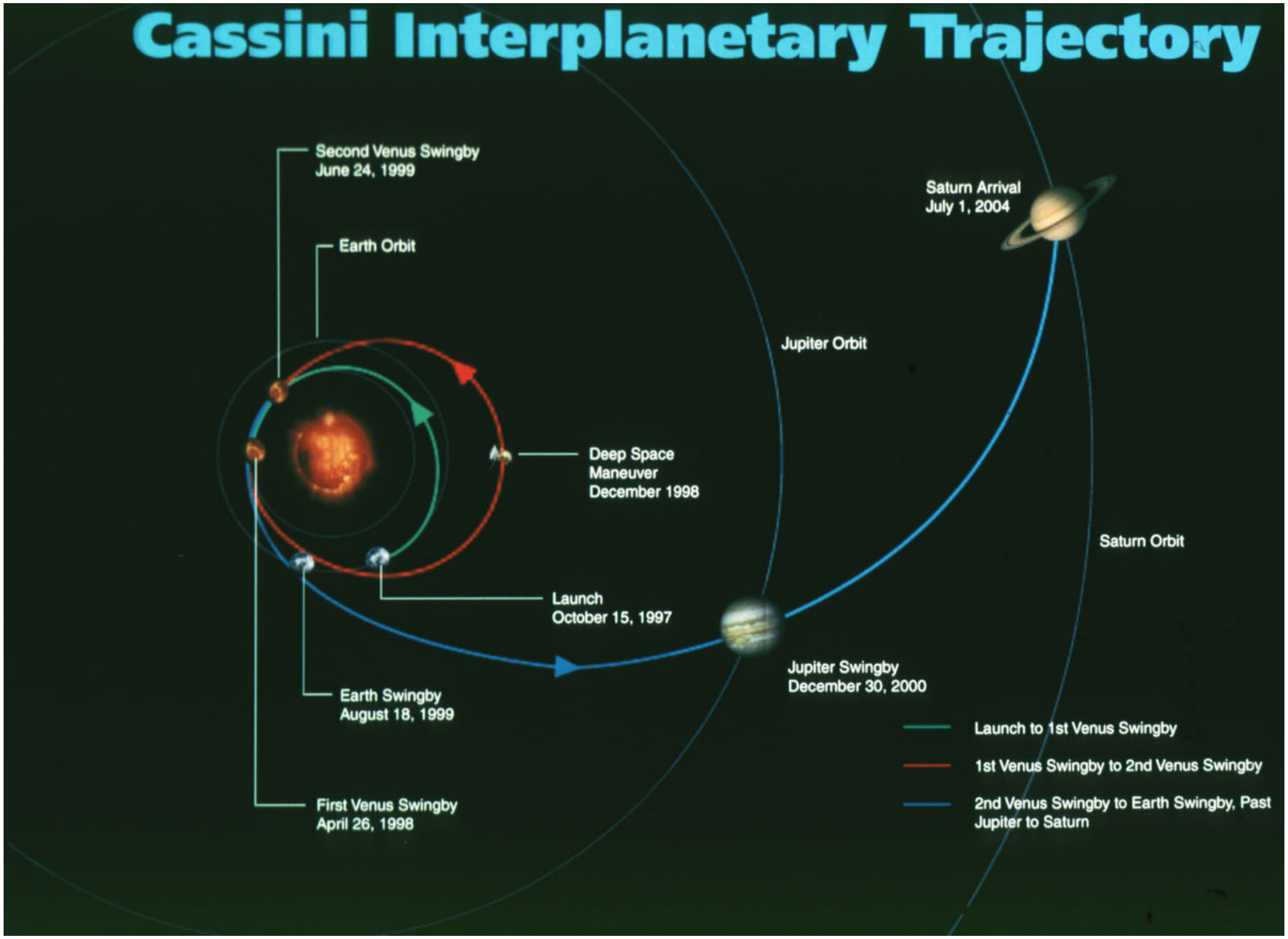
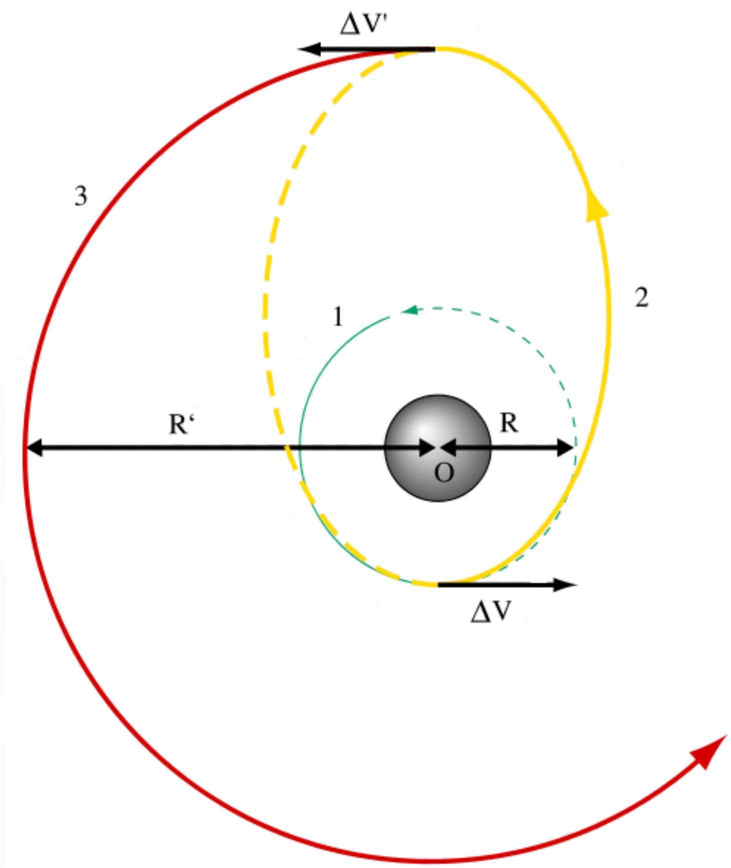
Orbital Mechanics



Orbital Maneuvers

We have already discussed one type of orbital maneuver, the Hohmann transfer, when we mapped out a potential mission to Mars.

