Interplanetary Senior Design

Fall 2019
Intermediate Program
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Overall Mission

Goal:

- Design an interplanetary trajectory to the Saturn system
- Utilize the atmosphere of Titan to perform an aerocapture
- Slow the spacecraft down enough to result in an orbit about Saturn that will allow for frequent flybys of Enceladus

Modeling the Final Orbit about Saturn

Goal:

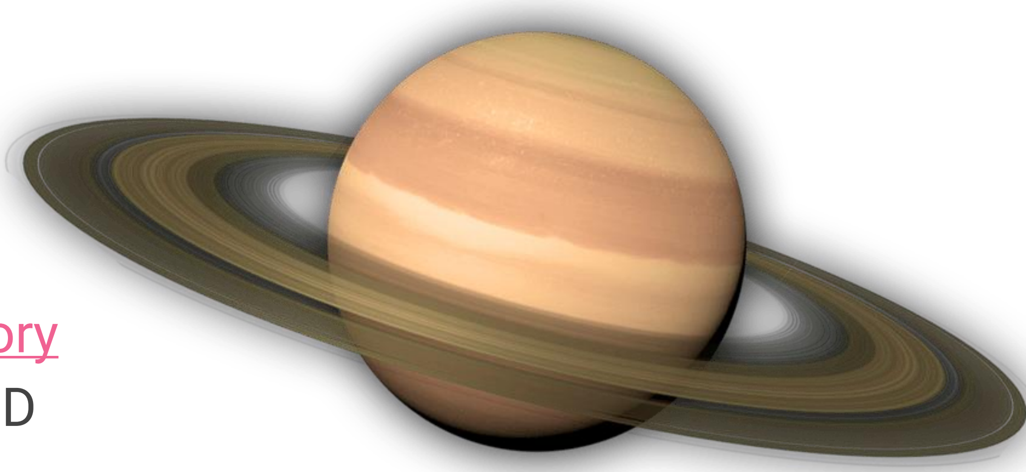
- Analytically determine an orbit around Saturn that allows for frequent flybys of Enceladus. Previous work has been done in 2D, we want to incorporate inclination

Assumptions:

- Enceladus and Titan’s orbits are circular and in the same plane
- No gravitational forces except Saturn’s
- Saturn-centered coordinate system, positive z-direction orthogonal to Enceladus and Titan’s orbital plane

Code

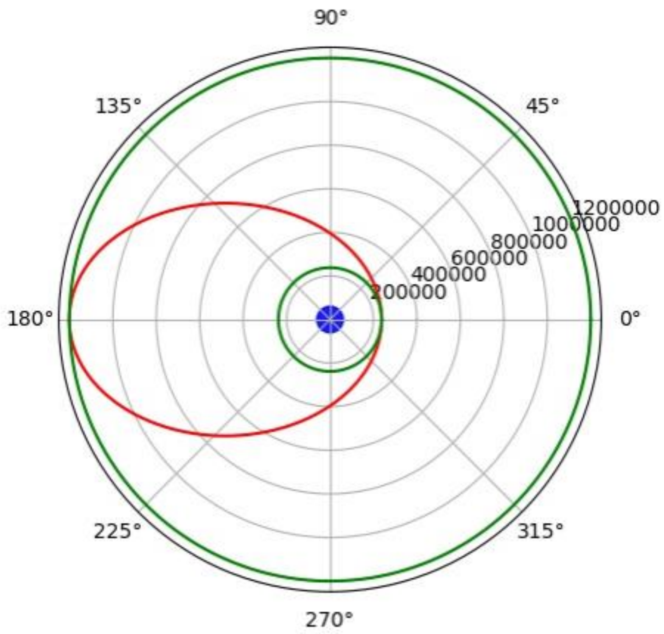
- Based in the Python language
- Conda, Matplotlib, Mayavi, Numpy modules used for additional functionality
- Version control via Git repository
- Two main files (2D case and 3D case)
  - 2D_Potato.py
  - 3D_Potato.py
- Older versions and examples in the repo



2D Case

Goal:

- Determine the family of velocity vectors which will result in an orbit about Saturn with a perigee radius equal to or less than Enceladus's orbital radius.



