

AN ARM MOUNTED “SCRATCH-AND-SNIFF” SAMPLE TRIAGE SENSOR M.R. Darrach¹, R. Kidd¹, L. Shiraishi¹. ¹Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA.

Introduction: A simple rock sample triage system based on the detection of volatiles released by mechanical abrasion is proposed. The instrument will be capable of detecting trace compounds which may be found in Mars rock and compacted permafrost soils with extremely high sensitivity. The sensor is based upon a miniature gas chromatograph mass spectrometer (GCMS) that has been developed through the Planetary Instrument Definition and Development Program (PIDDP), the human exploration Advanced Environmental Sensors (AES) program, and the flight Vehicle Cabin Atmosphere Monitor (VCAM) [1]. The total instrument mass will be approximately 2.8 kg, including GCMS, electronics and vacuum pumps. The proposed instrument will have radically smaller mass, volume, power, and simplicity than comparable instruments (e.g. MSL sample acquisition, processing and handling). This instrument is based upon technology and expertise developed in JPL’s Planetary Surface Instruments (PSI) and Planetary Sample Acquisition and Handling (PSAH) groups

Challenge Areas Addressed:

1. Interrogating the shallow subsurface of Mars, from the surface (e.g., sounding, drilling, excavating)
2. Lightweight and low-cost in situ instrumentation to identify and triage materials for analysis.
3. Concepts for detection of trace-level organic matter in rock and dust without extensive in situ sample processing.

Instrument Concept: The proposed approach, as shown in Figure 1, is based on an arm-mounted contact instrument and a miniature GCMS, mounted in the rover body, for analysis of the chemical species. The arm-mounted “Scratch-and-Sniff” module, detailed in Figure 2, is comprised of a mechanical abrasion tool, heater, and preconcentrator, sample pump, and valving. Nominal “scratch-and-sniff” operations proceed as follows:

1. Rocks or soils are mechanically abraded and heated which liberates trapped volatiles.
2. Volatiles are drawn into a preconcentrator (PC) by a sample pump where they are adsorbed.
3. The arm-mounted “scratch-and-sniff” module is drawn back to the rover body and the PC output ports are mated into the inlet ports of the GC/MS.
4. The PC is heated, releasing the trapped volatiles which are pushed into the GC/MS by an inert gas stream and analyzed.

5. The PC and associated tubing is cleaned by a long duration heating and inert gas purge.

Under the low temperatures that will challenge in situ experiments on planetary or satellite surfaces, or even some terrestrial extreme environments (such as polar deserts), most hydrocarbons are not in the vapor phase. The analysis of organic compounds held within rock is made even more complicated by the requirement for sample acquisition, preparation and distribution into an analytical instrument such as the Viking GCMS [2,3] or the SAM experiment that will fly on the Mars Science Laboratory (MSL). If there are organic molecules on Mars and other challenging environments, how do we access them?

Just approaching the rock and “sniffing” it with a vapor-phase GC/MS however will not reveal any volatile organic compounds (VOCs). This will be especially true at the low temperatures of Mars. This is due to many reasons, for Mars it is expected that any volatiles on the surface will have been destroyed by the UV flux or oxidizing perchlorates. Furthermore, the low temperatures and surface pressure at Mars impedes VOC detection as they must be volatilized for detection. Most importantly though, any VOCs present will be inside the rock and sequestered in pore spaces. Consequently, the interior of the rock must be accessed.

Numerous prior investigations have been performed on determining the composition and concentrations of trapped gases within meteoric, lunar, and Mars analogue rocks and soils [4-6]. These studies have found that the concentrations of simple volatile PAH organics (methane, ethane, ethylene and propane) and water have range from parts-per million ($\mu\text{g/g}$) to parts-per-billion (ng/g). Even at nanogram levels this repre-

Scratch and Sniff Detection Sensitivity

Require Detection Sensitivity for Trapped Gases in Rocks at Concentrations $\geq 1 \text{ ng/g}$.

