University of Kent

Cryobot Mission to Europa's Ocean

AIRBUS DEFENCE & SPACE

Orbiter

Overview

The orbiter mission is split into 3 stages:

1. **Mapping: 1 year**
   The orbiter will insert into a high inclination orbit around Europa and map the surface using optical, laser, and radar systems to determine a suitable landing site.

2. **Lander Deployment: 1 week**
   After finding a suitable landing site the orbiter will move into a more equatorial orbit. The lander will separate from the orbiter and descend to the surface.

3. **Communications relay: Remainder of mission**
   The orbiter will then act as a communications relay sending and receiving signals from the lander and Earth.

Communications

The orbiter communicates with Earth using a 3m High Gain Antenna (HGA) sending and receiving signals through NASA's Deep Space Network. This can provide data rates of around 6 Mbit/s depending on the distance between Earth and Jupiter

Shielding

Heavy shielding will be used to protect the equipment and electronics from the intense alpha, beta and gamma radiation emitted by Jupiter's magnetosphere.

Power

An 8 General Purpose Heat Source Segmented Modular Radioisotope Thermal Generator, which can only be used in vacuum, will be used to power the orbiter - providing 282W at launch and decaying at a rate of 1.9% year on year to 175W after 25 years. Solar panels cannot be used due to the amount of radiation exposure.

Lander

Overview

The lander will act as a surface base of operations for the europa subsurface mission. Its main purpose is to deploy and support the cryobot, to act as a communications relay point between the cryobot and orbiter and to conduct scientific research into the surface conditions on Europa

Scientific Equipment

The lander will conduct two main scientific experiments on Europa's surface:

1. Measure the surface radiation using a Radiation Assessment Detector (RAD)
2. Investigate the composition of the surface ice using a Miniature Thermal Emission Spectrometer (Mini-TES)

Communications

The lander will communicate with the orbiter used an ELECTRA UHF radio and is capable of transmitting up to 10Mbit/s.

Power

Four 16 General Purpose Heat Source Hybrid Segmented Modular Radioisotope Thermal Generators, which can be used in both vacuum and atmosphere, will be used on the lander providing from 2360-1461W from beginning to end of mission. The main purpose for this amount of power is to provide the heat point with electrical power via a thin insulated copper cable from the bottom of the lander to the top of the cryobot.

Aquabot

Design

Once the Cryobot has drilled through Europa's ice shell the heat point will be dropped away and the Aquabot will deploy.

The aquabot uses strong spherical chambers to overcome the extreme pressures expected at Europa and will be equipped with AI capable to navigating the ocean independently of Earth using the sonar pods located on the top and bottom of the hull to navigate. It can also use a thermal imaging camera to aid with navigation and data collection.

The aquabot will utilise a single motor propeller for propulsion, which can be moved with the fins and rudder to provide thrust vectoring, and the pumps for the ballast tanks will be able to control the direction of their input and output, allowing for them to be used to aid in maneuvering the aquabot when not being used to fill or drain the ballast tanks.

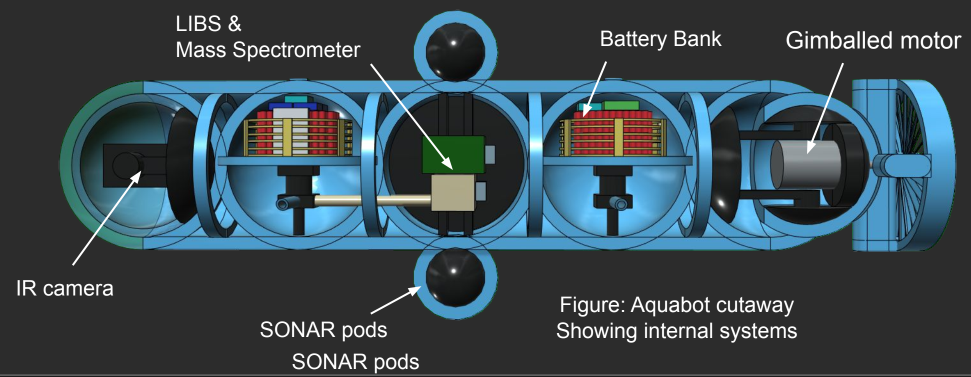


Figure: Aquabot cutaway
Showing internal systems

Communications

Due to the limitations of radio communication in water, the aquabot will communicate using SONAR. Due to the limited data rates produced by sonic communication, only telemetry and aquabot commands will be sent in this way. All scientific data will be uploaded to the cryobot through wired fibre optic connection during recharging

Power

456 AA sized rechargeable Fluorinated Graphene batteries, which have a much higher energy density than Lithium Ion batteries, will be used to power the aquabot. They have a total capacity of 10.4kWh which will allow for up to 32 hours of continuous exploration before needing to head back to the cryobot to recharge. Charging will take up to 24 hours from 0-100% charge using the electrical power from the RTG in the cryobot.

Scientific Equipment

The aquabot will use two pieces of equipment to perform its experiments.

