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Targeting Lunar Volatiles with ESA's PROSPECT Payload

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1. 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. 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 ProSPA analytical laboratory [1] (Fig. 1). In ensemble, PROSPECT has a number of sensors and instruments (ion-trap and magnetic sector mass spectrometers, cameras, and sensors for temperature, pressure, permittivity and torque) that form the basis for a range of science investigations [2]. These investigations will be led by the PROSPECT Science Team (appointed in 2019).

2. Development status and current activities

Tests of the PROSPECT Drill Module, ProSEED, in 2019 are intended to demonstrate drilling and sampling functionality in ambient, cold and thermal vacuum (TV) laboratory conditions (at CISAS, University of Padova). Drill development model tests comprise drilling into, and sampling from, lunar regolith simulant characterised and supplied by the Sample Analogue Curation Facility (SACF) at ESA/ECSAT [3]. Regolith density-depth profiles and grain size distributions in test materials are selected to cover plausible ranges expected for lunar regolith, informed by parameters measured from Apollo cores and retrieved from thermal infra-red orbital observations [e.g. 4]. Most relevant to polar regions, material for tests in TV is prepared with water content representative of regolith that ranges from 'dry' to 'saturated' (0 - ≲12 wt. %). In addition, both completed work [5] and on-going efforts seek to better quantify the potential effect of possible volatile loss during sampling, including the effect on measured D/H of sublimation of lunar water ice.

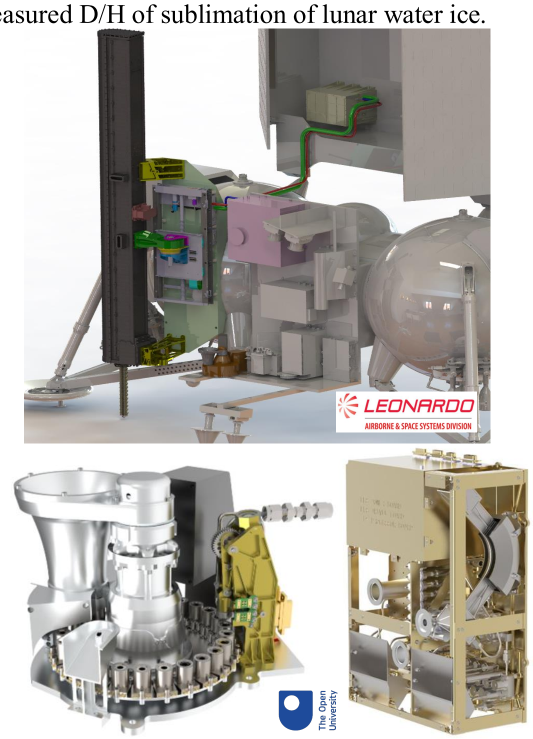

Figure 1: Renderings – Top: PROSPECT (non-grey items) mounted on Luna 27, including ProSEED drill module (left). Bottom left: Solids Inlet System to receive samples from drill sampling mechanism, with sample camera assembly (Sam-Cam) and carousel of ovens for volatile extraction from regolith samples. Bottom right: ProSPA analysis package, containing magnetic sector and ion-trap mass spectrometers.

3. Access to subsurface volatiles

Abundant yet not totally aligned evidence regarding the presence of water ice on the lunar surface (visible to far-IR) and in the near subsurface (radar, neutrons, LCROSS [6]) leaves much to be determined regarding the distribution of volatiles at the lunar poles. Work by [7] identified regions of volatile stability, where temperatures never exceed a volatility threshold (~110K, but dependent on diffusion rates of water molecules in regolith) such that sublimation to vacuum results in loss rates < 1 kg m^{-2} Ga^{-1} (Figure 2). Many locations at the lunar south pole show such zones, and many zones extend to the surface in PSRs (lightest blue in Figure 2).

