The ESA PROSPECT Payload for Luna 27: Development Status

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Overview

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 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.

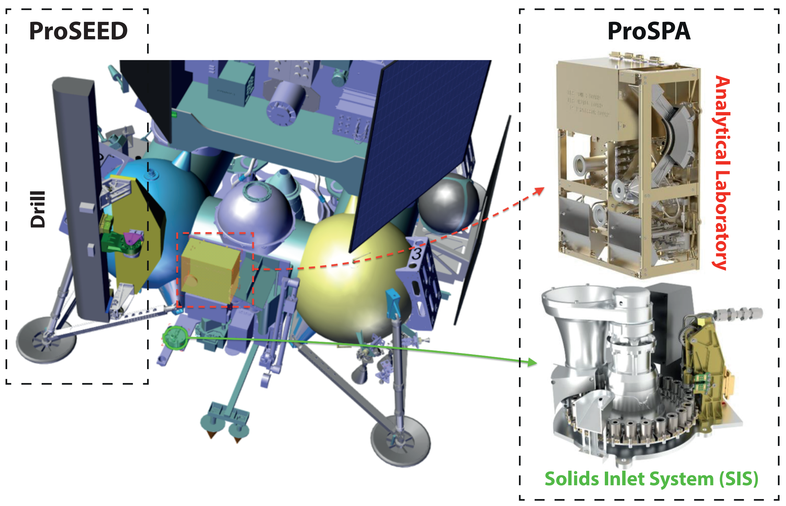
PROSPECT Payload Elements

ProSEED Drill System

ProSEED will retrieve samples from up to 1 m depth in lunar polar regolith and is designed to enable volatile preservation during sampling, and during transfer to the Solids Inlet System (SIS), part of ProSPA. It will also house a multi-spectral camera and permittivity sensor mounted in the drill rod for investigation of subsurface properties.

ProSPA Sample Handling and Analysis

ProSPA enables to measure the volume of drilled samples, hermetically seal them in ovens for heating up to ~1000°C, and measure the abundance and composition (inc. isotopic) of evolved volatiles using ion-trap and magnetic sector mass spectrometers.



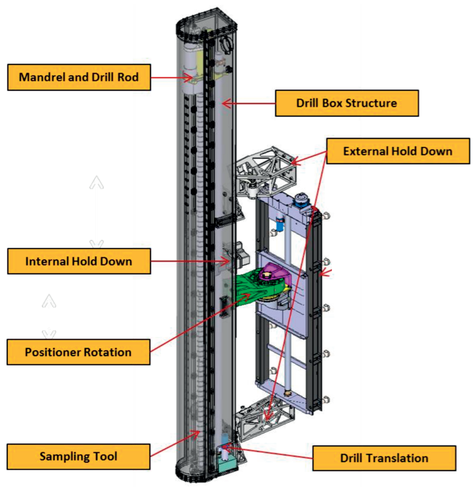
Development Status

The PROSPECT payload is an element of the European Exploration Envelope Programme (E3P) in ESA's Directorate of Human and Robotic Exploration (HRE).

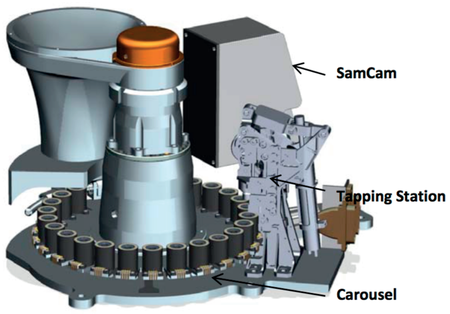
PROSPECT Phase C, 'detailed definition', began in December 2019. An plan of research activities is in progress to gain from and guide ongoing development, build strategic scientific knowledge, and to prepare for operation of the payload.

PROSPECT Investigations on Lunar Regolith Samples

In ensemble, PROSPECT has a number of sensors and instruments (including 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:



ProSEED drill and positioner components.



ProSPA SIS CAD showing carousel, ovens, tapping station (for oven sealing) and SamCam.

1. Drilling, Geotechnics, and Sample Handling

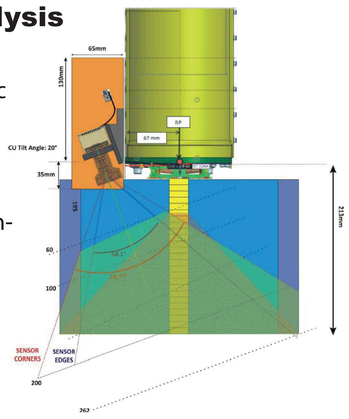
Data returned from the ProSEED drill system can be used to derive regolith physical properties.

This Investigation will retrieve and analyse mechanical and other relevant physical properties of lunar regolith at the landing site, to provide both context to the other measurements made and to support development of future exploration systems targeting similar lunar polar landing sites.

