



SATELLITES: ACTIVE WORLDS AND EXTREME ENVIRONMENTS

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Areas of interest

- **How did the Satellites of the outer solar system form and evolve?**
 - What were the conditions during satellite formation?
 - What determines the abundance and composition of satellite volatiles?
 - How are satellite thermal and orbital evolution and internal structure related?
 - What is the diversity of geologic activity and how has it changed over time?
- **What Processes control the present-day behavior of these bodies?**
 - How do endogenic processes shape satellites surfaces and influence their interiors?
 - What processes control the chemistry and dynamics of satellite atmospheres?
 - How do exogenic processes modify these bodies?
 - How do satellites influence their own magnetospheres and those of their parent planets?
- **What are the processes that result in Habitable environments?**
 - Where are subsurface bodies of liquid water located and what are their characteristics and histories?
 - What are the sources, sinks and evolution of organic material?
 - what energy sources are able to sustain life?
 - Is there evidence for life on satellites?

Proposed Missions

- Europa Orbiter
- Titan Saturn System Mission (TSSM)
- Enceladus Orbiter

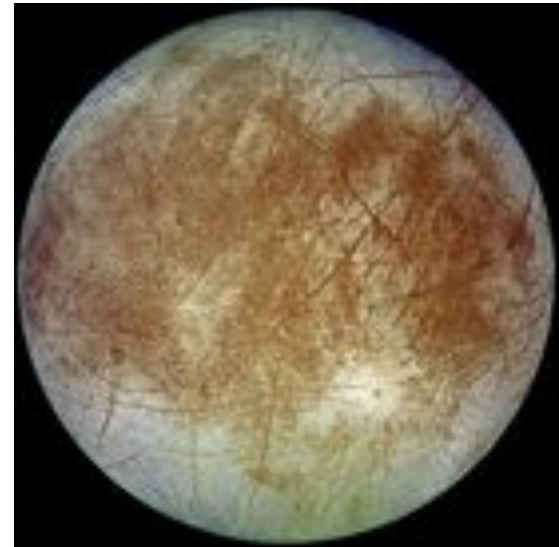


Europa

- An icy Satellite of Jupiter
- Shows evidence of recent complex resurfacing
 - probably harbors a subsurface liquid ocean

Its low crater density also suggest ongoing geologic activity.

- Radius: 1561 km



Items of Interest at Europa

- What is the thickness of Europa's ice shell and subsurface ocean?
- How much non-synchronous rotation has Europa's shell undergone, and how have the resulting stresses shown on the surface?
- Has material from the subsurface ocean been transported to the surface? How?
- Does Europa have organics on its surface?
- What is the nature of biologically relevant heat and energy sources on Europa?

Necessary Science for Europa

- Measurement of static gravitational fields,
- Topography to probe the interior structures of the moon,
- Radar mapping of the outer sphere,
- Global reconnaissance with a 100m scale imaging and high-resolution mapping (~10m/pixel).
- Look at how Europa plays a role in populating Jupiter's magnetosphere.
- Subsurface sounding from orbit to investigate the presence of near-surface water and deep oceans.
- Observations on the surface of Europa should be able to determine the presence of organics.
- Improved observations of currently active processes of loss of volatiles, tidal effects on the moon.

Suggested means.

- A lander will be needed to fully characterize organics on the surface.
- An orbiter for Europa that survives huge radiation doses and meets planetary protection requirements.

Titan

- Radius: 2576 km
- Thick Atmosphere: Nitrogen
- Bodies of liquid methane
- Potential for a subsurface liquid body
- Not perfectly differentiated



Items of interest at Titan

- Why are Titan and Calisto apparently imperfectly differentiated
 - whereas Ganymede underwent complete differentiation?
- Why does Titan uniquely have an exceptionally thick atmosphere?
- What does the volatile inventory tell us about its history?
 - How is the methane resupplied given its rapid photochemical destruction in the upper atmosphere?
- What is the relationship between Titan's surface morphology and its surface processes?
- Does Titan have an internal liquid water ocean?
- What is the age of Titan's surface?
 - Have cryovolcanism and tectonism been important processes?
- What processes control Titan's weather?
- How do Titan's clouds originate and evolve?
- Are the lakes fed primarily by rain or underground methane-ethane aquifers?
- What is the nature of atmospheric processes on Titan that convert small organic gas-phase molecules observed in the upper atmosphere into large macro molecules and eventually into solid haze molecules?
- What is the fate of organics on the surface of Titan and their interaction with the seasonally varying lakes of liquid hydrocarbons?
- Is hydrocarbon based life possible on Titan?

