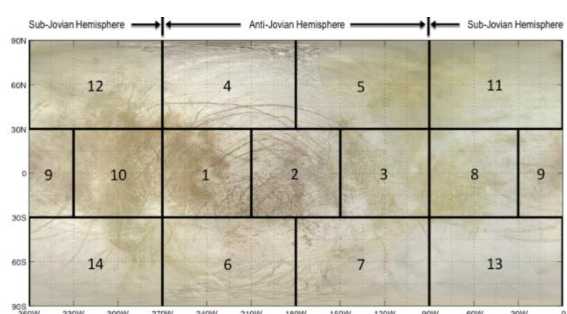
OCEANUS (Organisms and Compounds of Europa – an Analysis Under the Surface) – Concept Mission Design. M.V. Heemskerk[1], G. de Zeeuw[1], W. van Westrenen[1], B. H. Foing[1,2].
[1]VU University Amsterdam, de Boelelaan 1105, 1081 HZ Amsterdam, The Netherlands, (m.v.heemskerk@student.vu.nl, g.de.zeeuw@student.vu.nl, w.van.westrenen@vu.nl) [2]ESA ESTEC, Keplerlaan 1, 2201 AZ Noordwijk, The Netherlands (bernard.foing@esa.int)

Introduction:
In 2022, ESA (European Space Agency) will launch an orbiter – JUICE (JUpiter ICy moon Explorer) – which will collect atmospheric data of Jupiter and three of its Galilean moons; Ganymede, Europa and Callisto [1]. As this is but an orbiter, further exploration of the (sub)surface remains out of reach. As of today, the most suitable prospect for the occurrence of extra-terrestrial life forms appears to be Europa. Europa contains liquid water [2], simple organic compounds [3], a subsurface power source [4] and a lot of ice. Convection and tidal flexure could also give way to a possible zone for the emergence of life, for the bottom of this subsurface ocean may house hydrothermal vents [5].
In November-December of 2017, the Vrije Universiteit Amsterdam brought an introduction to the Planetary Sciences, in cooperation with ESA – the concept mission 'OCEANUS' (Organisms and Compounds of Europa – an ANalysis Under the Surface) was designed in this context. The goal of this mission is to further explore one of JUICEs prospects, Europa, to learn how its ice was formed and to be able to elaborate more on the possibility of living organisms in the subsurface. Additionally, Europa is not only a moon of the oldest planet of our solar system, Jupiter [6], its orbit suggests it is one of few to be thought to be formed at approximately the same place as it is today. The further exploration of Europa will hereby lead to a deeper understanding of the formation of solar systems and the necessary conditions for the emergence of life [7].

OCEANUS Mission concept:
The mission will be composed of a lander, the Europa Surface Station (ESS), and a drill, the Europa Crust Melting Device (ECMD). The ECMD is stored inside the ESS during the flight and landing. After the landing, the ESS will power the ECMD via a glass fiber cable as it drills its way down through Europa.
A. Science Objectives: The overarching goal of the OCEANUS Mission is to further investigate the habitability of Europa. A NASA-appointed Europa Science Definition Team (SDT) has derived a set of objectives for Europa exploration, which will also be the main objectives of OCEANUS [8];

1. Buildup of the ice crust and its ocean; Understanding how recent and/or current tidal and geological processes are formed.
2. Chemical composition; Characterizing the properties of the ocean and its crust to descry the origin of organic compounds.
3. Geomorphology; Understanding the formation of surface features

B. Model Instrument Payload: The lander payload consists of two high-definition reconnaissance cameras, a magnetometer, an altimeter, a short-wave infrared spectrometer, a gamma and X-ray detector, a radiation shielding, the ESS, and the ECMD.
The ESS will be deployed as soon as the lander touches down, with the drill head of the ECMD facing the ground surface. The ESS model payload will be comprised of a nuclear power source, Pu^{238}, a radioisotope thermoelectric generator, a high-energy fiber laser generator (20 kW), an ice-penetrating radar, telecommunication systems, a 4-meter-long antenna, and a data storage unit.
The ECMD will be the device that will produce most of the data during the mission. It is linked via a 32 km long optic fiber cable to the ESS and contains a melting head that consists of hot-water jets, heat exchangers and beam-dispersion optics, a short distance radar, a water sampler, a mass-spectrometer, a sample cleanser, a battery, a small data storage unit, and a 25-cm ø spool of optic fiber cable.
C. Key Design Strategy: The landers' first priority is to bring the ESS with the ECMD safely to the ground. To do this, an altimeter, in combination with two optic cameras will be used to be able to brake autonomously when descending. The spectrometer is pro-



