TRANSFERS

Goal: Shift to an orbit that does **NOT** intersect the original orbit.
Use multiple-impulse transfers.

Limiting factor:

Approach for transfer problems:

1. Define transfer geometry

   Given a transfer orbit type

   - What are the departure & arrival conditions?
   - What are the departure & arrival points?
   - Find ΔVs

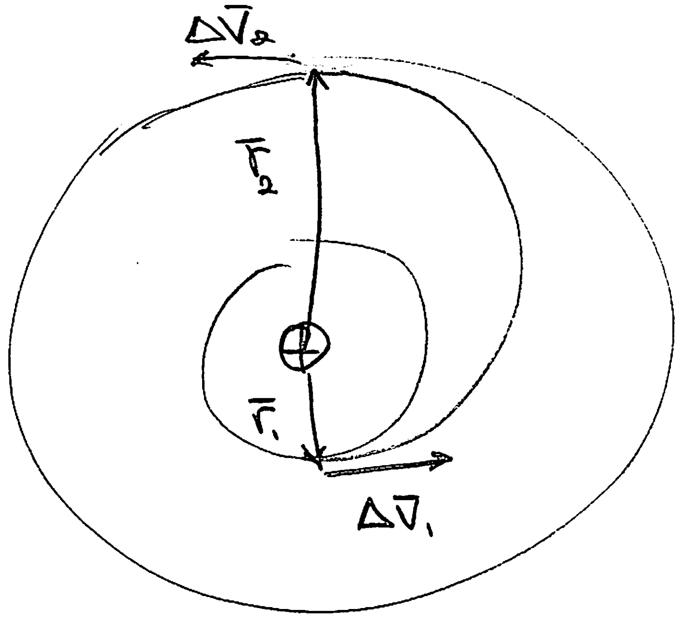
OR 2. Define departure/arrival points

SOLVE for the transfer arc itself to meet specifications

Start with simplest 2-impulse transfer.

Hohmann Transfer

Simplest version of Hohman is circle-to-circle



Example

Given: $r_1 = 2R_\oplus$ $\quad r_2 = 4R_\oplus$

1. Establish current orbit

$a =$

$e =$

2. Conditions at thrust <u>before</u> maneuver

$r_1 =$

$V_1 =$

$\gamma_1 =$

3. Define transfer ellipse

a_T

$r_p = a_T(1 - e_T)$

$\Rightarrow e_T$

4. Conditions after maneuver

r

V_p

γ

5. Vector Diagram

6. Move to next maneuver point in transfer orbit

r

V

γ

7. Conditions required <u>after</u> maneuver

r_2

v_2

γ_2

8. Vector diagram for $\Delta \bar{V}_2$

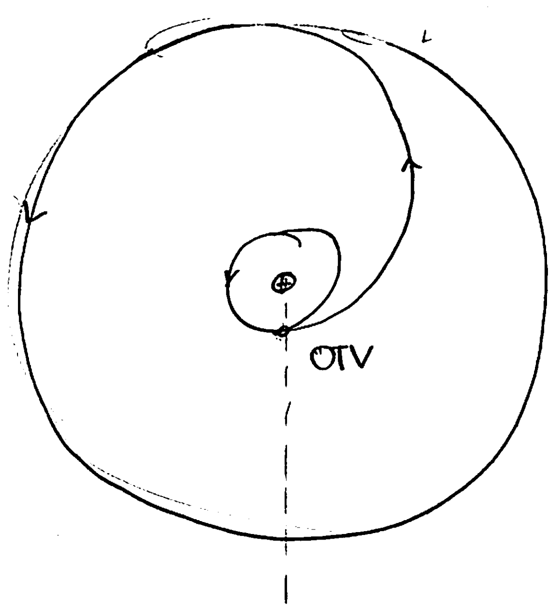
9. Total ΔV

Conditions for Rendezvous

Transfers shift vehicles from one planet to another.

