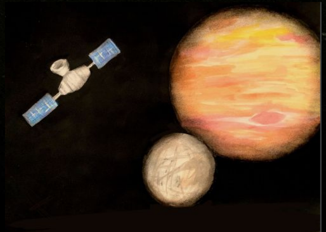
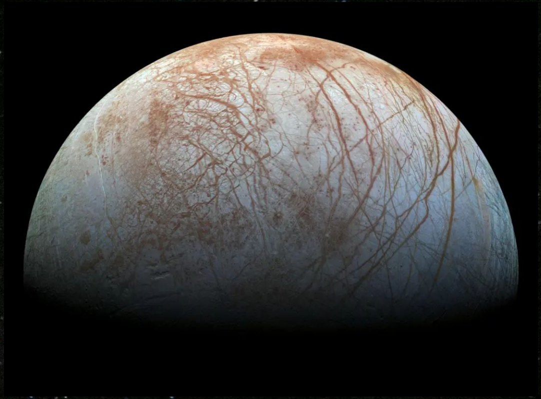
Europa Habitat and Composition Observation (ECHO) Lander

Design Team 1: Katie August, Joseph Bowers, Constantine Childs, Andrew Olson, Chloe Powell, Aaryan Sonawane, Mae Tringone



Mission Overview

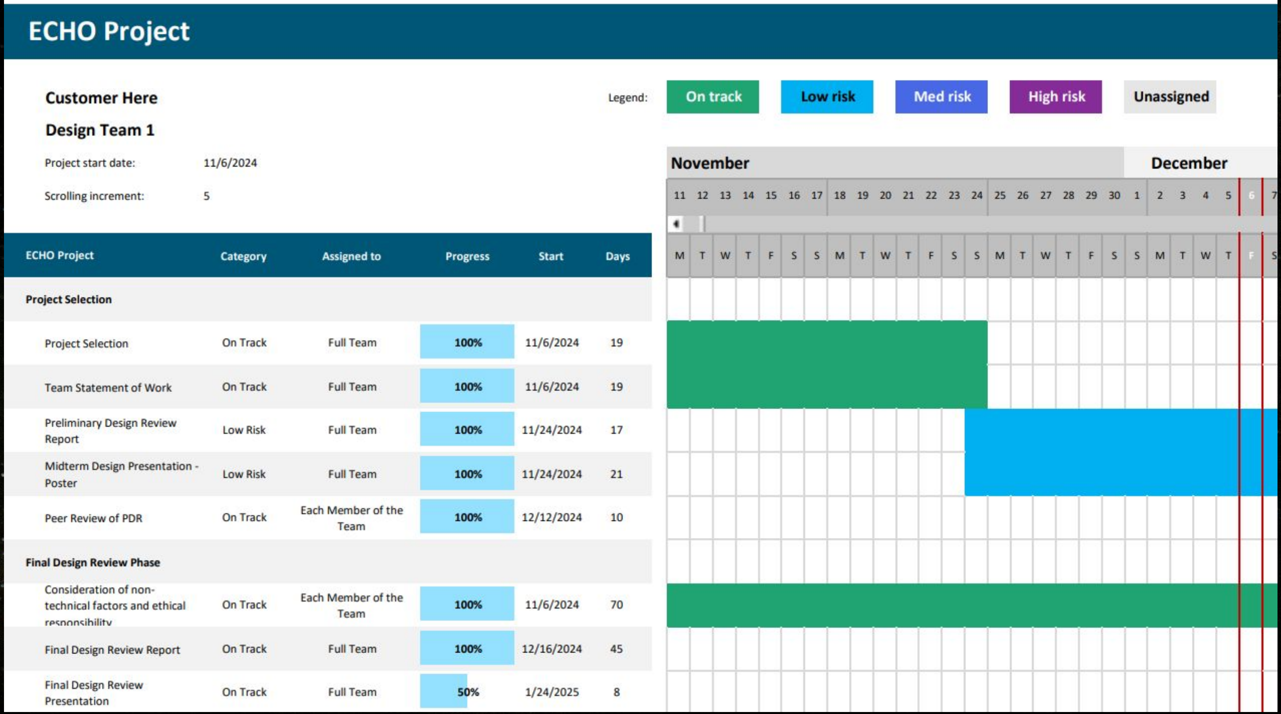


- Analyze Europa composition to determine habitability for NASA's Planetary Science Division
  - Analyze surface ice composition and potential subsurface liquid water
- Return data and high-resolution images to earth
- Mission lifetime of 6 months upon landing
  - Launch with Falcon Heavy
  - Mass budget 1,000 kg
  - Cost budget $1,160,000,000

