A SUBSURFACE SOIL COMPOSITION AND PHYSICAL PROPERTIES EXPERIMENT TO ADDRESS MARS REGOLITH STRATIGRAPHY

L. Richter[1], M. Sims[2], T. Economou[3], C. Stoker[4], I. Wright[5], and T. Tokano[6]. [1]DLR Institute of Space Simulation, Linder Hoehe, D-51170 Cologne, Germany (lutz.richter@dlr.de), [2]University of Leicester, UK, [3]University of Chicago, [4]NASA Ames Research Center, [5]Open University, UK, [6]University of Cologne, Germany.

Introduction: Previous in-situ measurements of soil-like materials on the surface of Mars, in particular during the on-going Mars Exploration Rover missions, have shown complex relationships between composition, exposure to the surface environment, texture, and local rocks. In particular, a diversity in both compositional and physical properties could be established that is interpreted to be diagnostic of the complex geologic history of the martian surface layer. Physical and chemical properties vary laterally and vertically, providing insight into the composition of rocks from which soils derive, and environmental conditions that led to soil formation. They are central to understanding whether habitable environments existed on Mars in the distant past.

An instrument – the Mole for Soil Compositional Studies and Sampling (MOCSS) - is proposed to allow repeated access to subsurface regolith on Mars to depths of up to 1.5 m for in-situ measurements of elemental composition and of physical and thermophysical properties, as well as for subsurface sample acquisition. MOCSS is based on the compact PLUTO (PLanetary Underground TOol) Mole system developed for the Beagle 2 lander and incorporates a small X-ray fluorescence spectrometer within the Mole which is a new development. Overall MOCSS mass is ~1.4 kg.

Taken together, the MOCSS science data support to decipher the geologic history at the landing site as compositional and textural stratigraphy – if they exist - can be detected at a number of places if the MOCSS were accommodated on a rover such as MSL. Based on uncovered stratigraphy, the regional sequence of depositional and erosional styles can be constrained which has an impact on understanding the ancient history of the Martian near-surface layer, considering estimates of Mars soil production rates of 0.5…1.0 m/billion years [1] on the one hand and Mole subsurface access capability of ~1.5 m.

MOCSS Overview

MOCSS (Mole for Soil Compositional Studies and Sampling) is an instrument that obtains depth profiles of soil chemical, physical and thermophysical properties and can repeatedly obtain subsurface soil samples from depths up to 1.5 m to be used by lander or rover-based (whatever the accommodation) instruments as desired. MOCSS uses a tethered, electro-mechanical penetrometer or 'Mole' that travels into the subsurface by soil displacement through the action of an internal hammering mechanism and can reach depths of more than 1 m depending on soil compaction and strength properties. MOCSS carries an X-ray fluorescence spectrometer (XRS) and temperature sensors. From Mole soil penetration behavior, depth-resolved physical properties of the regolith (cohesion, friction angle, bulk density, and porosity) are deduced and subsurface temperature measurements allow determination of thermal diffusivity, thermal conductivity, and soil characteristic grain size. The XRS allows vertical profiles of soil chemical properties to be obtained from undisturbed soil. A sampling device built into the Mole tip can retrieve a 5 gm sample from each Mole subsurface excursion. A tether reel being part of the MOCSS system retrieves the Mole to the surface, supported by Mole reverse hammering, and allows repeated subsurface deployments.

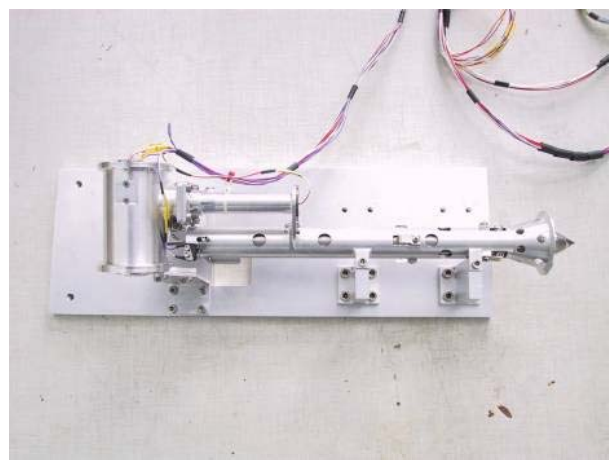

Fig. 1: View of PLUTO Mole system (length 365 mm, mass 860 g) providing heritage to MOCSS.

Figure 2 illustrates the concept of MOCSS operation. MOCSS is closely based on the PLUTO (PLanetary Underground TOol) subsurface soil sampling system flown on the Beagle 2 lander which however lacked an XRS internal to the Mole [2].

