Open Research Online

The Open University's repository of research publications and other research outputs

PROSPECTing for Lunar Polar Volatiles: the ProSPA Miniature In-situ Science Laboratory

Conference or Workshop Item

How to cite:

Barber, S. J.; Smith, Phillipa; Wright, Ian; Abernethy, Feargus; Anand, Mahesh; Dewar, Kevin; Hodges, Martyna; Landsberg, Peter; Leese, Mark; Morgan, Geraint; Morse, Andrew; Mortimer, James; Sargeant, Hannah; Sheard, Iain; Sheridan, Simon; Verchovsky, Sasha; Goesmann, F.; Howe, C.; Morse, T.; Lillywhite, N.; Quinn, A.; Missaglia, N.; Pedrali, M.; Reiss, P.; Rizzi, F.; Rusconi, A.; Savoia, M.; Zamboni, A.; Merrifield, J.; Gibson, Everett; Carpenter, J.; Fisackerly, R. and Houdou, B. (2017). PROSPECTing for Lunar Polar Volatiles: the ProSPA Miniature In-situ Science Laboratory. In: European Lunar Symposium (ELS) 2017, 2-3 May 2017, Munster, Germany.

For guidance on citations see FAQs.

© 2017 The Authors

https://creativecommons.org/licenses/by-nc-nd/4.0/

Version: Version of Record

Link(s) to article on publisher's website:
https://els2017.arc.nasa.gov/

Copyright and Moral Rights for the articles on this site are retained by the individual authors and/or other copyright owners. For more information on Open Research Online's data policy on reuse of materials please consult the policies page.

oro.open.ac.uk

PROSPECTing for Lunar Polar Volatiles: the ProSPA Miniature In-situ Science Laboratory. S. J. Barber[1], P. H. Smith[1], I. P. Wright[1], F. Abernethy[1], M. Anand[1], K. R. Dewar[1], M. Hodges[1], P. Landsberg[1], M. R. Leese[1], G. H. Morgan[1], A. D. Morse[1], J. Mortimer[1], H. M. Sargeant[1], I. Sheard[1], S. Sheridan[1], A. Verchovsky[1], F. Goesmann[2], C. Howe[3], T. Morse[3], N. Lillywhite[4], A. Quinn[4], N. Missaglia[5], M. Pedrali[5], P. Reiss[6], F. Rizzi[7], A. Rusconi[7], M. Savoia[7], A. Zamboni[7], J. A. Merrifield[8], E. K. Gibson Jr.[9], J. Carpenter[10], R. Fisackerly[10] and B. Houdou[10]. [1]School of Physical Sciences, The Open University, Milton Keynes, MK7 6AA, UK (simeon.barber@open.ac.uk), [2] Max Planck Institute for Solar System Research (MPS), Germany, [3]RAL Space, UK, [4]Airbus Defence and Space, UK, [5]Media Lario Technologies, Italy, [6]Technical University of Munich, Germany, [7]Leonardo S.p.A., Italy, [8]FGE Ltd., UK, [9]ARES, NASA Johnson Space Center, USA, [10]ESA ESTEC, Netherlands.

Introduction: The Package for Resource Observation and in-Situ Prospecting for Exploration, Commercial exploitation and Transportation (PROSPECT) is in development by the European Space Agency (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 2021. PROSPECT will search for and characterize volatiles in the lunar polar regions to answer science questions and investigate the viability of these volatiles as resources.

ProSPA is the name given to the Sample Processing and Analysis element of PROSPECT. Its functions are to receive samples extracted from the lunar sub-surface by the ProSEED drill, and to perform a suite of analytical experiments aimed at understanding the nature, source, evolution and utility of the volatiles therein. These functions are distributed across two physical units – a Solids Inlet System (SIS) comprising a series of single-use sample ovens on a rotary carousel together with a sample imager, and a miniature chemical analysis laboratory incorporating two mass spectrometers and associated ancillary and control systems (Figure 1). The science output is anticipated to be the identity, quantity and isotopic composition of volatiles as a function of depth within the first 1.2 m of the lunar surface.

