Planetary Flyby Concept

Planetary Flyby Concept

If an **arriving** spacecraft does not **impact**, it will **pass** the planet **by** if no further **action** is taken.

This motion is termed **flyby** as the spacecraft **flies** around the **planet** and, in the process, gets **influenced** by its gravitational field, **without** forming an **orbit.**

Planetary Flyby Description

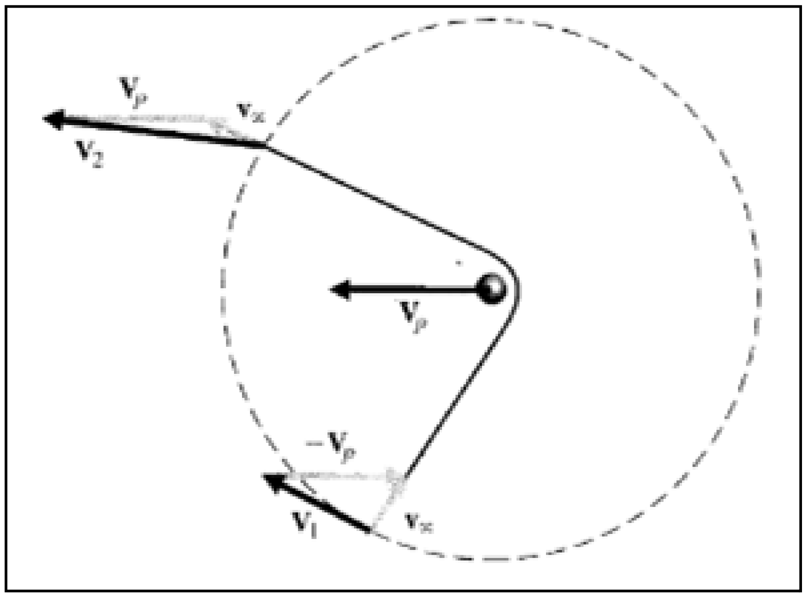
However, as **spacecraft** remains in planet's **gravitational** field, there are **changes** to its energy and angular momentum that need to be **characterized.**

Flybys are extremely useful **techniques** to travel great distances in **space.**

Unconstrained Flyby Solution

Planetary Flyby Concept

Consider the **schematic** of a **flyby** as given below.



Unconstrained Flyby Solution

Here, $\mathbf{V_1}$ is the approach **velocity**, $\mathbf{V_p}$ is the planet orbital **velocity** and $\mathbf{V_2}$ is the exit velocity.

Also, subscript **'1'** is for the **entry** and subscript **'2'** is for the **exit** parameters.

