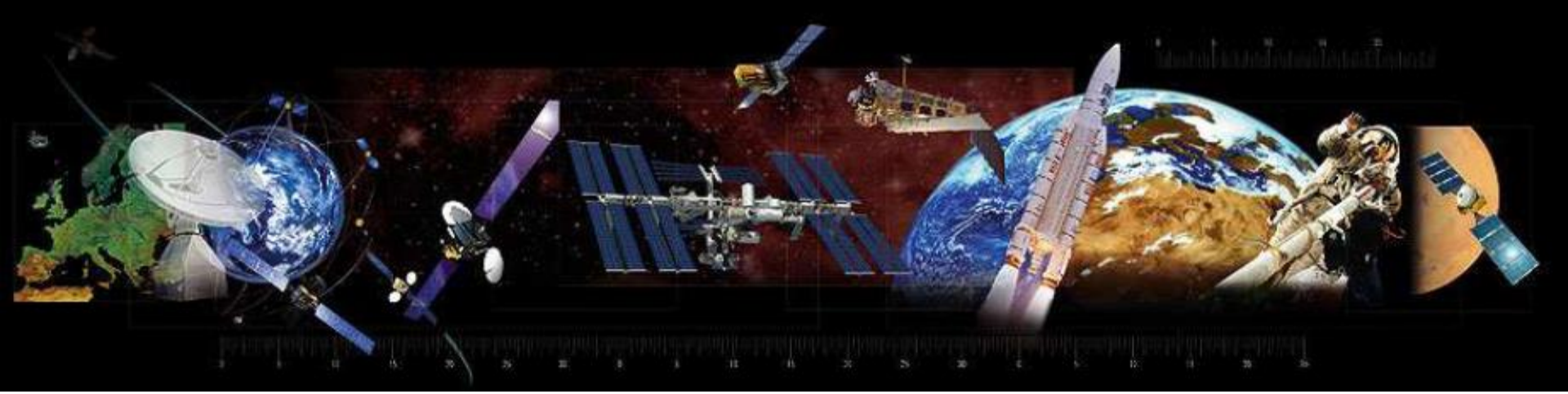

Space Segment

Satellites: LEO, MEO & GEO

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Presentation Content

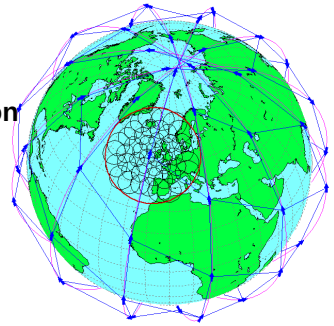
Satellite Space Segment: LEO, MEO & GEO

1. Satellite System Elements.
2. Classification of Satellite Orbits.
3. GEO Satellites.
4. MEO Satellites.
5. LEO Satellites.
6. Satellite Categories & Examples.
7. Satellite Services & Usage.
8. Satellite Coverage & Footprint.
9. Satellite Frequency Bands.
10. LEO Constellations: Iridium & GlobalStar.
11. MEO Constellations: GPS.
12. GEO Constellations: Inmarsat.

GPS Satellite Constellation

GlobalStar Satellite Constellation

Iridium Satellite Constellation



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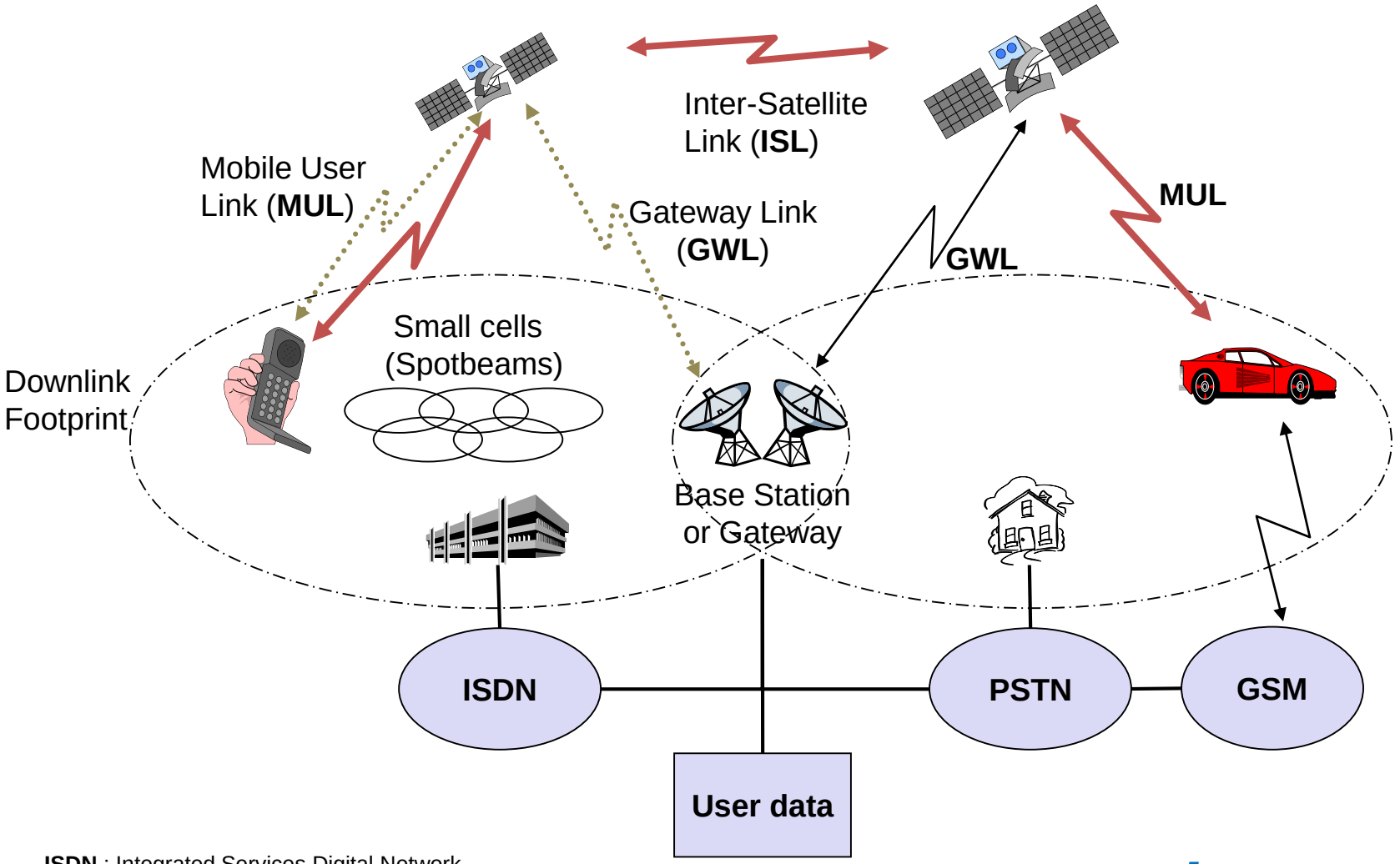
Benefit & Strengths of Satellites

Satellite Space Segment

1. **Coverage**: Suitable for wide geographical coverage areas on Earth.
2. **Broadcast**: Large data collecting & broadcast characteristics.
    A. Bypass very crowded terrestrial communication networks.
3. **Connectivity**: Extremely suitable for localized services worldwide.
    A. Multipoint-to-Multipoint, Point-to-Multipoint and Multicasting (IP, multimedia).
4. **Mobility**: Suitable for long range mobility: Direct-to-User services.
    A. One-way services, like: Direct TV & radio broadcasting.
    B. Two-way services, like: Data & voice communication.
5. **Deployment**: Rapid deployment time & prompt service implementation.
6. **Flexibility**: Service & traffic capacity can be adapted & reconfigured.
7. **Integration:** Seamless integration capability with terrestrial networks.
8. **Capacity**: High channel capacity (> 100 Mb/s) & low error rates (< 10^{-6}).
9. **Costs**: Transmission costs are independent of distance within satellite area.
10. **Barriers**: Erases geographic, technical, time, and political barriers.

Satellite System Elements

Space Segment, Ground Segment, Control Segment



ISDN : Integrated Services Digital Network.
PSTN: Public Switched Telephone Network.
GSM : Global System for Mobile Communication.

Classification of Satellite Orbits

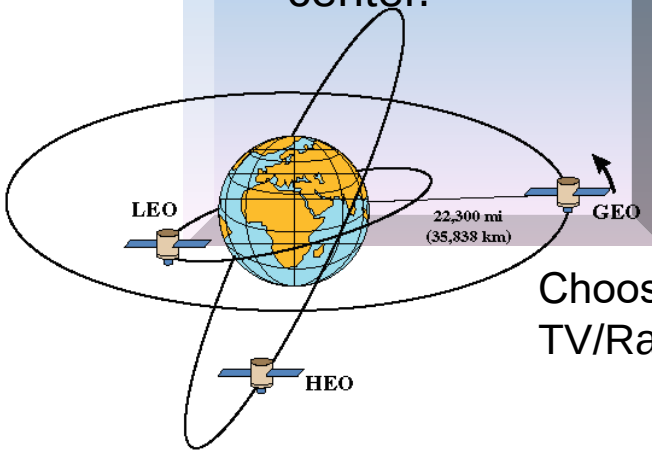
Types of Orbits:

Circular Orbit:

- Circular around Earth's equator.

Elliptical Orbit:

- Elliptical with foci at Earth's center.



Orbital Planes:

- **Equatorial** orbit above Earth's equator. **0° incline.**
- **Polar** orbit has 90° incline from Earth's equator & satellite passes over both poles.
- **Inclined** orbit is tilted above the Earth's equator.

Orbital Altitude:

- **GEO**: Geosynchronous Earth Orbit.
- **MEO**: Medium Earth Orbit.
- **LEO** : Low Earth Orbit.
- **HEO**: Highly Elliptical Orbit.

Choose a satellite's orbit based on its service characteristics: TV/Radio broadcasting, mobile users, weather observation, etc.

