Accessing, Drilling and Operating at the Lunar South Pole: Status of European Plans and Activities

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ASTRA 2015
Lunar Exploration Programme: European Products

**PILOT**

1. **Characterise**
   - landing sites

2. **Access**
   - landing sites precisely and safely

**PROSPECT**

3. **Acquire**
   - samples of interest for exploration

4. **Analyse**
   - samples

**SPECTRUM**

5. **Communicate & Operate**

- **Landing Sites Analyses**
- **Relative & Absolute Navigation**
- **Hazard Avoidance**
- **Lunar Drill**
- **Sample Handling**
- **Volatile Extraction & Analysis**
- **IR Spectrometer**
- **Ground Support**
- **UHF Proximity Link**

Prepare future missions
PROSPECT Goals

• Establish and demonstrate European competence in key areas for future international missions in the areas of:
  • Drilling
  • Sampling
  • Sample handling and processing
  • Sample analysis
• Generating knowledge which address unknowns for resource utilisation and fundamental scientific questions
• Engage and increase public and stakeholder interest and understanding of lunar exploration and its benefits
• Provide a drill that meets Russian requirements and expectations and ensure that Europe benefits from the provision of that drill
Robotic Precursor Phase of Lunar Exploration: Russia as the First Partner

- Lunar exploration is major goal of Russian exploration programme
- Compatible and complementary interests between ESA & Roscosmos identified, both in technology and science
- Detailed investigation, in-situ and by sample return, of volatiles in the polar regions plus complementary science at the poles

- Principle of product based approach is to have elements and capabilities which are also available for cooperation with other partners
1) Get icy, volatile-containing samples from here...

2) ...to here, in a form which allows detailed analysis of volatile content and other properties...

3) ...whilst ensuring, throughout the chain, that the volatile content is preserved.
Russian robotic sampling arm:
• Obtains samples directly from lunar surface
• Receives samples from European drill
• Transfer samples to Russian instruments
**PROSPECT: Key challenges**

**OBJECTIVE:** drill 2m into lunar surface at the poles, extract samples, preserve volatiles/ices, chemical extraction, chemical analysis

- **ENVIRONMENT:** COLD (~120K; shadowed side of the lander)
- **MATERIAL:** Highland regolith?, Icy? [0%, ppm, 5%, saturated, ice lenses...?]
- **ICES/VOLATILES:** behaviour in vacuum, loss mechanisms?
- **TECHNOLOGY:** some heritage, new combinations, new applications

**MATERIAL**
- Dry, loose, powdery, easily lost but also ‘sticky’
- Saturated, hard, stronger than reinforced concrete

**ICE LOSSES**
- Rapid, highly temperature dependent loss of ALL icy material
- Slower, less temperature dependent loss, strongly influenced by sample size/nature

- Delicate frost
- Dirty snowball
PROSPECT: Sampling & Sample Analysis Package

LUNAR DRILL DEVELOPMENT
HERITAGE

• ROSETTA-PHILAE (low temperature drilling and sample handling)
• EXOMARS (extensive development & testing, incl. components)
• R&D: DeeDri, Downhole Hammering Mechanism, ExoMars Motor Env. Testing

ACTIVITY FOCUS

• Access samples from potentially very high strength material (cold, icy)
• Ensure preservation of sample volatile content (maintain low temp.)
• Establish operational approach compatible with minimal resources
LUNAR DRILL DEVELOPMENT
Kickoff: 01 September 2014
End date: 30 September 2015

PRIME: SELEX-ES (I)
Sub-cos: Maxon Motors (CH)
Astronika (PL)
Pol. di Milano (I)

KEY TECHNICAL AREAS

- Single rod rotary drilling system
- Integrated hammering device with electromagnetic drive
- Drill translation & positioning system
- Thermal preservation of samples during drilling and sample transfer
- Environmental testing of motor/gearbox combinations
- Flexible operational control
- In-situ measurement capabilities (e.g. temp, permittivity, IR-spectra)

Preliminary Drill Concept, Selex-ES (I)

Options for hammer-device location, Selex-ES, Astronika (I)

MUPUS comet penetrator
Rosetta – Philae
CBK-PAN (PL)

Drill test HW available for concept tests – Selex-ES (I)
PROSPECT: Sampling & Sample Analysis Package

Lunar Generic Regolith Acquisition/Sampling Paw L-GRASP
HERITAGE

• ROSETTA SD2 development
• ExoMars Drill tool development

ACTIVITY FOCUS

• Review of current knowledge of icy sample properties, state-of-the-art in lunar regolith simulants and experimental approaches
• Evaluation of sample acquisition and ejection tools for icy lunar samples, focusing on robustness to range of icy sample properties
• Assessment of sampling tool concepts by review, and by concept breadboarding and testing

ExoMars and Rosetta-Philae SD2 drill tip configurations – Selex-ES (I)

Phoenix’s scoop after it had been inverted and a motor in the scoop had been run to jar the sample of icy dirt loose. The image, taken on July 28, shows that much of the sample remained stuck inside the scoop.

