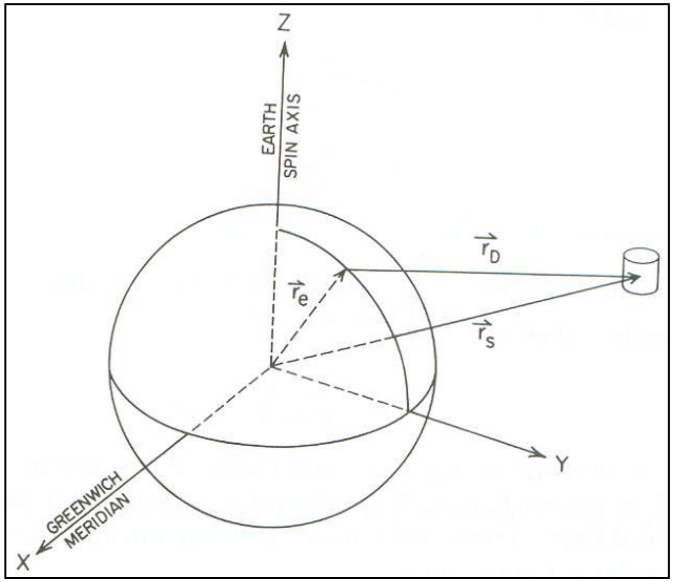
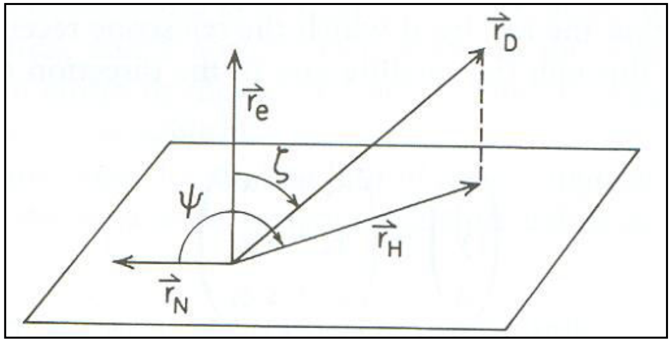
satellite navigation and the global positioning systems.

Satellite Tracking

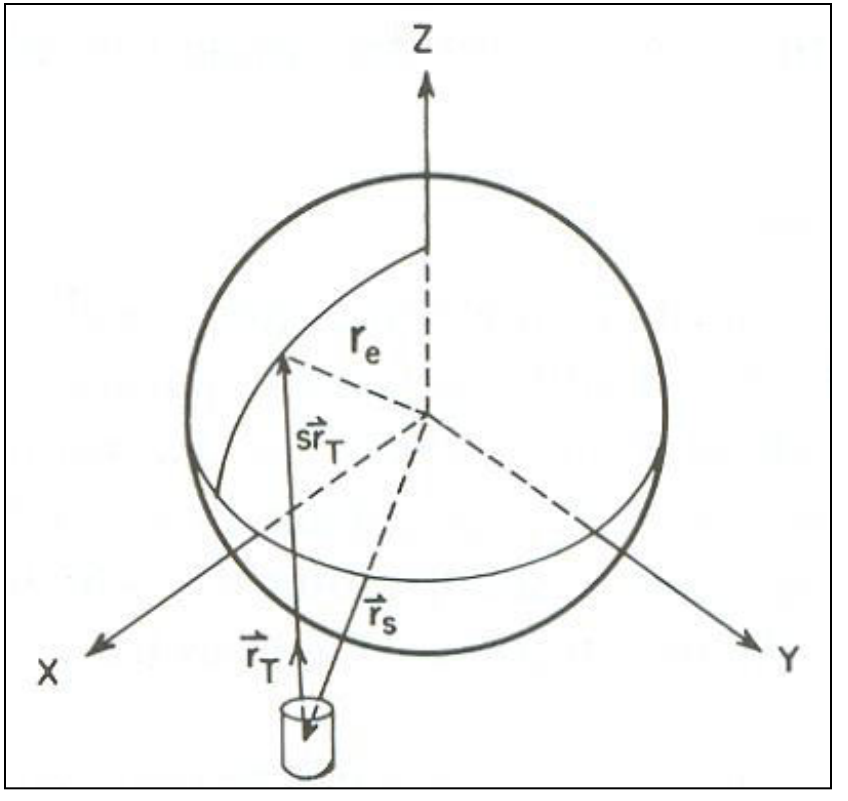
To “track” a satellite, one needs to be able to point one’s antenna at it. This requires calculating the azimuth and elevation angles for the satellite. Fundamentally, this is a geometry problem, which is discussed in section 2.5.2 of the text.





