Europa Clipper CubeSat
A Model For Deep Space Exploration

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Design Concept for MINOS
(Magnetic INduction Ocean Sounder)

Structure
- Thermopile
- Diodes
- Antenna
- Radio
- ACS-Propulsion Interface
- Triaxial Fluxgate Magnetometer
- LiSOCL2 Batteries
- Shielded Avionics Bay
- Al-Ta Bilayer Shielding

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

Guidance & Nav.
- Aerojet R-6D
  - .454 kg
  - 5 W
  - 22 N
  - 294 s Isp
- Command & Data
  - MSP430
  - Multiple SD Cards

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

Feasibility

Payload | EPS | Comm | CDO | Structure | GN&C |
--- | --- | --- | --- | --- | --- |
LiSOCL2 | Primary Battery | AstroDev Li-1a | FRAM based MSP430 | Al-Ta Bi-Layer | Thermopiles, Photodiodes, & IMU w/Magnetometer | Aerojet R-6D Bi-propellant Rocket Engine |
Rosetta, Deep Space 1 | Cassini-Huygens | CubeSat-Heritage | Various | Various | 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

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