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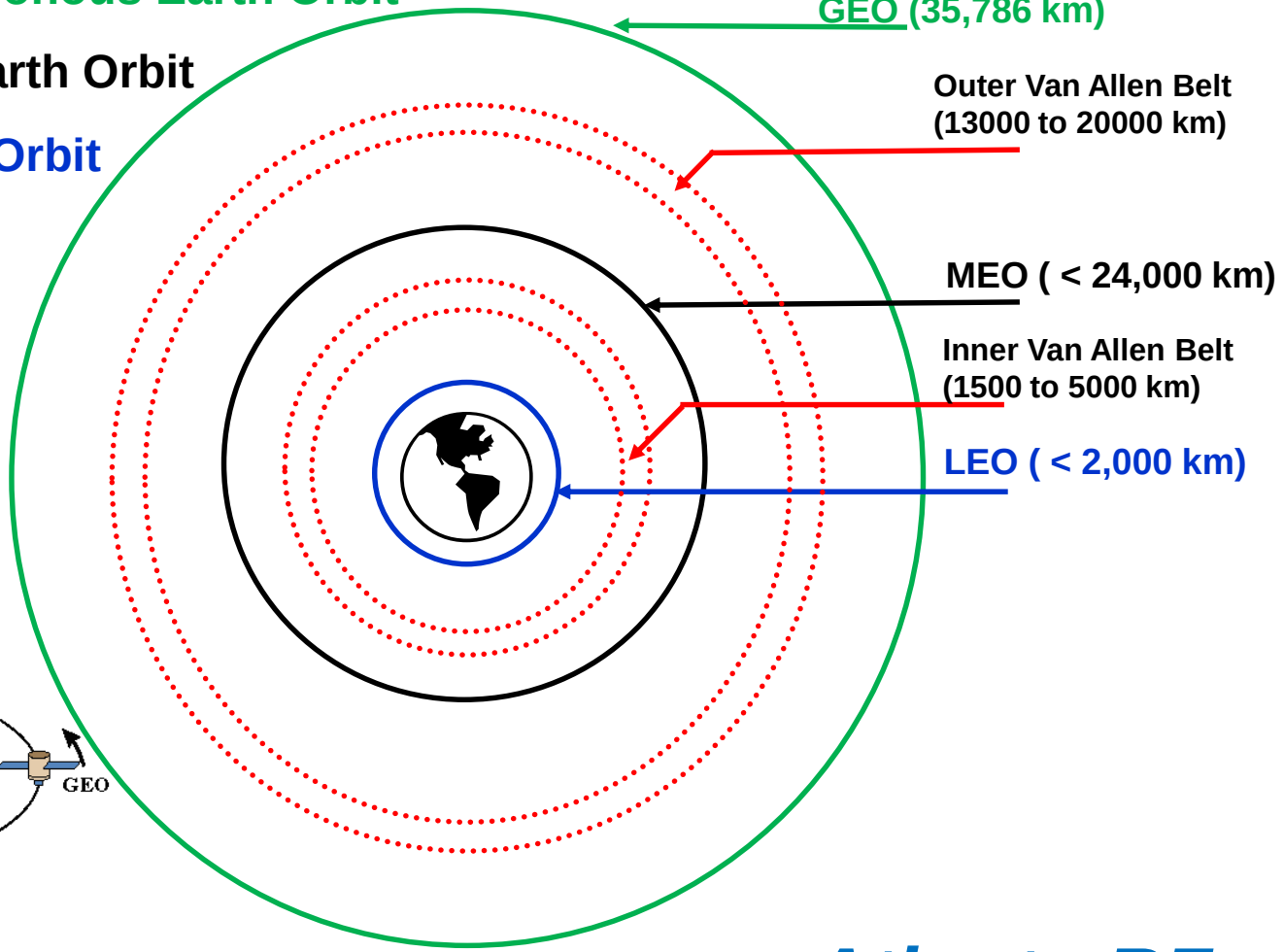
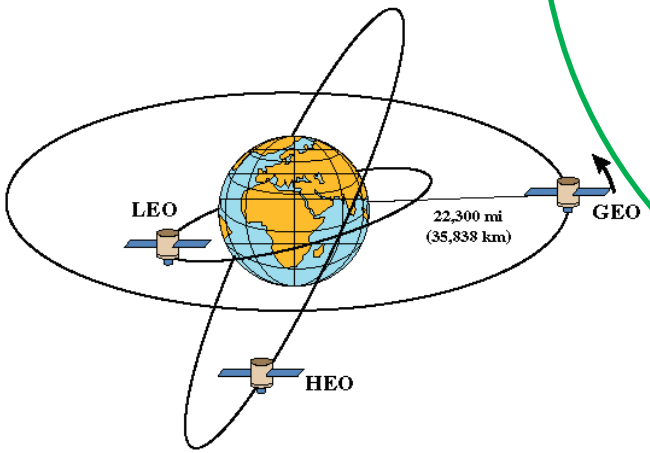
Space Segment: Satellite Orbital Locations

LEO, MEO & GEO Satellite Orbits

- **GEO: Geosynchronous Earth Orbit**
- **MEO: Medium Earth Orbit**
- **LEO: Low Earth Orbit**





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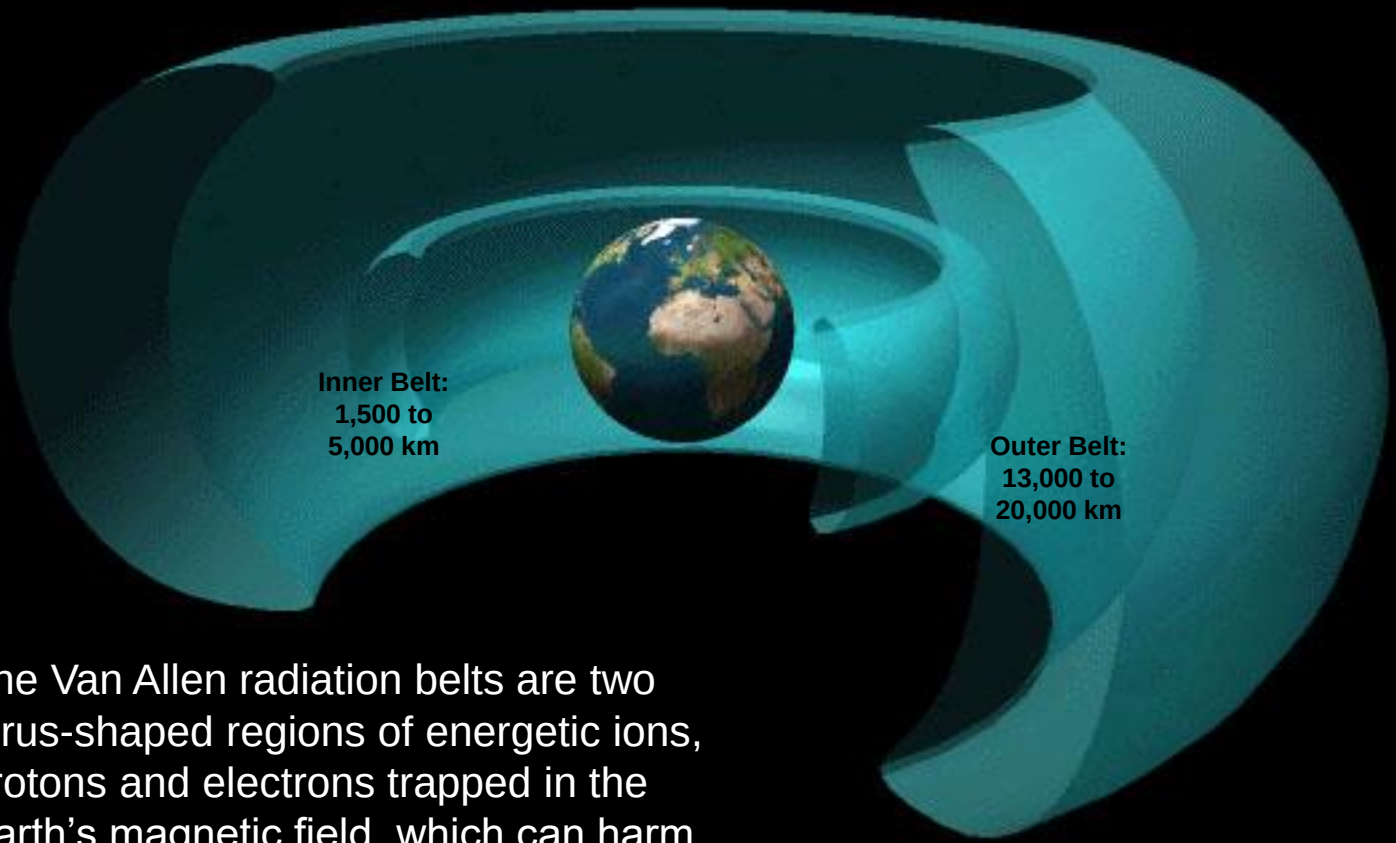
The Van Allen Radiation Belts

Van Allen Radiation Belts were discovered by James Van Allen in 1958



The Van Allen radiation belts are two torus-shaped regions of energetic ions, protons and electrons trapped in the Earth's magnetic field, which can harm electronic circuits onboard a satellite.

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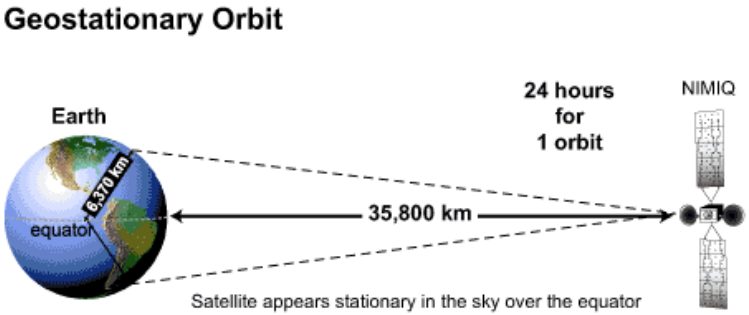
GEO Satellites

Geosynchronous Earth-Orbit Satellites



I. Features:

A. GEOs location appears 'stationary' above Earth.
B. Transmitted signal from one onboard antenna can cover 42% of Earth's surface (17° beam).
B. Onboard antenna footprint/patterns send Tx signals to specific ground service areas.
B. Able to process higher throughput data rates.
C. Uses: Global communications, broadcast TV and radio services, weather observation, military applications and more.

