

# Space Environment & Technology

**Space Policy and Law Course 2016**

*Characteristics of Space, Their Use and Space Objects*

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**LONDON INSTITUTE OF SPACE POLICY AND LAW**

# The Space Environment and Space Technology: Orbits and Spacecraft

(or...The consequences of  
physical laws for space lawyers  
(and everyone else!))

# Wg Cdr Gerry Doyle

- HQ Air Command
- Illustrations from UK Military Space Primer (DCDC, 2008-10) (free online: <https://www.gov.uk/government/publications/the-uk-military-space-primer> ).
- Feedback encouraged.

# Outline

- The Space Environment.
- Orbital Motion and Kepler's Laws.
- Satellites and orbits:
  - Belts or bands of orbits.
  - Ground tracks.
  - Missions and orbits.
- A few words about launch and launch sites.

# The Space Environment

- Airless. (= hostile to life and to equipment)
- Radiation – solar and other. (= hostile to life and equipment)
- Temperature Extremes. (= hostile to life and equipment)
- Debris – natural and artificial. (= hostile to life and equipment)
- Inaccessible – launch is stressful and hazardous, repair or resupply is challenging.

# Defining Space

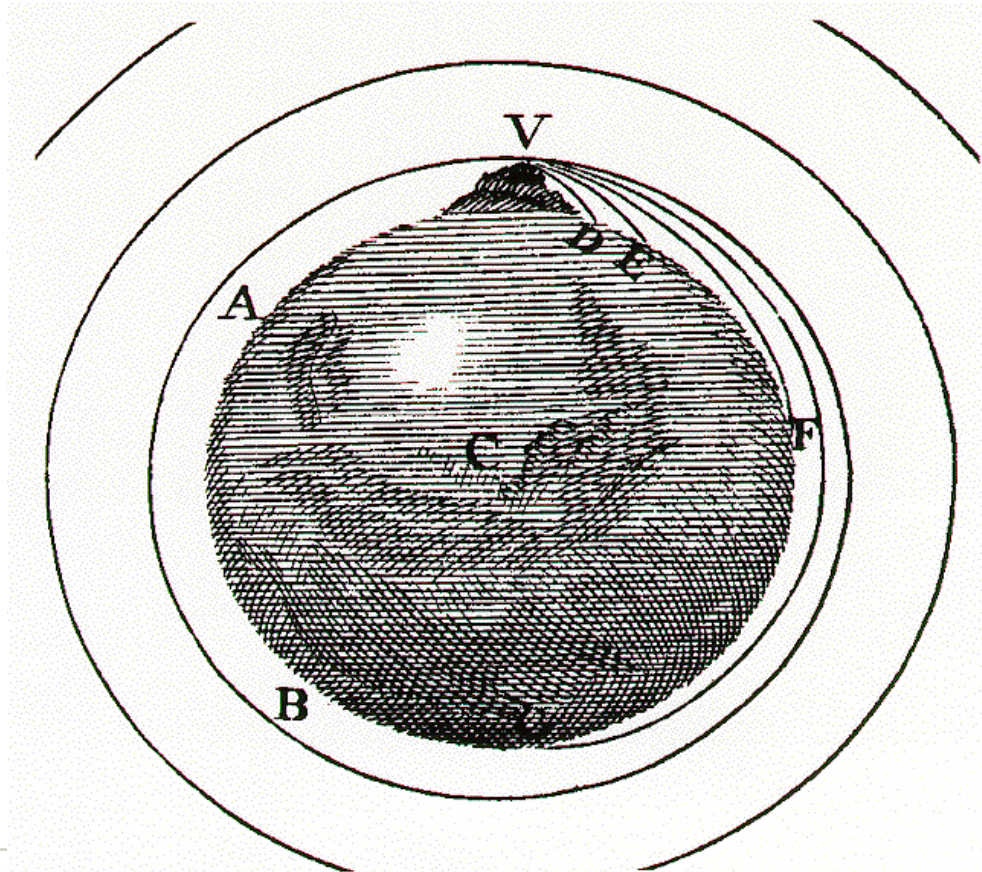
- There is no legal definition of space... But we can arrive at a pragmatic one (there are also arbitrary definitions).
- Aerodynamic flight (aviation) relies on lift from the craft's shape moving through the atmosphere, and usually on thrust from air-breathing engines.
- Orbital motion is different— continuous flight around the Earth, without thrust, in a (relatively) stable path.
- But only if you can get above the atmosphere. Otherwise drag/friction/air resistance burns you up or slows you down.
- So space is the altitude where orbit becomes possible. 'Beyond the atmosphere?' – but the atmosphere has no 'hard' boundary.

# Orbital Motion

- Things fall towards the centre of the Earth (*vertically*) in a predictable way.
- If a falling object is also moving across the surface of the Earth (*horizontally*), its path is a smooth curve.
- If it is moving fast enough, its path matches the curvature of the Earth's surface.
- So although it is falling towards the Earth, the Earth's surface is falling away from it at the same rate, and it never reaches the surface. This is orbital motion.

# The Cannon on the Mountain

- Newton (c 1687)
- Period of orbit close to Earth's surface 84 mins



# Practical Orbits?

- Where does orbital motion become possible?
- Above about 200 km, short duration orbits (days/weeks).
- Around 300 km, fairly stable orbits possible.
- Atmospheric drag/friction insignificant above about 500 km.