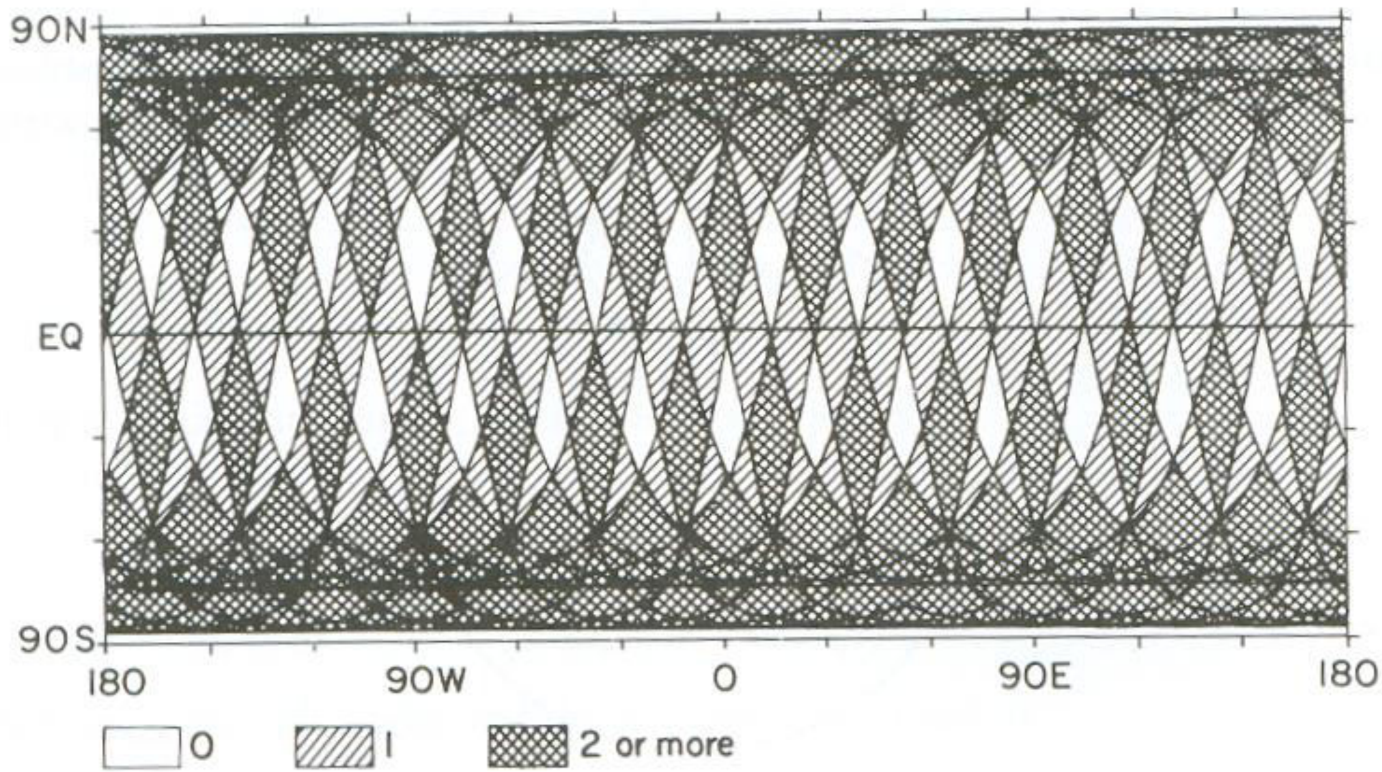
Satellite Navigation

Navigation means calculating the location of the spot being sensed. This is also a complex geometry problem which is discussed in section 2.5.3 of the text.



