**EUROPA LIFE EXPLORER: A minimum-cost lander mission to Europa.** R.J. Dancy[1,2] and B.H. Foing[1,3], [1]École Polytechnique Fédérale de Lausanne, 1015 EPFL, Switzerland, [2]University of Waterloo, 200 University Ave. W, Waterloo, ON N2L 3G1, Canada (rdancy@uwaterloo.ca), [3]LUNEX EuroMoonMars, EuroSpaceHub Academy, Leiden and EPFL (foing strw.leidenuniv.nl).

**Introduction:** Growing interest in the potential habitability of Europa motivates a lander mission to directly investigate the putative Europan subsurface ocean. The *Europa Life Explorer* (ELX) mission concept aims to place a lander on Europa to drill into the Europan ice to search for signs of life as inexpensively as possible. The ELX mission was designed in the Spacecraft Design and System Engineering course at the École Polytechnique Fédérale de Lausanne in Switzerland. This abstract summarizes the ELX mission concept.

**Background:** The quest for evidence of extraterrestrial life occupies an important place in scientific interest and the popular imagination: discovery of life that evolved outside Earth would revolutionize our understanding of our place in the Universe and finally answer the question, "Are we alone?" Europa is considered one of the most likely locations in the Solar System to harbour extraterrestrial life due to the likely presence of a subsurface ocean [12]. Furthermore, it is speculated that so-called "chaos regions" on the Europan surface—large, straight gashes in the ice—might allow access to material originating from the subsurface ocean, or even the ocean itself [12]. The ocean, however, has not yet been directly observed [4]; data on the nature and composition of the ocean and "chaos regions" will prove invaluable both for understanding the geology of the moon and for the design of future Europa missions, such as divers aiming to swim through the ocean. This motivates our proposed ELX mission, a lander mission to a "chaos region" to directly investigate the properties of the Europan ice and ocean and search for biosignatures. ELX will land in a "chaos region" and use an ExoMars-style drill system [7] to retrieve and analyze ice samples from a depth of 2 m. To improve chances of obtaining funding, we additionally propose to keep the mission's cost as small as possible: our target budget is $650 million (small L-class). NASA's Europa Lander mission [4] has similar scientific goals, but ELX is distinguished by reduced scope, reduced cost, and focus on specifically investigating "chaos regions" and the subsurface ocean. ELX consists of a lander and an orbiter. Observations of Europa that can be done from orbit are well-covered by upcoming missions such NASA's Europa Clipper [8]; hence, for cost savings, we propose to place instruments exclusively on the lander and to use the orbiter only as a communications relay. Due to the harsh Europan radiation environment [13], our operational lifetime is small: we plan a lander lifetime of 17 days, with the orbiter surviving slightly longer to transmit data.

**Trajectory and Orbit:** We propose to launch ELX to Europa following a trajectory similar to that proposed by Sweetser [11]: 1) launch at C3 = 20 $km^2/s^2$ on an Earth escape trajectory, using a recoverable SpaceX Falcon Heavy to minimize costs; 2) three successive Venus gravity assists; 3) on arrival at Jupiter, a Jupiter Orbital Insertion (JOI) manoeuvre with a Ganymede gravity assist into a 200-day Jupiter elliptical orbit; 4) a Perijove Raise manoeuvre (PJR) at apojove to raise the perijove to Europa's orbit; 5) a tour found by Chen-Wan Yen [14] to insert into the Europa frame with low $\Delta V$; 6) a Europa Orbit Insertion manoeuvre to change into our final orbit. This trajectory is estimated to take $\Delta V$ = 3 km/s and 7.5 years. Landing the lander will take an additional $\Delta V$ = 2.5 km/s, and propelling the orbiter to Europa escape for disposal will take $\Delta V$ = 220 m/s. We propose an elliptical orbit with eccentricity 0.55 with the landing site close to directly under apoapsis to maximize coverage.

