EPSC Abstracts
Vol. 10, EPSC2015-56, 2015
European Planetary Science Congress 2015

Volcanic Outgassing and In-situ Surface Observations of the Jovian Moon Io

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Abstract

This is a proposal for a future mission with focus on orbital and in-situ exploration of the Jovian moon Io. Io is heated up due to the tidal effects by the gravitational force of Jupiter, which results in an active surface where volcanoes are common. By collecting particles from volcanic eruptions in the atmosphere and surface samples, it is possible to understand the evolution of Io. There might also be a possibility to find evidence of past and present existence of life, e.g. remnants of microorganisms. This is a possibility since it has been detected on Earth that some life forms have the ability to live on for instance radioactive matter, near volcanoes, and also around hot springs where the temperature can reach 40–100° C. The mission will include a lander, which will be deployed from a carrier satellite, which will also perform observations in orbit. During the deployment, a high-altitude balloon will inflate and the lander will be able to collect dust samples from a volcano over a time period of ≈ 2-3 weeks. In the second stage, the lander will land on a site, far from a volcano, where it will examine the collected particles from the atmosphere. It shall also drill on Io's surface and perform chemical analysis of the samples with the aid of instruments. The site will be determined after a heat map analysis, where the ideal area is one far from a volcano and not hot enough. In addition, cameras will be mounted on the lander, where it will take panoramic images of its surrounding, but also the surface during the drilling process. The images will be used for scientific investigations, likewise for commercial and educational purposes. The orbiting satellite will also 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 life, in form of microorganisms, as remnants or living ones. This will give us an understanding of how common life is in other words besides our own planet. Besides 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. The 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, important knowledge that can be applied to exoplanets as well.

1.1. Dust particles

Below are data for the dust particles collected by the Galileo and Cassini missions during their flybys.

Table 2: Data about the Jovian dust streams **[1]**

Dust data	
Density	1.35-1.75 g/cm^3
Dust stream speeds	220/450 km s^{-1}
Charge Potentials	5.5/6.5 V

The measured height of Io's atmosphere is ≈ 8 km, to wholly rarefied ≈100 km where the mean free path is >1 km **[2]**. Substantial atmospheric escape can happen above the exobase (which varies from 200-400 km **[3]**) because of collisional sputtering by energetic Jovian plasma.

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 imaging in the visible, near IR and near UV wavelengths. This will allow a temperature mapping and it will likewise help to find the best landing site for the lander. An instrument for radio science investigation, where the objective is to attain more knowledge about for instance Io's gravitational field, nucleus and its thermal properties. The lander will be equipped with a particle collector, which will perform chemical analysis (a mineralogy and chemistry lab*)* of the samples from Io's atmosphere as it orbits the moon with the aid of the high-altitude balloon. The objective is to search for organic and inorganic components in the samples. A microwave oven onboard the lander will be a part of this process. Additionally, a drill will help to collect and analyze samples from the surface. To be able to study these samples in an easy manner, a vibrating instrument will be used to break the samples into smaller pieces. A mass spectrometer, x-ray diffraction and gas analyzer is planned to study the samples. Lastly, an imaging system will take panoramic images of the lander's surrounding, but also smaller cameras close to the drill, which will be of great value when the digging process is started. The images will be used for not only scientific investigations, but also for educational and commercial purposes.

3. Spacecraft and Lander Design

Below are the **preliminary** design of both the carrier satellite and the lander. The internal instruments, for instance the OBC, are not shown.

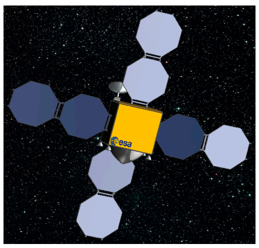

Figure 1: Satellite with the heat protective shell on the bottom

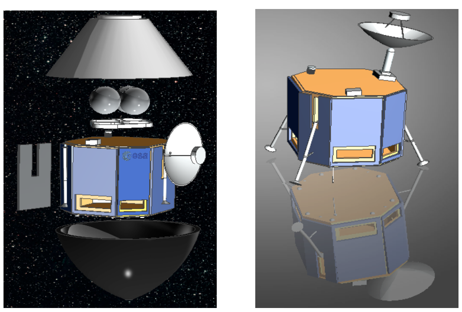

Figure 2: The satellite with the helium thanks for the high-altitude balloon, and heat protective panels on the side, which will be released automatically after the deployment of the lander from the balloon. Note that only one panel is shown in the figure, which is to decrease the image size. The holes on the structure of the lander are where the dust particles from the volcanoes will be collected in for later analysis.

4. Mission design: Launcher, Orbit and balloon

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 swing-by. It will then perform a Deep Space Maneuver (≈ 480 x 10^6 km), and travel back to Earth for a second Earth flyby followed by a Hohmann transfer to send the satellite to Jupiter. This technique will give enough of force and speed to send it on a trajectory towards Jupiter. As the spacecraft approaches Jupiter, it will use the gravity of the planet with the aid of a flyby (≈500 km), to reach the final destination, i.e. Io. The entire flight will take approximately 7 years and 7 months. The total mission time, i.e. the EOL stage, will be reached after 10 years (≈ three years of observation of the satellite and between 1-2 years for the launcher).

5. Summary and Conclusions

The mission proposed here will provide a one of a kind opportunity to study Io and its topology. The combination of topographic, gravity, and magnetic field measurements will lead to an important improvement of understanding active moons and their geology, which can be applied to exoplanets as well. Additionally, the understanding of the method of using high-altitude balloons for observations will increase and can be applied for future planetary exploration. In conclusion, this mission is proposed to increase and develop a general understanding of planetary geophysics and evolution of terrestrial (or terrestrial like) planets and moons.

References

[1] Pearl et al., Io's Surface, Atmosphere and Volcanism, 1979

[2]-[3] Philip L.; Moore, Chris H.; Deng, Hao; Goldstein, David B.; Levin, Deborah; Varghese Trafton, Laurence M.; Stewart, Bénédicte D.; Walker, Andrew C, Simulation of Plasma Interaction with Io's Atmosphere, May 2011.