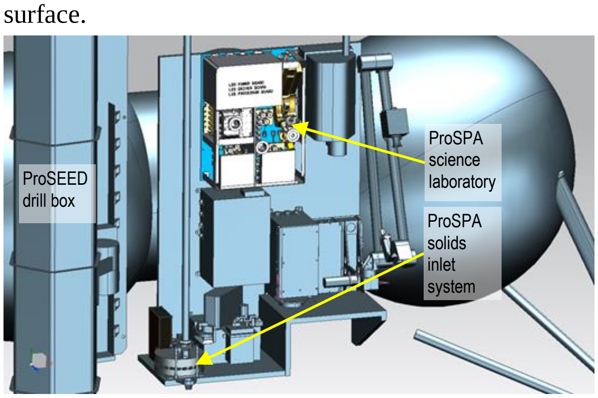

Figure 1: Location of ProSPA units and ProSEED drill box on Luna-27 lander (credit IKI/Roscosmos)

Volatiles Preservation: The local regolith temperature in the sampled site is assumed to be ~120 to 150 K. A wide range of volatiles may be present in a variety of forms, including physically (loosely) bound and chemically (more strongly) bound species. A key challenge is to minimize the uncontrolled loss of volatiles before they can be sealed in the ProSPA oven for analysis. The stability (hence rate of loss) of lunar volatiles is a strong function of temperature [1] as well as particle size [2]. For this reason the drill and operations strategy will be optimized to minimize the heating of the regolith during sampling, and attention will be paid to the time-temperature profile of the samples following excavation. The SIS is thermally isolated from the "warm" enclosure of the chemical analysis unit, allowing the oven to be at 120 K or colder when the sample is directly transferred into it from the drill. After sample transfer the carousel is rotated to place the sample-containing oven under an imager which confirms the presence of sample and enables estimation of the sample volume (up to a few tens of cubic mm). Then the sample oven is rotated to the "tapping station" position where an actuator is used to seal the oven to a pipe which runs to the chemical analysis laboratory. The duration from sample extraction to sealing will be minimized to reduce volatile losses.

Volatiles Extraction: Volatiles are extracted from the sample through heating within the sealed sample oven. A number of heating profiles are envisaged to accomplish a variety of analysis modes (Figure 2).

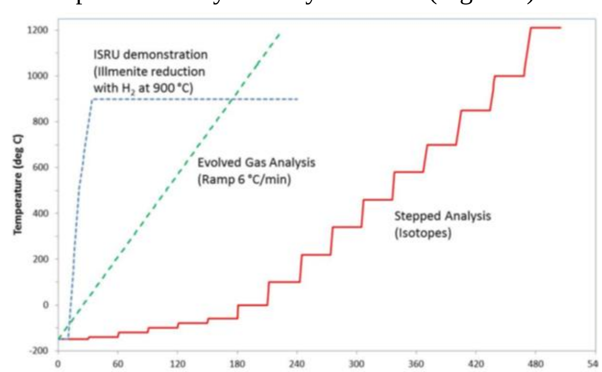

Figure 2: Example sample heating profiles

Evolved gas analysis: the oven is heated at a ramp rate of 6°C/min and the released gases are continuously analyzed by mass spectrometer to afford evolved gas analysis plots of the type previously presented for analysis of Apollo samples [3].

In Situ Resource Utilization (ISRU) demonstration: the oven is heated to 900 °C in the presence of added hydrogen feed gas to extract oxygen through reduction of mineral phases.

Stepped pyrolysis or combustion: gases released at a series of fixed temperatures from samples in vacuum or in oxygen respectively are sequentially processed for isotopic analysis in a magnetic sector mass spectrometer.

Volatiles Analysis: Volatiles released through the previously described extraction processes are passed to the ProSPA chemical laboratory for analysis. This comprises an ion trap device for analytical mass spectrometry (target m/z range 2-200 amu) and a magnetic sector instrument for stable isotopic analysis (~per mil level precision), together with the associated gas handling and processing components including open/closed valves, metering valves, micro-reactors, pressure sensors, reference materials etc. The subsystems of the chemical laboratory are shown in Figure 3.

