ProsPA: A MINIATURE CHEMICAL LABORATORY FOR IN-SITU ASSESSMENT OF LUNAR VOLATILE RESOURCES. S.J. Barber[1], J.D. Carpenter[2], I.P. Wright[1], A.D. Morse[1], S. Sheridan[1], G.H. Morgan[1], E.K. Gibson Jr.[3], C. Howe[4], P. Reiss[5], L. Richter[6], R. Fisackerly[2], B. Houdou[2]. [1]The Open University, Milton Keynes, MK7 6AA, UK, [2]ESA ESTEC, The Netherlands, [3]ARES, NASA Johnson Space Center, USA, [4]RAL Space, UK, [5]Technische Universität München, Germany, [6]OHB System, Germany. simeon.barber@open.ac.uk

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 2020.

Establishing the utilisation potential of resources found in-situ on the Moon may be key to enabling future sustainable exploration. PROSPECT will support the identification of potential resources, assess the utilisation potential of those resources at a given location and 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.

PROSPECT comprises two main elements: a drill system named ProSEED designed to access samples from depths up to 2 m, and ProsPA (Figure 1), a miniature chemical laboratory for the extraction and characterisation of volatiles within those samples.

Objectives: ProsPA aims to extract, identify, quantify and isotopically characterise the volatile species present within samples extracted from up to 2 m depth. The speciation and abundance of volatiles is likely to vary widely with location on the surface of the Moon, with depth and potentially with time. ProsPA is therefore designed to identify a wide range of volatiles in a variety of chemical and physical forms, and to have wide dynamic range to determine both trace and more abundant species. At all locations on the Moon ProsPA 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. In the lunar polar regions ProsPA is able to target water ice and other cold-trapped volatiles. In summary, ProsPA will:

- extract water, oxygen and other chemicals of interest in the context of resources
- identify the chemical species extracted.
- quantify the abundances of these species
- characterise their stable isotope compositions such that their origins, emplacement processes and evolution on the Moon can be established.

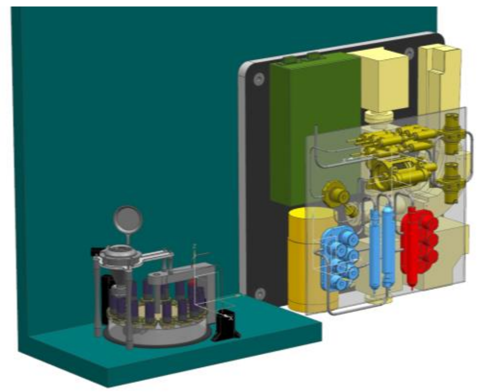

Figure 1. Conceptual representation of ProsPA. The main unit (right) containing the chemical laboratory and the electronics is housed separately from the sample ovens and carousel (left) which must be maintained cold prior to sample introduction to prevent loss of volatiles.

Operational description: The ProSEED drill will obtain and handle samples and transfer these to ProsPA with minimal alteration. The samples are then sealed in ovens, derived with heritage from those developed for EXOMARS [1], Rosetta and activities performed through the German LUISE [2] programme. Samples can then be heated to temperatures as high as 1000°C or more. Heating in vacuum extracts ices and solar wind implanted volatiles and pyrolyses some volatiles from minerals. Reagent gases 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 pure oxygen [3], oxidation using fluorine [4] and reduction using hydrogen and methane [5]. Such extractions may provide demonstration of the feasibility of in-situ resource utilisation (ISRU) on the lunar surface.

The heating process can be undertaken in either of two ways. By using a continuous heating ramp the evolved gases can be monitored in real time, using an ion trap mass spectrometer based upon that recently operating in the Rosetta mission [6]. This gives a qualitative measure of the composition, and provides an indication of the overall concentrations of volatiles within the sample, allowing subsequent analysis steps to be tailored accordingly. This mode is well-established as a means of detecting a range of released volatiles and the release temperature is diagnostic of the nature of the starting material in the sample (Figure 2). As a goal it may also possible to detect phase changes taking place during the heating process.

Alternatively the heating may be undertaken in steps (in vacuum i.e. stepped pyrolysis or in oxygen i.e. stepped combustion – Figure 3). The gases evolved in each step are purified or subjected to certain pre-preparations [3], before isotopic determination in a magnetic sector mass spectrometer derived from the Beagle 2 Gas Analysis Package. This yields results with sufficient accuracy and precision to enable comparison with laboratory measurements on Earth.

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 ProsPA element builds on extensive flight heritage and capabilities developed over decades by a number of groups across Europe and is targeting flight readiness by 2020.

