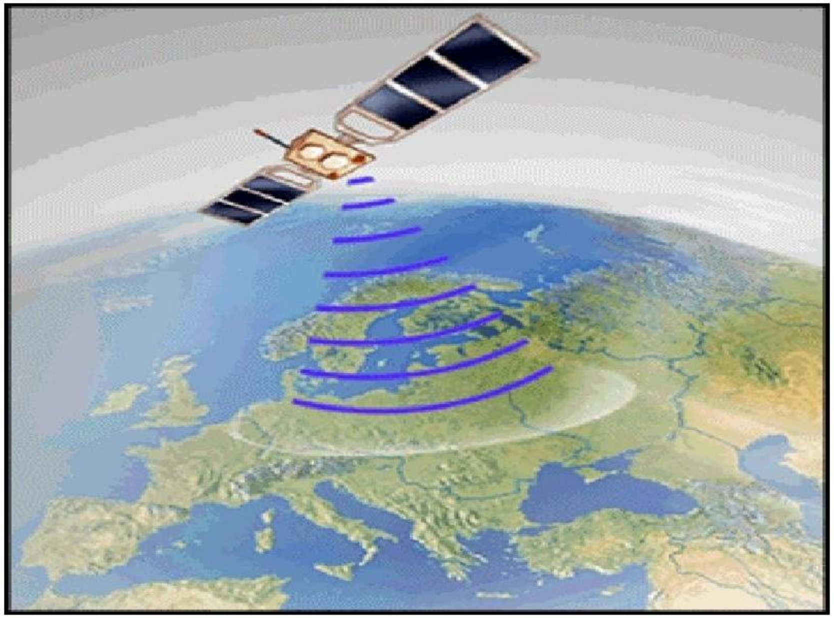
Mobile Communications
Chapter 5: Satellite Systems



- **support mobile communications**
- **global coverage without wiring costs for base stations**
- **implementation of varying population densities**

Satellites

History of satellite communication

1945	Arthur C. Clarke publishes an essay about “Extra Terrestrial Relays“ Satellite communication began after Second World War. Scientists knew that is was possible to build rockets that could carry radio transmitters into space.
1957	first satellite SPUTNIK The satellite was launched by the Soviet Union and the event chocked the Western world.
1965	first commercial geostationary satellite Satellite “Early Bird“ (INTELSAT I): It weighed 68 kg and offered 240 duplex telephone channels or 1 TV channel, 1.5 years lifetime.
1982	first mobile satellite telephone system INMARSAT-A
1998	global satellite systems for small mobile phones

Today more than 250 geostationary satellites orbit the earth!!

Applications

- Traditionally
  - weather satellites, delivering infrared or visible light pictures
  - radio and TV broadcast satellites
  - military satellites
  - satellites for navigation and localization (e.g., GPS)

- Telecommunication
  - global telephone connections
  - backbone for global networks

  replaced by fiber optics

  - connections for communication in remote places or underdeveloped areas
  - global mobile communication

➔ satellite systems to extend cellular phone systems (e.g., GSM)

