ERDOS: Europa Radiation and Dust Observation Satellite

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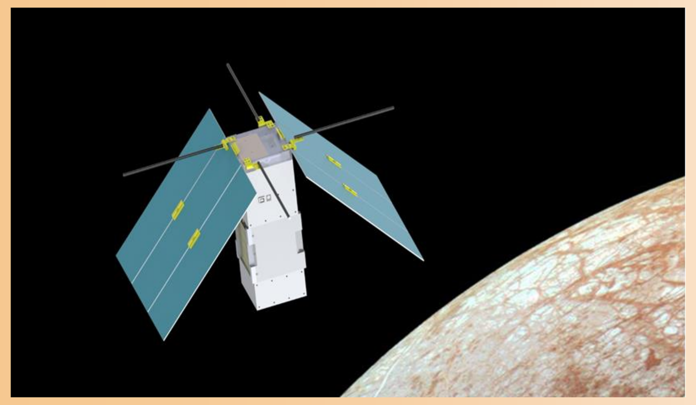
Science Objectives

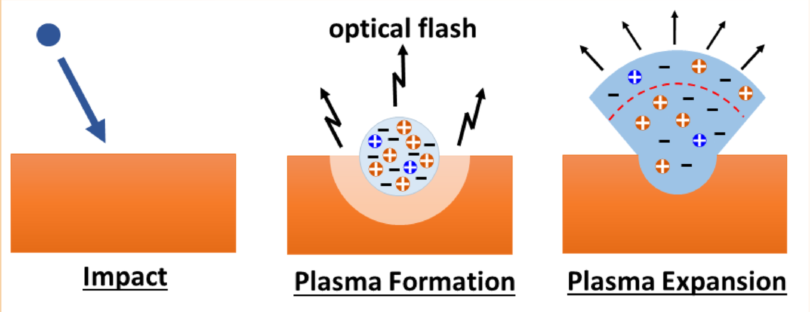


ERDOS - Europa Radiation and Dust Observation Satellite is a 3U CubeSat that can be deployed by Clipper for carrying out measurements of the radiation and dust environment before impacting Europa's surface.

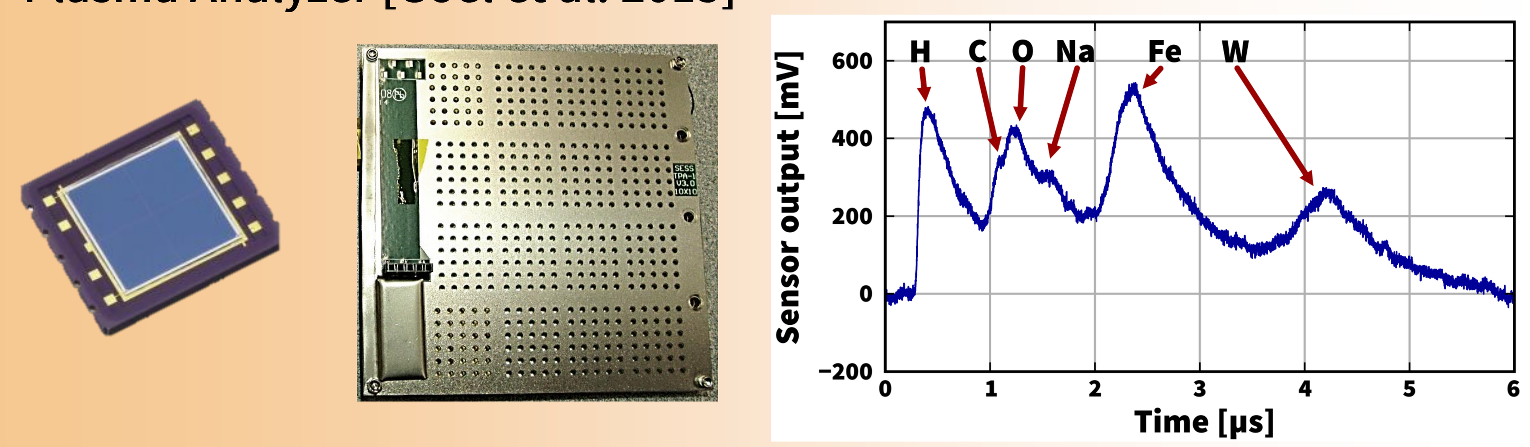
Dust Measurement: The dust population near the surface of Europa contains ejecta from the impact of meteoroids and other interplanetary and interstellar dust particles. Studying the properties and elemental composition of these dust particles serves as a proxy for studying the composition and mineralogy of the surface of Europa.