References: [1] Schulte W. et al. (2010), *Proceeding of i-SAIRAS*. [2] Reiss P. et al. (2014) *ELS*, 65-66. [3] Wright I.P. et al. (2012) *Planetary & Space Science*, 74, 1, 254-263. [4] Sebolt W. et al, (1993) in Resources of Near Earth Space, University of Arizona Press, 129. [5] Schwandt et al., (2012) *Planetary & Space Science*, 74, 1, 49-56. [6] Andrews et al., *Planetary & Space Science*, 66, 1, 179-186. [7] Gibson E.K., Jr. et al. (1972) *Proc. Lunar Sci. Conf.* 2029-2040.

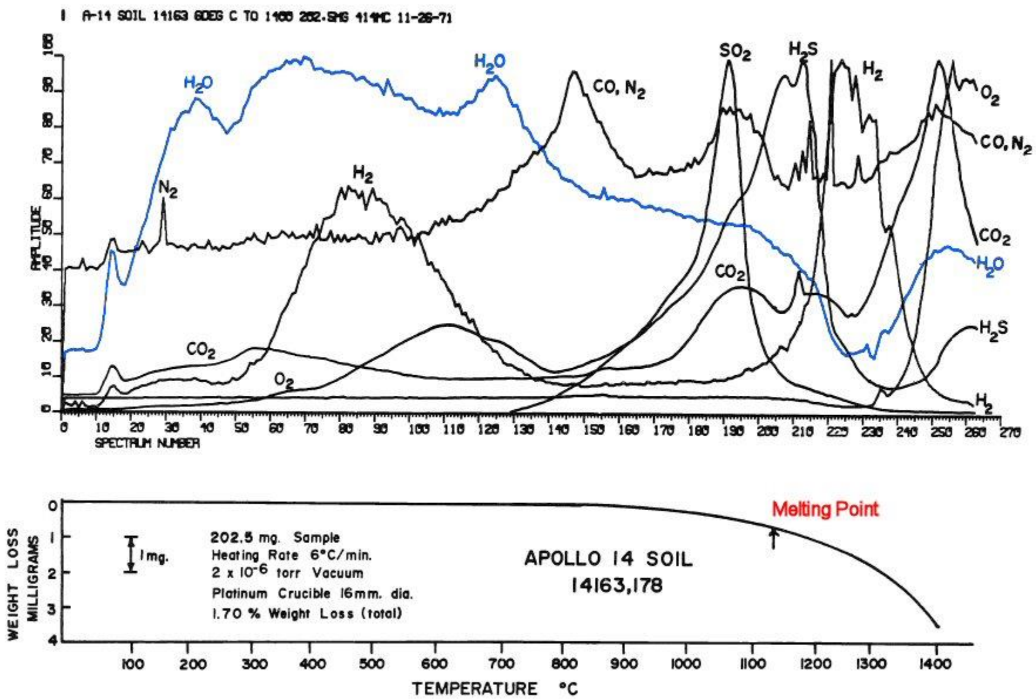

Figure 2. Evolved gas release from Apollo 14 lunar soil 14163 [7]. Volatiles released during heating lunar soil 14163 at 6°C/min from room temperature to 1400°C. Gas releases are normalized to 100% at the temperatures of greatest abundance.

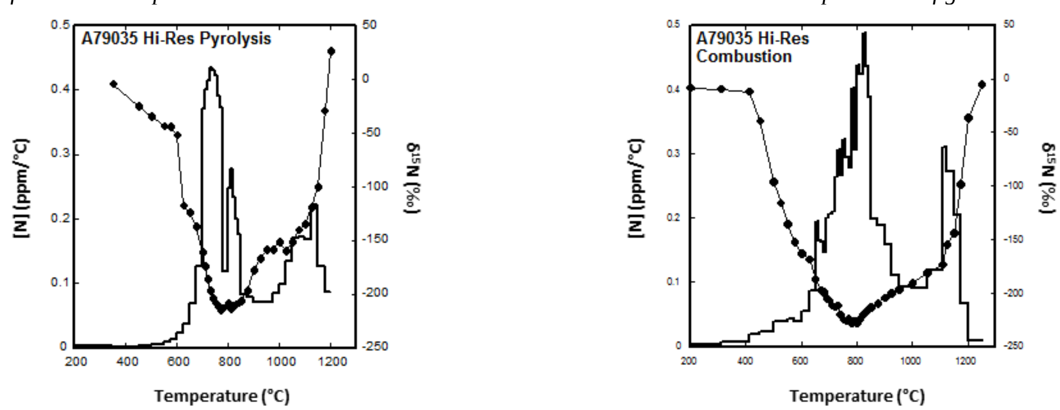

Figure 3. Stepped extraction by a) (left) pyrolysis b) (right) combustion of nitrogen from lunar breccia 79035; the profiles are similar but not identical and demonstrate that nitrogen in lunar regolith samples is a complex mixture. Credit: CT Pillinger