HESTEMP

Comparative Thrust Analysis of Small Satellite Orbital Maneuvers

Transversal, Tangential and Radial Thrust

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Historical Background

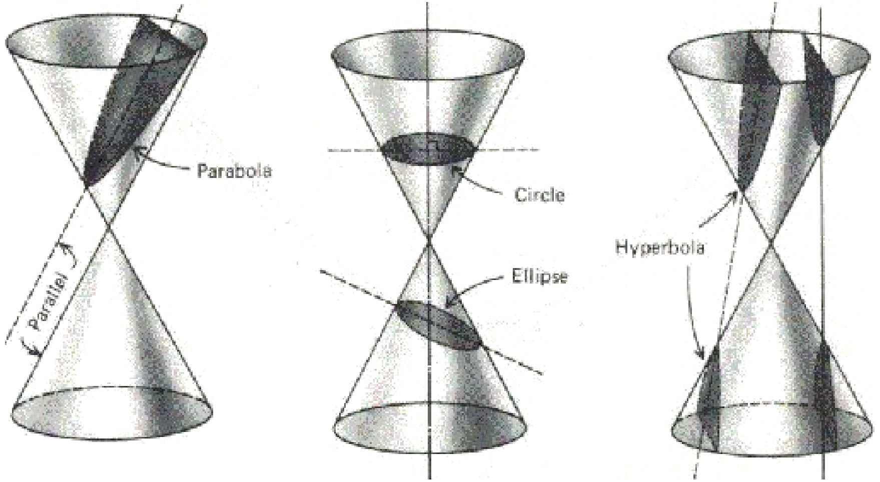
- Authors Bate,Mueller and White suggested in their book *Fundamentals Of Astrodynamics* that Isaac Newton mentioned orbital maneuvers and satellites in his famous *Principia 1687*.
- Actual satellite maneuvering didn't actually happen until until after sputnik on *Oct 4,1957.*
- Jan 2,1959 the Soviets launched Luna 1 requiring many maneuvers such as circularizing the the initial orbit

Materials Covered

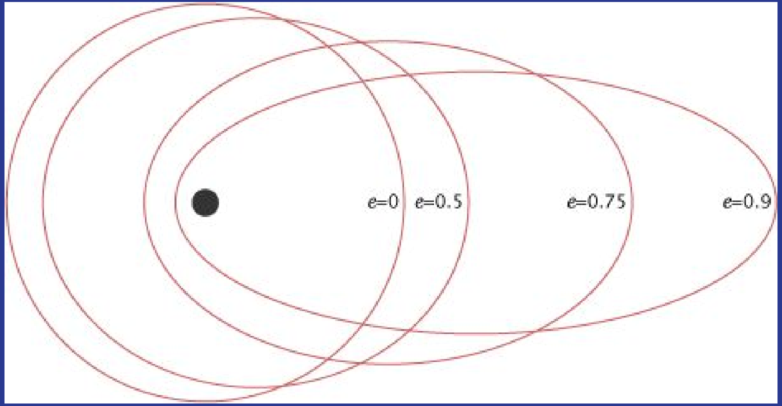
1. Introduction to NASA Ames and Small Satellite Technology Development
2. Coordinate Systems and Transformation
3. <u>Equations of Motion</u>
4. Orbital Maneuvering

Orbital Maneuvering

Maneuvers



- The weight of Small Satellites is critical when considering any maneuvers therefore efficiency is essential.
- Efficiency can mean using the minimum amount of fuel to accomplish given task