II. Characteristics:

A. Altitude: Located 35,786 km (22,236 miles) above the Earth's equator in a circular orbit.
B. One orbit: 23hr 56min 4sec (= Earth's rotation).
C. Orbital velocity: 11,066 km/hr (6,876 miles/hour).
D. Angular separation: ~ 2° (1,476 km ; 920 miles).
E. No variation in up/downlink propagation delay or Tx/Rx antenna's elevation 'look angle'.
F. Visible time with Earth Station: 24 hours.
G. Fix-mount Earth Station/User antenna.
H. Service life expectancy: 15 yrs or more.

III. Advantages:

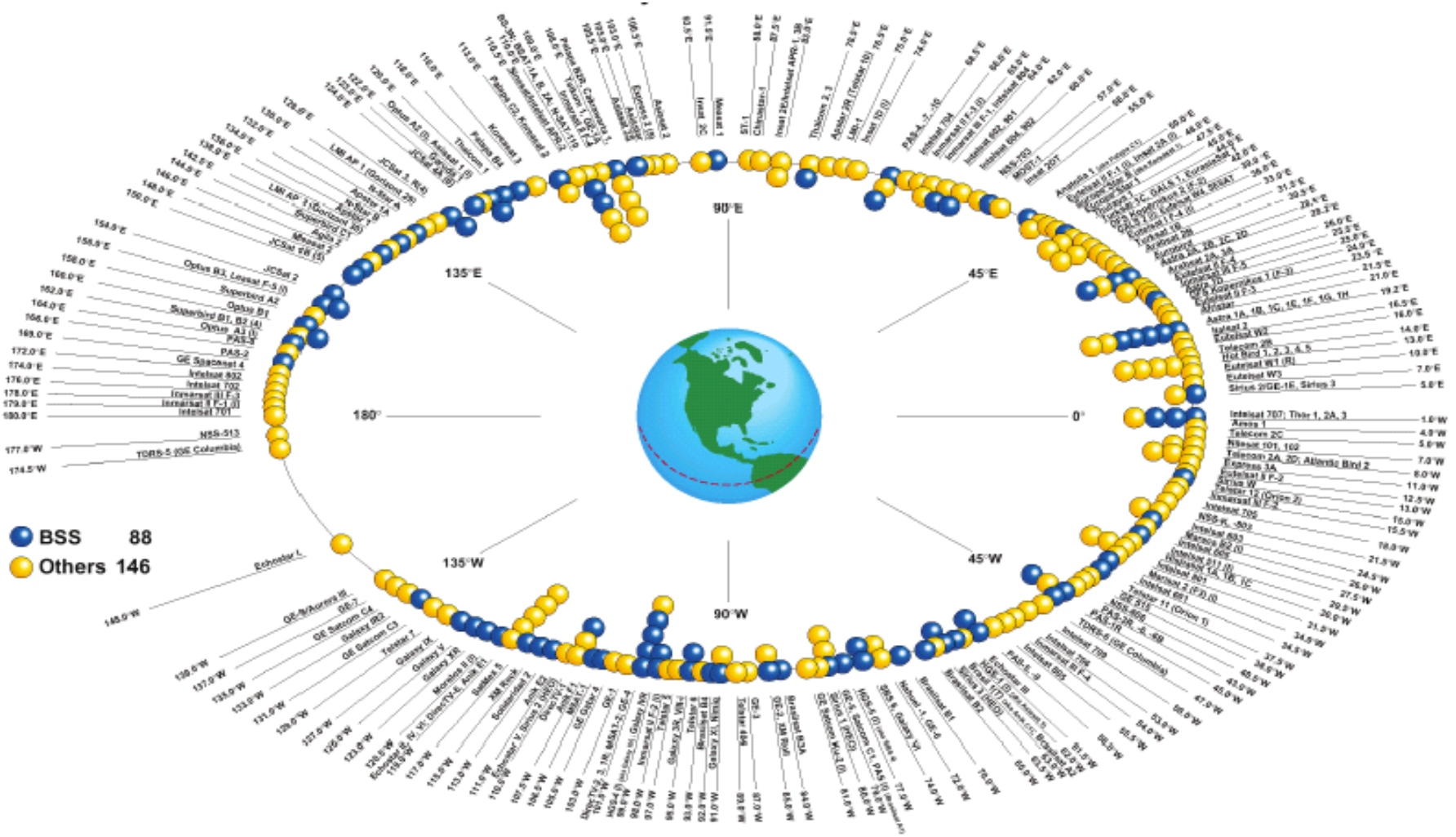
A. Earth station/User terminals do not have to track the satellite's position above the Earth: Lowers cost.
B. Only a few GEO satellites (3 to 4) needed to provide global Earth coverage of their transmitted signals..
C. Simplest orbital space configuration/locations.
D. Simple Space Control System in Earth Stations.
E. No 'handover' of uplink/downlink signals to visible satellites, as is needed for LEO & MEO satellites.

IV. Disadvantages:

A. After travelling 22,300 miles, their transmitted signals are very weak at the earth's surface.
B. Design trade-off between higher transmit signal power & larger onboard antennas for narrow beams.
C. Poor/low Rx signal levels occur above 72° latitude, at northern and southern polar regions.
D. Round-trip (up/downlink) signal delay exceeds 0.5 sec, which is challenging when used for interactive services (Voice over IP) & mobile-to-mobile communications.
E. Challenging to repair the satellite if something fails.

Commercial Communication Satellite Locations

GEO Satellites located around the 'Clarke Belt'



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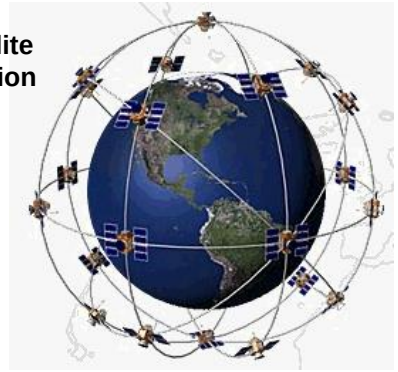
Medium Earth Orbit Satellites

Satellite Space Segment

GPS Satellite Constellation



I. Features:

A. 10 to 15 MEO satellites are needed to provide continuous global coverage 24 hours a day.
B. Onboard antennas cover a service area at/near 10,000 to 15,000 km diameter.
C. Uses: Mobile telephone communications, Global positioning systems, navigation, search & rescue missions, remote sensing, spy & optical imaging.

II. Characteristics:

A. Altitude: Located 8,000 to 24,000 km (5k to 15k miles) above the Earth's surface in circular orbit.
B. Most MEO constellations are inclined from the equator, up to polar orbit (90° inclination). Multiple inclination planes are often used.
C. One orbit: 6 to 14 hours, depending on altitude.
D. Orbital velocity: ~18,000 km/hr (11,184 miles/hr).
E. Visible time with Earth Station: 75 min to 8 hours, depending on altitude.
F. Service life expectancy: Longer then LEOs, but less then GEO satellites.

III. Advantages:

A. Fewer satellites to deploy and operate; cheaper TTC&M systems than LEO, but more expensive than GEOs.
B. Less transmission latency/delay then GEOs.
   1) Round-trip signal delay: < 250 ms.
C. Onboard antenna size & Tx power modest.
D. Improved 'look angle' to ground receivers located at higher latitudes.

IV. Disadvantages:

A. More MEO satellites to deploy & more expensive launch costs than GEO satellites, but less than LEOs.
B. Ground antennas are generally more expensive and complex because of the need to track MEO satellites.
C. Must hand-off User signals to a visible MEO satellite, which increases cost & data processing complexity.
D. Increased exposure to Van Allen Belt radiation creates degradation/hazards to onboard electronic systems.

Low Earth Orbit (LEO) Satellites

Satellite Space Segment

GlobalStar Satellite Constellation

I. Features:

A. More than 32 LEO satellites needed to provide continuous global coverage 24 hours per day.
B. Diameter of service area coverage: 8,000 km.
C. Uses: Mobile telephone & data communications, reconnaissance, search & rescue, imaging of Earth's natural resources, localized weather.

II. Characteristics:

A. Altitude: 320 to 2000 km (200 to 1,250 miles) above the Earth's surface in a circular orbit.
B. Most LEO constellations have a circular orbit, which is inclined from the equator, up to polar orbit (90° inclination). Multiple inclinations used.
C. One orbital period: 90 minutes to 3 hours.
D. Orbital velocity: ~28,080 km/hr (17,448 miles/hr).
E. Angular separation: 30° to 60°, depending on number of LEOs in each inclined plane.
F. Visible time with Earth Station: 10 to 20 minutes.

III. Advantages:

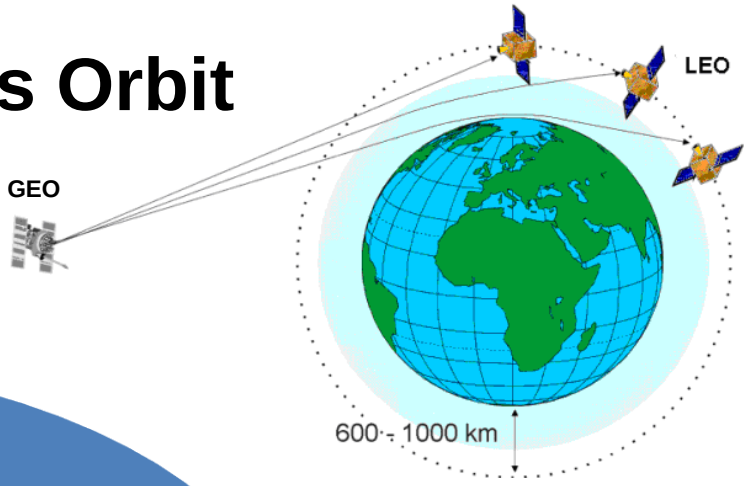
A. Higher 'look angle', especially at higher latitudes.
B. Short Round-trip signal latency/delay: < 60 msec.
C. Less free-space path loss or beam spreading.
D. Inter-satellite cross-links and on-board processing for increased performance.
E. Easier to operate to low-power/low-gain ground antenna terminals.
F. Practical to repair LEOs if something onboard fails.