Basics

Satellites in circular orbits

- attractive force $F_g = m\, g\, (R/r)^2$
- centrifugal force $F_c = m\, v^2/r$

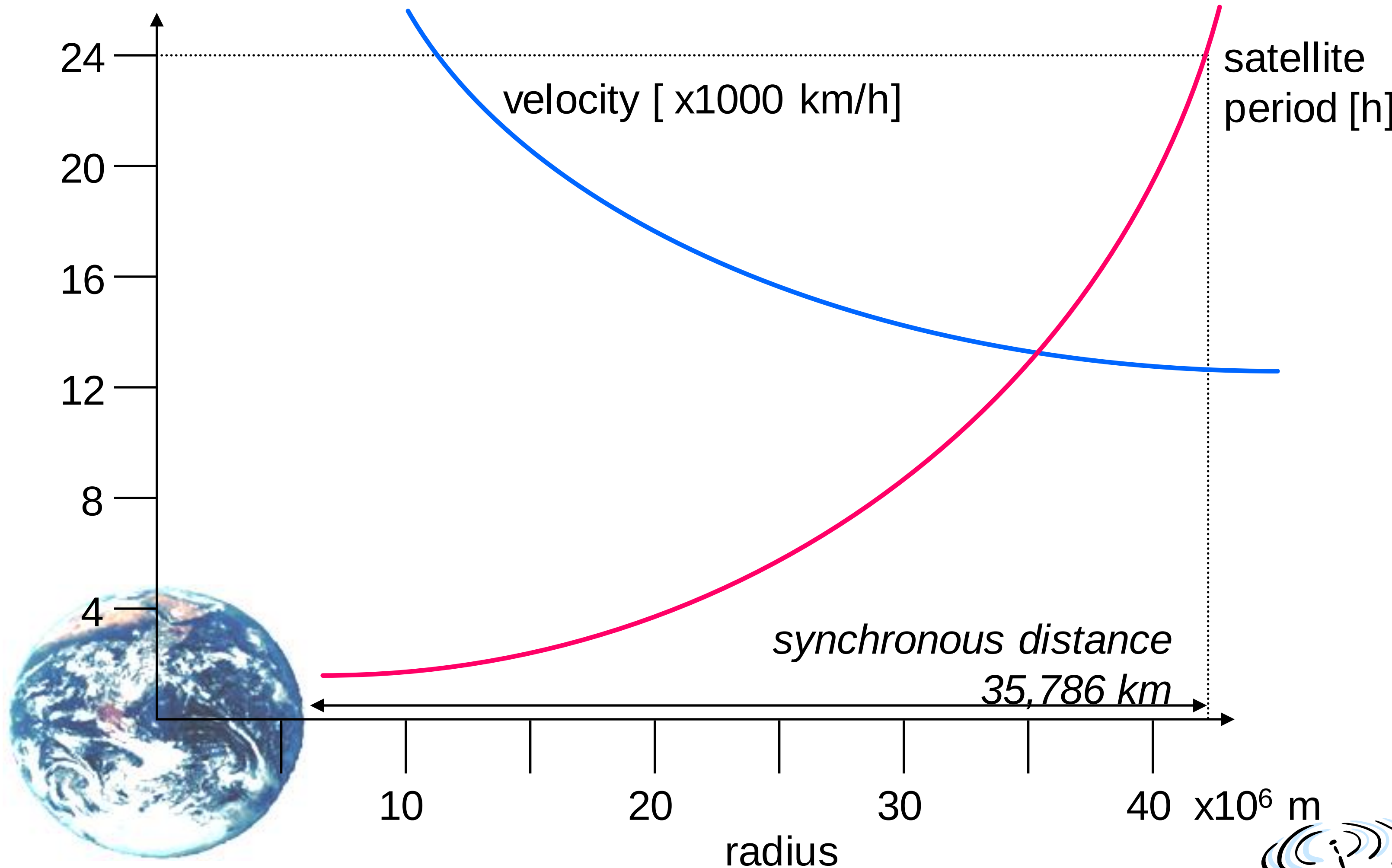
- m: mass of the satellite
- R: radius of the earth (R = 6370 km)
- r: distance to the center of the earth
- g: acceleration of gravity (g = 9.81 m/s²)
- v: satellite speed

Stable orbit

- $F_g = F_c$

$$mgR^2/r^2 = mv^2/r \qquad r = g\, R^2/v^2$$

Satellite period and orbits



Basics

- elliptical or circular orbits

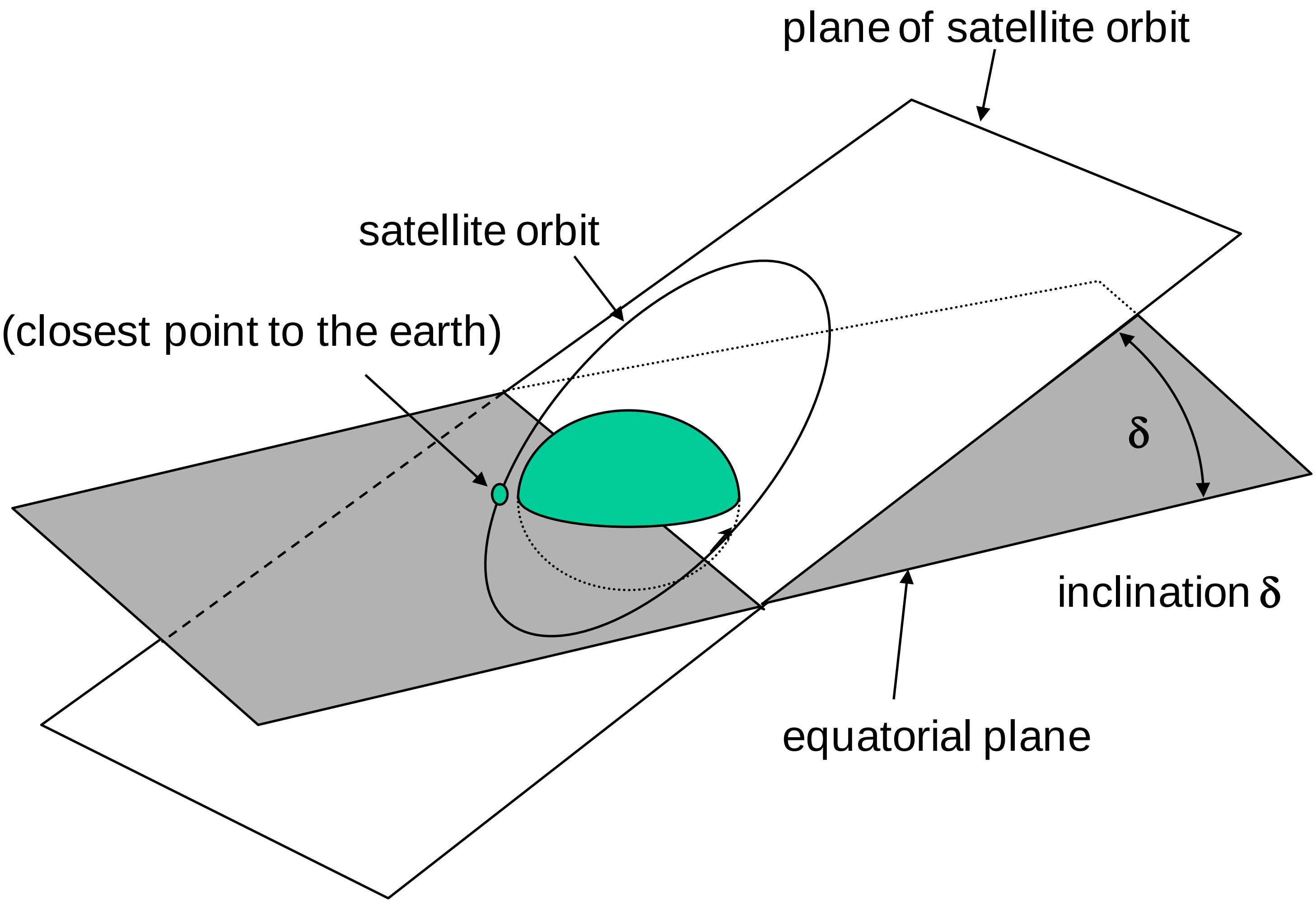
- complete rotation time depends on distance satellite-earth

