PROSPECT: ESA'S PACKAGE FOR RESOURCE OBSERVATION AND IN-SITU PROSPECTING FOR EXPLORATION, COMMERCIAL EXPLOITATION AND TRANSPORTATION. E. Sefton-Nash[1*], J. D. Carpenter[1], R. Fisackerly[1], R. Trautner[1], the ESA Lunar Exploration Team, the PROSPECT User Group and the PROSPECT Industrial Team. 1. ESA/ESTEC, Keplerlaan 1, 2201 AZ, Noordwijk, The Netherlands (e.sefton-nash@cosmos.esa.int).

Introduction: The Package for Resource Observation and in-Situ Prospecting for Exploration, Commercial exploitation and Transportation (PROSPECT) is in development by ESA for application at the lunar surface as part of international lunar exploration missions in the coming decade, including the Russian Luna-27 mission planned for 2022. Establishing the utilization potential of resources found in-situ on the Moon may be key to enabling sustainable exploration and lunar habitability in the future. The purpose of PROSPECT is to support the identification of potential resources, to assess the utilization potential of those resources at a given location and to provide information to help establish the broader distribution. PROSPECT will also perform investigations into resource extraction methodologies that maybe applied at larger scales in the future and provide data with important implications for fundamental scientific investigations on the Moon.

Objectives: PROSPECT aims to assess the in-situ resource potential of lunar regolith at any given location on the Moon. In order to achieve this PROSPECT is required to:

- Extract samples from depths of at least 1m.
- Extract water, oxygen and other chemicals of interest in the context of resources.
- Identify the chemical species extracted.
- Quantify the abundances of these species.
- Characterize isotopes such that the origins and emplacement processes can be established.

In the lunar polar regions PROSPECT is able to target water ice. At all locations on the Moon PROSPECT is able to extract solar wind implanted volatiles from the regolith through heating and aims to extract oxygen and other chemicals of interest as resources from minerals by a variety of techniques.

System Functions:

Drilling and sampling. PROSPECT includes a drill system (ProSEED) (Figure 1) that is required to access the subsurface to depths of at least 1m. Once at the required depth a sampling tool removes small samples, whilst preserving sample temperature. Samples must then be extracted and handled whilst minimizing alteration of the samples. The drill is derived from that being developed for the ExoMars Rover [1] and the Rosetta drill [2]. Modifications are considered to account for unique lunar mission requirements and material properties.

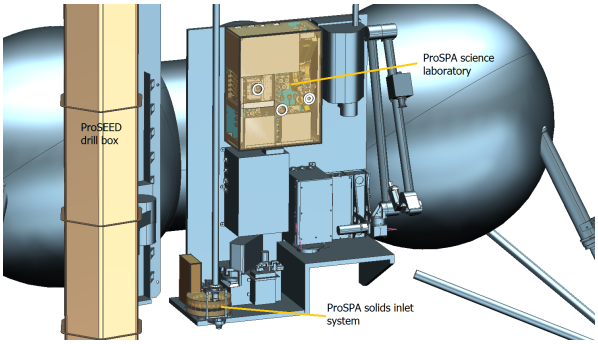

Figure 1: ProSEED and ProSPA Elements of PROSPECT on board Luna 27 platform.

Sample heating and chemical extraction. Samples are sealed in ovens, derived with heritage from those developed for ExoMars [3], Rosetta and activities performed through the German LUISE programme. Samples can then be heated to temperatures as high at 1000°C. Heating in vacuum extracts ices and solar wind implanted volatiles, and pyrolyses some volatiles from minerals. Reacting gasses may also be introduced to the ovens to extract additional chemistry of interest, including combustion with oxygen [4] and reduction using hydrogen and methane [5].

Gas compositional analysis: Evolved gasses can be analyzed using an ion trap mass spectrometer [4] in the 'ProSPA' laboratory for masses up to around 200AMU. This gives a qualitative measure of the composition.

Gas chemical processing: Target gasses are prepared for isotopic analysis through refinement or conversion to other chemicals [4]. Such conversion can prepare chemicals, which are better suited than the original compounds to analysis using a mass spectrometer and can remove isobaric interferences.

Gas isotopic analysis: Isotopes of the elements of interest are measured using a magnetic sector mass spectrometer, along with measurements of reference standards [4]. Using this technique accurate analysis is achieved, allowing comparison with laboratory measurements on Earth.

Science Questions: The described functionality allows in three key analysis modes linked to separate heating profiles: Evolved gas analysis (volatile inventory and abundance), stepped analysis (to retrieve isotopic composition) and ISRU demonstration. These can be tied to 3 overarching science questions:

1. Is water released, how much, and what else?
2. Where did it originate? Comets, asteroids, indigenous processes, etc..
3. Can we extract it via ISRU to support future exploration?

Conclusion: PROSPECT is a package for the investigation of lunar volatiles and other potential resources with potential applications for both exploration and fundamental science. The package builds on extensive flight heritage and a unique set of capabilities, developed over decades by a number of groups across Europe. PROSPECT is in development for flight on the Russian led Luna-27 mission as part of the first phase of lunar resource characterisation [6] and could be available as part of international missions in this timeframe.

References: [1] Magnani P. et al. (2010) Proceeding of i-SAIRAS. [2] Marchesi M. et al. (2001), Proceedings of the 9th European Space Mechanisms and Tribology Symposium, 91 - 96. [3] Schulte W. et al. (2010), Proceeding of i-SAIRAS. [4] Wright I.P. et al. (2012) Planetary and space science, 74, 1, p. 254 - 263. [5] Schwandt et al., (2012) Planetary and space science, 74, 1, 49-56. [6] Carpenter et al. (2016) Space Policy, 37, 2, p. 52 - 57.

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