EEPEC:
Europa And Enceladus Plume and Exosphere Cubesat

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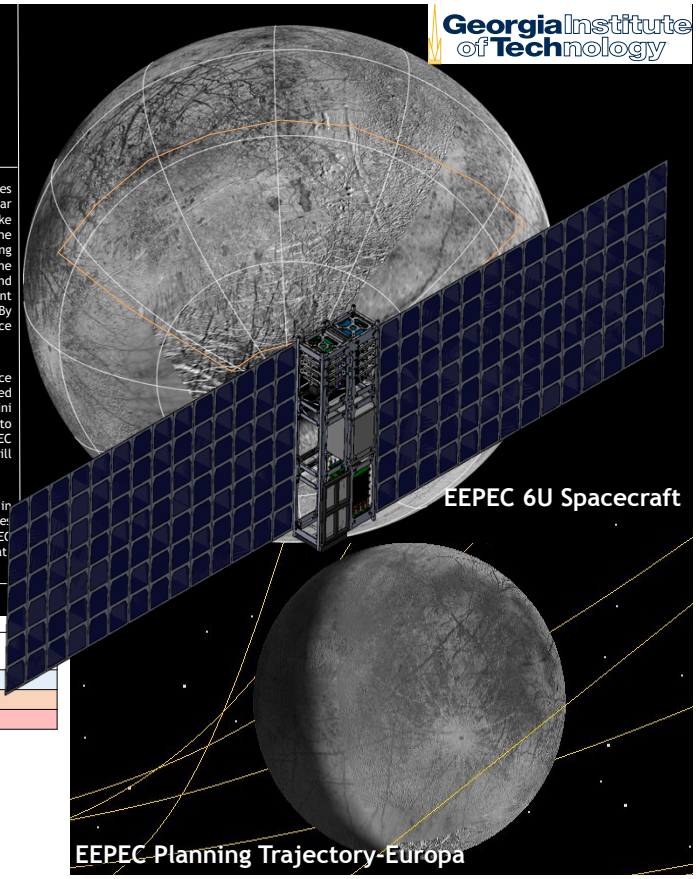
The Europa and Enceladus Plume and Exosphere CubeSat (EEPEC) is a mission concept for a small spacecraft that can make observations of the plumes and/or exospheres of these two ocean worlds. Europa and Enceladus are active ocean worlds that are prime targets in the search for life in the solar system. Enceladus has demonstrated constant activity since the detection of its south polar ice-vapor plumes. Recent detections of potential plume-like activity on Europa and a well-known variable exosphere make it certain that higher mass particles, or "dust", also play a key role in the evolution of the surface and near surface environments on Europa. Lessons from Enceladus tell us that dust detectors provide unique perspective on plume and ring dynamics and composition; the dust and grains have provided information about the composition of the ocean below including its interactions with the seafloor. The spatial and mass distributions of dust and ice grains at both Europa and Enceladus thus have the power to constrain available energy and source for surface processes, detect and characterize geologic activity, as well as constrain the chemistry of the ice shell and ocean. These represent three of the top five priorities of the decadal survey for Europa; for Enceladus, they would mark an enhancement to the results of Cassini. By implementing a series of dust investigations designed for high-risk environments on a small companion satellite to a larger mission, high caliber science is achieved both on a cadence the primary mission cannot support and with minimal risk to the primary spacecraft.

EEPEC is designed as two single flyby or one multi-flyby mission to explore *in situ the* exospheres and plumes of material emanating from the subsurface by conducting 25-km or lower flybys of active sources. EEPEC will carry as its main payload a deep space and Jovian- or Saturnian-system-optimized version of the PDD dust detector instrument that is flying on the Armadillo CubeSat. This dust detector is a miniaturized version of the Cassini Compositional Dust Analyzer that uses a combination of charge-gating and piezoelectric detectors to characterize impacting dust and ice grains and to sort first order chemical composition. Our payload also has an optional miniaturized mass spectrometer for more detailed grain chemistry. Thus EEPEC will provide robust in situ measurements of material erupted from the subsurface or sputtered from the surface of Europa, sampling material that will be key to understanding Europa's habitability.

The planning science objectives for EEPEC are to: 1) Measure the spatial and velocity distribution of particles in ocean world plumes and exospheres in order to characterize endogenic and exogenic activity, including plume dynamics; and 2) Measure the composition of the particles in ocean world plumes and exospheres to constrain both the composition and energy in the exosphere and surface, in turn constraining ocean world habitability. EPEC complements, but does not repeat, science objectives achievable with the Europa Clipper payload. With either multiple flybys from one EEPEC cubesat or two chances to observe two different areas with two EEPECs, the EEPEC mission provides new, high-reward observations to planetary science.