The XRS proposed for MOCSS is based on heritage from the Pathfinder APXS and Beagle 2 XRS instruments but is somewhat miniaturized to allow accommodation within the Mole.

XRS Accommodation: The XRS instrument is placed inside the rear of the 25 mm diameter Mole which itself is modified from the Beagle 2 Mole to allow easier integration of the XRS. Front end electronics functions are within the Mole whereas the overall MOCSS back-end electronics functions are implemented in local electronics mounted to the MOCSS assembly.

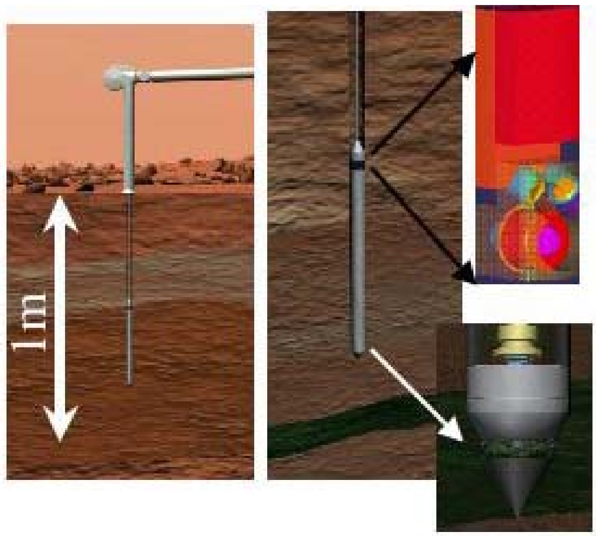

Fig. 2: Principle of MOCSS Mole deployment and locations of XRS in Mole back end and of sampling device in Mole front.

The Beagle 2 XRS used a dual-source concept for sample excitation with Fe-55 and Cd-109. This same concept is implemented in the MOCSS XRS. A silicon PiN diode detects X-rays fluoresced from the sample by the sources, providing primary X-rays of Mn (5.90 keV and 6.49 keV) and Ag (22.16 keV and 24.94 keV). The instrument is sensitive to X-rays in the 1 – 27 keV range, allowing the detection of elements from Z = 11 (Na) to Z = 46 (Pd), including the capability of in-situ trace element analysis for elements of interest including Rb, Sr, Y, Zr which is currently unavailable with the MER Alpha Proton X-ray Spectrometer (APXS).

Impact on Mars Science: An integrated interpretation of depth-dependent regolith chemical analyses, Mole penetration rate and temperature measurements yields fairly direct measurement of many properties of Martian materials. Moreover, the fulfilment of the science objectives of the MOCSS investigation benefits by correlating all data sets obtained as a function of depth. The data are complementary and taken together provide great insight into the geological history of the site investigated. A past history of liquid water, particulary sediments deposited in an evaporitic environment would likely concentrate Cl, Br, Sulfate, and possibly carbonate. Furthermore, cohesion of evaporitic materials would likely be higher since many evaporates act as cements. Layers of different chemical composition would be deposited by evaporation of liquid water or ice. Even though the XRS instrument cannot measure ice directly, MOCSS measurements of thermal diffusivity and thermal conductivity derived from temperature measurements yield direct information about the presence of ice in soils, thus complementing the XRS results. The thermophysical properties of soil also provide key information for modelling the transport of volatiles between the atmosphere and regolith. In particular modelling the exchange between water vapor and ice in soil is crucial to understanding how any ice identified was emplaced in the planet's past. Finally, samples obtained with MOCSS and analyzed in analytical instruments on the host spacecraft (rover or lander) may yield information about the nature of oxidizing compounds, their depth distribution, and correlation with presence/absence of organic compounds in soils [3]. This helps answer the question whether the subsurface of Mars preserves biosignatures that are destroyed on the surface.

References: [1] G.J. Flynn (1990). Accretion of Meteoritic Material onto Mars: Implications for the Surface, Atmosphere, and Moons. In *The Environmental Model of Mars* (COSPAR summary, edited by K. Szego), [2] L. Richter, P. Coste, V.V. Gromov, H. Kochan, R. Nadalini, T.C. Ng, S. Pinna, H.-E. Richter, K.L. Yung (2002). Development and testing of subsurface sampling devices for the Beagle 2 lander. *Planetary and Space Science* **50**, pp. 903-913, [3] Stoker C.R., and Bullock M.A. (1997) *JGR* 102 E5, pp. 10,881-10,888.