[1] [2]

Project and Semester Objectives

To offer an efficient and cost-effective solution to land and conduct scientific analysis on Europa



ECHO Project

Customer Here

Design Team 1

Project start date: 11/6/2024

Scrolling increment: 5

Legend: On track | Low risk | Med risk | High risk | Unassigned

ECHO Project	Category	Assigned to	Progress	Start	Days
Project Selection					
Project Selection	On Track	Full Team	100%	11/6/2024	19
Team Statement of Work	On Track	Full Team	100%	11/6/2024	19
Preliminary Design Review Report	Low Risk	Full Team	100%	11/24/2024	17
Midterm Design Presentation - Poster	Low Risk	Full Team	100%	11/24/2024	21
Peer Review of PDR	On Track	Each Member of the Team	100%	12/12/2024	10
Final Design Review Phase					
Consideration of non-technical factors and ethical responsibility	On Track	Each Member of the Team	100%	11/6/2024	70
Final Design Review Report	On Track	Full Team	100%	12/16/2024	45
Final Design Review Presentation	On Track	Full Team	50%	1/24/2025	8

Technical Analysis

Structures

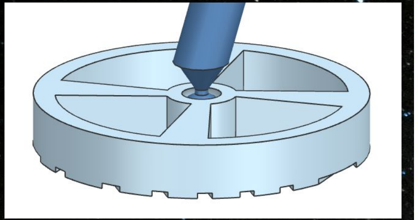
Hexagonal frame and skin structure with deployable truss landing legs

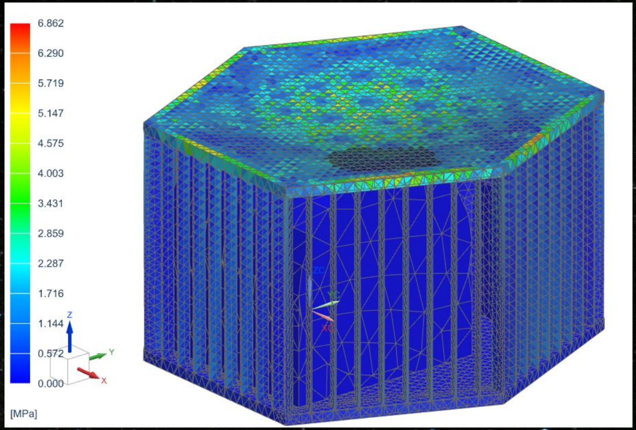
<u>Materials and Layout</u>

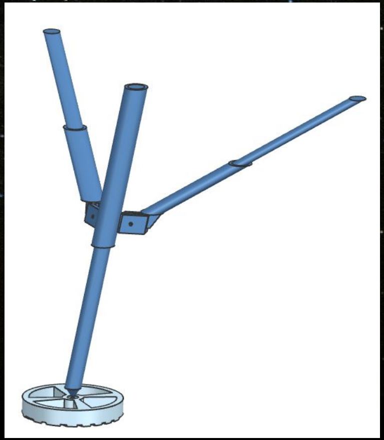
- Titanium skins
- Aluminum framing
- Aluminum legs with ball-joint plates

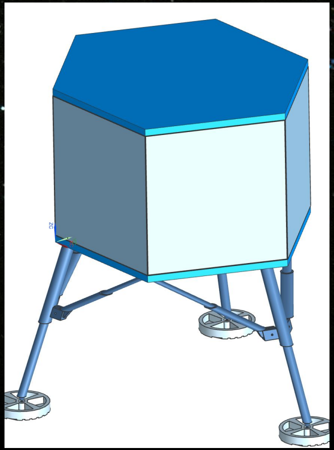
<u>Finite Element Analysis</u>

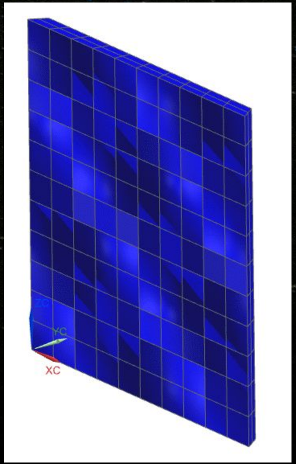
- Quasi-Static 6 G loading
- Quasi-Static loading on landing
- Acoustic/vibrational loading on panel natural frequencies