Thrust Transfers

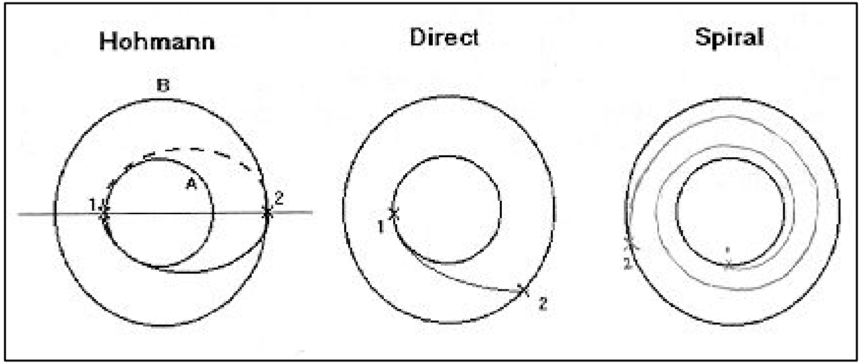
Low Thrust Transfer

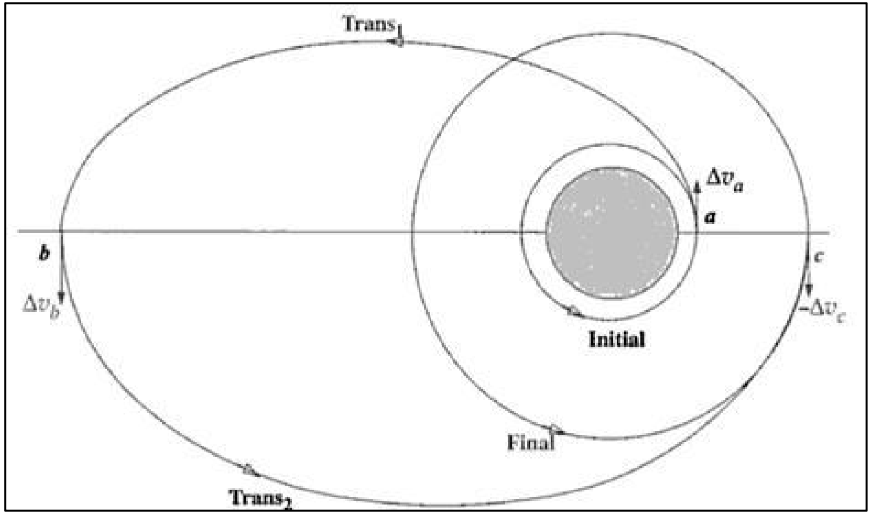
- High Isp ⟶ Low Thrust
- Alfano Transfer

≶

High Thrust Transfer

- Low Isp ⟶ High Thrust
- Bi Elliptic Transfer





Low Earth Orbit

Equations of Motion

Differential Equations defining space craft orbit use following assumptions

1. The Force of the thrust is constant and always in the plane of motion.
2. The vehicle has a fixed propellant mass flow rate
3. The vehicle's acceleration is due solely to the force of thrust and an inverse- square, central gravitational field that is spherically symmetrical

$$\dot{r} = V_r \quad (1)$$

$$\dot{\theta} = \frac{V_\theta}{r} \quad (2)$$

$$\dot{V}_r = \frac{c\beta}{m} e_r - \frac{\mu}{r^2} + \frac{V_\theta^2}{r} \quad (3)$$

$$\dot{V}_{theta} = \frac{c\beta}{m} e_\theta - \frac{V_r V_\theta}{r} \quad (4)$$

$$\dot{m} = -\beta \quad (5)$$

(6)

Definitions:

$$V_r = Radial - Velocity \quad (7)$$

$$V_\theta = Transversal - Velocity \quad (8)$$

$$r = Radius\ from\ COM\ of\ Earth\ to\ Small\ Satellite \quad (9)$$

$$c = Specific\ thrust\ impulse \quad (10)$$

$$\beta = Mass\ flow\ rate \quad (11)$$

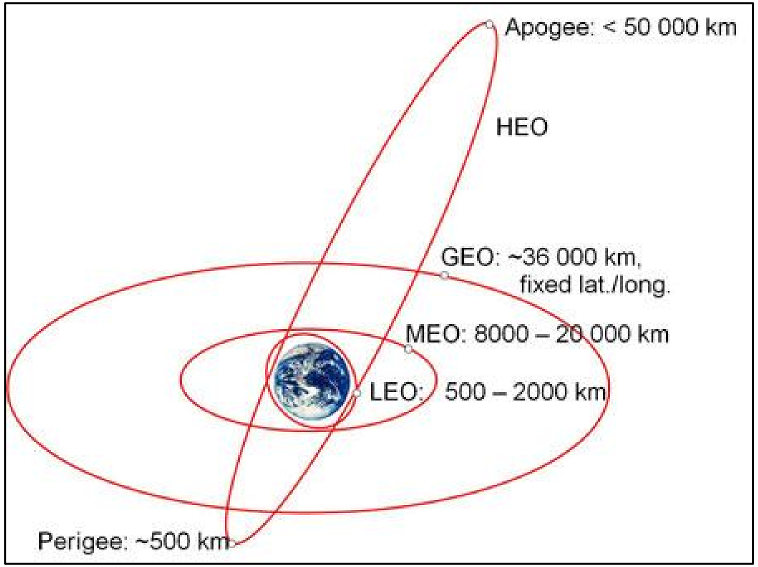
$$m = Mass \quad (12)$$

$$e_r = Unit\ vector\ perpendicular\ to\ thrust\ for\ r \quad (13)$$

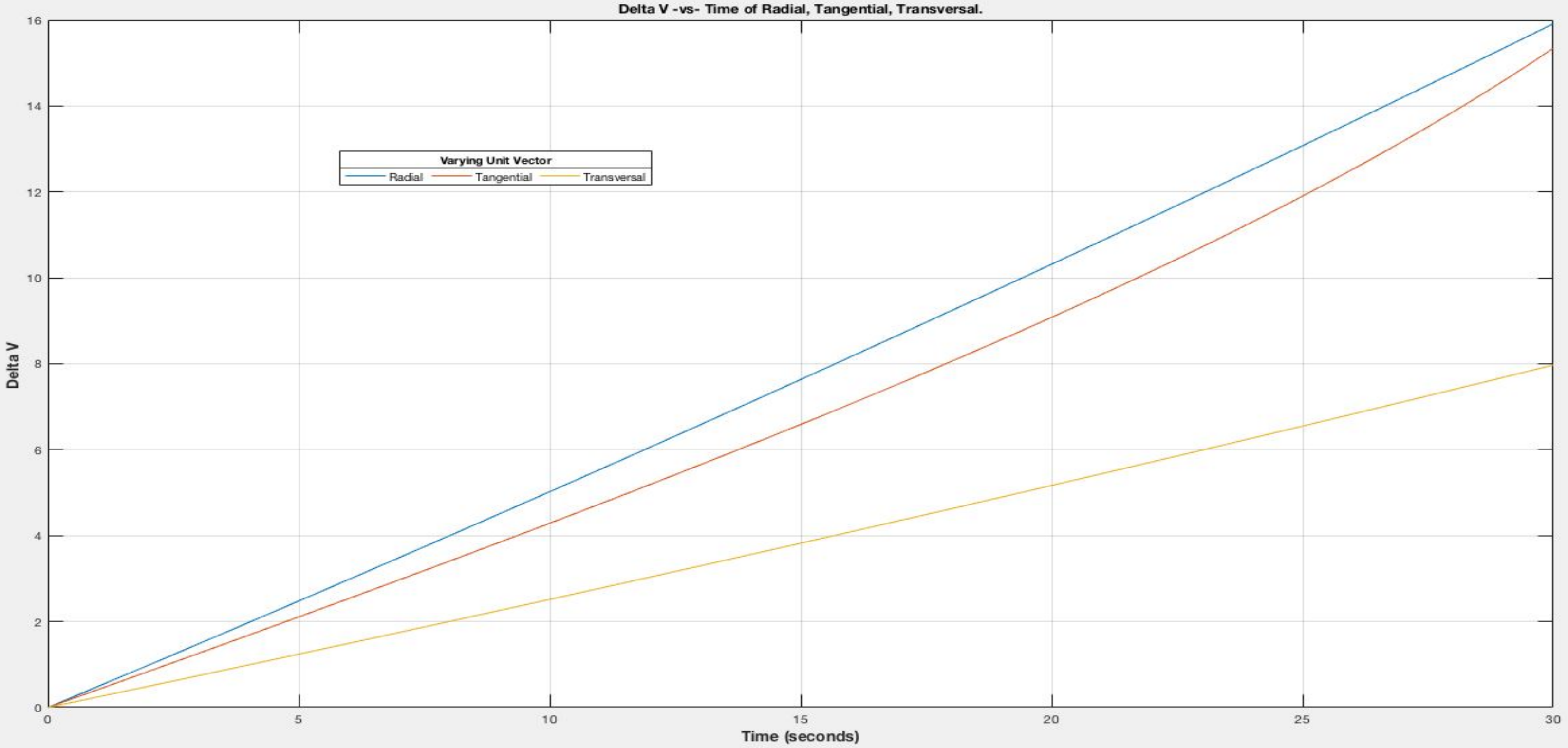
$$e_\theta = Unit\ vector\ perpendicular\ to\ thrust\ for\ \theta \quad (14)$$

