SWIM – Sensing with Independent Micro-swimmers

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Introduction: The next decades of space exploration will focus on Ocean Worlds – especially Europa, Enceladus, and Titan – whose liquid oceans beneath kilometers of icy crust are some of the most likely locations beyond Earth to harbor life. To access these aquatic environments, NASA is developing and maturing numerous ocean-access mission concepts, including the Scientific Exploration Subsurface Access Mechanism for Europa (SESAME) class of thermo-mechanical drilling robots. We propose developing SWIM – Sensing with Independent Micro-swimmers – to dramatically expand the capabilities of SESAME-class ocean-access robotic missions and significantly increase their likelihood of detecting evidence of habitability / biomarkers / life once they reach the ocean-ice interface.

Science Goals: The three primary science objectives of SWIM robots are to: 1) search for and characterize life, (2) characterize chemical environments / processes, and (3) characterize physical environments / processes at Europa's ice-ocean interface.

Concept: The SWIM concept consists of approx. fifty swimming micro-robots (micro-swimmers) each 60-75 cm^3 in volume and 12 cm in length, which are equipped with MEMS sensors, propelled by miniature actuators, and wirelessly controlled via ultrasound communication with a SESAME robot mothercraft. The micro-swimmers are deployed individually or as a swarm from a single SESAME mothercraft, which has limited mobility once reaching / anchoring at the ocean-ice interface. The SWIM design presented here is the product of an extensive trade study (including subsystem performance modeling / simulations) that explored multiple potential platforms with unique designs for structure, propulsion, power, sensing, and communication subsystems.

Individual robots are designed to operate continuously for ~2 hours in ocean currents predicted to be up to 1 m/s, have >100 meter range from the mothercraft, and use staggered deployments to collect data at multiple times over at least one Europan diurnal cycle (85 hours). Each robot transports a sensor payload consisting of at least MEMS temperature, pressure, salinity / conductivity, and IMU sensors, and we are investigating the viability of pH, redox, and resonator-type gravimetric sensors (for specific biomarker identification). Data is transmitted back to the mothercraft via ultrasound (>1 km range at 9.6 kbit/sec).

Impact: SWIM enables active sampling of ocean water beyond the reach of the SESAME robot (increasing the chances of detecting biomarkers), as well as temporally- and spatially-distributed measurement of desired ocean properties, habitability metrics, and potential biomarkers (infeasible with a single robot). Current ocean-access missions employing SESAME-class robots (or similar platforms) are highly volume-constrained and current state-of-the-art oceanographic robots are unable to fit within available payload volumes. SWIM overcomes these constraints, while introducing new multi-robot capabilities that may enable scientists to better characterize / understand the alien ocean's composition and habitability on NASA's first ocean-access mission.

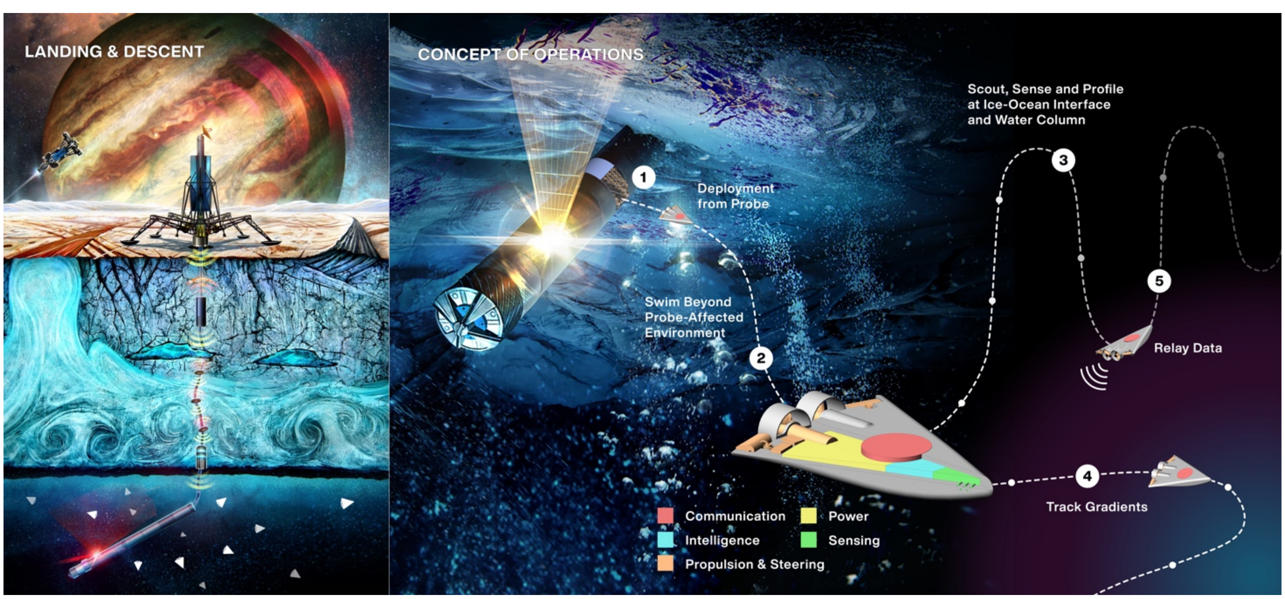

Fig 1. Mission Concept for SWIM, integrated into a larger ocean-access mission on Europa.