handle co-ordination, the gathering of requirements and very specific support activities rather than drafting standards and specifications.
- **Specialist Task Force (STF)** – groups of technical experts who come together for a defined period (typically a few months) to work intensively on specific items. STFs operate under the guidance of a TC or EP.

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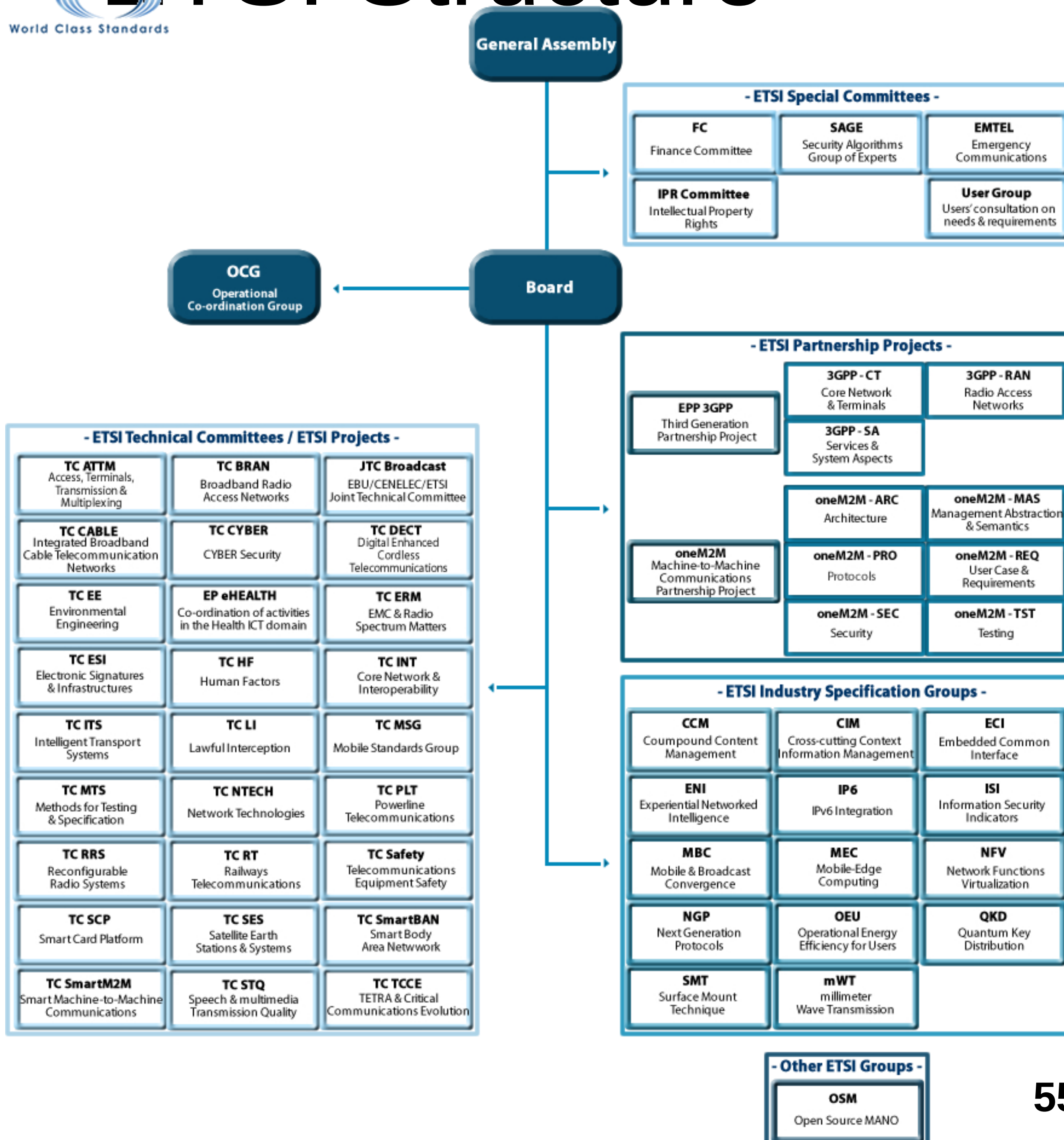
ETSI Structure



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Technical Committee (TC) Satellite Earth Stations and Systems (SES)

- Responsible for all aspects related to satellite communications
  - All types of satellite communication services and applications (including mobile and broadcasting),
  - All types of earth stations and earth station equipment, especially the radio frequency interfaces and network and/or user interfaces,
  - Protocols implemented in earth stations and satellite systems.
  - Responsibility outside ETSI - Primary Committee for coordinating the position of ETSI with relevant ITU Study Groups.

- Structure
  - **SCN** Satellite Communication and Navigation (created in July 2011)
    - previously MSS-Mobile Satellite Systems and BSM- Broadband Satellite Multimedia
  - **MAR ESV** Maritime & Railways Satellite Earth Stations on Board Vessels & Trains
  - **SatEC** Satellite Emergency Communications
  - **SDR** Satellite Digital Radio