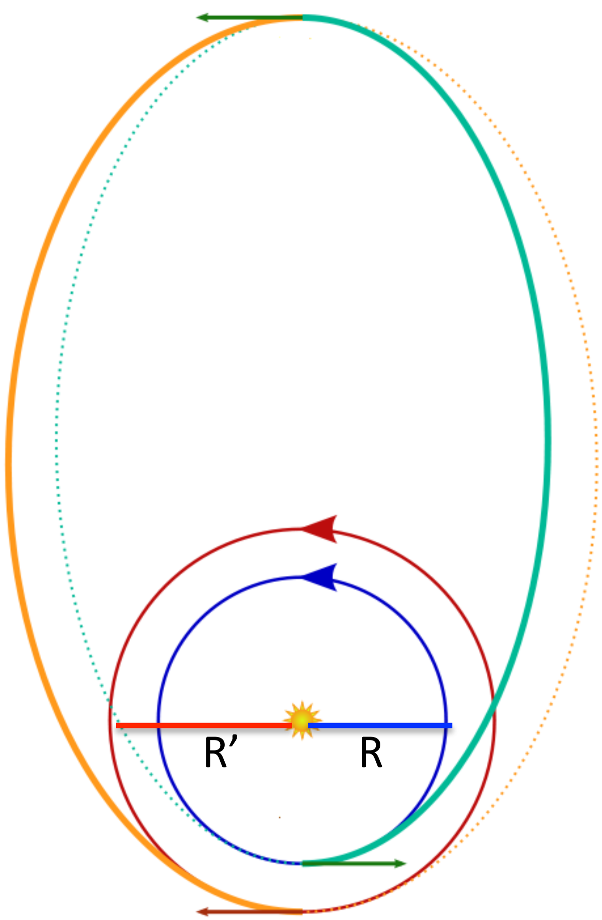


Hohmann transfer:

1. Transfer between two coplanar circular orbits
2. Requires two engine burns
3. Lowest energy transfer if R'/R < 12
4. Assume impulsive thrust

Orbital Maneuvers

Other orbital maneuvers are required for different applications.



Bi-elliptic transfer:

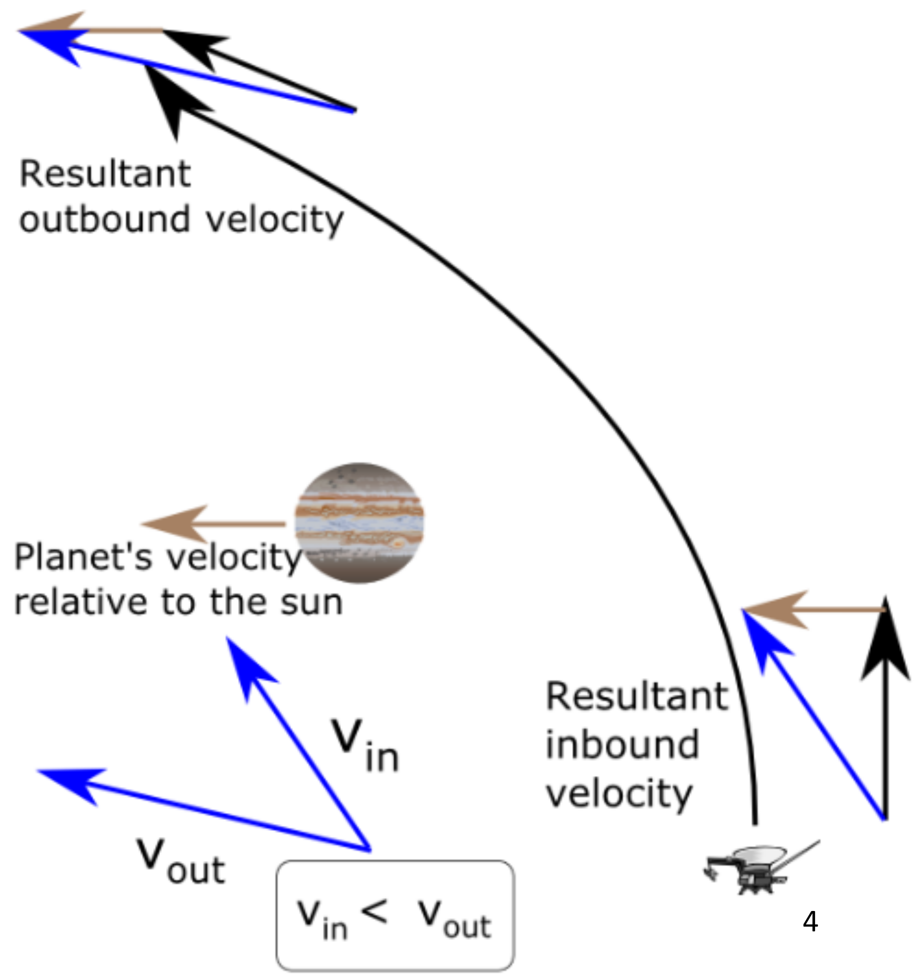
1. Transfer between two coplanar circular orbits
2. Requires three engine burns
3. Lower energy than Hohmann transfer if
   R’/R > 12
4. Assume impulsive thrust
5. Longer time than Hohmann transfer

Gravitational Assist

Sometimes using a Hohmann transfer or bi-elliptic transfer is too energy intensive. Our rocket cannot carry that much fuel.