# Johannes Kepler (1571-1630)

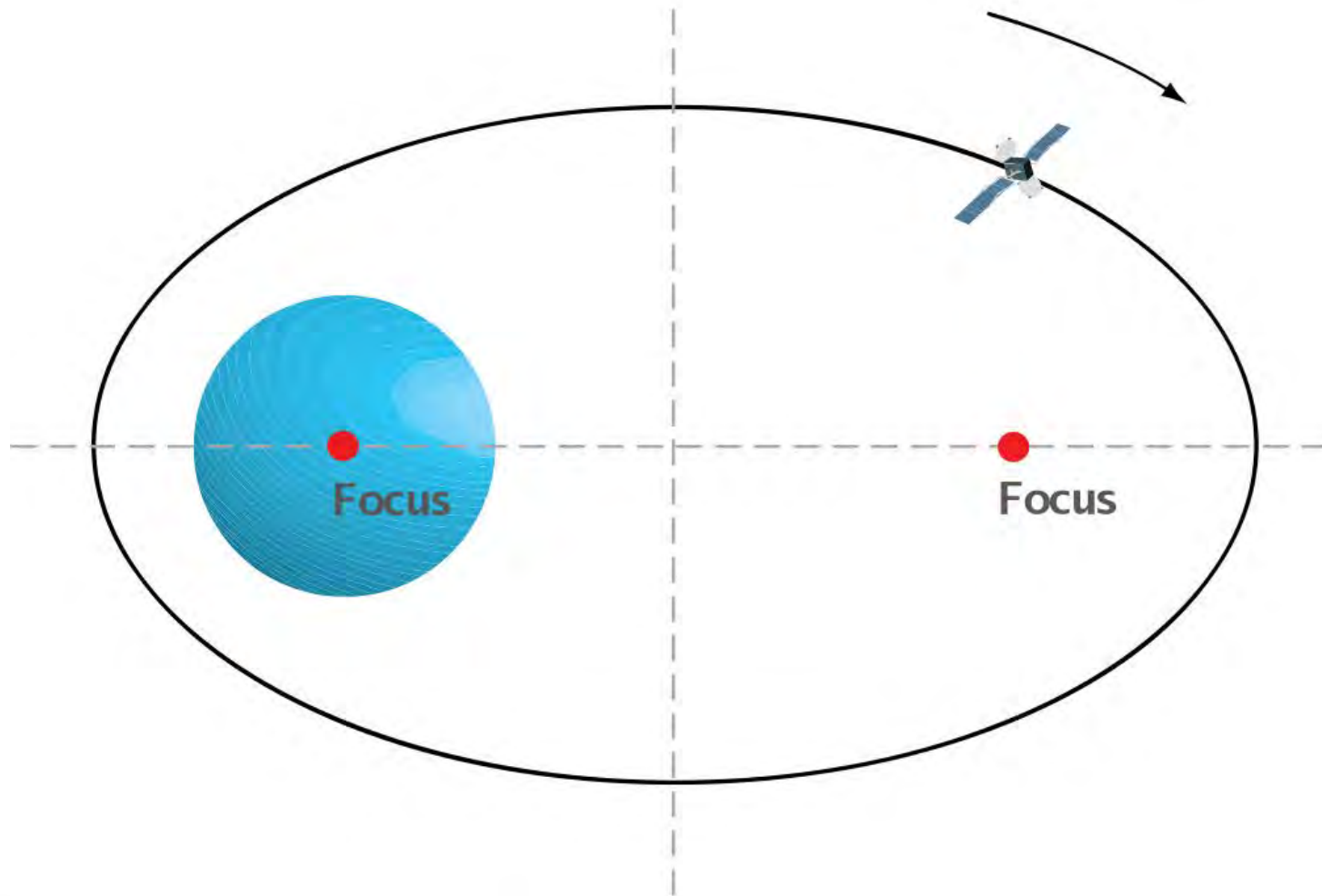


- Began as assistant to Tycho Brahe (d 1601) working on planetary orbits.
- Acquired Brahe's observations and tried to make (empirical) sense of them.
- Arrived at "Kepler's Laws".
- (and defended his mother from charges of witchcraft during 1620-21!)

# Kepler's Laws

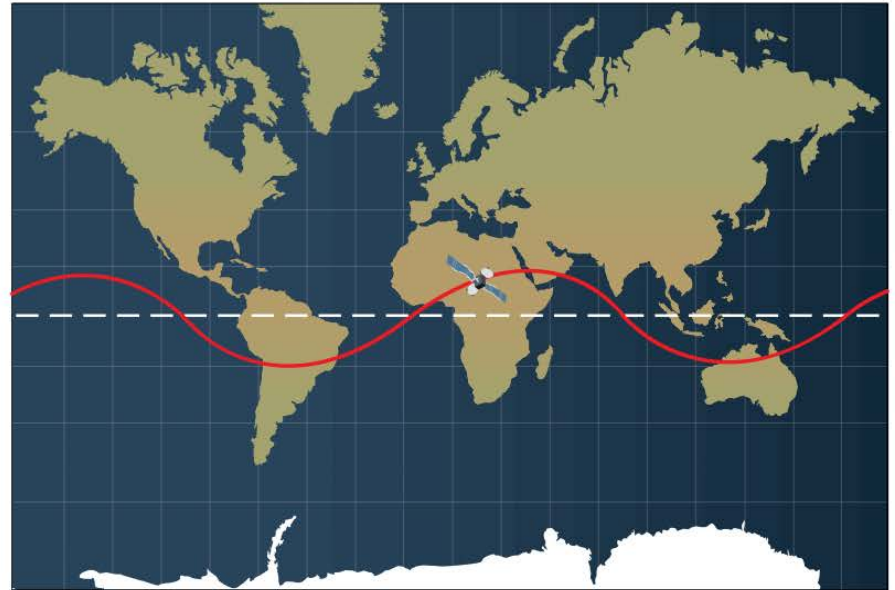
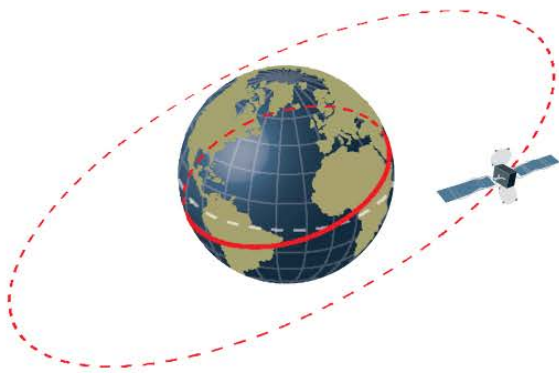
- Laws derived for planetary orbits around the Sun – but applicable to any gravitational orbit (though Kepler didn't know this...):
  - Orbits are ellipses with the Sun (central body) at one focus.
  - The radius vector sweeps out equal areas in equal times.
  - Semi-major axis and period are linked ( $r^3 \propto t^2$ ).