Radiation Measurement: Irradiation of Europa's surface with high-energy particles can lead to the formation of O_2, H_2O_2, CO_2 and other molecules critical to fueling life in the liquid ocean beneath the icy crust [Bayer et al. 2015]. Studying the variation of flux with altitude will also help us understand how the presence of Europa changes the local radiation environment.

Dust Measurement

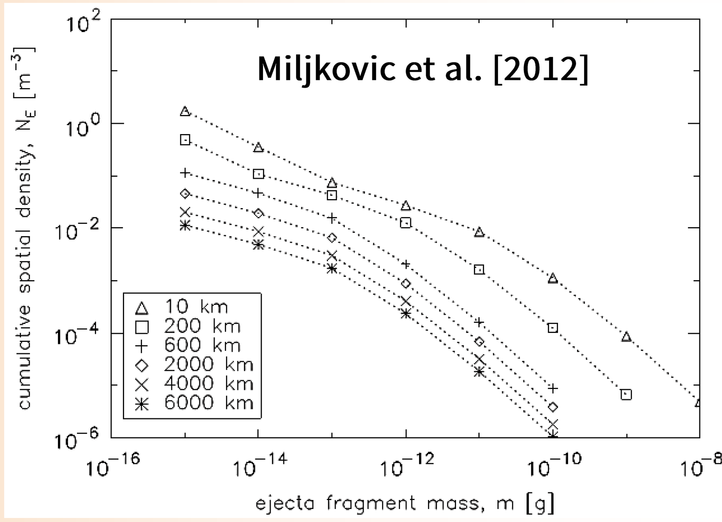


- Use undersides of deployed panels as impact surfaces
- Quad-photodiodes for estimating particle mass and velocity from impact flash measurements [Eichhorn 1976, Goel et al. 2015]
- Impose external electric field by biasing the sensor to -300 V
- Measure elemental composition based on time-of-flight with Transient Plasma Analyzer [Goel et al. 2015]



(left) Optical sensor; (center) Transient Plasma Analyzer; (right) Composition determination from time of flight measurements in ground-based hypervelocity impact tests [Lee et al. 2013]

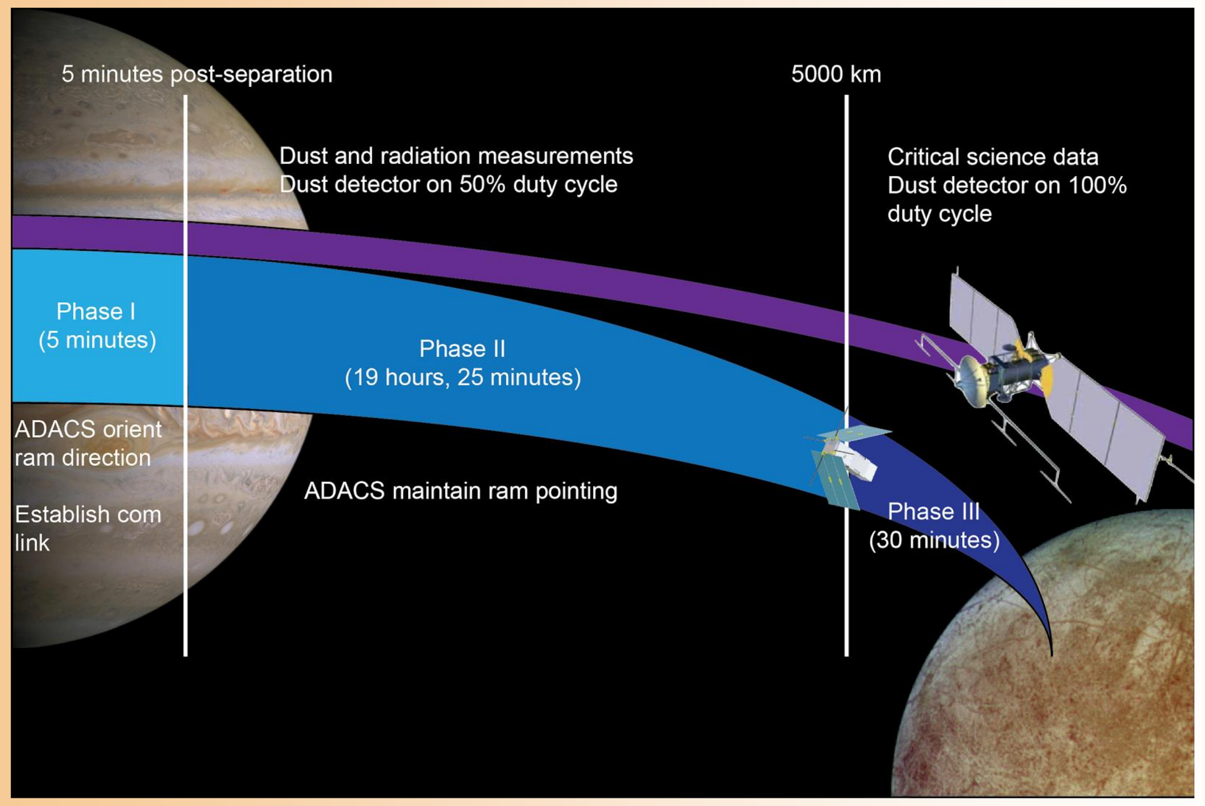
- Relative impact speed: 3-6 km/s
- $Q = Cm^{\alpha}v^{\beta}$
- Detection threshold set to 1 pg based on ground-based impact tests
- For altitudes below 200 km, impact rate is greater than 4 per second