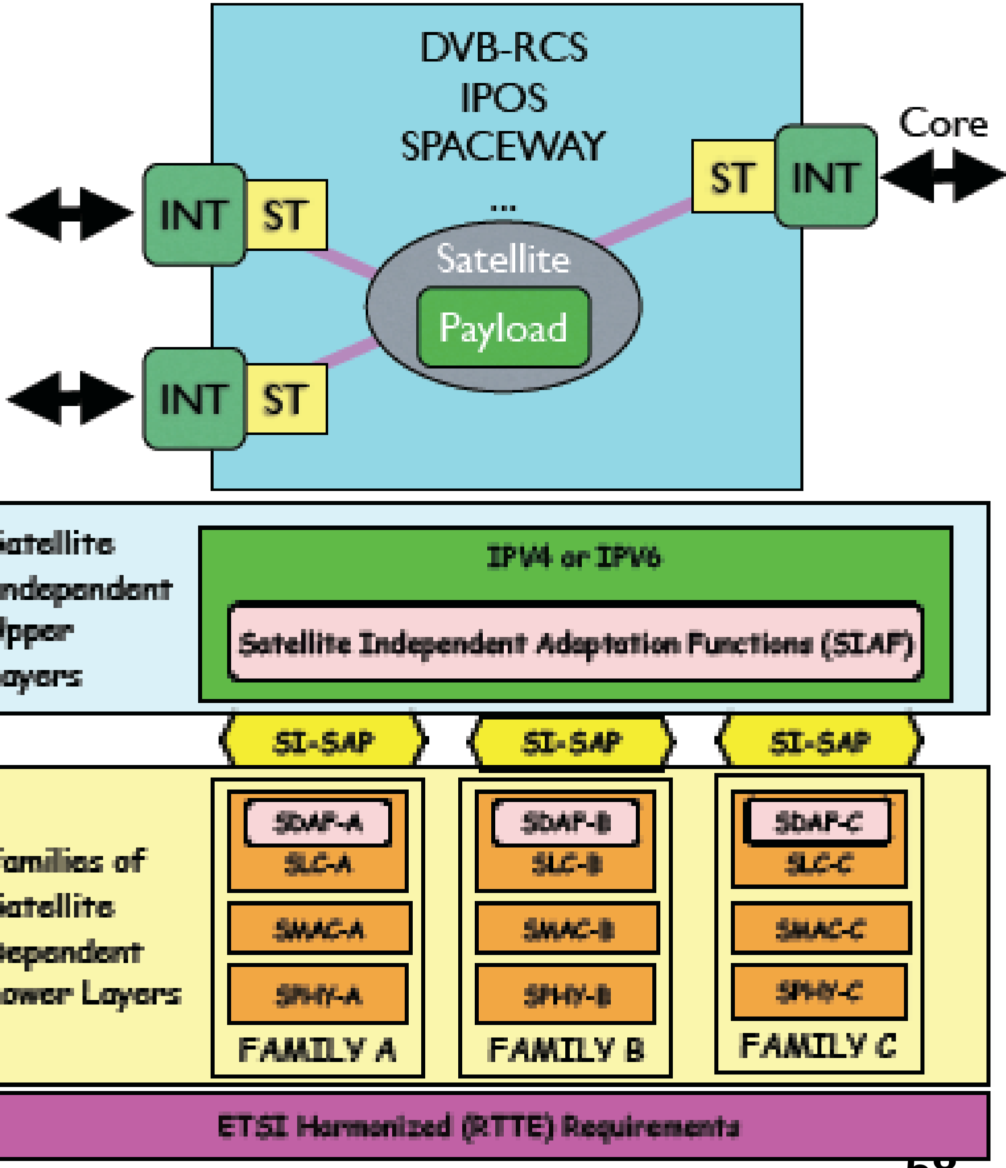
ETSI/TC-SES/ SCN WG

- Created in July 2011
- Responsible for radio and transmission aspects related to Fixed, Mobile and Global Navigation Satellite Systems operating in any bands allocated to FSS, MSS or RDSS.
  - To produce and maintain harmonized standards for satellite earth stations;
  - To produce and maintain technical specifications for satellite radio interfaces;
  - To encourage spectral efficiency on satellite links and harmonization of satellite radio interfaces;
  - To produce specifications that promote integration and inter-working between satellite and terrestrial networks.
  - To produce architecture and service requirements, interfaces (user, control and management planes), transport and network protocols, service enablers.
  - To encourage the development of network, transport and service layers compatible with various fixed and mobile satellite access networks.

ETSI former BSM WG

BSM = Broadband Satellite Multimedia

- **Hot Topics**
  - Connection Control Protocol
  - Service & Architecture
  - Performance Management & Performance MIB
  - Multicast Routing
  - IPv6



MAR-ESV

- Scopes
  - All types of Earth Stations installed on ships, vessels or trains operating in all types of frequency bands allocated to MSS, FSS and BSS
- Responsibility
  - This Working Group had received mandate from ETSI SES to produce and monitor standards for those Earth Stations including when transmitting on the move.
  - To analyze the Standards produced in ERM TG26, in order to resolve the potential conflicting specifications
- Liaison
  - Liaison with all other fora dealing with such Earth Stations, for example ITU R WP 4-9S, WP 4A, CEPT-ECC WG SE, SE40 and SE19 and CEPT-ECC WG RA5 and RA6

SatEC WG

- Scope activity
  - To perform standardization in the area of satellite emergency communication in particular involving broadband services.
- Liaison
  - The WG will liaise with any relevant bodies, in particular with EMTEL and MESA

