MMAE 411
Spacecraft Dynamics
Out-of-plane maneuvers
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Outline

- Out-of-plane changes

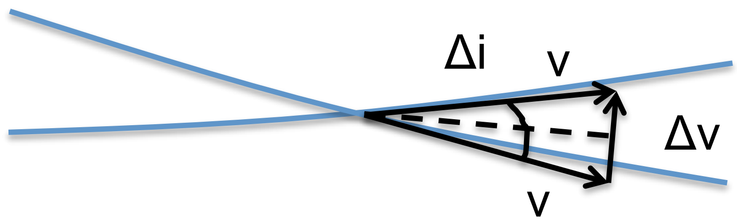
Recap

We have seen ways of changing the orbit of a spacecraft that stays in the plane of the original orbit. The Hohmann transfer is a fuel-efficient way of transferring between circular orbits. In general you need two Δv fuel burns: one to change from the initial orbit to the transfer orbit, and a second to change velocity from the transfer orbit to the final orbit. The Hohmann transfer changes only the speed, but the general coplanar transfer requires Δv that changes both speed and direction.

Now we consider the Δv that must be applied to change the plane of the orbit.

Out-of-plane orbit changes

Changing the plane of the orbit amounts to changing the inclination i of the orbit. Suppose you want to change the direction but not the speed of the orbit. Then the angle between the old velocity and new velocity vectors is Δi, and the side opposite is $\Delta \vec{v}$.



$$\Delta v \;=\; 2v \sin \frac{\Delta i}{2} \tag{1}$$

The burn for inclination change should happen at the relative line of nodes, i.e., where the two orbit planes intersect.

Cost of an inclination change

Changing the inclination of an orbit is costly, fuel-wise. To see this, consider a 60° inclination change:

$$\begin{aligned}\Delta v &= 2v\sin\frac{60}{2} & (2)\\ &= 2v\frac{1}{2} & (3)\\ &= v & (4)\end{aligned}$$

So to change the orbital plane inclination by 60° would mean needing a Δv as large as the speed of the orbit itself! Launching from a particular latitude λ will initially give an orbit inclined by the same amount $i = \lambda$.

In order to "equatorialize" an orbit, the inclination change burn would have to occur at the line of nodes. The maneuver would have to cause a $\Delta i = -\lambda$. This is why launch sites in the low latitudes are preferable for payloads that need to be in equatorial orbits.