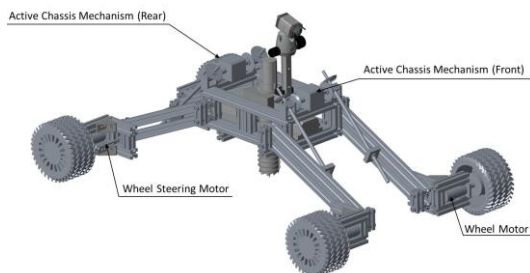


APPLICATION OF THE LVS SUBSURFACE PROBE ON THE LUVMI ROVER FOR A LUNAR VOLATILES EXPLORATION MISSION. J. Biswas¹, P. Reiss¹, J. Gancet², S. Sheridan³, S. Barber³, D. Dobra⁴, L. Richter⁴ and Neil Murray⁵, ¹Institute of Astronautics, Technical University of Munich, Boltzmannstr. 15, 85748 Garching, Germany, (j.biswas@tum.de), ²Space Applications Services NV/SA Leuvensesteenweg 325, B-1932 Zaventem, Belgium, ³The Open University, Milton Keynes, MK7 6AA, UK, ⁴OHB System AG, Manfred-Fuchs-Str. 1, 82234 Weßling, Germany, ⁵Dynamic Imaging Analytics Ltd, Milton Keynes, MK3 6EB, UK

Introduction: We present the latest iteration of the Lunar Volatiles Scout (LVS), a novel instrument to access and characterise lunar volatiles in-situ. The LVS is currently being developed in a cooperation between Technical University of Munich (TUM) and OHB System as part of the Lunar Volatiles Mobile Instrument (LUVMI) study, conducted in the frame of the EU Horizon 2020 initiative and led by the Belgian company Space Applications Services.

LUVMI aims to develop a comprehensive lightweight (20-40 kg) rover for investigations on volatiles in and around permanently shadowed regions on the Moon. The platform is envisioned as a possible secondary payload to one of the currently planned missions to the lunar poles. It features an active chassis with four independently steerable wheels, an innovative light-field camera, the Volatiles Sampler (represented by the LVS), and the Volatiles Analyser (miniature mass spectrometer).



LVS Instrument Concept: The LVS, as presented by [1], is a novel instrument capable of probing 20 cm deep into lunar regolith. It consists of a central heating rod and an enclosing shell, which captures the released volatiles. The enclosing shell is equipped with an auger and can be rotated in a screw-like motion to reach insertion depths of up to 20 cm into the regolith. The heating rod will thermally release bound volatiles, which will then diffuse towards the mass spectrometer for gas analysis. Information on the chemical phase and the amount of released volatiles is recorded. The design of the heating rod was extended to incorporate a thermocouple in the tip of the rod, which will measure the initial regolith temperature at the insertion depth.

- Penetrate at least 10 cm into the ground with a goal of 20 cm,
- Release all physisorbed volatiles enclosed by the instrument,
- Qualitatively determine the abundance of volatiles in the sample, and

- Measure the initial regolith temperature at the penetration depth.

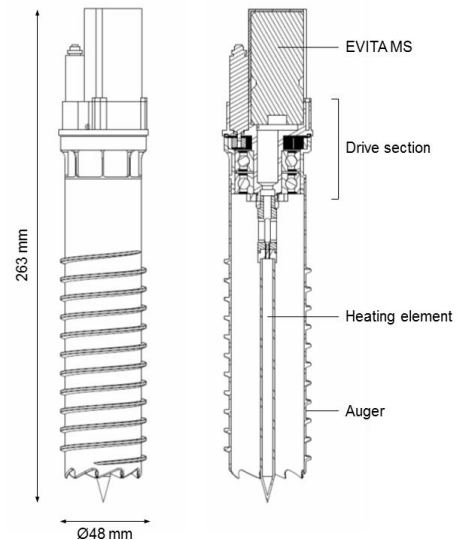


Figure 1: Preliminary CAD Model of the LVS

Derivation of Geotechnical Properties: A simple bearing capacity model, taking into account the regolith bulk density, gravity, angle of internal friction, and soil cohesion, was created to model the vertical force necessary to insert the LVS into the ground. The model shows good agreement with experiments at different bulk densities with a simple cone penetrator geometry as well as with an LVS prototype. Though simple, the model is regarded as a proof of concept for the derivation of cohesion, bulk density and angle of internal friction from penetration force measurements. A summary of the model and relevant results are presented.

Heating and Gas Extraction: A simulation model for the sample heating, implemented in COMSOL multi-physics, was presented previously [1]. The model is being extended to model the influence of sublimating water, both by accounting for the additional heat capacity and enthalpy of sublimation and by the enhanced thermal conductivity from the higher gas pressures. Currently, the model is used in trade studies to optimise heating duration, energy and power consumption, and the sample temperature distribution.