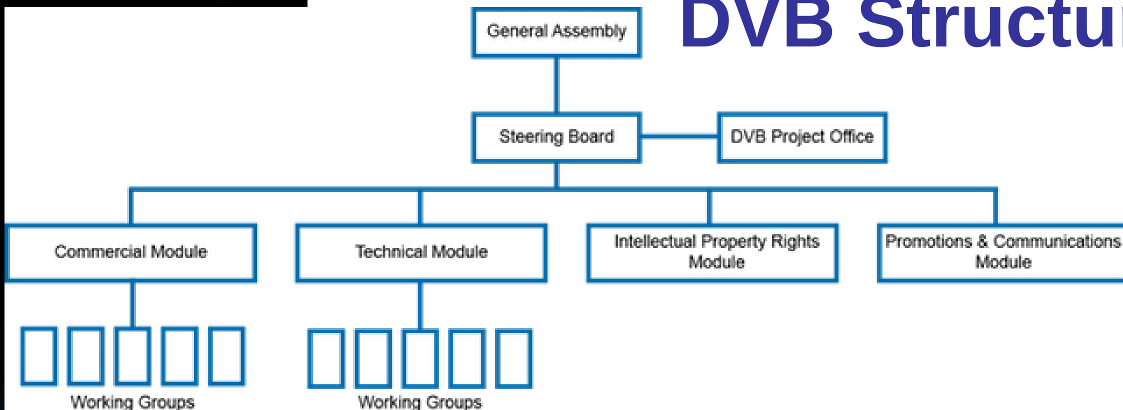
SDR

- Scope
  - To produce Technical Specification(s) or other ETSI deliverables for Digital Radio system.
- Responsibility
  - ETSI TC-SES gives TC mandate to this Working Group to produce Technical Specification(s) for Satellite Digital Radio (SDR) systems.
  - The Working Group will define the Technical Specifications for radio interfaces used by SDR systems to receive signals from the satellite and from the complementary terrestrial transmitters.
  - The working group shall also investigate whether there is a need to produce Harmonized Standards for transmitting elements of SDR systems, such as earth stations operating in the FSS uplink or complementary terrestrial transmitters.
- Liaison
  - The working group will liaise with any relevant body, inside and outside ETSI, on matters regarding the development of standards for SDR systems.

DVB (Digital Video Broadcasting)

- Industry led consortium formed in 1992
- 159 broadcasters, manufacturers, operators, software developers, regulatory bodies
- 35 countries

DVB Structure



General Assembly
The General Assembly is the highest body in the DVB Project and meets once a year, usually in November. All Members are represented in the General Assembly.

Steering Board
The Steering Board is elected by the General Assembly and meets 3 times per year. It sets the overall policy direction for the DVB Project and handles its coordination, priority setting and management. The Steering Board approves DVB specifications and offers them for standardization to the relevant international standards bodies.

Working Groups
The ad hoc Working Groups are where the real development of the DVB specifications takes place. Originating from the Modules and focusing on specific topics, they work towards clearly defined goals. Made up of experts, they are the beating heart of the DVB Project.

Modules
The activities of the DVB Project are carried out in four main Modules, each covering a specific element of the work undertaken. The Commercial Module and Technical Module are the driving force behind the development of the DVB specifications, with the Intellectual Property Rights Module addressing IPR issues and the Promotion and Communications Module dealing with the promotion of DVB around the globe.

Observers
A number of organizations have been granted a non-voting Observer status, including such entities as the European Broadcasting Union, the European Telecommunications Standards Institute, the Korean Electronics and Telecommunications Research Institute and CableLabs®.

DVB Procedure

- Commercial module and its WGs identify the Commercial requirements (CR)
- Technical module and its WGs develop specification
- Documents approved by voting (only members)
- Approval by steering board
- Standard issued by ETSI/SES or CENELEC (European Committee for Electrotechnical Standardization)
- DVB's Intellectual Property Rights Module addresses the issue of any intellectual property rights that may arise for DVB specs
- Promotions & Communications Module coordinates the flow of information regarding DVB specs to all parts of the world.

