# Assessing the Habitability of an Active Ocean World: the Etna Mission Concept to Enceladus' Tiger Stripes

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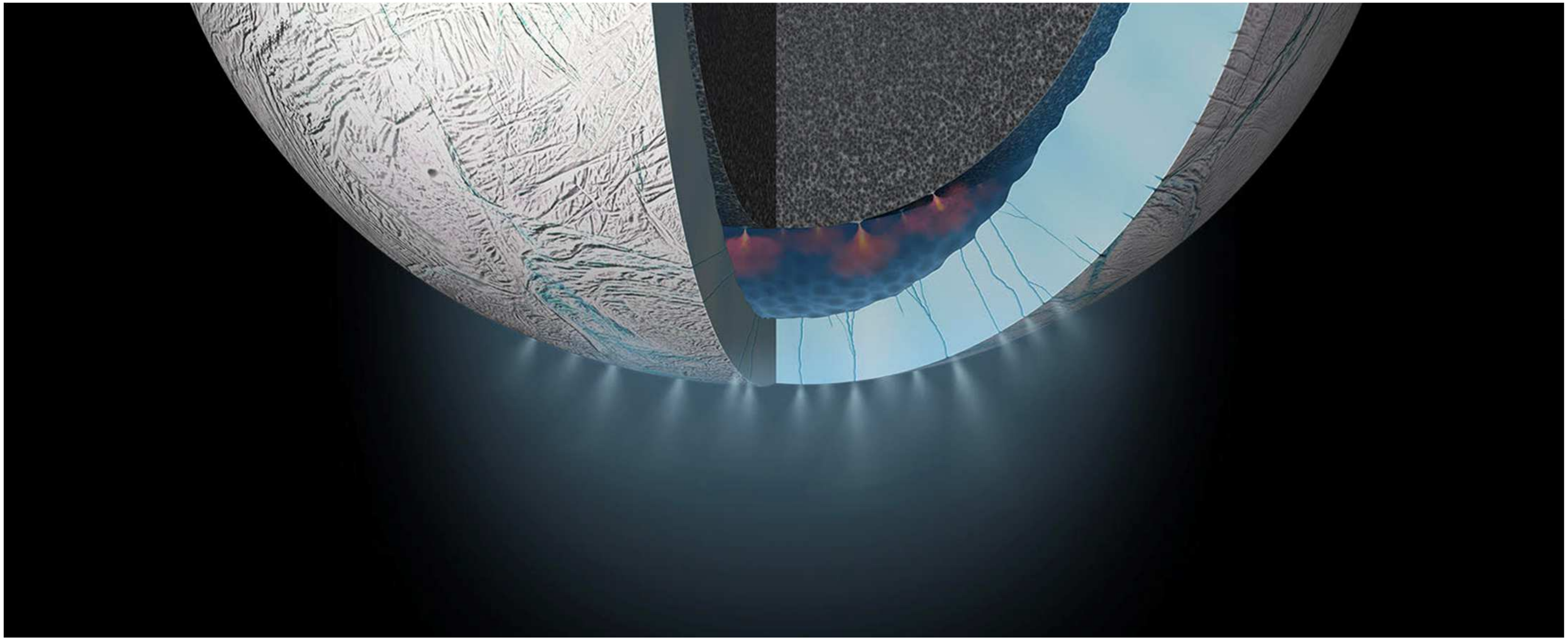
Planetary Exploration – Horizon 2061, Toulouse, 13th Septembre 2019

# Table of Contents

# Table of Contents

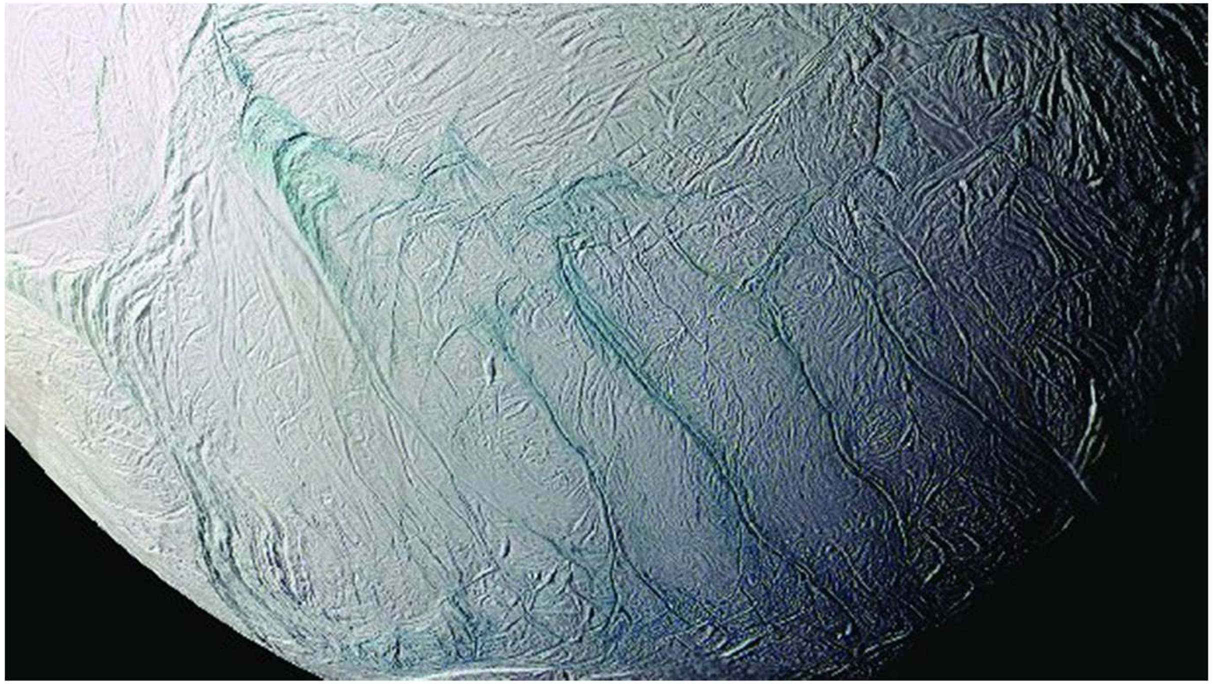
# Introduction and Motivation



Enceladus provides direct acces to the buried ocean and show evidences of being an active world

# Introduction and Motivation

The geothermal activity, the buried ocean, and the building blocks of Earth-like life promotes Enceladus as a paramount target to study the origin and evolution of life throughout our Solar System.