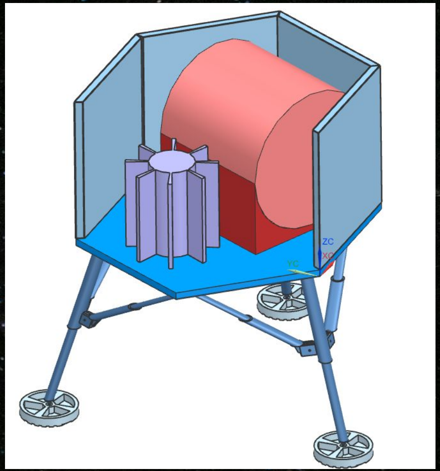






[3],[4],[5]

Structures

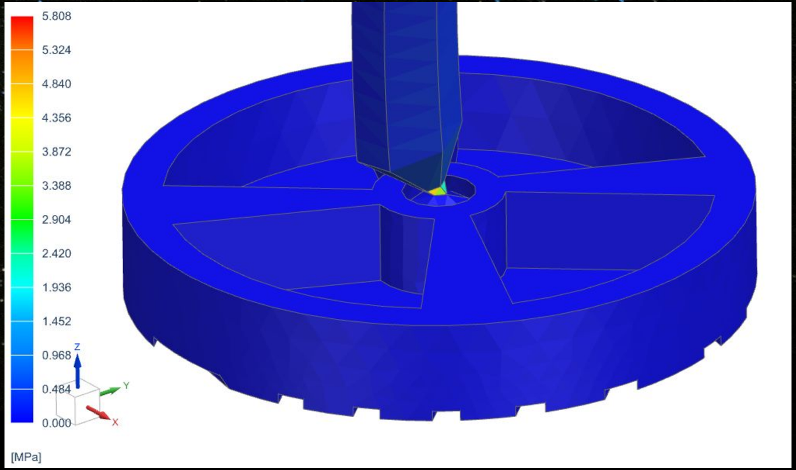


Risk

- Structural failure
  - Mitigated through FEA
- Radiation Exposure
  - Mitigated based on historical success
- Landing Failures
  - Mitigated through FEA

Future Work

- More detailed simulations with better machinery
- Mass budget
- New iteration of landing legs for strengthening joint



Mechanisms & Deployables

- Encompasses the mechanical components and moving parts that will aid ECHO in completing its mission

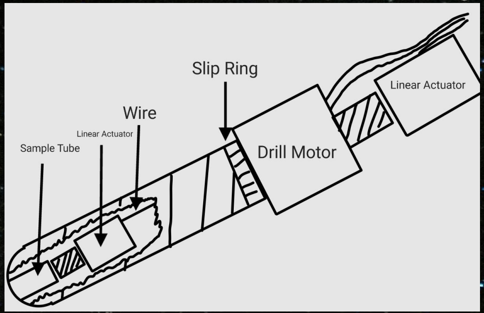
- Landing leg triad modeled with classical control theory
- Pin-puller deployment mechanism

$$\Sigma F_i = K_i(x_m - x_i) + D_i(\dot{x}_m - \dot{x}_i) + F_I = 0$$

$$\Sigma F_m = M\ddot{x}_m = \sum_{i=1}^{3}(K_i(x_i - x_m) + D_i(\dot{x}_i - \dot{x}_m))$$

- Risks:
  - Failure of pointing mechanism
  - Failure of landing leg deployment mechanism

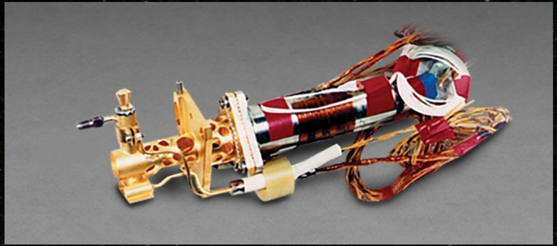
- Drill heavily inspired by Philae lander



- Bi-axial Telecom positioning mechanism

[6]