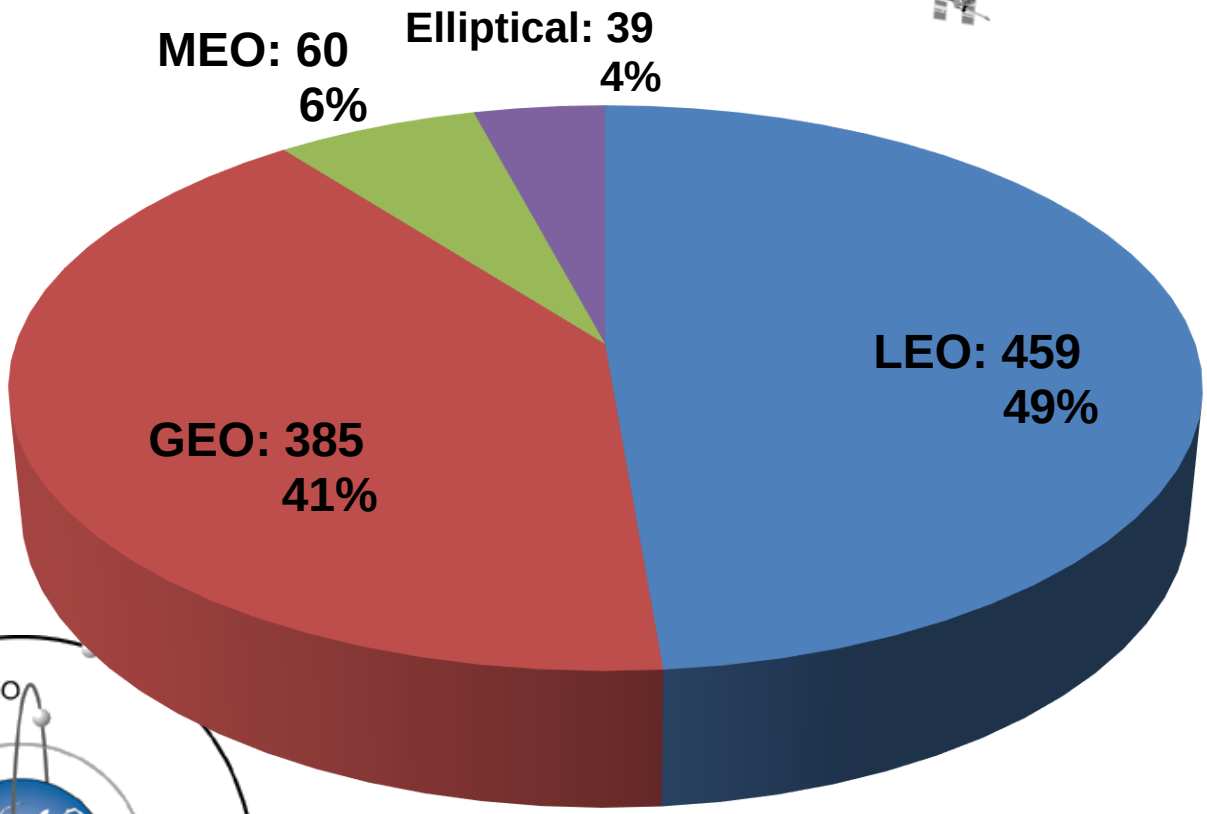
IV. Disadvantages:

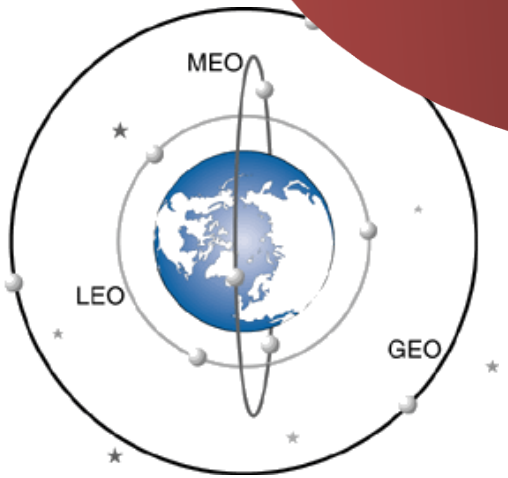
A. Tx/Rx signals cover a small service area, so a large number of LEO satellites are needed for uninterrupted connectivity & full Earth coverage.
B. Higher TTC&M operating costs to track & hand-off.
C. Higher costs to build, launch, deploy & operate a LEO satellite constellation.
D. Frequent hand-off of User signals to a visible satellite, which increases cost & data processing complexity.
E. System must cope with large Doppler shifts.
F. Shorter in-orbit lifetime due to orbital degradation.

Altitude where most Satellites Orbit

Satellite Space Segment







Source: Union of Concerned Scientists: www.ucsusa.org, July 2010

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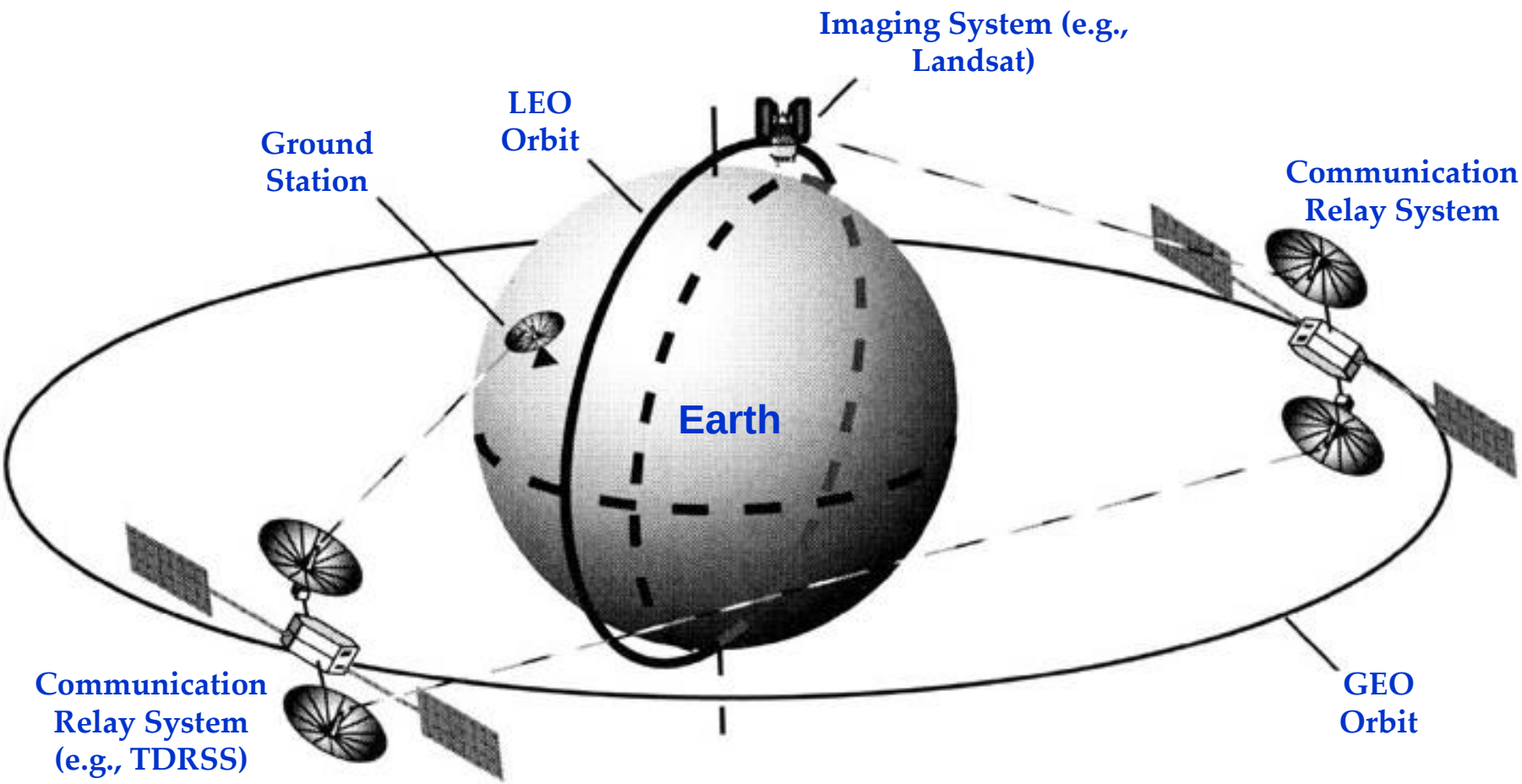
Some GEO Satellites relay signals to LEOs

Satellite Space Segment



Satellite Categories & Examples

LEO Satellites:

- GlobalStar: USA
- Gonets: Russia
- Iridium: USA
- LandSat: USA
- Orbcomm: USA
- Parus: Russia
- RapidEye: Germany
- Rodnik: Russia
- SB-WASS: USA
- SaudiaComSat
- Shijian: China
- Strela: Russia
- Yaogan: China

MEO Satellites:

- Compass: 3 Sats
  - ✓China
  - ✓Navigation
- Galileo: 2 Sats
  - ✓ ESA
  - ✓Navigation
- GLONASS: 33 Sats
  - ✓Russia
  - ✓Navigation
- GPS: 30 Sats
  - ✓U.S.A.
  - ✓Navigation

GEO Satellites:

- Astra: SES
- Compass: China
- DirecTV: USA
- DSCS III: USA
- Eutelsat: Europe
- Inmarsat: U.K.
- INTELSAT
- Optus: Australia
- Sirius/XM Radio
- TDRSS: NASA
- UFO: US Navy
- WGS: Air Force
- Many more. . . .

