PROSPECT: key aspects of drilling and collecting samples at moon south pole for Luna Resurs Mission

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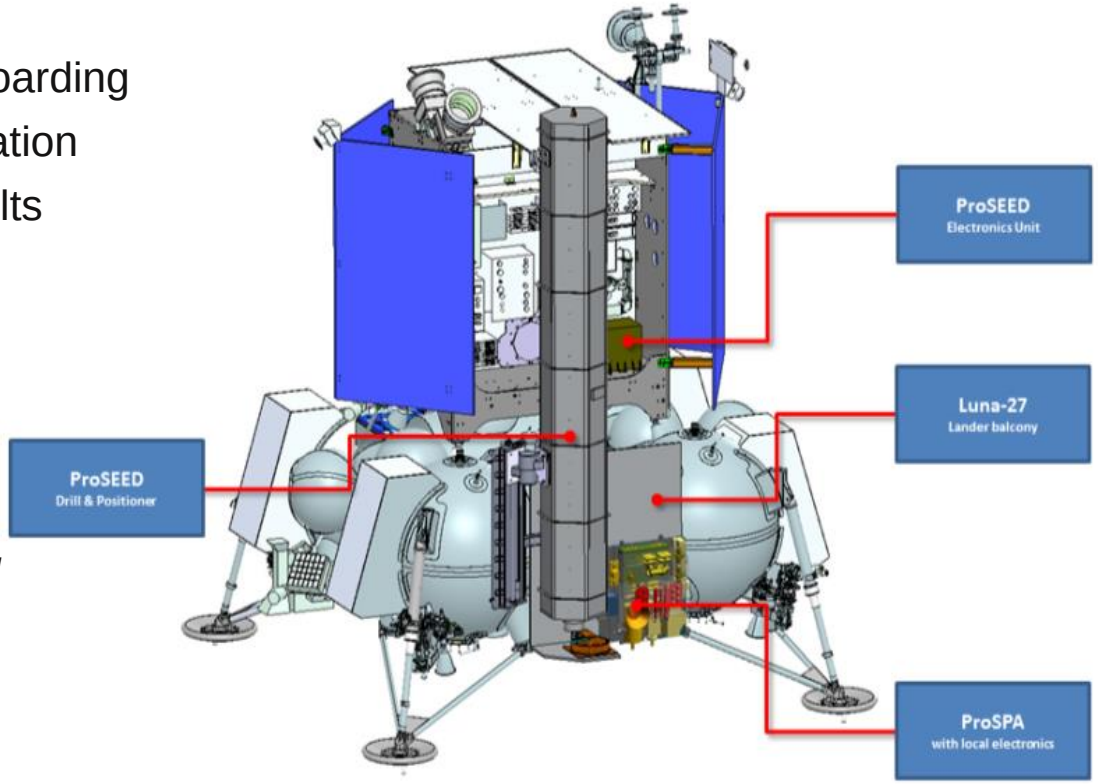
Summary

- PROSPECT is made up of two main elements: the **ProSEED (PROSPECT Sample Excavation and Extraction Drill) drilling and sampling system**, and the ProSPA (PROSPECT Processing and Analysis) sample analysis instrument.
- ProSEED
  - Preliminary design and breadboarding
  - Lunar soil simulant characterisation
  - Test campaign preliminary results

- *ProSPA Element, to be presented here after by S. Barber (the Open University)*

- *ProSEED Energy Exchange Model to be presented here after by M. Lavagna (Politecnico di Milano)*



Lunar Drill concept

- Hammering action supporting the drill roto-translation
- Capable of drilling materials with UCS up to 100MPa for 2 meters
- Sampling mechanism compatible with the hammering action
- Brushless motors for actuating the drill rotation, (translation) and sampling mechanism
- *Energy Exchange model prepared by PoliMI to asses the heat delivered to the soil and to the sample during the drilling action*

Sampling tool architecture

- Φ29 mm string diameter (including auger) and Φ12 mm sliding central pilot and sample chamber
- Embedded temperature sensors
- Carbide/PCD Diamond cutting bit
- Embedded mechanism, actuated by one EC-13 brushless motor, to create the sample chamber, to support the sample retention after coring (spiking system) and to push out the sample

