

Space Environment & Technology

Space Policy and Law Course 2018

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Orbits and Space

- The Space Environment
- The force of gravity in a vacuum
- Satellite Orbits
- Types of Satellite
- Attaining Orbit
- Re-entry and graveyard orbits
- Popular misconceptions and Q&A

The Space Environment

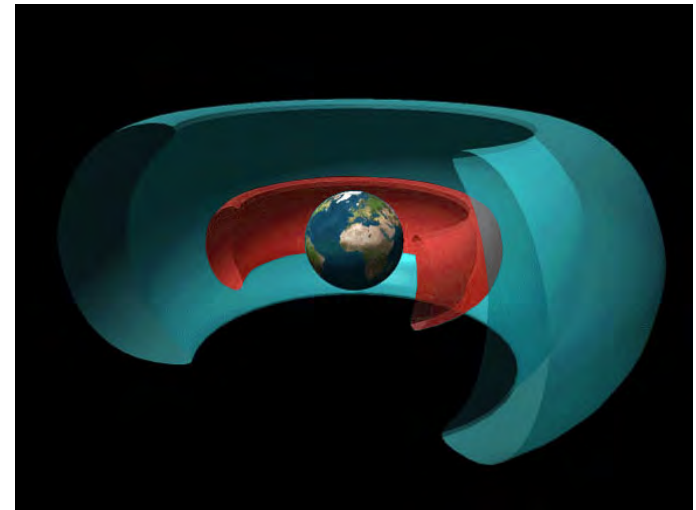
- Earth, Sun and Sky
- Radiation
- Microgravity
- Vacuum

Earth, Sun and Sky

- Earth – big, warm (20°C)
- Sun – very bright, very hot ($6,000^{\circ}\text{C}$)
- Sky – Black and very cold (-270°C)

Radiation

- Charged particles from the Sun and cosmos
- Including Van Allen Radiation belts
- Damage to:
 - Electronics
 - Optics
 - Solar panels
 - People
- Extreme UV causes satellites to ‘charge up’



Microgravity

- In orbit it ‘feels’ like you’re weightless.
- Everything is ‘falling’ together
- Satellites in space do not have to support their own weight and are not distorted by themselves – hard to test on the ground
- But they do have to survive their launch!

Vacuum



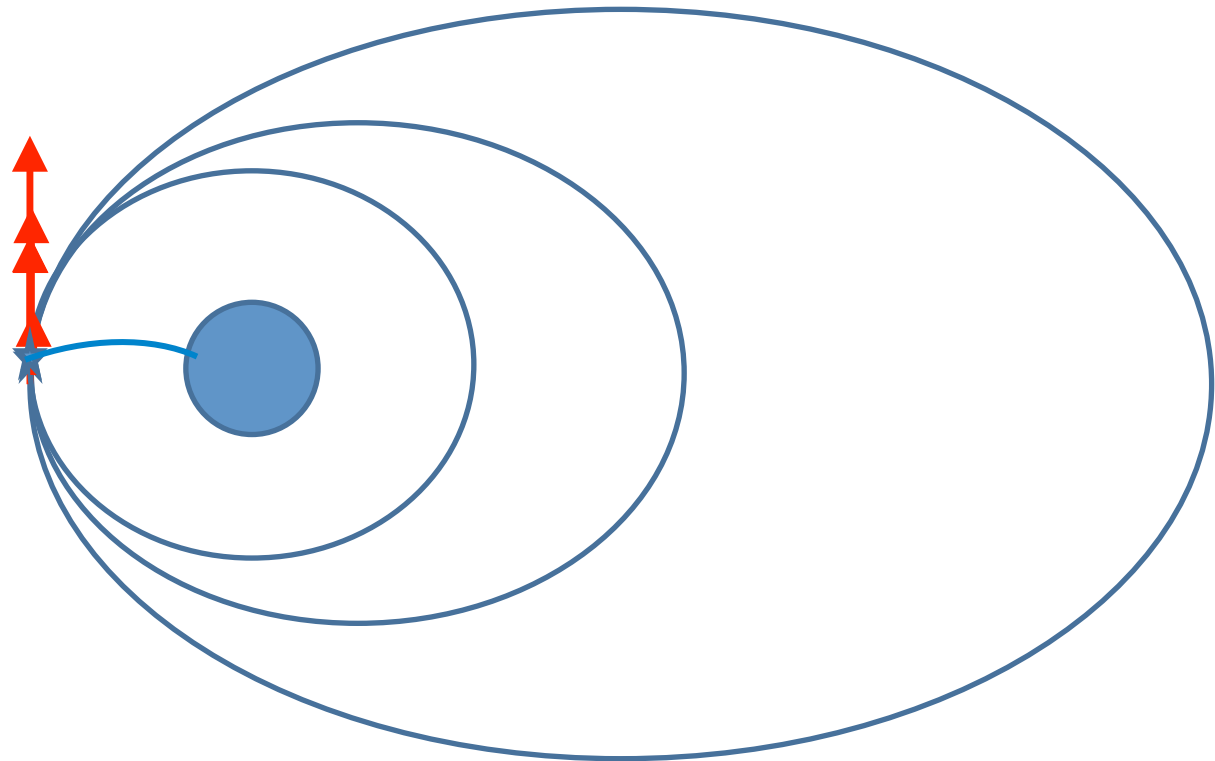
Newton's First Law

- An object will maintain a constant velocity in the absence of an external force (forever).
- In orbit there is (almost) no air resistance, let's ignore it for now but come back to it later.

Vacuum and heat

- No air = no convection = you can't use fans or air flow to cool things.
 - An engineering challenge for satellite builders
- Other issues include:
 - Cold welding
 - Life support
 - Outgassing and contamination

Gravity + Vacuum = Orbit

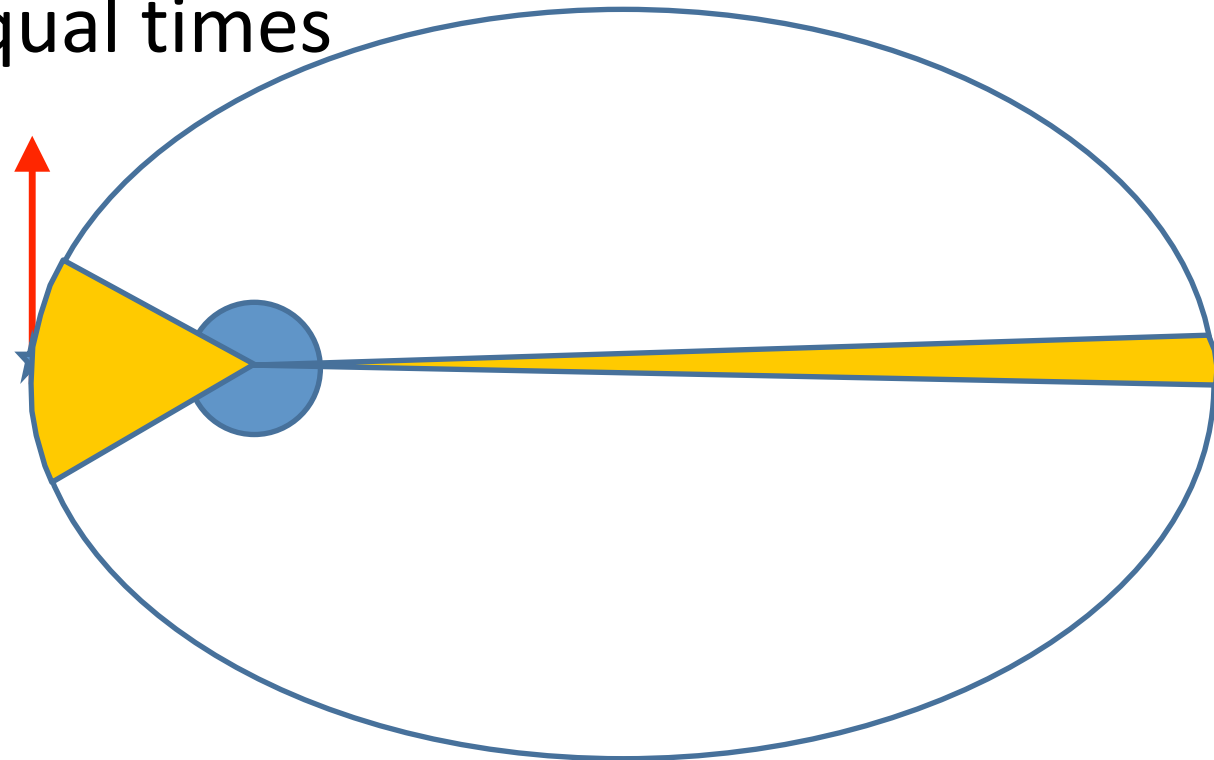


Definition of Space

- There isn't a universally accepted one
- There isn't a natural boundary
- 'Atmospheric' based definitions are not practical, they're affected by solar activity.
- Below around 20 km aerodynamic flight is possible
- Above 200km orbits with reasonable durations are possible
- Some use the Karman Line (100km), which is based on aeronautics