Radiation Measurement

- Measurement: Flux of energetic electrons in 200 keV to 1 MeV range
- 1500 μm thick solid state silicon detector (SSSD), 8 energy channels
- These sensors have flown on the Firebird CubeSats [Spence et al. 2012]

Mission Profile



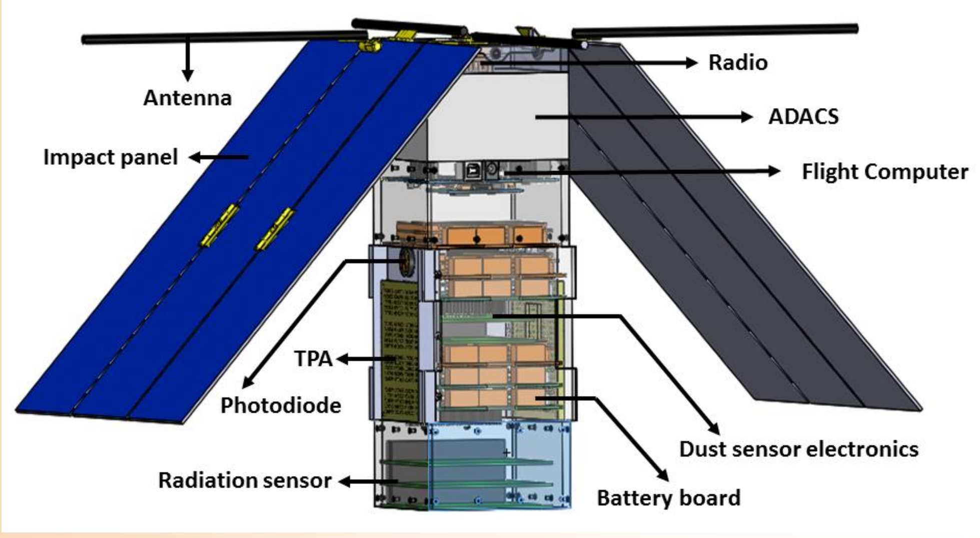
	High	Nominal	Low
Quasi-Impact Parameter	-3.56 km	-7.10 km	-10.82 km
Impact Angle	8.2 degrees	10 degrees	11.5 degrees
Release ΔV	1.5 m/s	1.6 m/s	1.7 m/s
Azimuth	345.74 degrees	345.03 degrees	344.31 degrees
Elevation	-37.14 degrees	-37.85 degrees	-38.54 degrees

Mission parameters for different release conditions

- Injection into Europa orbit ruled out due to high delta-V requirements
- Optimal trajectory chosen to maximize time spent below 5000 km, while ensuring that the CubeSat impacts the surface of Europa
- Mission duration limited by power and radiation shielding constraints
- Impacting the surface allows us to study surface geology using measurements of impact flash and impact crater
- Planetary protection concerns need to be addressed

CubeSat Configuration

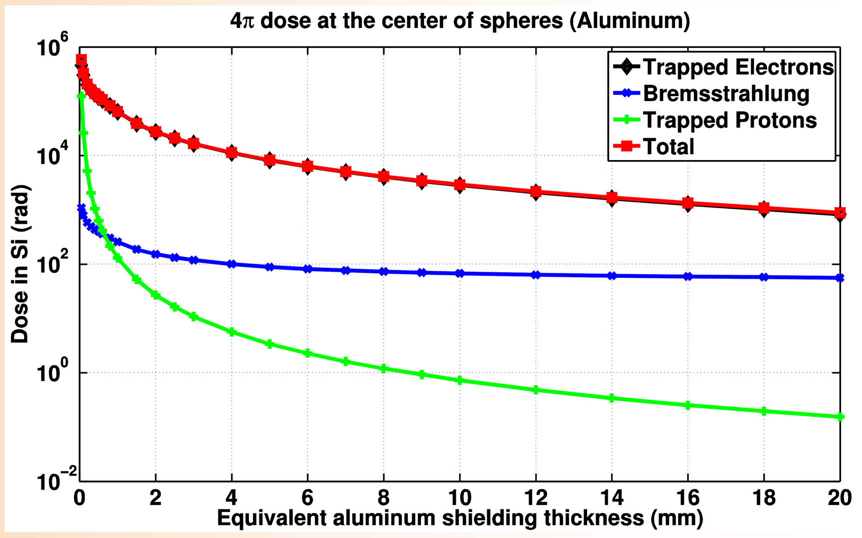
- Mass: 4.2 kg
- Peak power: 7.4 W
- Average power: 4.0 W
- Impact angle: 45°
- Two dipole antennas
- Link margin: 12 - 34 dB
- Two-way, half-duplex communication system