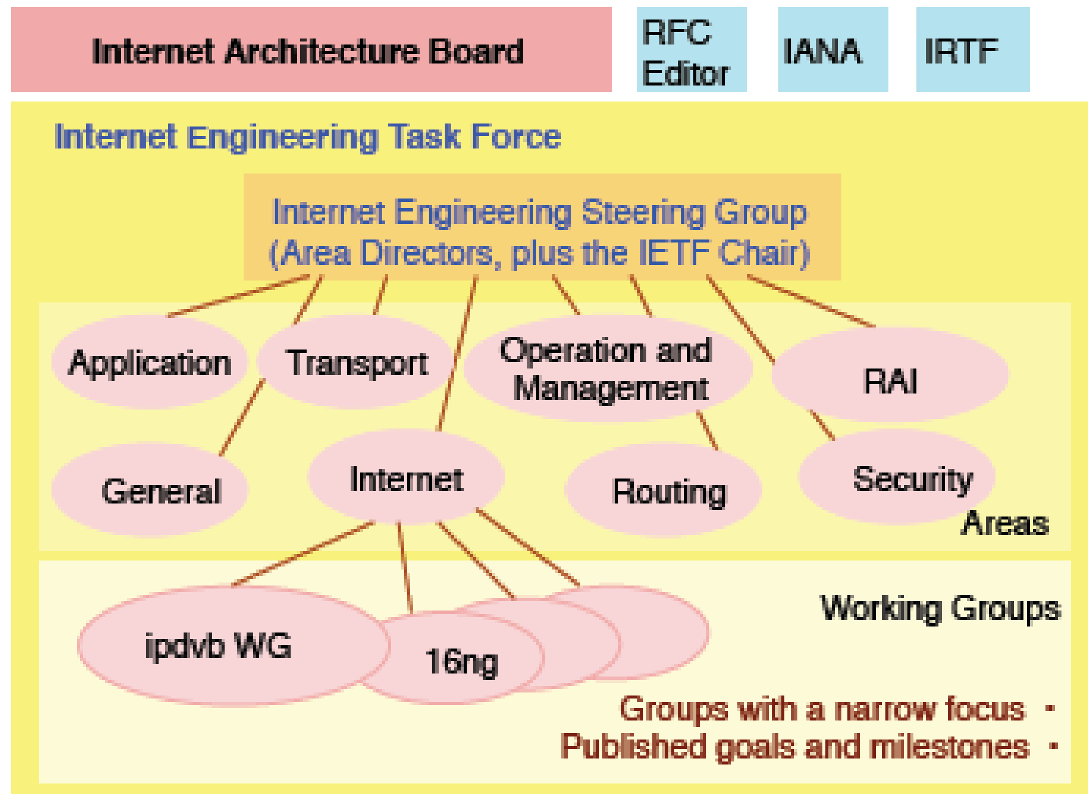
IETF MISSION

- To produce high quality, relevant technical and engineering documents that influence the way people design, use, and manage the Internet in such a way as to make the Internet work better. These documents include protocol standards, best current practices, and informational documents of various kinds.
- The IETF will pursue this mission in adherence to the following cardinal principles:
  - Open process - any interested person can participate in the work, know what is being decided, and make his or her voice heard on the issue. Part of this principle is the commitment to making documents, WG mailing lists, attendance lists, and meeting minutes publicly available on the Internet.
  - Technical competence - the issues on which the IETF produces its documents are issues where the IETF has the competence needed to speak to them, and that the IETF is willing to listen to technically competent input from any source. Technical competence also means that IETF output is expected to be designed to sound network engineering principles - this is also often referred to as "engineering quality".
  - Volunteer Core - participants and leadership are people who come to the IETF because they want to do work that furthers the IETF's mission of "making the Internet work better".
  - Rough consensus and running code - standards are based on the combined engineering judgment of participants and real-world experience in implementing and deploying specifications.
  - Protocol ownership - when the IETF takes ownership of a protocol or function, it accepts the responsibility for all aspects of the protocol, although some aspects may rarely or never be seen on the Internet. Conversely, when the IETF is not responsible for a protocol or function, it does not attempt to exert control over it, even though it may at times touch or affect the Internet.

IETF composition and structure

- ISPs and Carriers
- Researchers
- Vendors
- Inventors
- Liaison

Only individuals

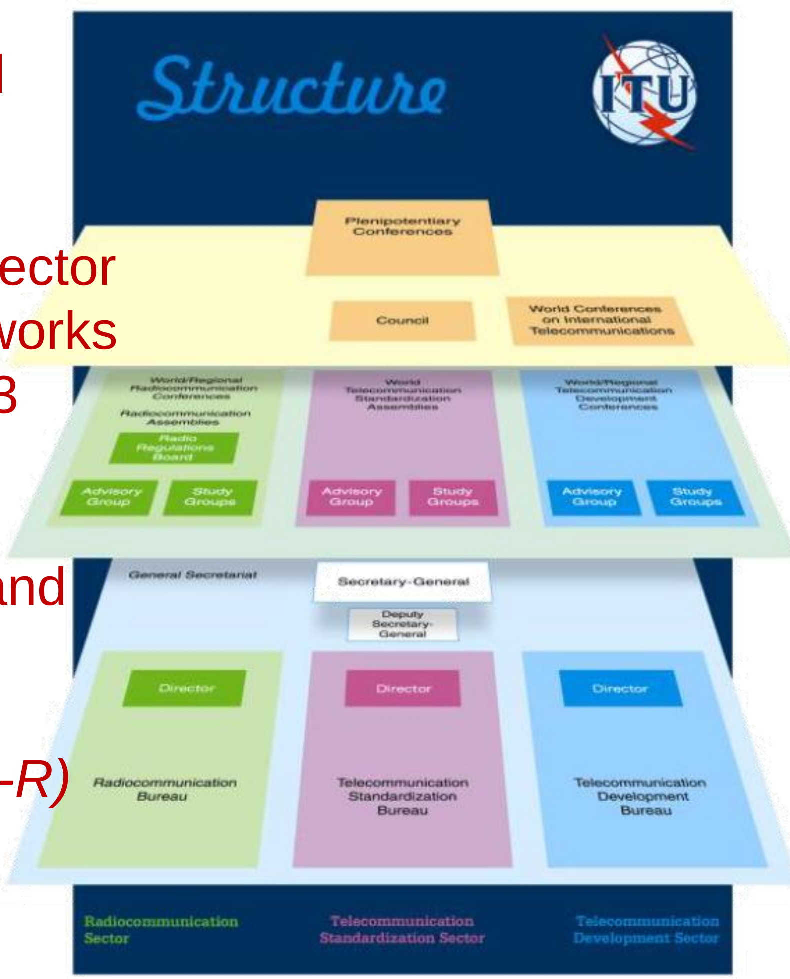


IETF Documents and RFC process

- Internet Draft (IDs)
  - Individual Submissions
  - Working Group Drafts
- Request For Comments (RFCs)
  - Informational
  - Best Current Practices (BCP)
  - Standard Track
    - Propose Standard
    - Draft Standard • Standard
  - Experimental
  - Historic

- ➢ Ideas
- ➢ Working Groups
- ➢ Internet Draft (ID)
- ➢ Working group last call
- ➢ IETF last call
- ➢ IESG (AD) - Internet Engineering Steering Group
- ➢ IANA (Internet Assigned Numbers Authority)
- ➢ RFC Editing Þ RFC issued

ITU structure



Headquartered in Geneva, Switzerland, is an international organization within the United Nations System where governments and the private sector coordinate global telecom networks and services. In addition to 193 Member States, membership includes ICT regulators, many leading academic institutions and 700 tech companies.

