



Space Environment & Technology

Space Policy and Law Course 2017

Professor Alan Smith
Mullard Space Science Laboratory
University College London
16 October 2017



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

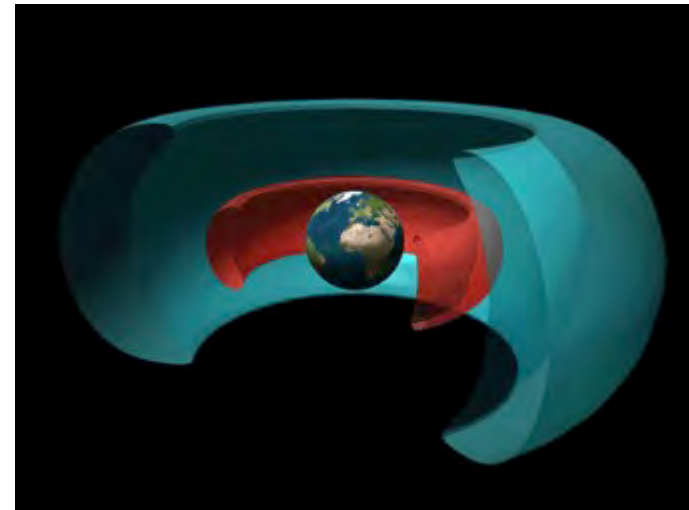


Earth, Sun and Sky

- Earth – big, warm (20°C)
- Sun – very bright, very hot (6,000°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

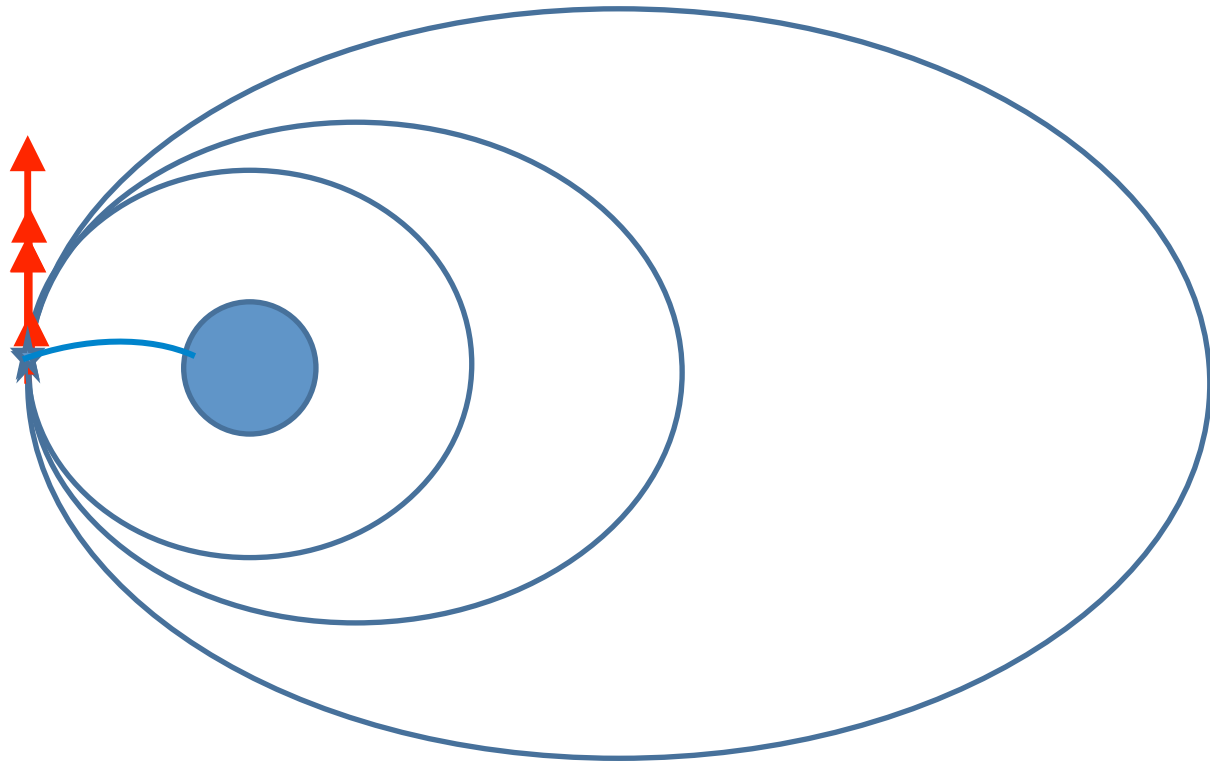
- An object will maintain a constant velocity in the absence of an external force (forever).
- In orbit there is (almost) no air resistance, let's ignore it for now but come back to it later.