# Kepler's First Law

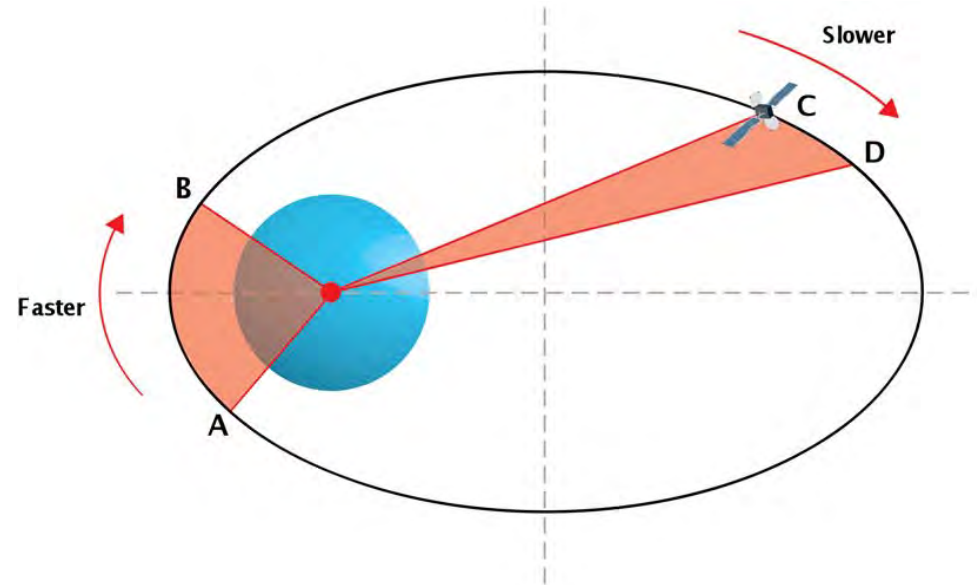
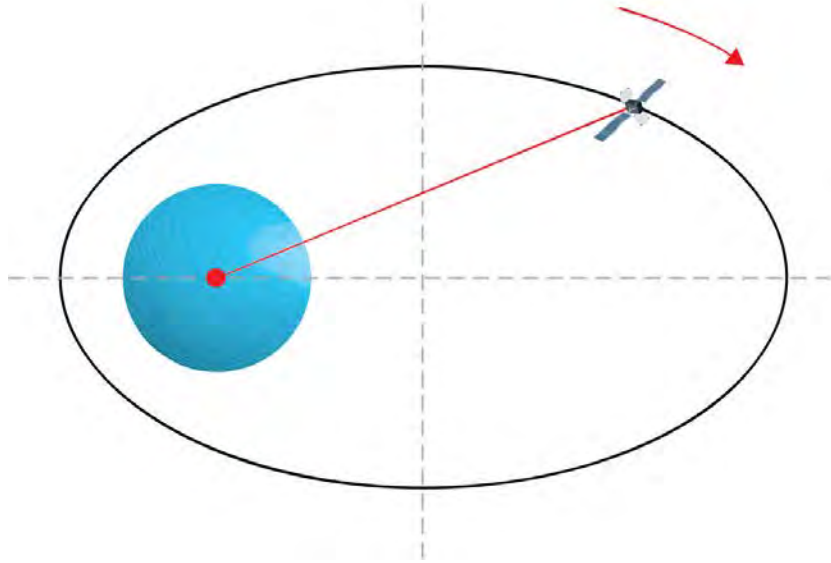


# Kepler 1 - implications

- Since the orbit includes the centre of the Earth, it either lies directly above the equator, or has parts North and South of it.

