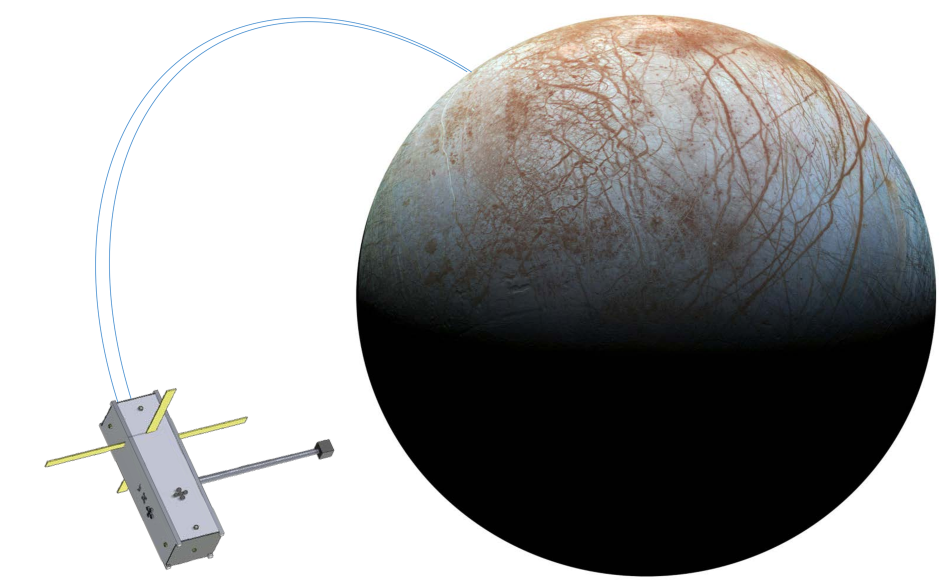
Europa Clipper CubeSat

A Model For Deep Space Exploration

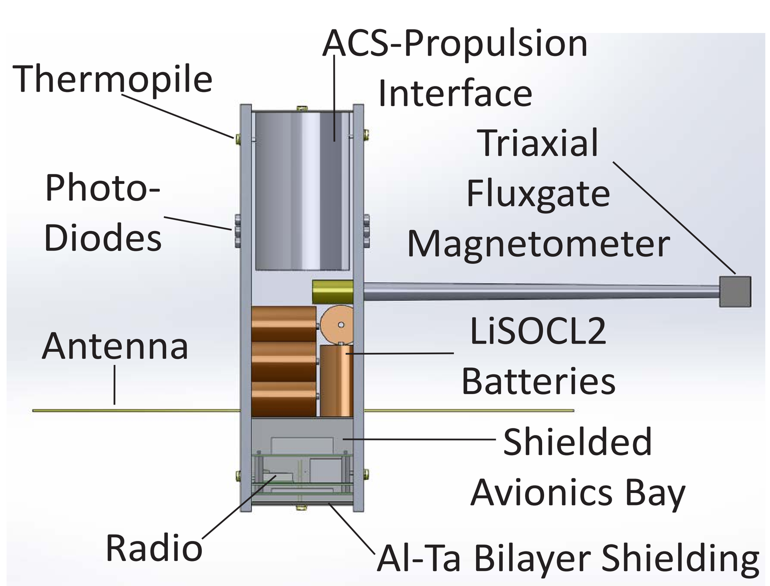
Bret Bronner & Casey Steuer
University of Michigan



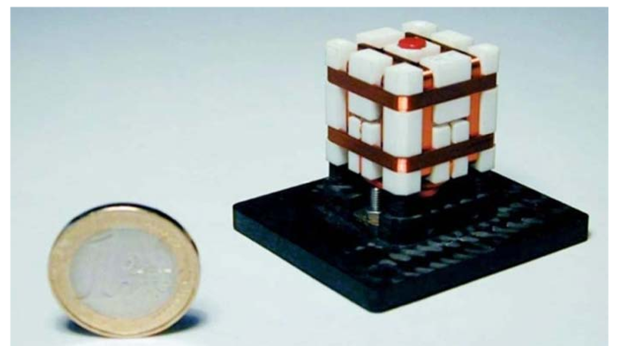
Design Concept for MINOS

(Magnetic INduction Ocean Sounder)