Three main sectors:

- *Radiocommunications (ITU-R)*
- *Standardization (ITU-T)*
- *Development (ITU-D)*

ITU Council (2019-2022) - 48 members

- **Region A (Americas):** 9 seats
  - Argentina, Bahamas, Brazil, Canada, Cuba, El Salvador, Mexico, United States, Paraguay
- **Region B (Western Europe):** 8 seats
  - France, Italy, Germany, Greece, Hungary, Spain, Switzerland, Turkey
- **Region C (Eastern Europe and Northern Asia):** 5 seats
  - Azerbaijan, Czech Republic, Poland, Romania, Russian Federation
- **Region D (Africa):** 13 seats
  - Algeria, Burkina Faso, Côte d'Ivoire, Egypt, Ghana, Kenya, Morocco, Nigeria, Rwanda, Senegal, South Africa, Tunisia, Uganda
- **Region E (Asia and Australasia):** 13 seats
  - Australia, China, India, Indonesia, Iran (Islamic Republic of), Japan, Korea (Republic of), Kuwait, Pakistan, Philippines, Saudi Arabia, Thailand, United Arab Emirates

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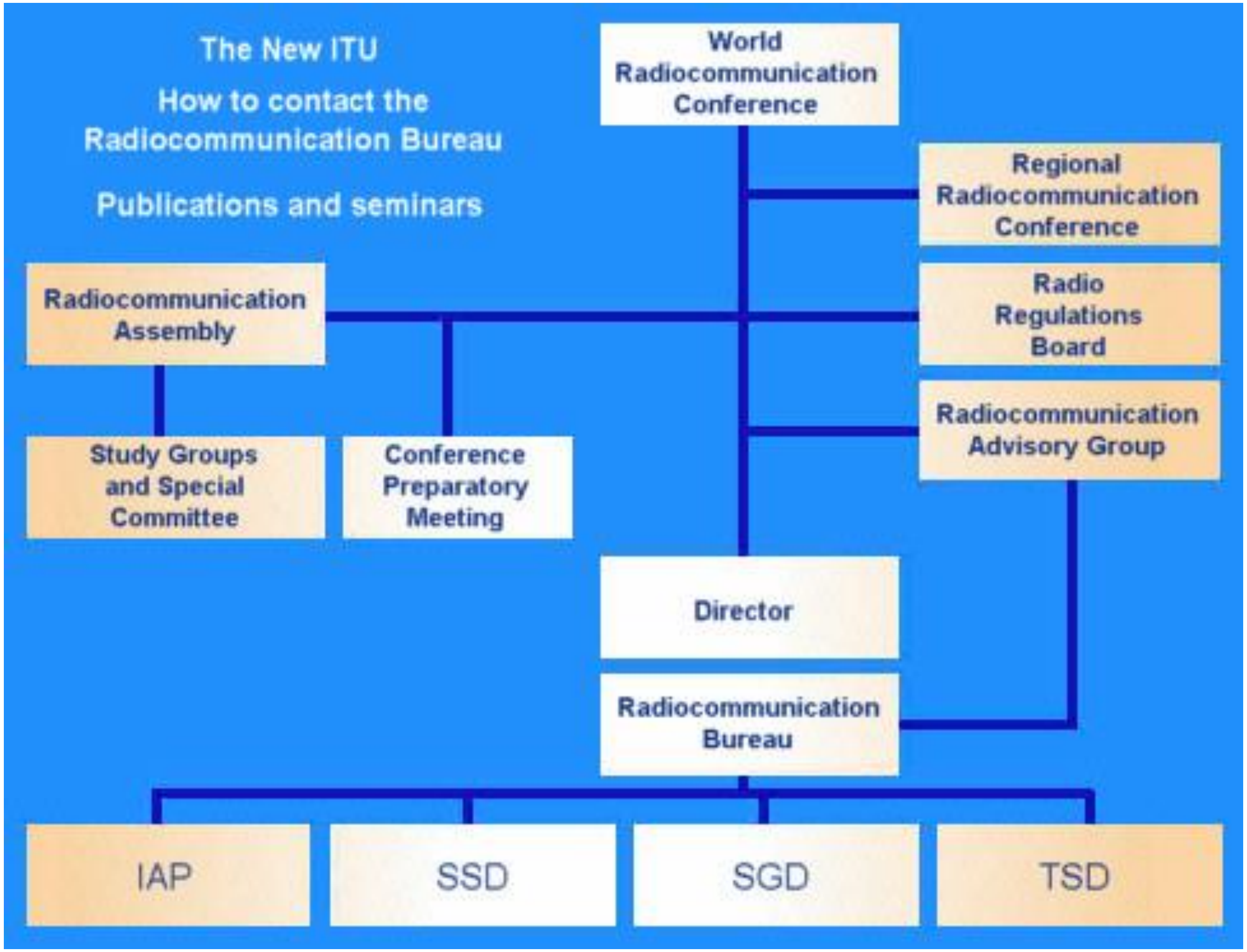
ITU-R Role

- The ITU-R plays a vital role in the management of the
  - radio-frequency spectrum
  - satellite orbits,
- for a large number of services
  - fixed,
  - mobile,
  - broadcasting,
  - amateur,
  - space research,
  - meteorology,
  - global positioning systems,
  - environmental monitoring
  - communication services that ensure safety of life at sea and in the skies.

ITU-R Structure



ITU-R Study groups

- SAT → **SG1 Spectrum Management**
- SAT → **SG3 Radiowave Propagation**
- SAT → **SG4 Satellite Service**
- **SG5 Terrestrial services**
- SAT → **SG6 Broadcasting Service (terrestrial and satellite)**
- **SG7 Science Services**

Group 4: Scope and working parties

- Systems and networks for the fixed-satellite service, mobile-satellite service, broadcasting-satellite service and radiodetermination-satellite service.
  - Working Party 4A - Efficient orbit/spectrum utilization
  - Working Party 4B - Systems, air interfaces, performance and availability objectives for the fixed-satellite service (FSS), broadcasting- satellite service (BSS) and mobile-satellite service (MSS), including IP-based applications and satellite news gathering (SNG)
  - Working Party 4C - Efficient orbit/spectrum utilization for the mobile- satellite service (MSS) and the radiodetermination-satellite service (RDSS)