Space-Time Sampling

How often is a particular point observed? This topic is covered in section 2.6 of the text.



MetSat Orbits

- Geostationary
- Sunsynchronous
- LEO
- MEO
- Molniya
- Formations
- Constellations

Geostationary Orbit

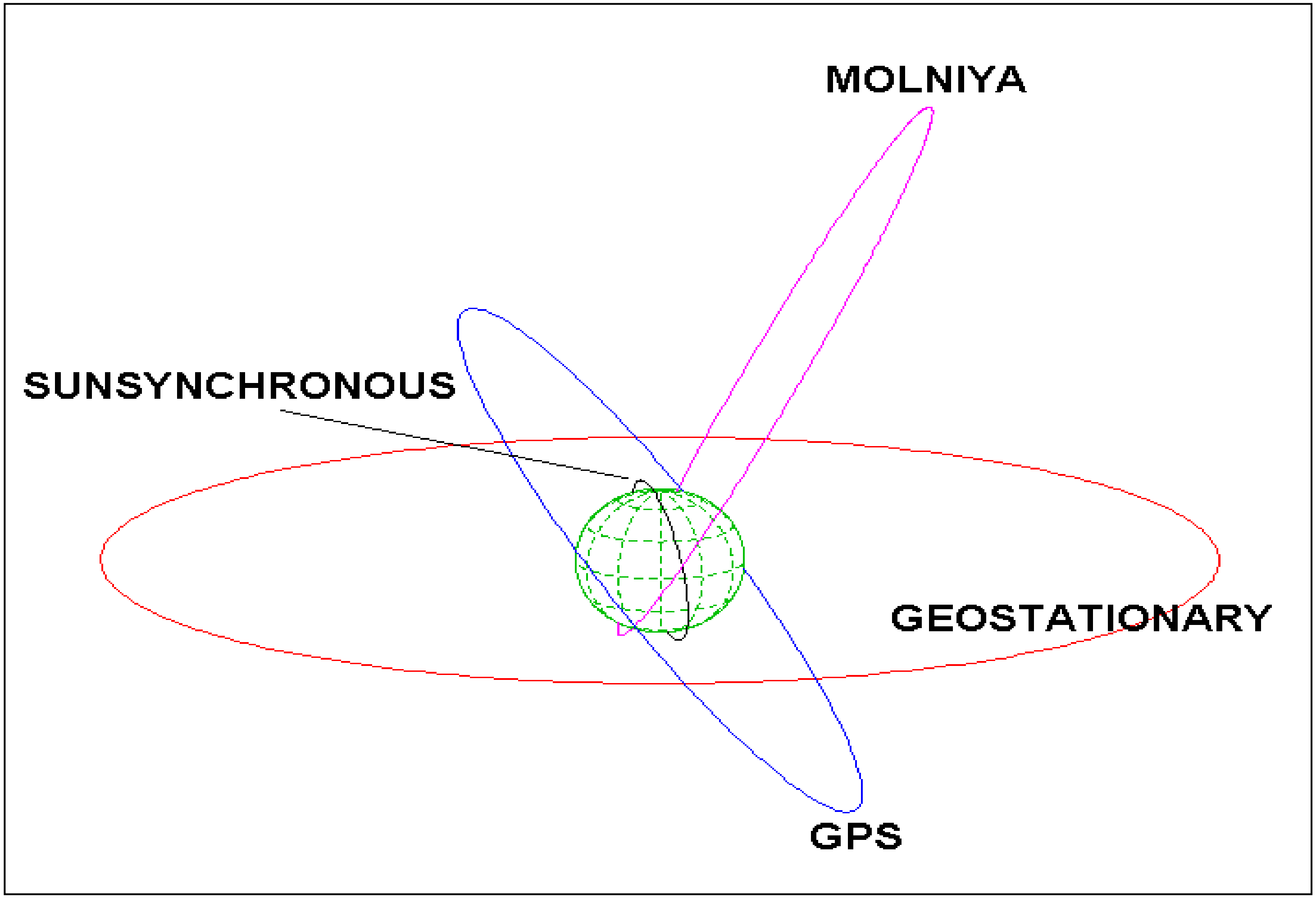
Geostationary satellites remain at a constant radius, latitude (0°), and longitude. Let's construct the orbital elements:

$\phi = \sin^{-1}(\sin\Gamma \sin i)$
highest latitude = i

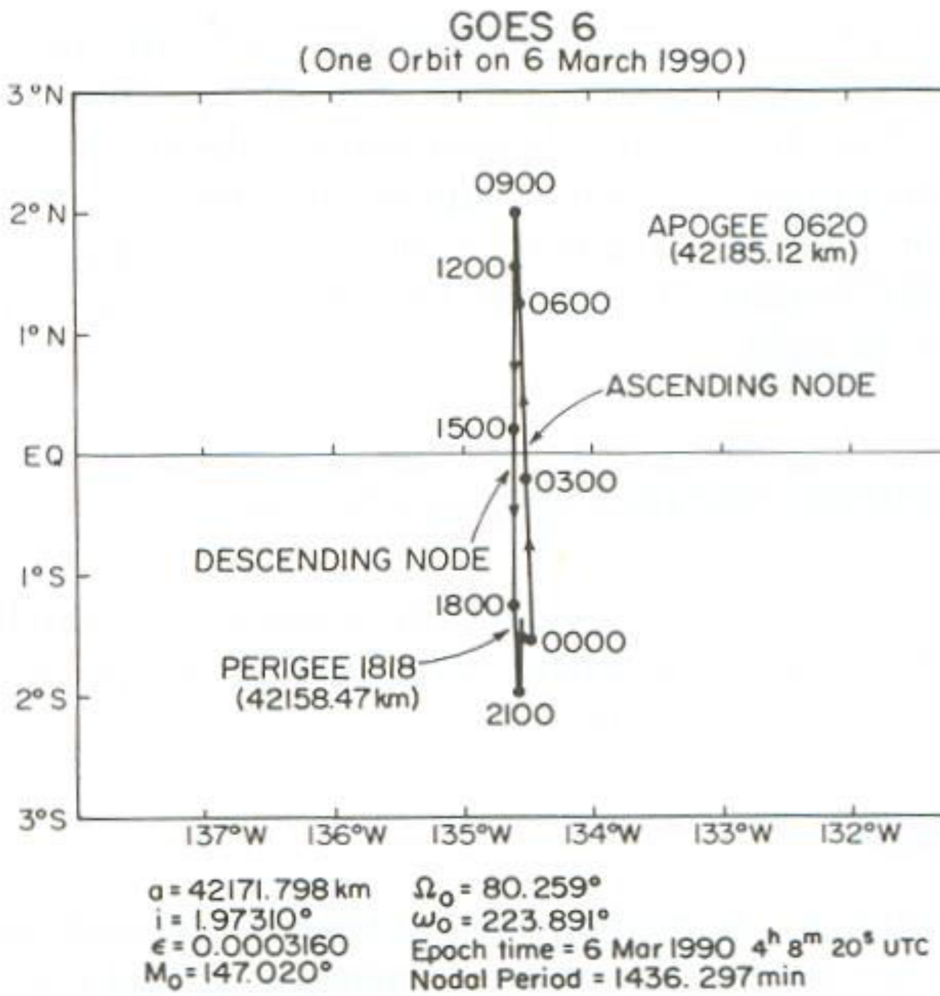
1. Circular orbit ➔ $\varepsilon = 0$
2. Stays at equator ➔ $i = 0$
3. Orbits at the same speed that the earth rotates (7.292115922 x 10^{-5} radians/s) ➔ a = 42,168 km
4. Ω doesn't matter for $i \approx 0$
5. ω doesn't matter for $\varepsilon \approx 0$
6. Choose M (consistent with Ω and ω) so that the satellite is at the desired longitude.