Structure

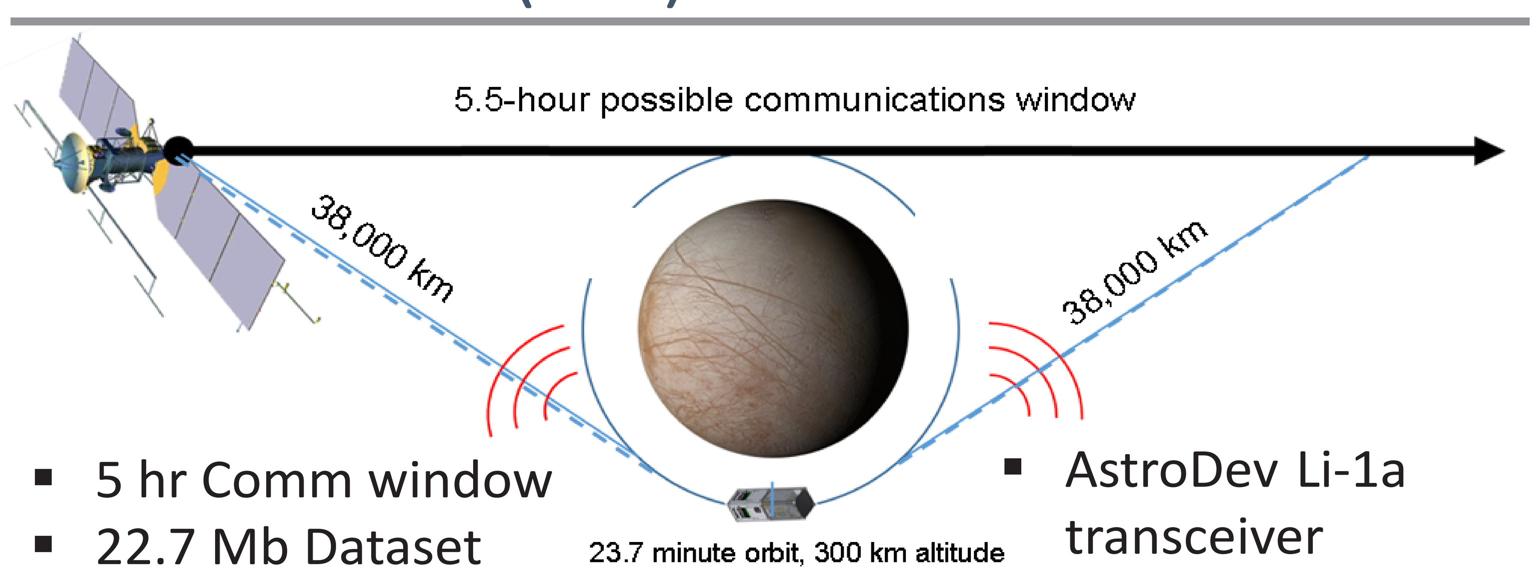


Payload



- Tri-axial Fluxgate Magnetometer
- Resolution: .031 nT
- Sample Rate: 1-50 Hz
- Power: 675 mWatts

Communication (UHF)

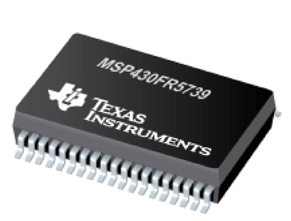


- 5 hr Comm window
- 22.7 Mb Dataset
- Complete Tx in .66 hr @ 9600 kbps

- AstroDev Li-1a transceiver

Command & Data

- MSP430
- Multiple SD Cards



Guidance & Nav.