Kepler's Laws

- 1: Orbits are ellipses
- 2: Equal areas in equal times
- 3: $P^2 \sim R^3$



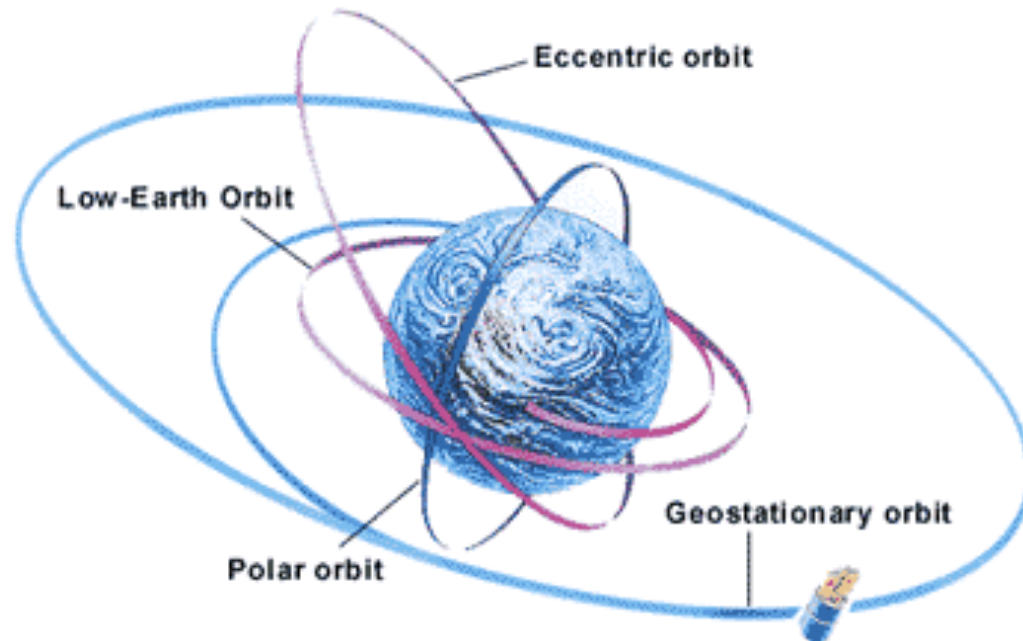
Recall the Earth Rotates

- Once every 23 Hours and 56 minutes



- It also orbits the Sun (365 x 4min ~ 1 Day)

Orbit classification



Low:LEO e.g. 500-1200km

Polar, Sun-synchronous: SSO

Earth observation

Inclined

Satcomms (Iridium, OneWeb)

Highly Elliptical:HEO

Molniya: polar sat-comms

Medium: MEO 15-25,000km

Satellite Navigation (GNSS)

Geostationary: GEO 36,000km

Sat-comms, broadcast TV

Meteorology

Precession

- Satellites in orbit are a little like gyroscopes. The plane of the orbit rotates due to the equatorial bulge of the Earth.
- The rate of precession depends on altitude and inclination
- For instance at 575 km and 82.3 degree the rate is: $360/365$ degrees per day.
What does this mean?



Mission examples LEO and MEO

MetOp: Sun synchronous LEO at 817km, 21.31 LTAN



Credit: ESA/AOES Medialab

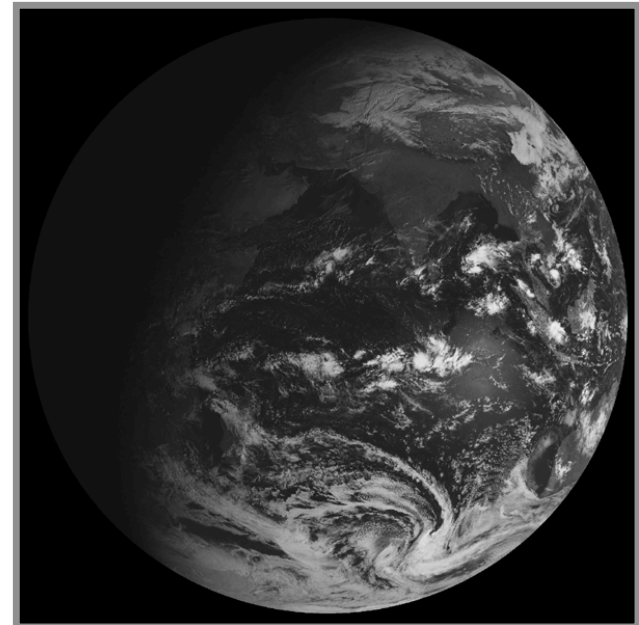
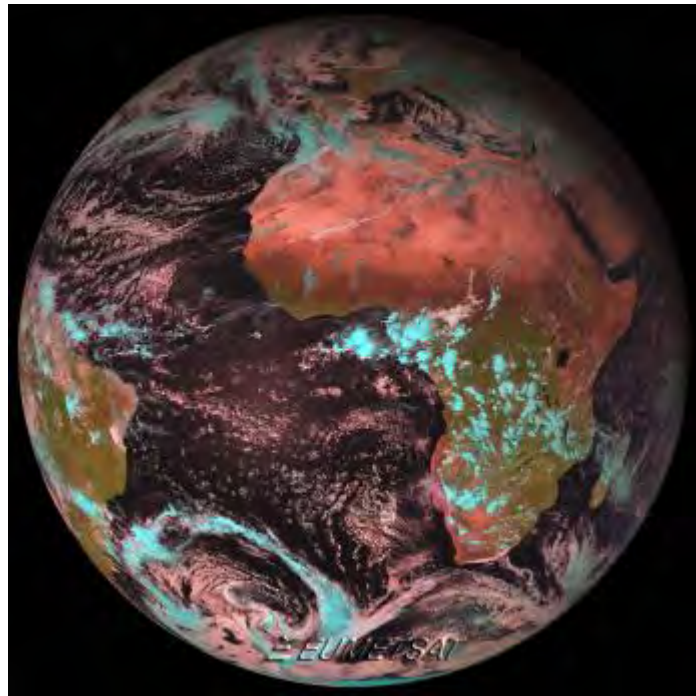
Galileo: 3 MEO planes each contain 10 sats at 23,000km