$$\mu = Earths\ Standard\ gravitational\ Parameter \quad (15)$$

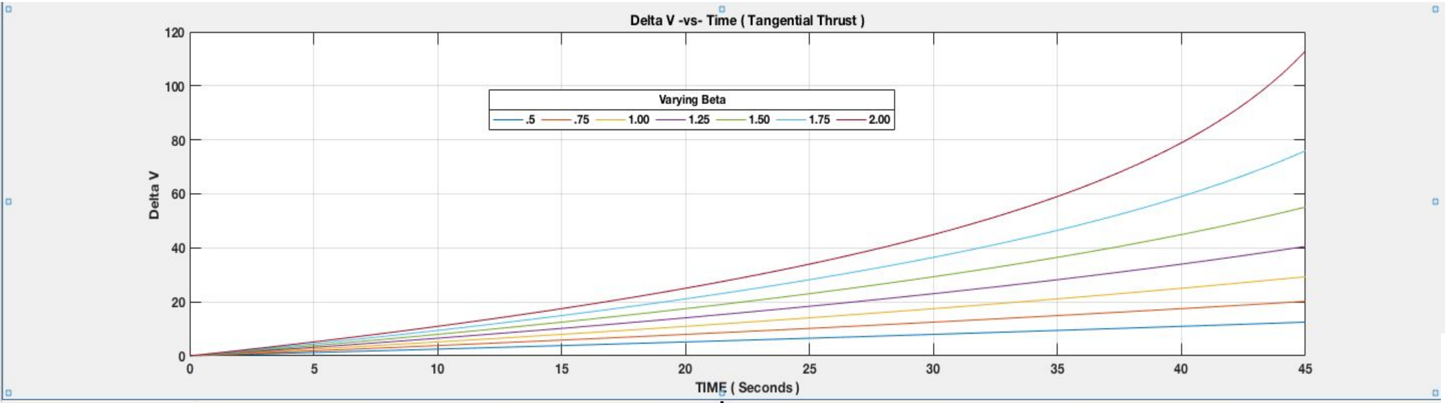
(16)