~ 6.6 earth radii

Geostationary Orbit



Geostationary Ground Track



At this time GOES 6 was **NOT** being precisely maintained

Sunsynchronous Orbits

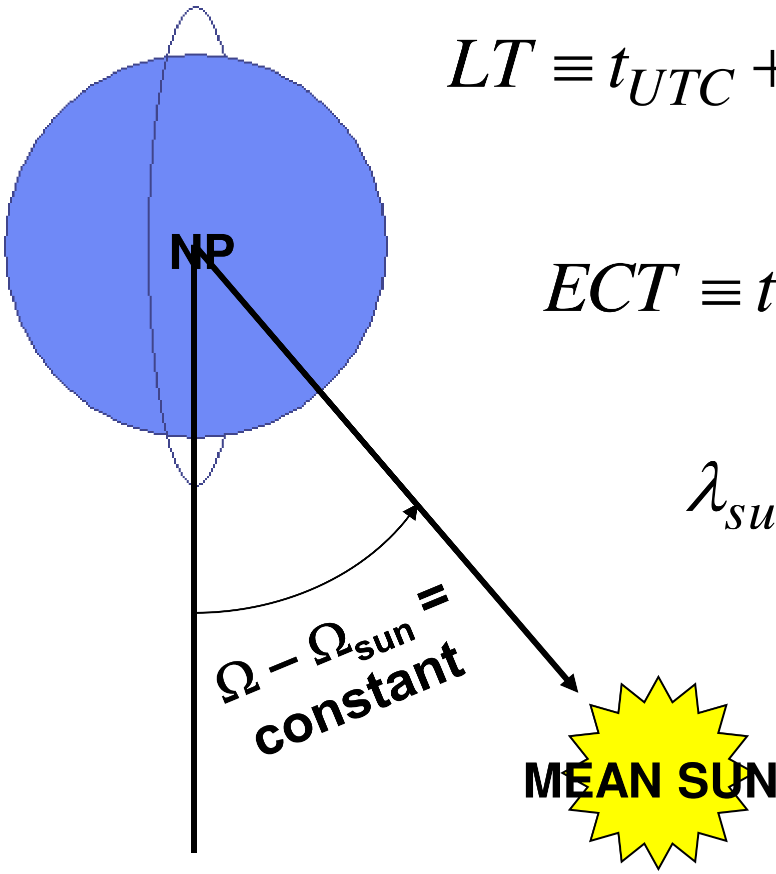
The right ascension of ascending node changes:

$$\frac{d\Omega}{dt} = -\overline{n}\left[\frac{3}{2}J_2\left(\frac{r_{ee}}{a}\right)^2\left(1-\varepsilon^2\right)^{-2}\cos i\right]$$

The inclination angle can be chosen such that Ω changes at the same rate that the earth orbits the sun, 2π radians per tropical year or 0.98565°/day.

Note that i > 90° (retrograde) for a sunsynchronous orbit. For NOAA satellites, $i \approx$ 99°.

Equator Crossing Time



$$LT \equiv t_{UTC} + \frac{longitude}{15^\circ}$$

Not the time on your watch!

