Preliminary design of a CubeSat for plume sampling and imaging at Europa

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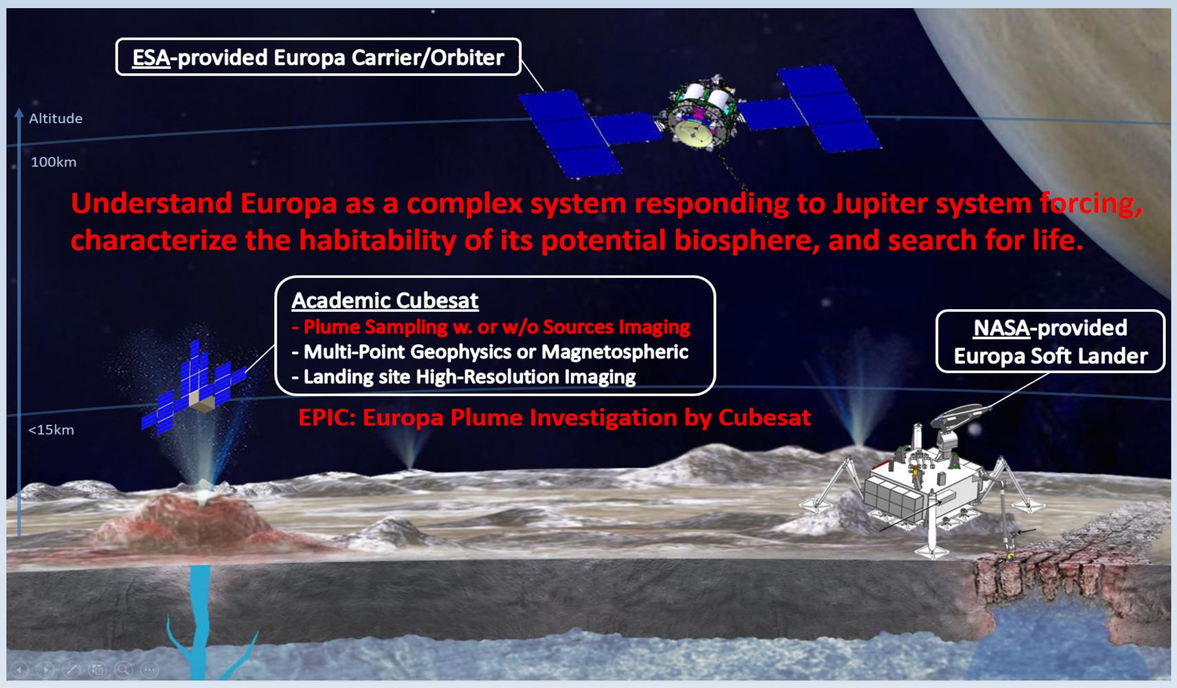
Abstract : Europa is the closest and probably the most promising target to perform a comprehensive characterization of habitability and search for extant life. A proposal to ESA's Cosmic Vision programme has recently been submitted in order to propose that NASA and ESA join forces to design an ambitious planetary mission (JEM, for Joint Europa Mission) to reach this objective. JEM will be assigned the following overarching goal: Understand Europa as a complex system responding to Jupiter system forcing, characterize the habitability of its potential biosphere, and search for life in its surface, sub-surface and exosphere. The proposed JEM mission will consist of two space platforms: a carrier/relay/orbiter platform (hereafter referred to as orbiter), and a soft lander platform.
Possible CubeSat additions to JEM can complement the science objectives in a unique way, in order to study phenomena of great interest not achievable by the orbiter. The recent observations by the Hubble Space Telescope of plumes rising hundreds of kilometres above Europa's surface rises the interest for directly sampling the material from these plumes, when occurring, as part of our life search strategy.
In this poster, we will present a preliminary design of a 12U CubeSat designed to be deployed by the Joint Europa Mission in order to study in detail potential Europa plumes through in situ measurements of their charged particles and magnetic field environments as well as imaging of their surface sources. Flying a CubeSat in the Jupiter/Europa environment constitutes a significant challenge and we will address in particular issues related to propulsion, power as well as radiation mitigation.