Aerojet R-6D

- .454 kg
- 5 W
- 22 N
- 294 s Isp

Propulsion Module with integrated ADCS

Power

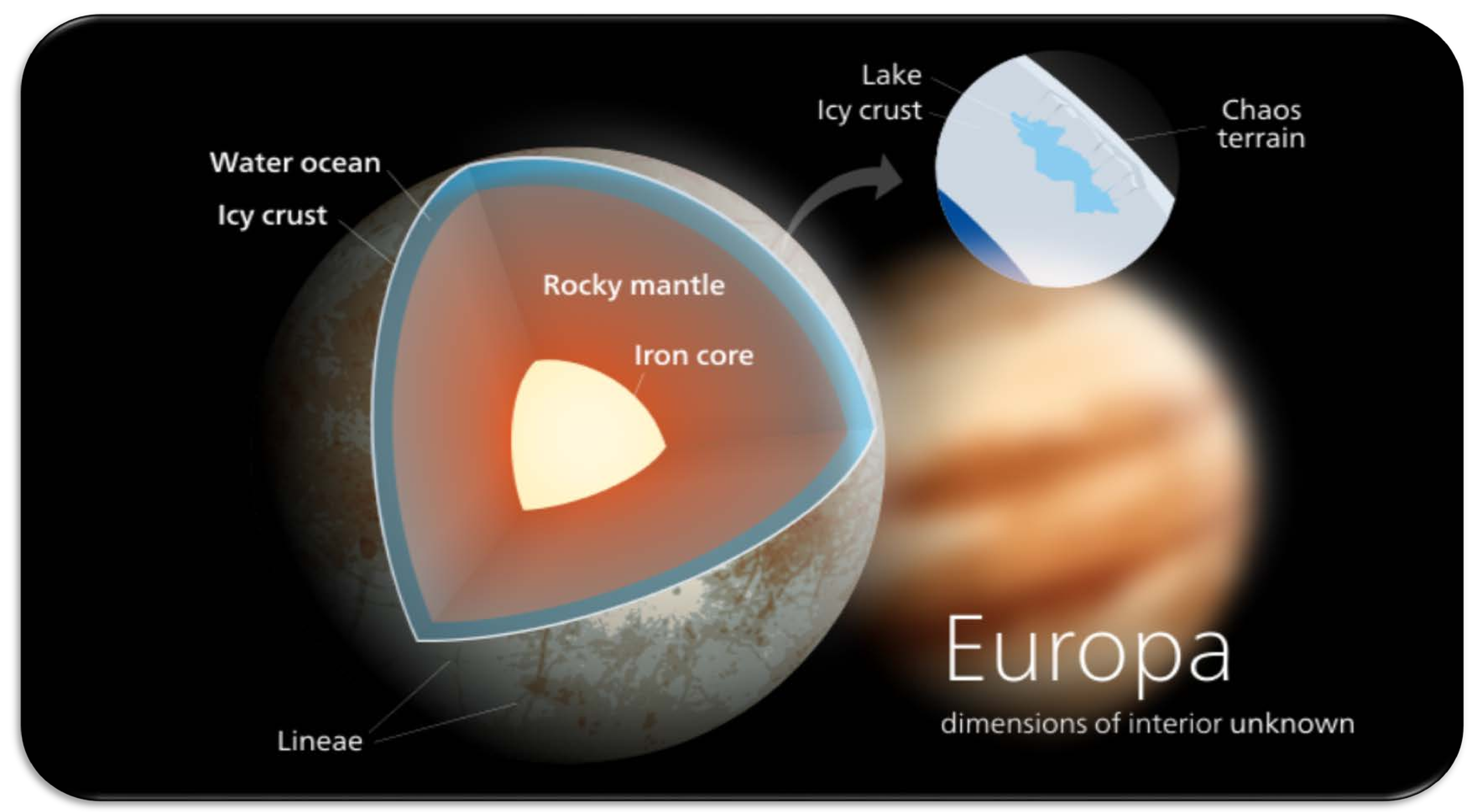
- Primary Li-SOCl2 Batteries
- 10 cells at .9 kg provide 1.1 W for 15 days at ~3.3 V

Feasibility

Payload	EPS	Comms	CDH	Structure		GNC		
				Rad.	Thermal	Attitude	Position	Propulsion
RPC-MAG	LiSOCL2 Primary Battery	Astrodev Li-1a	FRAM based MSP430	Al-Ta Bi-Layer	MLI & Joule Heating	Thermopiles, Photodiodes, & IMU w/ Magnetometer		Aerojet R-6D Bi-propellant Rocket Engine
Rosetta, Deep Space 1	Cassini-Huygens	CubeSat Heritage	CubeSat Heritage	Various	Various	None	none	none

Mission Overview

With vast reserves of water and a global subsurface ocean, Europa has become a high priority target for planetary science and astrobiology. At the behest of JPL, in concert with the Europa Clipper mission, the University of Michigan initiated a detailed investigation to determine the feasibility of conducting multi-frequency magnetic induction sounding of Europa's interior structure utilizing a CubeSat magnetometer payload.