Gravitational Assist:

1. Used to increase speed, decrease speed, and change direction
2. Relies on using the relative motion of the planet and spacecraft
3. Saves fuel, time, and money

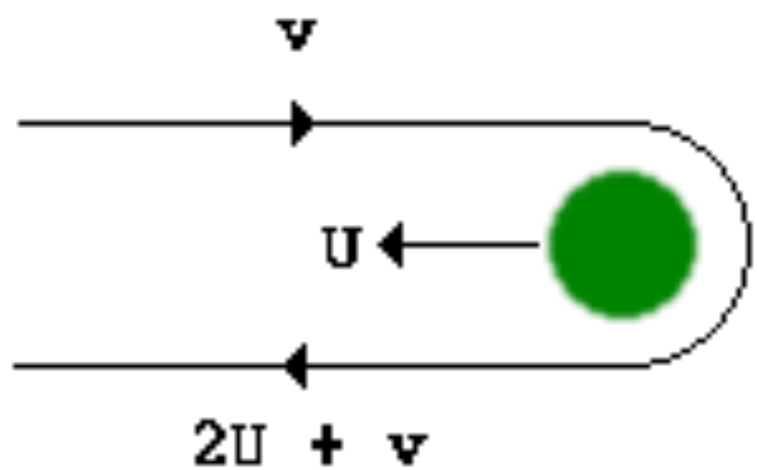


Gravitational Assist

Sometimes using a Hohmann transfer or bi-elliptic transfer is too energy intensive. Our rocket cannot carry that much fuel.

How it works (simplified):

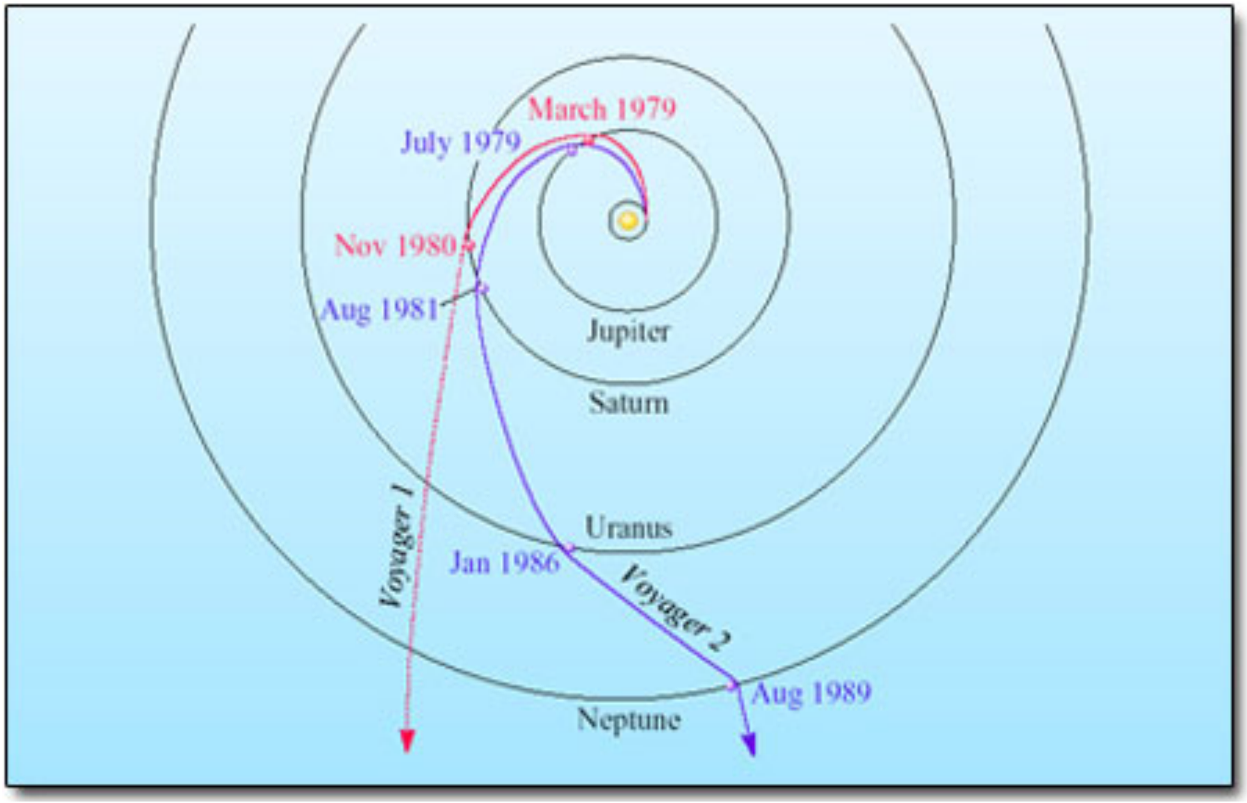
1. Spacecraft moves towards planet with speed v (relative to Sun)
2. Planet moving towards spacecraft at speed u (relative to Sun)
3. Spacecraft moves at speed u + v with respect to planet's surface (incoming)
4. Spacecraft moves at speed u + v with respect to planet's surface (outgoing)
5. Spacecraft moves away from the planet with speed 2u+v (relative to Sun)



Oberth Effect: gravitational assist with thrusters

Is this all science fiction?