Titan Saturn System Mission Goals

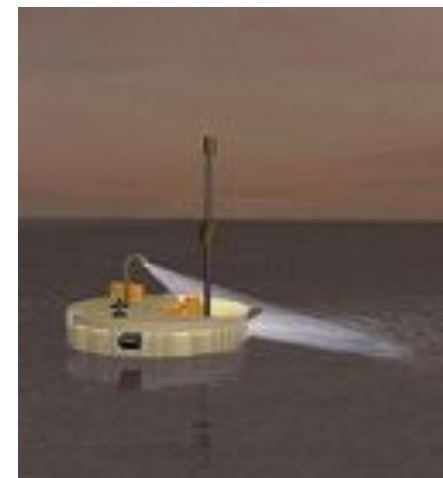
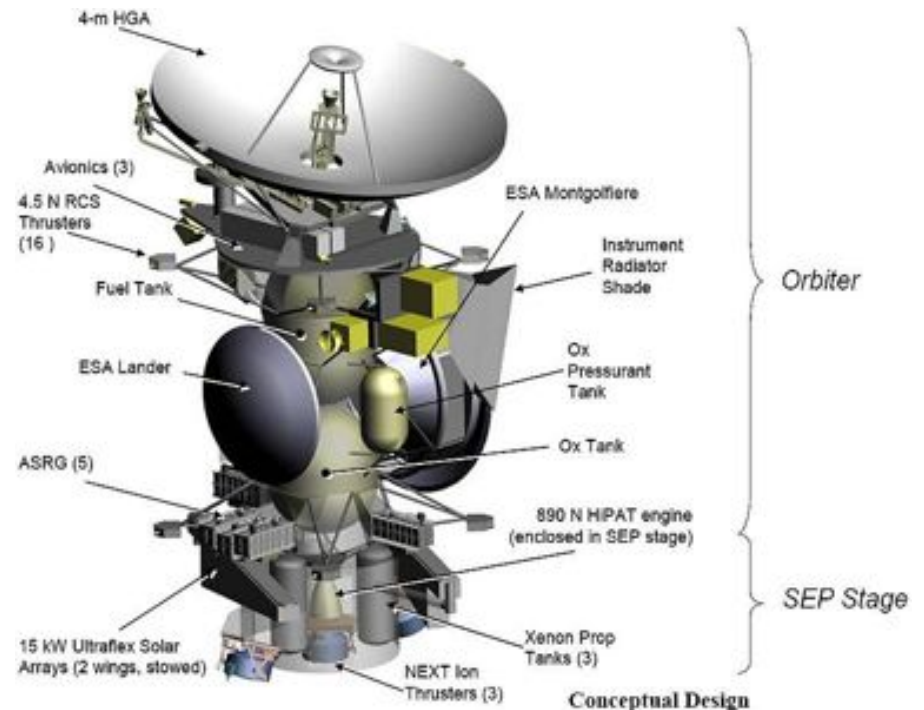
- Explore and understand processes common to Earth that occur on another body.
- Examine Titan's organic inventory, a path to pre-biotic molecules.
- Explore Enceladus and Saturn's magnetosphere—clues to Titan's origin and evolution.
 - This includes investigation of Enceladus's plume for clues to the origin of Titan ices and a comparison of its organic content with that of Titan, and understanding Enceladus's tidal heating and its implications for the Saturn system.

Necessary Science at Titan

- Global maps of Titan's surface morphology and surface composition to search for evidence for present day geologic activity.
- Continued observations of seasonal changes on Titan are vital to understanding the dynamics of its atmosphere and its interaction with the surface.
- Improved understanding of organic chemistry will require in situ atmospheric compositional measurements capable of characterizing complex organic molecules.
- Improved measurements of atmospheric and surface chemistry to increase understanding of biological availability of chemical energy.