Equations:

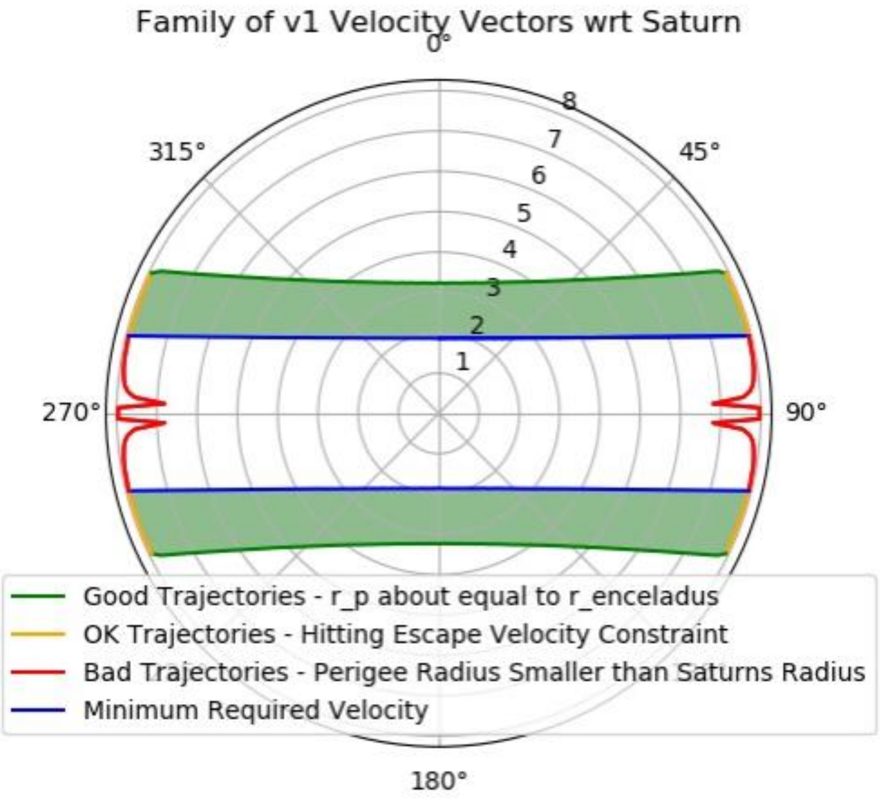
$$\varepsilon = \frac{1}{2}{v_1}^2 - \frac{\mu}{r_1} = \frac{1}{2}{v_p}^2 - \frac{\mu}{r_p}$$

