THE SIGNS OF LIFE DETECTOR (SOLID): AN INSTRUMENT TO DETECT MOLECULAR BIOSIGNATURES ON MARS. V. Parro[1], C. Stoker[2], A.F. Davila[3], R. Quinn[4]., Javier Gomez-Elvira[1] [1]Centro de Astrobiología (parrogv@inta.es), [2]NASA Ames Research Center (carol.stoker@nasa.gov), [3]Carl Sagan Center at the SETI Instituite (adavila@seti.org), [4]Carl Sagan Center at the SETI Instituite (richard.c.quinn@nasa.gov).

Introduction: The case for life on Mars grows stronger. Investigations at Gale Crater by *Curiosity* have revealed fine-grained sedimentary rocks inferred to represent an ancient lake environment suited to support life [1]. In addition, *Curiosity* tentatively found a heterogeneous distribution of organic carbon within these sediments [2], consistent with the detection of native organic C in Mars meteorites. Futhermore, modern potentially habitable environments have been recognized on Mars including the N. Polar region visited by Phoenix [3], gully featuers suggesting modern water flows [4], and RSLs that occur seasonally suggest liquid processes[5]. The time is ripe for missions to Mars incorporating a search for biochemical evidence of life.

The SOLID Instrument: The Signs of Life Detector (SOLID) is a mature instrument, that uses state of the art liquid extraction and lab-on-a chip immunoassay technology to detect and characterrize organic carbon on Mars (Fig. 1). The instrument has a lineage of technology development since 2000 [6-8]. The SOLID instrument concept is based on the automation of fluorescent microarray immunoassays. The instrument is divided into two physically separated units: the Sample Preparation Unit (SPU) for extraction of organic molecules from powdered rock using liquid sonication; and the Sample Analysis Unit (SAU) for production of fluorescence images with the results of the immunoassay.

Conceptually, immunoassays mimic our immune system in that a fleet of antibodies (Ab) is designed to chemically capture desired organic compounds termed antigens (Ag) in solution. Antibodies possess high specificity and affinity for their respective Ag, making immunoassays both reliable and sensitive, with confirmed detection limits of a few ppb for specific compounds. For analysis, the liquid extract obtained in the SPU is exposed to a fleet of Ab's designed to anchor to a specific region of the target organic compound. Special labeled Ab's containing a fluorescent tag that can be excited with a laser are used to reveal the presence of the Ag in the sample. State-of-the-art technology allows immunoassays-on-a-chip, whereby Ag identification occurs in a microchip, with minimal mass, volume and power requirement. SOLID can perform two assays, depending on the type of targeted organic compound: *Competitive Inhibitory Immunoassay* for relatively simple and small organic compounds such as amino acids, and *Sandwich Immunoassay* for larger and more complex organic compounds such as peptides or nucleic acids (Table 1).

SOLID performance features: SOLID extracts organic compounds from rock samples using liquid sonication, circumventing the problem of pyrolysis

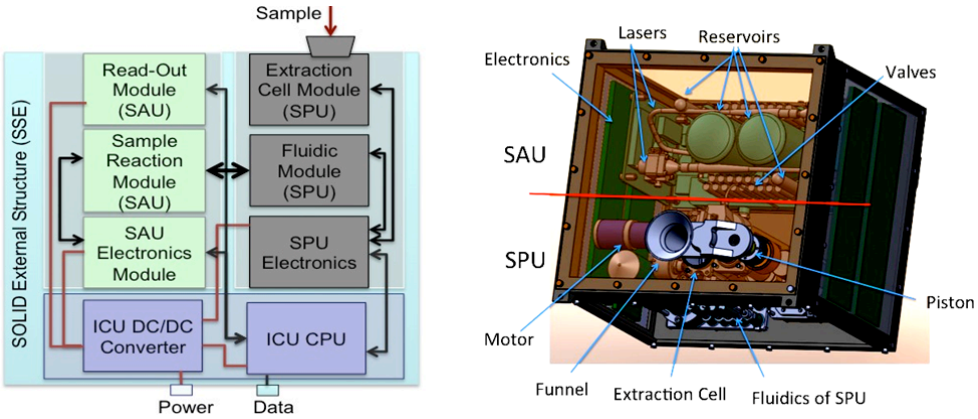

Figure 1 (Left) SOLID Instrument Block Diagram showing 3 main modules. Power is provided by ICU, which collects internal sensor and housekeeping information and generates internal commands. ICU is the single power and data interface with the rover. **(Right) The packaged SOLID instrument** has an external structure (SES) attached to the RAMP that isolates all internal units from the interior of the rover body, assuring that the instrument can't contaminate the rover body. Its sample delivery funnel is closed by a lid when not delivering sample. The SAU is attached to the lower wall of SES and the SPU to both upper and lower walls. All the electronics are attached to the lateral walls.

