CAL POLY POMONA

ARO 309 – Orbital Mechanics, Winter 2017

The Plumes of Europa

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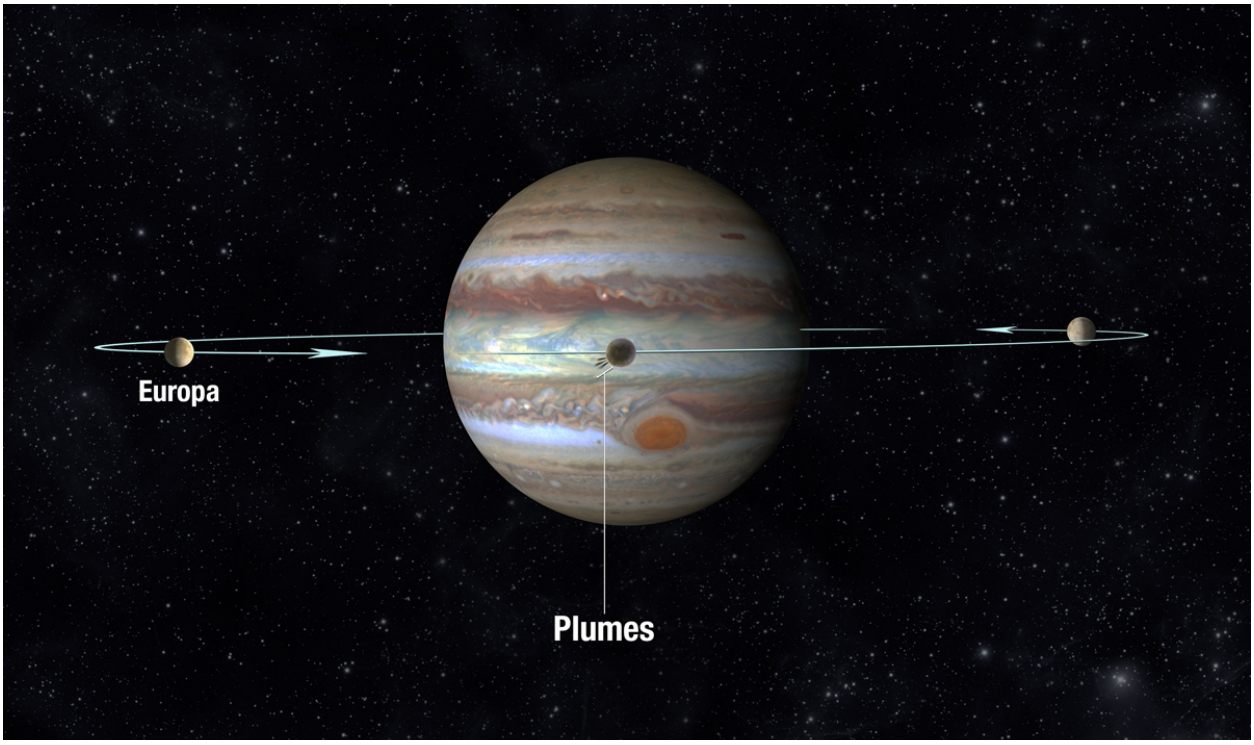
Introduction

In the recent years, our knowledge of planetary systems has expanded significantly and extended to the world beyond our Solar System. Exoplanets are in the center of attention for researchers to find possible locations that could harbor life in the universe. However, exoplanets are too far for any unmanned mission to reach out for further exploration. In our quest to find any form of life beyond Earth, our Solar System is the most accessible place to explore. A few years ago, NASA has started an initiative "Ocean Worlds: The Quest for Life" to explore a few locations that we believe with high certainty that water exists in our solar system and not just in little quantities. These candidates are mostly the moons of giant planets. These ocean worlds are the next frontier in the search for life beyond Earth. The following infographics illustrated these open worlds and what we know about them (click on the photo to view the high-resolution version).

Jupiter's icy moon, Europa, one of the four famous Galilean moons, is the target for an upcoming NASA mission. Scientists believe that underneath the icy shell of Europa, there exists a giant liquid water ocean which may harbor alien life. Besides Mars, Europa is the closest place with this possibility and the pieces of evidence are very promising. However, testing this hypothesis requires a sophisticated lander that could drill into miles of ice to reach the ocean beneath, which would be extremely expensive mission.

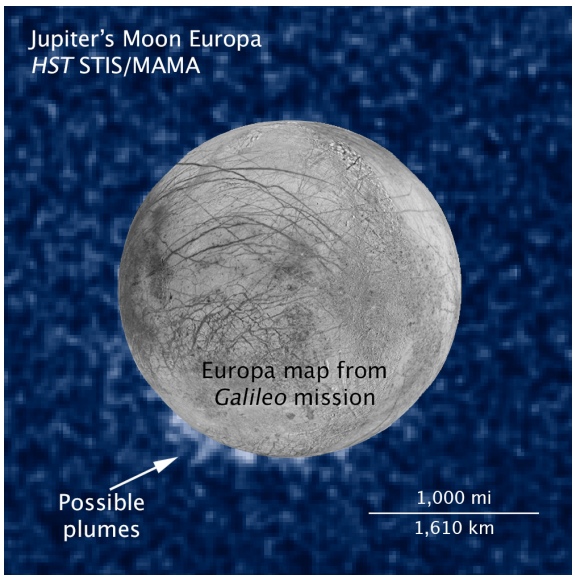
We are lucky that there is another way (much cheaper) to test this hypothesis! In 2012, NASA Hubble Space Telescope took a series of images with spectroscopic signatures of water vapor around Europa. Recently, Hubble took another series of images during the transit of Europa in front of Jupiter and in some of them, plumes of water vapor was observed directly in the images. The plumes are estimated to rise about 125 miles (200 kilometers) before raining back down onto Europa's surface. This enables the possibility of flying a spacecraft with scientific instruments through these plumes, testing the material to confirm the components, and if lucky, detecting some form of microorganisms as a proof of life on Europa (click on the picture below to watch an informative video on this discovery).