An experimental setup is being developed to verify the model for cryogenic conditions. For this purpose, samples of the regolith simulant NU-LHT-2M

are moisturized with 1 wt% of water, frozen with liquid nitrogen, and then exposed to vacuum while being continually cooled. This way, sublimation is avoided and the original water content is preserved. The samples are then heated and temperature profiles over time are measured at multiple points. The presentation shows an overview of the test setup, sample preparation procedures and compares preliminary results versus the simulation model.

Determination of the abundance of released volatiles: Preliminary experiments have shown that around 50% of the released volatiles escape through the open bottom end of the instrument [2]. The knowledge of this fraction is important to relate the amount of measured volatiles to the actual volatile content in the soil. The amount of lost volatiles depends on regolith bulk density, moisture content, temperature, and the pressure inside the instrument. Future research will investigate the influence of the

named parameters aiming to calibrate the instrument in order to allow the determination of the actual volatile content in the sample. For this purpose, the test setup will be extended to measure the amount of released gas. Furthermore, a mechanical actuation is planned, which will allow to measure the amount of volatiles released due to the mechanical disturbance during insertion of the instrument.

Future Work: In a stepwise approach, the established test setup with penetrator and heater will be extended to include the drive section of the LVS and the Volatiles Analyser. This will allow end-to-end experimentation and parameter studies with the fully integrated instrument to further refine the instrument design and raise its technology readiness level for future mission applications. **References:** [1] Reiss P. et al. (2016) ELS, 9-10. [2] Parzinger S. (2013) *43rd Int. Conf. on Environmental Systems*. AIAA 2013-3524.

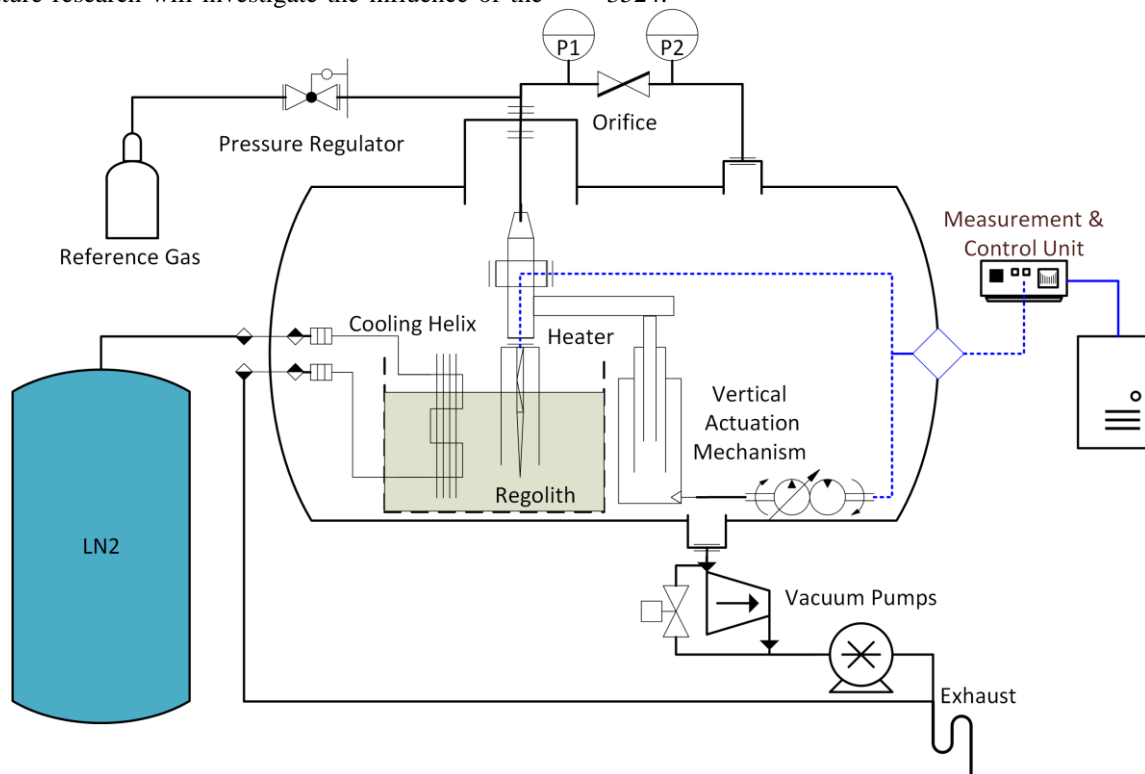


Figure 2: Sketch showing the extended test-setup for the characterisation of the LVS instrument