Credit: ESA-J. Huart

Mission example GEO

Meteosat in GEO at 36000km



Credit: Eumetsat

Satellite Congestion

~1000 satellites in space

~50% LEO

~8% MEO

~40% GEO

+ Space Debris

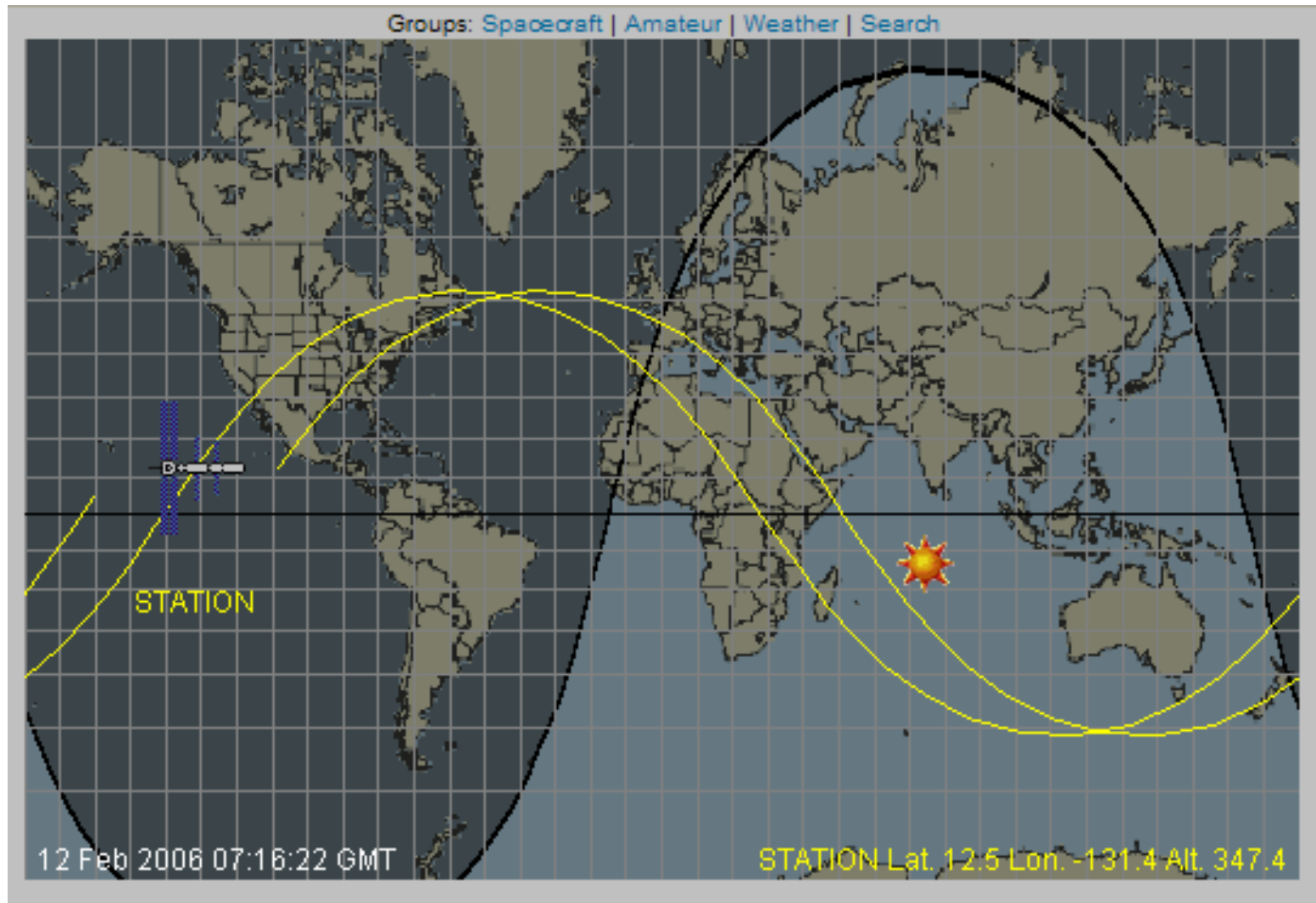
21,000 > 10 cm

500,000 > 1cm

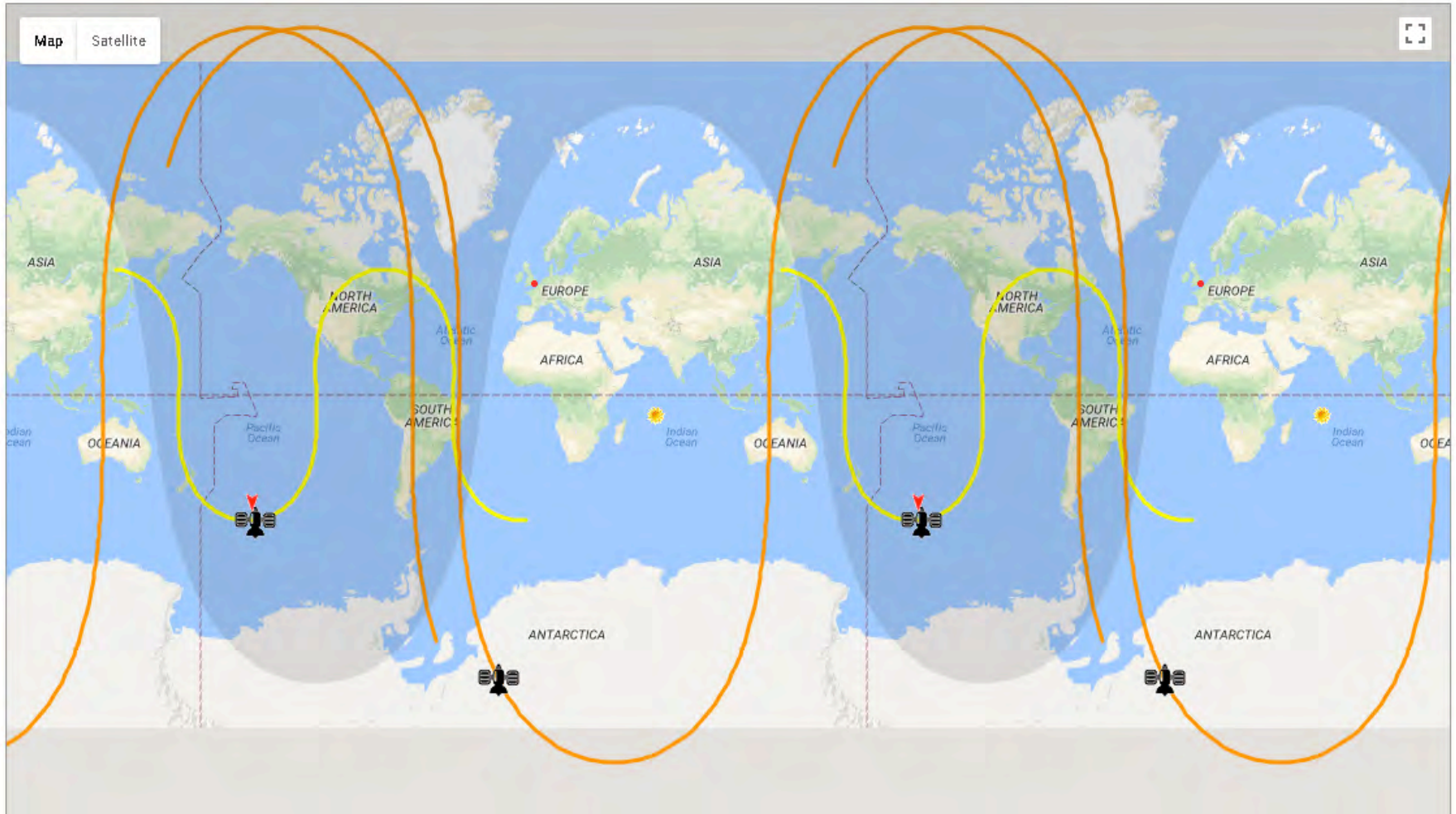


Ground station passes

- For a given ground station the number of satellite passes overhead depends upon:
 - Location of ground station
 - Altitude of Orbit
 - Inclination of Orbit



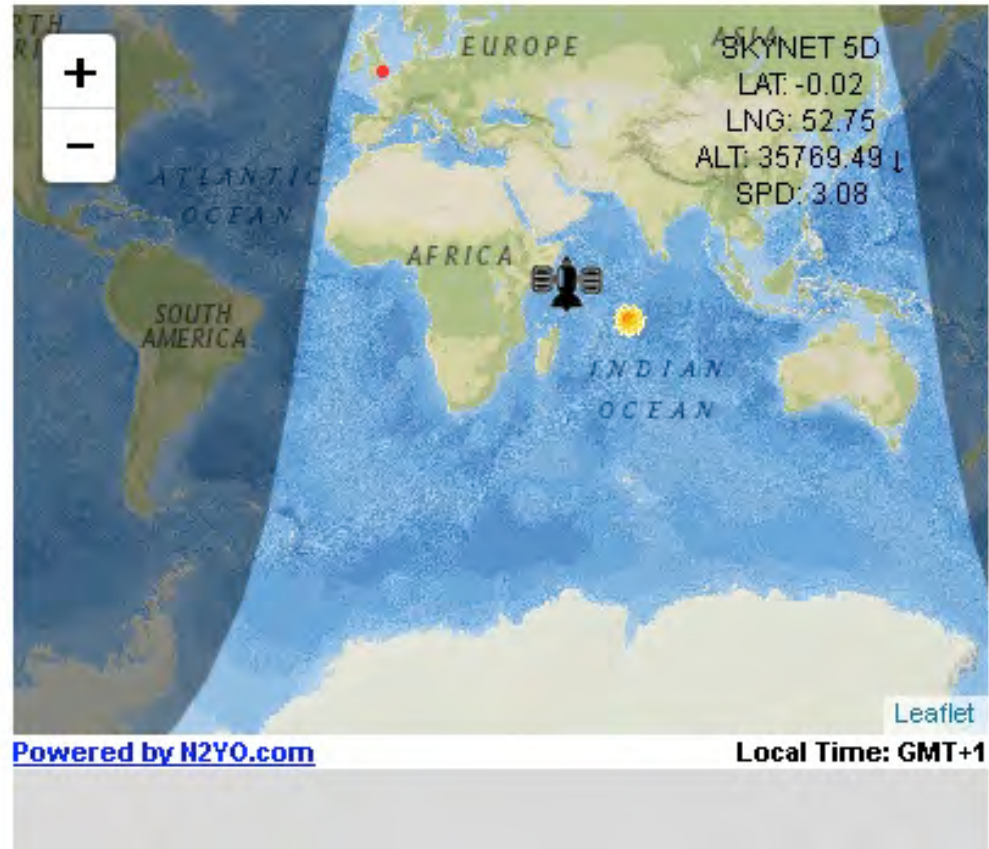
International Space Station, Inclination 51.6° .