extraction in the presence of thermally unstable perchlorate experienced by volatilization MS instruments. The instrument uses buffer solutions to compensate for strong pH changes during extraction, and can operate at higher than typical Martian salt concentrations, for example, liquid extraction and analysis is compatible with up to 20 times the average perchlorate concentration on Mars. SOLID's core sensor is the BioMarker Chip (BMC) a microarray with 1008 Ag-Ab reaction spots at pre-assigned and known locations. Each spot contains capturing Abs (for SI) or Ag-conjugates (for CI). SOLID is designed to conduct up to 30 sample analyses. Each analysis requires 2 grams of material. Tests using Martian soil simulant JSC Mars-1 have shown extraction efficiencies of 50% for highly hydrophobic compounds and more than 90% for water soluble ones.

To address possible terrestrial contamination (false positive) SOLID implements two strategies: 1) A control analysis is run prior to each sample analysis utilizing only the instruments internal buffers and antibody solutions. Possible contaminants from Earth are revealed in this control run, and subtracted from further analyses; 2) To distinguish fluorescence signal from terrestrial forward contamination, several antibody spots in the BMC are dedicated to detect microbial strains known to be present in clean rooms and resistant to thermal treatment.

SOLID performance: The lower limit of detection (LOD) for organic C compounds ranges from 1 to 500 ppb levels (ng ml^{-1}) in the liquid extract [7]. SOLID can differentiate between organic compounds ranging from simple amino acids to complex polymer and hydrocarbons, and detect as little as 10^4 cells/gr to assess forward contamination. SOLID can also detect chirality in amino acids, a strong indicator of biogenicity.

SOLID is capable of identifying up to hundreds of distinct molecules at once. However, a search strategy for extraterrestrial life requires identifying the most important molecules to look for. Table 1 shows a spectrum of common prebiotic and biotic molecules that SOLID can identify with high precision and specificity. These range from amino acids and PAHs delivered to Mars by meteorites, all the way to definitive biomarkers that can be preserved the geologic record and are likely to be found on Mars if either ancient or modern life was or is present.

SOLID's role in Mars Exploration: SOLID investigations can link directly to, and logically follow, the unprecedented successes achieved by the NASA Mars Exploration Program over the last two decades. SOLID can be used in the in situ search for evidence of ancient life on Mars, and is planned for incorporation in the Icebreaker mission to search for modern life in ice rich permafrost[9]. In a future sample return mission, SOLID could help identify the most important samples to bring back.

References: [1] Grotzinger et al. (2013) *Science* DOI:10.1126/science.1242777. [2] Ming et al. (2013) *Science* DOI:10.1126/science.1245267. [3] Stoker et al. (2010) *J. Geophys. Res.* doi:10.1029/2009JE003421. [4] Malin and Edgett (2000) *Science* 288, 2330-2335. [5] McEwen et al. (2011) *DOI: 10.1126/science.1204816.* [6] Parro et al. (2011) *Astrobiology* 11, 969. [7] Fernández-Remolar et al. *JGR* 118, 922. [8] Blanco et al. *Environ. Microbiol*. 14, 2495.[9] McKay et al., (2013) *Astrobiology* doi:10.1089/ast.2012.0878

Table 1. Molecules that can be detected with SOLID and the implications of their detection on Mars

Simple abiotic organics (Category 1)	Implications of detection
Meteoritic amino acids (Alpha-aa, D-aa, Ala, Asp, Glu, Val) **PAHs and photoproducts** (Mellitic, Benzoic Naphthalene, Pyrene, Anthracene, Quinoids) **Meteoritic nucleobases** (A, G, C, U, Xa)	Elevated potential for biosignatures. Meteorites deliver organics to Mars Building blocks of life are present Organics are preserved
Possible organic biomarkers (Category 2)	
Aromatic amino acids (Phe, Tyr, Try) **Nucleotide & derivatives** (AMP; GMP; C-GMP)	The potential for biosignatures is high. Prebiotic or biotic chemistry on Mars
Definitive organic biomarkers (Category 3)	
Hydrocarbons (n-Alkane, Kerogen, Alkyldibenzothiphene, Isoprenoid, Carotenoid, Alkylphenanthrene) **Lipids** (Hopanes, Steranes, Lycopanes, Carotanes) **Polymers** (Peptides, Nucleic Acids, Polysaccharides) **Heterocycles** (Porphyrin ring)	Definitive biosignatures Life once existed on Mars