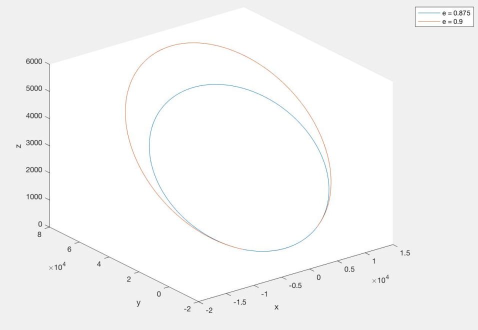


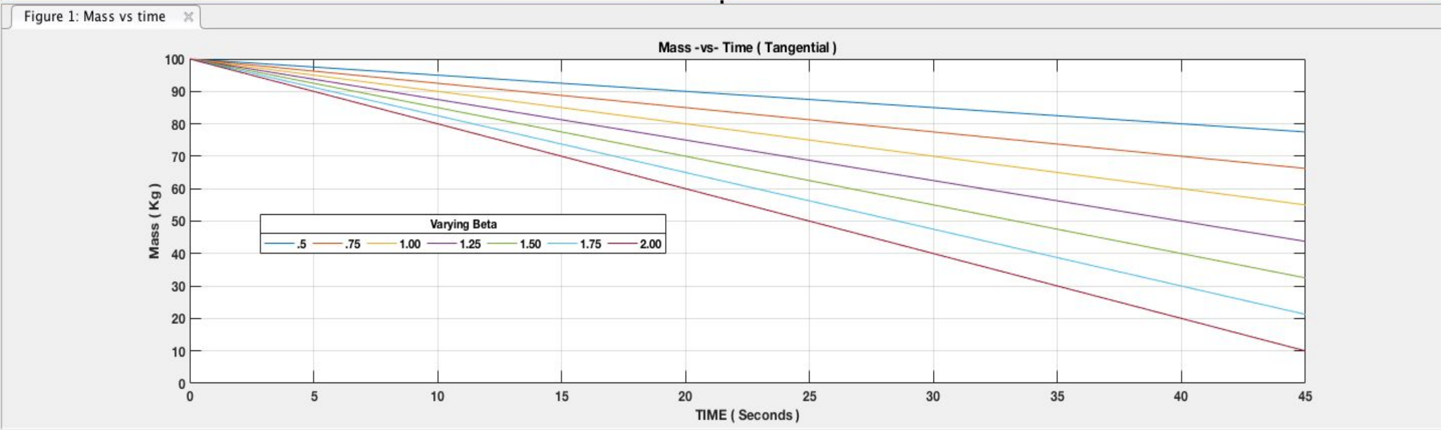
Delta V -vs- Time for Tangential -vs- Radial -vs- Transversal



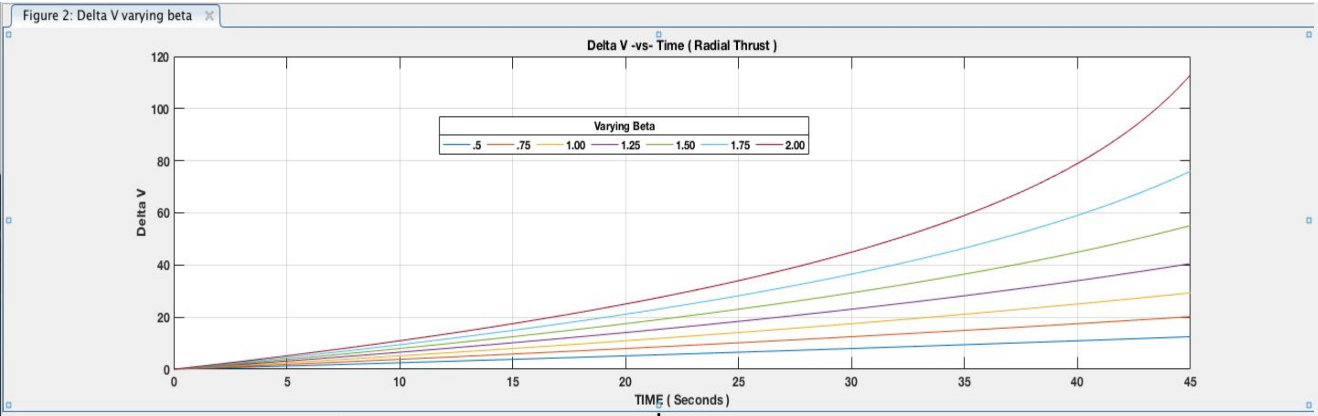
Mass & Delta -vs- Time for Tangential Thrust

