Europa Clipper Mission: A study in orbital dynamics using Python

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1 Abstract

The Europa Clipper Mission is NASA's first attempt to gather data on Jupiter's moon Europa specifically. Europa is Jupiter's icy moon potentially containing an under crust ocean that could be teeming with life. The exploration of Europa is essential towards NASA's long term goals of identifying extraterrestrial life, the Europa Clipper Mission will be the precursor mission gathering preliminary data for the Europa Lander which will hopefully be able to investigate the world that exists deep beneath Europa's Surface. The Europa Clipper Mission is one of NASA's most ambitious projects and will gather data about geological components of Europa, as well as images of the moon's surface. The orbiter mission also has to avoid remaining in Jupiter's radiation belt, as this will damage the orbiters instrumentation and be detrimental to the mission's success. The Europa Clipper Mission can fundamentally change how we perceive our own place in the universe and allow for an answer to are we alone.

2 Introduction

The Europa Clipper Mission is NASA's first attempt to launch a probe to Jupiter's moon Europa. Europa has been the subject of a mass of scientific inquiry and funding after it was theorized that under the moon's thick layer of surface ice laid a giant ocean of water (subsurface ocean). With the presence of such a great amount of water, many scientists believe that Europa is the most likely candidate to sustain life outside of earth. Scientists believe that Europa's ocean is similar to Earth's deep sea, with large hydrothermal vents pumping out minerals to the sea floor and allowing for the potential existence of bacteria. The Europa clipper mission is a complex program designed to gather precise data on Europa that can lead to further discoveries about the planet's components and potential to support life.

This mission is a collaborative project between the Johns Hopkins Applied Physics Laboratory and the Jet Propulsion Laboratory and is expected to incur

expenses of approximately two billion dollars. The mission consists of a series of flybys to be completed by the Clipper orbiter, and its purpose is to obtain data, photos, and other information regarding Europa. It is planned to be carried out sometime after 2022, as that is the earliest launch window for the rocket. The name Clipper is in reference to the sailing vessel, as the orbiter is intended to "sail" around Jupiter while gathering data on Europa.

3 Potential concerns

The goal of the Europa Clipper Mission is to gather more precise and specific preliminary data on Jupiter's moon Europa as well as determine a landing space for the future Europa Lander Mission. However, the mission faces a few key obstacles. The first is that Europa lies at the center of Jupiter's radiation fields; even an orbiter designed to survive in radioactive environments would last only a few months in these fields. The second major obstacle of the mission is the difficulty in selecting instrumentation: many instruments can collect data faster than the limited antennas can transmit it back to earth. The simplest way to resolve both problems of radiation and of instrumentation is to adjust the orbit of the rocket. In order to avoid the radiation of Jupiter, the ship is designated to orbit Jupiter rather than Europa itself. This allows it to complete forty five flybys of Europa while avoiding the majority of the radiation. Altering the Clipper's path so that it orbits Jupiter instead also allows the instruments to store the data from a pass and then transmit the data to Earth during the period in which the ship is orbiting the side of Jupiter facing away from Europa, allowing more data to be relayed.

At this point in time, the Europa Clipper Mission has many characteristics still up in the air as the project scrambles to acquire sufficient funding. However, there are a few pieces that seem established or incredibly likely: the instruments to be used during the mission and the rocket for the launch of the orbiter have been decided.

4 Instrumentation

The instruments to be incorporated into the mission are as follows:

1. *Plasma Instrument for Magnetic Sounding (PIMS)*
   The PIMS works in concert with the ICEMAG to determine the thickness of the ice that surrounds Europa's surface, as well as the ocean depth and salinity.
2. *Interior Characterization of Europa using Magnetometry (ICEMAG)*
   ICEMAG measures the magnetic field around Europa and collaborates with PIMS to calculate information about Europa's ocean such as the ocean's location, depth, and salinity.