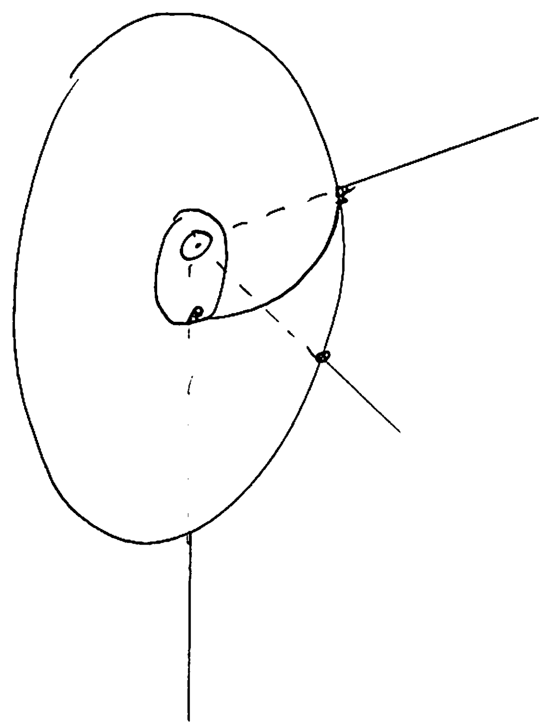
Additional complexity if rendezvous.

Example: ⊕ orbiting OTV departing LEO to rendezvous w/ space station.



General Phase Angle

What happens for noncircular, non-Hohmann orbit?

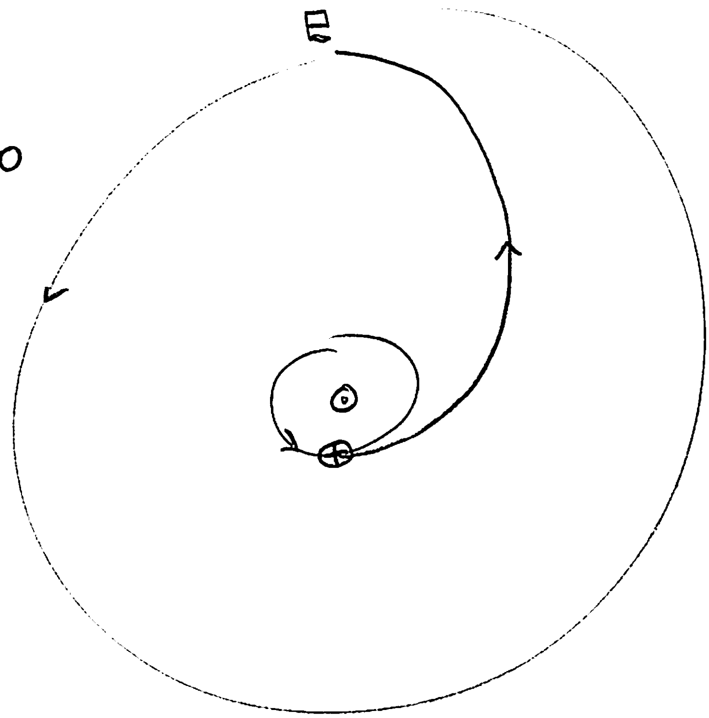


$\phi =$

where

Synodic Period

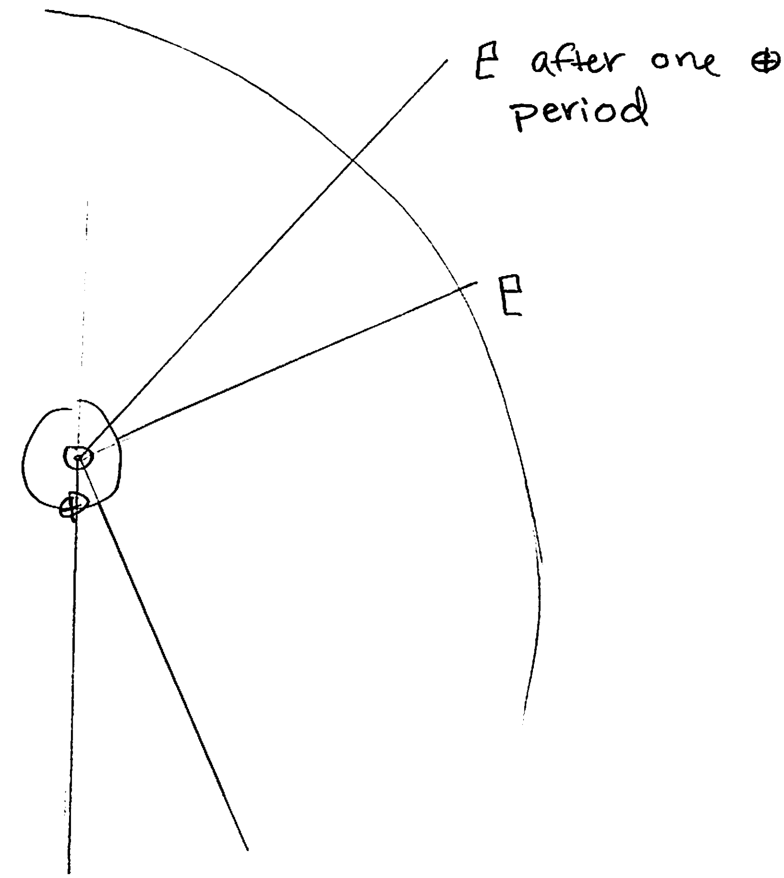
Example:
Earth to Pluto



Requirement for rendezvous/interception determines initial geometry.