**Assume an excavation = 20min at $1\text{cm}^3/\text{min}$.
Assume rock density $\approx 1.5 \text{ g/cm}^3$**

Total rock processed = $20 \times 1.5 = 30\text{g}$
Worst case VOC liberation efficiency of 1%
Total VOCs = $30\text{g} \times 1 \text{ ng/g} \times 1\% = 300\text{pg}$

Worst case PC Collection efficiency of 10%
Total VOCs collected = $300\text{pg} \times 10\% = 30\text{pg}$

Still more than 10x GCMS sensitivity of 2 pg

sents a substantial quantity of trace chemicals that are readily accessible and will yield important results in scientific investigations. For the “scratch-and-sniff” system assuming a VOC concentration of 1ng/g, even a total collection efficiency of less than 0.1% will still yield 10 times more material than the GCMS sensitivity of 2 pg. It is estimated though that the total collection efficiency will be approximately 1%, making the measurements much easier. Besides quantifying the trapped organics it is also very important to provide a basic distinction between biogenic and abiogenic sources on Mars. This can be affected, for example, by performing $^{13}\text{CH}_4:\text{CH}_4$ isotope ratios measurements to better than 10 parts-per-mil [7]. For the “scratch-and-sniff” system, assuming a collection efficiency of 1%, this isotopic measurement will be possible when the concentration is at least 1 ng/g.

References:

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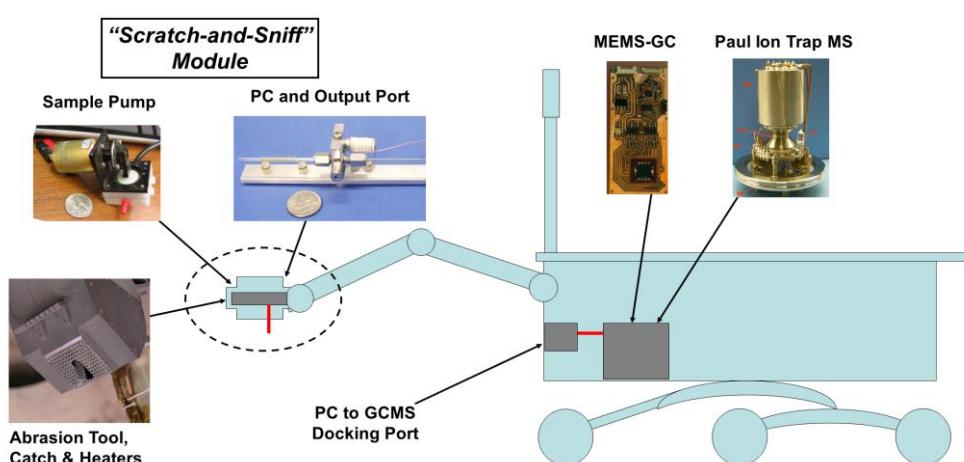


Figure 1: Illustration of the proposed sample preparation/handling instrument. The “**Scratch-and-Sniff**” module is located at the end of a rover arm and consists of a mechanical abrasion tool, pre-concentrator (PC), valves, sample pump, catch and associated tubing, heaters, etc. The chemicals adsorbed in the PC during abrasion will be analyzed by a miniature GC/MS (or other) instrument mounted inside the rover body. To perform this analysis the rover arm will retract and “dock” the PC output port with the inlet to the GCMS. This removes the need for a complicated arrangement of long heated tubes and flexible bellows in the rover arm to otherwise bring the vapors to the GCMS.

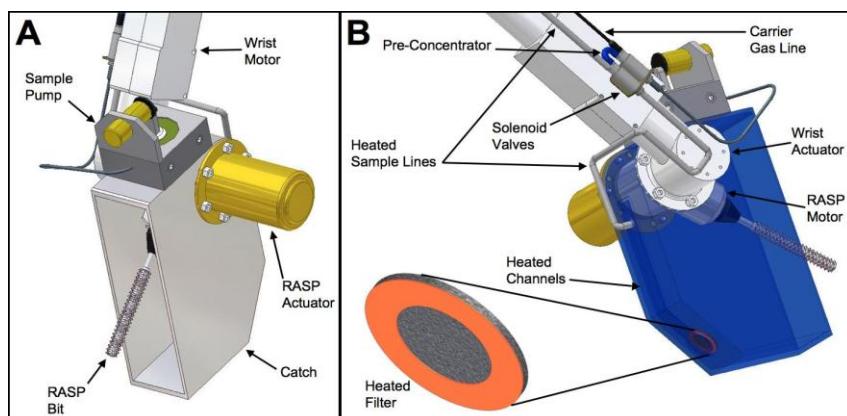


Figure 2: Example one possible configuration for the “Scratch-and-Sniff” instrument showing (A) view from the top, (B) a transparent view.