Microfluidic Approaches to Searching for Extant Life. R.C. Quinn[1], A.J. Ricco[1], T.D. Boone[1], N. Bramall[2], K. Bywaters[1], T.N. Chinn[1], A. Davila[1], D.M. Gentry[1], J. Forgione[1], M.F. Horne[1], J.E. Koehne[1], A.K.-S. Lee[1], G.C. McCutcheon[1], C.P. McKay[1], M.R. Padgen[1], M.N. Parenteau[1], M.X. Tan[1], L. Timucin[1], [1]NASA Ames Research Center, Moffett Field, CA 94035 [Richard.C.Quinn@nasa.gov], [2]Leiden Measurement Technology, Sunnyvale CA, 94089

Introduction: While no definitive definition of life exists, a living organism can be described as a "self-sustained and self-enclosed chemical entity capable of undergoing Darwinian evolution" [1]. Within this context, NASA Ames Research Center (ARC) is developing a multi-dimensional science and technology approach to the search for extant life that places biochemistry at the center, and focuses on aspects of life that are likely to be universal across the entire biochemical space.

In a biochemical context, self-sustenance requires the use of catalytic molecules to transform energy and drive the metabolic processes responsible for growth, reproduction, maintenance of cellular structures, and response to the environment. Earth life uses amino acids to build catalytic polymers (i.e. enzymes, a subset of proteins). In order to contain their metabolic machinery, organisms must be self-enclosed, and on earth this requires the use of membranes that separate the intracellular space from the exterior environment, regulating the traffic of chemical substances in and out of the cell. When faced with environmental challenges, populations must be capable of undergoing Darwinian evolution, and this requires that genetic information be encoded and stored in a manner that is reliable, stable, and transducible, but at the same time mutable. Lovelock [2] first pointed out that biochemistry at its most fundamental level occupies a relatively narrow chemical space, because life only utilizes a selected set of organic compounds to build larger, more complex molecules.

Methods: Mission constraints will inevitably limit searches for evidence of life to a few selected measurements. Our approach includes the search for simple building blocks, more complex biomolecules involved in basic biochemical functions and information storage, and structures that are required for cellular life to exist. This strategy allows us to cover a broad biochemical space and maximize the chances of a (true) positive result, even as the chances of a false positive result are minimized. This approach not only offers complementarity, but also reinforces the interpretation of the data and minimizes ambiguity.

Key to enabling this approach are ARC advances in the development of automated microfluidic handling and manipulation technologies for use in microgravity. These technologies have been successfully demonstrated through a series of small-sat NASA missions including GeneSat (3U cubesat), PharmaSat (3U), O/OREOS (3U), SporeSat (3U), and the upcoming EcAMSat (6U) and BioSentinel (6U). Currently, fluidic processing technologies derived from these systems (including fluid storage and metering, particle filtration, mixing, de-bubbling, gas expulsion, dry reagent storage and preparation, labeling, and sample concentration) are being coupled with measurement technologies to enable the search for extant life in the solar system. Microfluidic measurement technologies in development at ARC, among others, include luminescent imaging for identification of microscopic biological structures (Fig. 1) and chemical sensors for the detection of molecular biological building blocks and complex biomolecules. Our approach leverages ARC nanosatellite technology development and fabrication capabilities including stringent sterility and cleanliness assembly approaches, as well as microfluidic design, development, fabrication, integration, and test approaches.

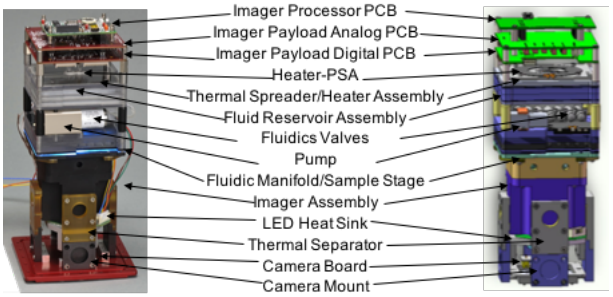

Fig. 1. Picture (left) and CAD model (right) of a TRL6 ARC microfluidic fluorescence microscope developed under the NASA Innovative Partnerships Program. The instrument is hermetically contained in a 2-liter volume (20x10x10 cm) and is an integrated payload system comprised of a fluorescence imager, LED light sources, a fluidics manifold with microorganism manipulation and sample stage, a valve-and-pump manifold, fluid reservoirs, associated peripheral components, and electronics. Leveraging this technology, the Luminescence Imager for Exploration (LIfE) instrument is currently being developed for the detection of filter-captured, cellular structures and sub-cellular fragments and the identification of key structural biomarkers contained in samples collected during Icy World missions.

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