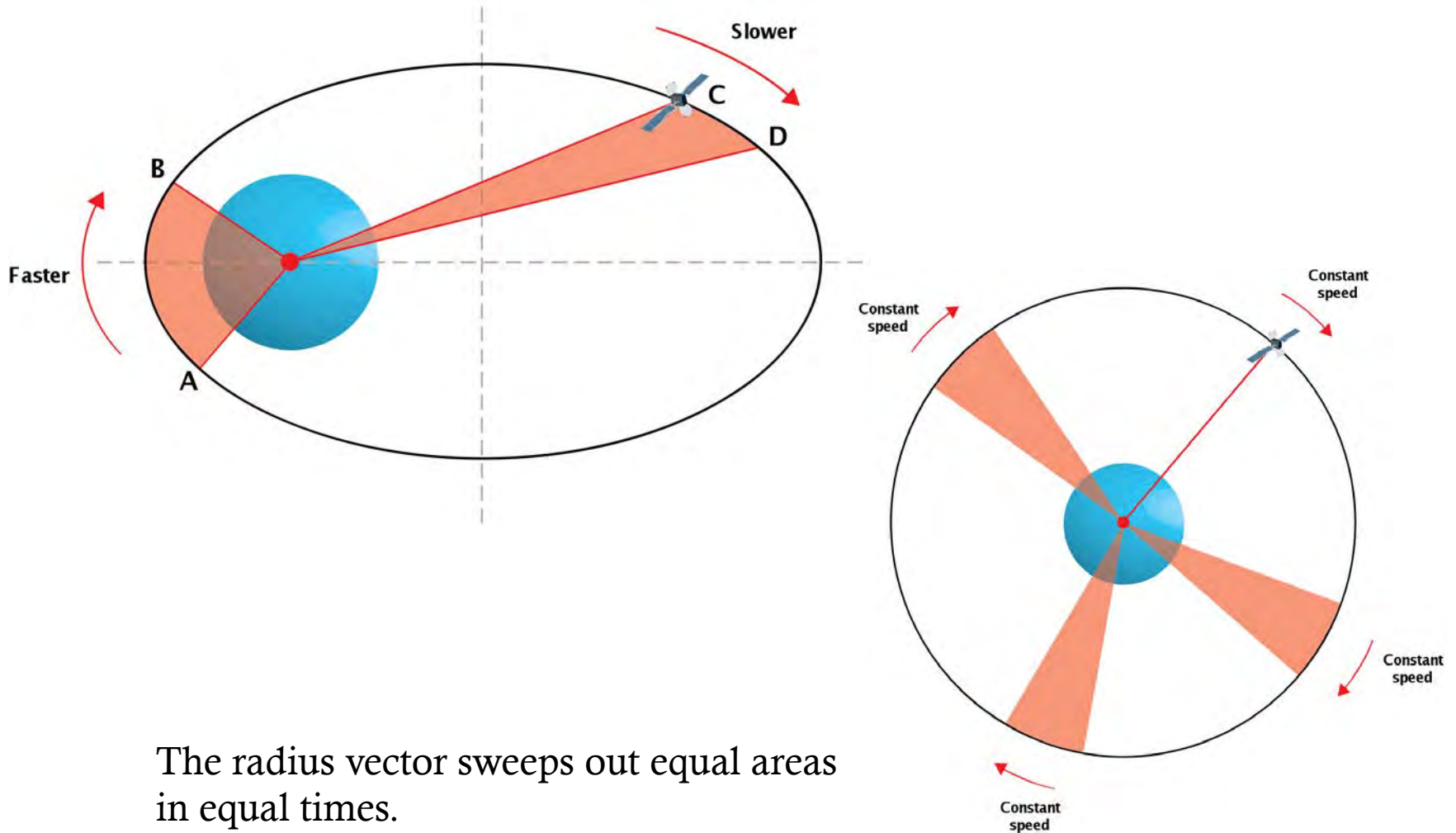


# Kepler's Second Law

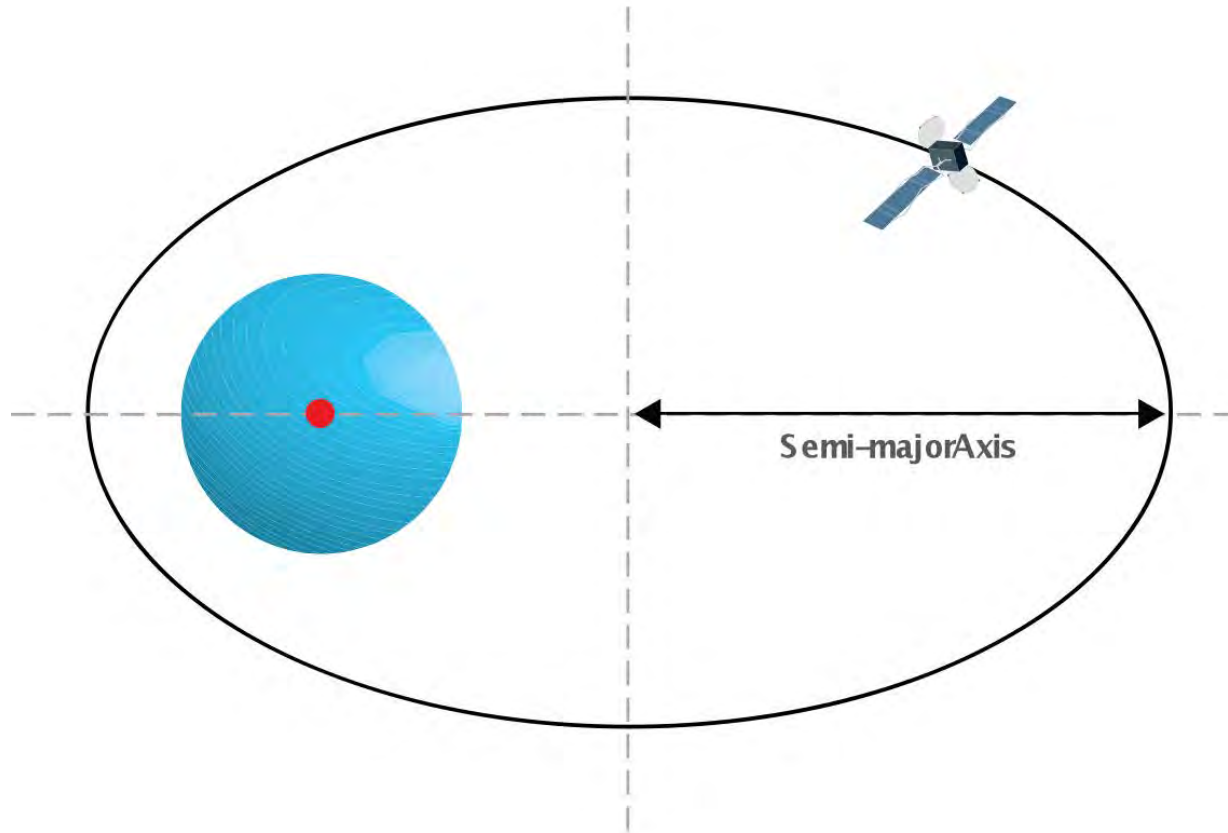


The radius vector sweeps out equal areas in equal times.

# Kepler 2 - Implications



# Kepler 3 - Implications



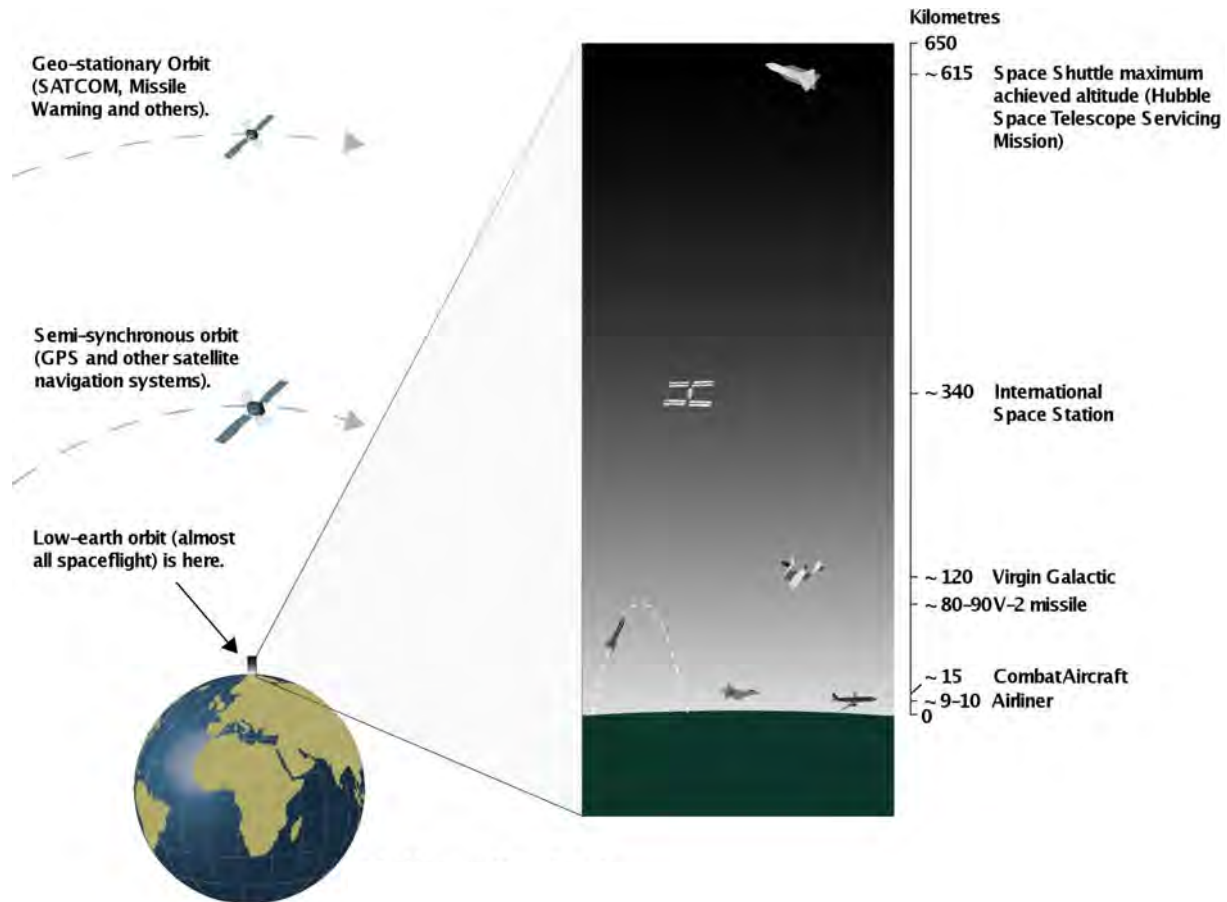
Semi-major axis and period are linked

ANY QUESTIONS ABOUT  
KEPLER?