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Satellite Services & Applications

Communications: Voice/Video/Data

- Mobile Satellite Phones
- Broadcast and Cable Relay
- VOIP & Multi-media over IP
- News Gathering/Distribution
- Internet Trunking
- Corporate VSAT Networks
- Tele-Medicine
- Distance-Learning
- Rural Telephony
- Videoconferencing

GPS/Navigation:

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

Direct-To-Consumer:

- Direct Broadcast Television/VSAT
- Digital Audio Radio Services (DARS)
- Video & Data to handhelds
- Interactive Entertainment & Games
- Broadband IP

Remote Sensing:

- Oil/Gas Pipeline Monitoring
- Infrastructure Planning
- Forest Fire Prevention
- Urban Planning
- Flood and Storm watches
- Air Pollution Management
- Geo-spatial Services

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Satellite Services & Usage

Type of Services:

- **FSS : F**ixed **S**atellite **S**ervice to Earth Stations, like: Weather observation.
- **MSS: M**obile **S**atellite **S**ervice to vehicles, ships & aircraft.
- **BSS: B**roadcast **S**atellite **S**ervice to specific geographic areas: TV & radio
- **PSS**: **P**ersonal **S**atellite **S**ervice to handheld devices, like: Mobile telephones.

General Usages:

- **Telecommunication**
- **Radio/TV Broadcast**
- **Observe Weather**
- **Remote Sensing**
- **Navigation**
- **Military**
- **Space Sciences**
- **Earth Sciences**
- **Experimental**
- **Amateur**
- **Many more. . . . .**

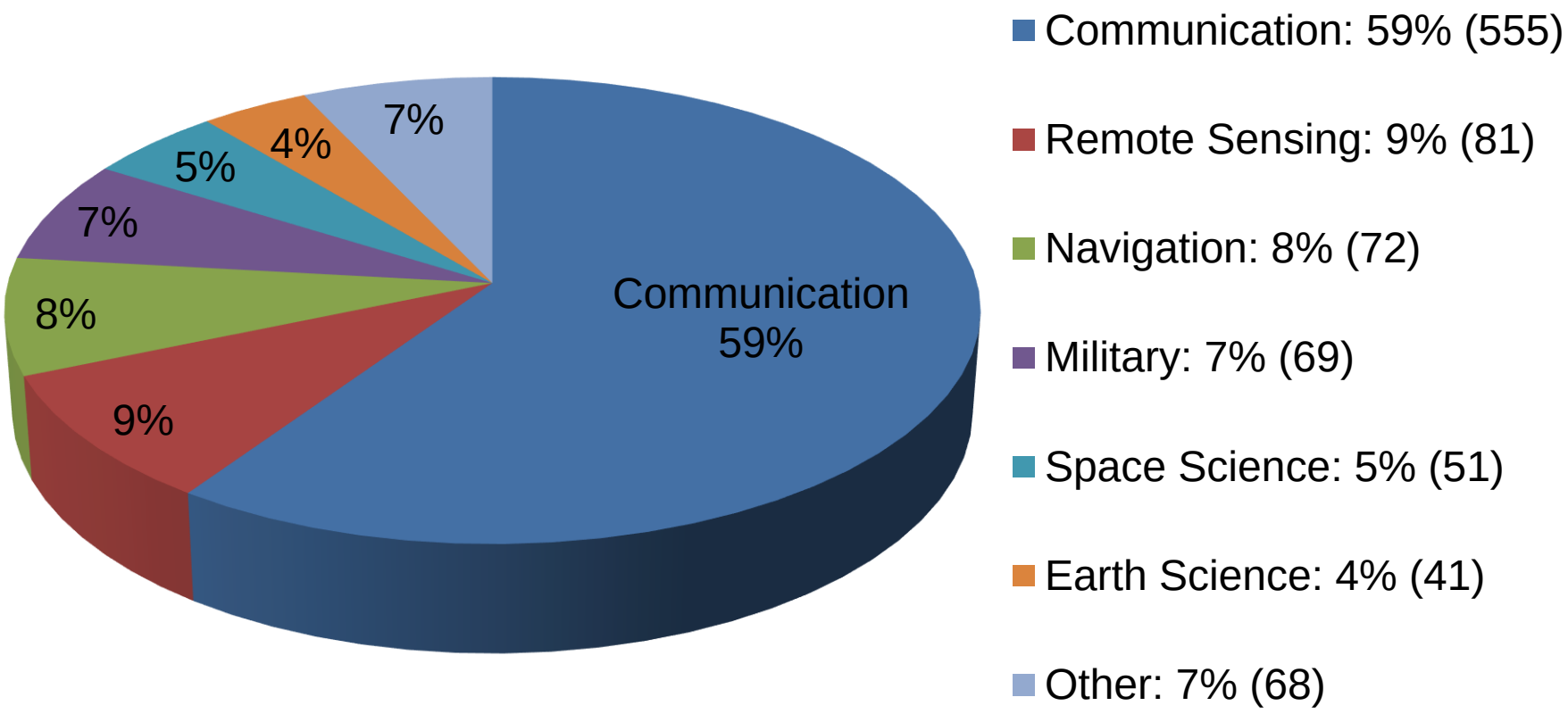
Marine

Military

Transportation

Satellite Services/Usage

Satellite Space Segment



Source: Union of Concerned Scientists: www.ucsusa.org, July 2010

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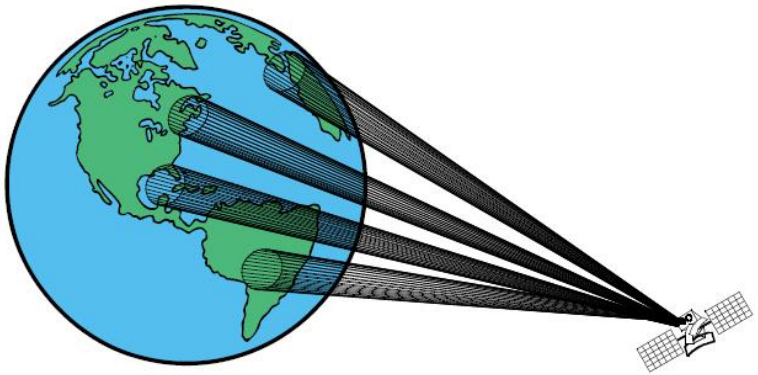
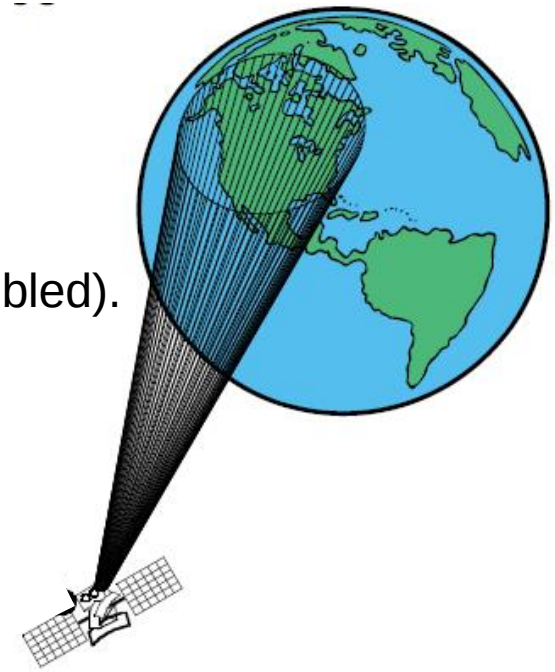
Earth Coverage Strategies for Satellites

Satellite Space Segment

1. Global Coverage: One downlink antenna beam.
    A. Simple antenna; small data capacity; transparent repeaters.
2. Spot Beams: Separated……not contiguous.
    A. Simple antennas; better data capacity; transparent repeaters.
3. Multiple Spot Beams: Separated & contiguous.
    A. Complex antennas (Beam-Forming Networks).
    B. High data capacity (frequency re-use).
    C. Comm payload has regenerative repeaters.
    D. On-Board Processing & routing capabilities.
4. Use of Dual Polarization: Overlapped beams.
    A. Increased data capacity (frequency re-use doubled).
    B. Higher interference: Uplink & downlink.





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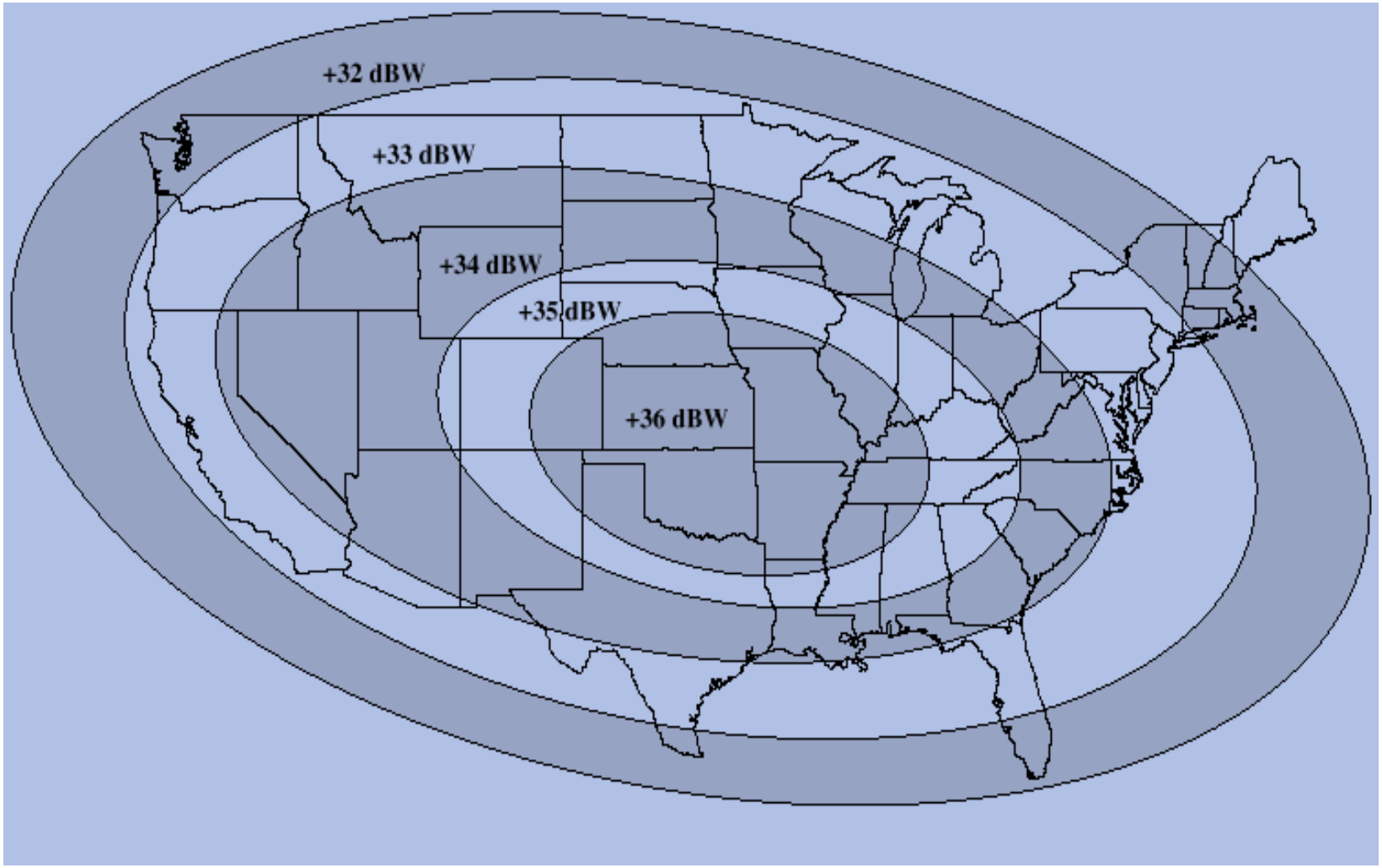
Typical GEO Satellite Downlink Footprint: CONUS