EEPEC Mission Draft Specifications and Operations

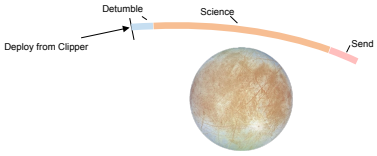
EEPEC - Mass Budget 3U

Subsystem	Component	Quantity	Unit Mass (g)	Margin (%)	Mass (g)	Volume (U)
Power	Eagle Picher Primary Battery	1	760	25	950	0.4
Instrument	PDD	1	250	25	312.5	1
Propulsion	VACCO MiPS 0.3U	1	542	25	677.5	0.3
ADCS	BCT XACT	1	850	25	1062.5	0.5
Communications	Iris Transponder	1	500	25	625	0.5
Structure	6U CubeSat Structure	1	270	25	337.5	
C&DH / FSW	CubeSat Kit Motherboard	1	103	25	128.75	0.25
Thermal	MLI blanket No.146663	1	36	25	45	
				Total Mass	4093.8	2.95
				Allowed	4000.0	3

EEPEC - Mass Budget 6U

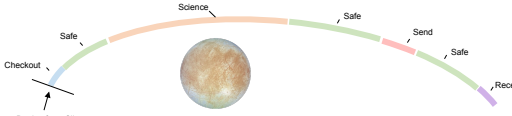
Subsystem	Component	Quantity	Unit Mass (g)	Margin (%)	Mass (g)	Volume (U)
Power	E-Hawk Array	2	678.0	25	1695.1	-
	SADA	2	329.6	25	824.0	-
	GomSpace P31us EPS	1	270	25	337.5	0.25
	GomSpace BP4 Batteries	1	240	25	300	0.5
Instrument	PDD	1	250	25	312.5	1
Propulsion	VACCO MiPS 0.3U	1	542	25	677.5	0.3
ADCS	BCT XACT	1	850	25	1062.5	0.5
Communications	Iris Transponder	1	500	25	625	0.5
Structure	6U CubeSat Structure	1	1100	25	1375	
C&DH / FSW	CubeSat Kit Motherboard	1	103	25	128.75	0.25
Thermal	MLI blanket No.146663	1	36	25	45	
				Total	7337.8	3.05
				Allowable	12000.0	6

Mode Name	Description
Detumble	• Detumble the spacecraft after deployment. Lasts for ~0.5 hours
Science	• Collect data
Send	• ~1/2 hour. Crosslink to Clipper

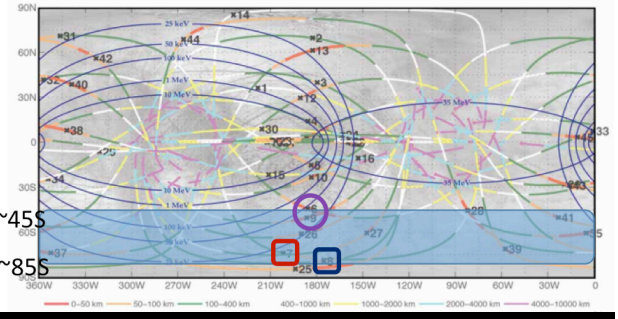


*Mode durations are notional

Mode Name	Description
Checkout	• Starts after ~2 days before flyby and lasts for ~2 hours • Detumble the spacecraft, establish communication, check out subsystems
Safe	• Recharge batteries
Science	• Collect data
Send	• ~1/2 hour. Send data to Clipper
Receive	• Receive from Earth



