THE ESA PROSPECT PAYLOAD FOR LUNA 27: DEVELOPMENT STATUS.

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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).

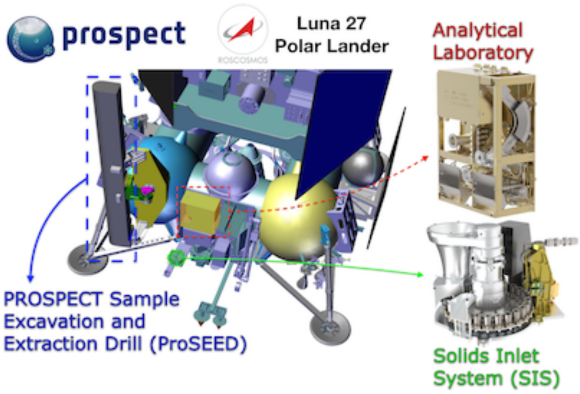

Figure 1: *Renderings of PROSPECT aboard Luna 27 polar lander, including the ProSEED drill module (left), and ProSPA (right). ProSPA comprises 1) the Solids Inlet System (lower right) to receive samples from drill sampling mechanism, with sample camera assembly (SamCam [2]) and carousel of ovens for 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.*

In ensemble, PROSPECT has a number of sensors and instruments (ion-trap and magnetic sector mass spectrometers, imagers, and sensors for temperature, pressure, and permittivity) that form the basis for a range of science investigations that are (almost all) 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, cryogenic (at Leonardo laboratories) and thermal vacuum 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 targtetted water contents ranging from 'dry' to 'saturated' (0-~10 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 at the Open University has been tested to demonstrate science performance against measurement requirements. Dedicated efforts in 2019 focused on verification of evolved gas analysis (EGA) via measurement of meteorite standards, constraint of 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].

Volatile Preservation: Particular efforts since 2018 have 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. 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. [8].

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 representative of ProSPA ovens [9]), and better constrain the potential effect on measured D/H of sublimation of lunar water ice (for example, elaborating from [10]). 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 compact uncertainties.

Landing Sites: Locations accessible to solar-powered landers seeking a volatile-rich subsurface must meet a complex combination of low mean solar illumination (leading to metrics of volatile stability [8, 13] and abundance [14]), sufficient solar energy for the lander, safe landing site characteristics, and suitable communication geometry to support data links. Such trade-offs constitute the core of lunar polar landing site studies [e.g. 15, 16].

In the event of landing at a location that does not contain cold-trapped volatile content in the accessible subsurface, we find that roughly half of PROSPECT's science and exploration objectives would be affected only negligibly, but the remainder would suffer a reduced degree of achievement. We are assessing the spatial distribution of favourable landing sites. These are identified as locations where landing ellipses (defined by the performance of ESA's PILOT precision landing package) contain sufficiently high fractions of terrain that meet a suite of operational requirements and scientifically favourable criteria.

PROSPECT Ion-Trap Mass Spectrometer (PITMS): A variant of the ion-trap mass spectrometer in the ProSPA analytical laboratory has been selected for flight on the Astrobotic Peregrine-1 mission, which will fly to *Lacus Mortis* in mid-2021. The instrument part of PITMS is supplied by the Open University and procured by ESA. PITMS is developed through the NASA-Provided Lunar Payloads (NPLP) Program, and part of NASA's Commercial Lunar Payload Services (CLPS). PITMS will monitor the decay in the local exospheric pressure following landing, providing knowledge on lander-sourced contamination by scanning up to m/z 150 at up to 10 Hz, and time-integrating mass spectra in-situ to build S/N [11]. PITMS is the second payload confirmed in the PROSPECT series (also see [12] regarding the lunar 'i-Drill') and will add strategic value to interpreting results of future lunar volatile detection instruments/payloads.

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