Group 6: Scope and working parties

- Radiocommunication broadcasting (terrestrial and satellite), including vision, sound, multimedia and data services principally intended for delivery to the general public.
- Production and radiocommunication, including the international exchange of programs as well as the overall quality of service.
  - Working Party 6A - Terrestrial broadcasting delivery
  - Working Party 6B – Broadcast service assembly and access
  - Working Party 6M – Programme production and quality assessment

World Radiocommunication Conference (WRC)

- Held every two to three years to review, revise the Radio Regulations, the international treaty governing the use of the radio-frequency spectrum and the geostationary-satellite and non-geostationary-satellite orbits.
- The agenda determined by the ITU Council, takes into account recommendations made by previous world radiocommunication conferences. The general scope of the agenda is established four to six years in advance, the final agenda two years before.
- Under the terms of the ITU Constitution, a WRC can:
  - revise the Radio Regulations and any associated Frequency assignment and allotment Plans;
  - address any radiocommunication matter of worldwide character;
  - instruct the Radio Regulations Board and the Radiocommunication Bureau, and review their activities;
  - determine Questions for study by the Radiocommunication Assembly and its Study Groups in preparation for future Radiocommunication Conferences.
- Conference preparatory meeting (CPM)
  - On the basis of contributions from administrations, the Special Committee, the Radiocommunication Study Groups, and other sources concerning the regulatory, technical, operational and procedural matters to be considered by World and Regional Radiocommunication Conferences, the CPM shall prepare a consolidated report to be used in support of the work of such conferences.

3GPP

- The 3rd Generation Partnership Project (3GPP) unites [Seven] telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC), known as "Organizational Partners" and provides their members with a stable environment to produce the Reports and Specifications that define 3GPP technologies.
- The project covers cellular telecommunications technologies, including radio access, core network and service capabilities, which provide a complete system description for mobile telecommunications.
- The 3GPP specifications also provide hooks for non-radio access to the core network, and for interworking with non-3GPP networks.
- 3GPP specifications and studies are contribution-driven, by member companies, in Working Groups and at the Technical Specification Group level.

3GPP structure

Project Coordination Group (PCG

TSG RAN
Radio Access Network

- **RAN WG1** – Radio Layer 1 spec
- **RAN WG2** – Radio Layer 2 spec; Radio Layer 3 RR spec
- **RAN WG3** – lub spec, lur spec, lu spec; UTRAN O&M requirements (Radio CN Interfaces)
- **RAN WG4** – Radio Performance Protocol aspects
- **RAN WG5** – Mobile Terminal Conformance Testing
- **RAN WG6** – GSM EDGE Radio Access Network

TSG CT
Core Network & Terminals

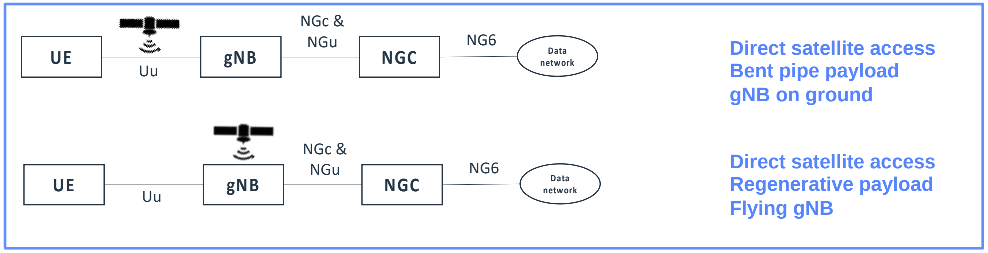
- **CT WG1** – MM/CC/SM (lu) (end-to-end aspects)
- **CT WG3** – Interworking with external networks
- **CT WG4** – MAP/GTP/BCH/SS (protocols within the CN)
- **CT WG6** – Smart Card Application Aspects

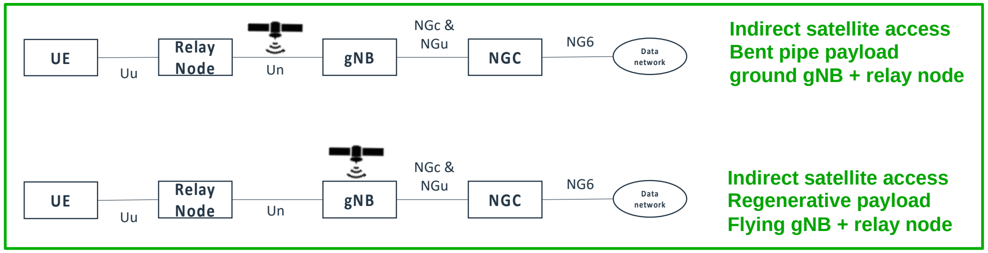
TSG SA
Service & Systems Aspects

- **SA WG1** – Services
- **SA WG2** – Architecture
- **SA WG3** – Security
- **SA WG4** – Speech, audio, video, and multimedia Codecs
- **SA WG5** – Telecom Management
- **SA WG6** – Mission-Critical Applications

Standardization activities concerning satellite in 5G

- SatCom related activities are currently on going at TSG-SA in the form of several study items that produce technical reports, and one work item in WG-SA1 that led to Change Requests to the top level 5G system services technical specification.
- Prioritization of the work items to be included in Release 17 are under way and will be finalized by December 2019. The 3GPP timeline for 5G foresees in fact the development of release 17 in 2020 with a planned completion for 2021.