Sample behaviour during handling, as evidenced by sensors (cameras, temperature sensors) may also be relevant information sources for this Investigation.

2. Imaging, Surface Modelling and Spectral Analysis

The PROSPECT payload has two cameras, each with the possibility to sample spectra using a broadband visible detector with filters at specific bandpassess:



1) Drill-mounted multi-spectral imager (6 LED groups ~450-960 nm) to monitor and analyse the drill work area, boreholes and drill cuttings, as well as the landing site, allowing interpretation of local geology and constraint of local topography and illumination. It will also monitor robotic sample transfer operations to ProSPA's Solids Inlet System (SIS) and the Russian robotic arm on Luna 27.

2) Sample camera (SamCam) allows depth-mapping of sample deposit surfaces after they have been deposited in ovens, to retrieve sample volume used in abundance measurements.

ProSPA Sample Analysis: 3. Noble gases 4. Light elements+isotopes

Volatiles released during oven heating, and optionally following reaction with reference gases, are passed to the ProSPA chemical laboratory for analysis.

Volatiles could originate from ices, chemisorbed volatiles, cosmogenic volatiles, and implanted solar wind. This Investigation focusses on analysis of the chemical composition and abundance of volatiles using gas pressure determination and the ion trap mass spectrometer, as well as isotopic analysis using ProSPA's magnetic sector mass spectrometer.

5. Thermal Environment and Volatile Preservation

Sublimation of some volatile content to vacuum is inevitable during the sample chain. Knowledge of the surface and subsurface thermal environment during operations, as well as sublimative fractionation of isotopes, is essential to minimising uncertainty on measured volatile quantities of abundance and composition.

In-Situ Resource Utilisation: 6. Precursor Experiments 7. Prospecting

ProSPA's ISRU experiment mode allows ovens to be heated to 1000°C and fed with H_2 or CH_4 in order to reduce the molecules in the regolith and extract oxygen. This will provide in-situ reference for terrestrial investigations into oxygen extraction processes that could be applied in future ISRU plants at the lunar surface. 2 Investigations address, 1. the preparation for science readiness of using ProSPA in ISRU mode, and 2. applying terrestrial resource estimation approaches to lunar resources informed by results from PROSPECT.

8. Permittivity Sensor

The ProSEED drill rod accommodates a permittivity sensor, which allows determination of the electrical permittivity of materials in contact with the sensor electrode. Permittivity measurements of borehole materials at specific drill rotation azimuth and depth will be made during drilling operations.

This will allow reconstruction of permittivity properties as a function of borehole depth and azimuth, leading to retrieval of profiles of H_2O content and other relevant geologic properties.

Recent PROSPECT Publications

Verchovsky, A.B. et al., A quantitative evolved gas analysis for extra-terrestrial samples Plan. Spa. Sci., 181 (2020) 104830 https://doi.org/10.1016/j.pss.2019.104830

Curran, N.M. et al. A database of noble gases in lunar samples in preparation for mass spectrometry on the Moon Plan. Spa. Sci., 182 (2020) 104823 https://doi.org/10.1016/j.pss.2019.104823

King, O. et al. The Oxford 3D thermophysical model with application to PROSPECT/Luna 27 study landing sites Plan. Spa. Sci., 182 (2020) 104790 https://doi.org/10.1016/j.pss.2019.104790

Abernethy, F. et al. Gas containment for in situ sample analysis on the Moon: Utility of sealing materials in the presence of dust Plan. Spa. Sci., 180 (2020) 104784 https://doi.org/10.1016/j.pss.2019.104784

Sargeant, H. M. et al. Feasibility studies for hydrogen reduction of ilmenite in a static system for use as an ISRU demonstration on the lunar surface Plan. Spa. Sci., 180 (2020) 104759 https://doi.org/10.1016/j.pss.2019.104759

Reiss, R. et al. Thermal extraction of volatiles from the lunar regolith simulant NU-LHT-2M: preparations for in-situ analyses on the Moon Plan. Spa. Sci., 175 (2019) 4666 https://doi.org/10.1016/j.pss.2019.05.001

Formisano, M. et al. PROSPECTING the moon: Numerical simulations of temperature and sublimation rate of a cylindric sample Plan. Spa. Sci., 169 (2019) 4650 https://doi.org/10.1016/j.pss.2019.03.002

Mortimer, J. et al. D/H fractionation during sublimation of water ice at low temperatures into a vacuum Plan. Spa. Sci., 158 (2018) 4540 https://doi.org/10.1016/j.pss.2018.05.010

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Luna 27, 'Luna-Resource Lander,' is part of the Russian Federal Space Agency's (Roscosmos) lunar exploration programme.

LEONARDO AIRBORNE & SPACE SYSTEMS

The PROSPECT Industrial Team is led by Leonardo (Italy).

The Open University

Development of the ProSPA chemical laboratory is led by the Open University (UK).