Basic Orbital Manoeuvres

Orbital Manoeuvres Concept

Most **ascent** missions release spacecraft in a **temporary** orbit**,** after which a series of **manoeuvres** place the satellite in the **desired** orbit/on the desired path.

Orbital Manoeuvres Concept

Orbital manoeu**vres** are typically **carried** out by burning fuel for a **short** duration, so that it **result**s in increase/ decrease in the **velocity.**

In this context, it is assumed that **burn** time is sufficiently **small** in comparison to the orbital **time period** so that all manoeuvres are generally **impulsive** in nature.

In view of the above, **manoeuvres** are typically described in terms of **required** velocity impulse, 'Δ**v**' at a specified **location** along the orbital **path.**

Chandrayaan-I Manoeuvres – Earth

Earth orbit burns		
Date	Burn time (minutes)	Resulting apogee
22 October Launch	18.2 in four stages	22,860 km
23 October	18	37,900 km
25 October	16	74,715 km
26 October	9.5	164,600 km
29 October	3	267,000 km
4 November	2.5	380,000 km

Chandrayan-I Manoeuvres – Moon

Lunar orbit insertion			
Date	Burn time (seconds)	Resulting periselene	Resulting aposelene
8 November	817	504 km	7,502 km
9 November	57	200 km	7,502 km
10 November	866	187 km	255 km
11 November	31	101 km	255 km
12 November Final orbit		100 km	100 km

Orbital Manoeuvre Types

In general, **orbital** manoeuvres involve following **tasks.**

Apogee Raising / Perigee Raising

Argument of Perigee Changing

Orbit **Shape** and Size Changing

Orbit **Plane** Changing

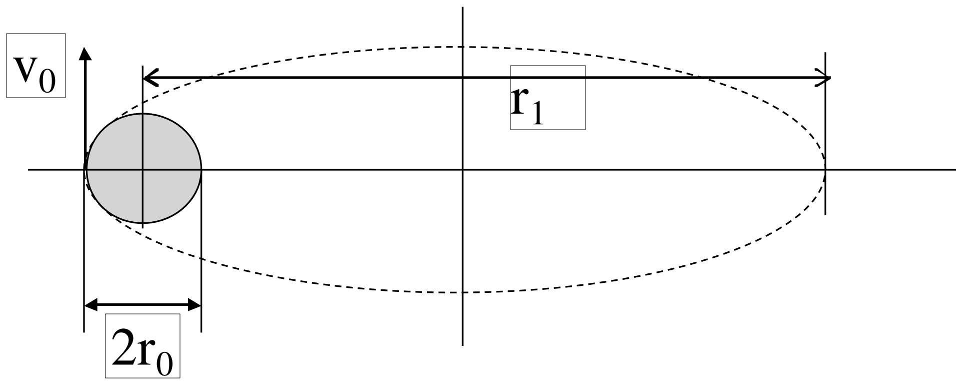
The above **tasks** are accomplished by providing appropriate **velocity** impulses.

Apogee Raising Manoeuvre

Circular Apogee Raising Manoeuvre

Apogee raising involves **increasing** ‘r_a’, while keeping ‘r_p’ same, by a **collinear** velocity change at **perigee**.

Consider the **schematic** of an orbit **raising** manoeuvre, from **circular** orbit, to an **elliptic** orbit as shown below.



Circular Apogee Raising Formulation

Basic equations for 'Δv', are as follows.

$$a_{elp} = \frac{r_0 + r_1}{2}; \quad e = \frac{r_1 - r_0}{2a_{elp}} = \frac{r_1 - r_0}{r_1 + r_0}; \quad v_{cir} = \sqrt{\frac{\mu}{r_0}}$$

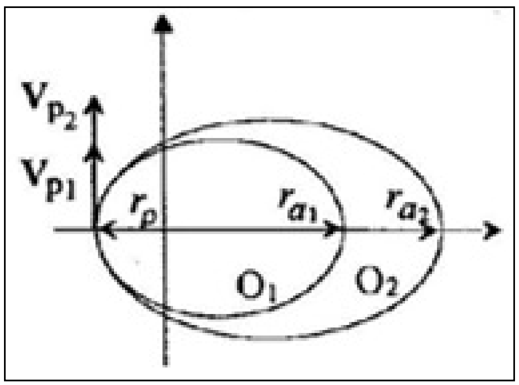
$$\varepsilon_{elp} = \frac{v_{elp}^2}{2} - \frac{\mu}{r_{elp}} = -\frac{\mu}{2a_{elp}} = -\frac{\mu}{r_1 + r_0}; \quad r_{elp}(\text{perigee}) = r_0$$

$$v_{elp}(\text{perigee}) = \sqrt{\frac{2\mu a_1}{r_0 (r_1 + r_0)}}; \quad \Delta v_{raising} = v_{elp} - v_{cir}$$

$$\Delta v_{raising} = \sqrt{\frac{2\mu r_1}{r_0 (r_1 + r_0)}} - \sqrt{\frac{\mu}{r_0}} = \sqrt{\frac{\mu}{r_0}} \left(\sqrt{\frac{r_1}{a_{elp}}} - 1 \right)$$