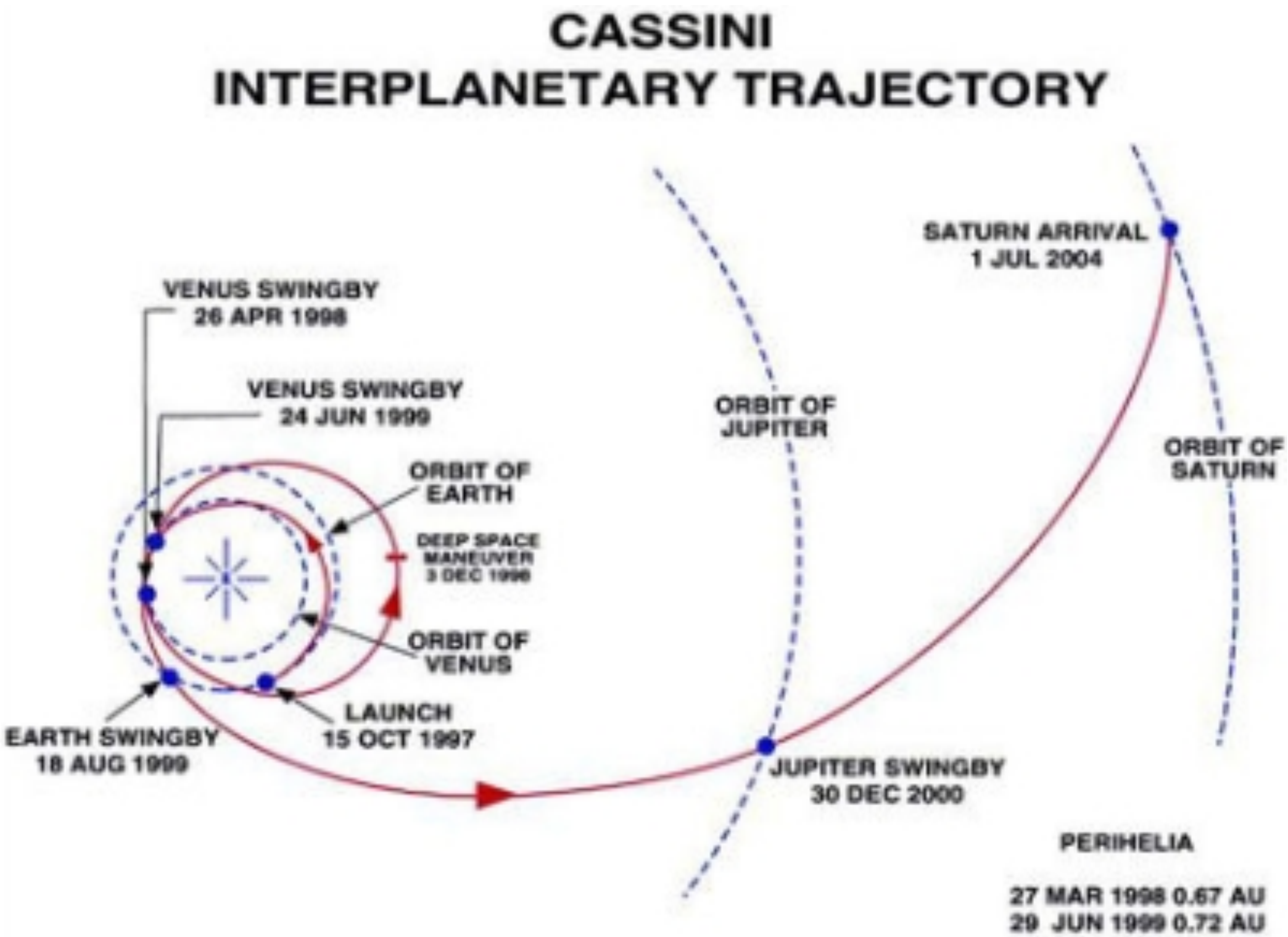
Gravitational Assist



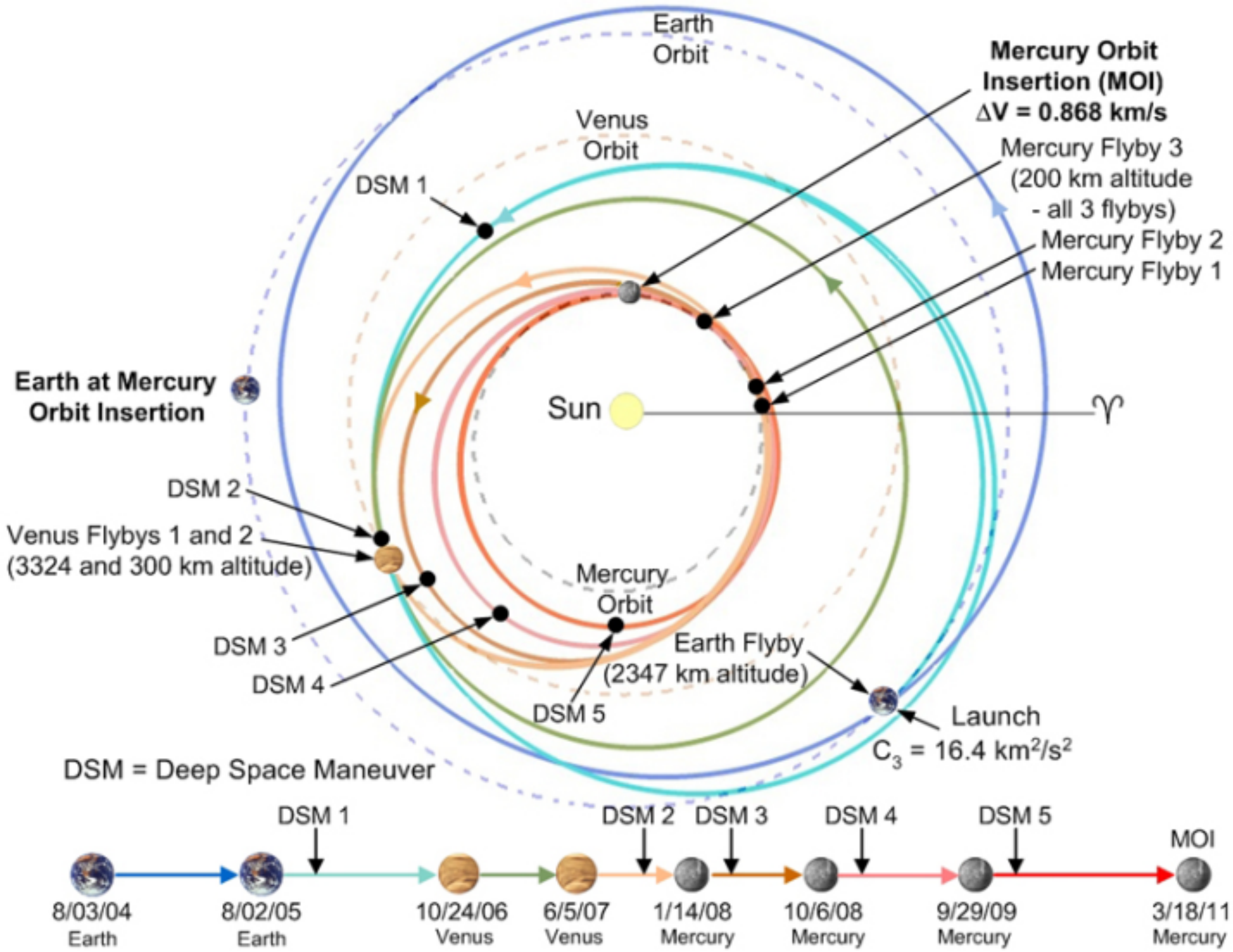
Notable uses:

1. Mariner 10
2. Voyager I & II
3. Galileo
4. Ulysses
5. Cassini
6. MESSANGER

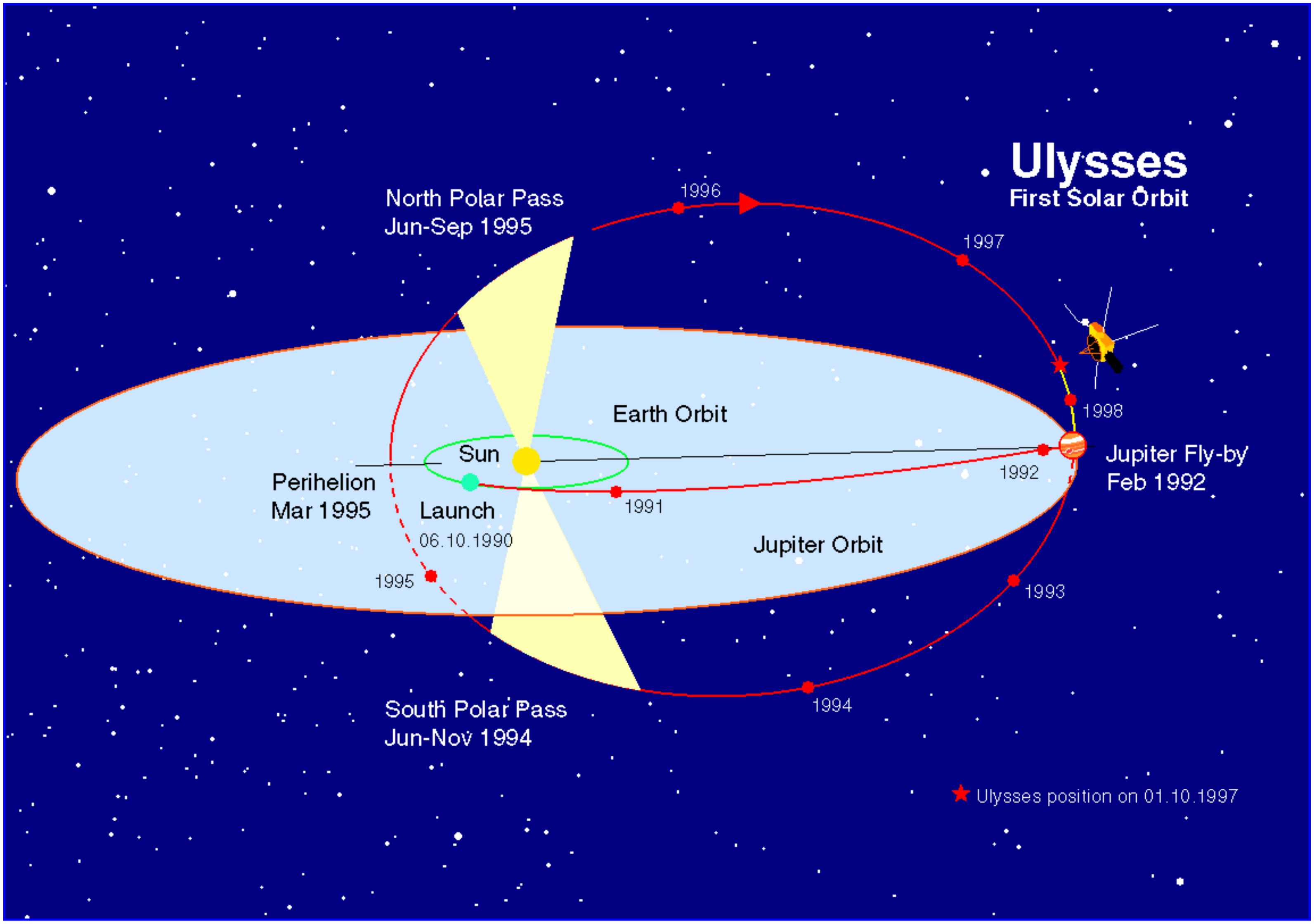
Gravitational Assist



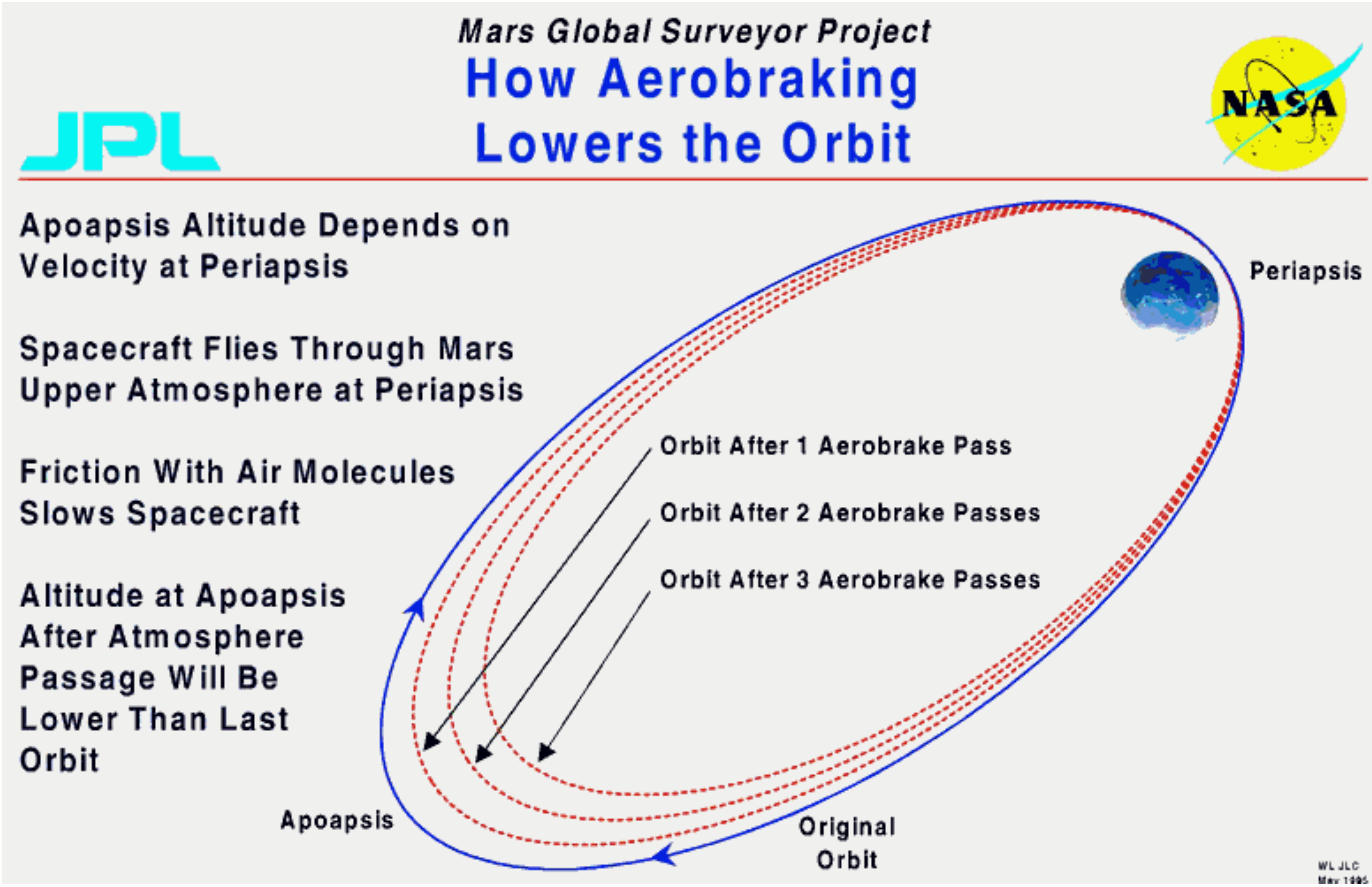