Radiation Shielding, Thermal Design and Attitude Control

Radiation Shielding

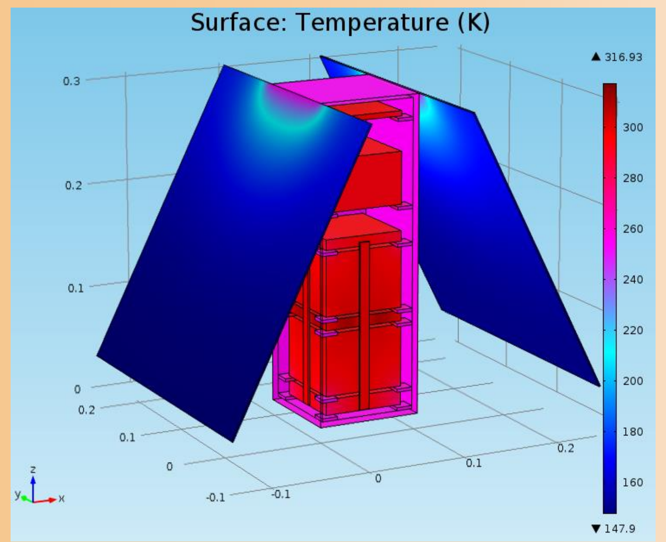
- Despite the short mission duration, the harsh radiation environment in Jupiter's magnetosphere poses a serious threat to satellite electronics.
- Trajectory modeled in SPENVIS, ESA's open-source space environment tool, to obtain radiation lifetime estimates for total ionizing dose and single event upsets
- Our analysis shows that 4 mm of aluminum shielding would be needed to keep the COTS electronics safe.
- The spacecraft chassis is hence 2.5 times thicker than typical CubeSats.



Effect	(bit^{-1})	($bit^{-1}s^{-1}$)	($bit^{-1}day^{-1}$)
Direct Ionization	1.63e-9	2.28e-14	1.97e-9
Proton-induced ionization	1.10e-7	1.53e-12	1.32e-7
Total	1.11e-7	1.55e-12	1.34e-7

(top)Total ionizing dose over the course of the mission lifetime for different shielding thicknesses; (bottom) Single Event Upset (SEU) rates for a typical memory unit

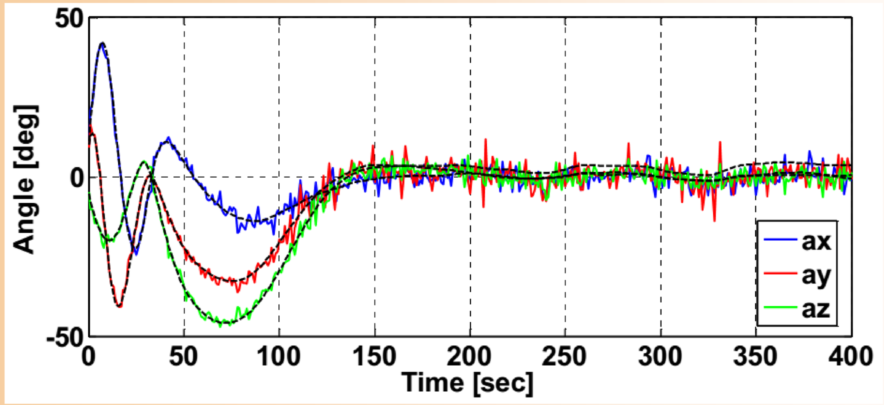
Thermal Design



- Ambient temperature can be as low as 100 K [Crum 2014].
- We are able to maintain the batteries and the electronic boards within the operating temperature range by using thermal paints and positioning the batteries around the data acquisition boards dissipating maximum power

Attitude Control

- Requirement: pointing in negative ram direction with 5° accuracy
- Determination: sun sensors, magnetometer
- Control: reaction wheels
- Saturation of reaction wheels has to be avoided since the magnetic field near Europa is too weak for desaturation using magnetic torque rods within the lifetime of the mission [Khurana et al. 2004]



Simulation results showing desired spacecraft orientation within few minutes of deployment

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