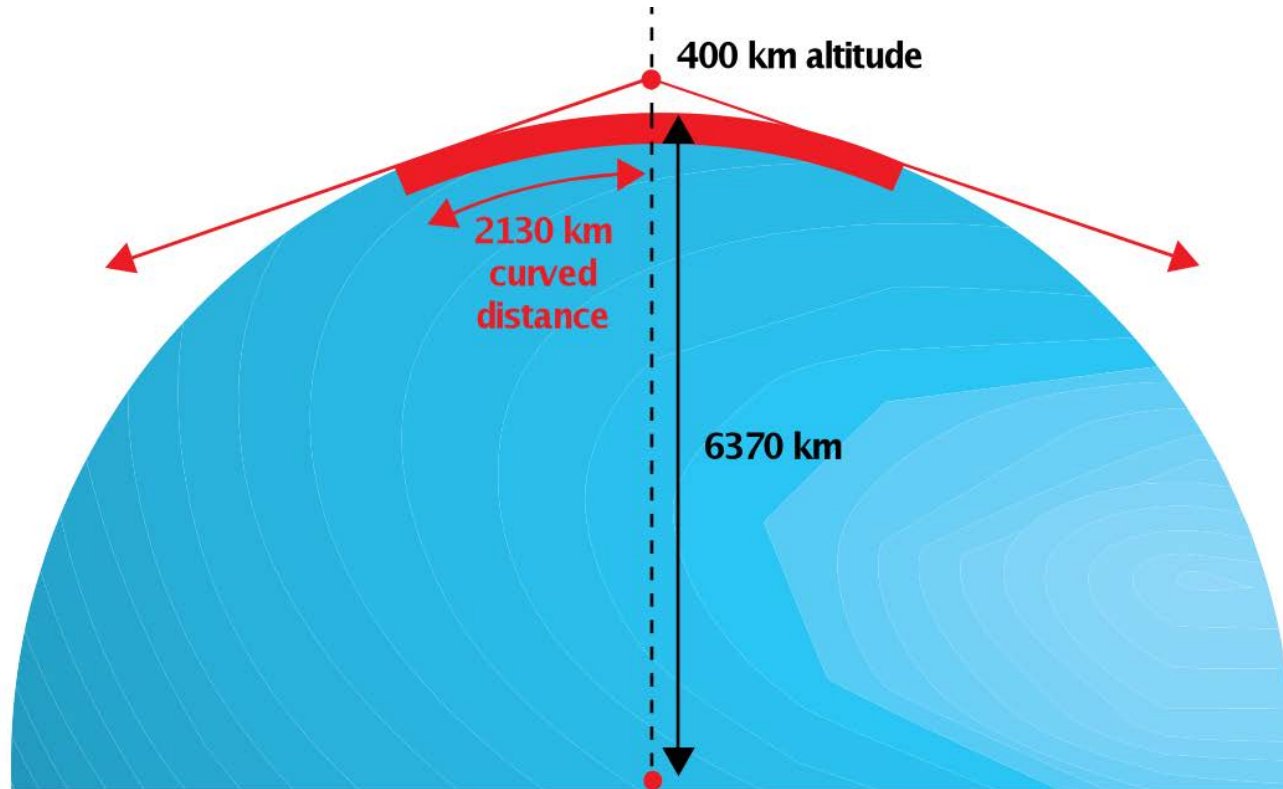
# Orbital Belts

- Low Earth Orbit (LEO).
  - 200-1200 km altitude?  $t=90-120$  mins
- Medium Earth Orbit (MEO).
  - 20 200 km altitude.  $t= 12$  hours
- Geostationary Orbit (GEO).
  - 35 800 km.  $t=24$  hours
- Highly Elliptical Orbits (HEO).
  - various

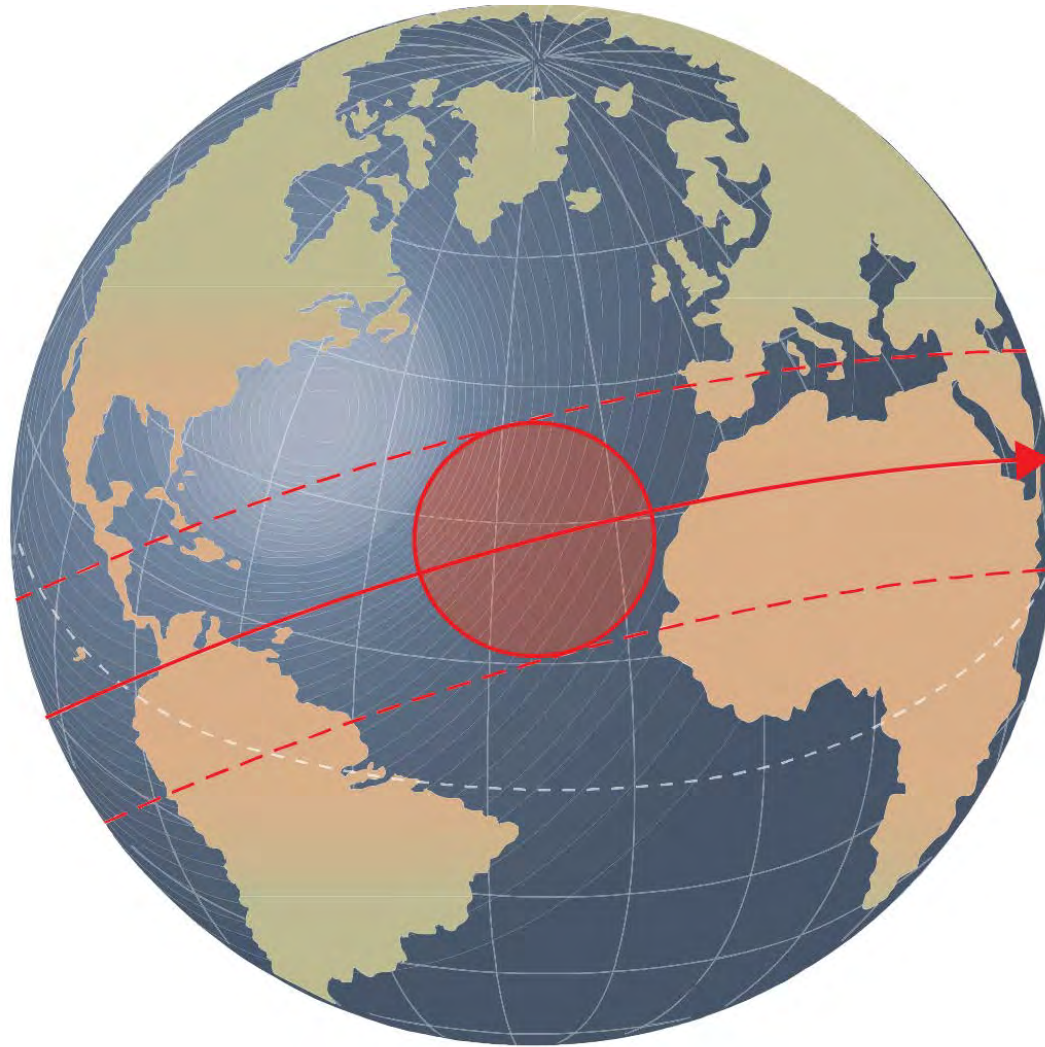
# Orbital Belts (to scale)