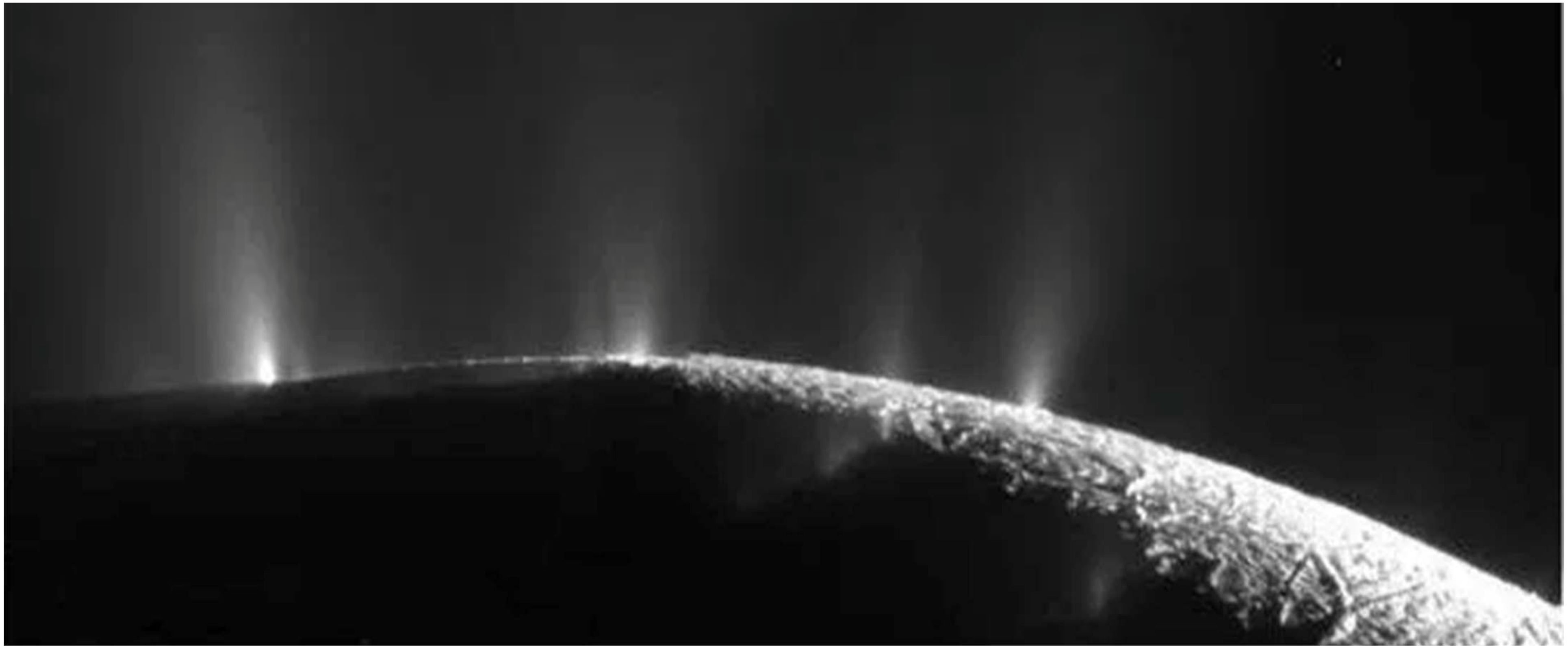
We propose here the ETNA mission concept to the Tiger Stripes at the South Pole Terrain of Enceladus

# Table of Contents

# Scientific Questions

**Driving Science Questions**

1. How does Enceladus provide habitable conditions?
2. What biotic or abiotic signatures characterize Enceladus?



# Scientific Questions

**Question 1: How does Enceladus provide habitable conditions?**

1. What are the dynamics of the energy sources that drive surface and subsurface interactions?
2. What is the chemistry and bulk composition of the subsurface?
3. What is the periodicity and the lifetime of these habitable conditions?

# Scientific Questions

**Question 2: What biotic or abiotic signatures characterize Enceladus?**

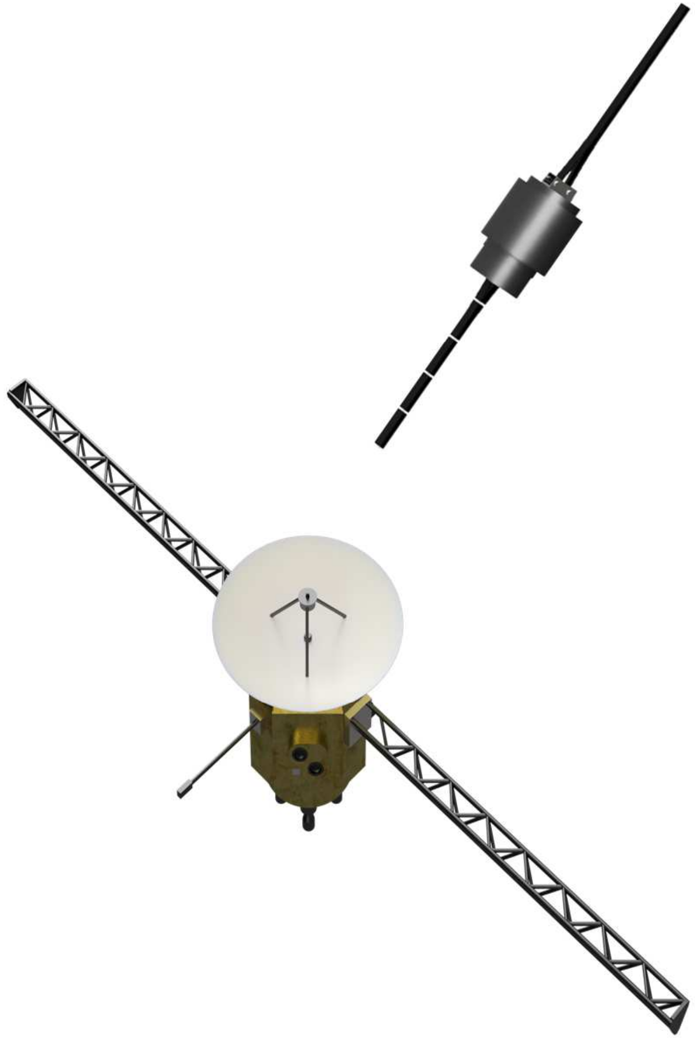
1. What are the composition, structure and ratio of subsurface molecules?
2. To what extent are visual biomarkers present in the Enceladus system?
3. How are H,C,O, and N produced?

# Table of Contents

# Mission Concept

**The mission architecture is composed of three subsystems:**

1. An orbiter
2. A fixed laboratory lander
3. Three geophones released by the lander



# Mission Concept

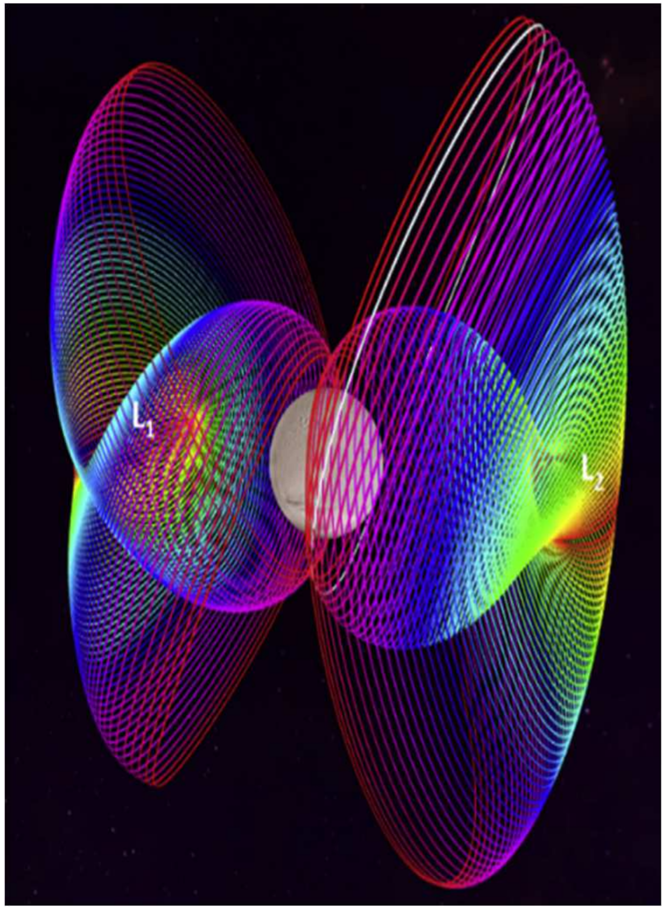
The Orbiter (1000 kg dry mass) is launched in March 2028 with SLS arriving on June 2039

On-orbit science campain are performed:

1. Imaging of the plume
2. UV Spectrometry
3. Ice Penetrating Radar
4. Plume Flythroughs

↓

Ensure science return without landing

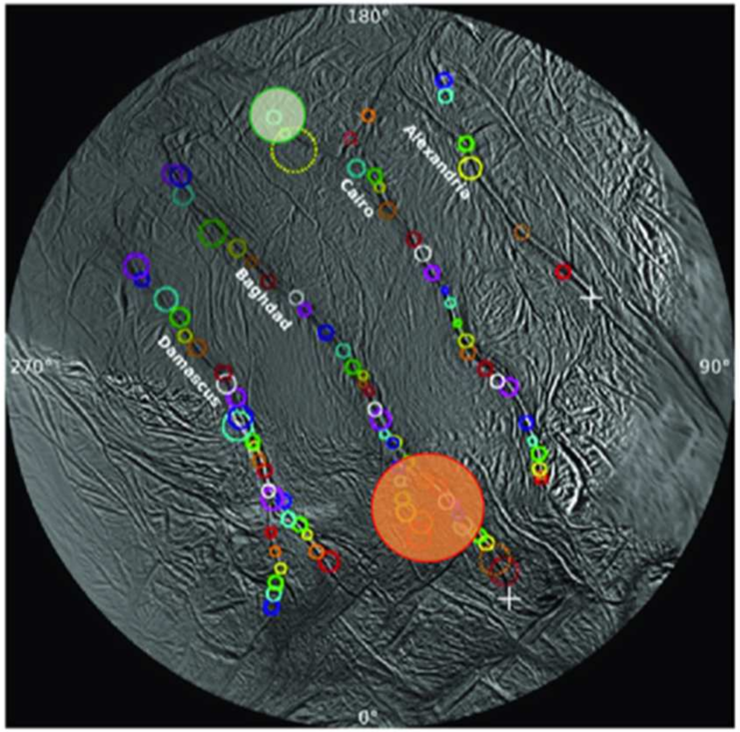


# Mission Concept

The lander is then deployed with Mass Spectrometer and Microscope and lands w/in 5 km of active plume

Operation for the lander are:

1. During descent the geophone are distributed on the surface
2. Lander performs active landing
3. Lander collects and analyse 4 samples
4. Lander collect geophones data for 1 week passively
5. An impactor (60 kg) is launched from orbit to characterize the icy shell at high frequencies

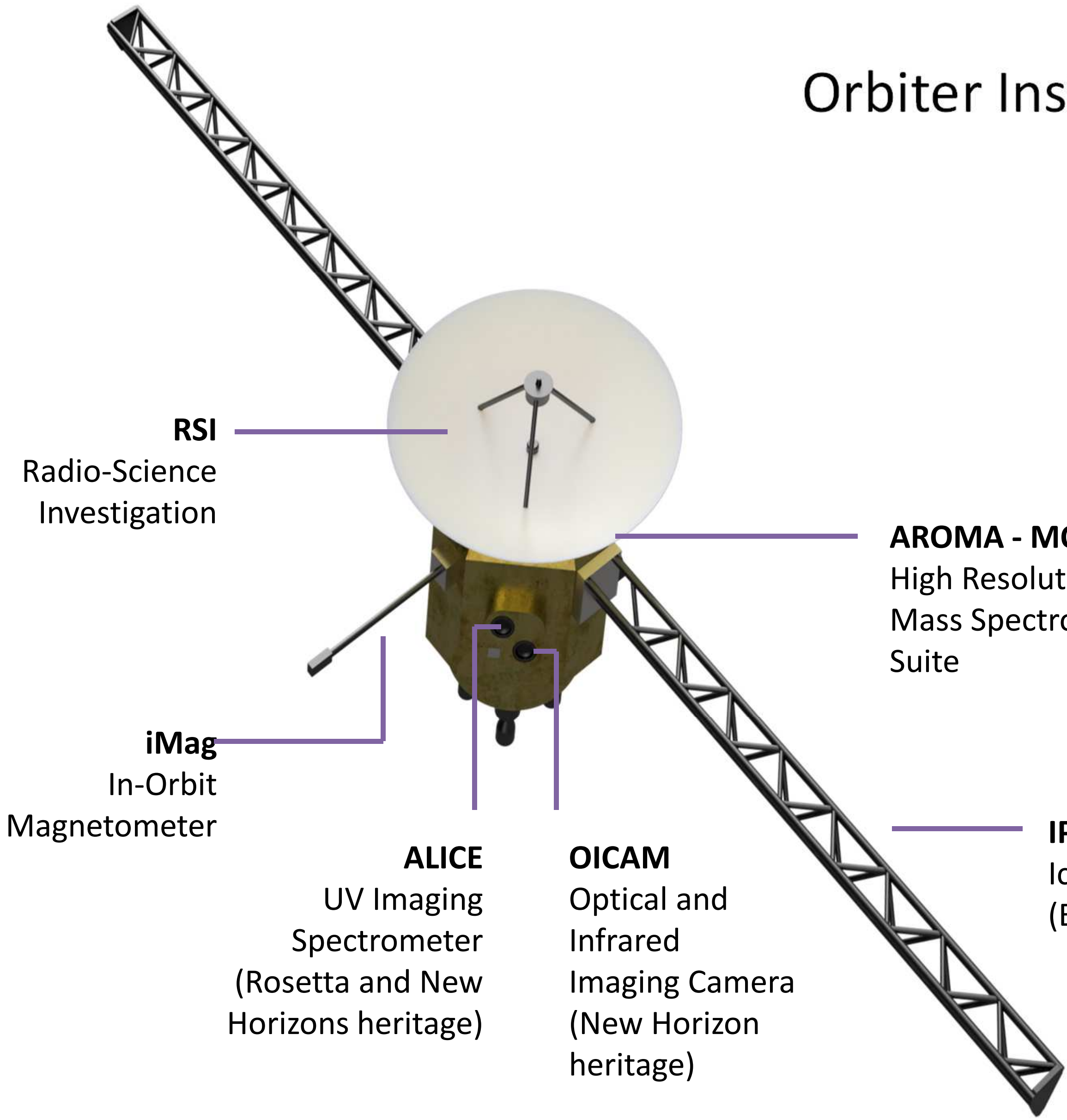


# Table of Contents

- Introduction and Motivation
- Scientific Questions
- Mission Concept
- Instrumentation
- Conclusion

