AA279B Progress Report: Orbit Trajectory from Low Earth Orbit to Europa

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1 Introduction

Europa is one of the most scientifically interesting celestial bodies in our solar system because of the presence of water on its surface. There have been fly-by missions of Jupiter which have taken photographs of the surface of Europa. However, a mission that lands on the surface would provide valuable information about whether there is life there. NASA is considering undertaking a mission to land on Europa's surface with a proposed launch date of 2025.

This project was performed to determine the trajectory for a spacecraft leaving Earth and landing on the North Pole of Europa, which simultaneously optimizes both time of flight and total Δv. Any mission to Europa will be costly and will take a long time, so minimizing those parameters will be key to getting the mission approved.

2 Approach

The first part of the mission is the path from Earth to Jupiter. For this, we used a Lambert solver to determine the required ΔV. We started with a launch date of 2025, the year of the planned NASA orbit, and then iterated over the entire year to find the optimal launch date. Simultaneously, we iterated over a range of arrival dates, ranging from 2027 to 2033. We calculated the ΔV required for each scenario. This data was then used to find a launch date and time of flight for the trajectory to Jupiter which would minimize ΔV.

The second part of the mission takes the spacecraft from Jupiter to Europa's surface. For this intermediate report we only looked at a trajectory to get the spacecraft into Low Europa Orbit, at an altitude of 1000km. This part of the mission was calculated in the Jupiter/Europa synodic frame using a shooting method. This method requires that the initial guess for angle and velocity be fairly good, so we ran the solver over a range of initial velocity from 0 to 60 km/s and a range of initial angle from 0 to 2π to find the initial error for each one. Then we used the values with the lowest initial error to get the starting guess for velocity and position, and ran the shooting method solver based on those.

3 Intermediate Results

Iterating over the launch dates and the arrival dates we found a minimum ΔV of 9.330401 km/s. This minimum is attained by launching on October 28th, 2025, and arriving on July 4th, 2030, for a time of flight of 4.68 years. These results can be visualized in the figure 1.

Using these optimal dates we propagated the transfer orbit using the FODE. This trajectory can be appreciated in figure 2.

For the trajectory from Jupiter to Europa, the shooting method found that an initial velocity of 55 km/s and an initial angle of $\frac{3\pi}{2}$ radians gave a trajectory to Europa that took 3 days. This was one of the few initial conditions that would actually converge, although in the future we hope to look at trajectories lasting different amounts of time. So far, we have only looked at trajectories of 3 days and 7 days due to

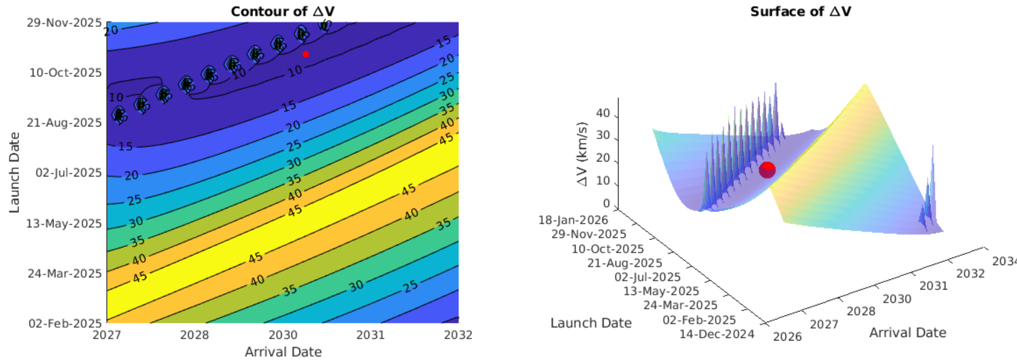

Figure 1: ΔV as a function of launch time and arrival time.

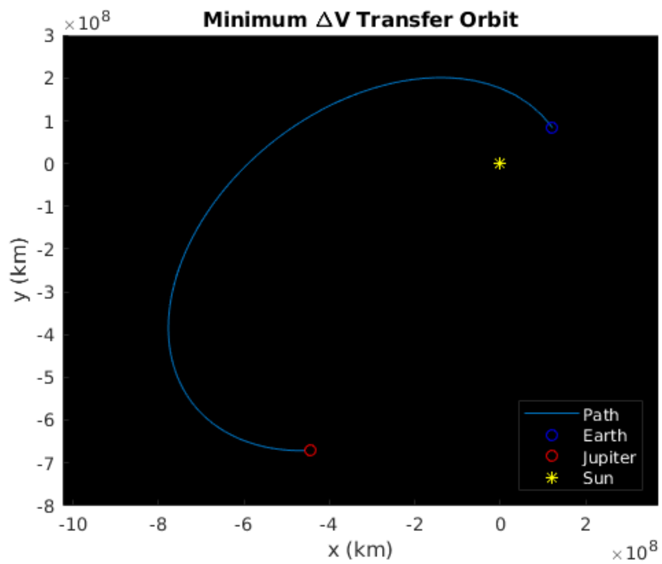

Figure 2: Trajectory from Earth to Jupiter using the dates that optimize fuel consumption.

computational constraints. The plot of the trajectory to Europa in the synodic frame can be seen in the left plot of figure 3. The same trajectory was also converted into the Jupiter inertial frame, and that path can be seen in the right plot of figure 3.

The initial velocity required to get to Europa seems very high. The shooting method for determining trajectories is very unwieldy since an accurate initial guess is required and the code takes a long time to run. Trying the program over different trajectory times could improve the initial velocity required.

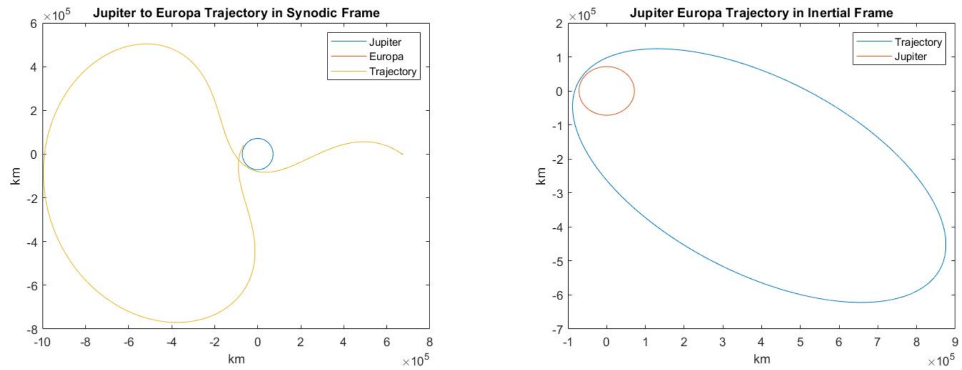

Figure 3: Trajectories from Jupiter to Europa in two different reference frames.

4 Conclusion

Now that we have a trajectory from Earth to Jupiter and from Jupiter to Europa, the next step will be to determine the orbit path from a low Europa orbit to landing on the surface. We plan to use a Lambert solver for this step. Europa has a thin atmosphere so we are hoping to model the atmosphere and include drag in our trajectory.

Additionally, it should be possible to further reduce ΔV if we use the incoming velocity of the spacecraft on its way from Earth to start the spacecraft on its trajectory to Europa. Using a gravity assist type approach may help with that, allowing the mission to use less ΔV by incorporating the incoming velocity into our model in the synodic frame.

5 Code

GitHub: https://github.com/jam14j/Earth2Europa