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



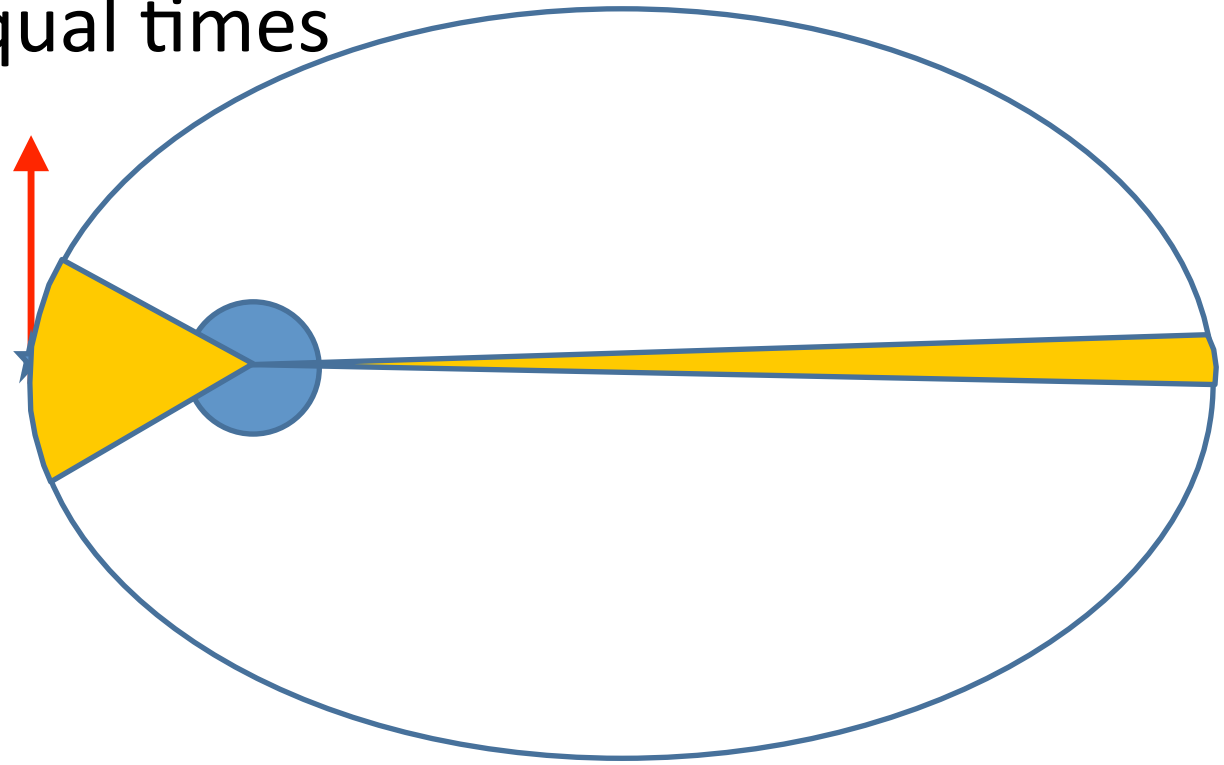


Definition of Space

- 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: $P^2 \sim R^3$



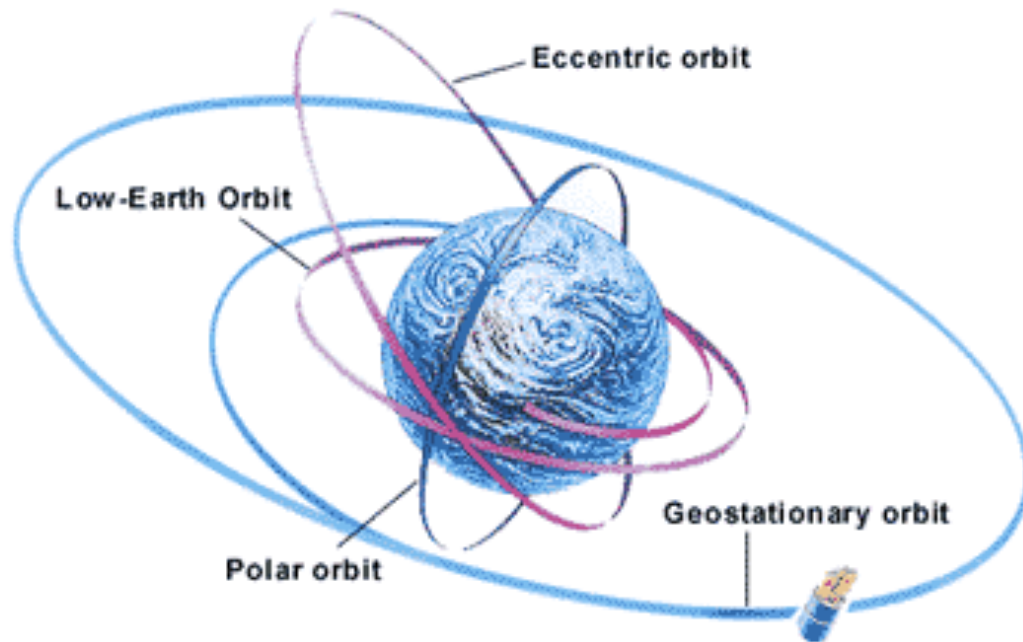
Recall the Earth Rotates

- 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

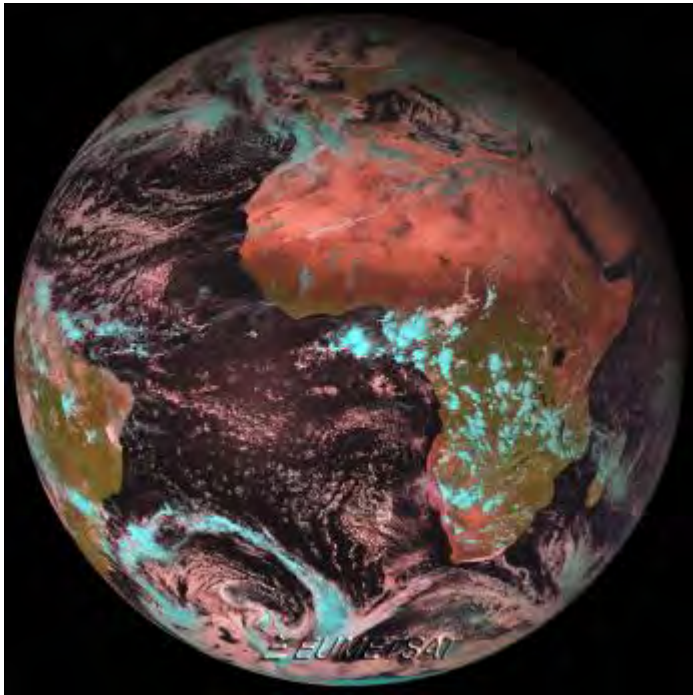
Galileo: 3 MEO planes each contain 10 sats at 23,000km