Science Mission

Joint Europa Mission (JEM) proposal as M5 for ESA Cosmic Vision

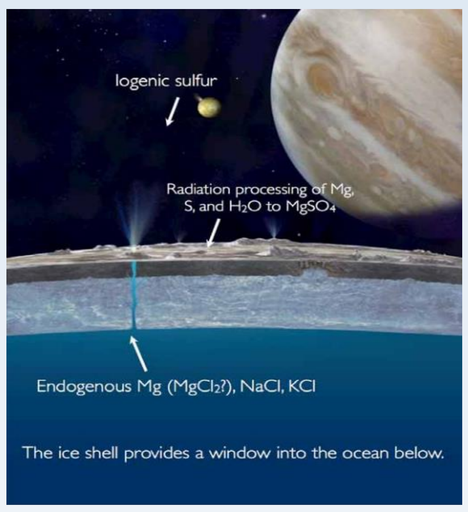


EPIC Science Objectives

Plumes provide the easiest access to the composition of the subsurface ocean

- Study **composition of plumes**
  - Dry Source ($CH_4, CO_2,\ CO,\ N_2,\ Ar$)
  - Liquide Water Source ($\boldsymbol{Na^+},\ \boldsymbol{Cl^-},\ \boldsymbol{CO_3^{-2}},\ Mg^{+2},\ SO_4^{2-}$)
- Take **images of sources** to better understand their structures
- Analyze the **density of plume** measuring drag forces
- Study **Europa magnetosphere**, and its interaction with Jupiter's
- Measure **cyclotron waves** produced by the ionization of plume's matter

Study the Habitability of Europa



EPIC Science Traceability Matrix

Science objectives

JEM Carrier/Orbiter
Study the Europa System at a global scale
Interior, Subsurface, Surface, Exosphere, Magnetosphere
Habitability

EPIC
- Direct sampling of Europa Plumes
- Study the moon-magnetosphere interactions
- Imaging plume sources on Europa

Enabling instrumentation

- Magnetometer, Radio Science
- Laser Altimeter
- ELS/IMS, INMS, Dust analyzers
- *Navigation Camera, Radiation Monitor*

- **Option: EPICom** (Focused on **Com**position) Magnetometer + Electrostatic Analyzer
- **Option: EPICam** (With a **Cam**era) Magnetometer + INMS + Camera

Constraints on platforms

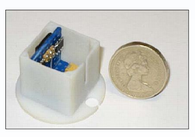
- 3D Coverage of Europa
- Low altitude 100-200km, near polar circular orbit
- Spatial resolution of 10's km horizontally

- AOCS for orbit and attitude control
- Low periapsis <15km, elliptical orbit
- Use JEM as relay
- Survivability during eclipses

Environment & Mission Constraints
1. Propulsion
2. Power
3. Radiation
4. Thermal

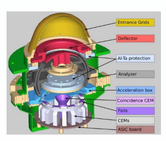
Strawman Payload Tailored for EPIC

EPICom

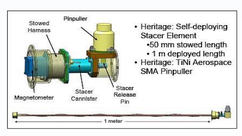


MAG (e.g. Imperial College)
-Size : 0,5U
-Weight : 104g + 120g for boom
-Power : 0,425W
-Range : ± 57,000 nT
-Resolution : 0.22 nT

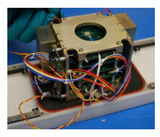
Electrostatic Analyser (e.g. IRAP)
-Size : ϕ130*170 (sensor head)
-Mass : 3kg total
-Power : 4,2W
-Mass range : 1-60amu
-Energy range : 10ev-10Kev