$$ECT \equiv t_{UTC} + \frac{\lambda_{AN}}{15^\circ}$$

Local Time at ascending node

$$\lambda_{sun} = -15^\circ \left(t_{UTC} - 12\right)$$

$$\Delta\lambda \equiv \lambda_{AN} - \lambda_{sun} = \Omega - \Omega_{sun}$$

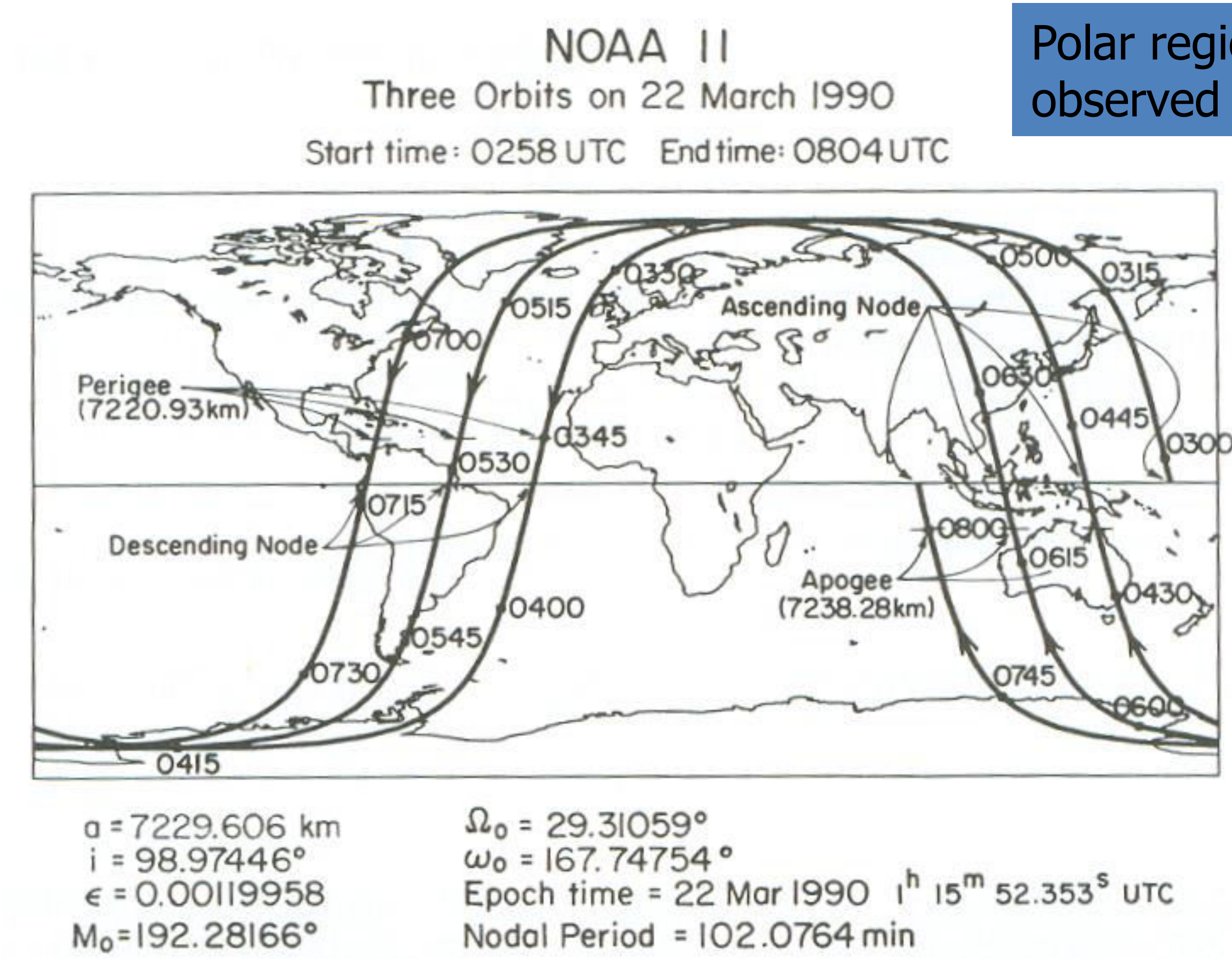
$$ECT = 12 + \frac{\Delta\lambda}{15^\circ}$$

Descending node ECT is 12 hr after ascending node

Sunsynchronous Orbital Elements

1. Choose a for the period that you want
2. Circular orbit ➔ $\varepsilon = 0$
3. Calculate i from $d\Omega/dt$ formula to make a sunsynchronous orbit
4. ω doesn't matter for a circular orbit
5. Choose Ω for the equator crossing time that you want (and launch at the right time)
6. M doesn't really matter because the orbits shift daily.