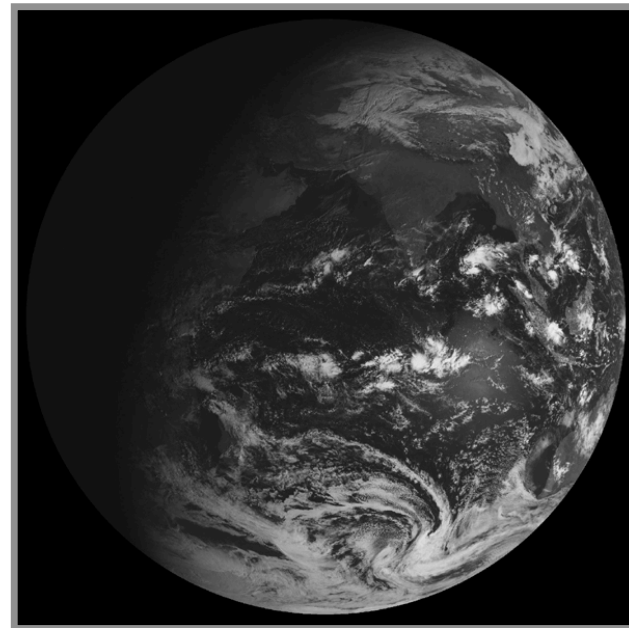
Credit: ESA-J. Huart

Mission example GEO

Meteosat in GEO at 36000km



Credit: Eumetsat



Satellite Congestion

~1000 satellites in space
~50% LEO
~8% MEO
~40% GEO

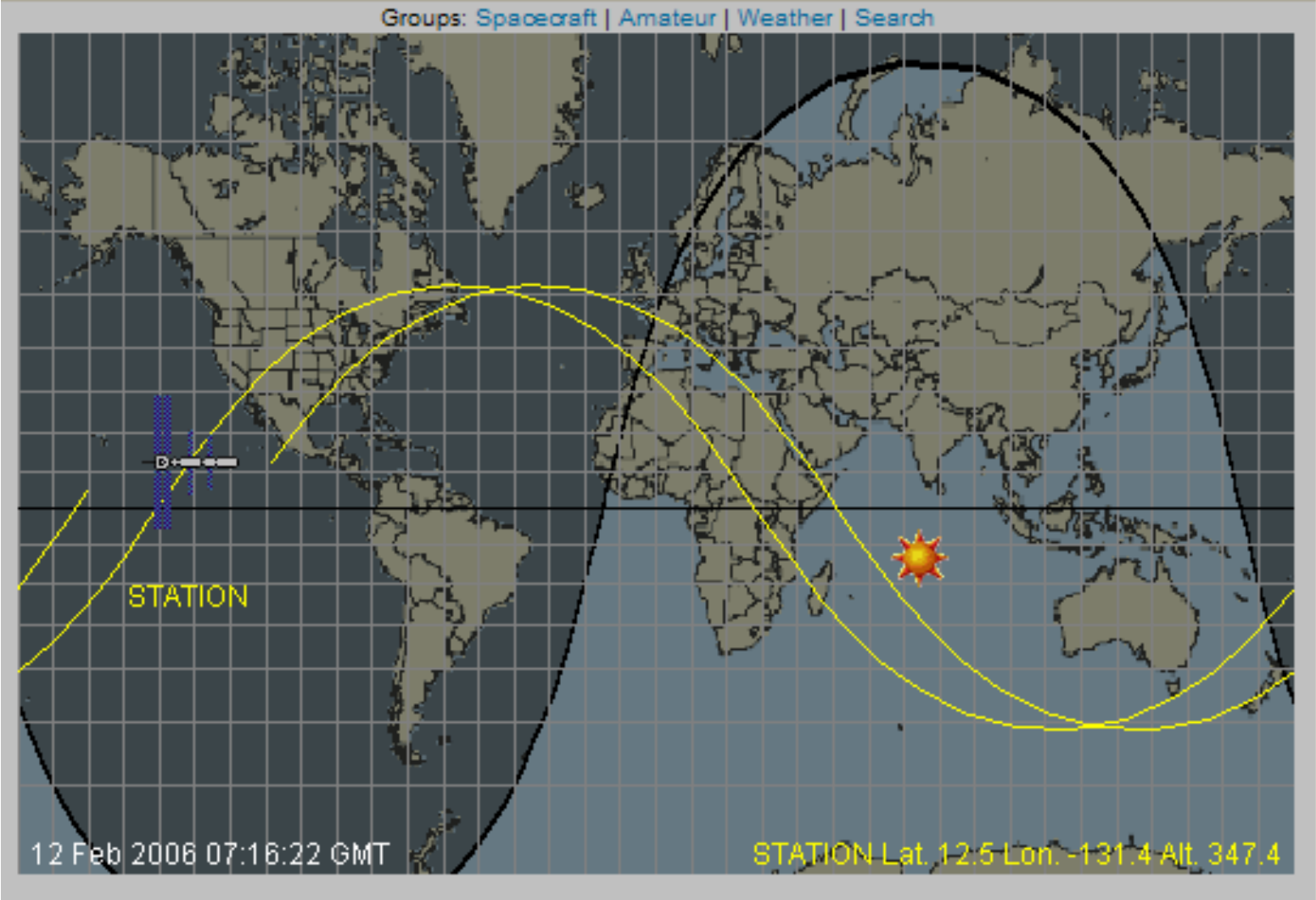
+ Space Debris
21,000 > 10 cm
500,000 > 1cm