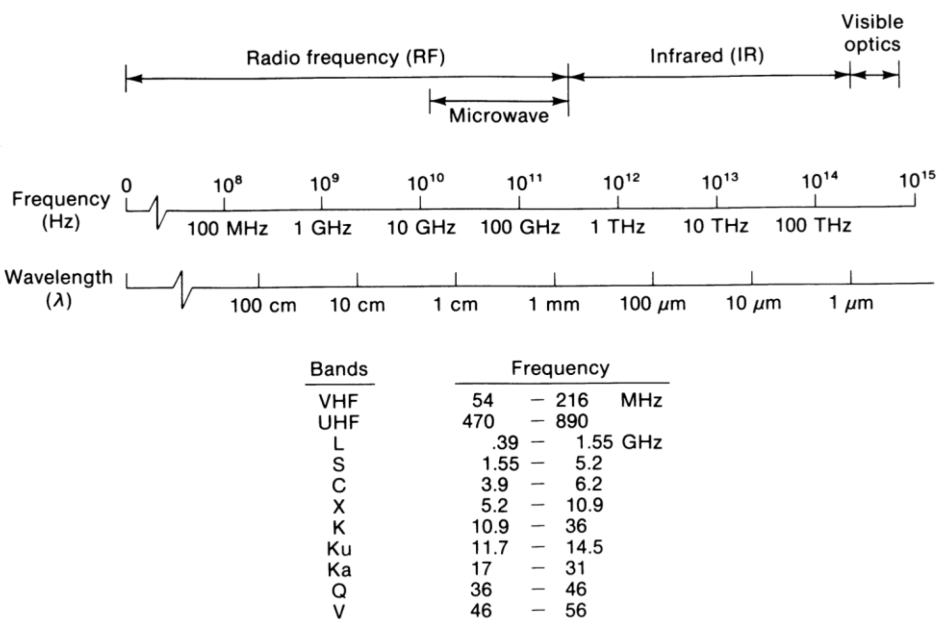


- Action plan

- By December 2019: promote and push as much as possible the SatCom industries to lobby in favour of kick-starting the normative phase on Non-Terrestrial Networks in Release 17. This action shall be
  - ➢ implemented before the TSG-RAN & TSG-SA meetings #86 (to be held in December 2019) that will decide the content of Release 17;
  - ➢ carried out through actual participations and contributions of the SatCom industries to the 3GPP meetings and through off-line discussion with the SatCom and Terrestrial stakeholders;

After December 2019: be involved as much as possible to the execution phase of the NTN related work items in 3GPP. This action shall be implemented by
  - ➢ dedicated ESA support studies of appropriate dimensions to be activated in the first quarter of 2020;
  - ➢ in continuity with the SSIG, the creation of a technical task force, consisting in industrial experts and scientific researchers, with the mandate of coordinating and facilitating, though provision of consultancies and direct R&D activities, the overall research and development of technologies in support of the 3GPP standardization;
  - ➢ the support of studies related to the analysis of possible benefits of the NTN component for vertical markets and cellular stakeholders.

The Radio Spectrum



ACRONYM		BAND	WAVELENGHT
VLF (Very Low Frequency)		3-30 kHz	100-10 km
LF (Low Frequency)		30-300 kHz	10-1 km
MF (Medium Frequency)		300-3000 kHz	1000-100 m
HF (High Frequency)		3-30 MHz	100-10 m
VHF (Very High Frequency)		30-300 MHz	10-1 m
UHF (Ultra High Frequency)		300-1000 MHz	100-30 cm
	L	1-2 GHz	30-15 cm
SHF (Super High Frequencies)	S	2-4 GHz	15-7.5 cm
	C	4-8 GHz	7.5-3.75 cm
	X	8-12 GHz	375-25 mm
	Ku	12-18 GHz	25-16.7 mm
	K	18-27 GHz	16.6-11 mm
	Ka	27-30 GHz	11-10 mm
EHF (Extremely High Frequency)		30-36 GHz	10-8.3 mm
	Q	36-46	8.3-6.5 mm
	V	46-56	6.5-5.3 mm
	W	90-94	3.3-3.2 mm
		Up to 300	1 mm

Band Allocation

	Up Link	Down Link
Fixed Services	5925-6425 MHz 7900-8400 MHz 13.75-14.5 GHz 27.5-30 GHz 30-31 GHz	3700-4200 MHz 7250-7750 MHz 10.95-11.2 GHz 11.45-11.7 GHz 12.5-12.75 GHz 17.7-20.2 GHz 20.2-21.2 GHz
Mobile Services	148-150.05 MHz 1626.5-1660.5 MHz 1610-1626.5 MHz 2170-2200 MHz 2655-2690 MHz 7900-8025 MHz 29.9-30 GHz 30-31 GHz	137-138 MHz 1525-1559 MHz 2483.5-2500 MHz 1980-2010 MHz 2500-2535 MHz 7250-7375 MHz 20.1-20.2 MHz 20.2-21.2 MHz

Spectrum Management

- A combination of technical and administrative procedures aiming at enabling radio stations everywhere to operate on interference free frequencies and without causing interference to other stations.
- Two levels: NATIONAL and INTERNATIONAL
- The procedures are described in the RADIO REGULATIONS
- **Category of allocation**
  - Primary or permitted
  - Secondary or subject to not causing interference
    - A station in the secondary service has to avoid causing interference to a station in primary service and it has to accept any interference caused by a station in the primary service
  - Subject to the application of certain procedures before being recognized on an equal footing with other services sharing the same band.
    - A station operating in out of band assignment must protect both the primary and the secondary services

Solutions to harmful interference

- Frequency adjustment
- Use of directional antennas
- Schedule adjustment or operational arrangements (time sharing)
- Change of class of emission
- Accommodation of individual channels in multichannel emission
- Transfer of traffic to other available frequencies
- Cessation of the station.