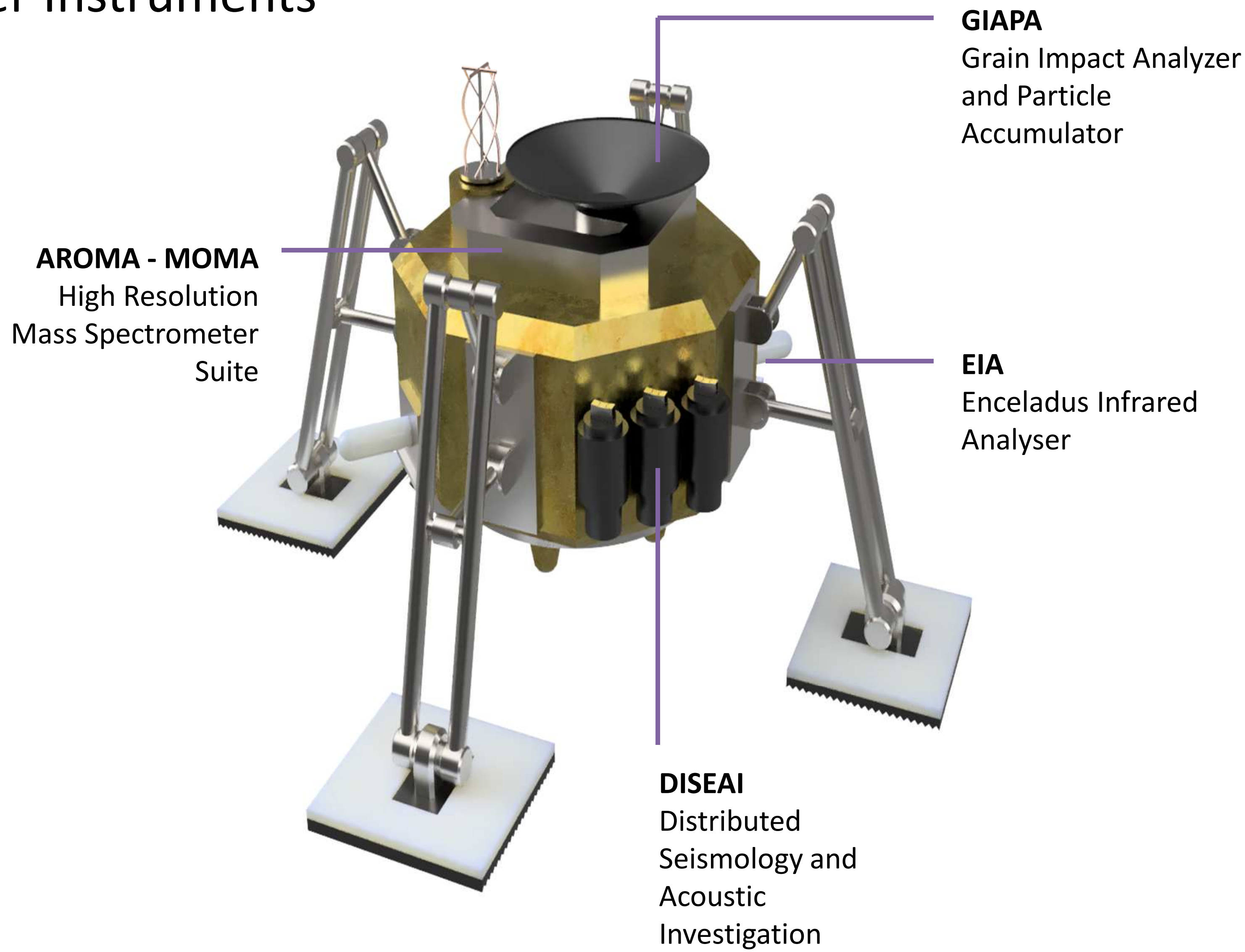
# Instrumentation

## Orbiter Instruments



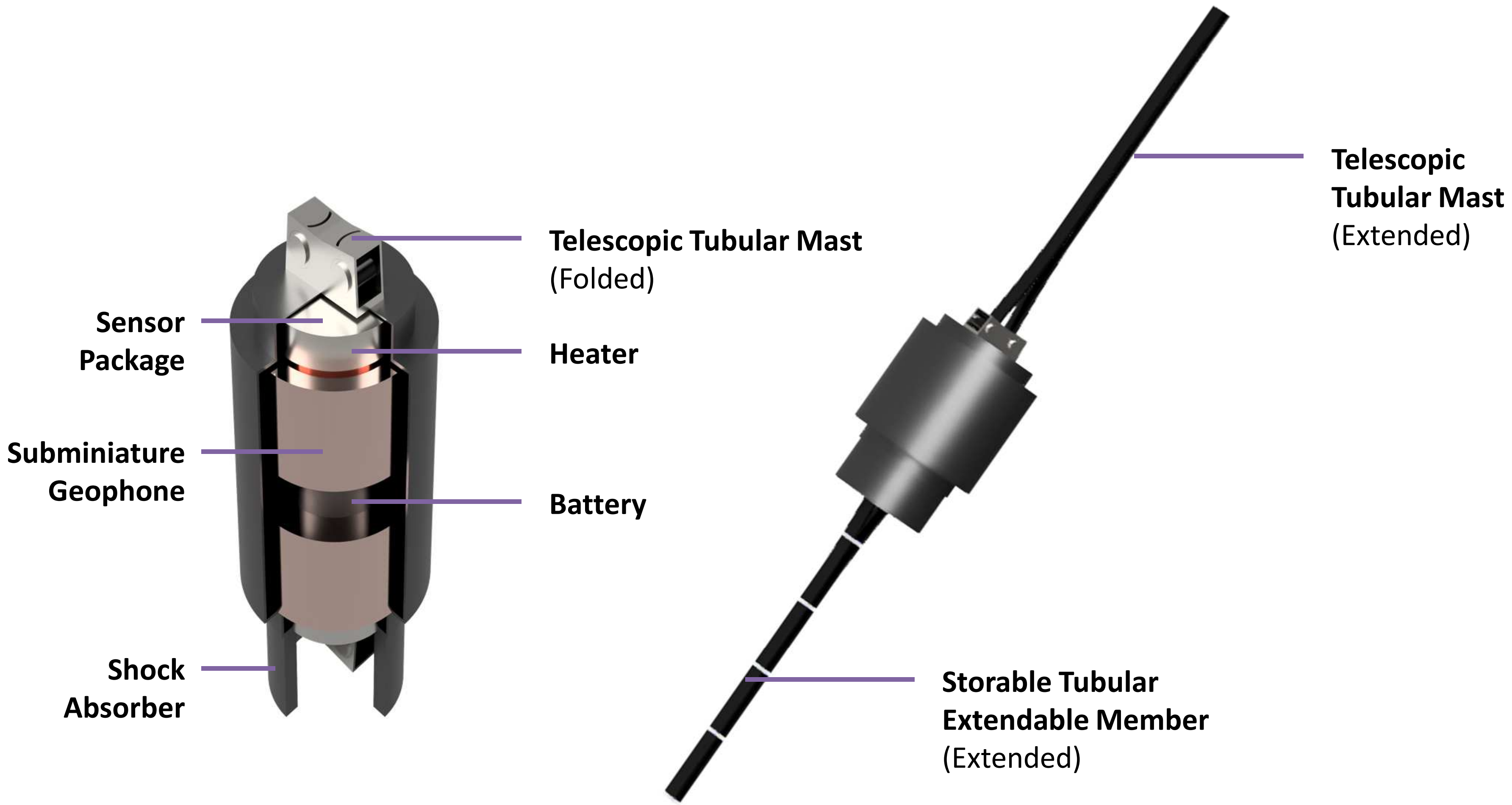
# Instrumentation

## Lander Instruments

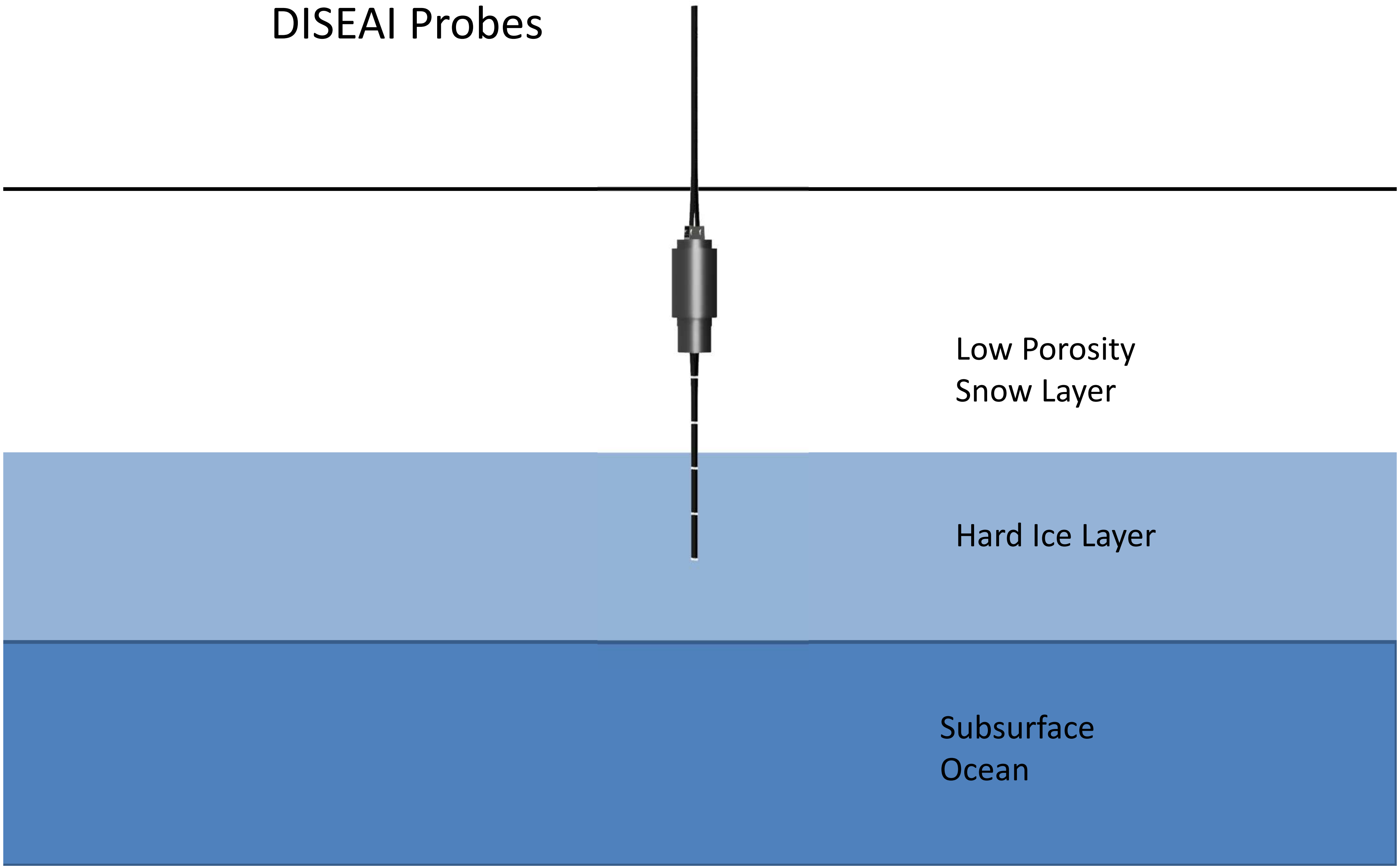


# Instrumentation

## DISEAI Probes



# Instrumentation



# Instrumentation

| Instrument | Question 1 | Question 2 |
|---|---|---|
| Ice Penetrating Radar | ✓ | |
| UV Imaging | ✓ | |
| Optical and Thermal IR Mapper | ✓ | |
| Radio Science Investigation | ✓ | ✓ |
| Mass Spectrometer | ✓ | |
| Grain Impact Analyzer and Particle Accumulator | ✓ | ✓ |
| DISEAI System | ✓ | ✓ |
| Lander IR Analyzer | | ✓ |