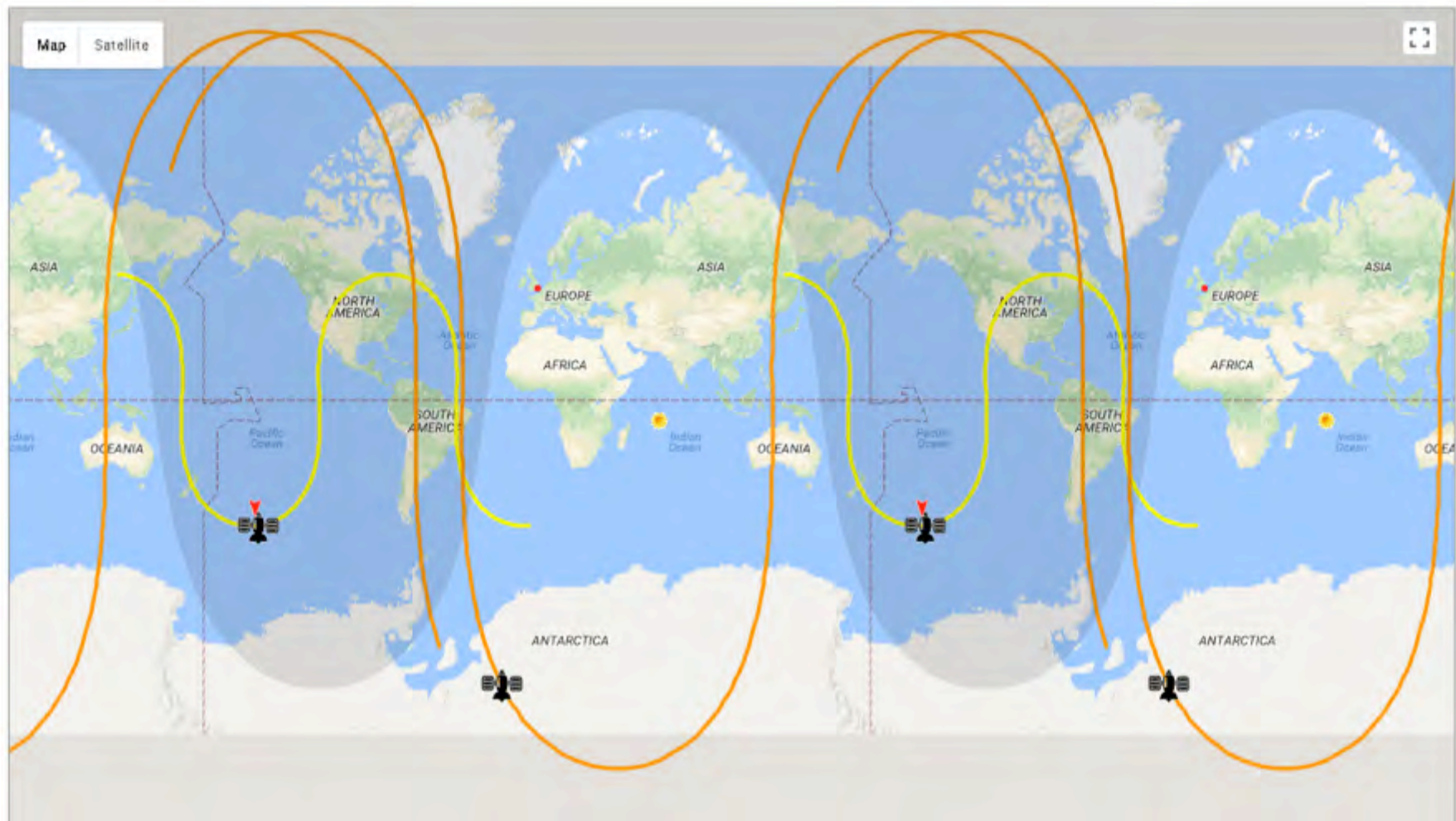


Ground station passes

- 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

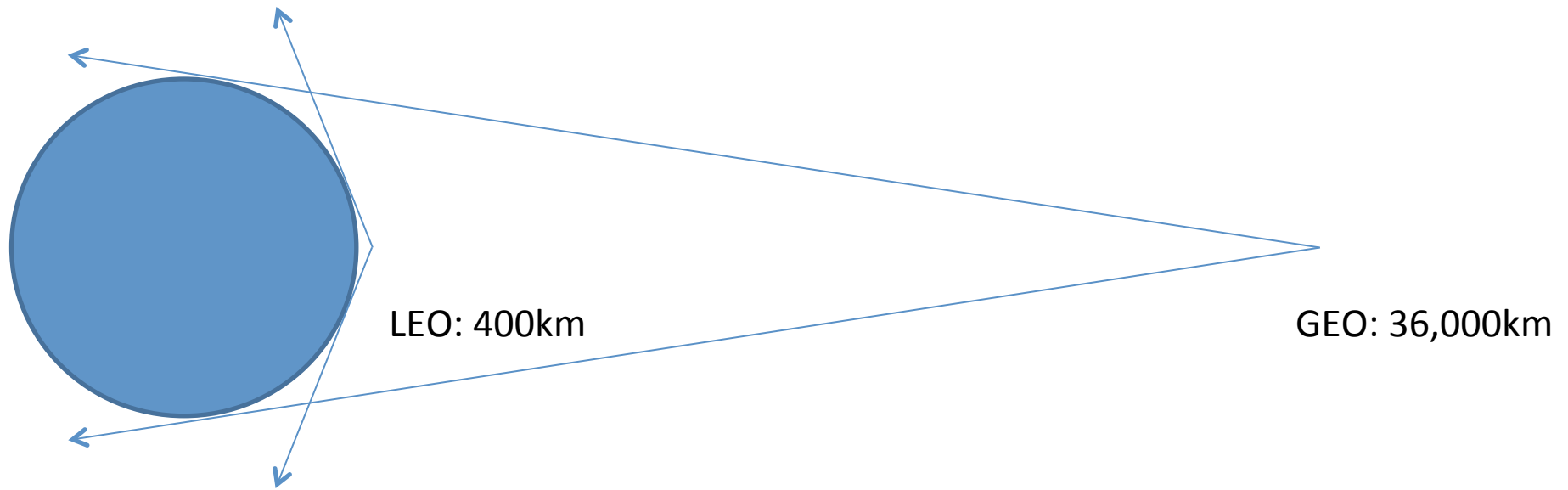
Ground track – Skynet 5

- 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

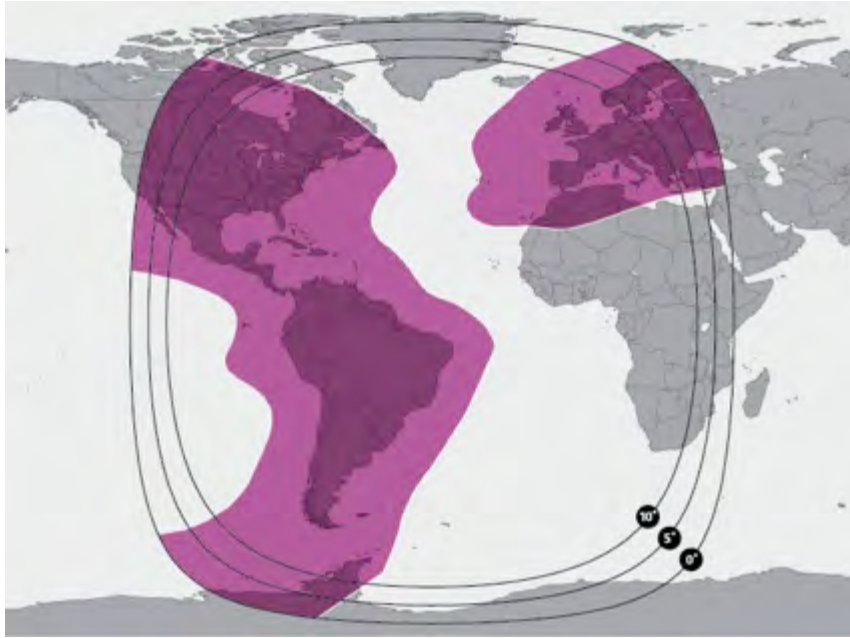
- Advantages of Synchronization, useful for inclined communications networks
- Relatively uncluttered