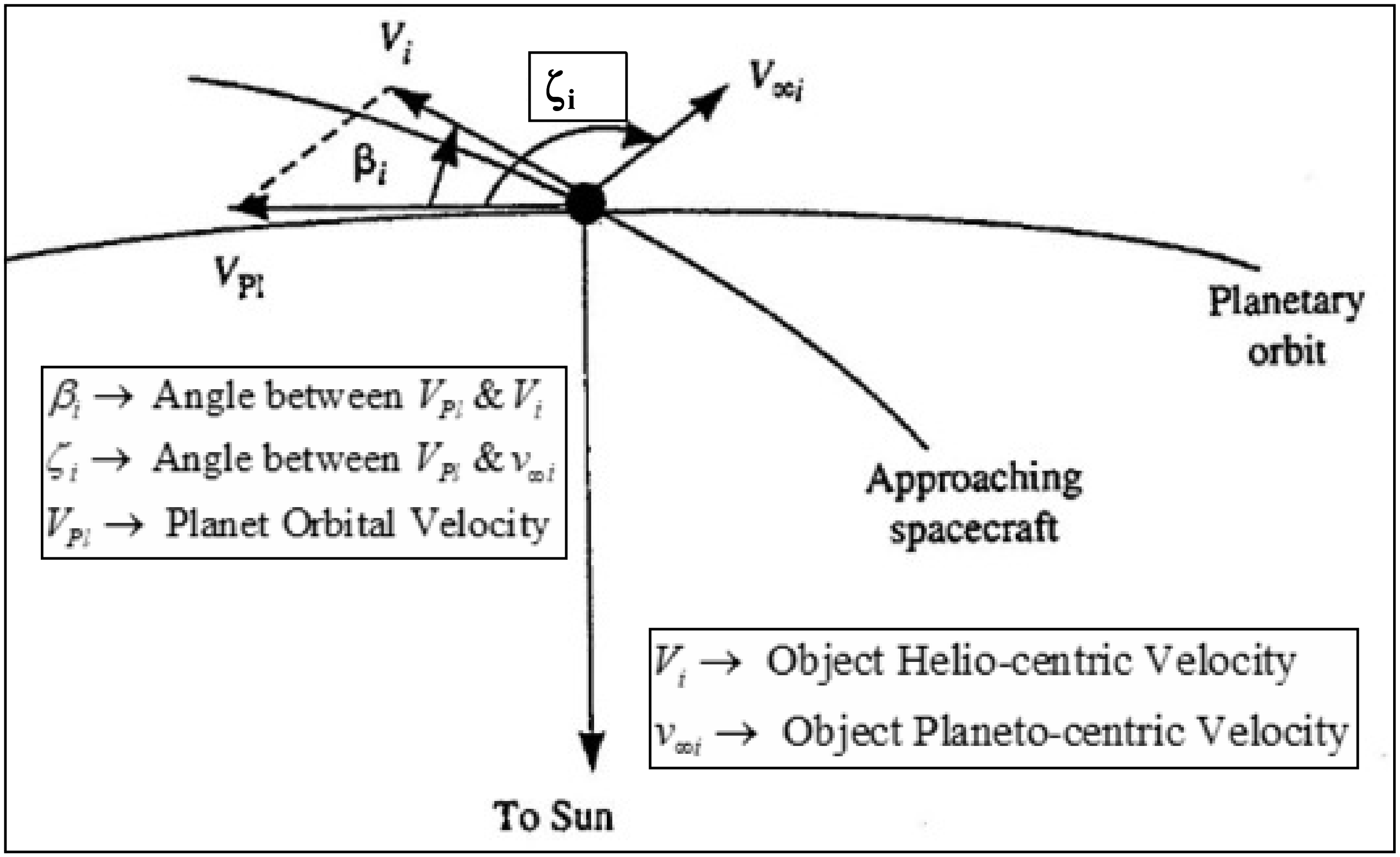
Unconstrained Flyby Solution

It is seen that the **velocity** vector gets **modified** due to the gravitational **field** of the planet.

As all **flybys** are executed on a **hyperbolic** path (arrival on **one** arm and departure on **other** arm), we can suitably **orient** it**,** in order to achieve specific **velocity** & direction**.**

General Flyby Formulation – Entry

Consider the **schematic** of general **flyby**, as given below.



General Flyby Formulation – Entry

The **basic** relations are as **follows**.

$$v_{\infty i} = \sqrt{V_{Pl}^2 + V_i^2 - 2V_{Pl}V_i\cos\beta_i}; \quad \frac{v_{\infty i}}{\sin\beta_i} = \frac{V_i}{\sin(180^o - \zeta_i)}$$

$$180^o - \zeta_i = \sin^{-1}\left(\frac{V_i\sin\beta_i}{v_{\infty i}}\right); \quad \text{If } \beta_i = 0^o \rightarrow \zeta_i = 180^o \text{ or } 0^o$$

It is to be **noted** that if $\mathbf{V_i \cos \beta_i < V_{Pl}}$**,** then $\zeta_i > 90^o$, otherwise, $\zeta_i < 90^o$. This means that when $\mathbf{\beta_i = 0}$, then $\zeta_i = 180^o$ for $V_{Pl} > V_i$ and $\mathbf{\zeta_i = 0^o}$ **for** $\mathbf{V_{Pl} < V_i}$**.**

General Flyby Formulation – Exit

Exit parameters after a **flyby**, are obtained as follows.

$$\alpha = 180^o - \zeta_o; \quad v_{\infty i} = v_{\infty o} = v_\infty; \quad \cos\alpha = -\cos\zeta_o$$