Question 1: How does Enceladus provide habitable conditions?

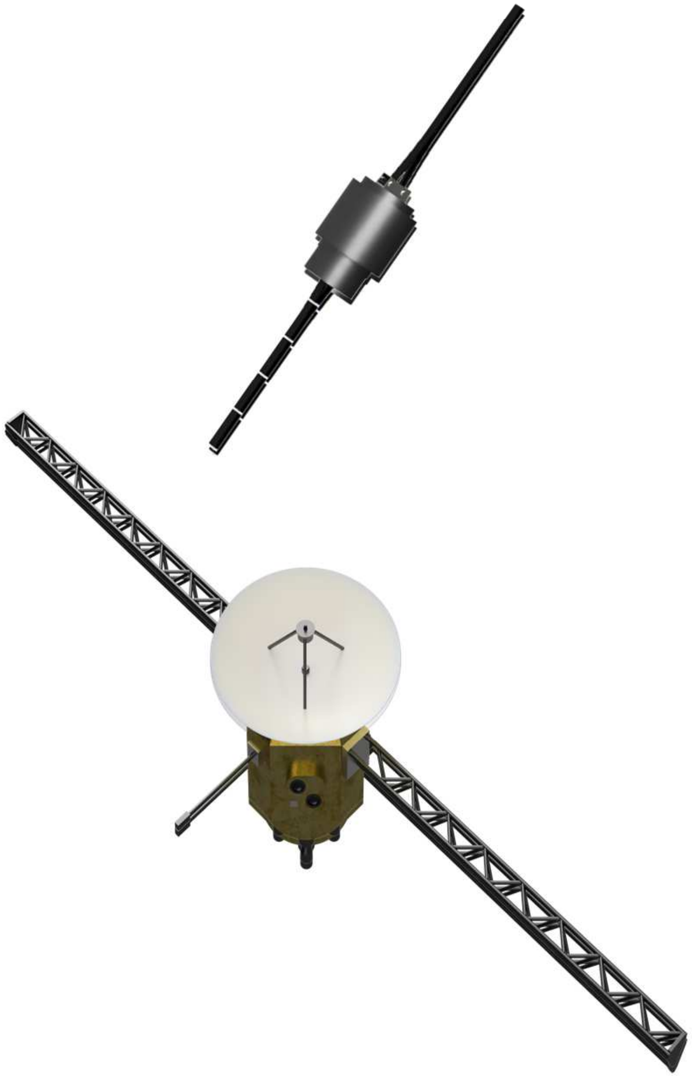
Question 2: What biotic or abiotic signatures characterize Enceladus?

# Table of Contents

# Conclusion

The ETNA mission concept has been presented with focus on:

- Scientific objectives
- Instrumentation
- Mission Concept



# Conclusion

## A special thanks to

Keck INSTITUTE FOR SPACE STUDIES

JPL

**Moore-Hufstedler Fund**

NORTHROP GRUMMAN

LOCKHEED MARTIN

GALCIT

AEROSPACE

Caltech

# Conclusion

**Thank you for the attention**
**Any questions?**

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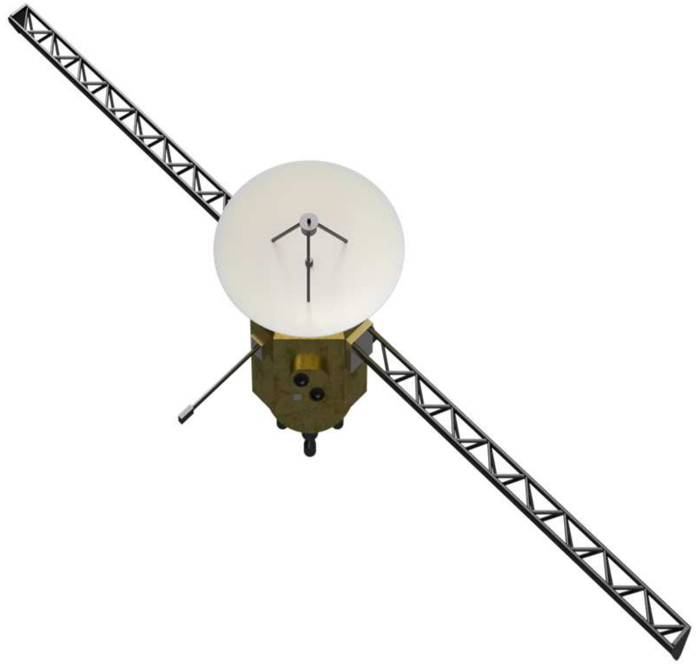
# Appendix

