CONCEPT OF A PLATFORM FOR IN-SITU LUNAR SAMPLES PRE-ANALYSIS IN THE LUNAR HABITAT EUROHAB.

S. D. Chevrel[1] and P. Weiss[2], [1]Institut de Recherche en Astrophysique et Planetologie (IRAP), Observatoire Midi-Pyrénées, Toulouse University, France (*Serge.Chevrel@irap.omp.eu*), [2]Spartan Space, France.

Context: NASA prepares to send astronauts back to the Moon in the frame of the future Artemis III mission. Potential landing sites have been identified, each of them being located within six degrees of latitude of the lunar South Pole. They collectively, contain diverse geologic features and they are tightly coupled to the timing of the launch window opportunities, so multiple regions ensure flexibility to launch throughout the year. Several of the proposed sites within the regions are located among some of the oldest parts of the Moon, and together with the permanently shadowed regions, yielding important information about the depth, distribution, and composition of water ice, provide the opportunity to learn about the history of the Moon through previously unstudied lunar materials. Many papers document the scientific interests and how to explore (geological traverses) some landing sites in the South Pole regions (e.g., [1], [2]).

Science at the South Pole of the Moon: Lunar South Pole regions represent some of the oldest parts of the Moon. The pole lies on the rim of the 21 km diameter Shackleton crater, which is located on the topographic rim of the 2500 km diameter South Pole-Aitken (SPA) basin, the largest and oldest basin on the Moon (~4.3 to 3.9 Ga).

The Shackleton impact probably penetrated and exposed purest anorthosite (PAN) representative of primitive crust [1]. Collecting rocks in these region will give strong constraints on the Lunar Magma Ocean (LMO) models to explain the formation of the primary anorthosic crust on the Moon. Rocks collected may potentially include urKREEP, lower crust and upper mantle materials from the SPA basin-forming event, and also layered terrains that likely represent a series of impact ejecta deposits that stratigraphically cover the crystalline crust. Probable availability of age signatures pertaining to the Shackleton, SPA, as well as the Tycho impact events (an ejecta ray originating at this crater is crossing the region), will also offer advancement of our understanding of the lunar cratering chronology and derived dating methods [2]. The South Pole regions also offer the possibility to study new type of highlands regolith far removed from the nearside KREEP-terrane as well as maria, and less affected by solar wind-induced maturation.

The relevance of in-situ pre-analysis of Lunar Samples at the South Pole: During future missions on the Moon, astronauts will perform various extravehicular activities (EVA) accumulating a large number rock and soil samples for geological purposes and to evaluate the ISRU potential of some materials. The amount of lunar materials to be brought back to Earth during a single Artemis mission could exceed the total amount returned during the Apollo missions. The weight and volume constraints for their return to Earth could result in a significant delay in studying the samples. The planned Human Landing System (HLS) (Starship) offers indeed a significant capacity to bring samples back to lunar orbit, however returning samples back to Earth might present limitations in terms of mass. This would constitute a significant obstacle to the advancement of science and for testing the use of materials as resources for living on the Moon. A requirement would be to select the samples on the Moon to be returned in priority on the Earth. This requirement is reinforced by the fact that in the old terrains near the South Pole, the regolith (which is twice as deep as it is within the lunar maria) must be well developed and therefore contains complex impact breccias, for which it is difficult to assess at first sight the scientific importance. Thus, for the new missions it would be a strong interest to develop an on-site pre-analysis platform which allows an autonomous examination of samples and a deeper assessment of samples scientific relevance to either determine whether they should be transported to Earth (immediately or by a consecutive mission) or discarded and left on site [3].

A dedicated facility in EUROHAB for in-situ lunar samples analysis: We propose an instrumentation and methodology for the pre-analysis of lunar rock and soil samples using the European secondary habitat EUROHAB to be potentially delivered on the Moon in the future by the European Logistic Lunar Lander (EL3) (Figure 1). It is a concept of a secondary habitat to be positioned on the lunar surface at proximity of the Artemis Human Landing System (HLS), serving as a “Base Camp” for the astronauts to extend their exploration range [4]. Positioning a habitat payload, such as EUROHAB, by a European robotic lander makes particularly sense since the lander can be positioned on sites that are not safe for HLS (e.g. higher slopes). Also it would need to be landed in a certain distance to future HLS landing sites to avoid becoming a hazard to HLS itself. The EL3 with EUROHAB as payload package would be landed in a safe distance of several km away from future HLS landing sites prior to the arrival of a first crew.

