ACCESSING AND ASSESSING LUNAR RESOURCES WITH PROSPECT. J. D. Carpenter[1], S. Barber[2], P. Cerroni[3], R. Fisackerly[1], A. Fumagalli[4], B. Houdou[1], C. Howe[5], P.G. Magnani[4] A. Morse[2], E. Monchieri[6], P. Reiss[7], L. Richter[8], F. Rizzi[4], S. Sheridan[2], L. Waugh[6], I.P. Wright[2], [1]ESA ESTEC, Keplerlaan 1, 2201AZ, Noordwijk, The Netherlands (james.carpenter@esa.int), [2]The Open University, UK, [3]INAF, Italy, [4]Selex-ES, Italy, [5]RAL Space, UK,[6]Airbus SD, UK, [7]Technische Universitaet Muenchen, Germany, [8]Kayser-Threde, Germany.

Introduction: A 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 2019.

Establishing the utilization potential of resources found in-situ on the Moon may be key to enabling sustainable exploration 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 up to 2m.
- 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 that is required to access the subsurface to depths of up to 2m. Once at the required depth a sampling tool removes small (~3 cm^3) 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 EXOMARS [1] (shown in Figure 1) and the Rosetta drill [2], currently in-situ at comet 67P/Churyumov-Gerasimenko. Modifications are considered to account for unique lunar mission requirements and material properties.

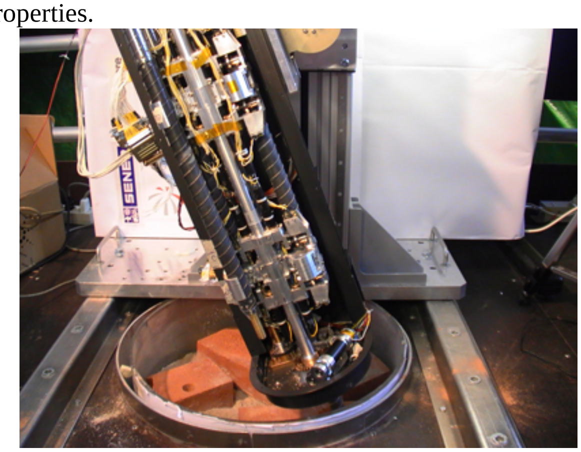

Figure 1. Breadboard of the Exomars drill from which the PROSPECT drill is derived.

Assessment of sample mineralogy and volatile content. Infrared spectra of samples are recorded, using an instrument derived from MAMISS [3] on EXOMARS, in order to provide an assessment of the mineralogy of the bulk sample and to investigate water content, prior to heating. A goal here is to extend the bandpass of the instrument from 2.2µm as for MAMISS up to 3.3µm.

Sample heating and chemical extraction: Samples are sealed in ovens, derived with heritage from those developed for EXOMARS [4], 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. A number of techniques are under investigation, based on a combination of flight heritage and laboratory investigations. These include combustion with oxygen [5], oxidation using fluorine [6] and reduction using hydrogen and methane [7].

Gas compositional analysis: Evolved gasses can be analyzed using an ion trap mass spectrometer [5]. This gives a qualitative measure of the composition. Additional separation of gas composition could be achieved through the addition of a MEMS GC, which is currently in development, but is not envisaged at this time.

Gas chemical processing: Target gasses are prepared for isotopic analysis through refinement or conversion to other chemicals [5]. Such conversion can prepare chemicals which are better suited than the original compounds to analysis using a mass spectrometer and can rremove 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 [5]. Using this technique accurate analysis is achieved, allowing comparison with laboratory measurements on Earth. The expected performance of isotopic analysis is shown in table 1.

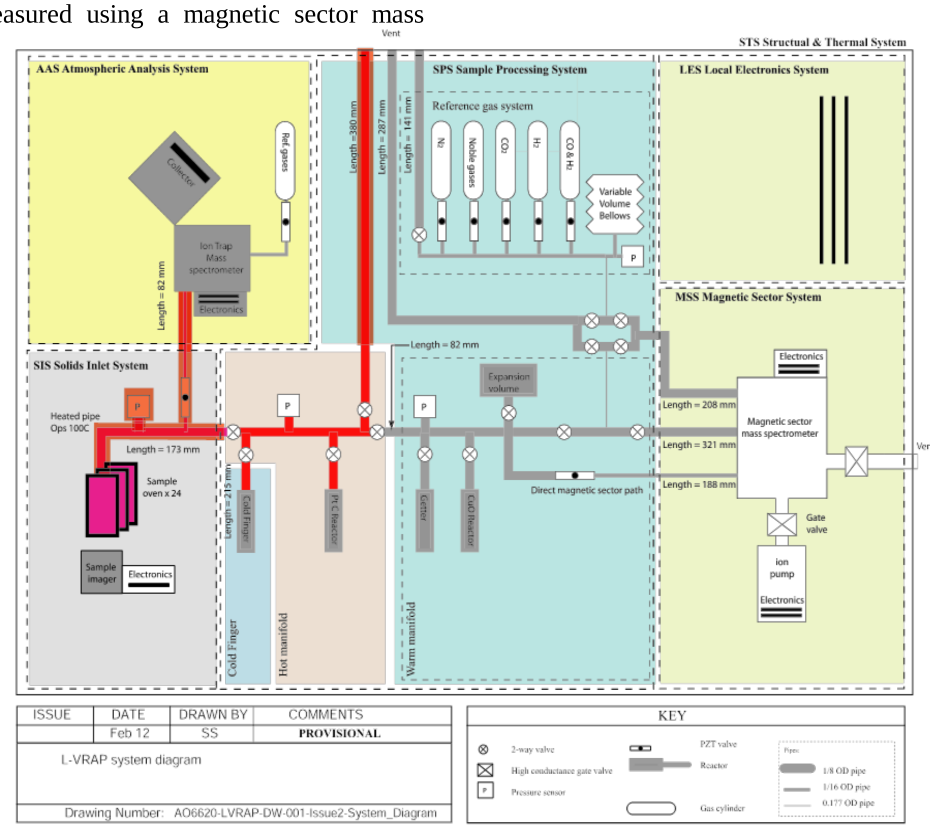

Figure 2. Schematic diagram of the PROSPECT processing and analysis system as defined during the ESA L-VRAP [5] study. In the current project phase additional functionality is being investigated to enhance the resource extraction demonstration capabilties of the system.

Isotopic ratio	Associated molecular species	Expected Precision
δD	H2, H_2O, -OH, hydrocarbons	10‰
δ^{13}C	CO, CO_2, hydrocarbons	0.1-1‰
δ^{15}N	N_2, NH_3, nitrogen oxides	0.1-1‰
δ^{18}O	H_2O, CO and CO_2	0.1‰

Table. Predicted isotopic performance of the PROSPECT analytical package, based on experience with existing flight and laboratory hardware.

Conclusions: 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 targeting flight readiness by 2019 and will be available as part of international missions in this time frame.

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] Coradini A. et al. (2011) EPSC-DPS EPSC-DPS Joint Meeting 2011 abstract. [4] Schulte W. et al. (2010), *Proceeding of i-SAIRAS*. [5] Wright I.P. et al. (2012) *Planetary and space science*, 74, 1, 254-263. [6] Sebolt W. et al, (1993) in Resources of Near Earth Space, The University of Arizona Press, 129. [7] Schwandt et al., (2012) *Planetary and space science*, 74, 1, 49-56.

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