- Power → 3 eMMRTG (330 W at EOL)
- Attitude control → OpNav, IR camera, Star Tracker, IMU, Sun sensors, reaction wheels, 16 thrusters
- Data Handling → 2 RUAG OBC and 200 Gb battery
- Thermal → MLI (JUICE heritage) + Radioidotope Thermal Unit
- Communication → X/Ka-band with 3m HGA, UHF for the lander
- Propulsion → Hydrazine system (JUNO heritage)



# Appendix

## Radio-Science Investigation (RSI)

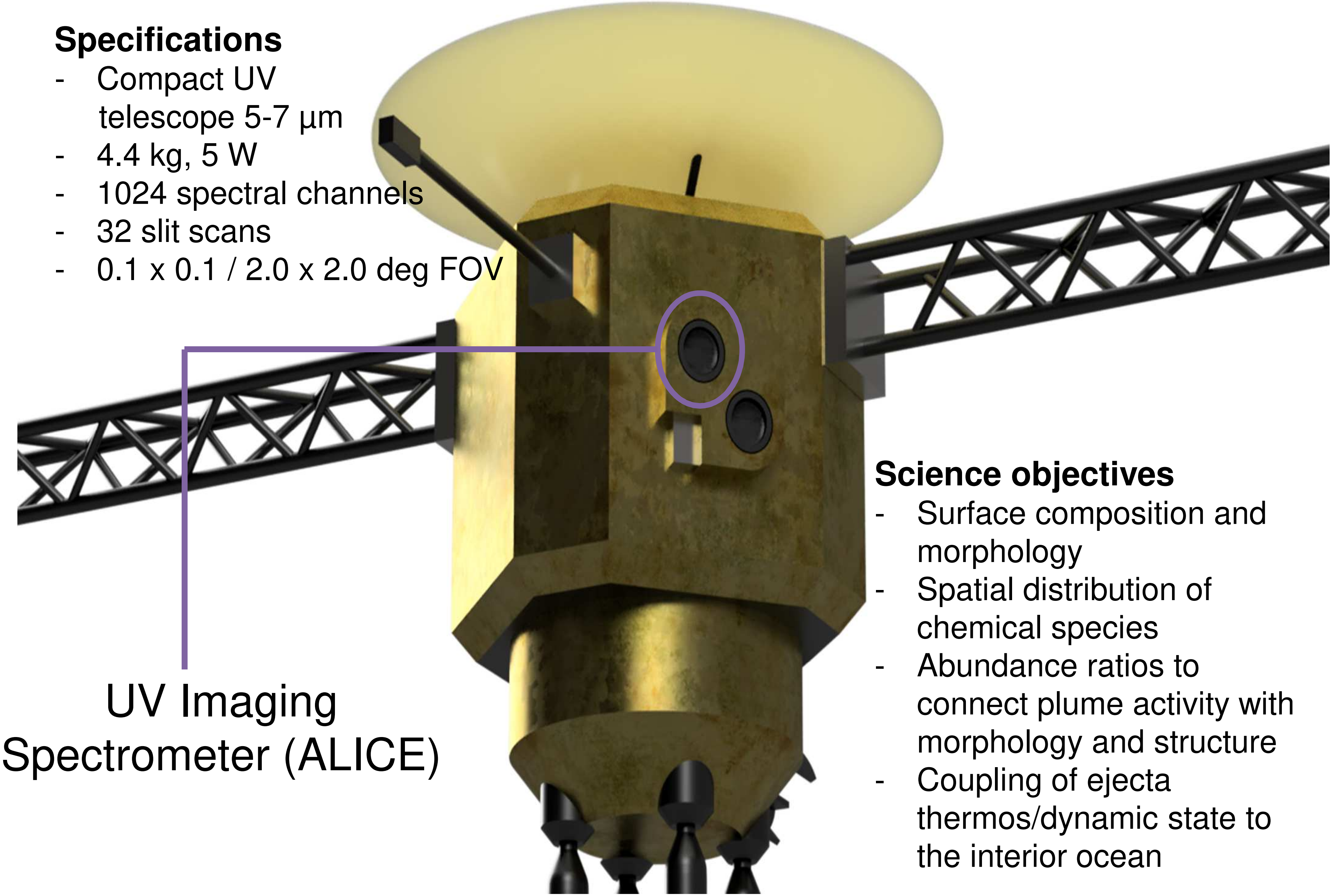
**Specifications**
- Reusability of spacecraft com system
- Dual-frequency X/Ka-band
- 2-way Doppler for gravity science
- 1-way Doppler for radio-occultation and bistatic radar
- Ultra stable oscillator (USO) of Allan Variance of $10^{-12}$

**Science objectives**
- Ephemeris of Saturn moons
- Enceladus mass, mass density, gravitational coefficients, and spin state
- Surface roughness and dielectric constant

# Appendix

**Specifications**

- Compact UV telescope 5-7 μm
- 4.4 kg, 5 W
- 1024 spectral channels
- 32 slit scans
- 0.1 x 0.1 / 2.0 x 2.0 deg FOV



UV Imaging Spectrometer (ALICE)

**Science objectives**

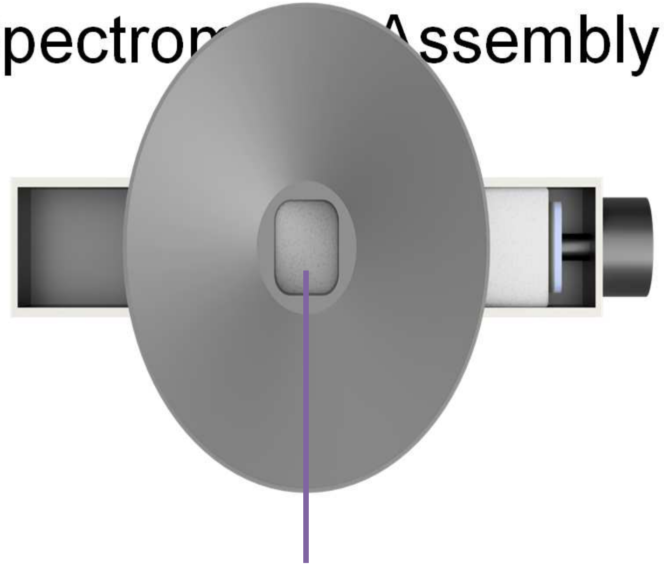
- Surface composition and morphology
- Spatial distribution of chemical species
- Abundance ratios to connect plume activity with morphology and structure
- Coupling of ejecta thermos/dynamic state to the interior ocean

# Appendix

## AROMA-MOMA Mass Spectrom ssembly

The Gas Chromatrography Mass Spectrometer (GCMS)
- ExoMars TRL 9 heritage
- Isotope differentiation and chirality

The Tandem Mass Spectrometer (MSMS)
- $10^3$ higher resolution factor than state of the art (MAPEX)