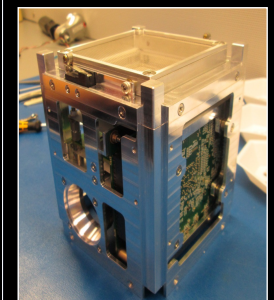
*Mode durations are notional

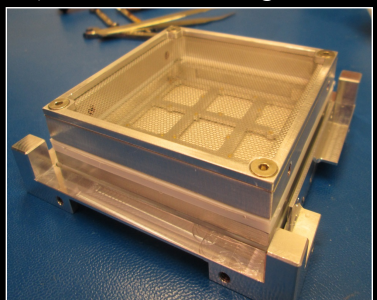


EEPEC Science Traceability-Europa

Goal	Objective	Investigation	Category	Measurement Requirement	Instrument Requirement	Spacecraft Design Requirement	Mission Design requirement
Explore the Dust Environment around Europa	1. Understand the nature of Europa's plumes.	A. Determine the source, flux (flow rate), average velocity, and density distribution of plume particles.	Geoscience	Contact with plume materials during eruption or before the material has dissipated. Measure particles with expected impact velocities of 4.5 km/s with a resolution of .1u in size and partile size distribution from 1 microns to 2 microns.	Piezoelectrid detector tuned to impact energies from .5u to 2u particles at 4.5 km/s	Nadir and Ram direction pointed sensors.	Responsiveness to Plume detection. Low ~25 km flyby.
		B. Determine the mass and charge of ejected particles to constrain the nature and first order composition of plume material.	Astrobiology	Contact with plume materials during eruption or before the material has dissipated. Measure charge to mass ratio over a range of 4.5 km/s with a resolution of .1u in size Determine particle size distribution from 1 microns to 2 microns.	Charge gate sensitive to particle charge. Piezoelectrid detector tuned to impact energies from .5u to 2u particles at 4.5 km/s. Mass Spectrometer.	Nadir pointed sensor.	Responsiveness to Plume detection. Low ~25 km flyby.
		C. Determine temporal and spatial distribution of any plume material.	Geoscience	Measurement of particle distribution in the Europa environment over several flybys to achieve spatial distribution; if the inclination is too low, it may be difficult or impossible to study higher-latitude regions. (5)	Piezoelectrid detector tuned to impact energies from .5u to 2u particles at 4.5 km/s.	Nadir and Ram direction pointed sensors.	3-5 flybys. Responsiveness to Plume detection. Low ~25 km flybys.
		A. Determine micrometeorite impact density and distribution in the European environment.	Space Weathering	Measure incoming and orbiting particles with expected velocities of 4.5 km/s with a resolution of .1u in size and particle size distribution from ejected materials of 1 microns to 2 microns.	Piezoelectrid detector tuned to impact energies from .5u to 2u particles at 4.5 km/s.	Nadir and Ram direction pointed sensors.	Detector on during orbit and flyby. 100 km flby.
	2. Understand the interaction of Europa's surface with the space environment. (1)	B. Determine deposition rate from Io.	Chemistry (Chemical/Material Exchange)	Measure incoming and orbiting particles with expected velocities of 4.5 km/s with a resolution of .1u in mass.	Piezoelectrid detector tuned to impact energies from .5u to 2u particles at 4.5 km/s.	Nadir and Ram direction pointed sensors.	Detector on during orbit and flyby. 100 km flyby.
		C. Determine if and to what extent plumes alter local plasma environment	Space Physics	Measurement of particle distribution in the Europa environment and outside the Europa environment over several flybys.	Piezoelectrid detector tuned to impact energies from .5u to 2u particles at 4.5 km/s.	Nadir or Ram direction pointed sensors.	Detector on during orbit and flyby. Responsiveness to Plume detection. Low ~25 km flyby and 100 km flyby.
	Understand the nature of materials from Europa.	Characterize the source of particles found in the exosphere surrounding Europa.	Geoscience	Measurement of particle distribution in the Europa environment over several flybys to achieve spatial distribution; if the inclination is too low, it may be difficult or impossible to study higher-latitude regions. (5)	Piezoelectrid detector tuned to impact energies from .5u to 2u particles at 4.5 km/s.	Nadir pointed sensor.	3-5 flybys. Responsiveness to Plume detection. 25-100 km flybys.
		Determine the nature of materials in the Europa environment.	Chemistry, Astrobiology	Measure charge to mass ratio over a range of 4.5 km/s with a resolution of .1u in size. Determine particle size distribution from 1 microns to 2 microns.	Charge gate sensitive to particle charge. Piezoelectrid detector tuned to impact energies from .5u to 2u particles at 4.5 km/s. Mass Spectrometer.	Nadir pointed sensor.	3-5 flybys. Responsiveness to Plume detection. 25-100 km flybys.

EEPEC Piezo Dust Detector, ARMADILLO Heritage





Based on the EPEC study, funded by NASA JPL Strategic University Partnership & Europa Cubesat Concept Study Program. EEPEC has been proposed to the Planetary Science Deep Space Small Satellites Program.