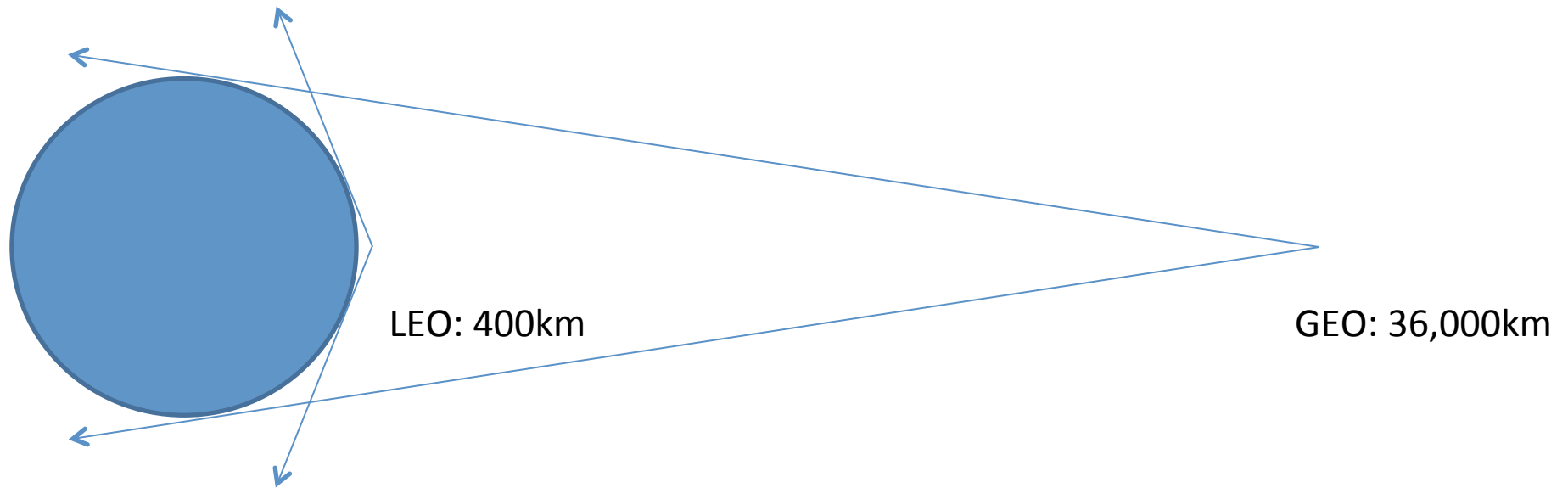
Galileo-FM2 (incl. 55.9°) and Iridium 4 (incl. 86.4°) Ground Tracks

Ground track – Skynet 5

- Perigee: 35,775.7 km
- Apogee: 35,810.3 km
- Inclination: 0.1°
- Period: 1436.1 min



Earth View



LEO

- Better signal strength
- More orbits per day, combined with high inclination leads to more frequent revisit and global coverage
- More detailed observations
- Lower radiation exposure (e.g. for human spaceflight)

MEO

- Advantages of Synchronization, useful for inclined communications networks
- Relatively uncluttered

GEO

- Continuous intercontinental Telecommunications, broadcast communications
- Inter-satellite Communications
- Large area monitoring (such as the weather) or surveillance (missile warning, ship movement)