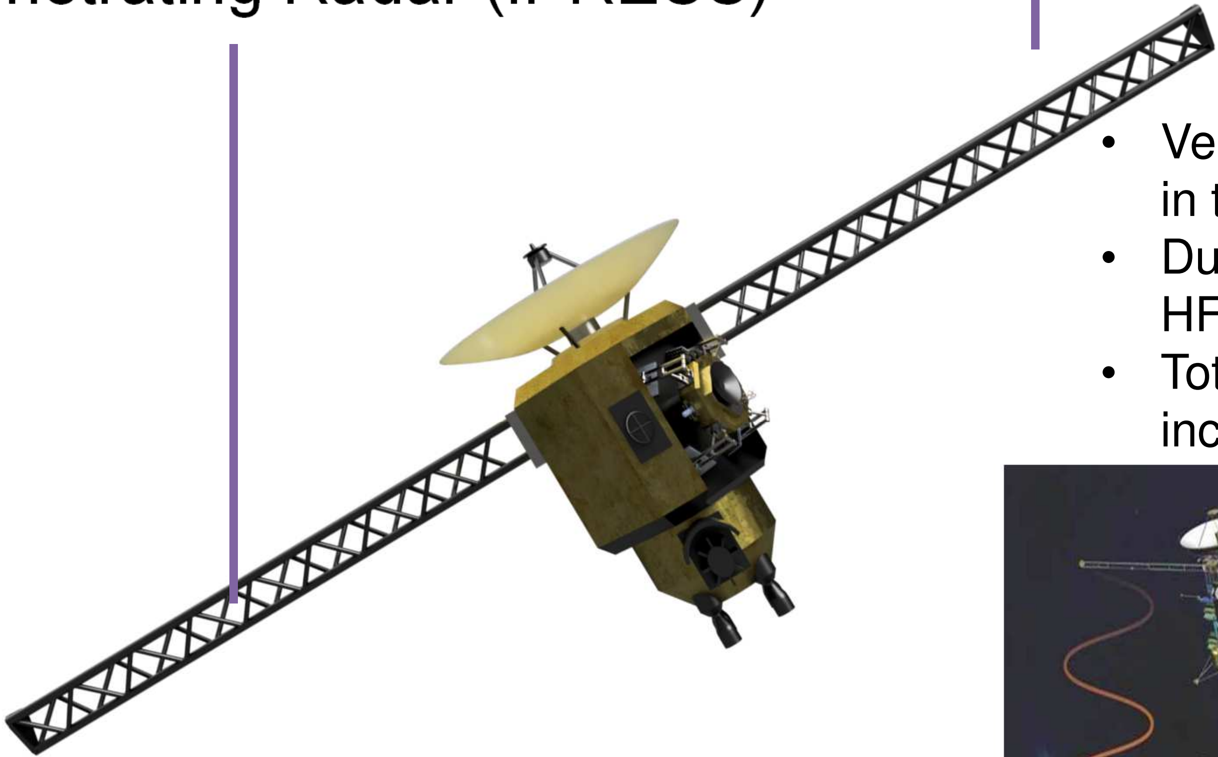
**Collection Plate**
- **Aerogel cubes exposed one at a time and pushed through to the spectrometer**

- Peak power: 40 W
- Mass: <10 kg
- Resolution: >120,000 m/Δm over 3.2 ppm

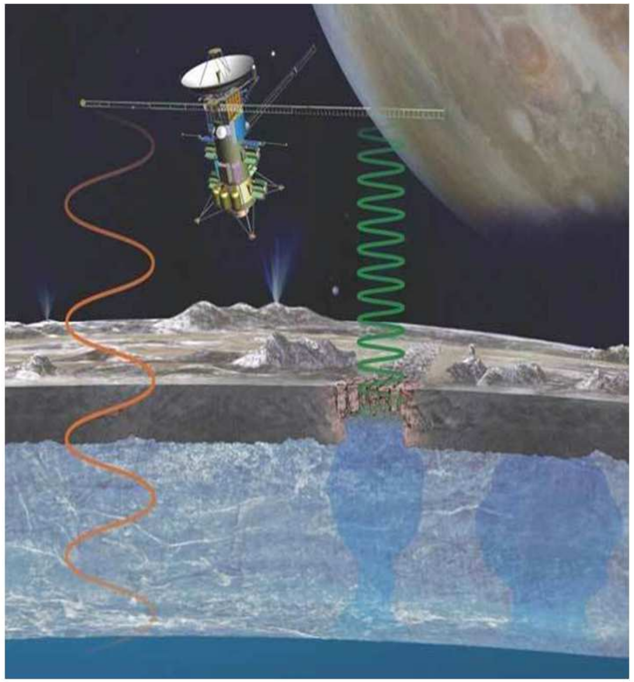
- Isotopic and chemical composition of core and plumes
- Relative abundance of amino/fatty/ carboxylic acids to glycine
- Chirality of elements

# Appendix

## Ice Penetrating Radar (IPRESS)



- Vertical resolution: 15 m in the ice; 150 m in ocean
- Dual frequency (VHF and HF)
- Total mass: 33 kg including 16 m antenna

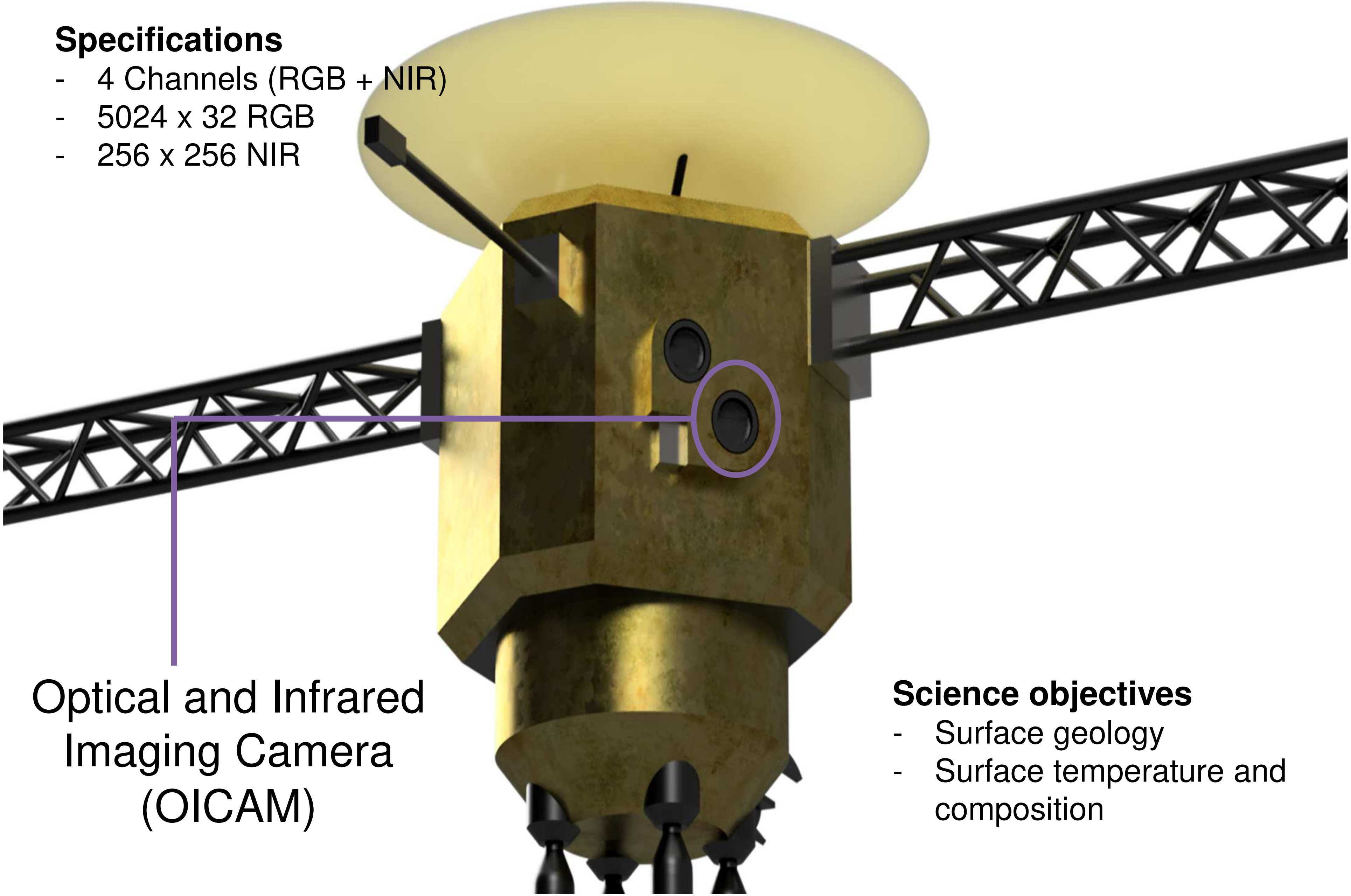


- Shallow and deep sounding of ice shell
- Altimetry
- Reflectometry to study surface roughness and permittivity
- Ionization in the plumes