**Instruments:** We propose that the ELX lander carry the following scientific instruments.

| Type | Heritage | Purpose |
|---|---|---|
| Drill | ExoMars RSP drill [7] | Retrieve samples |
| Drill optical spectrometer | ExoMars Ma_MISS [2] | Analyze sample near-infrared spectrometry |
| Mass spectrometer | ExoMars MOMA [3] | Detect organics in samples |
| Microscope | Phoenix MECA [9] | Detect cell-like structures in samples |
| Stereo camera | Phoenix SSI [6] | Take high-res stereo images of landing site |
| Ground-penetrating radar | Mars 2020 RIMFAX [10] | Look below surface and find water |

**Spacecraft:** The spacecraft is estimated to have a launch mass of about 3800 kg (constrained by the 3815 kg lift capacity of the launch vehicle), with the dry mass being about 480 kg for the lander and 180 kg for the orbiter. The lander component will house the main thruster to be used when cruising in deep space, with the target thruster model being the Aerojet Rocketdyne R-4D-15 300:1 liquid bipropellant thruster providing a specific impulse of 326 s [1], which allows the above mass to be delivered to Europa. This thruster will also be used for landing; a small dedicated cold gas thruster will be used on the orbiter to escape Europa orbit at end-of-mission. The lander, and the whole spacecraft while cruising, will be powered by a radioisotope thermoelectric generator (RTG) with 6.7 kg (at launch) of strontium-90, which is cheaper than plutonium-238, to provide at least 262 We continuously. This is greater than the maximal consumption of the lander or the spacecraft in cruise, estimated at 213 W in cruise mode, 197 W when the lander operates alone (262 W in the Europan night). The orbiter takes 210 when operating alone and transmitting and 273 W when operating alone and the Earth is in eclipse. The orbiter must operate independently for only the planned 17 days of surface operations plus an estimated 5 days to transmit data, so it will be powered by a cheaper hydrogen-oxygen fuel cell with 55 kg of fuel. An estimated dry-mass budget for the spacecraft is as follows.

| Subsystem | Mass – Lander | Mass – Orbiter |
|---|---|---|
| Thermal | 10 kg | 6 kg |
| ADCS | 2.3 kg | 5 kg |
| Telecom | 8.4 kg | 17 kg |
| C&DH | 10 kg | 10 kg |
| Structures | 81 kg | 56 kg |
| Propulsion (dry) | 210 kg | 0.04 kg |
| Instruments (total) | 42 kg | - |
| EPS | 68 kg | 74 kg |
| *Total* | *433 kg* | *167 kg* |
| *Total, 10% margin* | *476 kg* | *183 kg* |

Most subsystems are duplicated between the lander and the orbiter since they must operate independently. For communications, the orbiter acts as a store-and-forward relay between the lander and Earth; it will be equipped with a 4.9 $m^2$ parabolic antenna allowing X-band communications with Earth at 25 kbps using 55 W of power, which is sufficient to finish transmitting our estimated data return of at most 3.6 GB by staying in orbit for only 5 extra days. The lander will communicate with the orbiter via a 314 $cm^2$ Ka-band parabolic antenna allowing a 36 kbps data rate with 7.0 W of input power. The orbiter will use an onboard 3.1 GB flash buffer to store the data which has not yet been forwarded to ground. The mission has low pointing requirements since no science instruments are active in orbit, so attitude control is done using thrusters only with no reaction wheels. We estimate 94 m/s of pointing $\Delta V$ will be needed for disturbance rejection and slewing. For radiation-protection reasons, sensitive electronics on the lander and orbiter will be encased in a 1 cm thick titanium vault, similar to the Juno mission's radiation vault [5]; this should reduce an estimated total radiation dose of 21.2 Mrad to about 25 krad [5], which the electronics will be capable of tolerating. Triple-modular redundancy will be used in the flight computers to reduce risk due to single upset events.

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