If miss "launch" how long do we wait?

NOTE: Need ϕ to occur again. Don't require planets to be located in the same places.



E does not move far for one Earth $\mathbb{P}$,

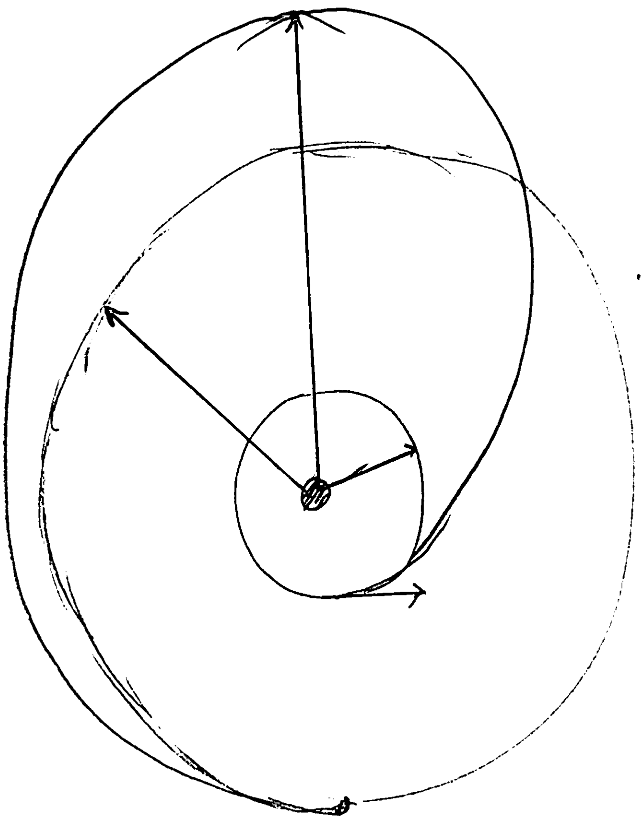
After one $\mathbb{P}_{\oplus}$, angle now

So we let the Earth "catch up"

Note : $\mathbb{P} = \frac{2\pi}{n} \Rightarrow n\mathbb{P} = 2\pi$

Bi - Elliptical Transfers

Extend Hohmann transfer to 3 impulses



TA =

r:

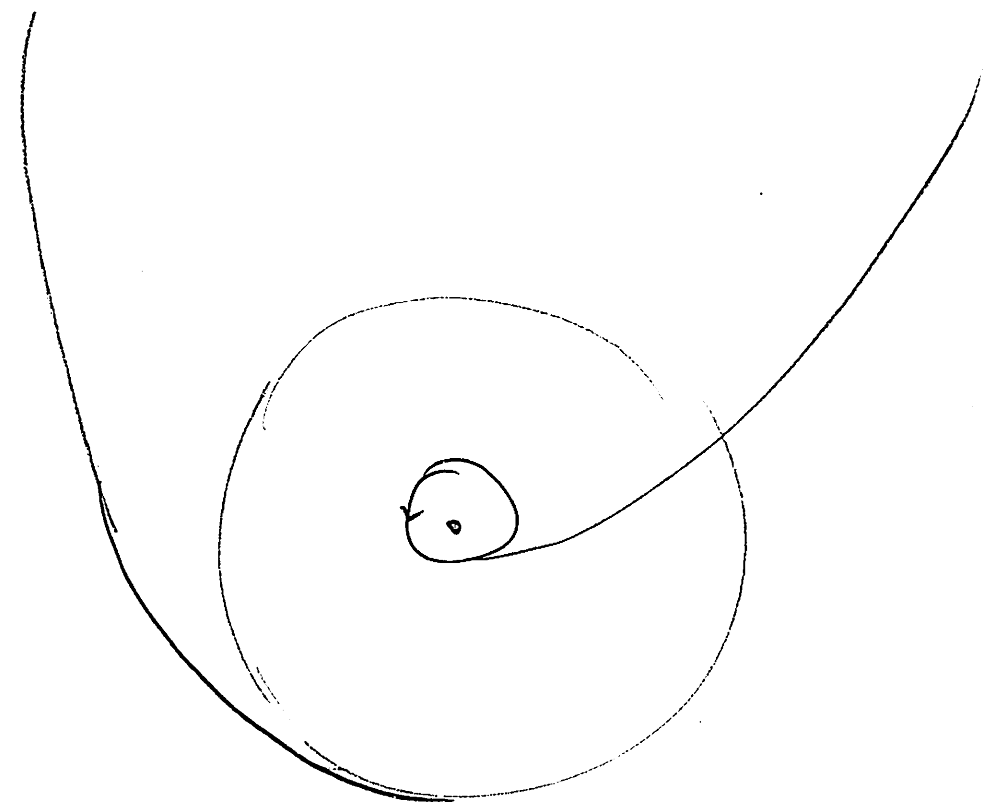
Characteristics:

1. Initial circular orbit
2. 1^{st} impulse applied tangentially, shift to Periapsis of transfer ellipse #1
3. Apogee on E_1 =
   2^{nd} impulse applied tangentially, shift from apoapsis of E_1 to apoapsis of transfer ellipse #2
4. Periapsis on E_2 =
   3^{rd} impulse applied tangentially, shift into final circular orbit.
5. Total cost:

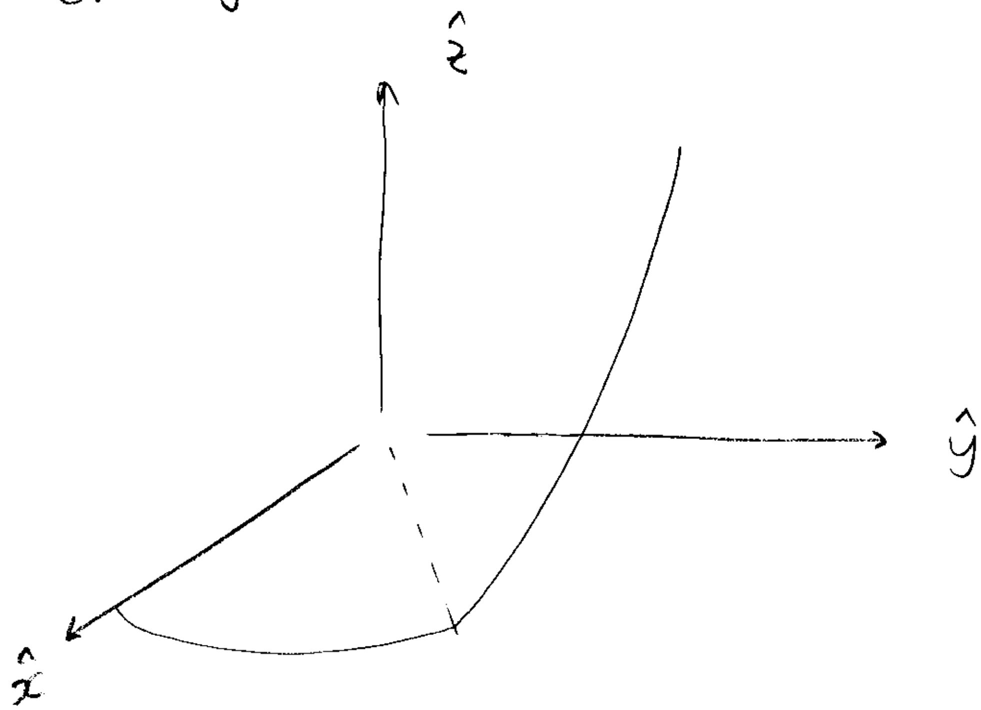
Bi-Parabolic Transfer

Move intermediate radius to infinity ($r \to \infty$)