Propulsion



Perform Orbital Maneuvers & ADCS Adjustments
Achieve soft touchdown on Europa

Propulsion Overview
- MMH & MON-3 Propellants
- Primary Thrusters:
  - 7 AR-49
- ADCS Thrusters
  - 12 MONARC-1
- Thrust Output
  - 777 N
  - TWR 2.9

Propellant Requirement
- 872 kg

Risk & Non-Technical
- Workplace Safety
- Handling & Storage of Propellants
- Component Failure

Future Work
- Decrease Mass Requirement

[7] [8]

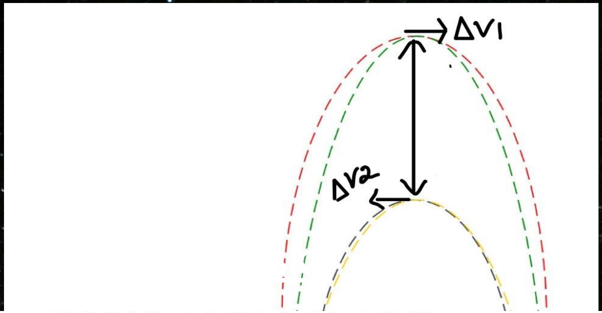
Orbital Mechanics

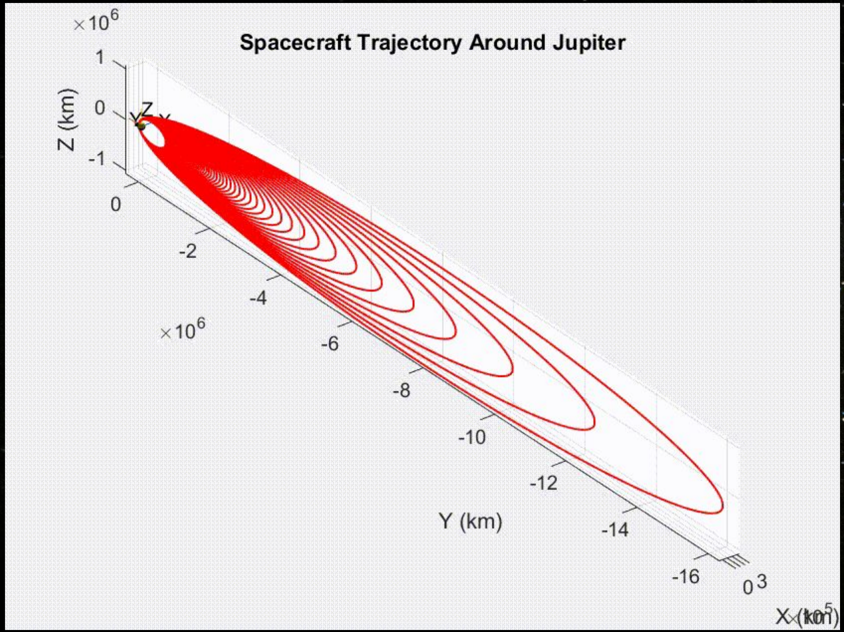
Analysis

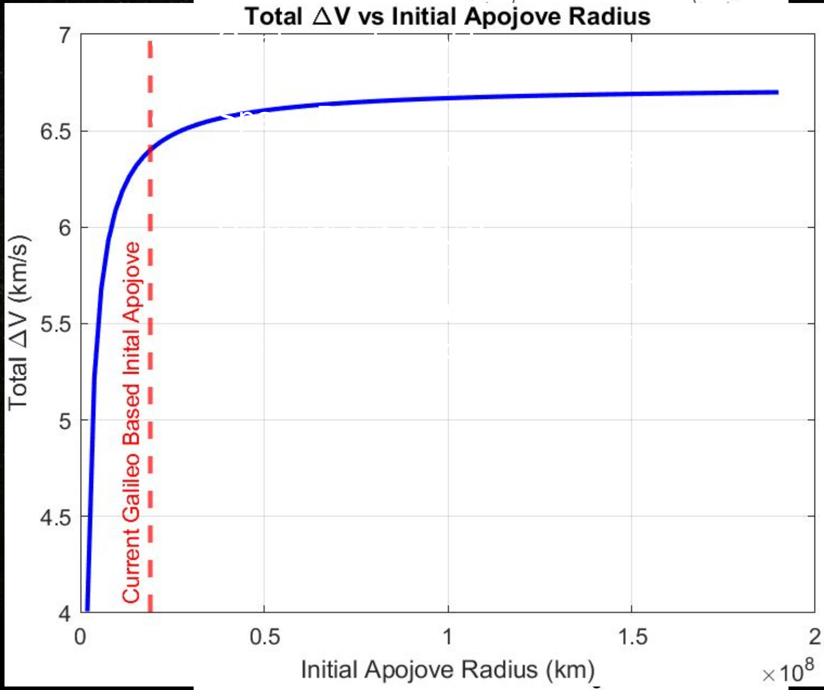
- PDR Analysis yielded ΔV of 6.400 km/s using Hohmann Transfer Series
- Aerobraking maneuver investigated to decrease ΔV requirements
- Analysis showed less efficient transfers, with the most efficient simulation yielding a ΔV of 7.998 km/s