Gravitational Assist



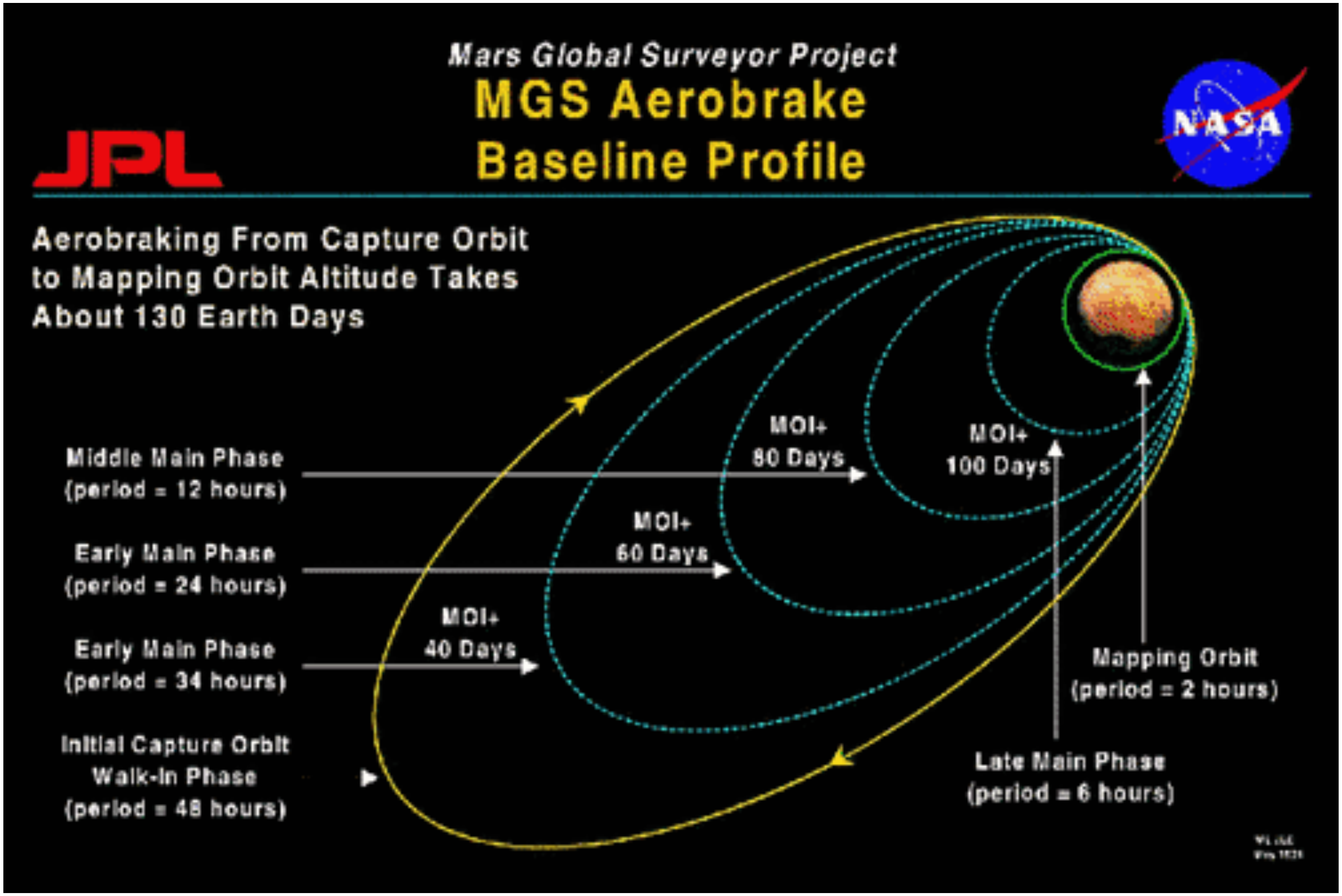
Gravitational Assist



Aerobraking



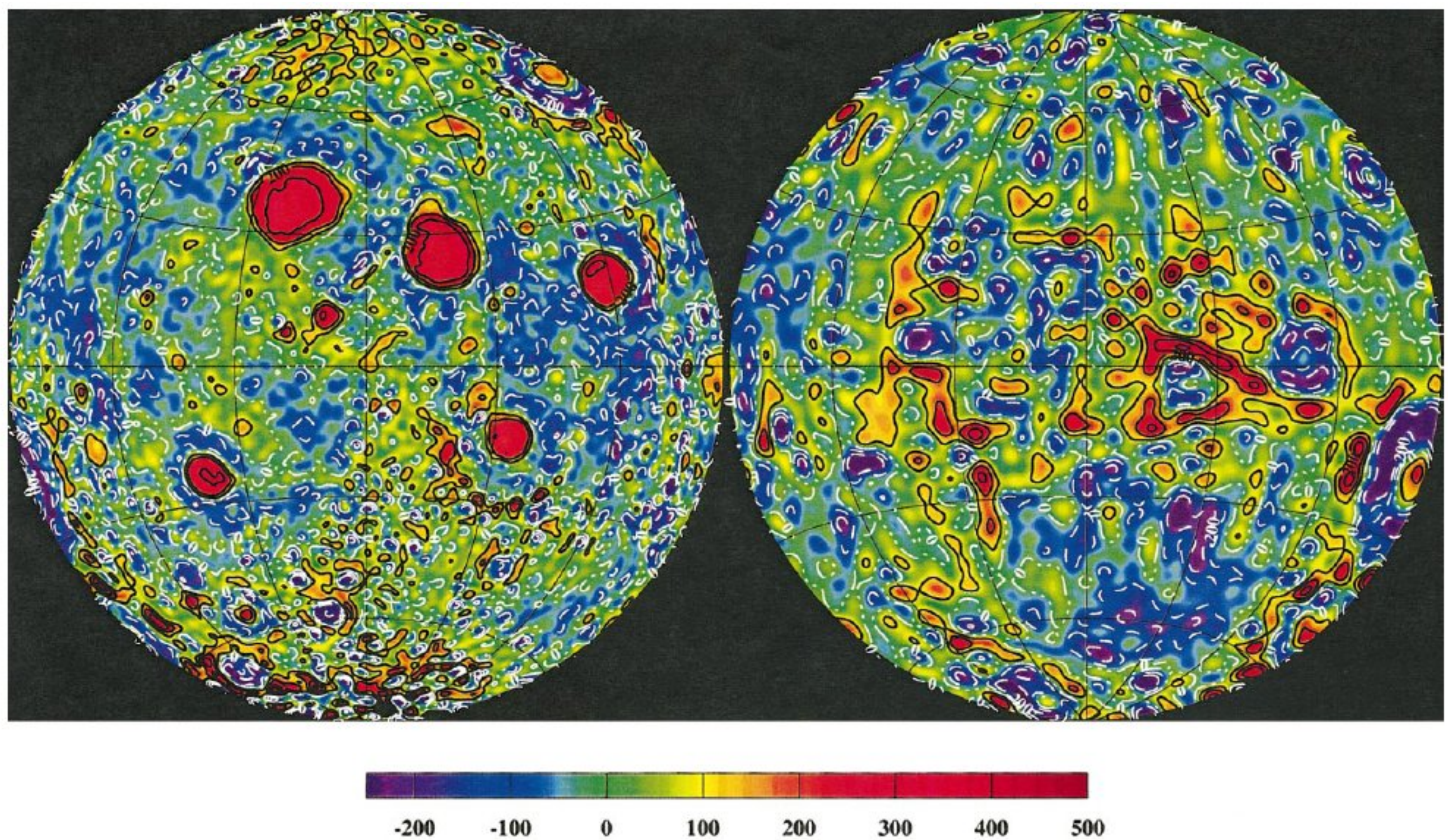
Aerobraking



But is it really that simple…

