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

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Enceladus provides direct access to the buried ocean and show evidences of being an active world
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.
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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?
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?
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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 campaign are performed:
1. Imaging of the plume
2. UV Spectrometry
3. Ice Penetrating Radar
4. Plume Flythroughs

Ensure science return without landing.
The lander is then deployed with Mass Spectrometer and Microscope and lands within 5 km of active plume.

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

IPREAS
Ice Penetrating Radar
(Europa Clipper heritage)

ALICE
UV Imaging Spectrometer
(Rosetta and New Horizons heritage)

OICAM
Optical and Infrared Imaging Camera
(New Horizon heritage)

AROMA - MOMA
High Resolution Mass Spectrometer Suite

iMag
In-Orbit Magnetometer

RSI
Radio-Science Investigation
Instrumentation

Lander Instruments

GIAPA
Grain Impact Analyzer and Particle Accumulator

AROMA - MOMA
High Resolution Mass Spectrometer Suite

EIA
Enceladus Infrared Analyser

DISEAI
Distributed Seismology and Acoustic Investigation
DISEAI Probes

- Telescopic Tubular Mast (Folded)
- Heater
- Battery
- Subminiature Geophone
- Shock Absorber
- Sensor Package
- Storable Tubular Extendable Member (Extended)
- Telescopic Tubular Mast (Extended)
## Instrumentation

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<th>Instrument</th>
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<td>Mass Spectrometer</td>
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<td>Grain Impact Analyzer and Particle Accumulator</td>
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<tr>
<td>DISEAI System</td>
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<tr>
<td>Lander IR Analyzer</td>
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**Question 1:** How does Enceladus provide habitable conditions?

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

The ETNA mission concept has been presented with focus on:

- Scientific objectives
- Instrumentation
- Mission Concept
Conclusion

A special thanks to

Moore-Hufstedler Fund
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)
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

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
AROMA-MOMA Mass Spectrometer Assembly

The Gas Chromatography 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)
- Peak power: 40 W
- Mass: <10 kg
- Resolution: $>120,000 \frac{m}{\Delta m}$ over 3.2 ppm

Collection Plate
- Aerogel cubes exposed one at a time and pushed through to the spectrometer
- 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
Optical and Infrared Imaging Camera (OICAM)

Science objectives
- Surface geology
- Surface temperature and composition

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

Collection Plate
- Aerogel cubes exposed one at a time and pushed through to the spectrometer
In-Orbit Magnetometer (iMag)

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

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