Project Overview

Based on Hubble Space Telescope observations, the plumes appear at a particular location on Europa which is shown in the image. "*This composite image includes data from Hubble's Space Telescope Imaging Spectrograph, which shows suspected plumes of water vapor erupting at the 7 o'clock position off the limb of Jupiter's moon Europa. The image of Europa, superimposed on the Hubble data, is assembled from data from the Galileo and Voyager missions.*" *(Credit: NASA, ESA, W. Sparks (STScI), the USGS Astrogeology Science Center, and Z. Levay (STScI))*

Although NASA Europa Mission will perform multiple flybys at Europa during the course of its mission, we will try an alternative low-cost mission to reach these plumes of water vapor at Europa. Your project is to design a mission to flyby through the plumes of Europa. Your mission consists of a primary spacecraft ("*mothership*") that will travel to Jupiter. The mothership carries a number of small spacecraft ("*daughters*") that are going to perform flybys at Europa and are capable of simple sampling and analysis of the water vapors. The can relay the data back to the *mothership* for transmission to Earth.



The goal is to minimize the overall cost of the mission by designing an optimized trajectory for the spacecraft to reach Europa and perform the flybys. When the mothership reaches Jupiter, it will be captured into a highly elliptical orbit around Jupiter. It then releases the daughters to

flyby Europa. We cannot guarantee that the plumes are active during the flyby. Thus, multiple opportunities must exist. The daughters will be released one-by-one and (not at the same time) to increase the chance of successful sampling.

The daughters should perform low altitude flybys through the plumes region at multiple instances. Each daughter has only one shot to perform the sampling and they have no significant propulsion system onboard. The requirement and limitations for your mission are listed in the following section.

Mission Requirements and Objectives

Your mission should achieve the objectives and satisfy all the requirements listed in this section. If for any reason, you decide to disregard any of the objectives or requirements, solid justification has to be provided.

1. Design the interplanetary mission from Earth to a capture orbit around Jupiter for the spacecraft.
2. The mothership carries 3 daughters that will be released for 3 flybys at Europa. The daughters are 50 (kg) each and they have no propulsion system onboard.
3. Design the flyby for each daughter at Europa.
4. The mother ship has to carry the fuel required for the entire mission after the launch including the releasing sequence of the daughters for flybys. You should calculate the dry mass and the wet mass of the entire spacecraft. The dry mass of the mothership without the daughters is 700 (kg). The cost of the mission will be a function of the wet mass at the time of launch.
5. Spacecraft must be launched on a vehicle specified on the NASA Launch Service Program: https://elvperf.ksc.nasa.gov/Pages/Query.aspx
6. Mission duration from launch to end of mission (spacecraft disposal) must not be greater than 15 years.
7. Design the disposal scenario. Due to planetary protection and potential life on Europa, the spacecraft cannot be disposed at Europa. All spacecraft must be disposed into either Jupiter, Io, Ganymede, or Callisto.
8. Due to Jupiter's strong radiation environment, the spacecraft lifetime at the Jupiter system is limited to 3 years.
9. Due to thermal consideration, the spacecraft cannot travel below 0.6 (AU) with respect to Sun.
10. Due to instrument limitation, the flyby speed through the plumes must be less than 6 (km/s) and have altitude of 180 (km) or less from the surface of Europa.

Grading and Important Due Dates

The result of your design will be presented to the reviewers and will be evaluated based on the completeness, correctness, and the creativity of your design.

You will prepare a powerpoint presentation following the suggested format in this document that clearly illustrates your design. Then, you will have to add narration over your presentation with the time limit of 15 minutes and explain your design. Microsoft PowerPoint is capable of creating this narrated presentation (to find out how, check this link).

The deadline to submit your presentation is **March 12, 2017 at noon**. The 15-minute slideshow will be shared with the reviewers and your grade and their evaluations will be given to you about a week after.

The following is the rubric that will be used to score your design:

- **(20 points)** Satisfying all mission objectives and requirements
- **(40 points)** Correctness of the calculations:
    - ✓ Interplanetary leg of the mission
    - ✓ Europa flybys
    - ✓ Launch vehicle selection
    - ✓ Disposal leg of the mission
- **(15 points)** Creativity of the design
- **(20 points)** The presentation of the mission
    - ✓ The design and clarity of the slides
    - ✓ The audio presentation
    - ✓ The visual illustrations of the mission (such as animations and graphs)
- **(5 points)** The overall mission design

Presentation Format

- **Title page:** This should include the project title, your name and the names of your team members with a photo of the team members.
- **Outline:** That explain what you will present in the following slides.
- **Mission Overview:** Provide a brief summary of the mission that describes the overall mission goals, concepts, and key results of your design.
- **Introduction:** Describes the background information related to the mission (in line with the project overview), together with an outline of your analysis. You should also explain the software(s) you have used.
- **Modeling Assumptions:** Describe the key assumptions made, theories you have used for calculations, and key physical constants used in the report.
- **Technical calculations and Analysis:** This section should include important calculations you have used to finalize your design and satisfy the mission requirements. Explain the tools you have used and the analysis you have performed to support your decision making. Any optimization or trade-off you have done should be explained clearly.
- **Final Design:** Present your final design and support your design with calculations and include the graphics and animations to better illustrate your mission at different stages.
- **Summary:** Explain your approaches to address each of the mission objectives and requirements.
- **Appendix:** Include the details of your calculation, and additional graphs and animation if needed in this section. This section does not need a narration and will not be included in your 15 minute presentation.