THE ESA PROSPECT PAYLOAD FOR LUNA 27: DEVELOPMENT STATUS. D. Heather[1], E. Sefton-Nash[1], R. Fisackerly[1], R. Trautner[1], S. J. Barber[2], P. Reiss[1], D. Martin[3], B. Houdou[1], the PROSPECT Science Team and Industrial Consortium. [1]ESTEC, European Space Agency, Keplerlaan 1, Noordwijk 2201AZ, Netherlands (David.Heather@esa.int), [2]The Open University, Walton Hall, Milton Keynes, UK, [3]ECSAT, European Space Agency, Harwell, Oxford.

Introduction: The Package for Resource Observation and in-Situ Prospecting for Exploration, Commercial exploitation and Transportation (PROSPECT) is a payload in development by ESA for use at the lunar surface. Current development is for flight on the Russian-led Luna-Resource Lander (Luna 27) mission, which will target the south polar region of the Moon. PROSPECT will perform an assessment of volatile inventory in near surface regolith (down to ~ 1 m), and elemental and isotopic analyses to determine the abundance and origin of any volatiles discovered [1]. Lunar polar volatiles present compelling science and exploration objectives for PROSPECT, but solar wind-implanted volatiles and oxygen in lunar minerals (extracted via ISRU techniques) constitute potential science return anywhere on the Moon, independently of a polar landing site. PROSPECT is comprised of the ProSEED drill module and the ProSPA analytical laboratory plus the Solids Inlet System (SIS), a carousel of sealable ovens (for evolving volatiles from regolith) (Fig. 1).

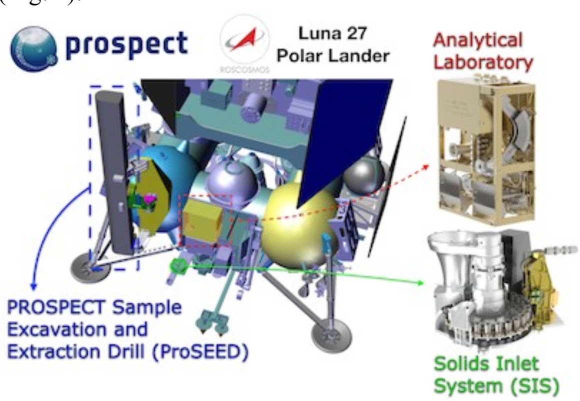

Figure 1: *Renderings of PROSPECT onboard Luna 27 polar lander, including the ProSEED drill module (left), and ProSPA (right). ProSPA comprises 1) the Solids Inlet System (lower right) to receive samples from drill sampling mechanism, with sample camera assembly (SamCam [2]) and carousel of ovens for volatile extraction from regolith samples, and 2) the analytical laboratory (upper right) containing a gas processing system, and magnetic sector plus ion-trap mass spectrometers.*

PROSPECT has a number of sensors and instruments (ion-trap and magnetic sector mass spectrometers, imagers, and sensors for temperature, pressure, permittivity and torque) that form the basis for a range of science investigations that are led by the PROSPECT Science Team:

- Imaging, Surface Modelling and Spectral Analysis
- Drilling, Geotechnics and Sample Handling
- ProSPA ISRU Precursor Experiments
- ProSPA ISRU Prospecting
- ProSPA Light Elements & Isotopes
- ProSPA Noble Gases
- Thermal Environment and Volatile Preservation
- Permittivity (ESA-led)

Development status and current activities: PROSPECT Phase C, ‘detailed definition’, began in December 2019. In parallel to the industrial schedule undertaken, an associated plan of research activities has been formulated to gain from and guide ongoing development, build strategic scientific knowledge, and to prepare for operation of the payload.

Drill Testing: A plan of tests of the ProSEED Development Model was carried out in December 2019 as part of the final Phase B activities. Test procedures were formulated to demonstrate drilling and sampling functionality in ambient, cold and thermal vacuum (TV) laboratory conditions (at CISAS, University of Padova). Tests included drilling into, and sampling from, well-characterized NU-LHT-2M simulant mixed with anorthosite inclusions of various sizes. Material in the test container was prepared according to a layered scheme that describe depth-density profile and distribution of inclusions. The scheme was derived by the Sample Analogue Curation Facility (SACF) at ESA ECSAT [3] to cover a plausible range of lunar regolith characteristics, and was informed by parameters measured from Apollo cores and retrieved from thermal infra-red orbital observations [e.g. [4]]. For tests in thermal vacuum, material was prepared for cases with water content representative of regolith that ranged from ‘dry’ to ‘saturated’ (0 - ≲12 wt. %).