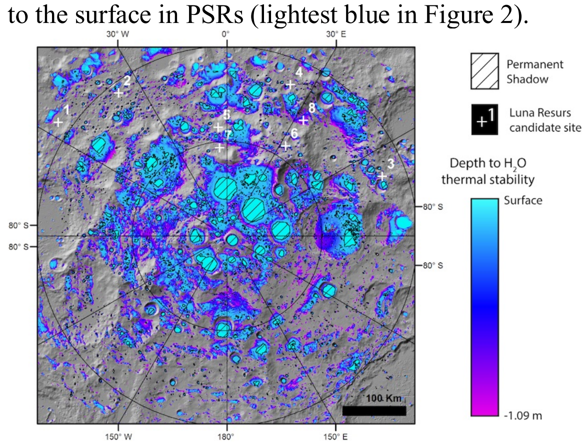

Figure 2: Lunar south polar region; Zones of thermal stability in the sub-surface permitting the presence of water-ice, data from [7]. Candidate sites identified by IKI/Roscosmos and Permanently Shadowed Regions (PSRs) [8] are also marked. The Luna 27 lander will not operate in PSRs.

The vast majority of zones of water-ice stability lie much shallower than 1m (Figure 3). Thus, if water ice exists and is stable in the lunar polar sub-surface, it is likely to be accessible in the top few 10s of cm. This result introduces a trade-space where competing requirements are oppositely-sensed for solar-powered spacecraft, such that solar illumination must be maximized for the purposes of power and thermal operational constraints, but simultaneously minimised such as to target areas where illumination is not so high that volatile stability criteria are not met in the shallow subsurface. Indeed, for missions targeting subsurface volatiles it is clear that careful landing site selection, precision landing and consideration of locally and seasonally-timed illumination conditions is of high importance.

The delivery function for lunar water is not well constrained over geologic time, and convolved with that uncertainty is another introduced by seasonal variation of insolation [9]. Moreover, Ga-scale variations in lunar orbit and obliquity have likely greatly modified the available cold-trapping area over time [10].

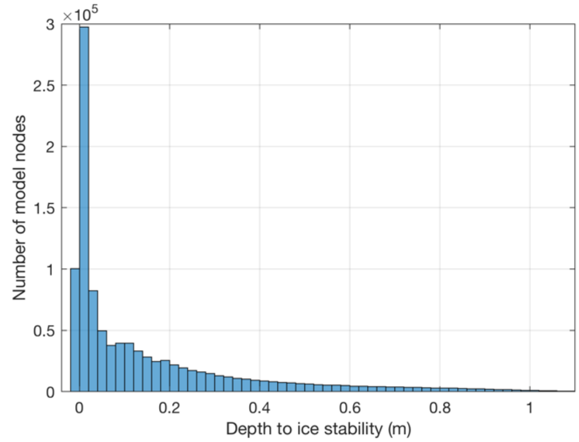

Figure 3. For locations where the water ice stability criterion is met in [7] (Figure 2), distribution of depth to stability.

The relative importance of scattering and shadowing to the lunar thermal environment increases at high latitudes, which has led to [11] combining a 1D heat-flow parameterisation [4] and ray-tracing models [7, 12] in order to better constrain subsurface thermal environments in lunar polar regions. This type of work will be crucial for lunar polar mission planning.

Acknowledgements

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References

[1] Barber et al., (2018), Euro. Lunar Symp. Abstract #099. **[2]** Sefton-Nash et al., (2018), Euro. Lunar Symp., Abstract 114. **[3]** Martin and Duvet (2019) 50th LPSC, LPI Contrib. No. 2132, Abstract #2663. **[4]** Hayne et al. (2017), J. Geophy. Res., 10.1002/2017JE005387. **[5]** Mortimer et al., (2018), Plan. Space Sci. 158, p. 25-33. **[6]** Colaprete et al., (2010), Science 330, p. 463-468. **[7]** Paige et al. (2010), Science, 330, 479. **[8]** Mazarico et al., (2011), Icarus 211, p. 1066-1081. **[9]** Williams et al. (2019), 50th LPSC, LPI Contrib. No. 2132, Abstract #2852. **[10]** Seigler et al. (2015), Icarus 255, p. 78-87. **[11]** Vasavada et al. (1999) J. Geophys. Res. 141, 179-193. **[12]** Warren et al., (2019) 50th LPSC, LPI Contrib. No. 2132, Abstract #2040.