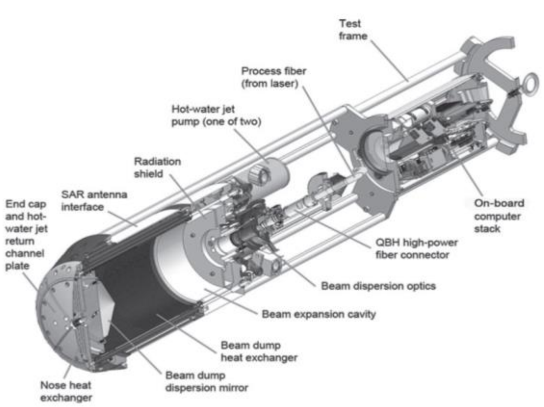
1: Cylindrical projection of Europa, centered on Europas anti-Jovian point, after B. Buffington.

vided to analyze the different layers of the thin atmosphere, while the radiation detector measures the evanescent magnetosphere of Jupiter on the far side of its moon. The specifics of the launch site will be provided by data from NASA's Europa Clipper orbiter mission, due to launch in 2022-2025, but is thus far planned in Sector 6, around 45º S, 210º W (fig 1[9]). The lander will use LOX-LH2 fueled retro-rockets to provide a slow, controlled descent, so any contamination of the moons' surface and atmosphere is avoided.

The ESS contains the main power source for the entire mission, Pu^{238} (PuO_2), linked to a radioisotope thermoelectric generator. The main power outlet will be the 20kW laser, also mounted on the ESS. To ensure that the energy production remains above this 20kW for at least 10 years (taking into account a 6.5-year journey, a 3-year Plutonium production time and a 6-months active mission lifetime) with an efficiency of 90%, the minimum required mass of Pu^{238} would be 39 kg [10]. The current production rate of Pu^{238} is less than 4 kg/year and most of the currently available Pu^{238} is already claimed for other missions and technologies. In the near future, production rates will likely go up, while production costs drop to around $8 million/kg [11].

The remaining payload on board of the ESS will be focused on transmitting and storing the data from the ECMD. This will be done via a moveable 4m-long antenna, in X-Band Satellite communication, to be received by the Deep Space Network of NASA. All data is stored in the ECMD, to exclude information loss when no contact is possible.

The ECMD will be largely based on the VALKYRIE concept, an optically powered cryobot by Stone Aerospace (fig 2 [12]). There will be some modifications, mainly because OCEANUS has no interest in a sample-return to the surface. The data collected will be stored inside the ECMD and sent back through the optic fiber in short pulses in which power transmission to the subsurface will be momentarily halted.



2 The latest VALKYRIE design, a concept of Stone Aerospace to explore deep ice caps.

Interplanetary trajectory:

A. Launch: OCEANUS is planned to launch from the Kennedy Space Center in Florida, USA. The SLS, currently in development by NASA, will be used, as this is the only launching vehicle currently in construction capable of bringing the needed amount of mass into the outer solar system.

The launch will be after the data from JUICE and Europa Clipper are fully analyzed, and a safe landing spot has been detected. As JUICE is scheduled to arrive in 2030, with an operation time of 3 years, OCEANUS is set to launch at the beginning of 2035.

B. Trajectory: A VEEGA Interplanetary Trajectory will be used, as described in the Europa Clipper Concept Mission Design [9]. Using multiple gravity assists (Venus, and Earth twice), more fuel can be spared to be used to brake when pushing into Jupiter and Europa orbits.

Budget:

As this is still but a conceptual design for a far-future mission, the costs are only to be very roughly estimated. Some costs can already be expected, such as launch costs (SLS, $500 million) and Plutonium ($312 million). As comparison, Europa Clipper and JUICE are targeted to cost $1.6 and $2.25 billion, making the rough estimate around $3 billion.

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