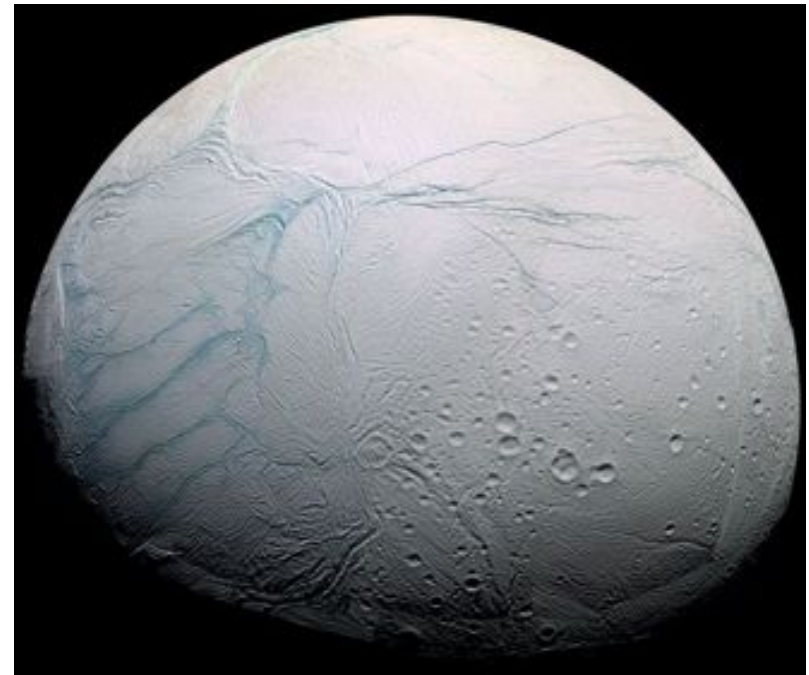
Suggested means

- Orbiter
- Hot Air Balloon (Montgolfière)
 - Fosters In situ elements enabling extensive Ariel coverage.
- Titan Mare Explorer (TiME)
 - To evaluate the feasibility and value of additional capability to directly sample the subsurface and lake bottom.



Enceladus

- Moon of Saturn
- Geologically active
South Pole
- Radius: 252 km
- Plumes
- Tiger Stripes



Items of Interest at Enceladus

- What does the plume material from Enceladus tell us about the volatile inventory of that body?
- What does the spatial distribution of Enceladus heat output and how has it varied in time?
- Does Enceladus have an ocean or some other means of providing large tidal dissipation and to what extent is this behavior dictated by its formation conditions?
- Why is Enceladus' geology so spatially variable? How has activity varied with time?
- What mechanisms drive and sustain Enceladus plumes and active tiger strip tectonics?
- If Enceladus is only intermittently active is it less attractive as a potential habitat?
- What is the source of the organic material in the plumes of Enceladus?
- What are the energy sources that drive the plume on Enceladus?
- Does life exist below the surface of Enceladus?

Main Goals for Enceladus Mission

- What is the nature of Enceladus' cryovolcanic activity including conditions at the plume source the nature of the energy source delivery mechanism to the surface and mass loss rates?
- What are the internal structure and chemistry, including the presence and chemistry of global or regional subsurface oceans?
- What is the nature of Enceladus' geologic history including tectonism, viscous modification of the surface, and other resurfacing mechanisms?
- How does Enceladus interact with the rest of the saturnian system?
- What is the nature of the surfaces and interiors of Rhea, Dione, and Tethys?
- Characterize the surface for future landing sights.

Necessary Science

- Investigations and measurements relevant to the abundance and composition of volatiles.
- Better understanding of the internal structure and thermal evolution requiring measurements of static gravitational fields and topography.
- Advancing understanding of the full range of the full processes requiring global reconnaissance and high resolution mapping.
 - In particular understanding of tectonics require such global maps.
- Acquisition of higher resolution of higher thermal and visible imaging of the active south pole of Enceladus including temporal coverage to elucidate plume generation mechanisms.
- Continued field and plasma field experiments and monitoring of plumes to better elucidate the roles of Enceladus and other icy satellites in populating Saturn's magnetosphere.
- Improved compositional measurements of gas and dust ejected from the plume.
- Detailed investigations of the organic chemistry of the plume with improved mass range and resolution compared to those provided by Cassini.

Suggested Means

- Enceladus Orbiter: mass spectrometer, a thermal mapping radiometer, a dust analyzer, an imaging camera, and a magnetometer.
 - major technological challenge is ensuring the reliability and lifetime of the ASRGs
 - Planetary Protection is also a challenge.

Economics

- Proposed mission cost due to CATE, which includes consideration for extra cost based on previous missions.
 - Titan:
Projected: 4.5 billion
CATE: 6.7 billion
 - Europa
Projected: 3.4 billion
CATE: 4.7 billion

Laboratory studies

Types of studies.

- Atmospheric composition and chemistry
- Surface composition
- Studied by using spectroscopic spectral labs created appropriate conditions for planetary materials
- Need increased spectral range to be able to produce more accurate data about temperatures and elements.
- Goal for technologic advances is mainly to lower mass, and increase power and data transmission.

Areas that need increased funding (ranked by Working Group on Laboratory Astrophysics)

- **Laboratory studies** that are related to in situ missions
- Development of spectroscopic databases covering mm waves to X-rays.
- Derivation of optical constants of cryogenic ices, organics, minerals, salts, and a mixture thereof in the 0.1 – 500 microns region.
- Detection of isotopes with high sensitivity.
- Understanding reaction mechanisms in the interior, surface, and atmosphere.
- Formation of aerosols from molecular precursors in planetary atmospheres.
- Better understanding of surface catalysis reactions involving gas-phase species.
- Simulations of interior processes.