EPICam



INMS (e.g. GSFC)
-Size : 1,5U
-Weight : 560g
-Power : 0,6 - 1,6W
-Mass range 1-40 amu
-Energy range 0-50 eV

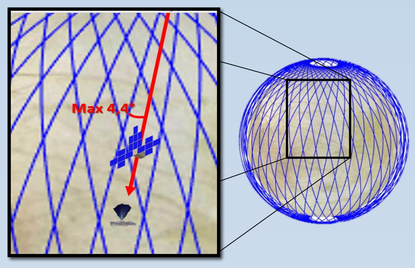


CAM (e.g. GomSpace)
-Size : 1U
-Weight : 277g
-Power : 0,8W
-2048*1536p, 0,68m/p at 15km

Mission and Environment Constraints

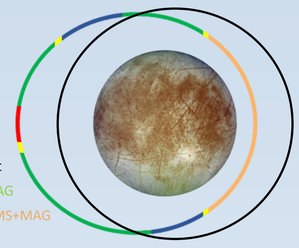
EPIC Mission Scenario

- Mission profile :
  - **JEM tracking** and determination of interesting plumes via a wide angle camera (up to 30 days)
  - **Ejection of the CubeSat** the nearest possible of an identified plume (max 1,8 days)
  - **Maneuver to reach the plume** at the periapsides of the orbits (15Km, and lower)
  - Transmission of the data to JEM thanks to a **S-Band transmitter**



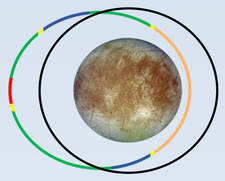
- Mission duration:
  - **3,5 days** (1 complete coverage of Europa's orbit around Jupiter) with a possible extension of a maximum of **10 Days** after deployment

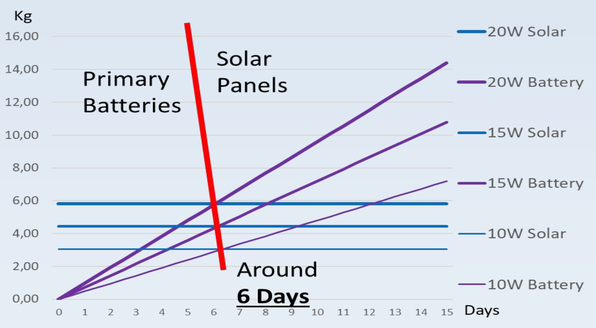
- Mission operations



Trade-Off Power Source

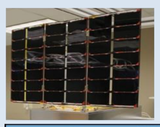
- Thrust Mode (11,5-23,2W)
- Guidance Mode (8,9)
- Com Mode (6,9W)
- CAM + INMS + MAG (15,6W)
- INMS+MAG (7,4W)





Solar Panel + Secondary Batteries

eHaWK Solar Array (MMA Design)	
Power	4,4W/kg



Gomspace BP4 (GomSpace)	
Capacity	38,50 W.h
Efficiency charge/discharge	0,9

Primary Batteries

Batteries LTC SL-760 (Tadiran)	
Specific energy	Around 500 Wh/Kg
Max continous discharge curent	100 mA
Weight	18g

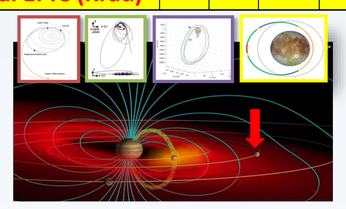
3,5 Day nominal mission → Primary Batteries possible

