Scientific and Technological Approaches to Searching for Extant Life in the Solar System. R. C. Quinn[1], A. J. Ricco[1], A. Davila[1] , J. E. Koehne[1], C. P. McKay[1], C. E. Dateo[1], M. L. Fonda[1], [1] NASA Ames Research Center, Moffett Field, CA 94035 [Richard.C.Quinn@nasa.gov].

Introduction: Future directions for investigations and measurements identified in the decadal survey Vision and Voyages for Planetary Science in the Decade 2013-2022 include direct methods to search for extant life. Within the framework a 35-year science vision for future decades extending into the 2020s and beyond, "Ocean Worlds" of the outer Solar System (e.g., Enceladus and Europa), as well as Mars, represent accessible targets that likely provide habitable environments that may support extant life. NASA Ames Research Center (ARC) is currently developing a multi-dimensional approach, led by astrobiology scientists in the ARC Space Sciences & Astrobiology Division, technologists in the ARC Exploration Technology Directorate, and small payload engineers in the ARC Mission Design Division, to enable the definitive detection of extant extraterrestrial life in future NASA missions.

Science Approach: 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]. 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 lipid membranes that separate the intracellular space from the exterior environment, regulating the traffic of chemical substances in and out of the cell even as they “sense” and respond to external stimuli. 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 and stable but at the same time mutable. Lovelock (1965) 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. Our approach to the development of methodical searches for extant life places biochemistry at the center, and focuses on aspects of life that are likely to be universal across the entire biochemical space.

Technology Approach: Our multi-dimensional technology approach leverages ARC nanosatellite space biology and astrobiology technology development and fabrication capabilities including stringent sterility and cleanliness assembly approaches, as well as microfluidic design, development, fabrication, integration, sterilization, and test approaches. Technical constraints will inevitably limit robotic missions that search for evidence of life to a few selected experiments. 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 at ARC, these fluidic processing technologies are being coupled, as front end systems, with measurement technologies to enable the search for extant life in the solar system. The measurement technologies in development at ARC, among others, include luminescent imaging for identification of microscopic biological structures, and chemical sensors for the detection of molecular biological building blocks and complex biomolecules. The combination of microfluidic systems with chemical and biochemical sensors and sensor arrays offer some of the most promising approaches for extant life detection using small-payload platforms. These systems can provide high sensitivity with limited power, mass, and volume requirements making them a logical choice for small payload implementation and an attractive alternative to traditional analytical instrument approaches. These microfluidic approaches also allow for in situ chemical synthesis of active sensor interfaces at time of use. Through in situ synthesis, shelf-life limitations of sensors that utilize detection mechanisms that rely on highly reactive chemical interfaces (e.g. enzyme, membranes, thin-films etc.) can be overcome providing viable technologies for long-duration space missions. **References:** [1] Benner, S.A. (2010) *Astrobiology, 10,* 1021–1030. [2] Lovelock, J.E. (1965) *Nature*, 207(997), 568-570