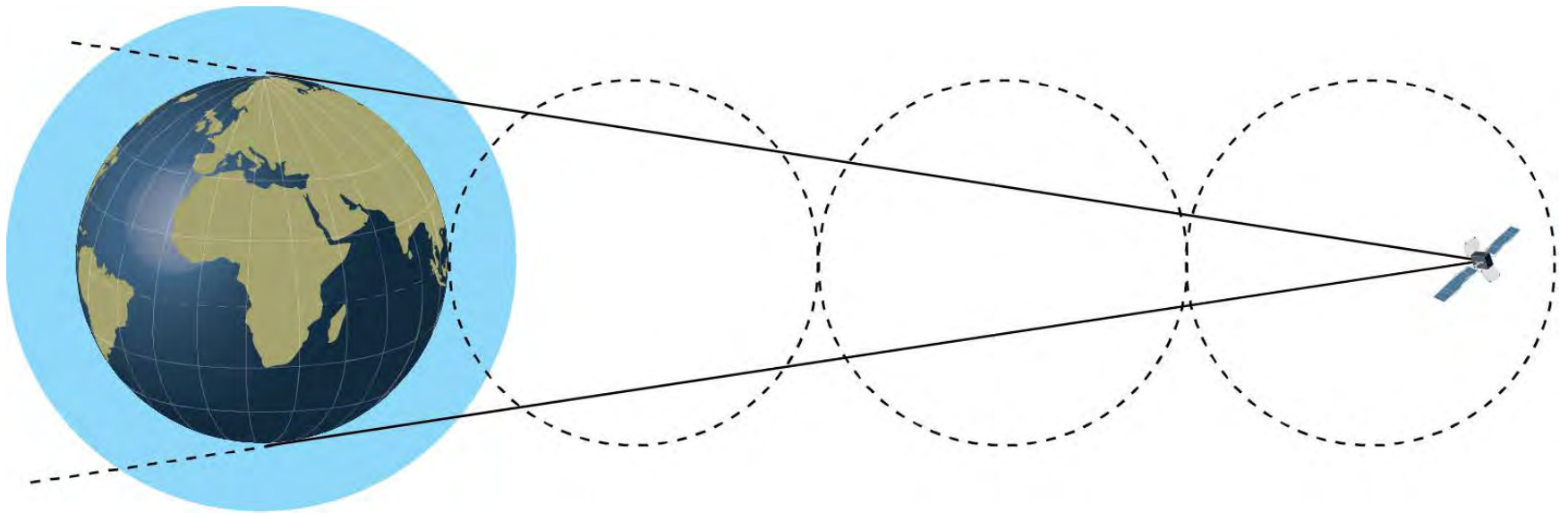
# Fields of View - LEO



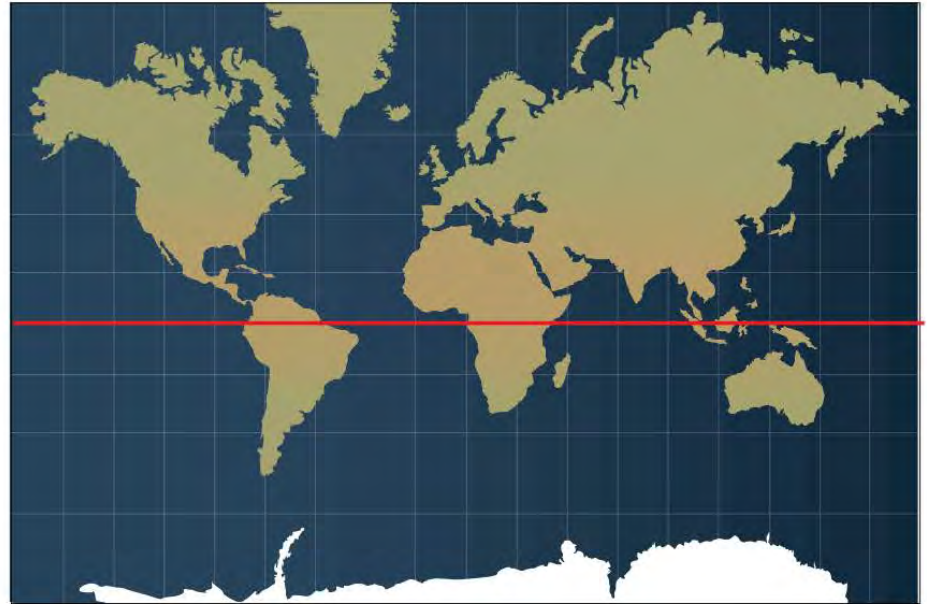
# Plan view (same altitude)