The outcome of drill tests was positive: the main functionalities of the drill system were demonstrated and required performances were achieved over the range of laboratory and representative conditions. This included: delivery from the drill sampling mechanism to ProSPA dummy ovens, delivery of a larger sample for analysis by Russian instruments, and successful drilling through/into a block of anorthosite (a single large inclusion deliberately placed in the drill path).

Simulants sampled during drill tests were collected and will be received at ECSAT [3] for curation and distribution to the Science Team, for analysis of materials to determine the extent of modification to regolith during handling.

ProSPA Bench Development Model (BDM): The BDM of the ProSPA analytical lab has been developed and tested at The Open University (OU) in UK to demonstrate science performance against measurement requirements. Dedicated efforts recently focused on verifying evolved gas analysis (EGA) via measurement of meteorite standards, constraining oxygen yield via demonstration of ISRU capabilities [5, 6] improving understanding of sensitivity of science requirements to regolith volatile abundance and possible contamination, and understanding the performance of oven seal materials [7].

Additional opportunities for PROSPECT related hardware: A variant of the ion-trap mass spectrometer in the ProSPA analytical laboratory has been developed for flight in the Peregrine Ion-Trap Mass Spectrometer (PITMS) instrument on the Astrobotic Peregrine-1 mission, which will fly to *Lacus Mortis* in mid-2021 [8]. The contribution is known as the Exospheric Mass Spectrometer (EMS) and is supplied by OU and procured by ESA. PITMS is led by NASA Goddard Space Flight Center and developed through the NASA-Provided Lunar Payloads (NPLP) Program, within NASA's Commercial Lunar Payload Services (CLPS). As will be the case on PROSPECT, PITMS will monitor the time-variant nature of the local exosphere as it responds to natural stimuli such as changing illumination, as well as the lander-induced effects. Mass spectra in the range m/z 10 to 150 will be acquired at up to 10 Hz, and time-integrated in-situ to build S/N [9]. EMS is the second payload element confirmed in the PROSPECT series (also see [10] regarding the lunar instrumented drill 'i-Drill'). Repeat flights of EMS are planned to other lunar localities, to further understand the global lunar water cycle and the impact of lunar missions on volatiles and exploration science. These additional flight opportunities for EMS will be extremely valuable not just in their own scientific return, but also to help us optimize the corresponding development and operations of the ProSPA ion trap mass spectrometer on PROSPECT.

Volatile Preservation: Particular efforts have recently focused on understanding the capability of PROSPECT to sufficiently preserve volatile content in regolith throughout the sampling-analysis chain: from drilling to sealing of the ovens, and until measurement of evolved gases in ProSPA's ion-trap and magnetic sector mass spectrometers [11]. PROSPECT's ability to meet science requirements must persist for the range of possible volatile contents expected in near-surface regolith at landing sites in the lunar south polar region, e.g. [12].

In 2020, a detailed plan of modelling and experimental work has been formulated and is being coordinated between the Science Team, industrial consortium and ESA project team to better understand water sublimation rates in realistic lunar surface operational environments, regolith structures, and geometries (such as those that are representative of the ProSPA ovens [13]), and better constrain the potential effect on measured D/H of sublimation of lunar water ice (for example, elaborating from [14]). Results stemming from this collection of work will ensure that even in a 'hot operational case', e.g. where local illumination and thermal conditions at the landing site cause non-trivial sublimation before regolith samples can be sealed in ProSPA ovens, the original inventory and isotopics can be determined with sufficiently constrained uncertainties.

CAPTEM sample analysis: In relation to the volatile loss and preservation, PROSPECT Science Team members also requested two samples of lunar regolith (2 g each) from the Apollo collections (14163 and 69921). The request was approved in summer 2020, and the team now await delivery of the samples to begin work (delayed as a result of the pandemic). The proposed experiments will investigate the loss of water ice from samples through sublimation in conditions analogous to the lunar environment. Of particular interest are the effects that the bulk properties and the ice-regolith coupling have on the sublimation process when compared with pure water ice and regolith simulants. Bulk chemical analyses will also be performed at OU, University of Manchester and CRPG. These studies will also be performed using the ProSPA BDM.

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