10 Day extended mission → On Solar panels + Secondary Batteries

Radiation Issues and Mitigation

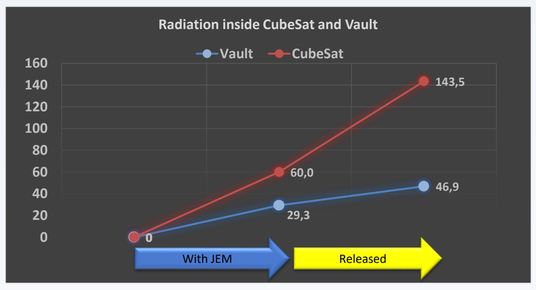
Dose for EPIC	Duration		2,5mm Al (Krad)	
	min	max	min	max
Interplanetery trip	4,9 Y		0	0
JOI + PRM + Jovian Tour	16 M		0	0
Lander Relay Phase	35 D	44 D	359	433
Tracking of plumes	1,8 D	30 D	18,3	309
Subtotal with JEM			513,3	629,6
Manœuvre	0 D	< 1,8 D	0	18,3
EPIC Operation Days	3,5 D	10 D	36	103
Subtotal Released			36	111,3
Total EPIC (Krad)			**550**	**1023**

With JEM / Released



Admissible Radiation Dose
- < 150Krad in the CubeSat
- < 50Krad in the Vault

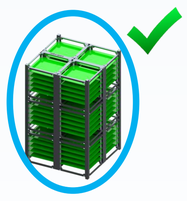
- Three layers of Aluminium
  - The deployer protects the cubesat until an interresting plume is detected (13 mm)
  - The external structure of the cubesat (3mm)
  - Vaults protect more sensitive components of the cubesat (6mm)



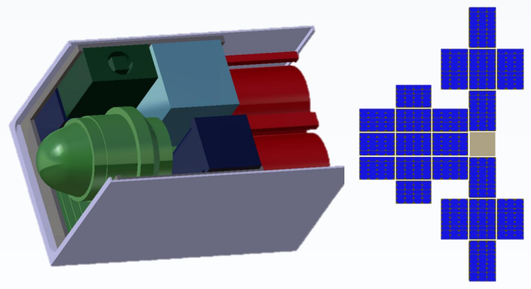
Preliminary Design of EPICom and Conclusion

Europa Environment Constraints
1. Propulsion
2. Power
3. Radiation
4. Thermal

- 12U CubeSat
  - Mass : 24Kg Max
  - Size : 218*238*365mm3



-MAG
-PASTELS
-Avionics
-Mic. Prop.
-Reac. Wheels
-Thrusters
-CubeSat Wall
-CubeSat Vault



EPICom 3,5 Day Nominal Mission With Primary Batteries		Margin	Sub-system	Mass (g)
Structure		30%	CubeSat MONA 12U Supaéro	2445
			Internal Shielding	1636
Propulsion system		30%	2 x MPS 130 Aerojet RocketDyne (1U)	3320
SCAO	AOCS Block	30%	XACT	910
	Micropopulsion		Vacco	1245
	Sun Sensor		5 x Sun Sensor FSS	15
	Support		Supports	150
AV	Power Supply card	30%	Gomspace P60	286
	S-Band			425
	Command Data Handling System		Ninano (Steel electronics)	85
	Interface			100
	Supports and rodes			415
Battery pack		30%	150 x LTC SL760 AA	2700,0
RF	S-Band	30%	2 x Syrlinks EWC31	230
Payload	Charged Particles Spectrometer	30%	PASTELS	2860
	Magnetometer		MAG	104
	Boom		BOOM MAG	120

Total Mass CubeSat	**22,173 Kg**
Margin Mass (Kg)	**1,827**
Margin Mass Ratio	**8,23%**
Total Mass CubeSat + Deployer	**> 40 Kg**

- Strong constraints for JEM but:
  - Provides **unique Science Returns**
  - Gives opportunity to **sample a plume 'freshly ejected'**
  - Relaxes risks for JEM

Open Questions

- Solar Panel:
  - Light deployment structure
  - Use of hardened Solar Cells or not regarding radiation
- AOCS:
  - Star-Trackers for EPIcam ?
  - Magnetorquer in Jupiter Magnetic Field or microprop.
- Thermal Regulation