GLACE Mission Concept: Ganymede's Life and Curious Exploration Mission

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1. Introduction

The exploration of the Jovian system contributes to our understanding on Giant Planet systems in the outer solar system. In addition, it helps us understand the emergence of habitable zones and environmental conditions necessary for life. If the existence of subsurface oceans are a common feature in the planetary architecture of our outer solar system, then the satellites of gas giants could possibly be high potential zones to support the emergence of life. The dedication of a space mission to the Jovian system with special focus on the Galilean satellite Ganymede will deepen understanding on the working of our own and other Solar Systems and the environmental conditions necessary for the emergence of life itself. The JUICE (JUpiter ICy moon Explorer) mission will be launched in the year 2022 and its nominal ending is set in the year 2033.

In the context of a planetary science course, a team of VU Amsterdam students created a potential Planetary mission. A concept-mission referred to as GLACE is the end-result. GLACE; Ganymede's Life and Curious Exploration Mission is a follow-up mission on the JUICE mission. The key science goals of the complementary GLACE mission are directly coupled to the research questions proposed by the JUICE mission and its aim is to advance and complement the data retrieval, in order to deepen our understanding of potential habitats and answer the research questions.

The GLACE mission is the third jovian mission and the second spacecraft in history entering the orbit around an ice satellite in the outer solar system. The GLACE mission has as objective to expand knowledge in scientific fields and to find biomarkers conclusive for life. A lander will be send to Ganymede to investigate the chemical composition of the ice shell, the presence of organic compounds in the ice, the atmosphere and the presence of shallow subsurface water. Data collected by the JUICE mission will be used to characterize the structure of the icy shell of Ganymede and determine the minimal thickness of this shell. The correlation between the dynamics in the ice shell and the structure and topography of the subsurface will also be studied. The lander will provide precise data next to the global satellite data. The landing site will be located on the bright plains because the material of these plains comes from deeper in the icy shell and can therefore give us information on the subsurface conditions of Ganymede.

2. GLACE mission profile

As a follow up mission of the JUICE, the GLACE mission will focus on a landing on Jupiter's largest moon Ganymede. A satellite will go into orbit around Ganymede and will collect the data from the lander. The GLACE mission profile can be divided into three major parts: a) the interplanetary transfer to Jupiter, b) the transfer to Ganymede's orbit, and c) propulsion-assisted landing on Ganymede's surface. The GLACE mission has an overall time-span of 12 years. Following a launch with Ariane 6, GLACE will use an earth-venus-earth-earth gravity assist strategy to transfer to Jupiter. The nominal launch date is June 2033, with an insertion into Jupiter's orbit at 2041. Two back-up launches are selected for the years 2034 and 2035. The robust mission profile will provide an outstanding science return that aims to fulfill our science objectives and scientific measurement requirements selected for GLACE 2033-2045.

06/2033	Launch by: new-generation launcher Ariane 6
06/2041	Jupiter orbit insertion
06/2043	Transfer to Ganymede (11 months)
05/2044	Ganymede orbit insertion high-altitude circular phases Low altitude (500 km) circular orbit
10/2044	Ganymede's landing
06/2045	End of nominal mission

JUICE mission is estimated to cost 870 million euros. In addition for the, Glace mission estimated that the lander will cost 200 million euros considering the instrument package that the lander will carry along with the addition of fuel.

3. Spacecraft design

The combined launch mass for the orbiter and lander will be around 5000 kg. Four solid rocket boosters are needed for the first stage. For the launch the new generation Ariane 6 launch system will be used. The exploitation costs of this launcher are half the costs of Ariane 5. The configuration of the spacecraft has several stages: the first stage uses two or four boosters on solid propulsion. The second and the third stage are fueled by cryogenic liquid oxygen and hydrogen propulsion. The spacecraft will be optimized for the cold environment in the Jovian system and will be covered in multi layer insulation. Manoeuvres such as orbit insertions and altitude reductions will be done using propellants. Because of the high velocity requirements which are needed for the gravity assist and flybys of the spacecraft there is a high wet/dry mass ratio with an appropriate fuel tank size.