Domains

Telecommunications

Navigation / GPS

Earth Observation

Space Science

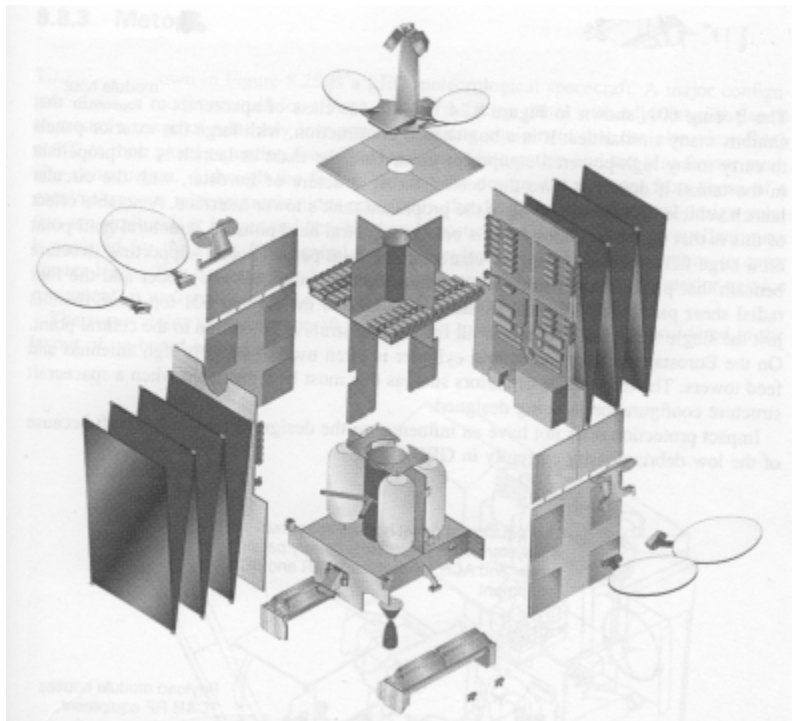
Human/Biology

Satellite elements

Platform

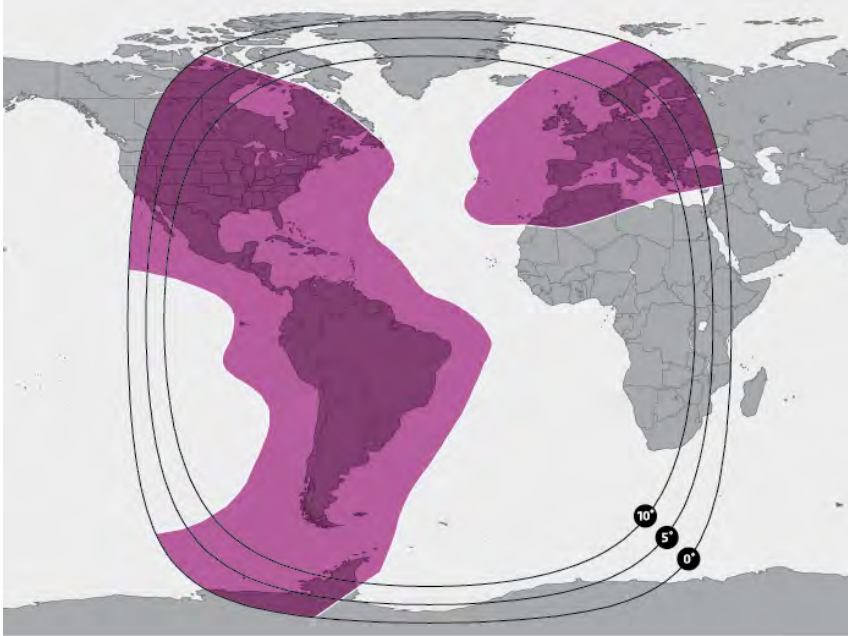
Payload

Telecommunications



Typical Telecomms Satellite

SES-6



C-band coverage

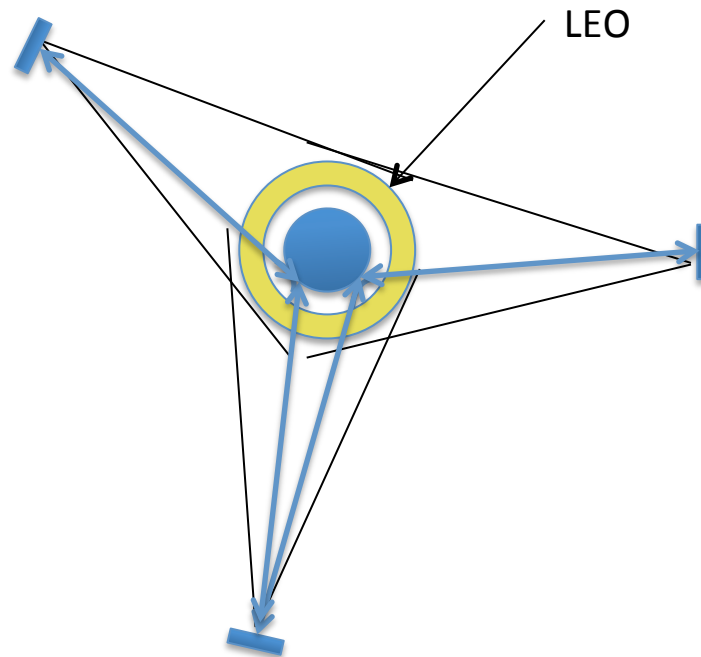


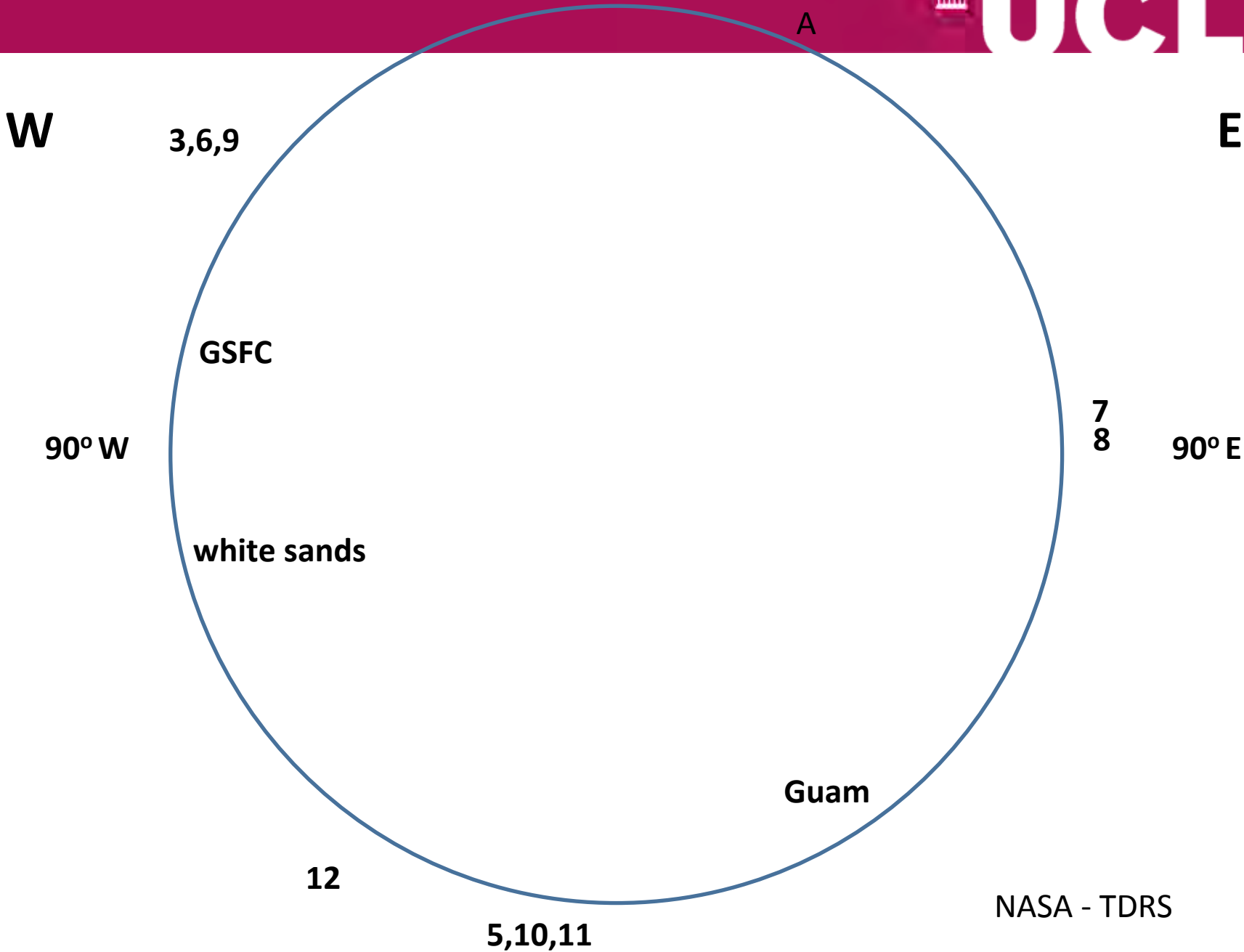
Ku-band coverage

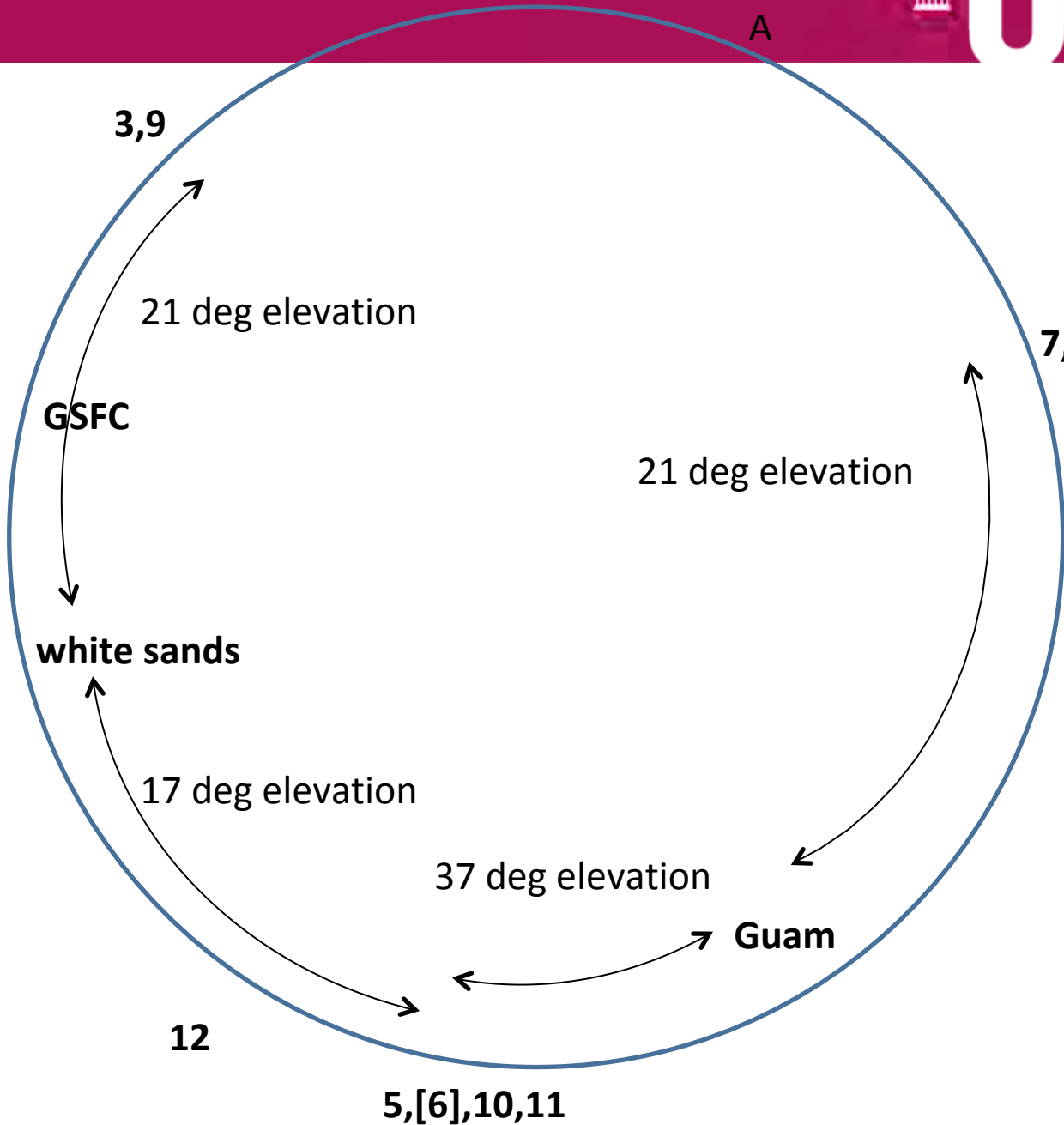
Frequency Bands

- **VHF Band**
 - 136 - 138 MHz; Mainly 137-138 MHz , meteorological satellites transmitting data and low resolution images, low data rate mobile satellite downlinks
 - 144 - 146 MHz Popular bands for amateur satellite activity. Most of the links are found in the upper half of the band (145 - 146 MHz).
 - 148 - 150 MHz uplinks of the satellites that downlink in the 137 - 138 MHz band.
 - 149.95 - 150.05 MHz positioning, time and frequency services; ionospheric research
 - 240 - 270 MHz Military satellites, communications.
- **UHF Band**
 - 399.9 - 403 MHz navigation, positioning, time and frequency standard, mobile communication, and meteorological satellites.
 - 432 - 438 MHz This range includes a popular amateur satellite band as well as a few Earth resources satellites.
 - 460 - 470 MHz Meteorological and environmental satellites, includes uplink frequencies for remote environmental data sensors.
- **L Band**
 - 1.2 - 1.8 GHz a very diverse range of satellites and encompasses many sub-allocations.; GPS and other GNSS ; SARSAT/COSPAS search and rescue satellites; mobile satellite communication band.
 - 1.67 - 1.71 GHz one of the primary bands for high resolution meteorological satellite downlinks of data and imagery.