- LOS (Line of Sight) to the satellite necessary for connection
  - ➔ high elevation needed, less absorption due to e.g. buildings

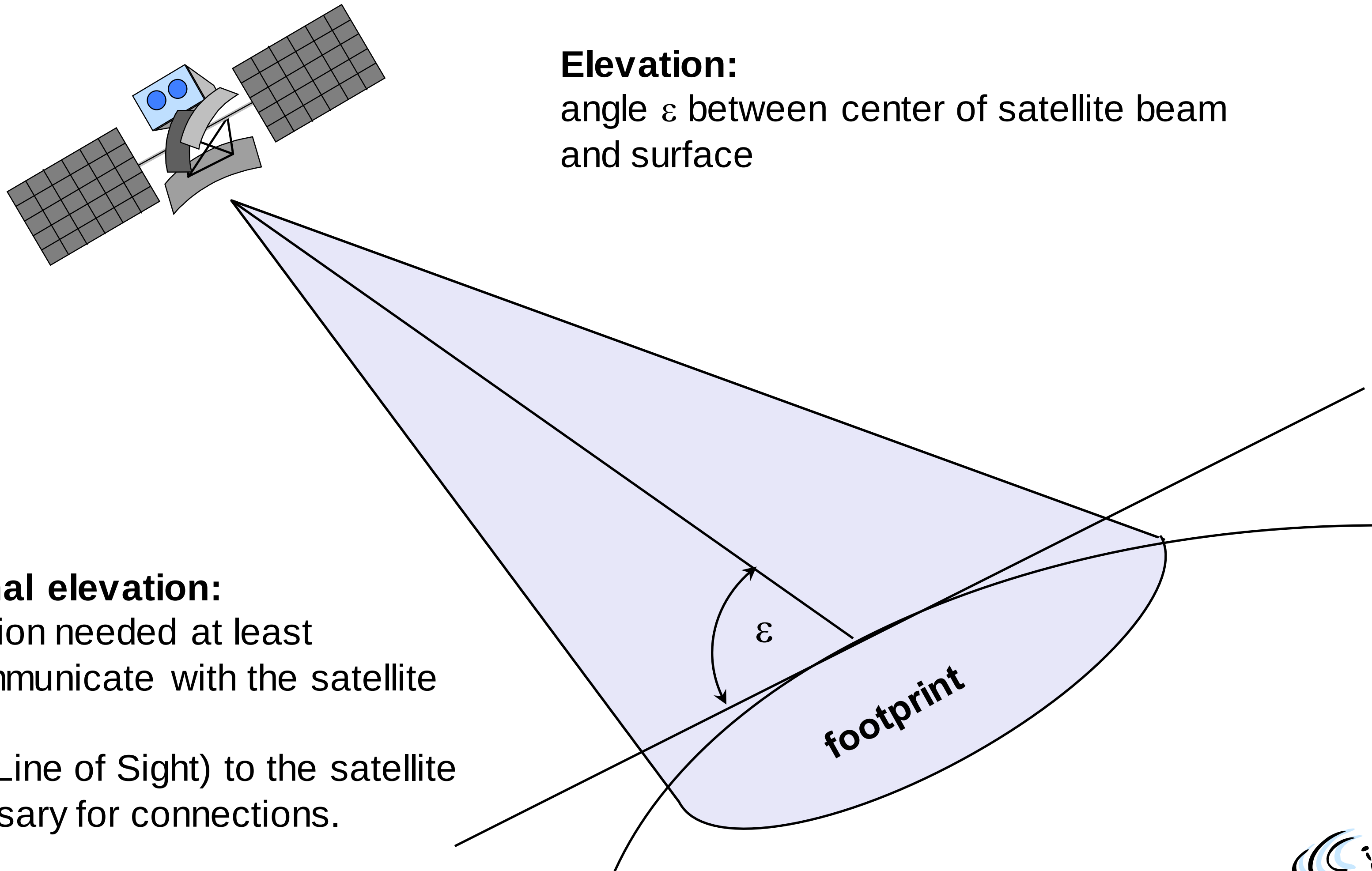
- Uplink: connection base station - satellite
- Downlink: connection satellite - base station