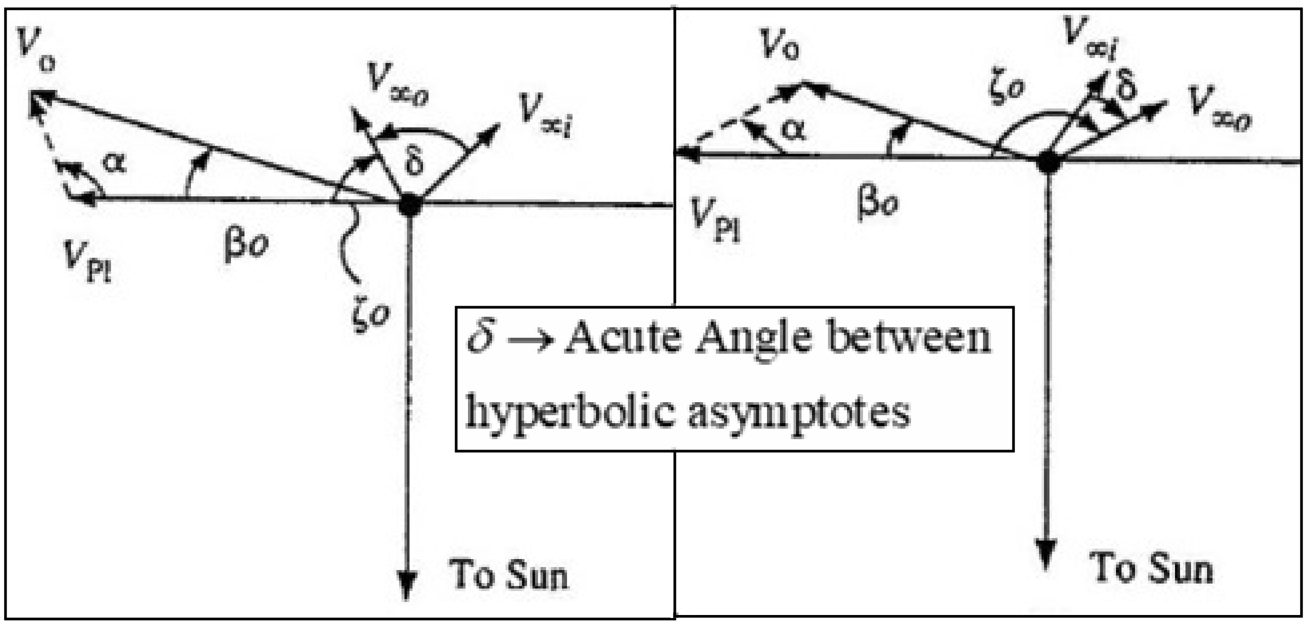
$$V_o = \sqrt{V_{Pl}^2 + v_\infty^2 + 2V_{Pl} v_\infty \cos\zeta_o}; \quad \zeta_o = \zeta_i \pm \delta; \quad \delta = 2\sin^{-1}\frac{1}{e}$$

$$\beta_o = \sin^{-1}\left(\frac{v_\infty}{V_o}\sin\zeta_o\right); \quad \varepsilon = \frac{v_{\infty i}^2}{2} = \frac{v_{\infty o}^2}{2} = \frac{v_\infty^2}{2}; \quad e = \sqrt{1 + \frac{2\varepsilon h^2}{\mu_{Pl}^2}}$$

$$v_{periapsis} = \sqrt{2\left(\varepsilon + \frac{\mu_{pl}}{r_{periapsis}}\right)}; \quad h = dV_\infty = r_{periapsis} v_{periapsis}$$

General Flyby Formulation – Exit

At the **end** of flyby **mission**, the velocity $v_{\infty i}$ **turns** by an **angle 'δ',** (Clockwise / Counter-clockwise), as follows.



Summary

Therefore, **we** see that flyby is executed on a **hyperbolic** path, and its nature is determined by the **arrival** parameters e.g. speed, **elevation** angle and the stand-off distance.