- **S Band**
 - 2.025 - 2.3 GHz Space operations and research, including 'deep space' links from beyond Earth orbit.; military; Earth resources downlink .
 - 2.5 - 2.67 GHz Fixed (point-to-point) communication and broadcast satellites.
- **C Band**
 - 3.4 - 4.2 GHz Fixed satellite service (FSS) and broadcast satellite service (BSS) downlinks; International TV broadcast.
 - 5.9 - 6.4 GHz This is the FSS/BSS uplink for the 3.4-4.2 GHz downlink band.
- **X band**
 - 8 - 9 GHz space research, deep space operations, environmental and military communication satellites.
- **Ku band**
 - 10.7 - 11.7 GHz Fixed satellite services (FSS)
 - 11.7 - 12.2 GHz Broadcast satellite service (BSS) downlinks; domestic TV programs.
 - 14.5 - 14.8 GHz The uplink for the previous Ku downlink band.
 - 17.3 - 18.1 GHz An alternate 'Ku' band BSS uplink.
- **'Ka' band**
 - 23 - 27 GHz A region that will be used increasingly by a variety of fixed link, broadcast, environmental and space operations satellites in the future.

Inter-satellite communication





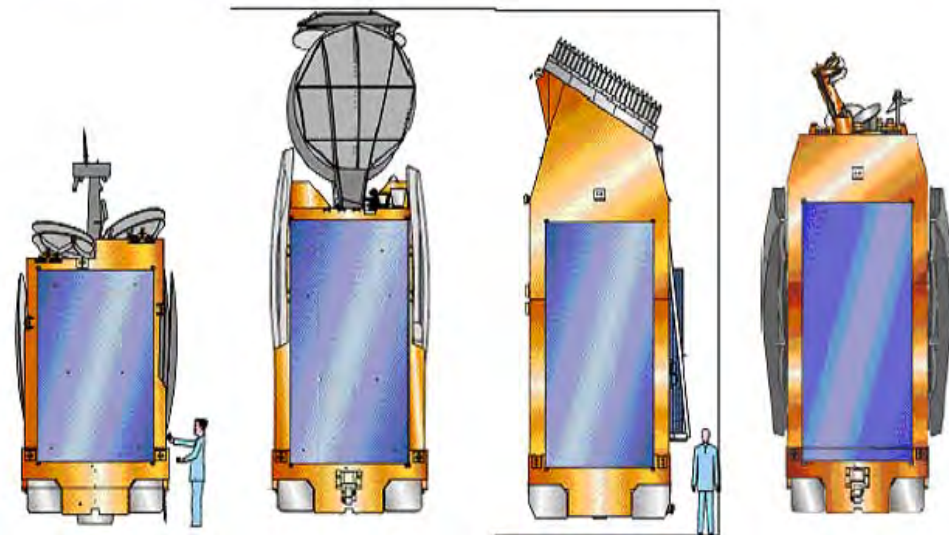
W

Eurostar E3000



- Communications Satellite Platform
- Provides structure, power, attitude and orbit control
- > 50 launches to date

Series	E3000S	E3000	E3000GM	E3000LX
Launch mass	5 tons	6 tons	6 tons	6.4 tons
Spacecraft power (BOL)	up to 12 kW	up to 14 kW	up to 14 kW	up to 20 kW
Payload power	6 kW to 8 kW	6 kW to 10 kW	6 kW to 10 kW	10 kW to 14 kW
Missions	FSS / BSS/ Broadband	FSS / BSS/ Broadband	GEO Mobile	FSS / BSS/ Broadband



Navigation Satellites

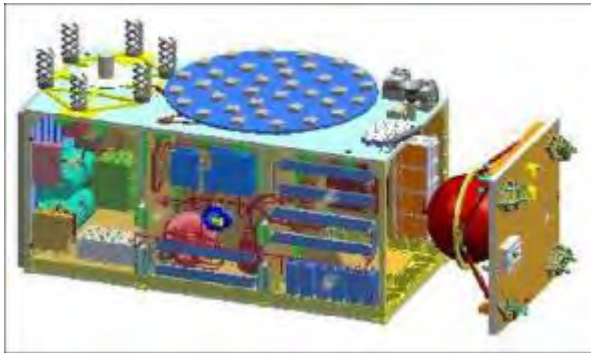
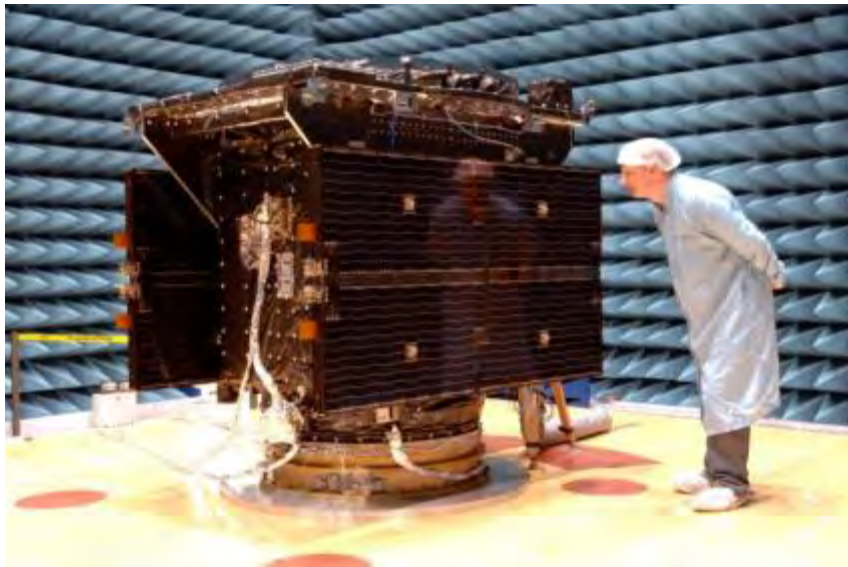