3. *Mapping Imaging Spectrometer for Europe (MISE)*
   MISE will examine the distribution of organics, salts, acid hydrates, and water ice phases to better determine the habitability of Europa's ocean.

4. *Europa Imaging System (EIS)*
   The EIS will take pictures of Europa's surface in order to map it.

5. *Radar for Europa Assessment and Sounding: Ocean to Near-surface (REASON)*
   REASON is an ice-penetrating radar that will reveal any hidden structures within Europa's ice shell, as well as the water within.

6. *Europa Thermal Emission Imaging System (E-THEMIS)*
   E-THEMIS provides thermal imaging of Europa's surface, like the vents that spew water and water vapor into space.

7. *MAss Spectrometer for Planetary EXploration/Europa (MASPEX)*
   MASPEX will test the composition of surface material ejected into space in order to determine the composition of surface and ocean of Europa.

8. *Ultraviolet Spectrograph/Europa (UVS)*
   UVS will detect small plumes of water and assist in providing data about the composition of Europa's atmosphere.

9. *Surface Dust Mass Analyzer (SUDA)*
   SUDA will gather and measure the make up of small particles ejected from Europa in plumes during low-altitude flybys.

5 Carrier

On launch day, the orbiter is estimated to have a mass of six metric tons. It will be loaded with two large solar panels that can generate six hundred watts of power to keep the instrumentation running. The orbiter is to be launched from the Space Launch System (SLS), one of NASA's largest and most ambitious rocket projects to date; the project is expected to cost anywhere from seven to nearly thirty five billion dollars by the conclusion of the project. The result is a large rocket with extremely powerful boosters that allow for the shipment of larger payloads into space. To give a sense of the rocket's capabilities: it is capable of carrying one hundred and fifty metric tons to Mars. This makes it an ideal selection for the purposes of the Europa Clipper Mission, which will require heavy instrumentation.

6 Mission path proposal

In order to reach Jupiter and perform the intended flybys, the rocket must be launched under specific conditions with special consideration to the gravitational energies of the involved celestial bodies. Therefore, we propose a path

involving Hohmann transfers through a number of orbits. The resulting paths are illustrated and described in detail below:

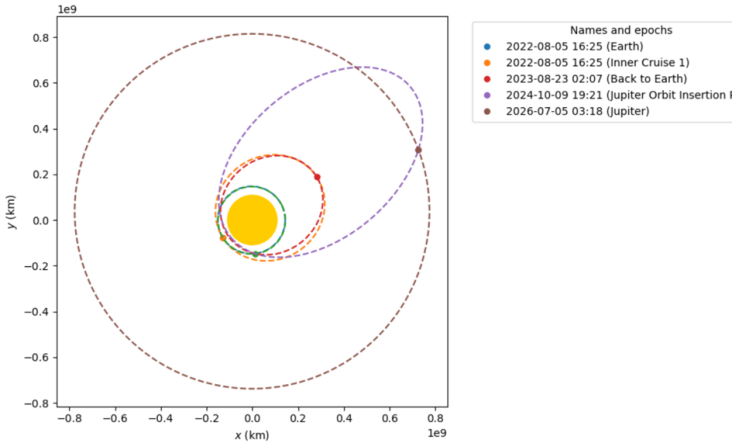

Figure 1: Proposed path

6.1 Earth

Prior to launch, the Clipper rests on the Earth's surface and follows its orbit (shown in blue/green).

6.2 Intermediate orbit

Immediately after launch, the Clipper escapes Earth's gravitational energy and enters Inner Cruise 1. This orbit is defined by the position of the Clipper's aphelion and flyby and is determined by Lambert's solution. However, the difference between initial velocity necessary for orbit and velocity at aphelion is too great. After passing the aphelion, we define an intermediate orbit as the "Back to Earth" orbit.

6.3 Jupiter orbit insertion

Following the intermediate orbits, the Lambert Solution is used again in determining the velocities necessary to enter Jupiter's orbit.