Designed to accompany the Europa Clipper spacecraft, this CubeSat would complement Europa Clipper's capabilities by providing coordinated observation over extended dwell times critical for high fidelity magnetic induction sounding. Equipped with a 3U rocket propulsion module, it would deploy from Europa Clipper during a flyby and execute an orbital insertion maneuver. For the next 7 Earth days, it would measure Europa's magnetic field using a sensitive magnetometer before entering sleep mode to conserve power. Fourteen days after deployment, upon Europa Clipper's reentry into communications range, it would transmit its data, successfully ending its mission.

Conclusion

Beyond producing extremely valuable science, the proposed mission serves as a new paradigm for space exploration. A 6U CubeSat with a highly capable propulsion system provides a template, not only for missions to Europa, but Ganymede, Callisto and Io as well. Future missions might deploy similar spacecraft to Enceladus, Titan, Mimas and beyond. ***In short, a nanosatellite with a focused, high impact payload and a propulsion system capable of orbital insertion could accomplish missions previously considered impractical, setting the stage for future achievements in deep-space exploration.***

Future Technology

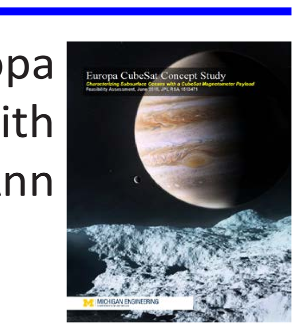
Most of the technologies necessary for deep-space CubeSat missions are sufficiently developed to enable orbital deployment to Europa. Much of the design concept relies on heritage technologies successfully deployed on previous missions. Guidance, navigation and control is the clear exception presenting the greatest challenge for CubeSat missions to the outer solar system.

The most common technology used for guidance and navigation is the star-tracker. The primary challenges to implementing this technology are mass and power. State of the art multi-camera star-trackers account for .5 kg of spacecraft mass in a .5U volume and consume 3-5 W continuously. Even if spacecraft mass and volume allocations are sufficient, 3-5 W continuous power consumption presents an insurmountable barrier for most deep-space CubeSat applications.

Similarly, while propulsion systems capable of the required delta-V are now available, none fall within the mass constraints of a 3U CubeSat. Many can be implemented in a 6U structural volume however, only electric propulsion systems, such as the CubeSat Ambipolar Thruster (CAT), are capable of achieving orbit within 6U mass constraints. Low thrust combined with high power consumption (~10 W), however, make CAT, and similar electric propulsion systems, an infeasible option for battery or solar powered CubeSats. Future deep-space CubeSat missions will require rocket propulsion systems with improved specific-impulse and electric propulsion systems with substantial reductions in power consumption.

References

Bronner, B., C. Steuer, E. van Wynsberghe et al., "Europa CubeSat Concept Study: Characterizing Subsurface Oceans with a CubeSat Magnetometer Payload," University of Michigan, Ann Arbor, Feasibility Report, JPL RSA 1513471, June 2015.



Acknowledgements

Principle Investigators: Dr. James Cutler & Dr. Xianzhe Jia

Additional Authors: Daniil Abramov, Nathan Boll, Gregory Carbott, Stuart Gegenheimer, Lara Hue, So-Hee Kang, Kathryn Luczek, Jose Muñoz, Huy-Duc Trung, Joshua Weiss, Erinn van Wynsberghe

Michigan Engineering
University of Michigan
Atmospheric, Oceanic and Space Sciences, University of Michigan
MXL Michigan eXploration Laboratory
JPL