All the electronic devices will be powered by solar cells. This is difficult because of the large distance from the sun. Therefore exposure of the solar cells must be optimal. The technique used in the JUICE mission which includes around 100 m2 of solar cells and a rotation of the spacecraft around the nadir axis for maximum exposure will be used on the GLACE spacecraft.

A technological challenge would be the landing itself as Ganymede has little to no atmosphere. So any use of parachutes or other drag related utility instruments would be of no use. Since the gravitational pull of Ganymede is quite low compared to it's size (1,428 m/s^2), the accuracy of a hard landing (with inflatable airbags) is poor. A soft landing with variable thrusters would be our top choice. A computer guided landing system, as was used in the Chang'e 3 landing, would have our priority.

Communication will be established between the lander and the satellite which will signal to earth in a round trip time of 1 hour and 46 minutes. The technique used will be the same as the JUICE mission using a high gain antenna for the data downlink system. The data downlink system will need a larger capacity due to the great amount of data that will be collected by the lander.

4. Glace mission instruments

The estimated total dry mass of the lander is 500 kg with +/- 80 kg of scientific instruments. The meteorological station is installed to measure the daily weather. Additionally, a lidar is installed, which will detect the distribution and amount of ice and dust particles in the atmosphere. The imaging system will be used to register smaller geomorphological features such as ice cracks and ripples, and together with the physical property package it will give us a complete database of the surface conditions on Ganymede.

The magnetometer will give more insights into the magnetic field of Ganymede. The seismometer will be used to expand our knowledge of the ice layer in high resolution and will give us insight in the thickness and layering of the ice and presence and interaction of shallow water reservoirs.

The Phoenix mission to mars was successful because of a wet chemistry lab. Therefore GLACE will carry a similar instrument. The drilled ice or sediment will be dissolved in water in order to determine pH, eH and the abundance of ions such as $Mg2+$, $Na+$, $Br-$ and $Cl-$. The wet chemistry lab measures reduced iron as a possible electron donor for microbial metabolism. The presence of soluble ions in the subsurface and their distribution with depth is a key measurement for understanding the origin and possible melting of the ice. The drilling device is installed in the center of the lander and is composed of a sampling auger, the rotary percussive drill head and the drill bit at positive cutting angle (ideal for ice or icy soils). The drill will reach a max depth of 50cm and will sample every 5cm in order to derive a profile of the uppermost ice layer. The heart of the lander is the high-temperature furnace and mass spectrometer. This will give information about the origin of the volatile molecules and possible biological processes that may occur in the subsurface ocean.

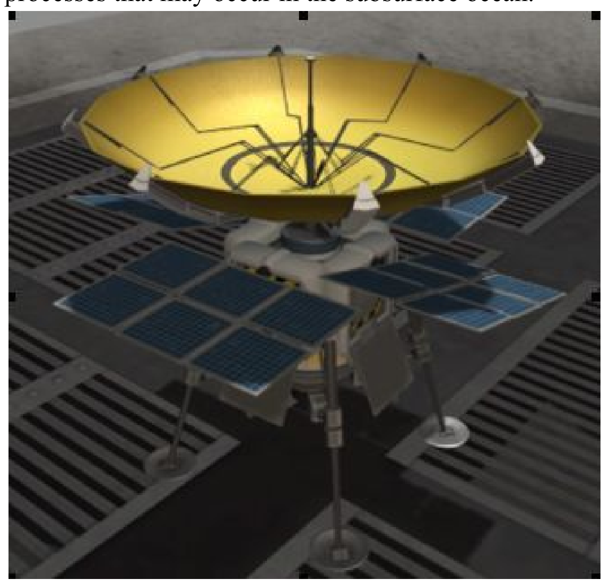

Figure 1: Visualisation of the GLACE lander. (Design by Siem Peters).

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