1. The first is a Laser Induced Breakdown Spectrometer (LIBS), which will detect the composition of any solid mass it may find in the sub ice ocean.
2. The second piece of equipment the aquabot will have is a Ion and Neutral Mass Spectrometer (INMS). This will take small samples of the water and analyse its composition, mainly looking for essential elements of carbon based life (Carbon, Oxygen, Nitrogen, Phosphorus and Sulphur).

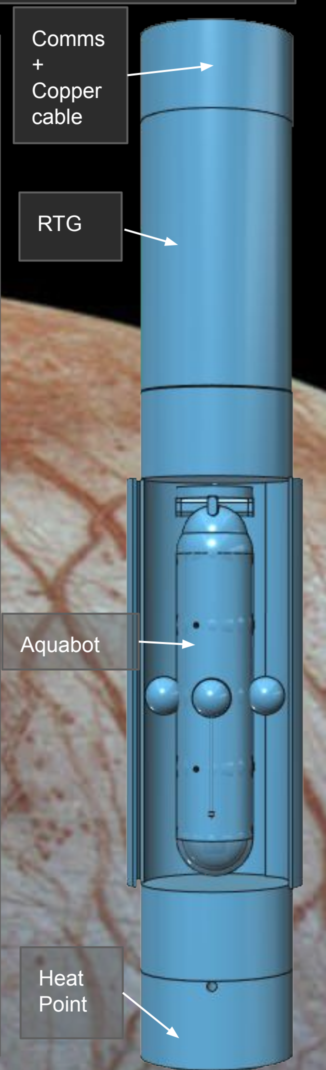


Figure: Cryobot model with Aquabot

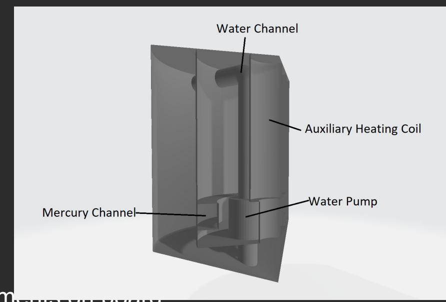
Background Image Credit: NASA
https://solarsystem.nasa.gov/moons/jupiter-moons/europa/in-depth/

Cryobot

Heat Point

The cryobot will descend through the ice using a heated metal point. An auxiliary heating coil will be placed in the centre of the heat point. It will include a passive attitude control system of a circular channel part filled with mercury. If the cryobot is at an angle, the mercury will collect in the lower side, weighing it down and returning the cryobot to an upright position.Turbulent flow of melt water helps to improve heat transfer. Three water pumps will recycle water towards the front, promoting the desired turbulent motion.The initial stage of the penetration will be slower, as the ice will sublimate in the lack of atmosphere which requires much more energy than melting. Once the full length of the cryobot is below the surface, the ice will slowly refreeze above it, forming a seal. Pressure will build up around the cryobot until the ice is free to melt. It will take roughly 12 years to bore through 15km of ice or 16 years for 20km. At the end, it will disconnect to release the aquabot into the water.

Figure: Heat point cross-section



Scientific Equipment

The Cryobot will have two main experiments on board:

1. Alpha Particle X-ray Spectrometer (APXS) which finds the composition of the ice as the cryobot descends.
2. Tunable Laser Spectrometer (TLS). This will be used to find the composition of the air in the tunnel, specifically methane or carbon dioxide, which are some of the most common byproducts of carbon based life processes such as respiration and excretion

Communications

Communication through Europa's ice is achieved using radio relays. When the signal strength to the cryobot is too low, a small Radio Transceiver Unit (RTU) is dropped into the ice. These RTU's relay data between the cryobot and the lander. Each relay consists of patch antennas on the outside, a small Radioisotope heater unit and memory storage. Predictions of the number of relays required was done using MATLAB. This predicted a maximum of 44 relays were required to provide a data rate of 10 Mbit/s. Due to the high dependency of attenuation on temperature two different ice models were considered; A brittle Lithosphere and a Convecting Sublayer.

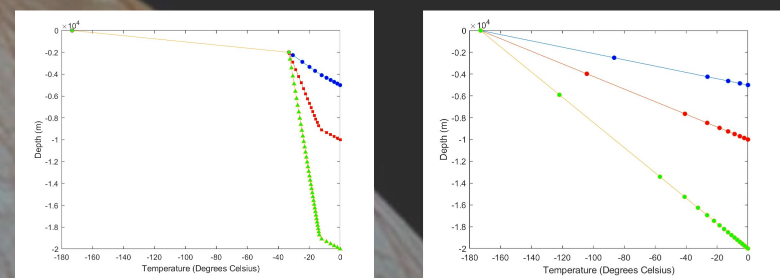


Figure: Relay placement for a Brittle lithosphere (left) and a convecting sublayer (right) of varying thickness

Power

A 16 General Purpose Heat Source Hybrid Segmented Modular Radioisotope Thermal Generator, which can be used in both vacuum and atmosphere, will be used for the cryobot providing 590-418W of electrical energy from beginning to end of mission, as well as 4069-2519W of thermal energy. The main purpose of this RTG is to provide the heat point with as much thermal energy as possible. 6 Aluminium-Ammonia loop heat pipes are required to transfer thermal energy from the fins of the RTG in the top of the cryobot to the heat point at the bottom.