Future Work

- Decreasing apojove while maintaining periapsis yields better efficiency for Hohmann Transfers
- Investigate a gravity assist with one of Jupiter's moons to lower apojove

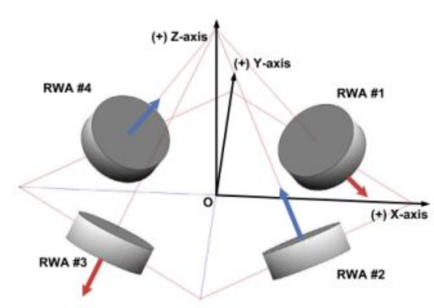






ADCS

Ensures proper orientation of the ECHO probe from separation to landing on Europa.



Sensor Suite

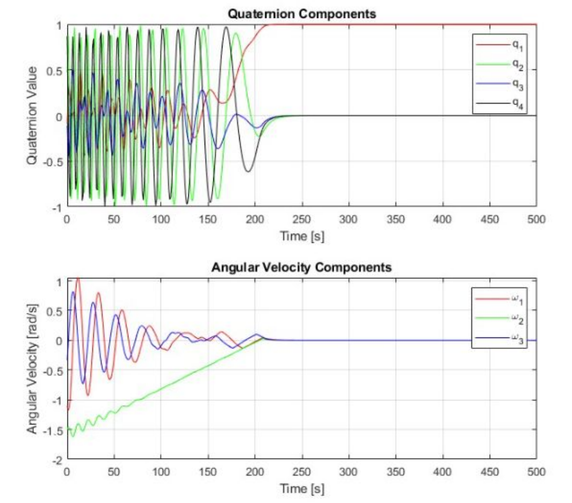
- Star Trackers x2
- Sun Sensors x4
- Magnetometers x2
- IMU x2

Actuator Suite

- Reaction Wheels x4
- RCS Thrusters x12

Control Law

$$M_C = -K_q \times qe - K_{om} \times om_{error}$$



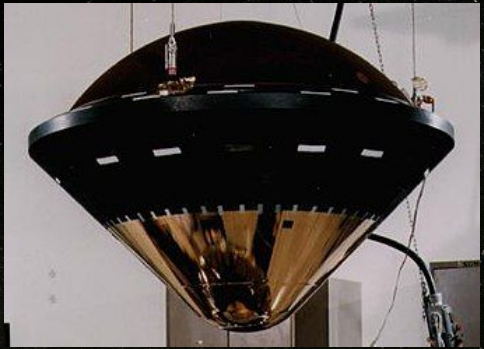
Risk: Part Failure → Redundancy incorporated, Hardware suitable for high temperature and radiation fluctuations

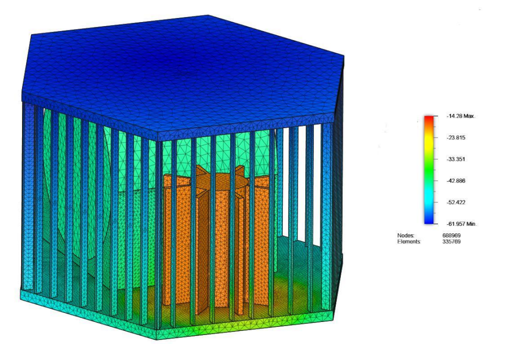
[10], [11]