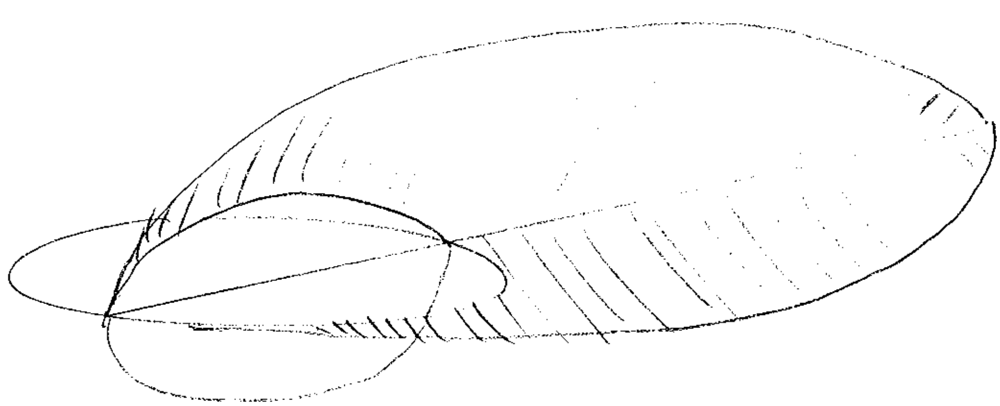
· Transfer becomes parabolic



Bi-elliptic useful for inclination changes.



Intermediate orbit to cut costs

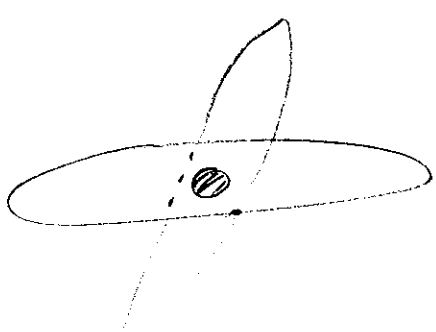


Example: Given a geosynchronous Earth orbit with an inclination of 30°, how much Δv do we need to have an inclination of 90° if we

A. Perform a single impulse maneuver.

B. Perform a bi-elliptic transfer with an intermediate radius of $40 R_{\oplus}$

A. Single Impulse



For a geosynchronous orbit,

$e =$

$\mathbb{P} =$

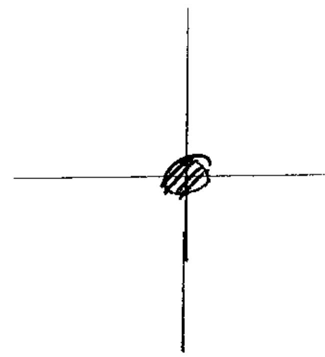
Conditions after maneuver:

$a^+ =$

$e =$

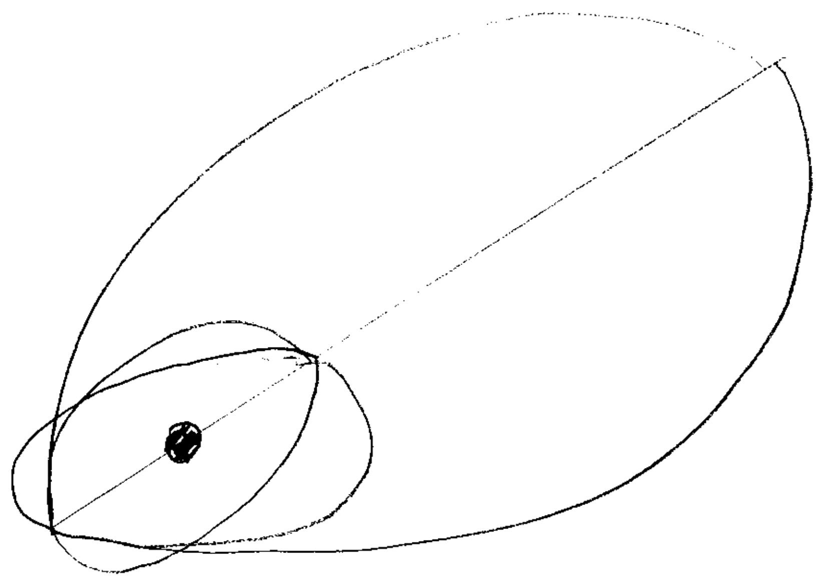
$V^+ =$

side view:



vector diagram:

B. Bi-Elliptic



C1: initial circular orbit

B1: Burn to E1

E1: 1^{st} Elliptical orbit

B2: Burn to E2

E2: 2^{nd} elliptical orbit

B3: Burn from E2 to C2

C2. second circular orbit

Conditions at C_1:

$a_i =$ $e_i =$

$V_i =$ $\gamma_i =$ $i_i =$

Conditions at E1 perigee

$a_{T1} =$

$r_{P1} =$

$V_{P1} =$

$\gamma_{P1} =$

Vector Diagram:

Conditions at apogee of E1

conditions at apogee of E2

Vector diagram:

Conditions at perigee of E2

Conditions at C_2

Vector Diagram

What is TOF?