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VOLATILE EXTRACTION AND DETECTION FROM FROZEN LUNAR REGOLITH SIMULANTS IN PREPARATION FOR THE LUVMI ROVER.

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Introduction: The Lunar Volatiles Mobile Instrumentation (LUVMI) is a novel lightweight platform designed for operations at the lunar South Pole. Conducted under the EU Horizon 2020 programme and following recommendations by the Lunar Exploration Analysis Group, it is envisioned as a secondary payload for currently planned lunar landing missions. Comprised of the Volatiles Sampler (VS), Volatiles Analyser (VA) and surface and sub-surface imaging instruments upon a mobile platform, LUVMI will prospect and extract volatiles from permanently shadowed regions up to a depth of at least 10cm [1].

Presented here is the work performed by the Open University (OU) in the support of the development of the VA, a miniature ion trap mass spectrometer, and the tests performed that have examined the release and detection of volatiles embedded in frozen lunar regolith simulants.

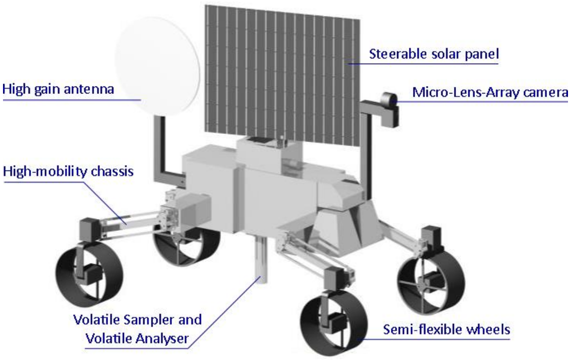

Figure 1 Model of the LUVMI rover

Extraction of Volatiles: In its final flight configuration the VS will combine a hollow rotating drill shell and heating rod to penetrate at least 10cm into the regolith, with a goal of 20cm [2]. The heating rod will heat the enclosed regolith to release the bound volatiles. It is anticipated that around 50% of these volatiles will pass through into the VA. The two instruments will be used together to characterise the volatile profile of the near-surface material and provide a volatile profile with increasing depth.

Volatiles Analyser: The VA is an ion trap mass spectrometer based upon the Ptolemy flight-proven instrument and the MoonLite penetrator deployable instrument. This is a low mass, compact and mechanically simple device capable of rapid detection of masses in the range of 10 – 150 *m/z*, enabling the detection of volatiles, including water, that may be released during regolith heating.

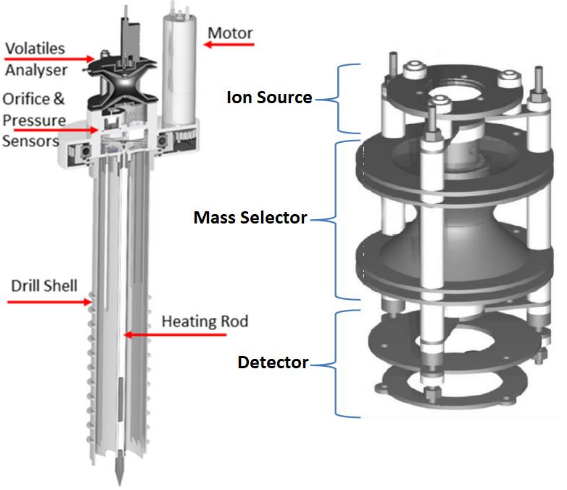

Figure 2 CAD models of the VA-VS system and the Ptolemy mass spectrometer

The VA consists of:

- An ion source, made up of an electron source that ionises the sample gases via electron bombardment
- A mass selector, formed from three hyperbolic electrodes, which create an electro potential region within the structure. Ions can be trapped or ejected by manipulating the amplitude and/or frequency of this potential
- A detector, made up of an electron multiplier that detects the individual ions leaving the mass selector
- A reference gas system developed by the OU for in-situ calibration and soil permeability measurements [3]

LUVMI Environmental test system: A thermal vacuum system for handling lunar simulant materials under representative conditions has been designed and built at the Open University. A schematic of the system is shown in Figure 3.