Coordination

- Bilateral negotiation to achieve an agreeable arrangement on the use of shared frequency bands.
- The procedures for coordination of space communication systems are established in the following provisions of the Radio Regulations (RR):
  - Article 11 Three main procedures of coordination
    - Geostationary satellite network with other networks
    - Earth stations with stations for terrestrial services
    - Transmitting terrestrial stations with earth stations
  - Resolution 46 (WRC 95)
    - Non geo systems and geo in certain frequency bands (the difference in the determination of the need to coordinate)
- Article 7 of Appendix 30
    - Fixed satellite services in the bands 11.7-12.2 GHz (Reg 2), 12,2-12,7 GHz (Reg 3) and 12,5-12.7 GHz (Reg 1) for broadcasting
- The required data to be supplied at the initial coordination stage is described by a single regulatory text in the RR: Appendix S4.

Coordination area

- Determined on the basis of technical assumptions that will provide interference free operation between the earth station and any terrestrial station lying outside the coordination area
- Whenever the coordination must be effected the coordination area will represent the geographical territory around the earth station location where it has the right to operate with its characteristics and levels of interference
  - An administration intending to put into operation terrestrial stations within the coordination area of an earth station and that have not been considered during the coordination of the earth station, shall request coordination to the administration responsible for the earth station
- Relevant procedures: Section IV of RR Art 11, sect IV of annex 1 to Res 46.

Coordination process

- Frequency allocation (RR art 8)
  - Only in case of frequency shared
- Regulatory procedures (Art 11 of RR and Res 46)
  - Based on bilateral discussion
- Coordination data (RR app 3)
- Coordination area (Art 11 of RR, Res 46)
  - Earth station in a fixed location
    - distance calculation method in Appendix 28 of RR
  - Mobile (not aero) earth station
    - Coordination area encompassing all the coordination areas determined for each location within the service area (App 28)
  - Aero station
    - 1000 km with (terrestrial) aeronautical mobile services
    - 500 km with terrestrial service, other than aeronautical mobile
  - Receiving stations in meteo service
    - The visibility distance as a function of the Earth station horizon elevation angle for a radiosonde at an altitude of 20 km above the mean sea level, assuming a 4/3 Earth radius.

Appendix S4: Network coordination

- At the end of the advance publication period, coordination is required with administrations whose satellite systems are identified by using the method of RR Appendix 29 (the equivalent satellite temperature of any link is increased by 6% due to interference from the other network)
- Coordination may need to be effected with administrations whose space systems have a frequency overlap with the planned systems (no particular method, responsibility of administration to decide if their service are likely to be affected by the system of the administration seeking coordination).
- Coordination is required (article 7 of Appendix 30) if there is frequency overlap and if the power flux density produced by the FSS assignment exceeds the value specified in Annex 4 of AP30.
- Actions required to administration planning the new satellite system for coordination
  - Collect all necessary Appendix S4 data for its planned satellite network
  - Send to the administrations, with which coordination is required, a formal request for coordination with the Appendix S4 data attached
  - Send to the Bureau a set of the Appendix S4 data and copies of the coordination required

Network coordination: Relevant Data and Forms

- Info required in Annexes 2A and 2B to Appendix S4
  - General information (network characteristics, orbital data) **Form ApS4/II-1a,1b**
  - Characteristics in the satellite receiving direction (for each satellite antenna beam) **Form ApS4/II-2a,2b**
  - Characteristics in the satellite transmitting direction (for each satellite antenna beam) **Form ApS4/II-3a,3b**
  - Overall link characteristics (up and down frequencies, transmission gain and equivalent satellite noise temperature for each link for Appendix 29 calculations) **Form ApS4/II-4a,4b**– Date of bringing into use and info on agreement obtained or requested
- Two types of earth station
  - Typical, to operate within a given service area
  - Specific, precise geographical coordinates must be provided
- Additional Info
  - Space station antenna beam coverage in graphical format
  - Steerable satellite antenna beam
  - Optional info (modulation, exact frequency, ...)
- After that the Radiocommunication Bureau will examine all the material and will provide or not the assignment.

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Appendix S4: Earth Station Coordination

- Coordination of an earth station with stations in terrestrial services is required with administrations of neighboring countries whose territory lie partially or entirely within the earth station coordination area, determined by the method of RR Appendix 28 (Article 11) or by predetermined coordination distance (Res 46)
- The administration responsible for the earth station shall:
  - Collect all necessary Appendix S4 data for its station;
  - Send to the administrations with which coordination is required a formal request with data attached, along with diagrams containing the station location and it associated coordination area;
  - Send to the Bureau data and attachments.

Earth Station Coordination: Relevant data and Forms

- Info required in Annexes 2A and 2B to Appendix S4
  - General information: (identify and location, associated space station) **Form ApS4/III-1**
  - Characteristics of the transmitting earth station (antenna characteristics, associated satellite receiving antenna beam, emission and frequency data) **Form ApS4/III-2a,2b**
  - Characteristics of receiving earth station (antenna characteristics, associated satellite transmitting antenna beam, emission and frequency data) **Form ApS4/III-3a,3b**

After that the Radiocommunication Bureau will examine all the material and will provide or not the assignment.

Graphical data (app 3 and 4 of RR)

- Measured radiation diagrams of earth station antennas;
- The horizon elevation diagrams of earth stations;
- The service area of the satellite networks;
- The antenna gain contours of geostationary space stations;
- The diagram of the antenna gain of geostationary space stations towards the geostationary-satellite orbit;
- The antenna radiation pattern of space stations.
- The Graphic Interference Management System (GIMS) allows to present data on a map in the following projections:
  - Orthomorphic
  - Cylindrical equidistant
  - Mercator
  - Cylindrical equal area
  - Equidistant conical with one standard parallel (only for Northern hemisphere)