SAMPLE ANALYSIS AT MARS (SAM) INSTRUMENT SUITE FOR THE 2011 MARS SCIENCE LABORATORY.

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Introduction: The Sample Analysis at Mars (SAM) suite of instruments is designed to explore the past or present habitability of Mars by exploring carbon chemistry through a sensitive search for organic componds [1], the chemical state of light elements other than carbon, and isotopic tracers of planetary change. The science goals of this investigation are listed in Table 1. Nine other instrument based investigations hosted on the Mars Science Laboratory will also support the ambitious goals of the mission [2] to quantitatively assess habitability through a series of chemical and geological measurements. With the SAM integration presently complete, this report will provide a summary of the science goals and measurement capabilities of this suite.

Table 1. Goals of the SAM Investigation that address present and past habitability	
Goal 1	Survey carbon compound sources and evaluate their possible mechanism of formation and destruction
Goal 2	Search for organic compounds of biotic and prebiotic importance including methane
Goal 3	Reveal the chemical and isotopic state of elements (i.e. N, H, O, S, C and others) that are important for life as we know it
Goal 4	Evaluate the habitability of Mars by studying its atmospheric chemistry and the composition of trace species that are evidence of interactions between the atmosphere and soil
Goal 5	Understand atmospheric and climatic evolution through measurements of noble gas and light element isotopes.

SAM Instruments and Supporting Subsystems: SAM (Figure 1) consists of three instruments and two major supporting subsystems. The instruments are a Quadrupole Mass Spectrometer (QMS), a Gas Chromatograph (GC), and a Tunable Laser Spectrometer (TLS). The QMS and the GC can operate together in a GCMS mode for separation (GC) and definitive identification (QMS) of organic compounds. The TLS obtains precise isotope ratios for C, H, and O in carbon dioxide and water and measures trace levels of methane and its carbon 13 isotope. The supporting systems are a sample manipulation system (SMS) and a Chemical Separation and Processing Laboratory (CSPL) that includes high conductance and micro valves, gas manifolds with heaters and temperature monitors, chemical and mechanical pumps, carrier gas reservoirs and regulators, pressure monitors, pyrolysis ovens, and chemical scrubbers and getters. The Mars atmosphere is sampled by CSPL valve and pump manipulations that introduce an appropriate amount of gas through an inlet tube to the SAM instruments. The solid phase materials are sampled by transporting finely sieved materials to one of 74 SMS sample cups that can then be inserted into a SAM oven and thermally processed for release of volatiles.

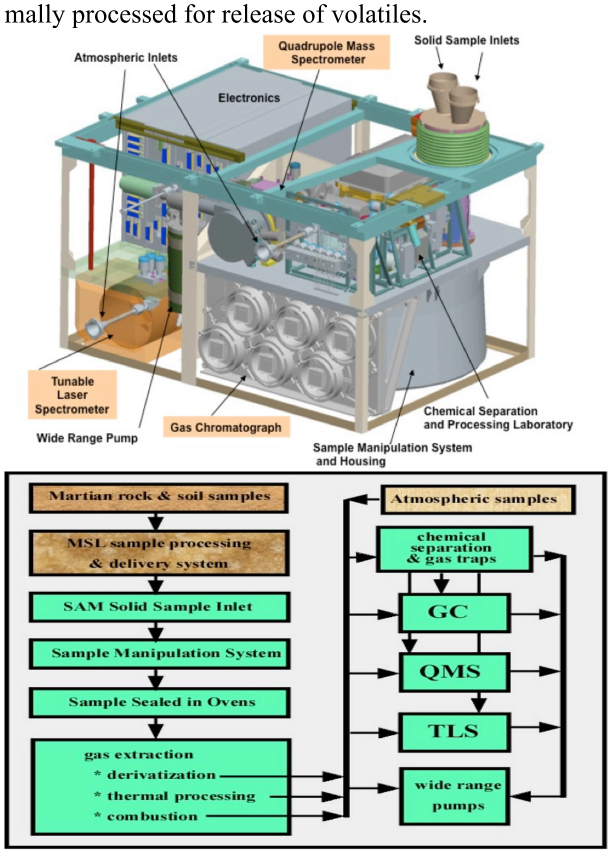

Figure 1. *The layout of SAM's instruments and major supporting subsystems is illustrated in the top portion of this figure and the flow of gas and sample to the instruments illustrated in the lower panel.*

The SAM Quadrupole Mass Spectrometer. The QMS analyzes both both atmospheric samples and gases thermally-evolved from solid phase samples to sub ppb sensitivity. QMS is the primary detector for the GC and can operate in static or dynamic mode. Its mass range is 2-550 Dalton and its ion detector dynamic range >10^{10} with both a channeltron pulse counting electron multiplier and a Faraday Cup. The crosstalk between adjacent peaks is greater than 10^6 which enables all the isotope measurements of interest to be made without crosstalk interference.