The sample material is contained within a liquid nitrogen cooled copper container, shown in Figure 4. The regolith temperature is monitored via embedded thermocouples and the container's temperature is managed by a Eurotherm temperature controller that opens and closes the liquid nitrogen control valve.

Figure 3 Thermal vacuum system

Figure 4 NU-LHT-2M sample held in the insulated copper container

Volatile Preservation Study: For these tests, 200g of NU-LHT-2M was used as the simulant material. This is a fine-grained (<1mm to dust) material designed to mimic the highlands regolith found at the lunar south pole, based upon core samples taken from Apollo 16 [4].

The system was initially used to evaluate the conditions similar to those seen by the LCROSS mission, where water contents of 5.6 ± 2.6% were observed in the ejecta plume created from an impactor striking the South Pole crater Cabeus [5]. A series of regolith samples were mixed with 2, 10 and 20 ml of water, giving 1%, 4.8% and 9.1% water mass contents respectively.

The doped regolith was held inside the system and cooled to -150°C in a dry nitrogen atmosphere to prevent atmospheric water being trapped in the cooling regolith. The system was then evacuated to a pressure of approximately 2 x 10^{-5} mbar. The sample was left under these conditions for varying lengths of time (1, 2 and 3 hours), before being brought back to atmospheric pressure. Analysis of the sample masses revealed that, when stored at temperatures below 150°C, minimal water vapour was lost (a maximum of 0.55% water mass for the 9.1% sample).

Volatile Extraction Study: Next, investigations into the ability to thermally evolve volatiles from the frozen lunar simulant were conducted. A custom-built temperature-controlled thermal probe was designed, shown in Figure 5. Thermal control of the probe was achieved through the use of a Eurotherm temperature controller. To mimic the operation of the VA, a Hiden Analytical Halo 201 RC quadrupole mass spectrometer was used to monitor the environment within the vacuum chamber. The study was repeated with identical 200 g samples that were prepared with 2, 10 and 20 ml of water, giving 1%, 4.8% and 9.1% water mass contents respectively. The same procedure was followed as detailed previously, though the chamber was evacuated to a vacuum in the order of 10^{-7} mbar to allow operation of the quadrupole mass spectrometer. A series of background spectra measurements were taken before the heater probe was switched on, to account for outgassing of the probe as it was heated. Once it reached a target temperature of 150°C, it was lowered and embedded to a depth of approximately 45 mm into the sample. The change in spectra readings were observed, focusing on the m/z 18 peak as an indicator for the presence of water. The probe was then extracted from the sample, and the quadrupole continued taking measurements for a set time. The results of these tests will be presented.

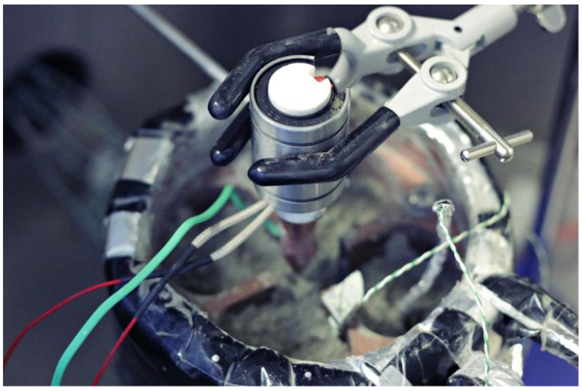

Figure 5 Heater probe set-up

Future Work: The system will be used for characterisation of the breadboard VA system prior to integration with the VS in the coming months

Summary: The Volatiles Analyser, an ion trap mass spectrometer for the LUVMI lunar rover, is being developed by the Open University. Studies have focused on the preservation of volatiles held within a lunar regolith simulant, and the extraction and detection of said volatiles with a thermal probe.

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