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Investigation of Enceladus' Topology and Underwater Exploration With a Robot

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Abstract

This is a proposal for a future mission with focus on orbital and in-situ exploration of Saturn's icy moon Enceladus, a good candidate for life-supporting celestial body. Enceladus is heated up due to the tidal effects by the gravity of Saturn, which results in an active surface where water plumes are present, but also a potentiality of an ocean of liquid water under the icy crust. By examining the water from the plumes and exploration of the environment under the surface, there might be a possibility to find life in form of microorganisms, present and/or remnants. This will give us a better understanding of the astrobiology and life conditions of bodies both inside and outside our Solar System. The mission will involve a robot that does observations in water. To be able to reach the waters, a nuclear power source will be onboard a vehicle, which permits it to access through the ice and travel downwards. This is due to the heat, melting the ice in the way. The vehicle will be installed on a mount**,** brought down with the aid of a sky crane. It is more stable to land a heavy spacecraft with radiative material with this method, especially since the landing will be done vertically. The robot will be automous and the problem of encountering possible collisions with surface obstacles will be resolved by using sensors on the robot, which will alert it in advance. The area where this process will occur shall be determined after surface observations of the carrier satellite, where it shall determine where the thinnest ice layer is situated. The data and images from the robot will be sent via a communication link between it, the mount and the carrier satellite. Additionally, the satellite in orbit will be equipped with a camera, which will create a heat map of the moon and send detailed images of its surface to the ground station on Earth.

1. Introduction

The search for life outside our planet has been a hot topic for years and one of the goals is to one day find living (or traces of) life, in form of microorganisms. This will give us an understanding of how common life is in other words besides our own planet. Except the planet Mars, the moons of Jupiter and Saturn are of great interest since they are active, with either volcanoes or liquid water under the surface. This mission is proposed to search for evidence of life, living or remnants, but also give information about Io's volcanic activity, atmospheric conditions and surface features.

1.1. Enceladus' plumes

One of the objectives of this mission is to study the water plumes for further detail regarding the moon. Below is an estimation of the composition of the plumes.

Table 1: The composition of Enceladus' plumes. Small amount of other species (Ch_3OH, N_2, ^{40}Ar, C_nH_n and C_nH_nO) exist, but their percentage is not indicated here. **[1]**

Molecule	**Percentage [%]**
H_2O	≈ 90
CO_2	≈ 5
CH_4	≈ 0.9
NH_3	≈ 0.8

As can be seen, the greatest proportion of the plume's composition is actual H_2O. This might suggest that the water is clean enough to support life as can be found here on Earth, or even other forms of life that we have not encountered yet.

2. Payload

To satisfy the goals of the mission, the satellite will carry the following instruments: A spectroscopic, optical and infrared remote imaging camera for taking images in the visible, near IR and near UV wavelengths. An instrument for radio science investigation, where the objective is to attain more knowledge about Enceladus' gravitational field, nucleus and its thermal properties. A spectrometer for visible, infrared and thermal imaging. This will allow a temperature mapping and it will likewise help to find the best landing site for the lander. Besides these, the lander will be equipped with cameras and lamps for detailed images of the area and give footage of the ice-melting process.

3. Spacecraft and Robot Design

Below is the preliminary design of the satellite, with the heat shield on-board, which has the skycrane and vehicle inside. A parachute will decrease the velocity of the heat shield as it enters the atmosphere of Enceladus. As mentioned, the satellite must take maps of the surface to find a site with ice that is relatively thin compared to the surrounding. It is worth to point out that the thickness might be ≈ 60 km. The vehicle has an edge around it so that the melted water can push it downwards faster.

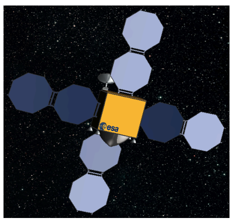

Figure 1: The satellite with the heat shield on-board.

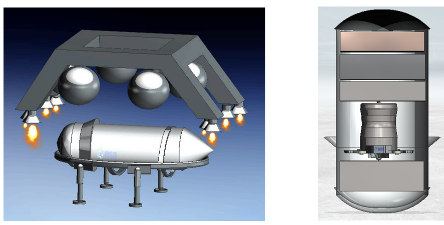

Figure 2: The skycrane leaving the vehicle on the decided site. Also, a cut-through of the vehicle with the robot inside can be seen.

From top we have a tether box for communication with the vehicle. The second is a nuclear power source, which was chosen due to the fact that the vehicle will be under the surface, where it is not possible to charge batteries with the aid of solar arrays. Beneath it is the on-board computer, followed by the robot. Lastly, the hot water pumps and jets for melting the ice and run through the ice. Note that the design of each instrument is not detailed in figure 2.

The vehicle will rest on a mount, which is equipped with a motor that moves the nose of the vehicle downwards to the surface in a ≈ 90° inclination.

Figure 3: The design of the robot. It will be equipped with two cameras, 5 lamps, a big turbine in the center for fast movement, and two smaller rotators that can move in 45° each side for sideways movement.

4. Launch and Orbital trajectory

This is a M-class (Medium size) mission and will be launched with a Soyuz rocket. The carrier satellite will reach its destination by the use of gravity assist after a bi-elliptic Hohmann transfer. That is, after the launch, the satellite will reach a LEO orbit (≈ 500 km), where it will perform an Earth flyby and move towards Venus. There, it will execute a Deep Space Maneuver (≈ 480 x 10^6 km), for a second Venus swing-by for a Hohmann transfer to reach Saturn. This technique will give enough of force and speed to send it on a trajectory towards Saturn. As the spacecraft approaches Saturn, it will use the gravity of the planet with the aid of a flyby (≈500 km), to reach the final destination, i.e. Enceladus. The entire flight will take approximately 7 years. The total mission time, i.e. the EOL stage, will be reached after 10 years (≈ 2-3 years of observation with the satellite and ≈ 1 week for the robot).

5. Summary and Conclusions

The mission proposed will provide a unique opportunity to study Enceladus, its plumes and the liquid ocean beneath its surface. The combination of topographic, magnetic, and gravity measurements will lead to a significant improvement of understanding active moons, which can be applied to exoplanets as well. That is, to and improvement in general understanding of planetary geophysics and evolution of terrestrial planets and moons.

References

[1] A. Bergantini, S. Pilling, B. G. Nair , N.J. Mason , and H.J. Fraser2, Processing of analogues of plume fallout in cold regions of Enceladus by energetic electrons, ESO 2014