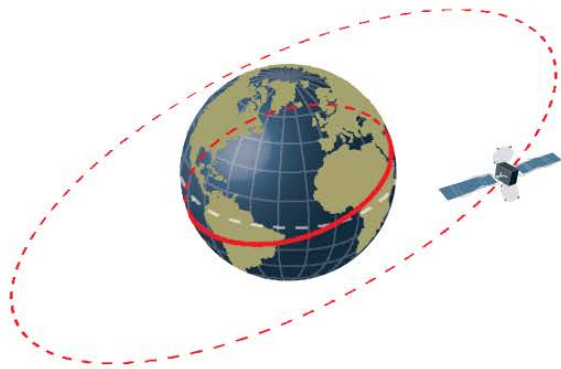
# Field of View - GEO



# An Equatorial Orbit



# A Circular Inclined Orbit



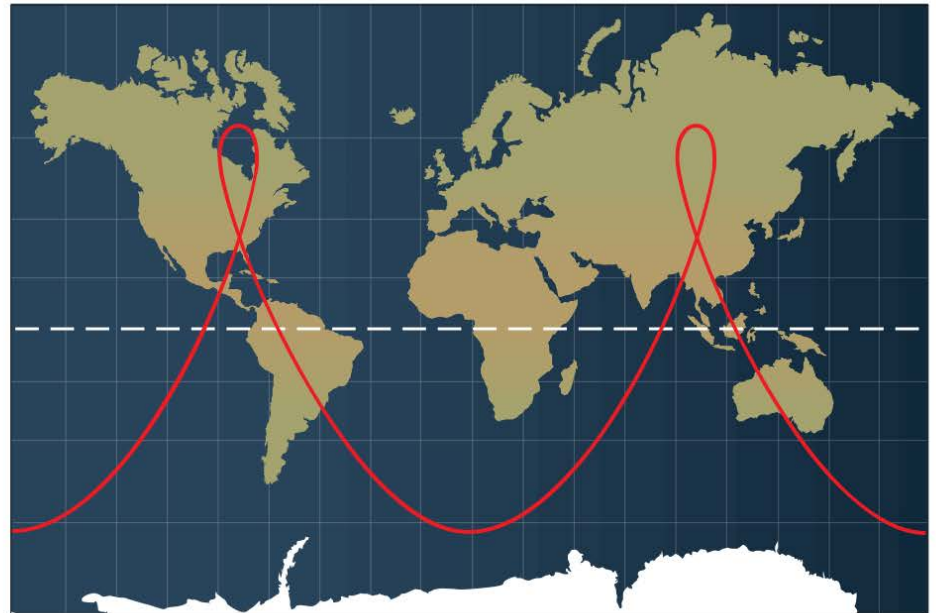
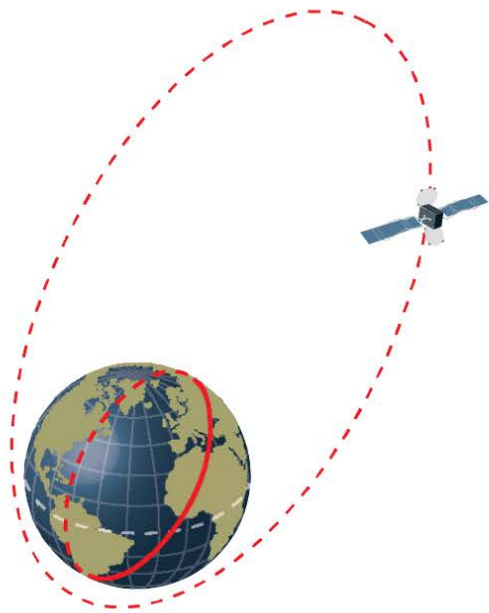
# Polar orbit



# Multiple Orbits



# Highly Elliptical Orbit (HEO)



# GEO



# Missions - LEO

- Anything that benefits from being near the Earth's surface:
  - Observation – the closer the better (for detail).
  - Manned spaceflight (for protection from radiation).
- Anything that benefits from short periods and potentially overflying all of the Earth's surface.

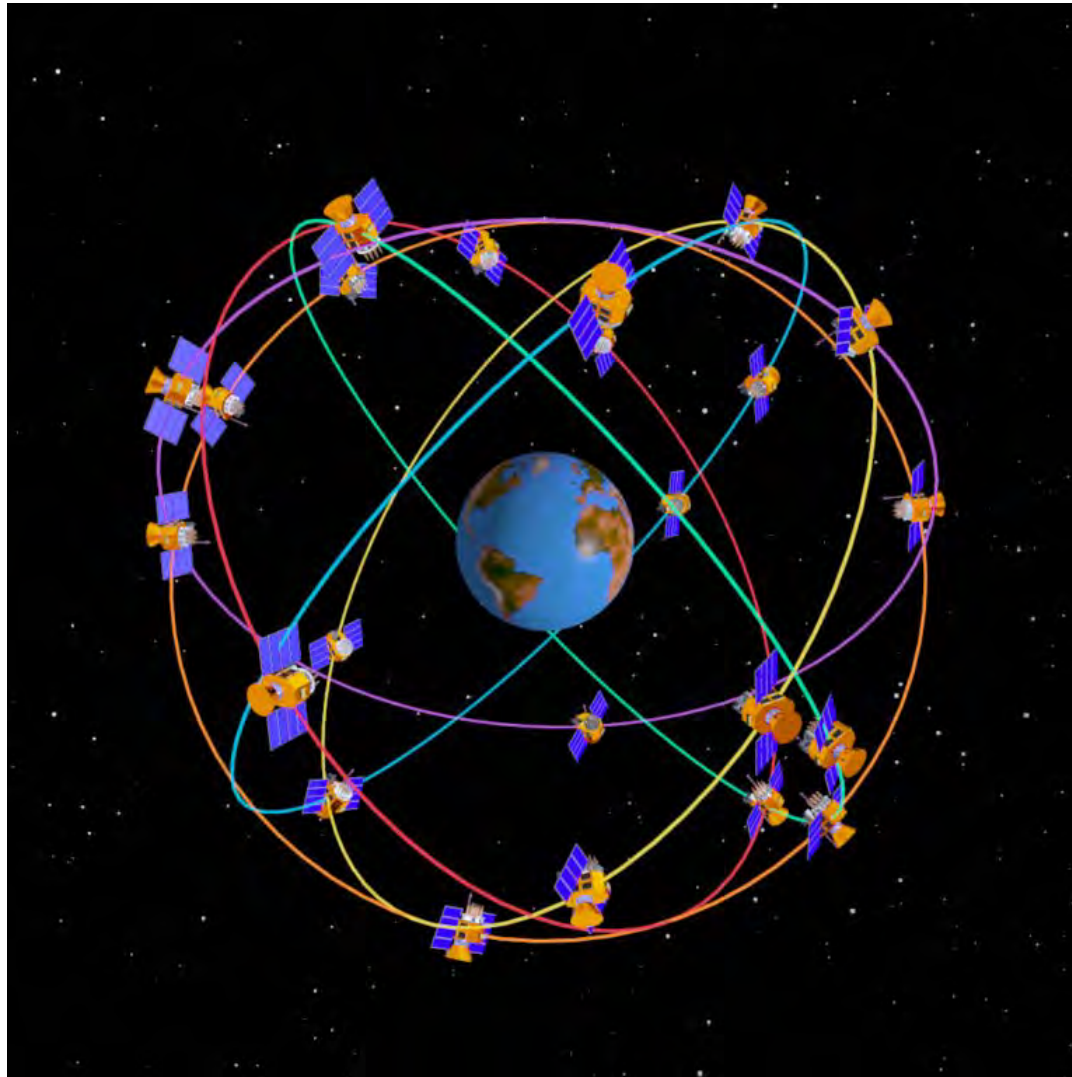
# Missions - GEO

- Anything that benefits from a fixed view of a large part of the Earth's surface:
  - Communications and Broadcasting (serve a large 'market' or span long distances).
  - Surveillance (missile warning, weather observation, other environmental monitoring).

# Missions - MEO

- Anything that benefits from the repeatability of the 12 hr semi-synchronous orbit.
  - Navigation – the satellites need to have their orbital positions determined periodically.
  - And the orbit is high enough to ensure stability and uncluttered enough to avoid manoeuvre.

# The GPS Constellation



# Launch Sites (1)

- Launch site constrains orbital inclination.
- Inclination at least equal to latitude of launch site – can be more, can't be less.
- So for low inclination (eg geostationary orbit), launch near the equator.

