ISPACE'S ROVING SPECTROMETER PROJECT: A COMMERCIAL ISRU EXPLORATION MISSION TO THE SOUTH POLE OF THE MOON.

A. Calzada-Diaz[1], K. Acierno[1]and J.A. Lamamy[1], [1]ispace Europe. Rue de l'industrie 5, Paul Wurth InCub, 1811 Luxembourg.

Introduction: ispace is lunar exploration company with its Headquaters in Tokyo, Japan, and subsidiaries in the U.S and Luxembourg. The company vision is to expand and sustain humanity's presence in space by utilizing resources available on the Moon. In order to accomplish this vision, ispace set a 3-step roadmap as illustrated in Figure 1. The first step is the competition for the Google Lunar XPRIZE. ispace developed, tested, and flight qualified the SORATO rover which contributed to winning the $500K Mobility Milestone Award. By signing a launch contract, ispace is one of only five finalist for the $20M Grand Prize and will use the XPRIZE to demonstrate its rover technology.

For Step 2, ispace intends to build-upon the rover technology to perform missions that will prepare the establishment of in-situ resource utilization (ISRU) on the Moon. With proven technologies (Step 1) and a solid understanding of the lunar environment and distribution of resources (Step 2), ispace will be ready to execute the processing and utilization of lunar resources in Step 3. The focus of this abstract is on step 2 and the Roving Spectrometer prospecting mission that is being developed by ispace Europe in order to better understand the distribution of hydrogen on the lunar surface.

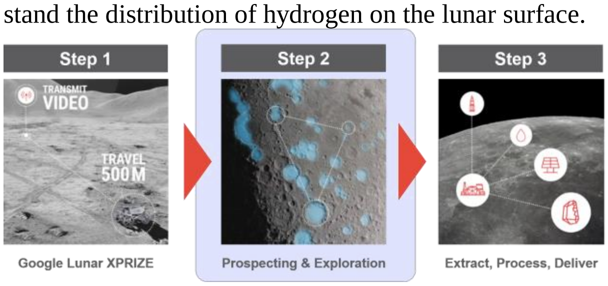

Figure 1. ispace's three-step approach.

Water on the Moon: The existence of lunar water was first suggested by Watson et al. (1961) and Arnold (1979) [1,2] where that water and other volatile species were delivered to the lunar surface by cometary impacts. The volatiles were then transported and trapped in permanently shadowed regions (PSR) at the lunar poles, where the temperatures are thought to have remained under 100 K for the majority of the geological history of the Moon (Lucey 2009, Anand et al. 2010) [3,4].

More recently, orbital observations provide strong evidence for the presence of water ice on the Moon [5,6,7]. However, the spatial resolution of the current remote sensing datasets (tens of km) is not sufficient to understand the nature of the H molecules and bulk deposits. At this stage, there is not enough information about lunar water to start the extraction, making early exploratory missions to perform in-situ H mapping and prospection at a local scales (from nanometers to meters) is mandatory.

Roving Spectrometer Project: The Roving Spectrometer Mission is an ISRU exploration mission and it will be the first project of Step 2 for ispace Europe.

This mission aims to identify and delimit the hydrogen and potential water ice deposits as well as to obtain information on the geotechnical properties of the polar regolith.

Science objectives:

1. To determine the local distribution and abundance of H in the subsurface regolith.
2. To characterize the form in which volatile species containing hydrogen are present in the subsurface regolith.
3. To assess the volatile-rich contamination produced by lander exhaustion plume.
4. To obtain soil mechanics information relevant for vehicle mobility, soil penetration, and the operation and maintenance of future ISRU equipment.

Landing Site: Lunar permafrost regions are areas that may receive some direct solar radiation during short periods of time, when solar lighting conditions are more favourable, but maintain annual maximum temperatures at depth that are sufficiently cold to prevent appreciable water loss due to sublimation [8,9]. These regions are considered prime regions of interest for in situ exploration of water resources with solar-powdered probes because their more hospitable thermal and illumination surface environment (Table 1).