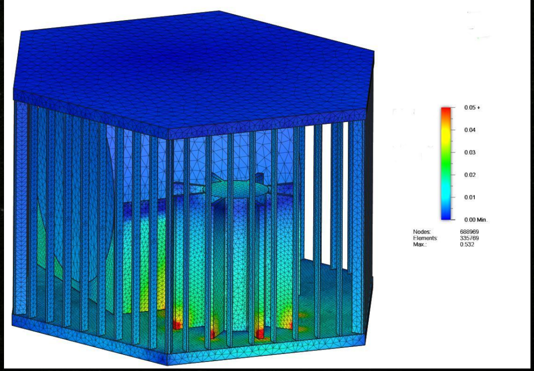
Thermal Management

Regulate temperature of lander components

- Hybrid system
  - Passive
    - MLI and paint
    - Heat Pipe (VCHP)
    - RHU
  - Active
    - Electric Heaters
    - Radiator
- Initial Thermal FEA
- Jupiter Atmospheric Entry
- Risk Mitigation
  - Radiation exposure from RHU
  - Electric heater failure
- Future Work





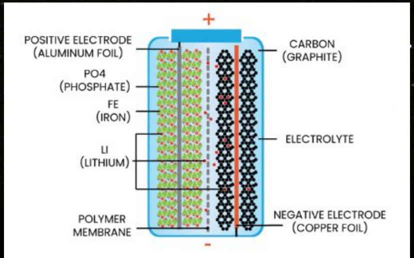


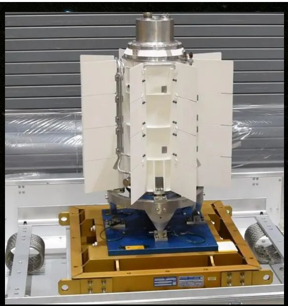
[12]

Power

- Responsible for providing the power necessary for all other subsystems to function for the entirety of their design life
  - Primary Power: NASA Multi-Mission Radioisotope Thermoelectric Generator
  - Secondary battery array: Lithium Iron Phosphate
- Power Scheduling
  - All components (aside from Thermal, command and data) kept at nominal voltage until needed
  - ADCS and Propulsion shut down after landing
- Risks:
  - Exposure of public to radioactive materials

	Stage			
Subsystem	Launch	Transit	Descent	Landed
Science Suite (Variable)	Nominal	Nominal	Nominal	Full
Mechanisms (30-40 W)	Nominal	Nominal	Partial (30 W)	Full
Telecommunication (4 W)	Nominal	Nominal	Full	Full
Command & Data (5 W)	Full	Full	Full	Full
Propulsion (50 W)	Nominal	Nominal	Full	Shutdown
ADCS (7.5 W)	Nominal	Nominal	Full	Shutdown
Thermal (25 W)	Full	Full	Full	Full
Total Power Required	30 W	30 W	34 W Marginal, potential peaks of >91.5 W	Average load of 49-89 W, potentially larger peaks during scientific activities



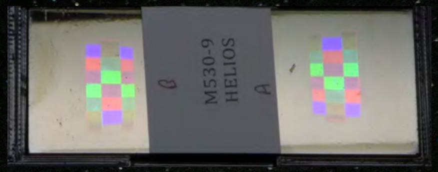


[16],[17]

Command & Data

The command & data subsystem consists of the highly integrated on-board computing system, data storage unit, and flight software.

OBC FERMI [12]



Sample HELIOS media [13]

On-board computing system:

- Using a centralized computing system based on analysis done in PDR
- Focus on reliability, radiation hardness assurance, size, and mass
- Argotec's OBC FERMI was selected

Risk mitigation:

- Follow all workplace safety regulations
- Testing before flight

Data storage method:

- Past missions used multi-layer or triple-layer cell solid state drives
- More recent technology, the Hardened Extremely Long Life Information Optical System (HELIOS), was also considered
- Focus on reliability, performance, endurance, and amount of data each unit is capable of storing
- HELIOS was selected

Flight software:

- Several pre-existing flight software options were considered, all of which must be modified in some way for actual use
- Focus on reliability, flexibility, performance, and portability
- core Flight System was selected

Future work:

- Implementation within the lander

Telecommunication

The telecommunication subsystem will use an X-band antenna to transmit engineering data and a Ka-band antenna to transmit scientific data.