Lunar soil simulant mechanical characterization

Uniaxial Compressive Strength (UCS) measured

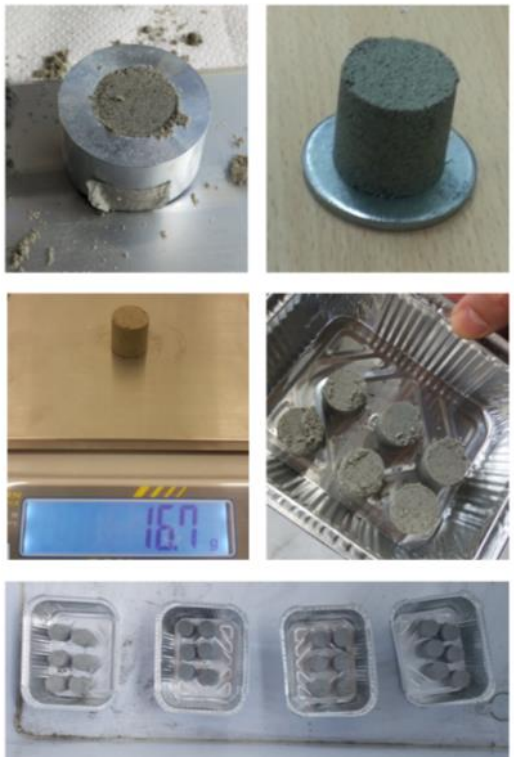
Two types of NU-LHT-2M (highland simulant) were procured from USGS and ZYBEK

Test parameters:

- Water content: 6% and 12%
- Sample dimensions: cylinder with 22 mm diameter and 22 mm height
- Highly compacted (up to 2 g/cm^3)
- 6 samples per type
- Thermal chamber facility at -120 *C

Summary results:

Simulant	UCS
6%	6 - 8 MPa
12%	15 - 20 MPa



Different sampling approach: microcorers

A different sampling tool, based on a micro-corer (Rosetta SD2 like), has been tested in order to verify the capability to collect small samples in a frozen lunar simulant including pebbles of 1-3 mm diameter

Main features:

- Corer diameter 2.7 – 3.5 mm
- Thin wall corer and PCD
- Instrumented setup to monitor the thermal perturbation during coring

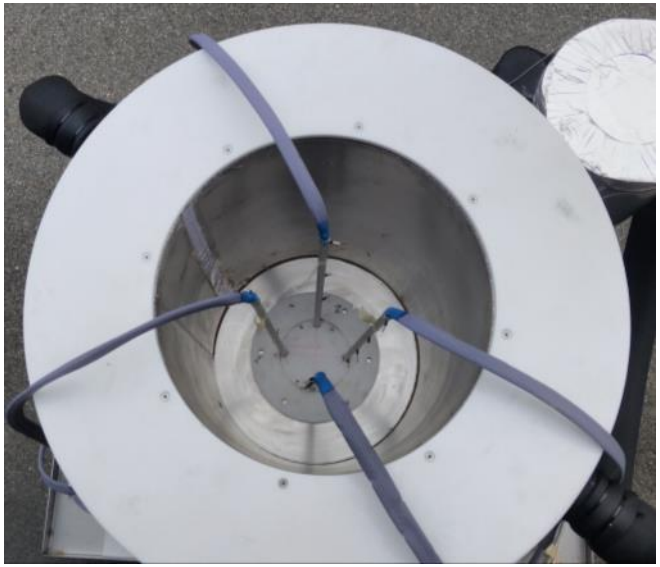
Main results:

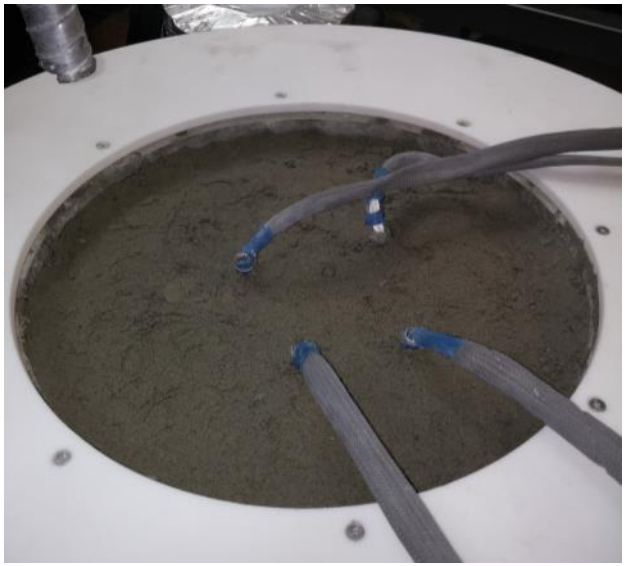
Power in the range 1 - 9 W

The corer copes with pebbles distributed into the soil

Test Set-up

- Cryogenic container filled with liquid nitrogen capable of cooling the simulant at -190 *C
- Temperature sensors embedded in the container to evaluate its state during operations





