Microfluidic Approaches to Searching for Extant Life on Mars. R.C. Quinn[1], A.J. Ricco[1], T.D. Boone[1], N. Bramall[2], K. Bywaters[1], M.M. Chin[1], T.N. Chinn[1], J.B. Forgione[1], D.J. Harrison[3], T. Hoac[1], E.T. Kelly[1], J. Koehne[1], G. Kintz[4], A.K.-S. Lee[1], G.C. McCutcheon[1], M.N. Parenteau[1], L.A. Radosevich[1], J.A. Shimada[1], M.X. Tan[1], L.R. Timucin[1], J.L. Wang[1]

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Introduction: A major lesson learned from the Viking Mission search for life on Mars is that an appropriate understanding of the exploration environment is needed to inform both instrument design and interpretation of results. Measurement targets may be affected by naturally occurring changes in environmental conditions over time, well as by rapid perturbation of samples from their natural environments during sample excavation and analysis. A lack of a priori understanding of the Viking lander environmental context resulted in both false positives (Labeled Release Experiment) and false negatives (Viking Gas Chromatograph Mass Spectrometer), which have taken decades to recognize and resolve. Using lessons learned from prior missions, 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.

Methods: Mission constraints for any given mission will inevitably limit searches for 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. In addition, critical sample geological and chemical parameters are characterized. These measurement parameters, which include sample pH, conductivity, and redox potential, not only provide science return independent of the presence or absence of indicators of life, they are also used as information drivers for results interpretation. 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. 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.
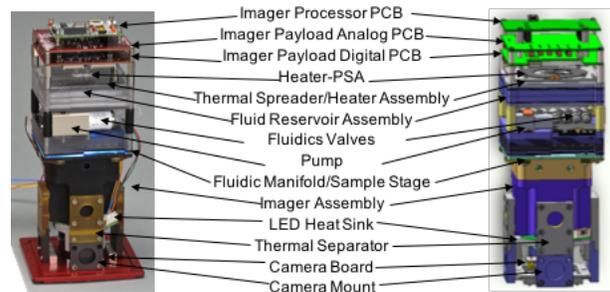

Fig. 1. Picture (left) and CAD model (right) of a TRL6 ARC microfluidic fluorescence microscope. The instrument is hermetically contained in a 2-liter volume (20x10x10 cm) and is an integrated payload system comprised of a fluorescence imager, LED light sources, a fluidics manifold and sample stage, 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.