SPLIce: Sample Processor for Life on Icy Worlds, a Microfluidic Front-end for Bio/Organic Analytical Instrumentation

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Relevant Abstracts (Mission Concepts): **Enceladus Orbilander**, **Enceladus multiple flyby (EMF)**, **Mars Life Explorer**, Centaur orbiter and lander (CORAL)

Technology Description: We will present the design, development, and laboratory test results for SPLIce [1], a microfluidic sample processing "front end" to enable autonomous detection of bio/organic signatures of life, measurements of habitability parameters, and chemical analysis of aqueous samples from Ocean Worlds and small icy bodies. SPLIce increases certainty of results, along with measurement reliability and accuracy, by handling and delivering low-concentration/low-volume (~µL) liquid samples to analytical instruments/suites. Multiple versions of this monolithic fluid processing-and-handling system (mass ~ 0.2 – 1 kg) have been/continue to be developed to support multiple mission scenarios, including fly-through of Enceladus' icy plumes, the Enceladus Orbilander, and the Mars Life Explorer.

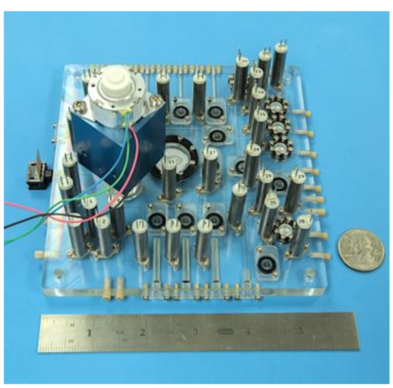

Figure 1. SPLIce 1.0 prototype with integrated liquid-handling components. Dimensions: 16 x 15 cm.

Instrument Suites: Each SPLIce system prepares samples and provides blanks, reagents, and calibrants to all instruments in an analytical (life-indicator) measurement suite. System performance characteristics are tailored to mission scenario; the anticipated number, type and quantity of samples; and the specific requirements of each instrument in the analytical suite. Instruments for which SPLIce functionalities have been designed/tailored include arrays of specific ion sensors and electrochemical redox/electron-transfer analyses [2,3]; multiwavelength fluorescence microscopy of biological and inorganic particles [4]; capillary electrophoresis coupled to laser-induced fluorescence or mass spectroscopy for detection [5]; nanopore analysis of polyelectrolytes and nano-scale particles [ref]; and gas chromatography coupled to mass spectroscopy [6].

Functionality: The microfluidic analog of the ubiquitous multilayer printed-circuit board, each SPLIce monolithic manifold comprises multiple fused polymer layers with networks of internal microchannels patterned at each layer-to-layer interface; interconnections between microchannel layers and to surface-attached components use through-layer vias. This technology was developed, pioneered, and space qualified for the BioSentinel 6U nanosatellite, scheduled to launch with Artemis-1 in late 2022 [7,8]. To serve various analytical suites, SPLIce integrates a range of fluidic functions under autonomous control, including: 1) retrieval of liquid samples from a sample-collection system; 2) internal multi-year storage and subsequent reconstitution of dehydrated reagents, including fluorescent labeling compounds; 3) integrated pressure, pH, redox potential, and conductivity sensing; 4) filtration, retention, and fluorescent staining of insoluble sample fractions/particles for characterization by microscopy; 5) vacuum-driven concentration of nonvolatile samples by removal of water vapor; 6) removal of gas bubbles from liquids; 7) directional flow control; 8) active, multiple-flow-path routing; 9) metered micro-volume mixing and delivery of samples, reagents, and blanks.

Maturation of astrobiology sample-handling technologies to increase certainty and accuracy of results on planetary missions is critical to enable the assessment of the possibility of life on worlds beyond our own.

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