GEO

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

SES-6

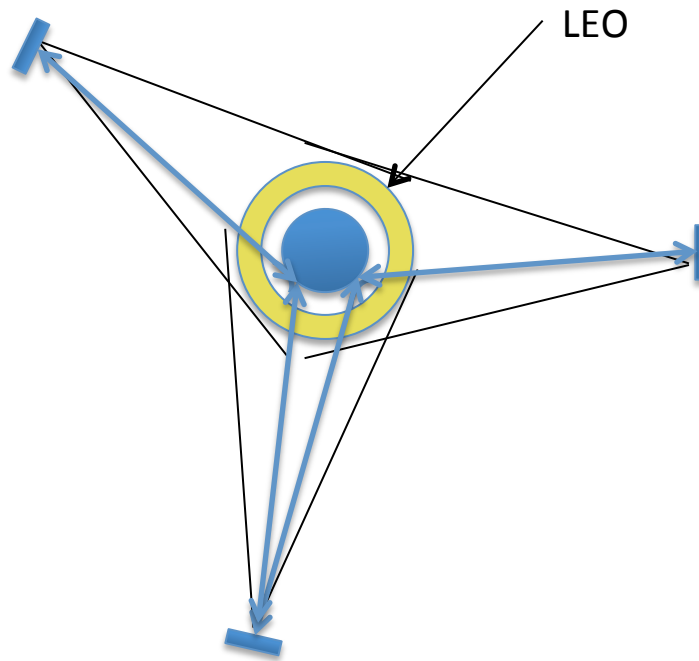


C-band coverage



Ku-band coverage

Inter-satellite communication





W

3,6,9

A

E

GSFC

90° W

**7
8**

90° E

white sands

Guam

12

5,10,11

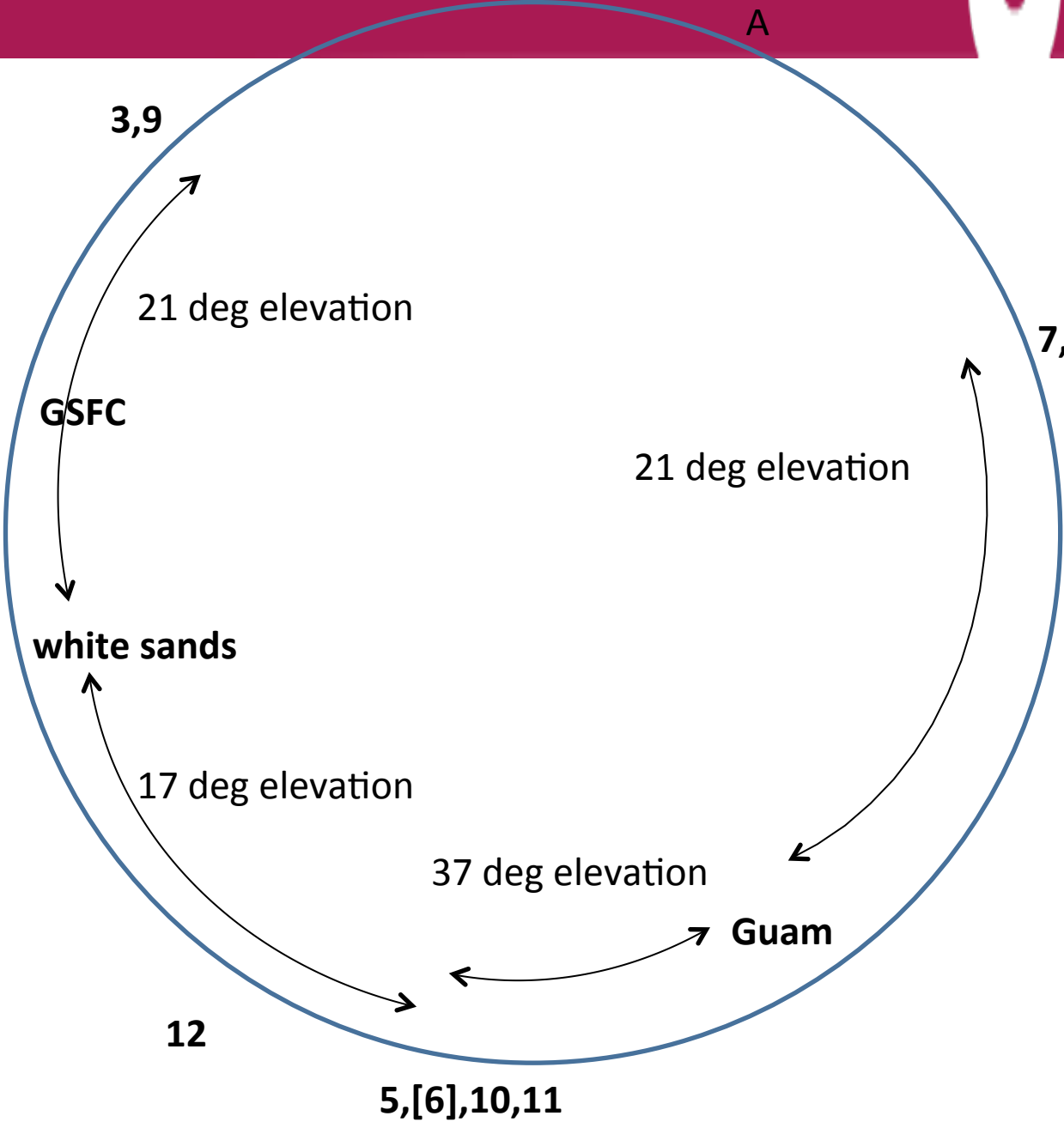
NASA - TDRS



W

A

E





Domains