Sunsynchronous Groundtrack



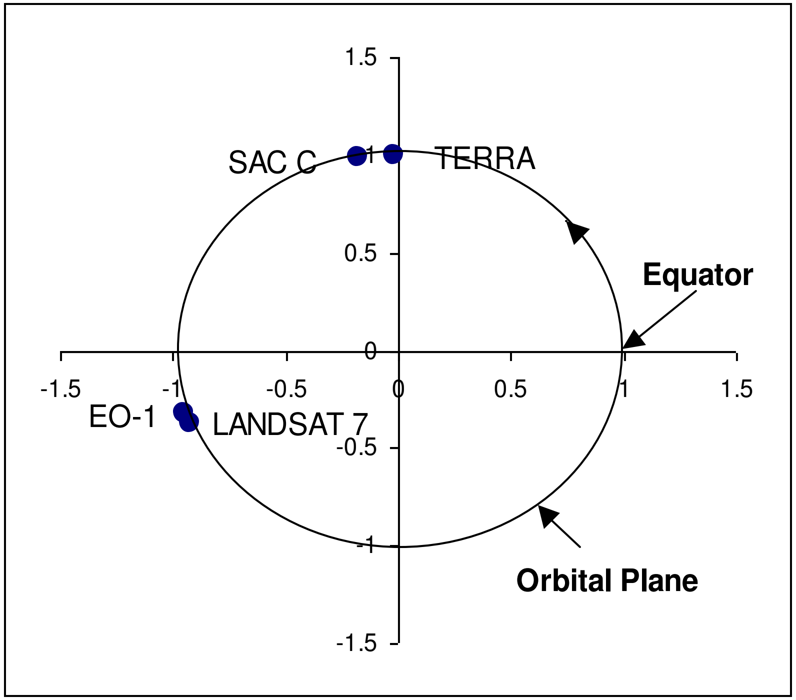
Polar regions are observed every orbit

Equatorial regions are observed twice per day per satellite

Formations

For two satellites to fly in formation, their orbital elements must be related.

- Their semimajor axes must be identical--else they would have different periods and would separate)
- Their inclination angles must be identical--else they would veer left and right)
- Their eccentricities must be identical (preferably zero)—else they would oscillate up and down
- And…



EO-1 flies 1 min behind Landsat 7

SAC-C flies 27 min behind EO-1

Terra flies 2.5 min behind SAC-C

Formations…

- Their mean anomalies and arguments of perigee must be related.

  Let Δt be the desired separation time. Then their angular separation must be:

$$\Delta\Gamma = \Delta\left(M + \omega\right) = 360^\circ \frac{\Delta t}{\tilde{T}}$$

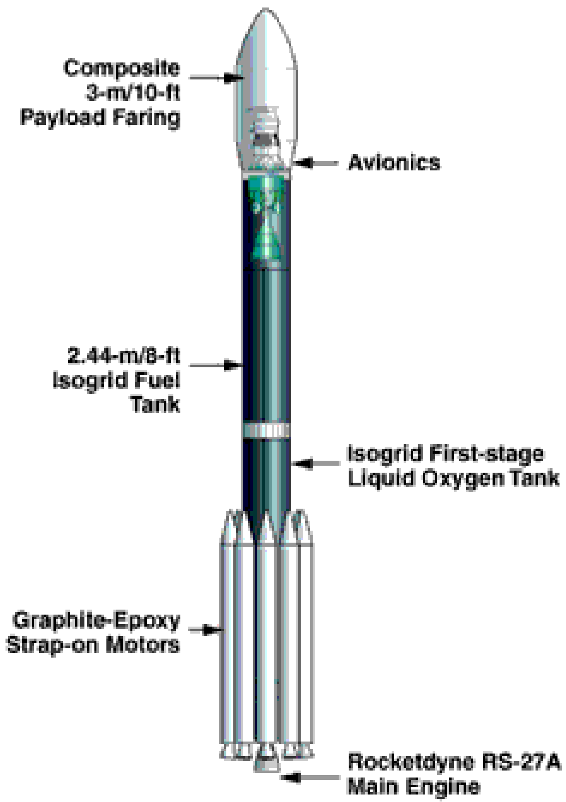
Assumes a circular orbit, for which $M = \theta$

- Their right ascensions of ascending node must be related so that they travel over the same ground track:

$$\Delta\Omega = \frac{d\Omega_{earth}}{dt}\Delta t$$

Launch Vehicles

Boeing’s Delta II



Payload delivery options range from about 1-2 metric tons (1,980 to 4,550 lb) to geosynchronous transfer orbit (GTO) and 2.7 to 5.8 metric tons (6,020 to 12,820 lb) to low-Earth orbit (LEO).