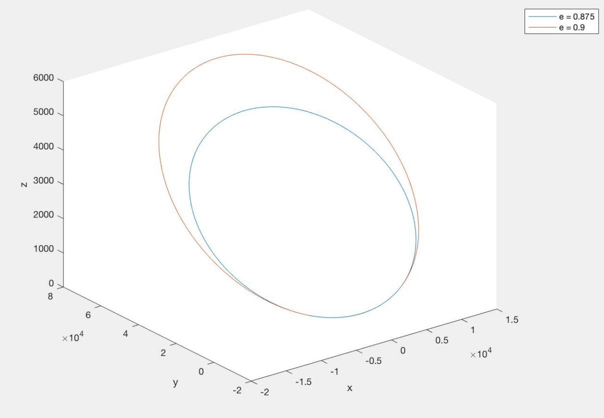


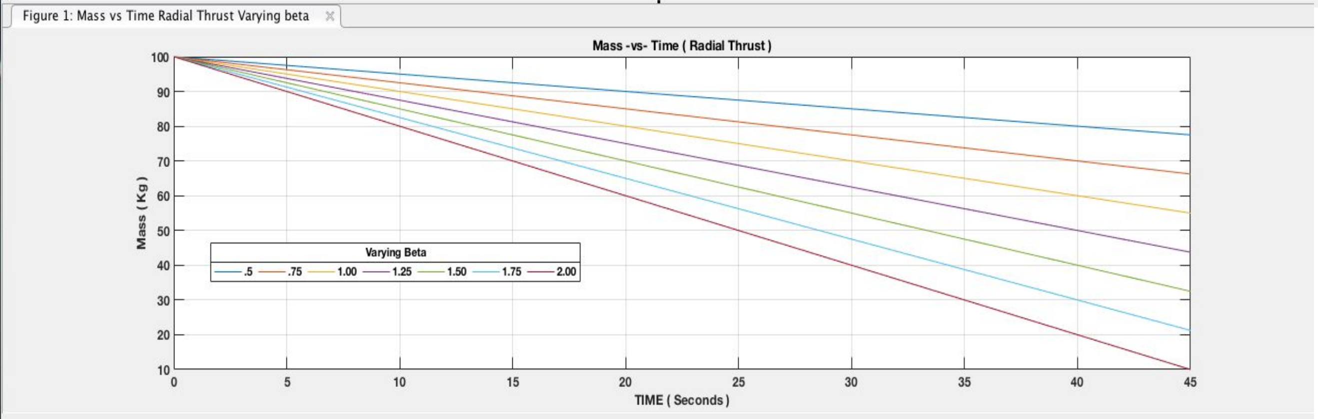




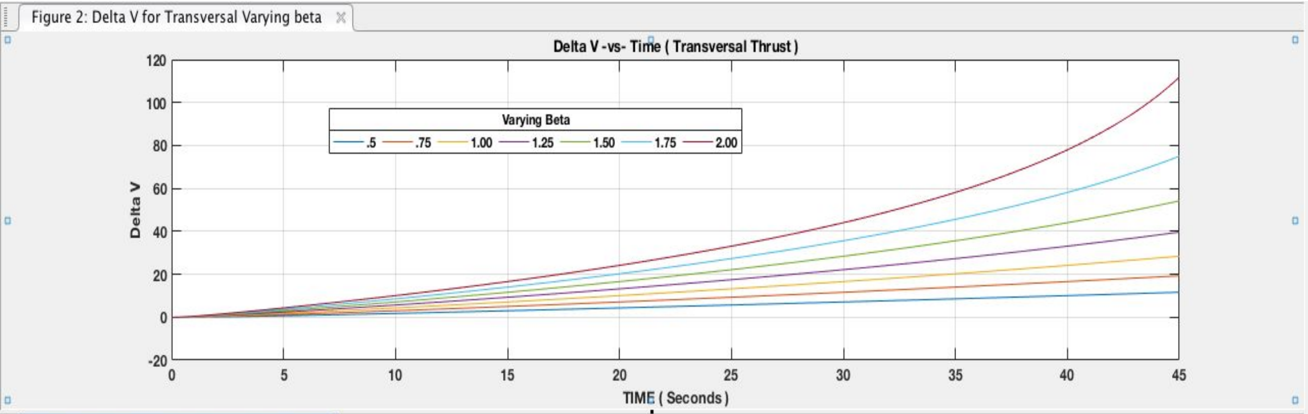
Mass & Delta -vs- Time for Radial Thrust