- typically separated frequencies for uplink and downlink

Inclination



Elevation

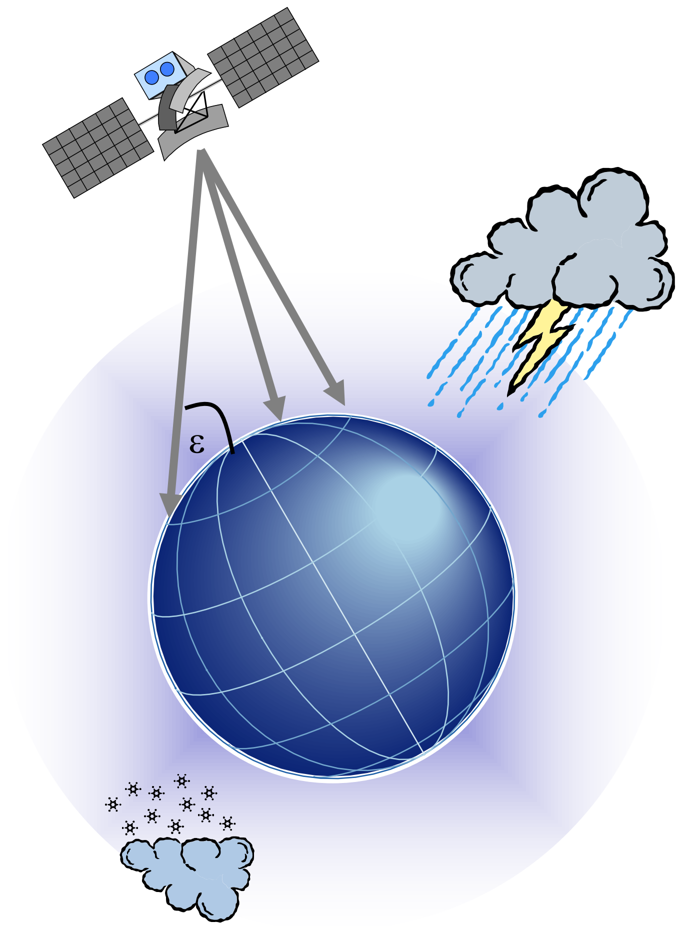


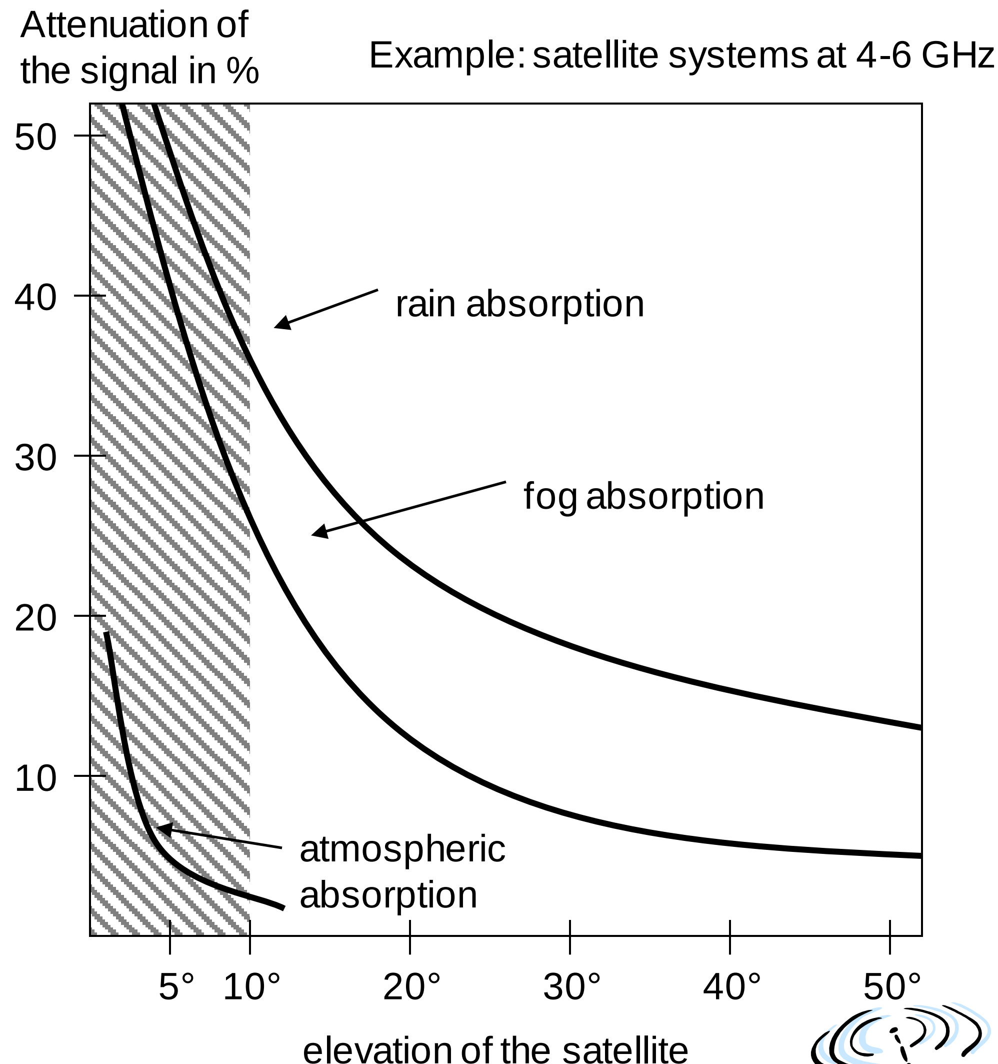
Elevation:
angle ε between center of satellite beam and surface

minimal elevation:
elevation needed at least to communicate with the satellite

LOS (Line of Sight) to the satellite necessary for connections.