Telecommunications

Navigation / GPS

Earth Observation

Space Science

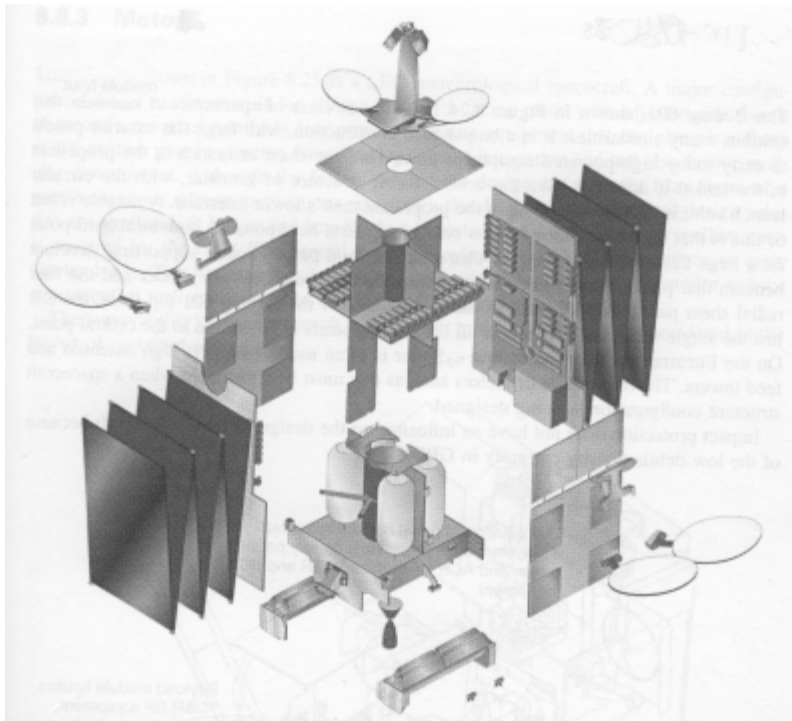
Human/Biology

Satellite elements

Platform

Payload

Telecommunications



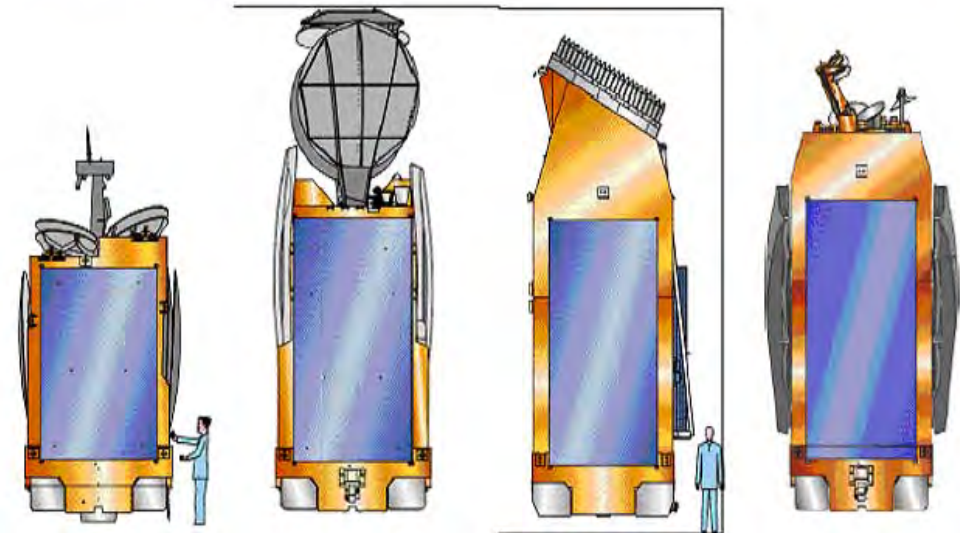
Typical Telecomms Satellite

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