- Lunar Mascons (aka mass concentrations) make stable low lunar obits difficult (impossible?) to find.

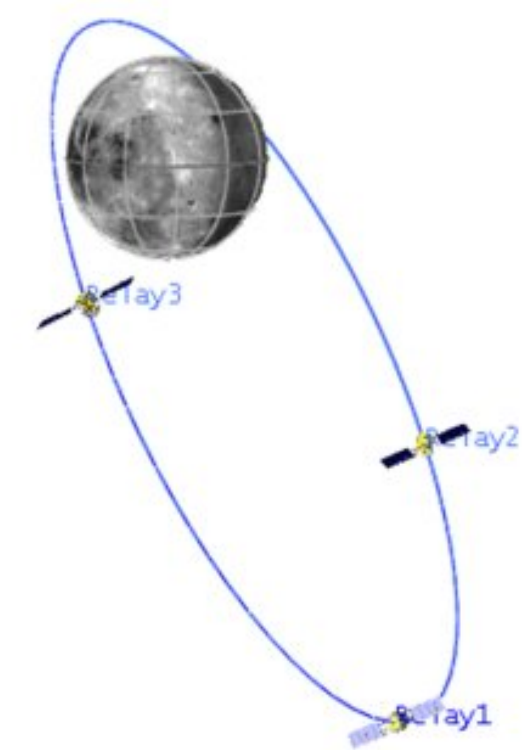
Konopliv *et al*, Icarus **150**, 1–18 (2001).