Credit: NASA/JPL-Caltech/University of Arizona/Max Planck Institute
KEY TECHNICAL AREAS

- Establishment of icy regolith simulant specification and preparation approach, with support of international simulant/lunar materials experts (Workshop in ESTEC: October 2013)
- Sample tool concept breadboarding and test campaign in icy regolith simulant (bottom right)

ACTIVITY OUTPUT

- Established test setup and icy regolith preparation procedure, and hands on European experience with icy samples
- Test data on nature and behaviour of icy regolith when sampling
- Preliminary sampling tool concept ready for integration in drill design, already subjected to initial test campaign
PROSPECT: Sampling & Sample Analysis Package

Prospect-Processing & Analysis system (Pros-PA)
**PROCESSING AND ANALYSIS**

Kickoff: 01 September 2014  
End date: 04 June 2015

**HERITAGE**

- Cometary, Martian, Lunar chemical processing and analysis laboratories
  - ROSETTA-Ptolemy,  
  - Beagle 2-GAP,  
  - Lunar Lander L-VRAP
- Volatile sample handling heating and gas extraction
  - ROSETTA-SD2  
  - EXOMARS-SPDS

**ACTIVITY FOCUS**

- Handle, contain and heat potentially icy regolith samples
- Thermochemical extraction of resource relevant chemistry
- Gas chemical processing and analysis of composition and isotopes

**SD2 oven, Ptolemy onboard Philae and a lab setup including a mass spectrometer**

**ExoMars SPDS and B2 GAP**
KEY TECHNICAL AREAS

- Diagnostic/context sample measurements (imaging/IR)
- High temperature ovens
- Reactants for thermochemical extraction
- Chemical yield determination (pressure / composition)
- Ion trap MS for composition and yield of extracted chemicals
- Chemical reactors for evolved gas alteration (e.g. to remove isobaric interferences)
- Gas separation thermal manifolds for gas separation
- Reference standard gasses (allowing lab quality measurements)
- Accurate and precise isotopic measurements (Magnetic Sector MS)
PROSPECT: Sampling & Sample Analysis Package

Handling Planetary Ices
HANDLING PLANETARY ICES
Kickoff: 18 March 2014
End date: 2nd half 2015

HERITAGE
- Laboratory and modelling experience, Rosetta

ACTIVITY FOCUS
- Understand the effects of temperature and handling of ice in vacuum and measurement implications.
- Apply this to develop sample handling concepts (in-situ & LPSR)
- Allow the application of models and lessons learned to hardware development
ProSpect: Element breakdown for next steps

ProsEED: ProSpect Excavation and Extraction Drill

ProsPA: ProSpect Processing and Analysis
ProsEED: PROSPECT Excavation & Extraction Drill – Current Architecture

Hammer-stage

Rotation stage and mandrel

Drill Box

Drill box structure

Lower plate

Active linear guide (positioner translation)

Passive linear guide

Connector

Translation screw

Spider

Drill string

Sampling tool

Sliding carriage (mandrel & hammer actuators)

Rail

Drill rotation motor reducer

Carbon fiber hammer rod

Hammer mass

Potentiometer

Motor reducer

Potentiometer nut

Piston nut

Pistons + Spikes + Piston Lead screw

Central bit

Spike system nat

Spike system

Axial – part of
ProsPA: PROSPECT Processing and Analysis Package – Current Architecture

ISSUE DATE DRAWN BY COMMENTS
1 Oct 22 2014 SS Rev6

ProsPA System Diagram

Drawing Number: OU-AD1948-ProsPA-DW-01

KEY
- 2-way valve
- High conductance gate valve
- Pressure sensor
- PET valve
- Reactor
- Gas cylinder
- Pipe
- 3/8 OD pipe
- 1/4 OD pipe
- 0.177 OD pipe
CMin2014: successfully integrated Lunar exploration activities, including PROSPECT development, within overall ISS programmatic framework as next step for exploration

- Pre-development/Phase A activities due to be completed by mid 2015
- Next step is Phase B+ to mature PROSPECT up to PDR (end 2016), with work starting in 4Q2015
- Following Phase C/D/E shall take PROSPECT up to flight and operations in 2020
Next Steps: Breadboarding, Material Characterisation & Pre-Qualification

- Low-T Component Pre-Qual
- Sample sealing
- Material strength tests
- Volatile preservation
- Thermo-chemical extraction
- Drilling efficiency tests
- Sample extraction tests

- Many activities have been initiated via Phase A/TRP
- Phase B will extend the use of existing HW, and where needed establish dedicated breadboard tests to address specific issues
Next Steps: Development Model(s) & Test Facilities

Instrument hardware and operational development

End-to-end requirements verification & validation in representative environment

Assessment of design robustness

ProsPA Functional Dev Model

ProsPA LAB DM (Front End)

DRILL LAB DM

DRILL FIELD DM

On the bench

In the chamber

In the field

ProsPA Func. DM test environment

PROSPECT LAB DM test chamber “Lunar Polar Simulator”

ProsEED Field Test Facility & Logistics
User Group

- A call will be released in the coming weeks for members of the PROSPECT User Group, which shall represent the future User community for PROSPECT

- User Group activities will include:
  - Review and update the PROSPECT science and other user objectives and requirements
  - Validate science and other user requirements and advise on verification approaches
  - Provide user support to Development Model test campaigns
  - Support the establishment of operational scenarios at the lunar surface
  - Represent a broad User Community for the data products that will be produced

- Users will include the scientific community, but also those preparing technologies for future missions
Conclusion

- European priority on specific exploration ‘products’ focuses resources on developing hardware and experience
- Russia represents our first partner for using these products, with complementary mission plans, objectives and capabilities
- Products can be considered for cooperation with multiple international partners

**PROSPECT**

- Builds on existing heritage
- Provides Europe with a key lunar exploration capability
- Answers fundamental exploration and scientific questions
- Development approach targets early HW testing
  - Providing test data for PDR
  - Creating foundation of expertise and facilities
  - Supporting involvement of product Users

**INVITATION:** to industries & institutes with relevant experience, facilities and/or interests in the PROSPECT product