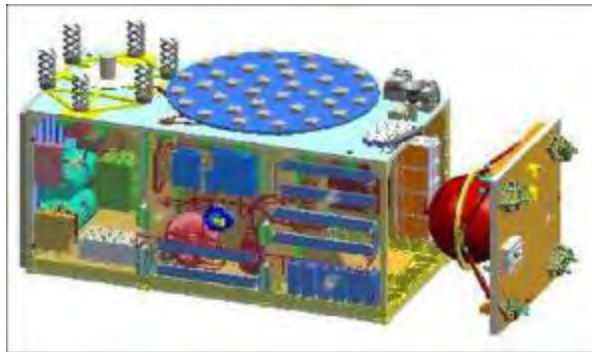
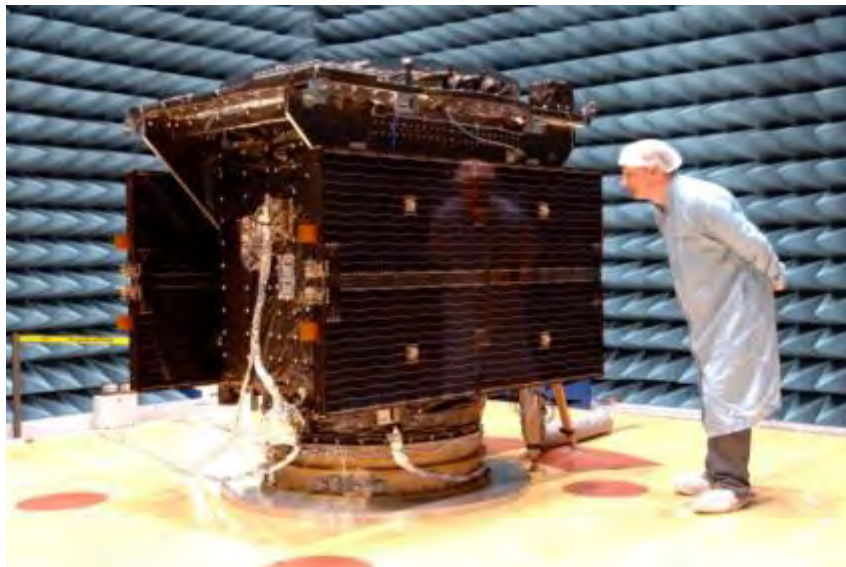


image credit:
OHB System

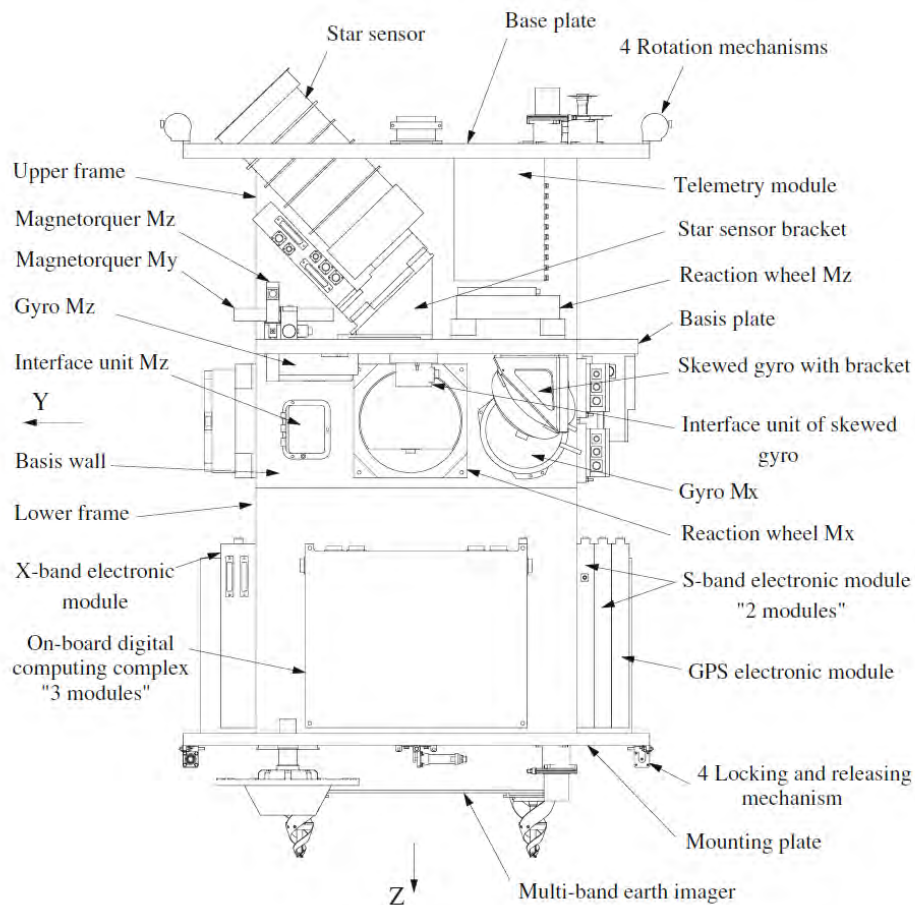


SSTL GIOVE-A, Galileo



Earth Observation Satellites

Earth Observation Small-Sat



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

Earth Observation Satellites (and planet orbiters)