image credit:
OHB System

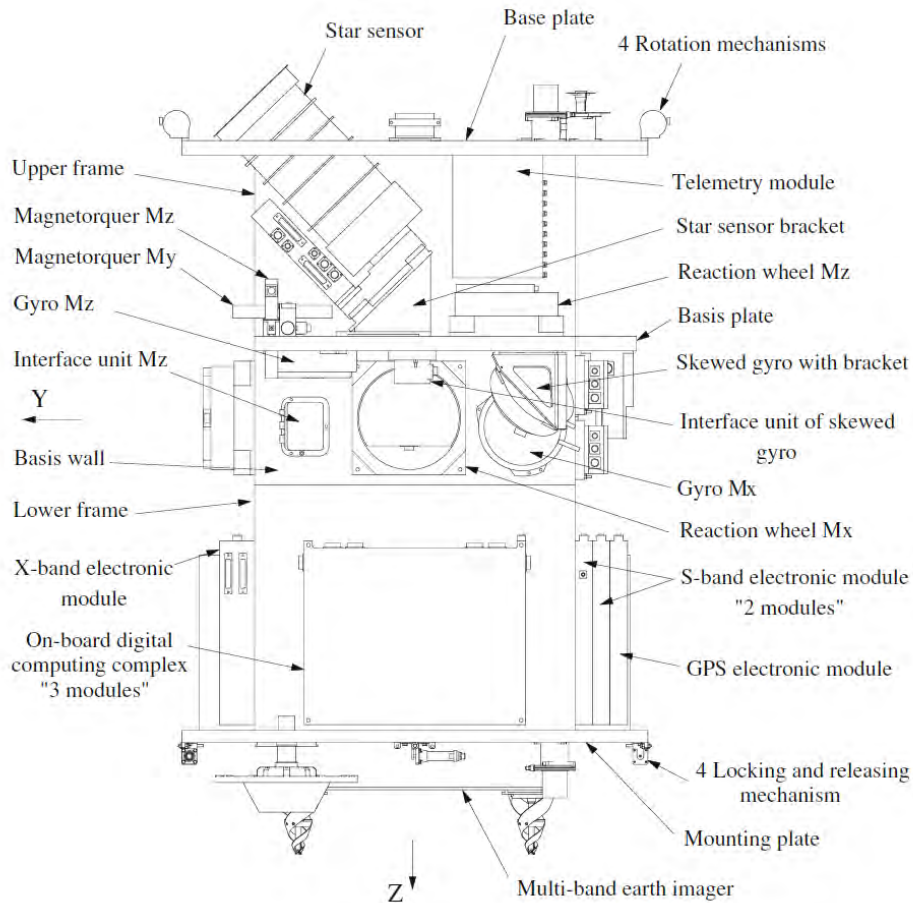


SSTL GIOVE-A, Galileo



Earth Observation Satellites

Earth Observation Small-Sat



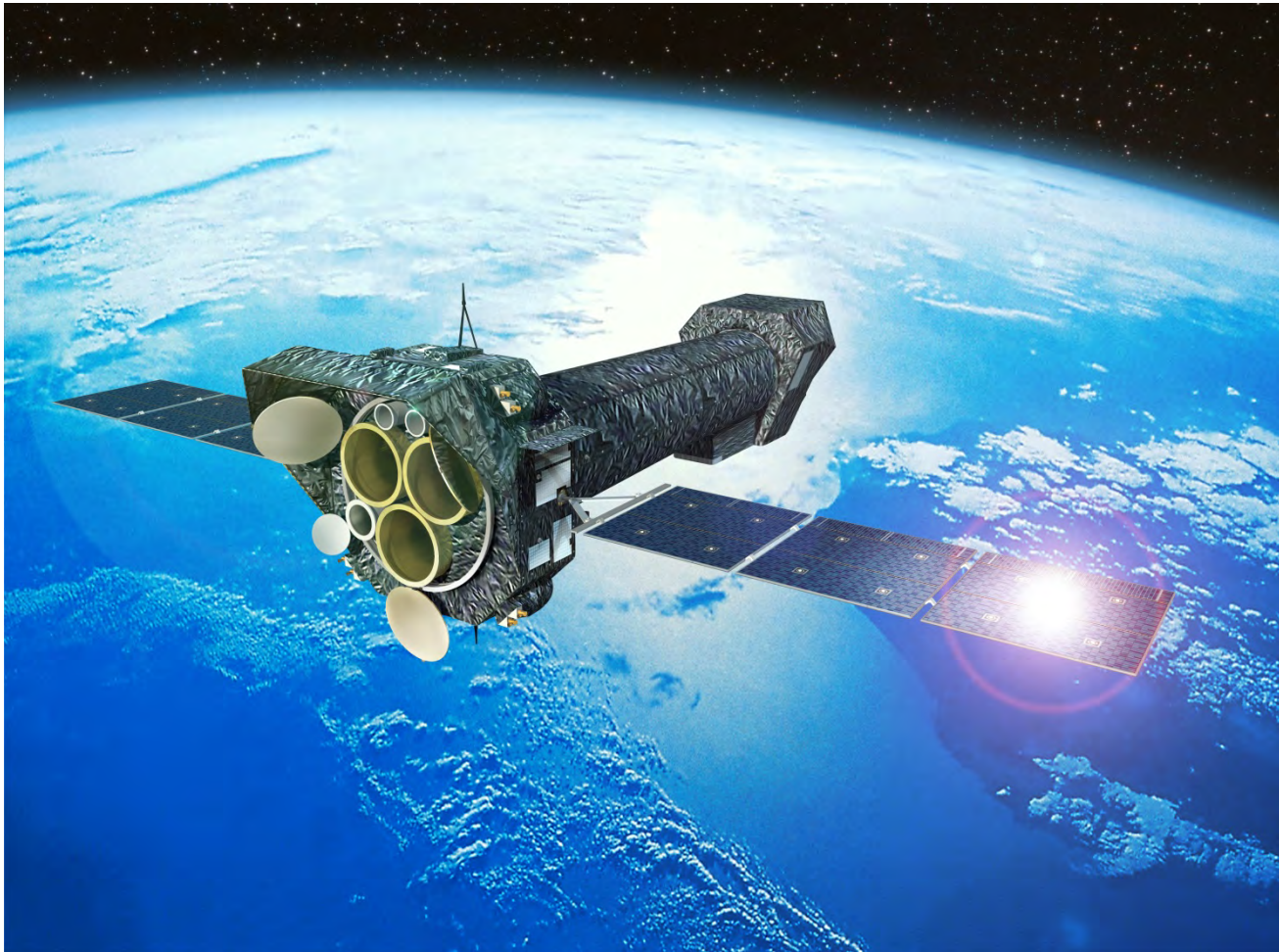
- LEO
- Inclined/Polar
- Eclipses
- Downpointing or Along-track

Earth Observation Satellites (and planet orbiters)