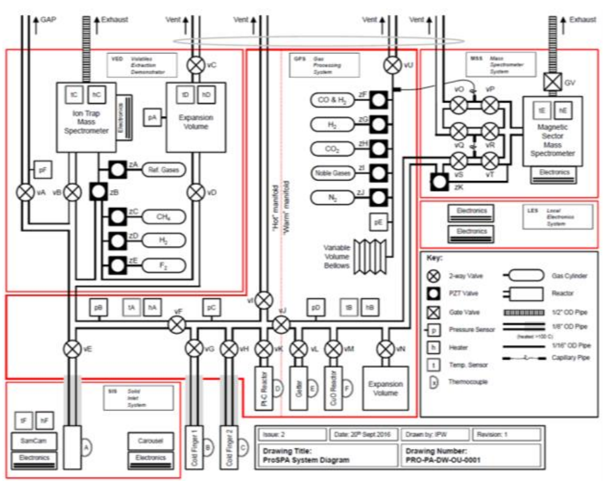

Figure 3: Schematic diagram of ProSPA Solids Inlet System and science laboratory

Instrument Heritage: To minimise development timescales in line with the schedule of the Luna-27 Roscosmos-ESA mission to the lunar south pole in 2021, the ProSPA instrument draws heavily upon European heritage in flight hardware. The Solids Inlet System is based upon similar systems flown on Rosetta Philae [4] and in development for ExoMars rover [5], adapted for the lunar environment and sample nature. The ion trap mass spectrometer is based on the lightweight (<500 gram all-in) device which made the first chemical analyses on the surface of a comet on board Rosetta Philae [6]. The magnetic sector instrument for isotopic analysis is based upon that developed for the Gas Analysis Package on the Beagle 2 Mars lander [7]. Further gas processing components, electronics and software share similar heritage and the team developing ProSPA is based on previous successful missions.

Current Status: ProSPA is currently in Phase B, with a Preliminary Design Review scheduled for Q4 2017. Theoretical and laboratory work is underway to develop and confirm key aspects of the instrument design and performance. The means for sealing the sample oven in the lunar environment has been investigated, including the design of elastomer seals resilient to moderate loadings of dust on their sealing surfaces. A combination of experimental work and modeling will be implemented to demonstrate the adequate preservation of volatiles between the point of delivery of samples from the drill up to and including their sealing within the oven. The temperature release profiles shown in Figure 2 will be iterated with a view to reducing the duration of the extractions in order to minimise the resource requirements (power, time, energy). The current predictions are that ProSPA requires 10 kg and peak power of ~70 W.

Conclusions: ProSPA is a powerful and versatile scientific laboratory for the analysis of lunar volatiles. Using techniques developed in the laboratory and refined in previous missions it will identify, quantify and isotopically characterise (D/H, $\delta^{13}C$, $\delta^{15}N$, $\delta^{18}O$) samples extracted from up to 1.2 m depth by the ProSEED drill. The acquisition of contextual images of the samples and the use of on-board reference materials will enable the results from ProSPA to be interpreted in the context of existing lunar data-sets.

Acknowledgement: ProSPA is being developed by a consortium led by The Open University, UK, under contract to the PROSPECT prime contractor Leonardo S.p.A., Italy, within a programme of and funded by the European Space Agency.

References:

[1] Zhang J. A. and Paige D. A. (2009) *Geophys. Res. Lett.*, Vol. 36, L16203 [2] Andreas E. L. (2007) *Icarus* 186 24–30 [3] Gibson E. K., Jr. et al. (1972) *Proc. Lunar Sci. Conf.* 2029-2040 [4] Finzi A. et al., (2007) *Sp. Sci. Rev. 128: 281–299* [5] Goetz, W. (2016) *Int. J. Astrobiology* 15 (3): 239–250 [6] Wright, I. P. (2015) *Science* Vol.349 (6247), pp.aab0673 [7] Wright, I. P. (2003) *Analyst*, 128, 1300-1303