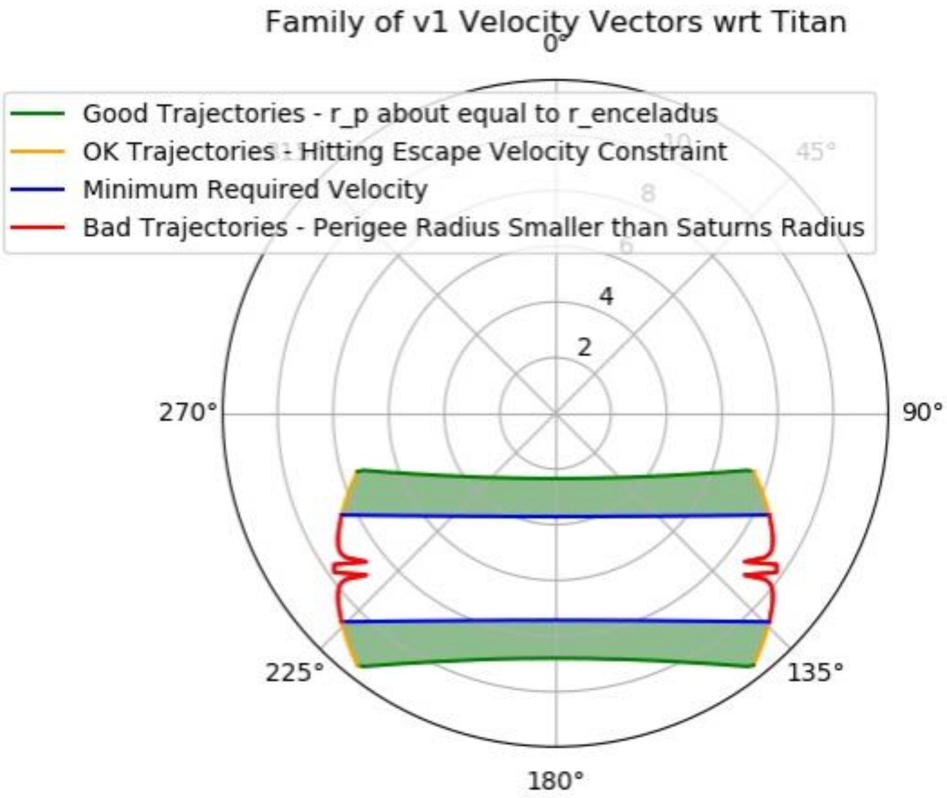
$$h = v_1 r_1 \cos(\gamma) = v_p r_p$$

Approach:

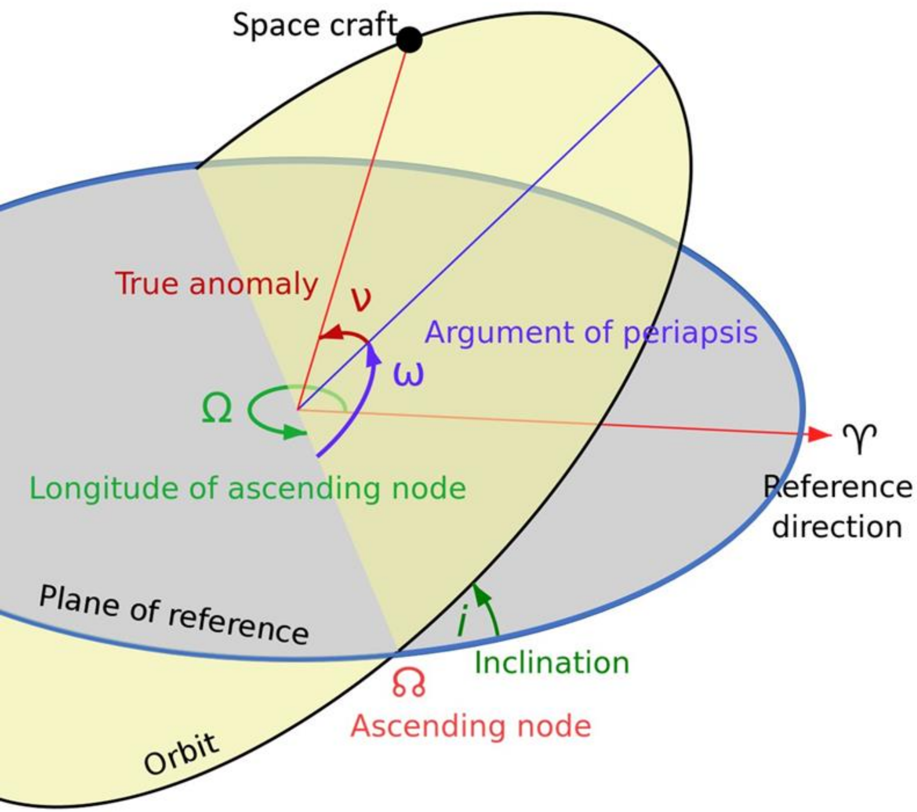
- For each flight path angle, vary v_1 and solve the system of equations until $r_p \leq r_{enceladus}$

Results and Reference Frame Change





3D Case



- For an inclined orbit, there will be only two locations where a potential crossing of Enceladus's orbit is possible:
  - Ascending Node
  - Descending Node
- For every combination of flight path angle and inclination:
  - Calculate the orbital elements
  - Determine velocities which will result in the radius at the nodes being equal to Enceladus's orbital radius.

- Execution in progress

Future Work

- Complete 3D Case
- Analyze results to find optimal orbits
    - Time of flight and Enceladus rendezvous opportunities
    - Ensure the spacecraft will not collide with other objects in Saturn's ring system
- Integrate results with the POST and MAnE teams