The Urey Instrument: An Integrated End-to-End in situ Analytical System Designed for the Ultra-sensitive Chemical Detection of Extant or Extinct Life on Mars. Frank J. Grunthaner (1), Jeffrey L. Bada (2), Alison M. Skelley (3), Richard A. Mathies (3), Richard Quinn (4), Aaron Zent (5), Peter Willis (1), Xenia Amashukeli (1), Allen Farrington (1), Andrew Aubrey (2) and Pascale Ehrenfreund (6). (1) Caltech/ Jet Propulsion Laboratory, USA, (2) Scripps Institution of Oceanography, UCSD, USA, (3) UC Berkeley, USA, (4) SETI Institute, NASA Ames Research Center, USA, (5) NASA Ames Research Center, USA, (6) Leiden Institute of Chemistry, NL.

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The Urey Instrument is an integrated suite of in situ instruments, formerly termed MOD/ MOI, which is designed to search the Martian regolith for chiral biomarkers at terrestrial laboratory state-of-the-art detection levels (part-per-trillion sensitivity) while profiling the presence and chemical reactivity of surface and atmospheric oxidants that might have reactively degraded organic compounds chemo-resistor oxidant sensors. The Urey instrument suite has been selected for the Paster payload in the European Space Agency’s (ESA’s) ExoMars rover mission and is considered a fundamental instrument to achieve the mission’s scientific objectives. The instrument is named Urey in recognition of Harold Clayton Urey’s seminal contributions to cosmochemistry, geochemistry and the study of the origin of life. This integrated end-to-end suite consists of two analytical systems, one for the measurement of trace organics and the other to measure the reactivity of the regolith and atmosphere. The weight of the full package as delivered to the ExoMars rover is approximately 4.4 kg, with external dimensions of 21 x 20 x 16 cm.

The Urey organic analyzer accepts solid samples as input, performs a liquid phase extraction, strips carrier solvent through freeze drying, concentrates analyte through sublimation, reactively labels target molecules for fluorescent detection, transports re-dissolved samples using microfluidics to a microchip capillary electrophoresis system that measures composition and chirality. The instrument is sequenced using an integral microcomputer and data is transferred to the science team through the ExoMars rover to satellite link. The Urey reactivity analyzer accepts a part of the solid sample input and directs the material onto an array of chemi-resistors. Each array has several different sensor materials, one array for each sample. The array is monitored to follow changes over exposure time in the resistance of thin film sensors. The temperature of the thin film sensors is controlled and water can be added to the sensor surface interface to trigger further reactivity.

In this paper, we will describe the component instruments, their development and characterization, including the Mars Organic Detector (MOD), the microchip Capillary Electrophoresis System (µCE), the Mars Oxidant Instrument (MOI) and our sub-critical water extractor (SCWE) and the issues involved in moving sample material between these components as required for the integrated low mass system. We will emphasize the experimental results of our Atacama Desert (Chile) and Panoche Creek (California) field campaigns through which we have demonstrated the sensitivity (pp trillion) [2] of our Amino Acid biomarker detection system to be several orders of magnitude greater than the pyrolytic GCMS systems utilized by Viking and the SAM instrument that is part of the upcoming Mars Science Laboratory (MSL) mission; established direct measurements of unique acid-derived oxidation systems triggered by molecular films of water that are consistent with Viking observations of Martian soils [1]; and showed the extreme variation of detectable organics over lateral distances of decimeters and over depths from the surface of centimeters. Solid samples from the ExoMars rover will include material from the regolith as well as subsurface samples from depths of up to 2 meters.

References:


For additional detail and papers describing the technology of Urey and the field validation experiments, see: http://astrobiology.berkeley.edu
Figure 1. (left) µCE eletropherogram showing amino acids and amines detected in an Atacama sample (from Skelley et al., 2005). Nucleobases were determined to be below the detection limit (<1 ppb) in this sample. (right) MOI sensor responses showing the detection of trace levels of oxidizing acids in Atacama dust using the MOI (from Quinn et al., 2005).

Figure 2. Concept drawing of Urey: Mars organic and Oxidant Detector