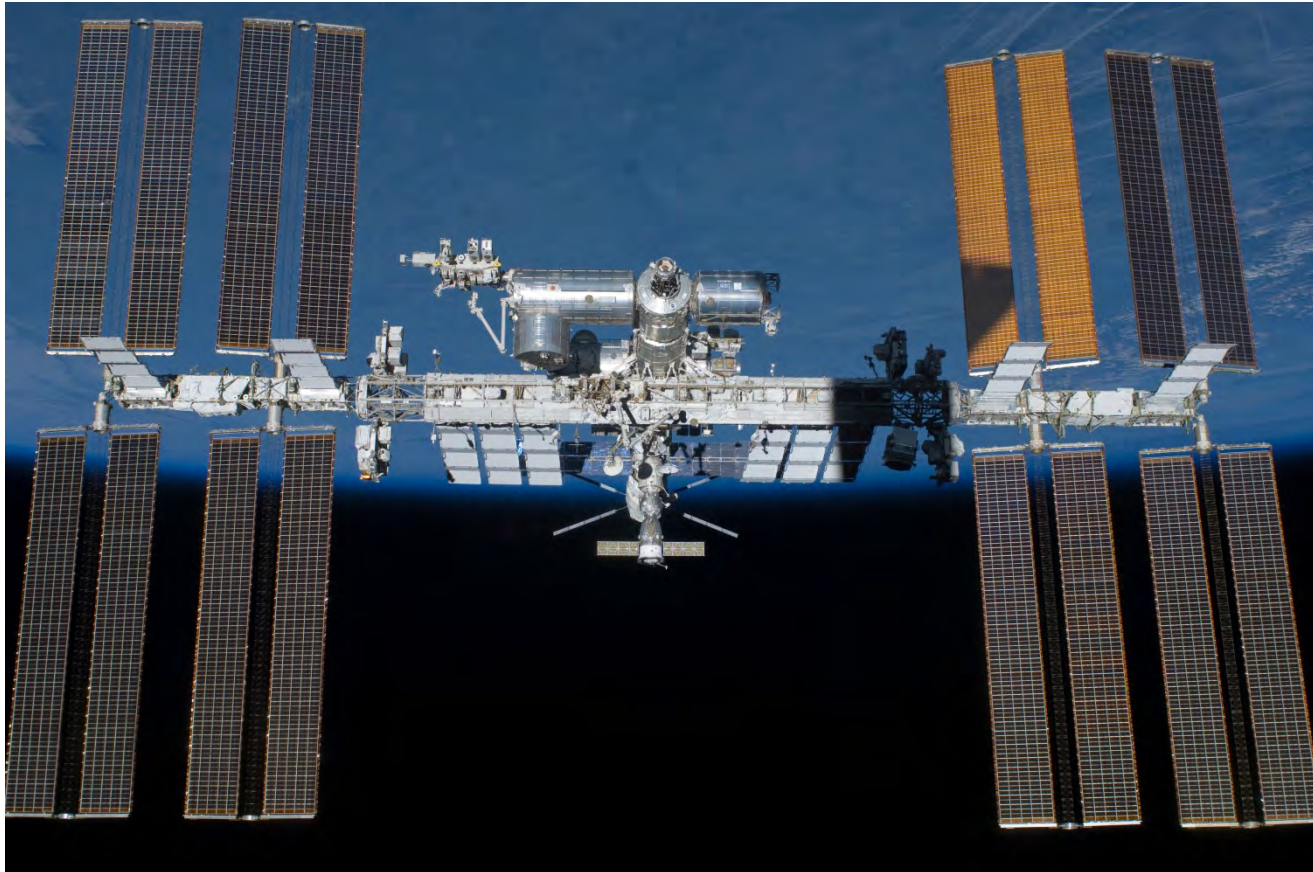


Envisat, ESA

Science Satellites



Human Spaceflight



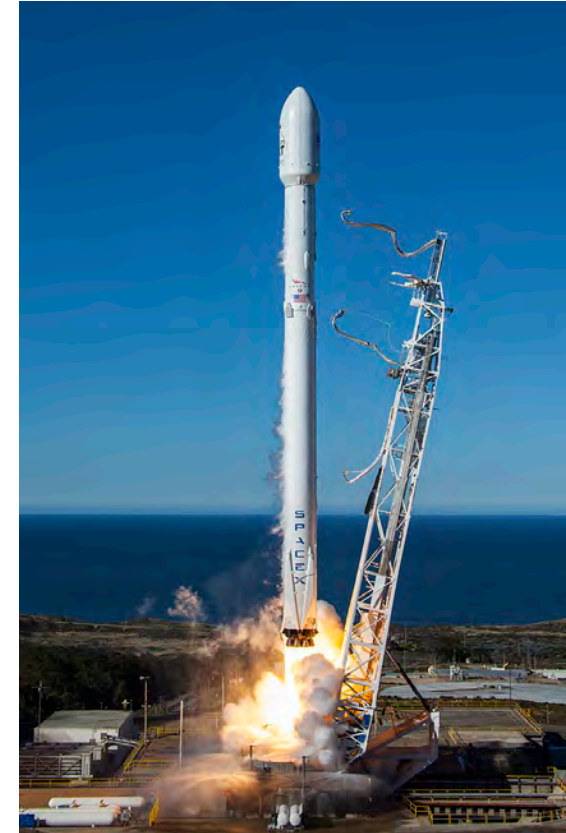
Getting into Space



Ariane 5
ESA Arianespace



Long March 3B
China



Falcon 9
SpaceX

Launchers

- Lifting power (e.g. kg to LEO)
- Number of stages: 2-4
- National provider
- Reliability
- Fuel
- Ability to be re-ignited
- Reusable

- New technologies (air breathing rockets)

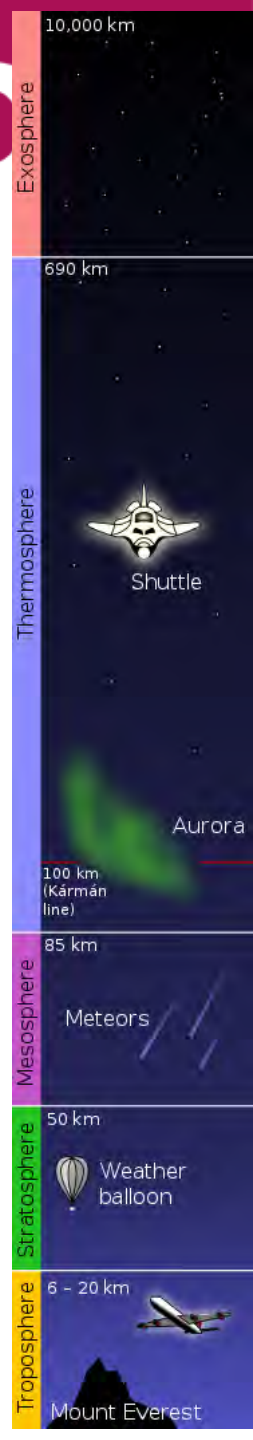
Launch strategies

- Direct injection: go straight into the right orbit
- Transfer: go to a transfer orbit and then more slowly adjust to that required
 - GTO, equatorial, eccentric orbit, raise perigee until GEO is achieved
 - A variant of this allows for GEO longitude changes

De-orbit

- The atmosphere doesn't just stop
- Even high orbits have some atmospheric friction.
- Gradually orbits will decay
- Eventually satellites will re-enter
- Most burn up but some parts may hit the ground
- It's very hard to predict the final stages of re-entry

200km – 1 day
 300km – 1 month
 400km – 1 year
 500km – 10 years
 700km – 100 years
 900km – 1000 years



Graveyard Orbits

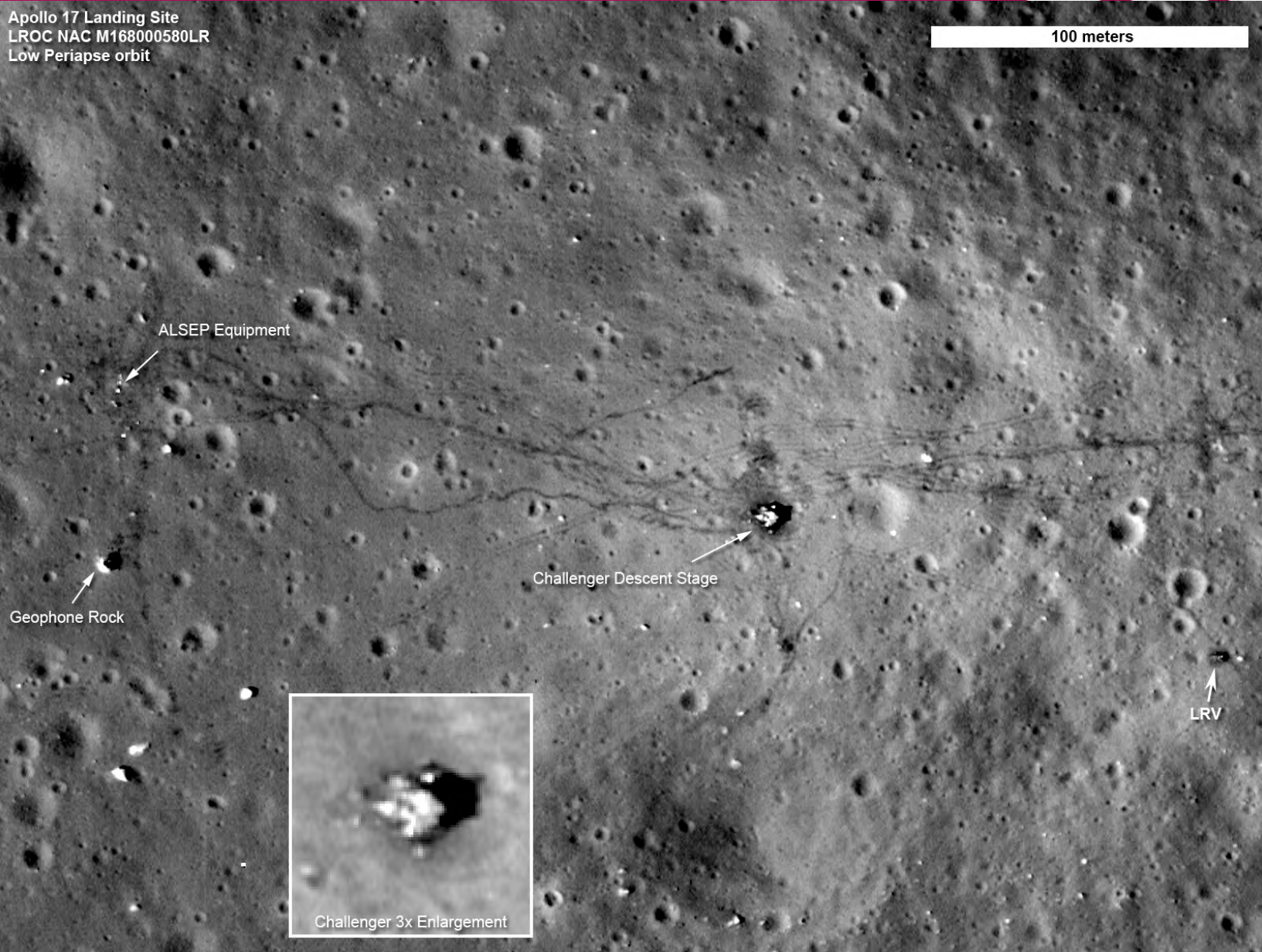
- To change an orbit requires a change in velocity, so called delta-V
- To change velocity requires a motor and fuel = mass = cost
- To de-orbit a GEO satellite requires 1500 m/s delta-V
- To lift into a Graveyard orbit out of the way of other GEO satellites requires just 1.5 m/s

Some Myths

- Satellites can't read newspapers from orbit, or recognise individuals
- Satellites can't be 'positioned' over anywhere on Earth – only at the equator and at very high altitude
- Man did go to the Moon!

Apollo 17 Landing Site
LROC NAC M168000580LR
Low Periapse orbit

100 meters



ALSEP Equipment

Geophone Rock

Challenger Descent Stage

LRV

Challenger 3x Enlargement

Questions?

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