Atmospheric attenuation



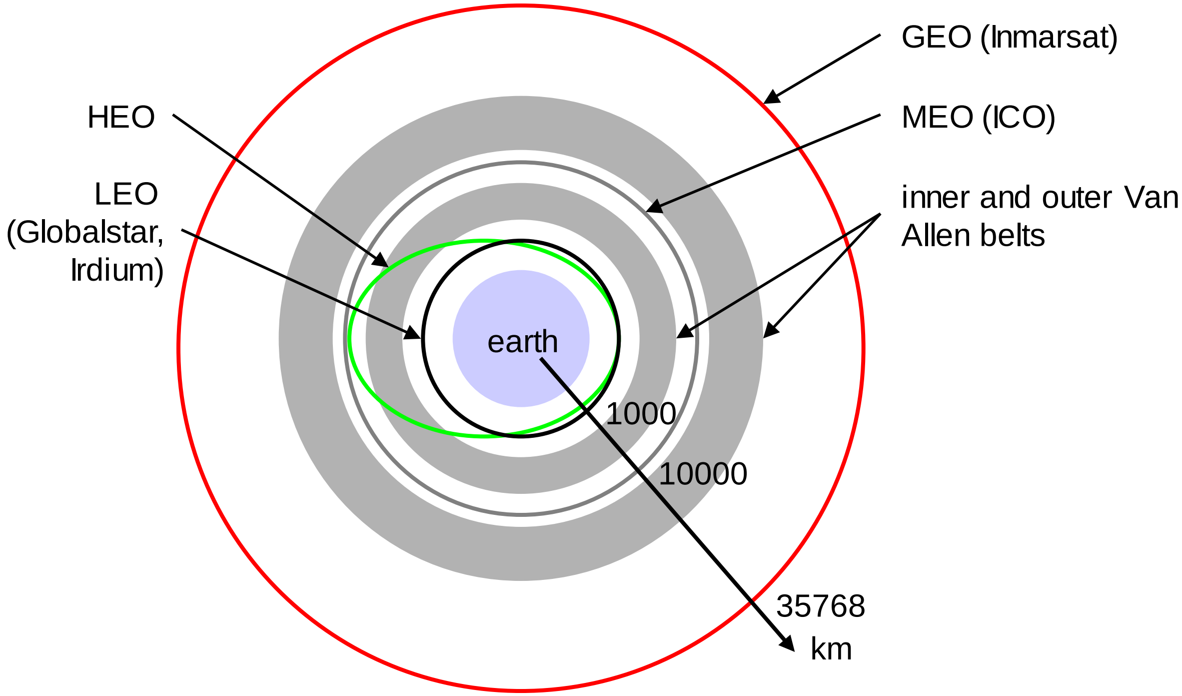


Orbits I

Four different types of satellite orbits:

- GEO: geostationary orbit,
  ca. 36000 km above earth surface
- LEO (Low Earth Orbit):
  ca. 500 - 1500 km
- MEO (Medium Earth Orbit) or
  ICO (Intermediate Circular Orbit):
  ca. 6000 - 20000 km
- HEO (Highly Elliptical Orbit) elliptical orbits

Orbits II



Van-Allen-Belts:
ionized particles
2000 - 6000 km and
15000 - 30000 km
above earth surface

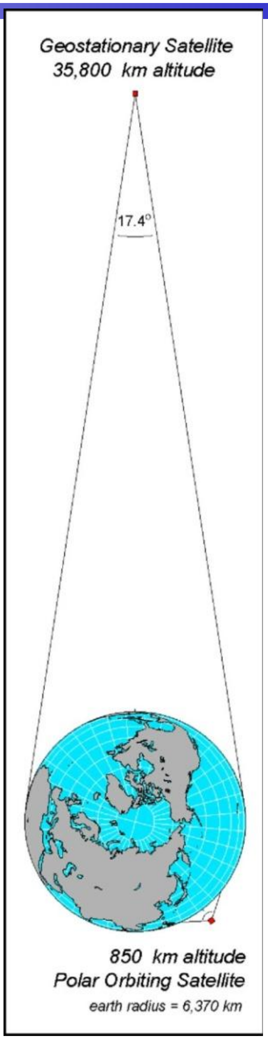
Geostationary satellites

Orbit 35,786 km distance to earth surface, orbit in equatorial plane (inclination 0°)

➔ complete rotation exactly one day, satellite is synchronous to earth rotation

- fix antenna positions, no adjusting necessary
- satellites typically have a large footprint (up to 34% of earth surface!), therefore difficult to reuse frequencies
- bad elevations in areas with latitude above 60° due to fixed position above the equator
- high transmit power needed
- high latency due to long distance (ca. 275 ms)