Test campaign

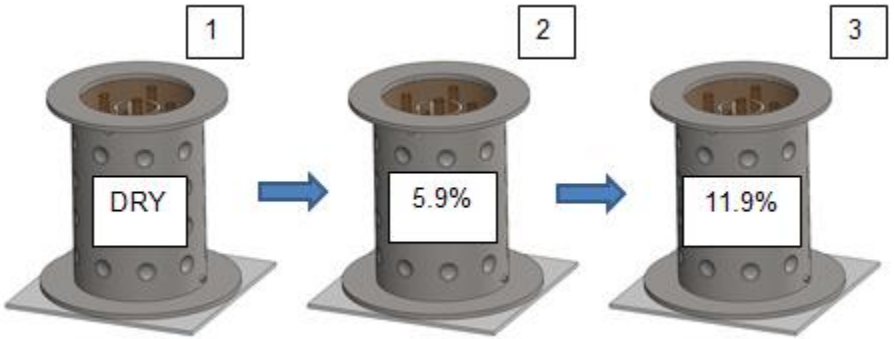
Test campaign objectives

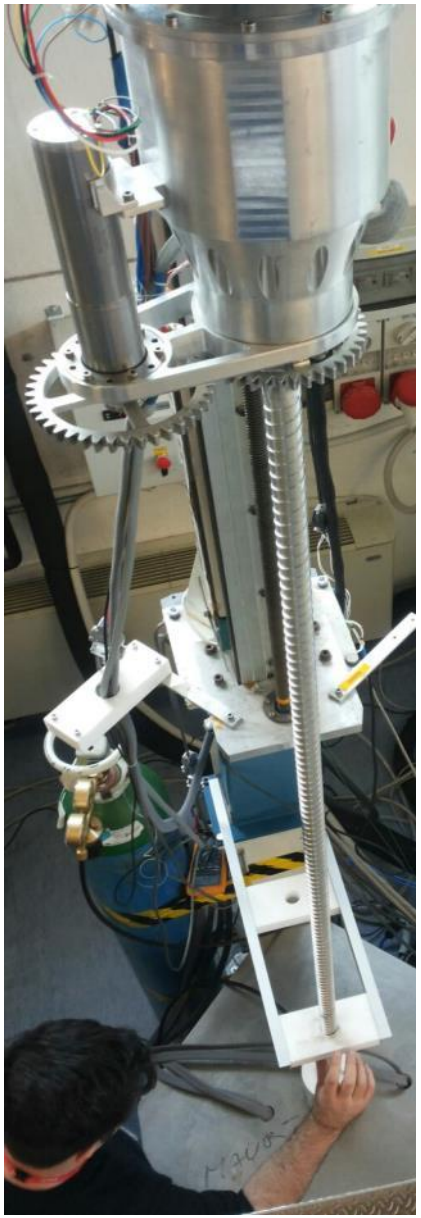
- Understand implications of different drilling parameters on sample temperature
- Understand the benefits of hammering action
- Characterize the drilling performances in representative soil simulant

Main performance parameters to investigate

- Soil, cutting bit and sample chamber temperature
- Mechanical drill power and advancing speed vs thrust

Three test sessions with different soil specimen





Test results with dry and 6% wet simulants

Dry Simulant at 60 rpm, advancing speed control

DRY SIMULANT (speed control)	DRILLING TEST #		
	1	2	3
TU speed [mm/min]	9	13	18
TU force [N]	5-10	5-10	5-10
Torque [N*m]	0.17	0.14	0.18

6% wet Simulant at 60 rpm, advancing speed control

6% WET (speed control)	DRILLING TEST #		
	1	2	3
TU speed [mm/min]	9	13	18
TU force [N]	20-25	40-50	60-80
Torque [N*m]	0.4	0.6	0.9

Test results with 12% wet simulant

HIGHLY COMPACTED WITHOUT HAMMERING ACTION at 60 rpm

12% WET (force control)	DRILLING TEST #				
	1	2	3	4	5
TU force [N]	200	300	400	500	600
TU speed [mm/min]	0.8	0.5	2.5	4.3	7.0
Torque [N*m]	2.78	2.03	3.72	3.61	4.38

HAMMERING ACTION at 60 rpm

12% WET (force control)	DRILLING TEST #							
	1	1HAM	2	2HAM	3	3HAM	4	4HAM
TU force [N]	300	300	400	400	500	500	600	600
TU speed [mm/min]	4.6	5.9	5.2	6.7	0.8	5.5	5	5.2
Torque [N*m]	1.82	1.79	2.25	2.46	2.58	3.18	3.66	3.55

Conclusions and lesson learnt

- The thermal and mechanical properties of the **Lunar soil simulant** have been characterized at low temperature (< -120° C)
  in dry, wet at 6% and saturated (at 12%) conditions
- The **drill performances** and wearing effects on the drill tool have been preliminarily assessed
- The **PCD cutting bits** are not compatible with hammering action even at low levels of hit energy (2-3 J) and frequency (10 Hz)
- The **hammering action** has a positive effect on the drill advancing speed; the torque is not affected; impacts on the overall power budget to be considered
- The **cutting bit temperature** increase during drilling is:
  - Negligible in the dry soil simulant
  - 5-10 K maximum in the 6% wet simulant
  - 50-60 K maximum in the 12% wet simulant

THANK **YOU** FOR YOUR ATTENTION

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