EUROHAB would serve several crews during several consecutive missions and might be a European contribution to the U.S. Artemis Program. Preliminary concepts and requirements for an in-situ lunar samples pre-analysis platform in EUROHAB are currently under study [3]. This facility would constitute a demonstrator for developing future more elaborate analysis laboratories in a lunar base and in mobile devices on the Moon (and, later on, Mars). Also, on-site analysis capabilities will help better understand the geology of the site and allow the crews to return to a given location for additional sampling or reorganize the route of the following EVAs.

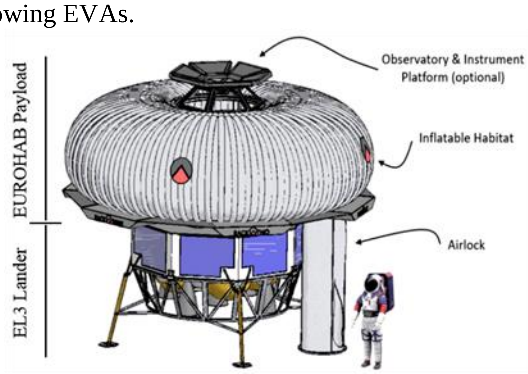

Figure 1. Principe of the secondary habitat payload.

Analyzing the samples in EUROHAB:

Objectives: The analyses will be conducted in a glove box on fresh sections of the rocks (Figure 2). The objectives are to obtain information on the texture and the mineralogical composition of the samples which are complementary for geological and ISRU studies. The data acquired will be both high resolution images (spatial resolution of the order of 0.1 mm) for the determination of the texture, and spectral images (in the range from 400 to 3000 nm; spectral resolution from 10 to 5 nm) for the characterization of the mineralogy, each mineral having its own spectral signature.

Operations: Samples to be in situ analyzed will be selected during the EVA based on their likely scientific interest which will be evaluated in real time both by the astronauts and by geologists assisting them from a backroom. The selection and the conditioning of these samples in bags will be two operations carried out by the astronauts during the EVA. For the analyses, the rock sample must present a so-called fresh break surface (that is to say not altered by the lunar environment), which will be simply obtained by breaking it into two parts using a hammer. The objective is to be able to observe the crystals in the case of a crystalline rock, or to the various fragments (clasts) and the matrix in the case of an impact breccia. The two parts of a given sample will be placed into two separate individual bags and later on, in special containers to be transferred into the habitat. The sample containers will open by the astronauts inside is a glove box. They will take the samples out of their bags, cleaning them if necessary (removal of dust by suction or other), and putting each sample in an individual special box. Then these boxes will placed on trays, to be further analyzed. At this stage the human presence is no longer necessary. The boxes will be handled by a robotic arm remotely operated from Earth. The arm is manipulating the box containing the sample, and not the sample itself, putting the box on a small goniometric platform under a lighting system. The instrumentations for the analyses (high resolution and spectral imaging systems) are placed on the top of the glove box. Once the measurements are made, the box is put back on the tray and another box with its sample is placed on the platform. These operations can be repeated at will on the same sample by modifying some geometric parameters such as its orientation (goniometric part of the platform) or the lighting. The samples to be brought back to earth as a priority can be packaged and placed in a special container, thanks to the robotic arm, which will be recovered by the astronauts before their departure.

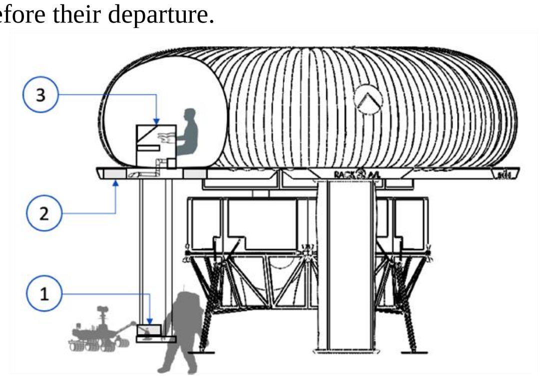

Figure 2. *Integration of the Sample Pre-Analysis facility into EUROHAB: (1) Sample offloading platform with lift, (2) Sample storage facility, (3) foldable glovebox with analysis instruments and robotic arm*.

Conclusion:

The purpose of the facility in EUROHAB for in-situ lunar samples analysis is to carry out *pre-analyses* in order to select the most interesting samples for in-depth analyzes on Earth. However, the spectral analyzes carried out in situ can already provide very important information on the samples, particularly in the case of complex impact breccias. The facility will serve as a testbed for future laboratories on Moon and it will help to better planning future lunar geological activities.

References: [1] Gawronska A. J., et al. (2020) *Ad. Space Res.*, *66*, 1247-1264. [2] Bernhard H., et al. (2022) *Icarus*, *379*, 114963. [3] Chevrel S.D., et al. (2022) *IAC 73rd*, *IAF 2022*. [4] Weiss P., et al. (2021) *IAC 73rd*, *IAF 2021*.