➔ not useful for global coverage for small mobile phones and data transmission, typically used for radio and TV transmission



LEO systems (Low Earth Orbit)

Orbit ca. 500 - 1500 km above earth surface

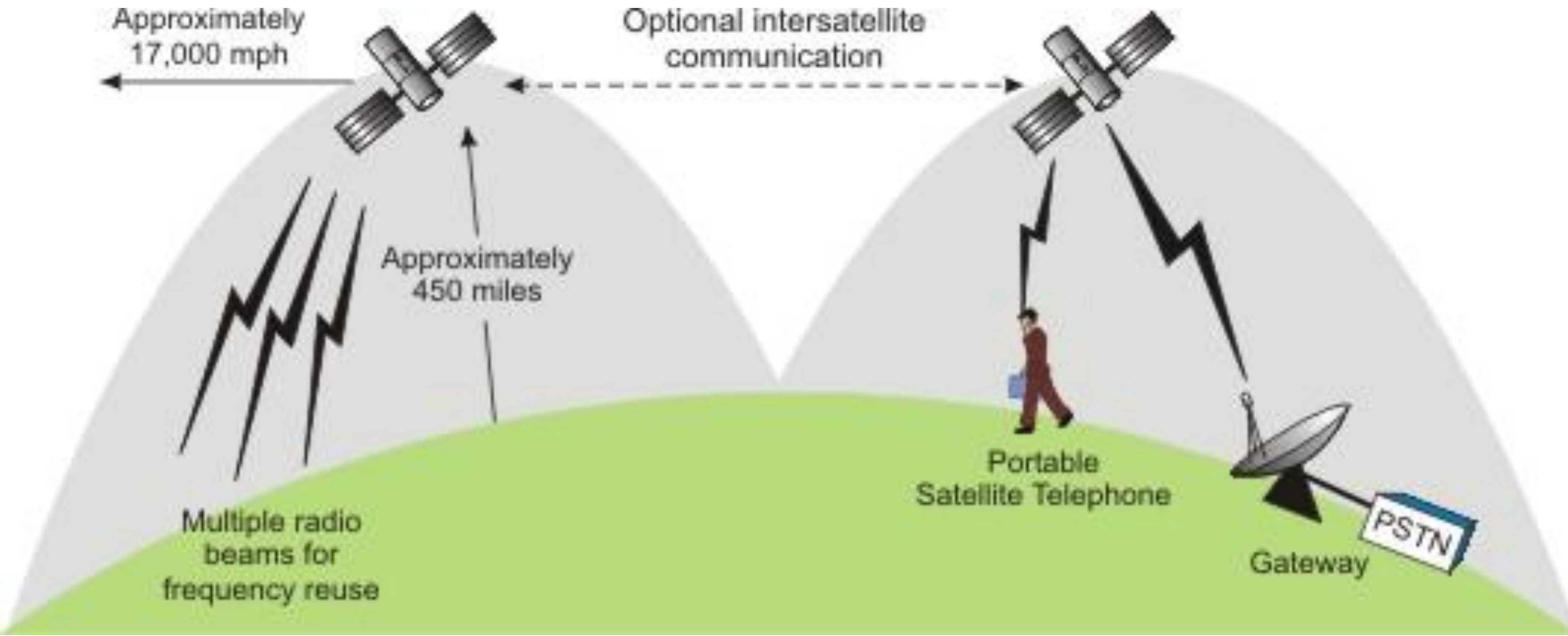
- visibility of a satellite ca. 10 - 40 minutes
- global radio coverage possible
- latency comparable with terrestrial long distance connections, ca. 5 - 10 ms
- smaller footprints, better frequency reuse
- many satellites necessary for global coverage
- more complex systems due to moving satellites

Examples:

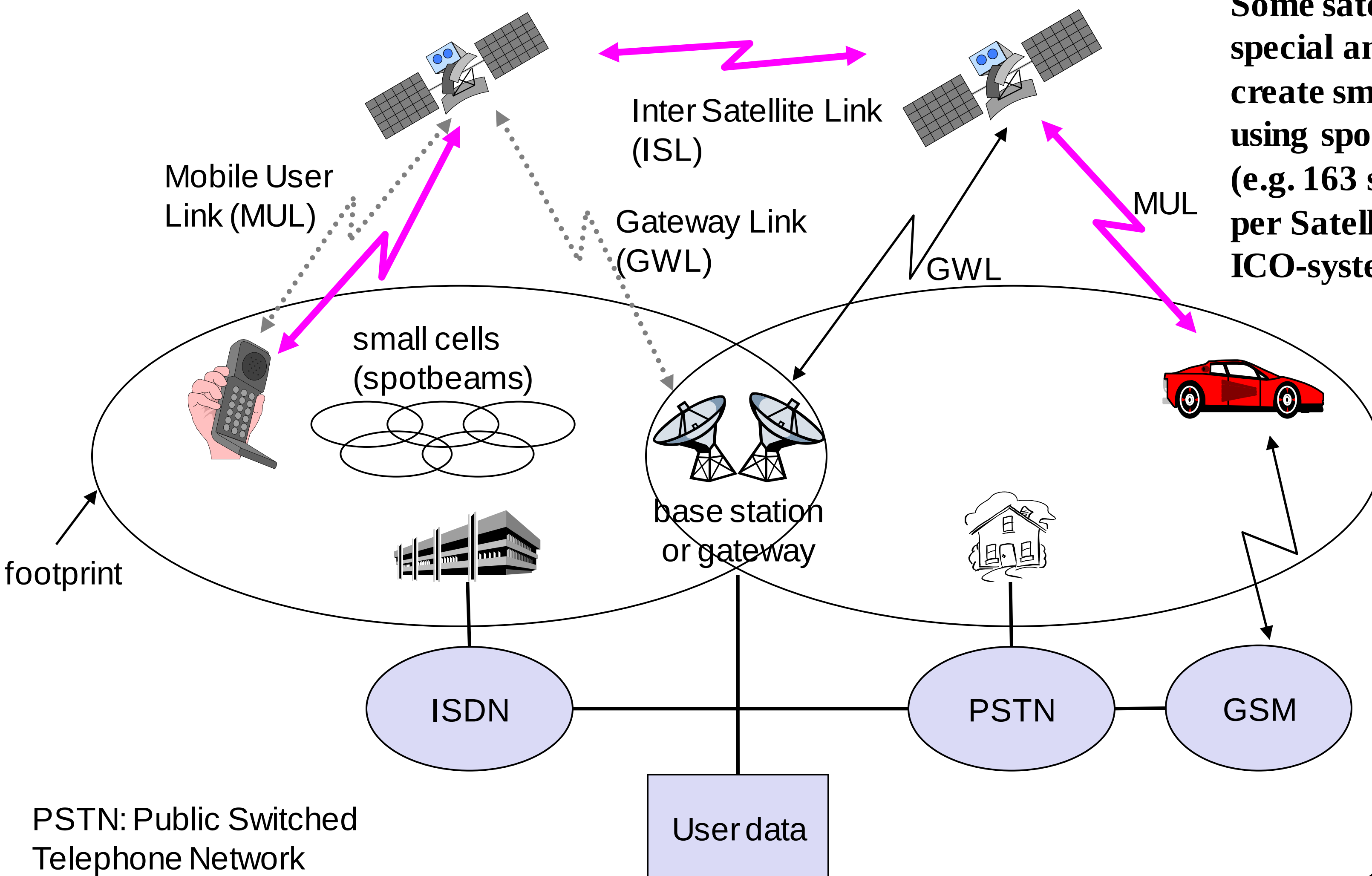
Iridium (start 1998, 66 satellites)

Globalstar (start 1999, 48 satellites)