'Rings' show RF power level from satellite's transmit antenna



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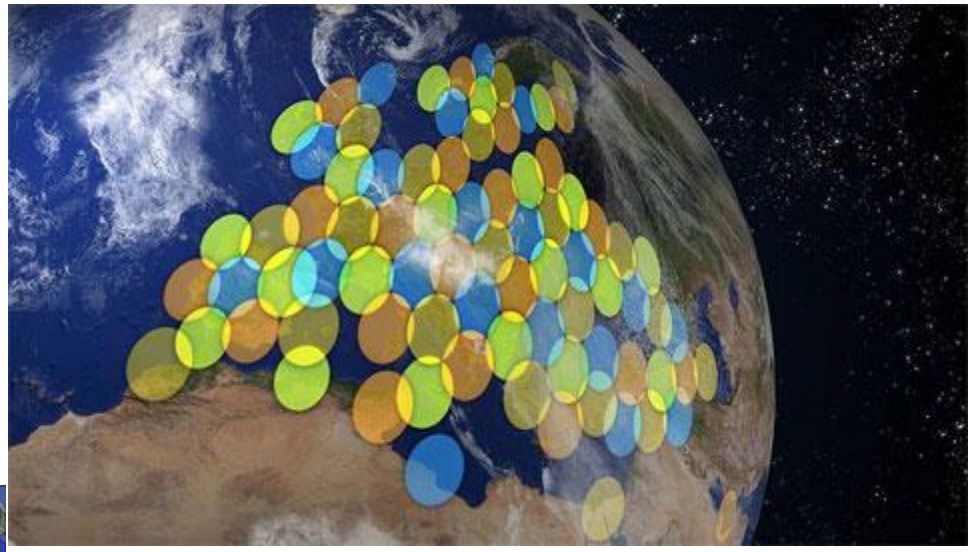
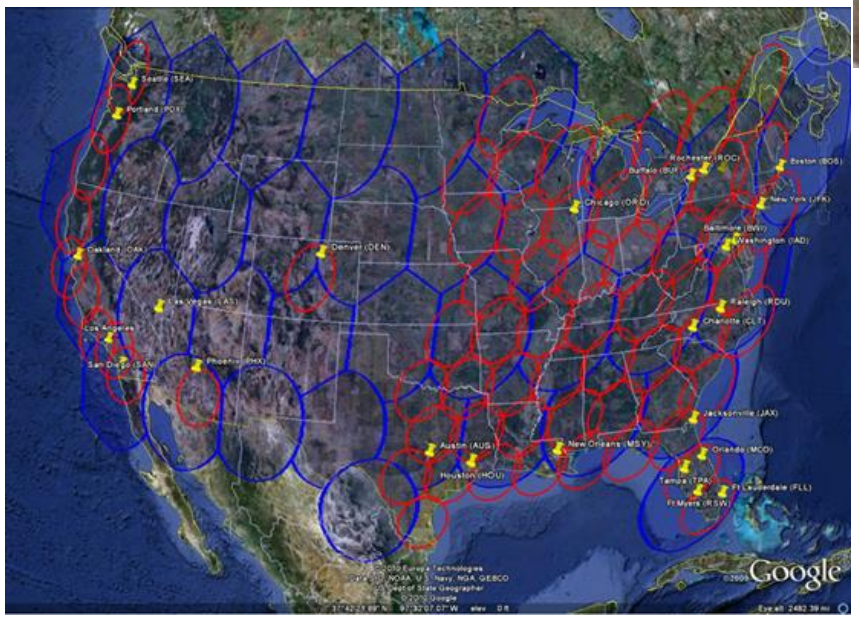
Satellite's Spot-beam Downlink Coverage

Satellite Space Segment

Spot-beam coverage
over Europe (Ka-SAT)





Spot-beam coverage
over continental USA

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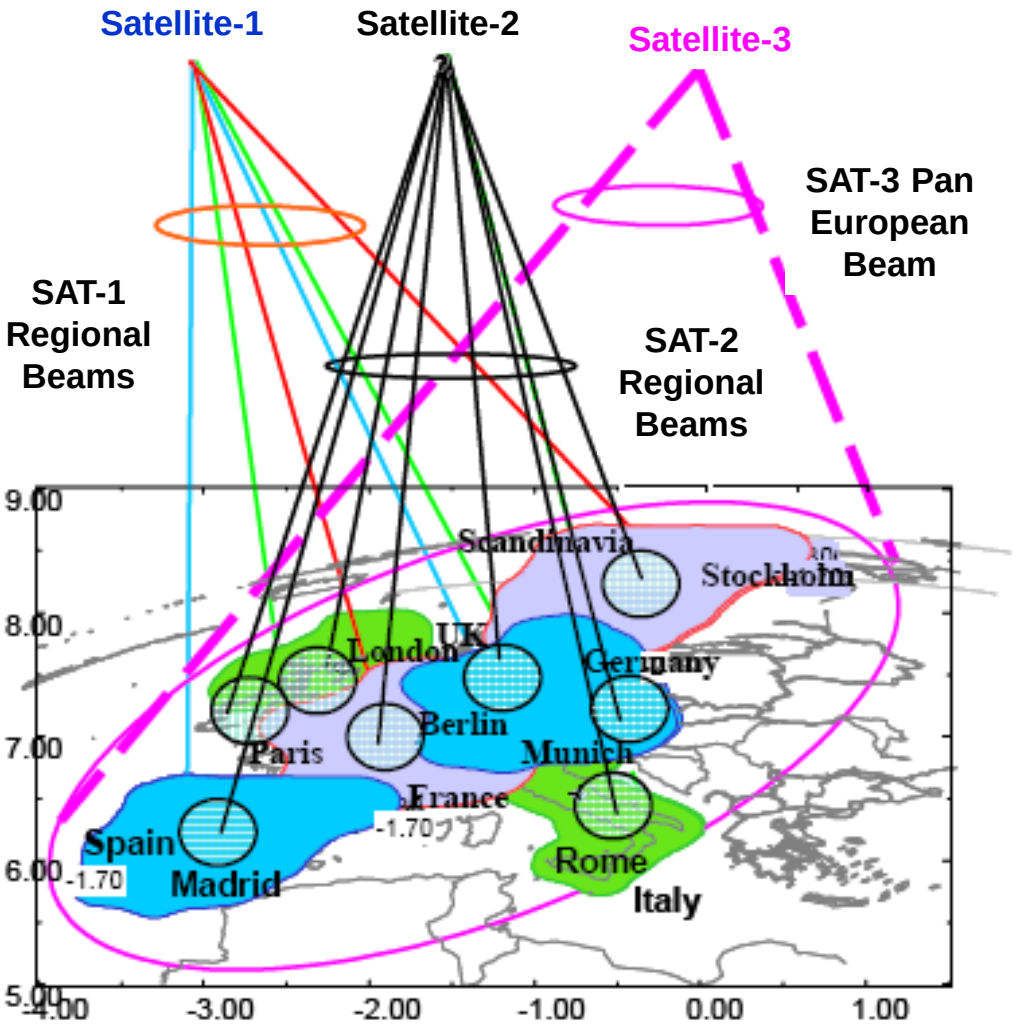
Satellite Downlink Coverage Area

Spotbeams & Amplitude-tailored Contoured Beams



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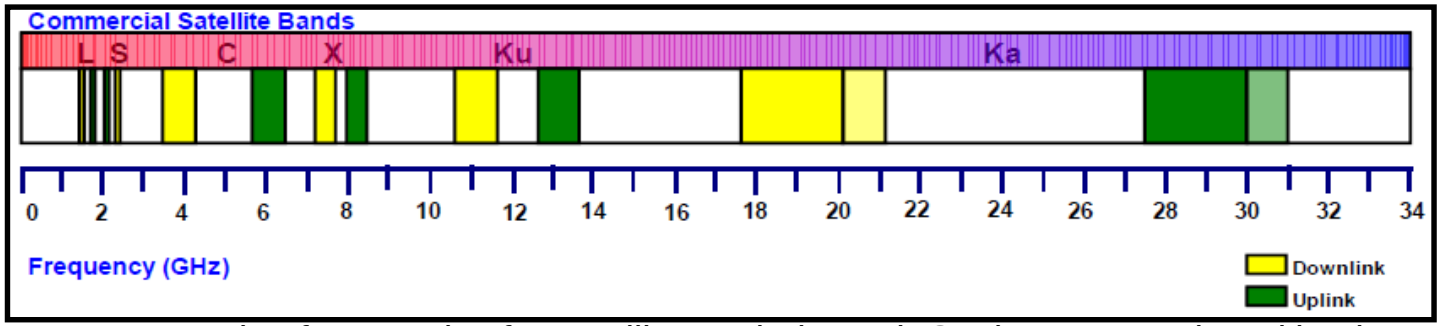
Satellite Communication Frequency Bands

Common for LEO, MEO & GEO Satellites

Most Earth Stations transmit their uplink signals to the satellite at the higher operating frequency of the communication link, while satellites transmit the lower operating frequency. Reason: Cost.