- X-band frequency signals experience less attenuation in harsh conditions than Ka-band frequency signals
- Patch antenna selected based on analysis in PDR
- Focus on reliability, power consumed, gain, mass, and volume

Future work:

- Link budget report based on simulation

X-band antenna:

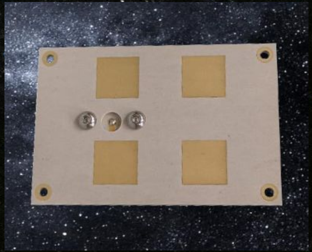
- IQ Spacecom X-band patch antenna was selected

Ka-band antenna:

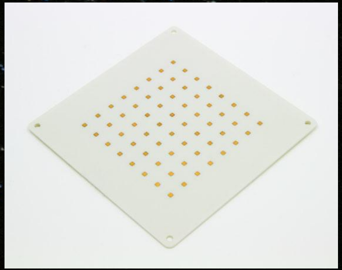
- Printech Ka-band patch antenna was selected

Risk mitigation:

- Follow all workplace safety regulations
- Testing before flight



IQ Spacecom X-band antenna [14]

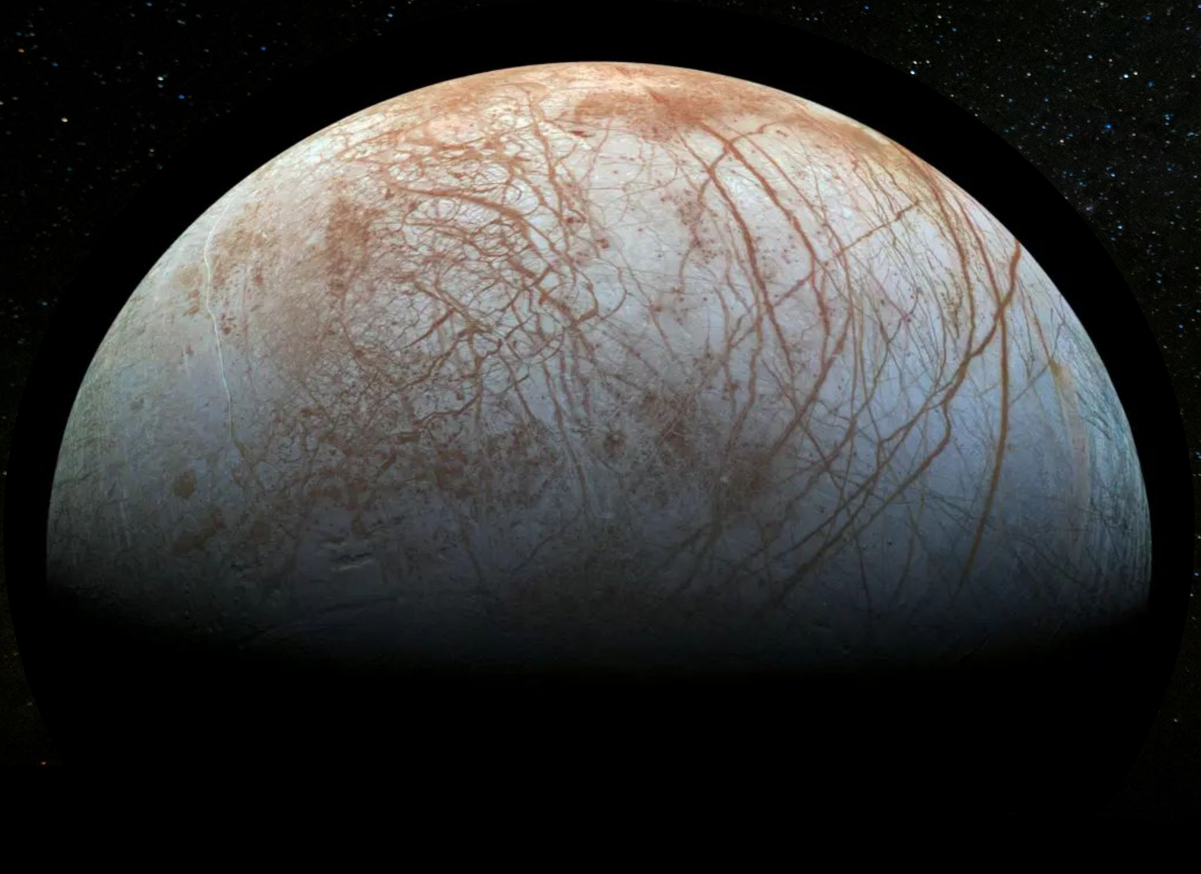


Printech Ka-band antenna [15]