Communication satellites



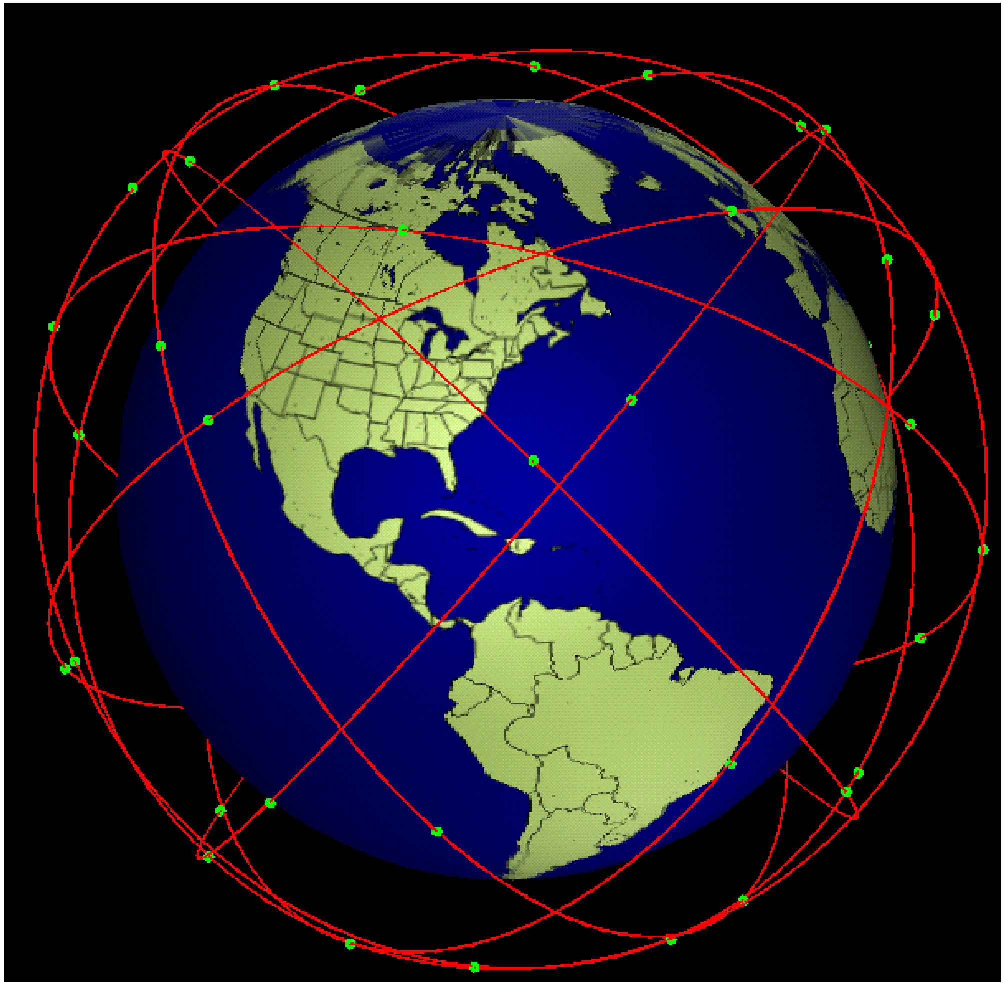
Classical satellite systems



Some satellites have special antennas to create smaller cells using spot beams (e.g. 163 spot beams per Satellite in then ICO-system)

PSTN: Public Switched Telephone Network

Satellites

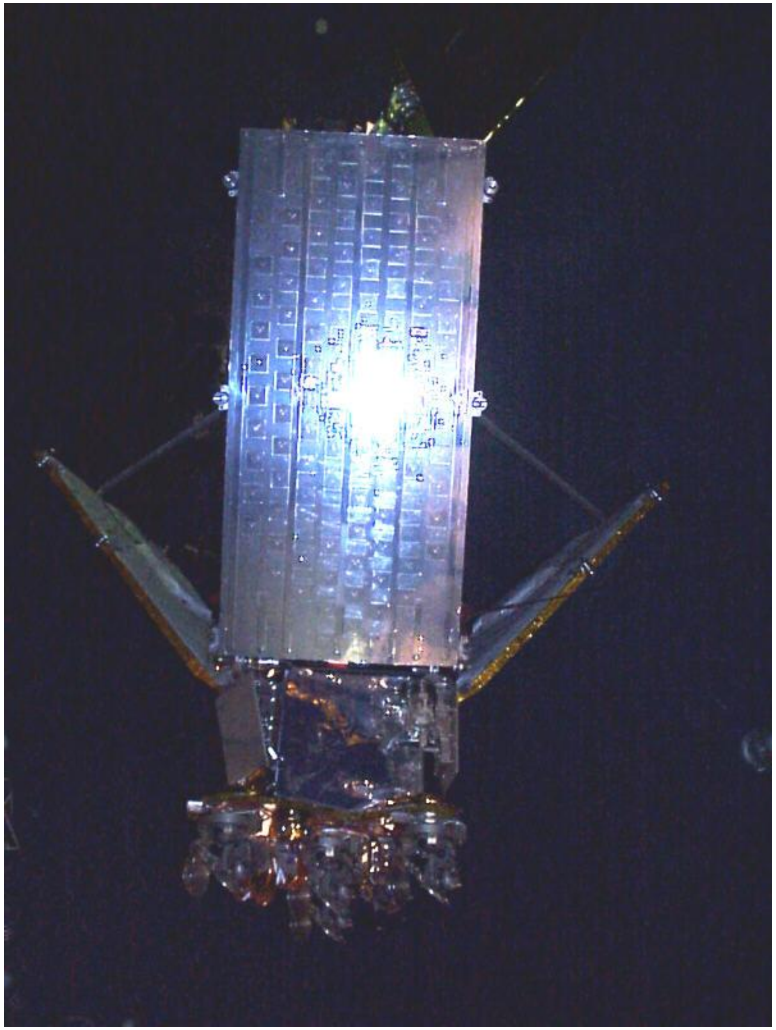


- Iridium (LEO)
- Globalstar (LEO)
- ICO (MEO)

The have all gone Bankrupt!

LEO: low earth orbit
MEO: medium earth orbit

Iridium satellites



MEO systems

Orbit ca. 5000 - 12000 km above earth surface

comparison with LEO systems:

- slower moving satellites
- less satellites needed
- simpler system design
- for many connections no hand-over needed
- higher latency, ca. 70 - 80 ms
- higher sending power needed
- special antennas for small footprints needed

Example:

ICO (Intermediate Circular Orbit, Inmarsat) start 2000

- Bankruptcy, planned joint ventures with Teledesic, Ellipso – cancelled again, start planned for 2011

Routing

One solution: inter satellite links (ISL)

- reduced number of gateways needed
- forward connections or data packets within the satellite network as long as possible
- only one uplink and one downlink per direction needed for the connection of two mobile phones

Problems:

- more complex focusing of antennas between satellites
- high system complexity due to moving routers
- higher fuel consumption
- thus shorter lifetime

Handover in satellite systems

Several additional situations for handover in satellite systems compared to cellular terrestrial mobile phone networks caused by the movement of the satellites

- Intra satellite handover
  - handover from one spot beam to another
  - mobile station still in the footprint of the satellite, but in another cell
- Inter satellite handover
  - handover from one satellite to another satellite
  - mobile station leaves the footprint of one satellite
- Gateway handover
  - Handover from one gateway to another
  - mobile station still in the footprint of a satellite, but gateway leaves the footprint
- Inter system handover
  - Handover from the satellite network to a terrestrial cellular network
  - mobile station can reach a terrestrial network again which might be cheaper, has a lower latency etc.

End