Frequency Band	Downlink Frequency	Uplink Frequency	Typical Bandwidth	Comments
L-Band	0.9 to 1.6 GHz	0.9 to 1.6 GHz	15 MHz	Shared with terrestrial
S-Band	1.610 to 1.626 GHz	2.483 to 2.5 GHz	70 MHz	Shared with ISM Band
C-Band	3.7 to 4.2 GHz	5.925 to 6.425 GHz	500 MHz	Shared with terrestrial
X-Band	7.25 to 7.75 GHz	7.9 to 8.4 GHz	500 MHz	Government/Military
Ku-Band	11.7 to 12.2 GHz	14 to 14.5 GHz	500 MHz	Attenuation due to rain
Ka-Band **- Military**	17.7 to 21.2 GHz 20.2 to 21.2 GHz	27.5 to 31 GHz 30 to 31 GHz	3,500 MHz 1,000 MHz	High equipment cost; Attenuation due to rain



Most operating frequencies for satellites & their Earth Stations are assigned by the International Telecommunication Union (www.itu.int), who coordinates with many other domestic & overseas communication agencies.

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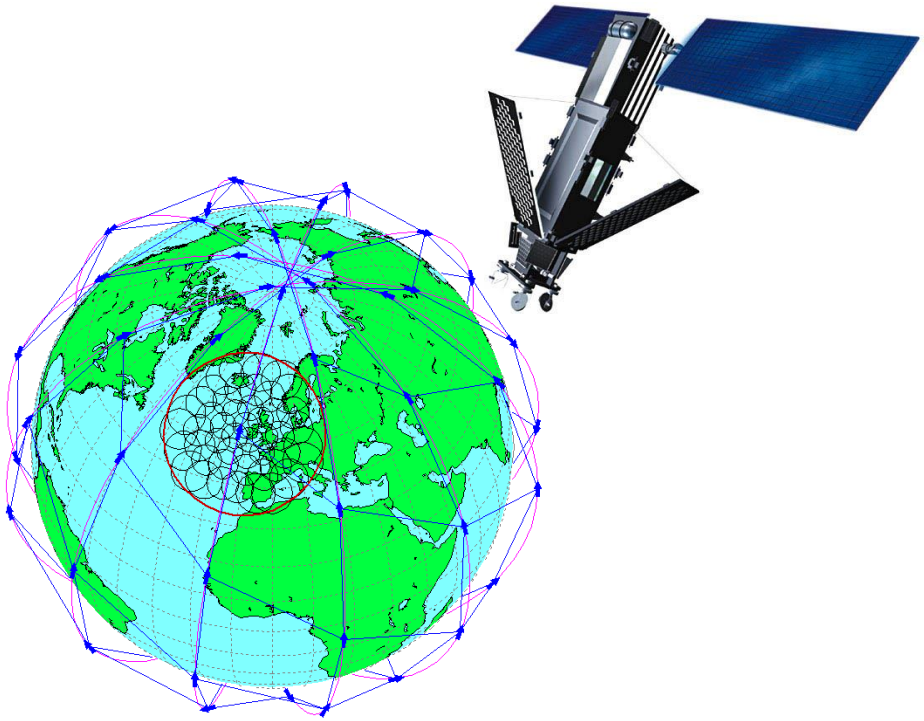
Iridium Satellites

LEO Satellite Constellation



www.Iridium.com

I. Features:

1. Use: Satellite telephone & low-speed data communications: Voice, data & messaging.
2. Industry: Mining, offshore drilling rigs, CNN, aviation, maritime, entertainment, etc.
3. Mobile User Antenna: Three L-band phased-array antennas with 16 spot beams: 4,500 km footprint.
4. 48 spot beams/satellite at 400 km diameter each.
5. Two Inter-satellite & two Intra-satellite Ka-band cross-links; 7 onboard signal processors.
6. Iridium constellation operational since 1998.

II. Characteristics:

1. Constellation: 66 satellites + 10 spare satellites.
2. Orbits: 6 inclined planes at 86.4° from equator, 11 satellites per plane. Full earth coverage.
3. Altitude: ~ 780 km (485 miles): LEO orbit.
4. Orbital period: ~100 minutes (26,800 km/hr).
5. Visible time with User terminal: 7 to 11 minutes.
6. Satellite Link Frequencies:
   a. Mobile User Up/Down: 1,616 to 1,626.5 MHz.
   b. Gateway Uplink : 27.5 to 30.0 GHz.
   c. Gateway Downlink: 18.8 to 20.2 GHz.
   d. Inter-Satellite cross-links: 22.55 to 23.55 GHz.

III. Advantages:

1. Full duplex voice channels at 4.8 Kbps and half-duplex data channels at 2.4 Kbps.
2. Signal capacity allocation: FDMA Uplink and TDMA downlink.
3. 80 channels /beam; 230 duplex conversations.
4. 3168 beams globally (2150 active beams).
5. Signal latency: < 60 msec, round-trip.

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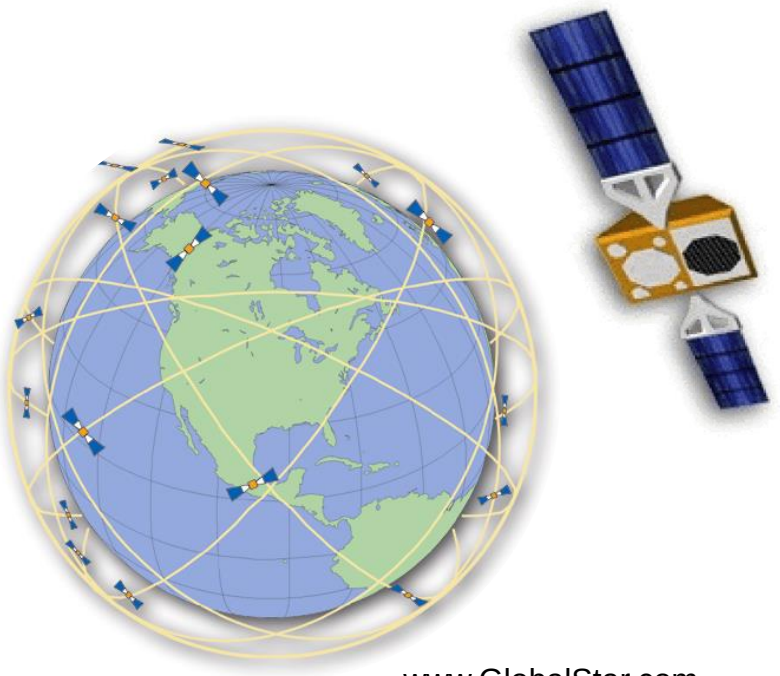
Globalstar Satellites

LEO Satellite Constellation



www.GlobalStar.com

I. Features:

1. Use: Satellite telephone & low-speed data communications: Voice, data, messaging.
2. Simple transparent 'bent-pipe' repeater onboard.
3. Mobile User Antenna: One 16-beam L-band phased-array antenna on each satellite.
2. No intersatellite link: Ground gateways provide connectivity from satellites to PSTN & Internet.
4. Globalstar operational since February 2000.

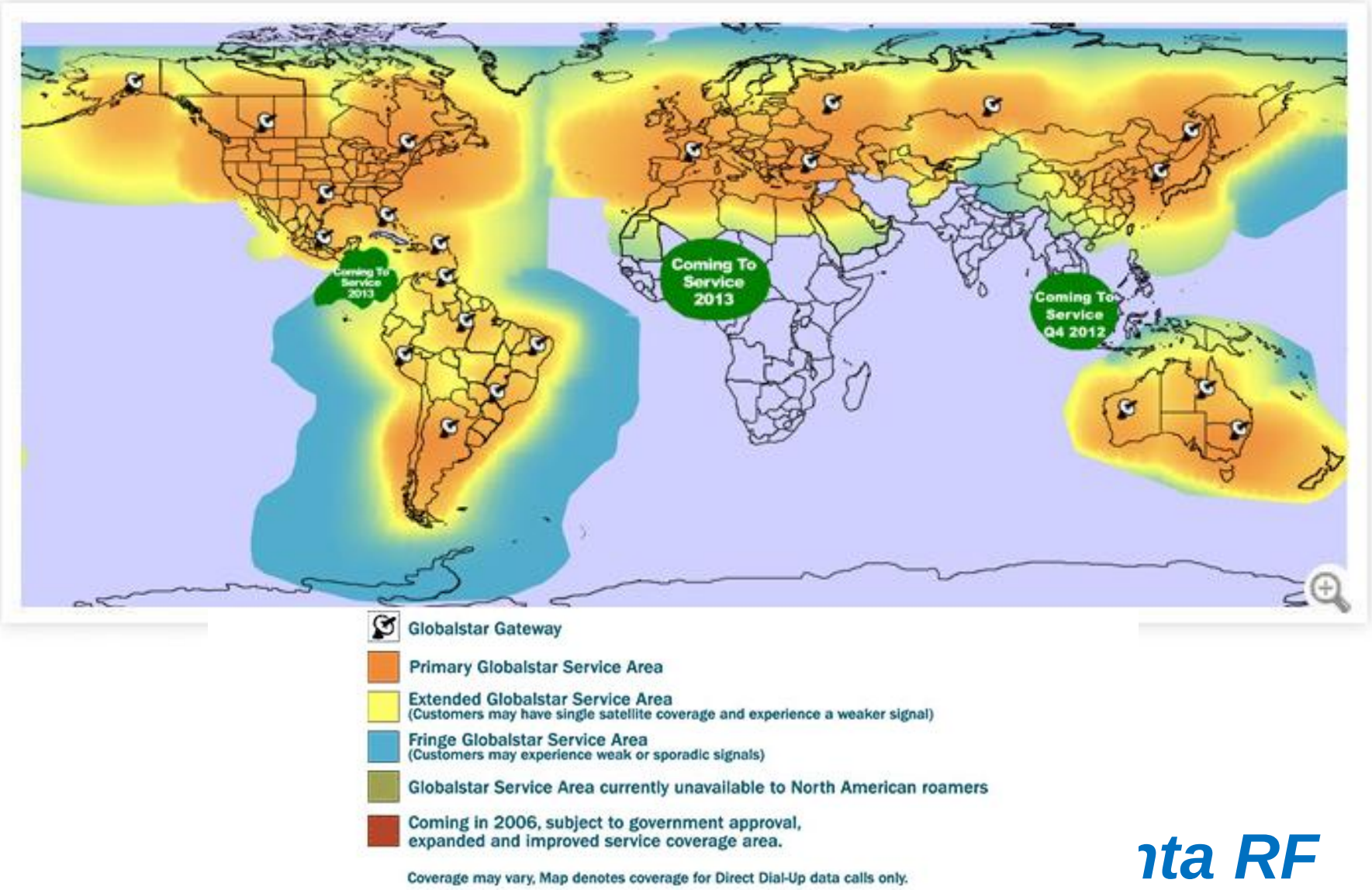
II. Characteristics:

1. Constellation: 48 satellites + 4 spare satellites.
2. Orbits: 8 inclined planes at 52° from equator, 6 satellites per plane. No polar coverage.
3. Altitude: ~ 1,410 km (876 miles): LEO orbit.
4. Orbital period: ~ 1.9 hours.
5. Visible time with User terminal: ~ 16 min.
6. Satellite Link Frequencies:
   a. Mobile User Uplink: 1,616 to 1,626.5 MHz.
   b. Mobile User Down : 2,484 to 2,500 MHz.
   c. Gateway Uplink : 5.025 to 5.225 GHz.
   d. Gateway Downlink: 6.875 to 7.075 GHz.
   e. Inter-Satellite cross-links: None.