# Appendix

**Specifications**

- 4 Channels (RGB + NIR)
- 5024 x 32 RGB
- 256 x 256 NIR

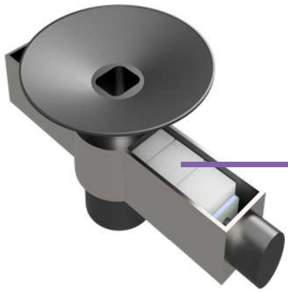


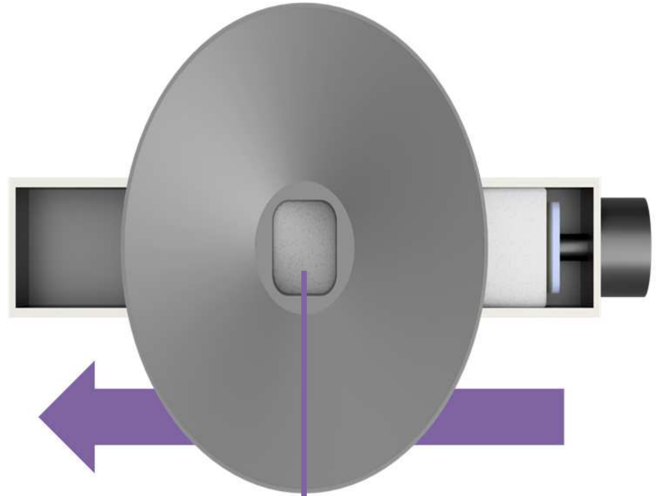
Optical and Infrared Imaging Camera (OICAM)

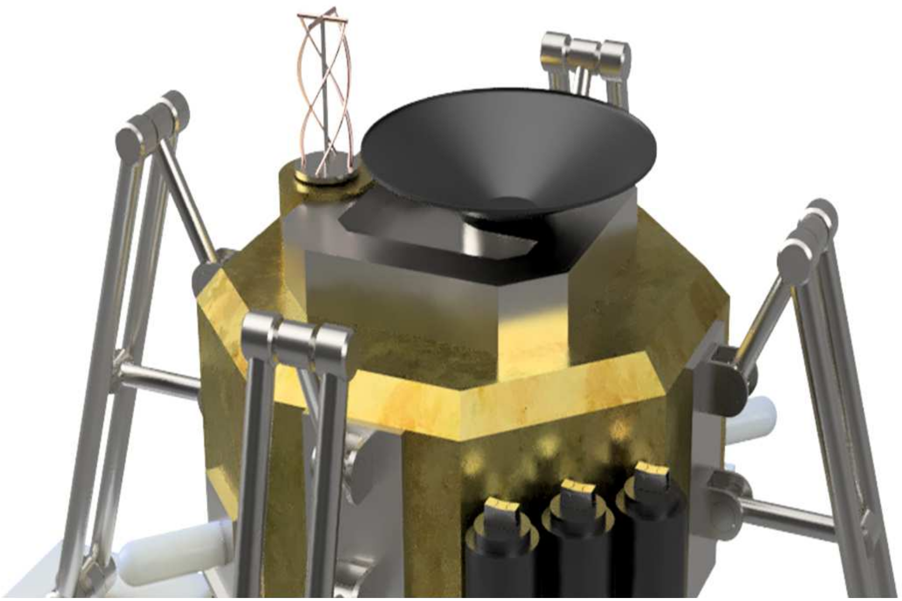
**Science objectives**

- Surface geology
- Surface temperature and composition

# Appendix

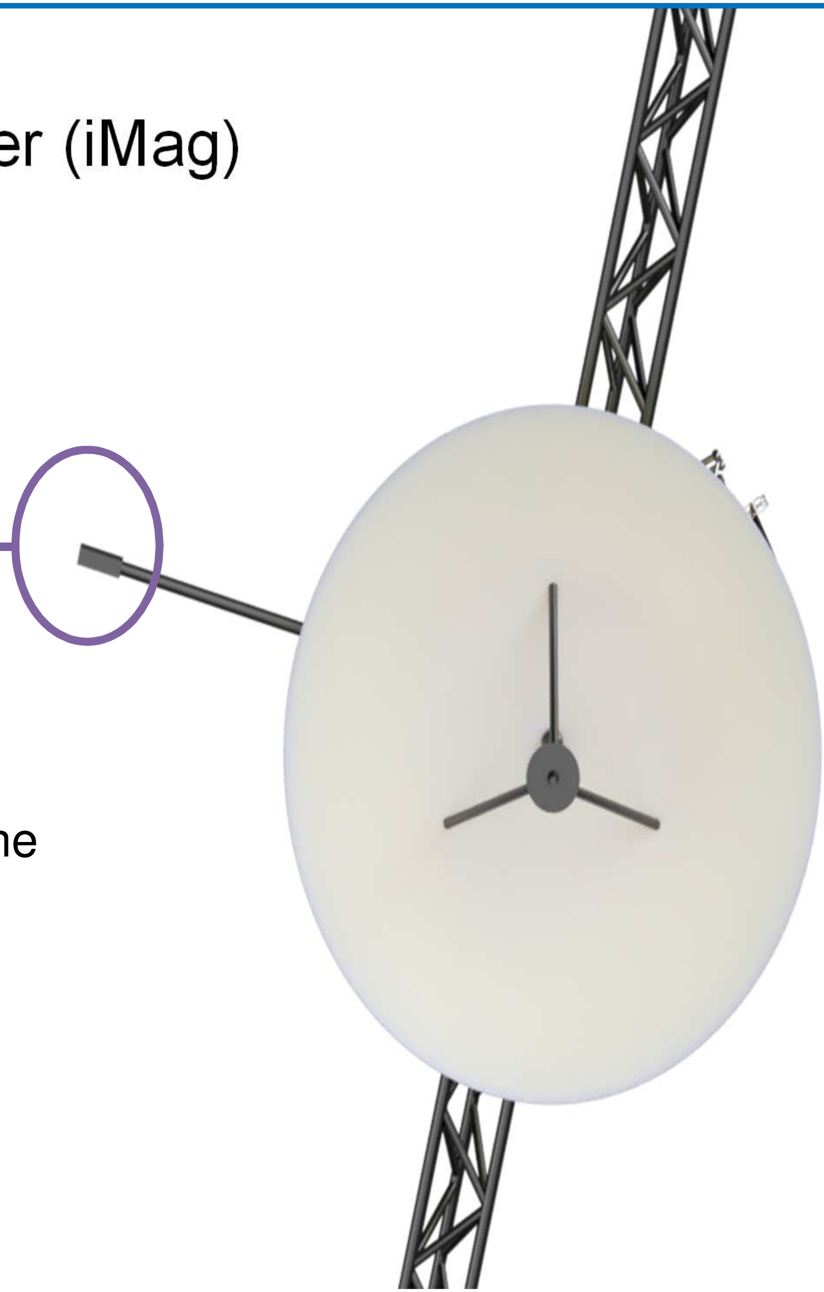

Aerogel Cubes


Collection Plate
- Aerogel cubes exposed one at a time and pushed through to the spectrometer



# Appendix

## In-Orbit Magnetometer (iMag)



**Science objectives**
- Characterized depth of subsurface ocean
- Probe ionization state of the plumes

**Specifications**
- + - 16384 nT
- Resolution 20bit / 31 pT