References

- [1]NASA, "Europa: Facts - NASA Science," *science.nasa.gov*, 2024. https://science.nasa.gov/jupiter/moons/europa/europa-facts/
- [2]"Europa Clipper – NASA's Europa Clipper Mission," NASA, Oct. 13, 2024. https://blogs.nasa.gov/europaclipper/tag/europa-clipper/
- [3] J. Mehta, "Structural Evolution of the TeamIndus Spacecraft That Will Land on the Moon," *Medium*, Feb.26,2019. https://medium.com/teamindus/structural-evolution-of-the-teamindus-spacecraft-that-will-land-on-the-moon-b5aa6bc73ccc (accessed Dec. 04, 2024).
- [4] Anderson, K. S., "Space Vehicle Systems Engineering," Spacecraft Design, Dynamics & Control Primer, RPI, https://www.rpi.edu/~anderk5/space_vehicle_systems.pdf
- [5] M. S. Escartí-Guillem, L. M. Garcia-Raffi, and S. Hoyas, "Review of Launcher lift-off Noise Prediction and Mitigation," Aug. 2024,Accessed:Dec.04,2024.[Online].Available: https://www.sciencedirect.com/science/article/pii/S2590123024009344#br0010
- [6]M. Inc., "Type 22 Antenna Positioning Mechanism," New. Accessed: Dec. 08, 2024. [Online]. Available: https://www.moog.com/products/space-mechanisms/antenna-pointing-mechanisms/type-22.html
- [7] "MONOPROPELLANT THRUSTERS", 2024, Moog Inc. https://www.moog.com/content/dam/moog/literature/sdg/space/propulsion/moog-MonopropellantThrusters-Datasheet.pdf
- [8] "Bipropellant Tanks", Ariane Group, https://www.space-propulsion.com/spacecraft-propulsion/bipropellant-tanks/index.html
- [9] "IADC Space Debris Mitigation Guidelines Issued by IADC Steering Group and Working Group 4," 2020. Available: https://orbitaldebris.jsc.nasa.gov/library/iadc-space-debris-guidelines-revision-2.pdf
- [10] https://www.satcatalog.com/component/coarse-sun-sensor-pyramid-type
- [11] H. Yoon, H. H. Seo, and H.-T. Choi, "Optimal uses of reaction wheels in the pyramid configuration using a new minimum infinity-norm solution," *Aerospace Science and Technology*, vol. 39, pp. 109–119, 2014. [Online]. Available: https://doi.org/10.1016/j.ast.2014.09.002.
- [12]Galileo Probe during final assembly. Available: https://nasa.fandom.com/wiki/Atmospheric_entry?file=Galileo_probe.jpg
- Orbital Mech:
- [12] "8.0 Small Spacecraft Avionics - NASA," *NASA*, Oct. 16, 2021. https://www.nasa.gov/smallsat-institute/sst-soa/small-spacecraft-avionics/#8.3
- [13] R. Solomon, E. Rosenthal, R. Grubbs, and B. Solomon, "Next Generation Big Data Storage For Long Space Missions," Jun. 2021. Available: https://ntrs.nasa.gov/api/citations/20205007793/downloads/Next%20Generation%20Big%20Data%20Storage%20for%20Long%20Space%20Missions_final.pdf
- [14] "IQ Spacecom X-Band Antenna," *IQ Spacecom*, May 2024. https://www.iq-spacecom.com/images/Datasheets/IQspacecom_X_Band_Antenna_datasheet_05.2024.pdf
- [15] "Ka-Band Microstrip Patch Array for Cubesat Systems | satsearch," *satsearch*, 2024. https://satsearch.co/products/printech-circuit-laboratories-ka-band-microstrip-patch-array-for-cubesat-systems
- [16]First Phosphate, "About the LFP Battery," First Phosphate Corp. Accessed: Dec. 08, 2024. [Online]. Available: https://firstphosphate.com/phosphate-industry/about-the-lfp-battery/
- [17]U.S. Dept. Of Energy, "What is a Radioisotope Power System?," Energy.gov. Accessed: Dec. 08, 2024. [Online]. Available: https://www.energy.gov/ne/articles/what-radioisotope-power-system

Questions?



RENSSELAER POLYTECHNIC INSTITUTE
KNOWLEDGE AND THOROUGHNESS
• 1824 •