Envisat, ESA

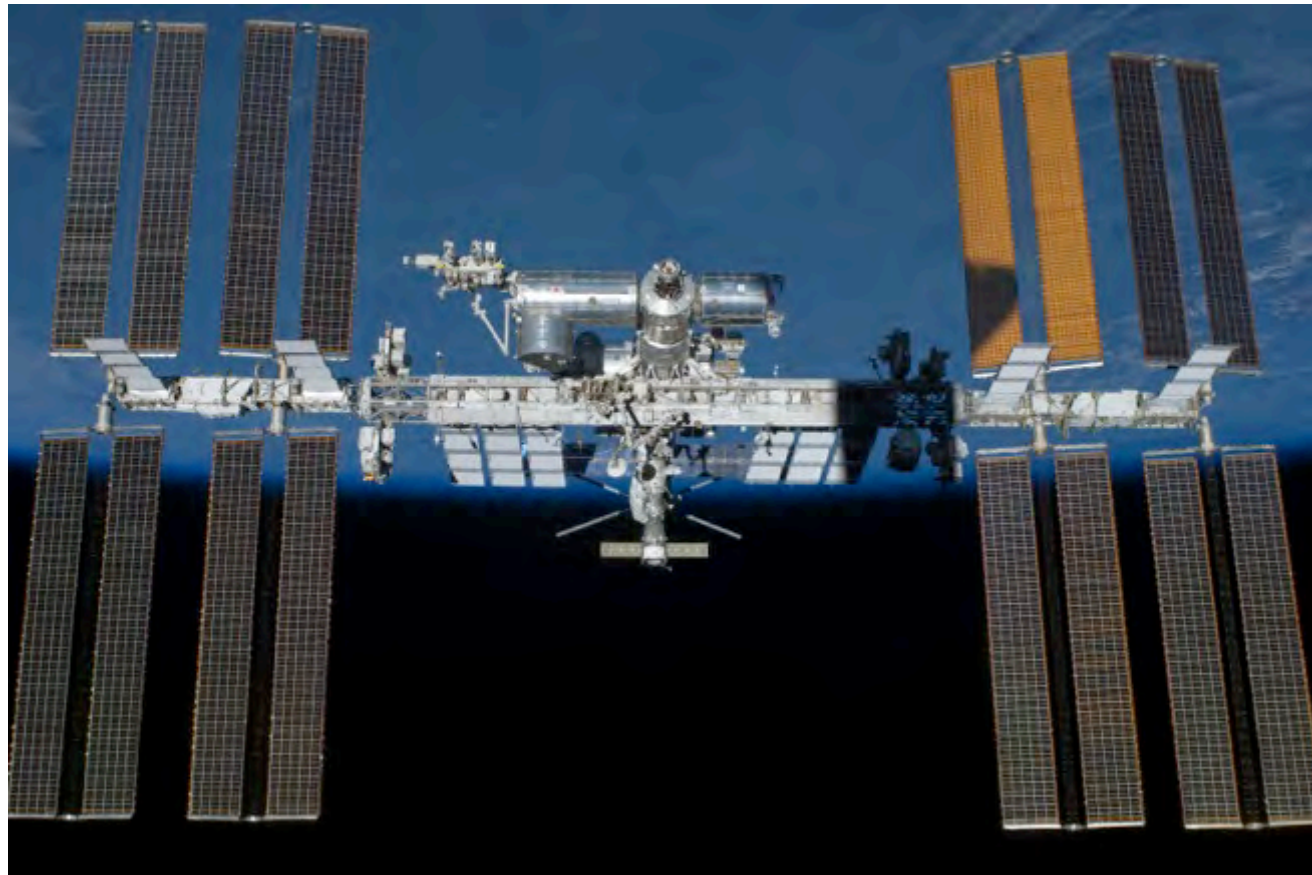


Science Satellites





Human Spaceflight



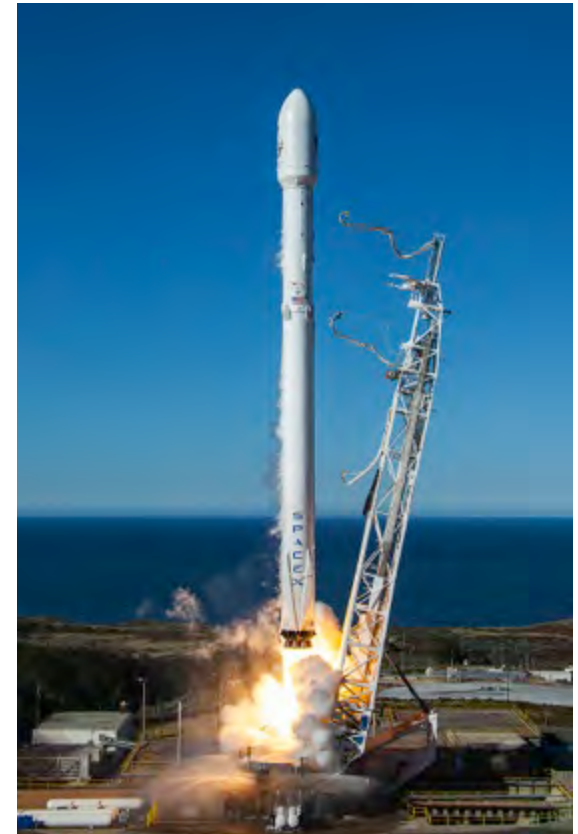
Getting into Space



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?

alan.smith@ucl.ac.uk

01483 204100