The SAM Gas Chromatograph. The GC separates complex mixtures of organic compounds into molecular components for QMS analysis and for detection of compounds with the thermal conductivity detectors on 5 of the 6 columns. Before analysis by the QMS, the 6 columms of the GC allow the separation of a wide range of species, including permanent and noble gases, light and heavy volatile organic compounds, pyrolysis and derivatization products, and enantiomers. The detection limit of the combined GC/QMS system exceeds the part per billion mission requirement for organic detection.

The SAM Tunable Laser Spectrometer. The TLS is a two channel Herriott cell design spectrometer that provides high sensitivity, unambiguous detection of targeted species (CH_4, H_2O, and CO_2) and the selected isotope ratios $^{13}C/^{12}C$, $^{18}O/^{16}O$, and $^{17}O/^{16}O$ in carbon dioxide, D/H in water, and $^{13}C/^{12}C$ in methane. The direct detection methane sensitivity for atmospheric gas ingested into the TLS Harriott cell is < 1 ppb and the detection limit can be greatly reduced by methane enrichment in SAM's CSPL.

Analysis of Solid Samples: Solid sample analysis, atmospheric sampling, and calibration sequences will be interleaved over the course of the surface mission. The solid sample sequences include

A. Direct evolved gas analysis followed by GCMS analysis and
B. Chemical derivatization followed by GCMS analysis
C. Combustion of refractory organics followed by isotopic analysis in the TLS

In sequence A several tens of cubic millimeters of powdered sample are deposited into one of the quartz cups in the SMS and heated with a programmed ramp from ambient to ~1100 ^{o}C while continuously sampling evolved gas with the QMS. A portion of the evolved gas can be directed at any time through a hydrocarbon trap for later release and analysis by chromatography with the GC and the QMS. In sequence B the sample is introduced into a solvent that also contains a chemical derivatization agent that is selected to transform polar molecules such as carboxylic acids into volatile species that can be analyzed by GCMS. Sequence C utilizes an oxygen gas reservoir to combust the refractory carbon in a sample into CO_2 whose $^{13}C/^{12}C$ can be analyzed by the TLS.

Analysis of Atmospheric Samples: Regular direct atmospheric sampling by ingestion of a gas sample into the CSPL manifold enables diurnal and seasonal variations to be measured over the course of the two year mission by the QMS and the TLS. In addition, specialized gas sampling experiments include a methane enrichment experiment to increase the density of methane in the TLS for improved precision of the $^{13}C/^{12}C$ measurement in CH_4. Likewise, the noble gas enrichment experiment separates out chemically reactive gases to provide noble gas enriched samples to the QMS for static mass spectrometry and isotope and noble gas elemental ratio analysis. Both of these experiments utilize chemical getters and scrubbers to separate out the interfering gasses.

Calibration Sequences: A mixture of several calibration gases is brought to Mars in SAM to be used at regular intervals during the mission. The calibration gas cell includes N_2, CO_2, Ar, and a Xe mix that is heavily spiked with ^{129}X to insure that there is no danger of mistaking this gas for martian xenon if a leak were to develop in the microvalve seat separating the gas from the inlet manifold. In addition, three fluorocarbon compounds are included in this cell so the performance of the GCMS system can be evaluated over the course of the mission. These calibration gases will be used in several SAM comprehensive performance tests to be carried out after SAM is delivered to JPL for integration into the MSL rover. TLS carries on-board isotopic reference gas cells for both CH_4 and CO^2.

Organic Check Material: The possibility of a false positive detection of organic molecules on Mars even after careful attention to MSL and SAM contamination control [3], will be addressed by use several times during the mission of an organic check material (OCM). In this experiment a very pure amorphous silica impregnated with a distinctive set of synthetic fluorocarbons will be sampled by the MSL drill and rock powdering system and delivered into the SAM inlets for GCMS analysis. The sample processing will directly mimic that of a Mars rock and possible terrestrial cross contamination of this sample from the rover during the sample processing and transport process revealed. The OCM experiment will be most useful following a tentative detection of organics in a Mars rock sample by SAM. Six such experiments can be carried out over the course of the mission.

References: [1] Mahaffy, P.R., Space Sci. Rev. 135, 255 (2008). [2] Crisp, J. et al., Ground Truth from Mars conference contr. 1401, 24 (2008). [3] ten Kate I. L. et al., Astrobiology 8, 571 (2008).

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