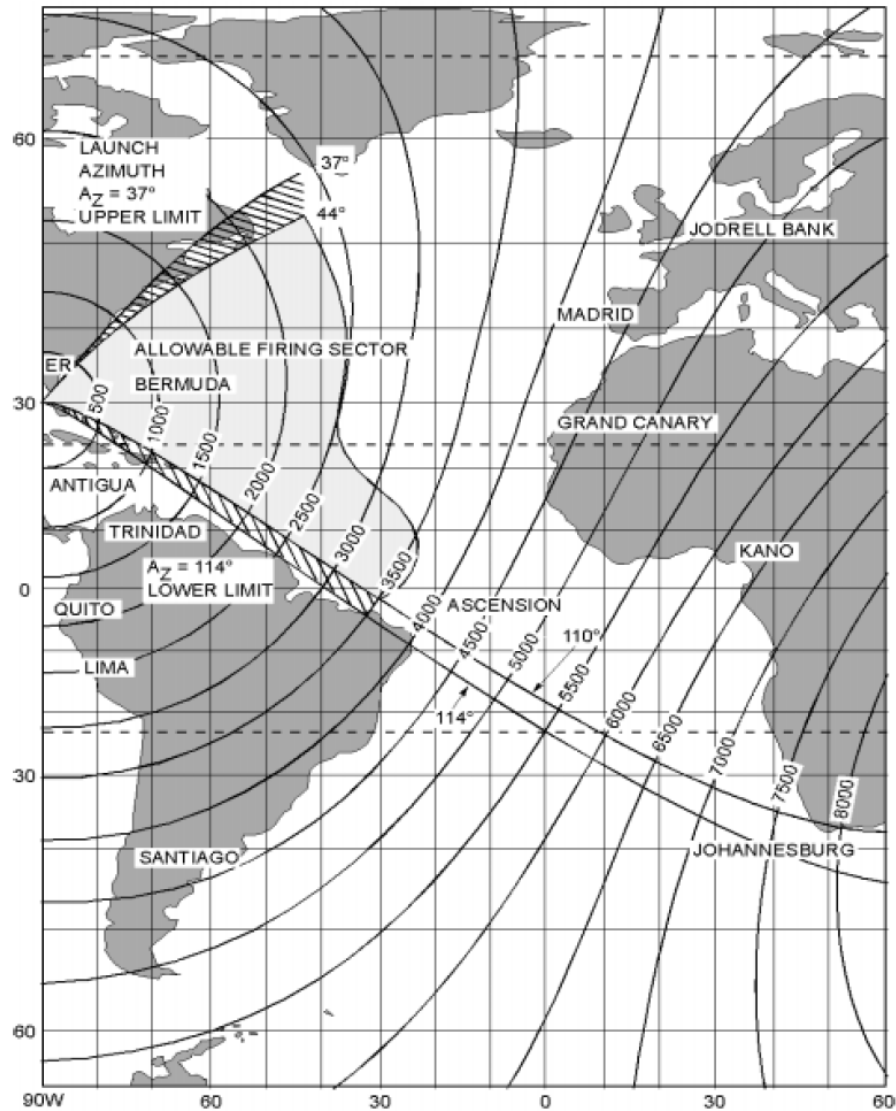
# Kennedy Space Center - 28°N



## Launch Sites (2)

- Launch hazards – fuel risk / explosion at launch – degree of isolation desirable.
- Launch hazards – failure in initial fly-out or planned recovery/jettison of components – need safe impact area.

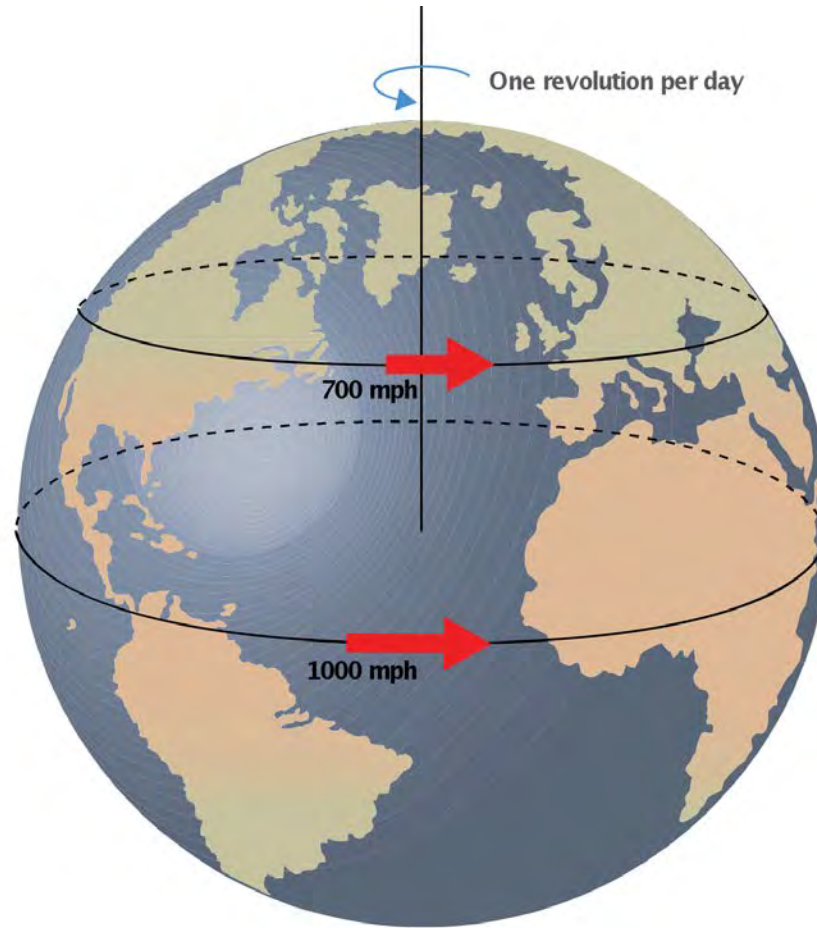
# KSC Range Safety



## Launch Sites (3)

- For equatorial orbits, there are performance advantages in launching from a site at low latitudes.
  - Meet constraints on latitude v inclination.
  - The rotation of the Earth provides 'free' velocity (speed in the correct direction). This can permit use of a smaller launcher, or carriage of an increased payload.
  - Kourou, French Guiana ( $3^{\circ}\text{S}$ ) is a good example.

# Launch Sites (3)



# Conclusions

- 'Practicality of orbit' is a pragmatic definition of space.
- Orbital motion is a combination of horizontal velocity and vertical acceleration towards (the centre of) the Earth.
- Kepler's Laws have concrete consequences for spaceflight.
- The combination of orbit type, altitude and the resulting ground track facilitate the various satellite missions.
- Launch site constraints have significant implications for achievable orbits.

Thank you for your attention!

Any questions?

# Further questions and correspondence welcomed

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