Potential landing site parameters	
Latitude	>80º S
Type	Permafrost region
Deposit depth	0.1-0.5 m
LS elipse Size	>1 km
Target	Floor of impact crater Intercrater areas

Table 1. Parameters of potential landing sites for this mission.

Rover: The rover (Figure 2) is currently under development (will be remodeled after SORATO). It allows to be scalated according to the size of the payload and necessary power, maintaining the same architecture. The body is built in carbon fiber and has special designed wheels allowing it to drive stably on lunar regolith. It has 4 HD cameras that capture images in 360 degrees that will be used for localization and hazard detection.

The lander is designed to carry from 30 to 50 kg of payload to the lunar surface. The rover is protected within the spacecraft structure during flight and then deployed once it landed.

Figure 2. SORATO rover's camera imaging test in the field.

Payload: Several instruments have been reviewed to address their feasibility to accomplish the objectives set for this mission. Three criteria are used to identify instruments for further considerations:

1. The instrument fulfils at least one of the science objectives.
2. The instrument design is mature.
3. The instrument can be easily procured.

Neutron Spectrometer: Neutron spectrometers (NS) measures epithermal and thermal neutron flux measurements providing a highly sensitive measure of the H content of the regolith [e.g. 7,10]. This instrument will detect areas with enhanced hydrogen signatures that may indicate the presence of subsurface water ice.

Ground Penetrating Radar (GPR): This instrument can detect, localize and characterize homogeneous units like segregated ice [11]. In combination with the NS allows more accurate mapping of the water ice deposits on the subsurface.

Mass Spectrometer: Mass spectrometry (MS) is an analytical technique that ionizes chemical species and arranges the ions based on their mass-to-charge ratio (m/z) to produce a mass spectrum. The result is a plot of the ion signal as a function of the mass-to-charge ratio. These spectra will be used to characterize the form in which the H-rich species are present in the polar regolith.

Mission Concepts: Several missions concepts have emerged by the combination of those instruments. These concepts fulfill from one to four science objectives. In addition to scientific aspects, programmatic, management and business considerations have to be taken into account in order to select the concept that provides with a better cost/benefit ratio. These concepts are summarized in Table 2.

Concept	Red Lion	Gold-crest	Rose	Melusine	Fox
Imaging	HD cameras	HD cameras	HD cameras	HD cameras	HD cameras
Sensing		2 NS	2 NS	2 NS	2 NS
Mapping					GPR
Sample analyses			Ion Trap MS	Magnetic Sector MS	
Objectives fulfilled		1,4	1,3,4	1,2,3,4	1,2,4

Table 2. Mission concepts for the Roving Spectrometer Project.

Mission Funding: As a private company, ispace must consider new and innovative approaches to cover the costs and even make revenue from its mission. While a portion of the research and development costs associated with this mission will be covered by Luximpulse, a Luxembourg National Program, ispace intends to also earn revenue by selling the data generated by this mission. The data can be sold to space agencies, research institutes, or scientists interested in the most up-to-date data on the lunar surface.

Conclusions: Orbital imagery and analyses of lunar samples have indicated the presence of H-molecules that could be in form of water ice on certain areas of the lunar poles. However, the spatial resolution of the current remote sensing datasets (tens of km) and the uncertainties about the lunar environment and regolith does not make possible to start water extraction right away.

This work provides the background, the rationales and the scientific objectives for the ispace Roving Spectrometer Project, an ISRU exploratory mission that aims to raise knowledge about the lunar environment that is necessary for the harvest and utilization of lunar resources.

The particularity of the Roving Spectrometer project is that it is run by a private space company. The company is responsible for formulating the vision and high-level goals and for tracing the success for particular objectives for the Roving Spectrometer project.In addition, the company must develop new and innovative ways to cover the costs associated with the mission.

References:

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