III. Advantages:

1. Global roaming coverage.
2. One phone for both cellular & satellite calls.
3. Short message service (SMS).
4. Signal latency: < 60 ms.
5. Signal Capacity Allocation: CDMA.
6. Digital voice & data services up to 9.6 kbps.

Globalstar's Downlink Coverage Map



GPS: MEO Satellite Constellation

Navigation Satellite Timing & Ranging (NAVSTAR) Global Positioning System

I. Features:

1. Use: Land, sea & air navigation, tracking & timing.
2. Industry: Mapping, survey, shipping, military, etc.
3. Provides: Location, velocity & direction of travel.
3. Operating Modes: Standard Positioning System.
   Precise Positioning System.
5. First launch: 1978 ; Operational since 1994.
6. Owned & operated by United States Government.

www.gps.gov

II. Characteristics:

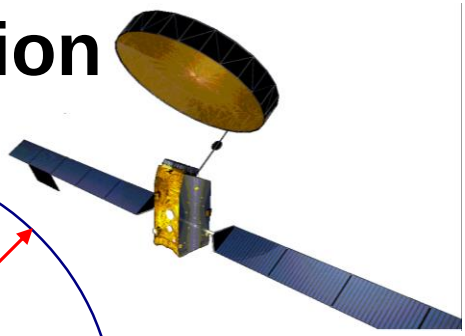
1. Constellation: 24 satellites + 3 spare satellites.
2. Orbits: 6 inclined planes at 55° from equator,
   4 to 5 satellites per plane. Full earth coverage.
3. Altitude: ~ 20,200 km (12,550 miles): MEO orbit.
4. Orbital period: 11 hours 58 minutes (~8,600 m/hr).
5. Satellite Link Frequencies:
   a. User Downlink: 1,575.42 MHz (L1 for SPS).
   1,227.61 MHz (L2 for PPS).
   1,176.45 MHz (L5 for Military).
   b. Code modulation: Coarse Acquisition (C/A).
   Precision Code (P-code).
   Military codes (M-code).

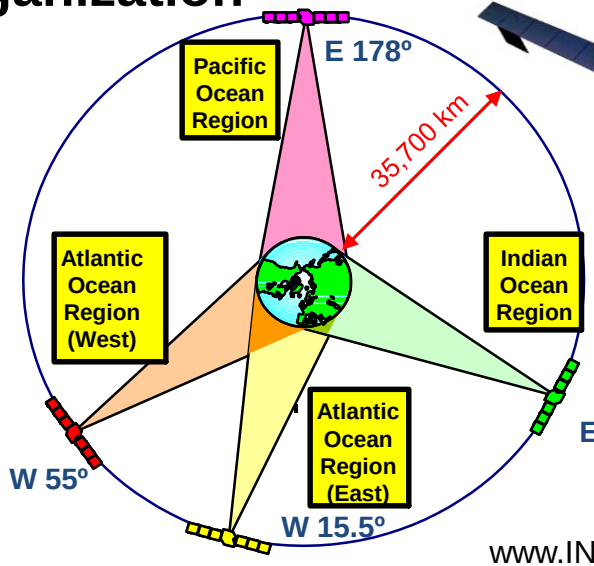
III. Advantages:

1. Global coverage; Mobility.
2. Reliable: Weather independent.
3. Free 24-hour day or night use.
4. Highly accurate time & velocity.

INMARSAT: GEO Satellite Constellation

International Marine Satellite Organization





www.INMARSAT.com

I. Features:

1. Use: Voice & data for mobile land, maritime & aeronautical communications & navigation.
2. Industry: Shipping, airlines, disaster management, land transport, oil & gas, telephone, FAX, etc…
3. Coverage: One global beam, 19 regional beams & 200 narrow spotbeams for BGAN.
4. Onboard transparent 'bent pipe' transponders.
5. INMARSAT operational since 1982.

II. Characteristics:

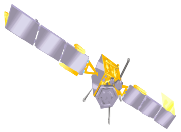
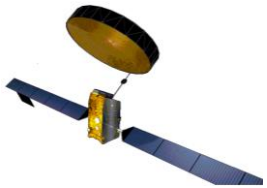
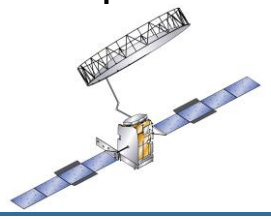
1. Constellation: 4 satellites + 5 spare satellites.
2. Orbit: Geosynchronous (= Earth's orbital period).
3. Altitude: 35,786 km (22,236 miles): GEO orbit.
4. Orbital period: 23 hrs 56 min 4sec.
5. Visibility time with User terminal: 24 hours.
6. Satellite Link Frequencies: Thru Inmarsat-4
   a. Mobile User Uplink: 1,626.5 to 1,660.5 MHz.
   b. Mobile User Down : 1,525 to 1559 MHz.
   c. Gateway Uplink : 6,424 to 6,575 MHz.
   d. Gateway Downlink: 3,550 to 3,700 MHz.
   e. Inter-Satellite cross-links: None.

III. Advantages:

1. Mobility & reliability.
2. 400 simultaneous phone calls and several thousand messages.
3. Interoperability across multinational coalition forces.
4. Compatible with key encryption devices.
5. Expanding to Ka-band with Inmarsat-5 (2014?).

INMARSAT's L-band GEO Space Segment

Satellite Space Segment

	Inmarsat-2	Inmarsat-3	Inmarsat-4	Alphasat
				
No. Satellites	4	5	3	1 + 2 options
Earth Coverage	1 Global Beam	7 Wide Spots 1 Global Beam	≈200 Narrow Spots 19 Wide Spots 1 Global Beam	~400 Narrow Spots, 19 Wide Spots & 1 Global Beam
Mobile Link EIRP	39 dBW	49 dBW	67 dBW	70 dBW
Signal Channels	4 channels (4.5 to 7.3 MHz)	46 channels (0.9 to 2.2 MHz)	588 channels (200 kHz)	750 channels (200 kHz)
S/C Dry Mass	700 kg	1000 kg	3310 kg	3520 kg
Solar Array Span	14.5m	20.7m	45m	40m
Voice (4.8kbps)	250 (Inm B)	1000 (mini M)	16000 (BGAN)	32000 (BGAN)
GAN (64 kbps)	N/A	200	2250	3750
BGAN	N/A	N/A	~500 x 400 kbps	~750 x 500 kbps

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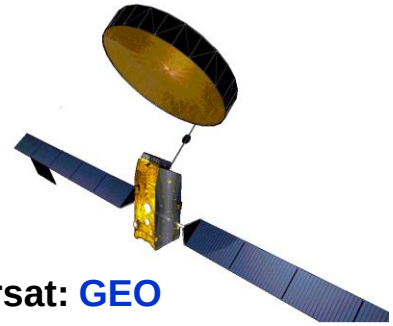
Comparison: LEO, MEO & GEO Satellites

Satellite Space Segment

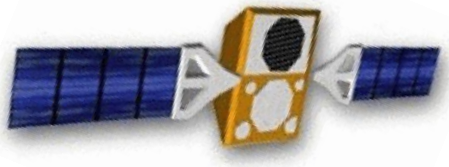
Parameter	LEO Satellites	MEO Satellites	GEO Satellites
1. # Satellites Needed	Large	Moderate	Small
2. Satellite Life	3 to 7 yrs	10 to 15 yrs	15^{+} yrs
3. Hand-held Terminal	Possible	Possible	Difficult
4. Transmission Delay	Short	Medium	Long
5. Propagation Loss	Low	Medium	High
6. Network Complexity	Complex	Medium	Simple
7. Signal Hand-off	Frequent	Medium	None
8. Visibility of a Satellite	Short	Medium	Mostly Always
9. Broadcast Capability	Poor	Poor	Good

Iridium: LEO

GPS: MEO



Inmarsat: GEO



GlobalStar: LEO

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Atlanta RF LLC was founded to provide engineering solutions, design software solutions, and product development solutions to the high-frequency RF/microwave industry in the areas of: Telecommunications (ground segment), Satellite (space segment) and military/defense (RF front-ends).

Through teamwork, Atlanta RF applies our diverse technical experience to your project's challenges with creative and innovative solutions while holding ourselves accountable fo the results. With professionalism and commitment to our clients, Atlanta RF will be there for you, both today and tomorrow.

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- Atlanta RF ***Services*** : **Services@AtlantaRF.com**
- Atlanta RF ***Software*** : **Sales@AtlantaRF.com**
- Atlanta RF ***Designs*** : **Designs@AtlantaRF.com**

Or, contact Atlanta RF by phone at: 678-445-5544, to reach our Atlanta-area office in Georgia, USA, and discuss our support to your current or future projects & products.

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5. Link Budget: Digital Modulation Part 2 (M-FSK).
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