But is it really that simple…

- So why not just fly high altitude orbits? Because the Earth gravitationally disturbs high altitude, circular orbits.

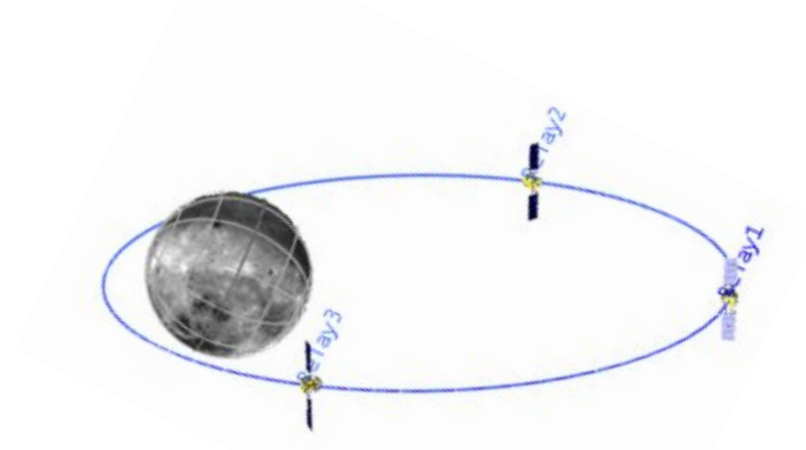
- But there might be highly elliptical, high inclination orbits that could be stable for about 100 years.

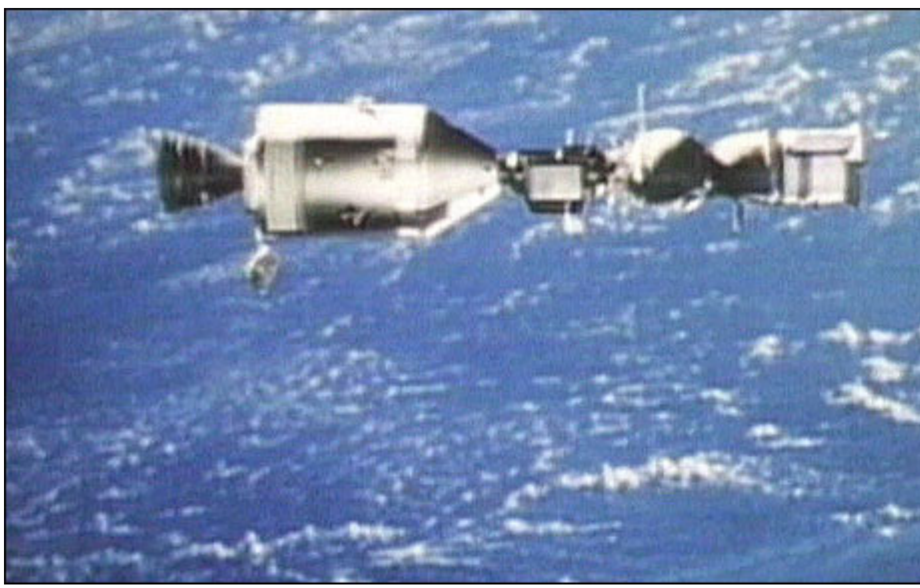


Todd Ely and Erica Lieb, Stable Constellations of Frozen Elliptical Inclined Lunar Orbits, Journal of the Astronautical Sciences, vol. 53, No. 3, July-Sept 2005, pp. 301-316

Other Orbital Maneuvers

- Orbital Inclination Change
- Phasing
- Rendezvous
- Docking





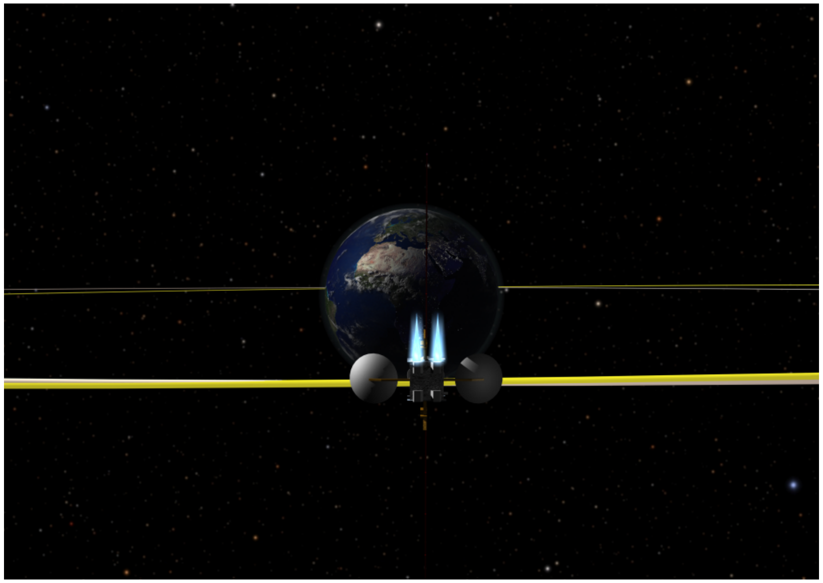
Orbital Station-Keeping

Any real orbit will change with time due to perturbations from other bodies in the solar system.

Example: satellite is orbit around the Earth is perturbed by the Sun, Moon, Jupiter…

Orbital Station-Keeping: firing thruster to keep a spacecraft in a particular orbit

Typically a small set of thrusters are used. These are called the *attitude control system* (ACS).



Now this process is automated by an onboard computer that collects telemetry and makes corrections.

Station-keeping is critical for satellites that must be oriented in a certain direction to communicate with Earth (communication satellites)