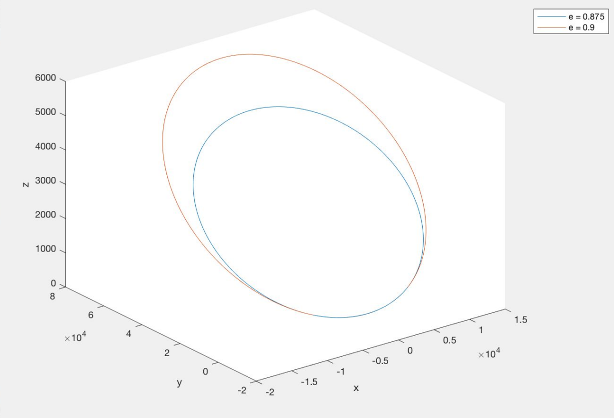


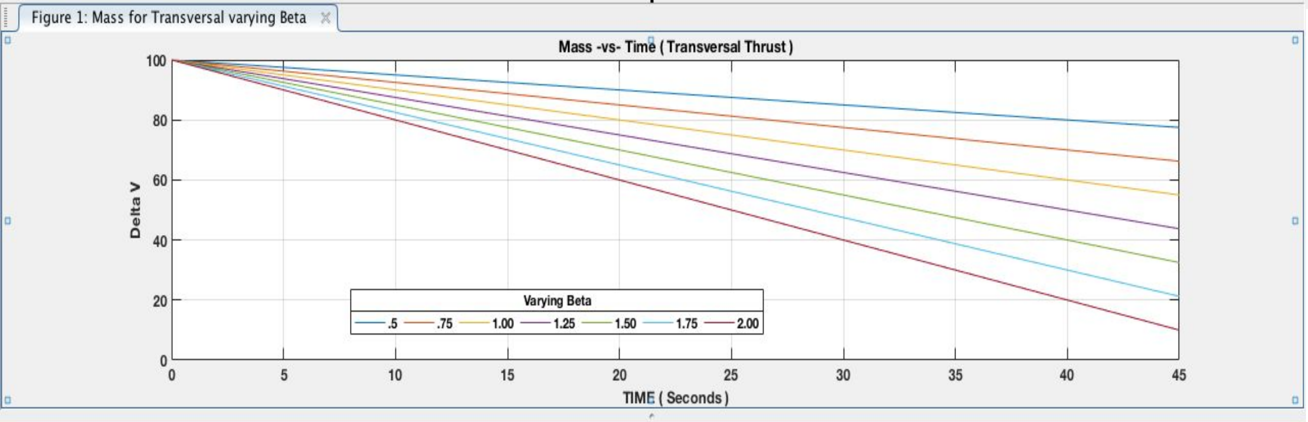




Mass & Delta -vs- Time for Transversal Thrust







Future Research

- *Establish relationship between thrust vector and parameters of the final orbit*
- *Introduce other variables needed for more accurate simulations*

References

- Vallado, D. A., & McClain, W. D. (2001). *Fundamentals of astrodynamics and applications*. Dordrecht: Kluwer Academic.
- Bate, R., Mueller, D. D., & White, J. E. (1971). *Fundamentals of astrodynamics*. New York: Dover Publications.
- https://www.nasa.gov/mission_pages/smallsats
- Edelbaum, T., Sackett, L., & Malchow, H. (1973). Optimal low thrust geocentric transfer. *10th Electric Propulsion Conference*. doi:10.2514/6.1973-1074
- Curtis, H. D. (2005). *Orbital Mechanics for Engineering Students*. Butterworth-Heinemann.