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NEMO: A mission to search for and return to Earth possible life forms on Europa

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Abstract

The Nuclear Europa Mobile Ocean (NEMO) mission would land on the surface of Europa, and deploy a small, lightweight melt probe powered by a compact nuclear reactor to melt down through the multi-kilometer ice sheet. After reaching the sub-surface ocean, a small nuclear Autonomous Underwater Vehicle (AUV) would deploy to explore the sub-ice ocean. After exploration and sample collection, the AUV would return to the probe and melt back to the lander. The lander would have replenished its H_2 propellant by electrolysis of H_2O ice, and then hop to a new site on Europa to repeat the probe/AUV process. After completing the mission, the NEMO spacecraft would return to Earth with its collected samples. The NEMO melt probe and AUV utilize enriched U-235 fuel and conventional water reactor technology. The lander utilizes a compact nuclear thermal propulsion (NTP) engine based on the 710 tungsten/UO_2 cermet fuel and high-temperature H2 propellant. The compact nuclear reactors in both the NEMO melt probe and AUV drive a steam power cycle, generating over 10 kW(e) for use in each. Each nuclear reactor's operating lifetime is several years. With its high-mobility and long-duration mission, NEMO provides an ideal platform for life detection experiments.

1. Introduction

Europa is a high priority for an exploration mission. Voyager revealed Europa as a world swathed in ice and geologically active. The Galileo spacecraft passed approximately 500 miles above the surface and provided detailed images of what appears to be long linear fractures and upwellings. The pictures appear to show a relatively young surface of ice, possibly only a few kilometers thick in some places. Internal heating of Europa from Jupiter's tidal pull could form an ocean of liquid water beneath the surface. Magnetometer measurements appear to indicate that such an ocean exits under Europa's ice sheet.

On Earth, large colonies of chemosynthetic life forms are found around hydrothermal vents on the deep ocean floor, sustained by the chemical energy, in the materials emitted from the vents. Europa's ice sheet rises and falls several tens of meters from the tidal forces generated by Jupiter. The tidal forces on Jupiter's innermost satellite, Io, produce strong internal heating and high-temperature local volcanic eruptions. On Europa, such eruptions would

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probably occur in the form of a network of hydrothermal vents on its deep ocean floor similar to those existing on Earth, which are generated by heating from radioactive decay.

How life began on Earth still remains an open question. However, some researchers believe that it originated at hydrothermal vents [1]. If so, life may also exist on Europa around its hydrothermal vents. The discovery and investigation of non-Earth life forms in the Solar System would be of immense importance and significance, not only for its scientific value, but also because it would establish that life is not a rare event, but a common phenomenon in the Universe.

Because Europa appears to be the most promising place in the Solar System for the potential discovery of non-Earth life, exploring it and its sub-surface ocean should be a prime priority for the space exploration program.

NASA's present plans focus on the JIMO (Jupiter Icy Moon Orbiter) mission that will orbit Europa, Ganymede, and Callisto. Using Nuclear Electric Propulsion (NEP), the JIMO spacecraft will orbit the first moon 9 years after departing from Earth. The spacecraft would then spend the next 3 years successively orbiting the three moons, for a total mission time of 12 years. Assuming a start date of 2015 AD, data from the JIMO mission would not commence until 2024, and not be completed until 2027 AD.

While the proposed JIMO mission would substantially extend our knowledge of the three Jovian moons, it has four limitations:

(1) The JIMO spacecraft cannot land on the surface of Europa and the other moons, because the thrust level supplied by its NEP propulsion engine is orders of magnitude too weak to overcome even the low gravity of the moons. Without landing and exploring the undersea oceans of Europa, it probably will be impossible to answer the fundamental question of whether or not life exists there. Moreover, it will not collect and return to Earth samples from the moons, including life forms if they are present.
(2) The NEP engine must operate continuously for many years at full power, posing problems of reliability and long-term operability. Establishing this capability will require long-term testing on Earth and in space prior to the mission.
(3) The cost of the development program for JIMO will be very large, since it requires a reliable long-term new nuclear reactor and power conversion system, together with long-term electric thrusters.
(4) The combination of the long development time and the long flight time (12 years) for the JIMO mission raise questions as to whether funding support for the mission can be sustained over the next 20 years.

We describe here a different possibility for a mission to Europa, which would be based on Nuclear Thermal Propulsion (NTP) instead of NEP. This mission, termed NEMO (Nuclear Europa Mobile Ocean) would land on Europa's surface and deploy a probe that would melt a channel down through Europa's ice sheet. Upon reaching the sub-surface ocean, the probe would release a small Autonomous Underwater Vehicle (AUV) that would explore the ocean, collecting samples and telemetering data to the spacecraft on the surface above. After completing its search the AUV would return to the probe and melt its way back to the spacecraft with the collected samples.

After the probe/AUV unit was re-attached to the spacecraft, it would hop to a new site on Europa's surface, to repeat the probe descent and AUV exploration process at the new location. Following the completion of exploration at the various planned sites, the NEMO spacecraft would lift off for the return to Earth with all of its collected samples.

Such a mission can only be carried out using NTP. The high thrust capability of NTP is mandatory for landing and taking off from planetary bodies or moons because the thrust of NEP engines is far too small. An Europa mission based on NEP could land a small probe on the surface using a chemical rocket, but the available payload would be much too small to melt through the ice sheet and explore the sub-surface ocean.

Studies of probes, such as the Cryobot [2], that use a radioactive isotope as a power source, indicate that the probe probably could melt a pathway down through the ice sheet. However, because of its low power capability, such a probe would not be able to carry out an extensive exploration of the sub-surface ocean. Moreover, its descent rate would be very slow, i.e., a few meters per day, requiring a large time to descent through a multi-kilometer thick ice sheet. Also,