Elliptic Apogee Raising Formulation

Apogee raising for an **elliptical orbit** is as shown below.



$$v_{p1} = \sqrt{\left(\frac{\mu r_{a1}}{r_p a_{elp1}}\right)}; \quad v_{p2} = \sqrt{\left(\frac{\mu r_{a2}}{r_p a_{elp2}}\right)}$$

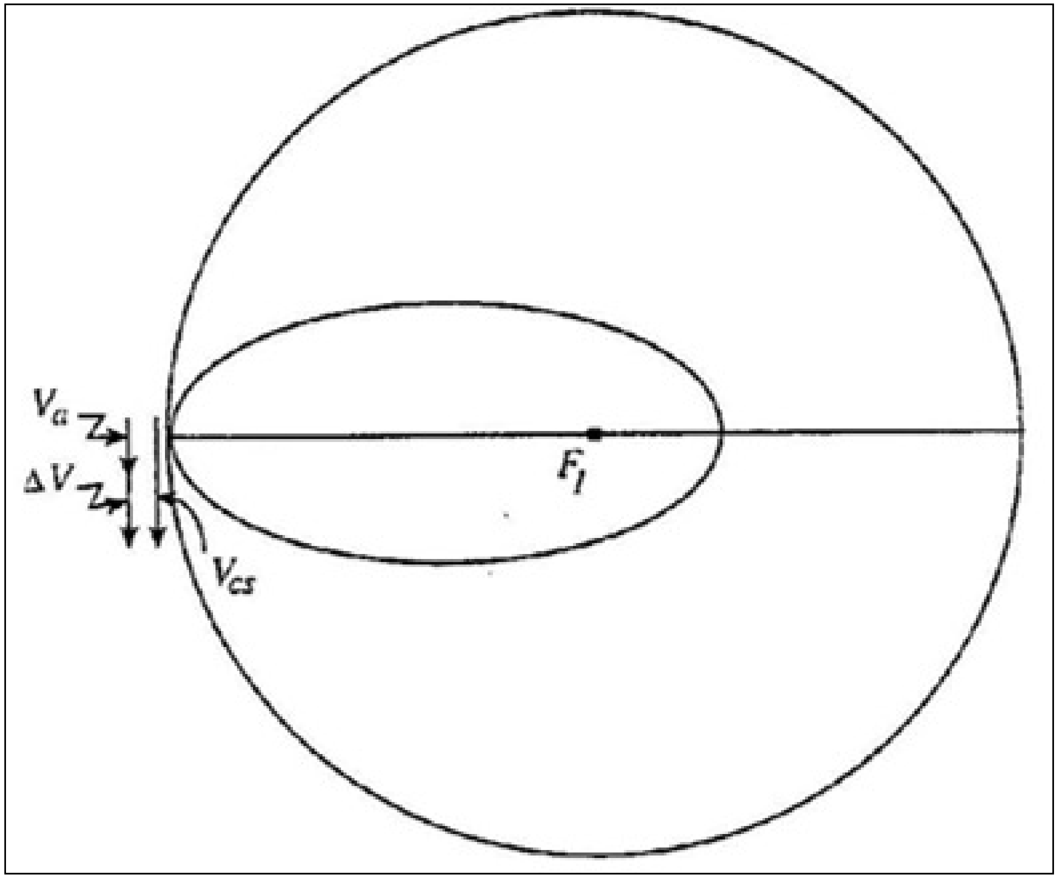
$$\Delta v = v_{p2} - v_{p1} = \sqrt{\frac{\mu}{r_p}} \times \left[\sqrt{\left(\frac{r_{a2}}{a_{elp2}}\right)} - \sqrt{\left(\frac{r_{a1}}{a_{elp1}}\right)}\right]$$

Perigee Changing Manoeuvre

Perigee Raising Manoeuvre

Perigee raising involves velocity **change** at apogee, as shown along side.

The **manoeuvre** is also employed for **circularizing** an existing **elliptic** orbit.



Perigee Raising Solution

The solution for **perigee** raising impulse is as follows.

$$r_0 \rightarrow \text{Perigee}, \quad r_1 \rightarrow \text{Apogee}, \quad a_{elp} = \frac{r_0 + r_1}{2}$$

$$v_{cir} = \sqrt{\frac{\mu}{r_1}}; \quad \frac{v_{elp-a}^2}{2} - \frac{\mu}{r_1} = -\frac{\mu}{2a_{elp}}$$

$$v_{elp-a} = \sqrt{2\left(\frac{\mu}{r_1} - \frac{\mu}{r_1 + r_0}\right)} = \sqrt{\left(\frac{\mu r_0}{r_1 a_{elp}}\right)}$$

$$\Delta v = \sqrt{\frac{\mu}{r_1}} - \sqrt{\frac{\mu r_0}{r_1 a_{elp}}} = \sqrt{\frac{\mu}{r_1}}\left(1 - \sqrt{\frac{r_0}{a_{elp}}}\right)$$

Summary

We see that orbital manoeuvres are **easily** set up with basic orbital **parameters** in terms of velocity **impulses** that are given either at **perigee** or at apogee.