## Orbital Mechanics Calculator User Guide v1

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### 1 Introduction

The calculator is designed to provide a quick way of doing simple calculations on elliptic orbits, including coplanar single burn manoeuvres. Support for hyperbolic trajectories and non-coplanar manoeuvres will be added in the upcoming versions.

## 2 Structure

The workbook is divided into two sheets: the first one, "Main" is the calculator interface with orbit definition, inputs and outputs. The second sheet, "Workspace" contains intermediate steps for relatively more complicated calculations like Time-of-Flight and manoeuvres. The user is required to only interact with the Main sheet. Cells are color coded based on their I/O type. Pale orange fill indicates inputs, while grey-filled bold cells are outputs. In order to prevent corruption of the formulae, the sheet is protected allowing only the input cells to be editable. It is important to follow the units specified for each parameter for obtaining correct outputs.

#### 2.1 Orbit Definition

The orbit definition section shall be used to provide orbital elements (Keplerian Element System) to fix the orbit in 3-D space. Although it is not required to define each and every element, at least the Semi-Major Axis (SMA) and Eccentricity are required for co-planar calculations. Defining the other angular elements often allows reliable interpretation of results from the I/O section.

#### 2.2 Intermediates & Constants

This section is only for reference and does not need editing. All values here are calculated from the definition section and will be further used for the specific calculations.

| A A                             | R        | C D                        | L L       | F G                               | Н             |               | J                                 | K                                   | L            | M                 | N             |
|---------------------------------|----------|----------------------------|-----------|-----------------------------------|---------------|---------------|-----------------------------------|-------------------------------------|--------------|-------------------|---------------|
| Orbit Definition                |          | Intermediates & Constants  |           | CALCULATOR - I/O                  |               |               |                                   |                                     |              |                   |               |
| Orbital Elements                | Value    | Conserved Quantities       | Value     | True Anomaly at Radius            |               | Radius at Tru |                                   | ue Anomaly                          |              | Period to SMA     |               |
| Semi Major Axis (km)            | 25000    | Sp. Angular Momentum (SI)  | 9.42E+10  | R (km)                            | 25000         |               | Nu (deg)                          | 20                                  |              | P (hours)         | 24            |
| Eccentricity                    | 0.33     | Sp. Mechanical Energy (SI) | -7.96E+06 | Nu (deg)                          | 109.27        |               | R (km)                            | 17004.45                            |              | SMA (km)          | 42226.91      |
| Inclination (deg)               | 11       | Orbital Period (s)         | 3.94E+04  |                                   |               |               |                                   |                                     |              |                   |               |
| RAAN (deg)                      | 5        | Mean Motion (rad/s)        | 1.60E-04  | Velocity at Radius                |               |               | Flight Path Angle at True Anomaly |                                     |              |                   |               |
| AoP (deg)                       | 0        | Semi Parameter (m)         | 22277500  | R (km)                            | 15025         |               | Nu (deg)                          | 60                                  |              |                   |               |
|                                 |          | Periapsis Radius (km)      | 16750     | V (km/s)                          | 6.09          |               | FPA (deg)                         | 13.783159                           |              |                   |               |
| Mass of the central body (kg)   | 5.97E+24 | Apoapsis Radius (km)       | 33250     |                                   |               |               |                                   |                                     |              |                   |               |
| Radius of the central body (km) | 6371     | Gravitation Constant (SI)  | 6.67E-11  |                                   |               |               |                                   |                                     |              |                   |               |
|                                 |          | mu (SI)                    | 3.98E+14  | Time of Flight through True Anoma |               | malies        |                                   | Impulsive Burn Manoeuvre            |              | (Co-planar LVLH)* |               |
|                                 |          | Vesc at surface (km/s)     | 11.18     | Nu1 (deg)                         | 0             |               |                                   | Delta V azim                        | uthal (km/s) | 0.5               |               |
|                                 |          | Vesc at Periapsis (km/s)   | 6.90      | Nu2 (deg)                         | 60            |               |                                   | Delta V radial (km/s)               |              | 0.5               |               |
|                                 |          | Orbital Period (hours)     | 10.93     | ToF (hours)                       | 0.950         |               |                                   |                                     |              | 0                 |               |
|                                 |          |                            |           | ToF (%Period)                     | 8.69          |               |                                   | Nu at delta V (deg)                 |              | 30                |               |
|                                 |          |                            |           |                                   |               |               |                                   | New SMA (km)                        |              | 42843.44          |               |
|                                 |          |                            |           | True Anomaly for Time Interval    |               |               |                                   | New Eccentricity                    |              | 0.62              |               |
|                                 |          |                            |           | T1 (hours since las               | st periapsis) | 0             |                                   |                                     |              |                   |               |
|                                 |          |                            |           | T2 (hours since last periapsis)   |               | 2             |                                   | New Periapsis Radius (km)           |              | 16433.87          |               |
|                                 |          |                            |           | Delta-Nu (deg)                    |               | 104.17045     | 7045 New Apoapsis Radius (km)     |                                     | 69253.00     |                   |               |
|                                 |          |                            |           |                                   |               |               |                                   | * LVLH - Local Vertical Local Horiz |              | Horizontal fra    | me of referen |
|                                 |          |                            |           |                                   |               |               |                                   | Co-planar - burn does not ch        |              | ange inclination  |               |
|                                 |          |                            |           |                                   |               |               |                                   |                                     |              |                   |               |
|                                 |          |                            |           |                                   |               |               |                                   |                                     |              |                   |               |

Figure 1: A screenshot of the Main sheet

## 2.3 Calculator I/O section

This section deals with the specific calculations the user might be interested in performing. Most of the conversions / calculations are self explanatory if the user has a little background in orbital mechanics. If not, please see the references section for reading.

# 3 Glossary

Most of the parameters are named and/or abbreviated as per convention used in either the literature or the industry. Nevertheless, some of them are listed below for convenience of the user.

1. SMASemi Major Axis 2. RAAN Right Ascension of Ascending Node 3. AoP Argument of Perigee 4.  $\mu$  - Product of gravitational constant and mass of the body mu5. Vesc Escape Velocity 6. Sp. Specific  $\nu$  - True Anomaly 7. NuFlight Path Angle 8. FPA 9. ToF Time of Flight degrees - planar angle 10. deg 11. (SI) meaning 'in SI units'

## 4 Author & Feedback

This work is available on my github. Feedback is most welcome.

- Github
- This work
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## References

- [1] NASA "Basics of Space Flight", Section-1, Chapters 3-5, https://solarsystem.nasa.gov/basics/chapter3-1
- [2] Vallado, David A., 1997, "Fundamentals of Astrodynamics and Applications".
- [3] NASA "General Mission Analysis Tool (GMAT)", https://software.nasa.gov/software/ GSC-17177-1