SCIENTIFIC EXAMINATION OF THE LUNAR SAMPLE RETURN MISSION "HERACLES".

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Introduction: The HERACLES (Human-Enhanced Robotic Architecture and Capability for Lunar Exploration and Science) mission is designed to demonstrate key elements and capabilities for sustainable human exploration of the Moon while maximizing opportunities for unprecedented scientific knowledge gain [1, 2, 3]. It is planned to launch a sub-scale demonstration mission in the mid-2020's time frame to test key components of lunar vehicles, including the three following elements: The Lunar Ascent Element (LAE) will be provided by the European Space Agency (ESA), the Lunar Descent Element (LDE) will be provided by the Japan Aerospace Exploration Agency (JAXA), and the rover will be provided by the Canadian Space Agency (CSA).

The coordination of the planning of science opportunities is performed by the multi-agency HERACLES Science Working Group (SWG). The SWG is also responsible for developing a mission science management plan to describe science themes and science payload instruments selection processes, and data and sample policies. The SWG engaged the science communities of each country and organized the HERACLES international Science Definition Team (iSDT). The iSDT will generate a prioritized list of investigations and will provide input for the landing site selection. In the initial phase of mission planning, the HERACLES study team has developed a nominal scenario with Schrödinger basin as the reference landing site with the purpose of driving engineering requirements. On the basis of the recommendations of the 2007 NRC report [4] and several subsequently published documents [e.g., 5], Schrödinger basin might be a potential landing site that could satisfy many science objectives although other sites are also considered (Fig. 1) [6, 7].

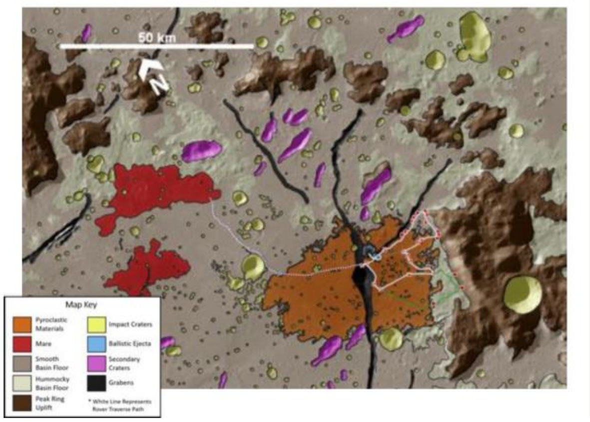

Fig. 1. Example of a potential traverse in Schrödinger basin from Morse et al. [6].

Recently, the iSDT also discussed the science scope of the HERACLES mission. The iSDT agreed that the following five non-prioritized topics are the most important lunar science themes that should be addressed by HERACLES; (1) crustal anorthosite composition and crystallization age, (2) mantle composition, (3) improvement of chronology with crater counting of young basalts (<2.5 Ga), (4) internal structure: surface, subsurface, crust, mantle, and core, (5) mechanism of material transport (e.g., water) to the Moon. Furthermore, the iSDT has identified several potential landing areas to accomplish these science themes: Jackson crater, Moscoviense basin, Copernicus crater, Schrödinger basin, and some young basalts in the Flamsteed region.

Jackson crater: Jackson crater (22N, 163.3W) is located at the mid-low latitude of the farside highland region, and exhibits purest anorthosite (PAN) outcrops on its central peak [8, 9]. In addition, there is the highest Mg# [10] and lowest Th concentration [11] of this region. Therefore, in this area PAN is likely to be a primitive crustal material. Hence, it will contribute to the understanding of the composition and age of the initial crust. The iSDT is utilizing SELENE terrain camera (TC)/ multiband imager (MI)/ spectral profiler (SP) data to find flat landing areas that likely have boulders from the PAN outcrops near the central peak.

Moscoviense basin: The Moscoviense basin (27N, 147E) is filled with one of the largest mare deposits on the lunar farside. If we recover samples from Mare Moscoviense, we can for the first time study differences in volcanic activity between the nearside and the farside because the Apollo mission did not return basalt samples derived from the farside. Morota et al. [12] found a young basalt unit (Ehtm, ~2.6 Ga) in Mare Moscoviense and PAN and olivine outcrops may also be exposed at the Moscovience basin [e.g., 13]. Currently, the iSDT is conducting detailed chronological analyses of this region. Unfortunately, because the distance between PAN and olivine outcrops and the Mare Moscoviense basalts is over 50 km, no single landing site covers all relevant science themes, i.e., (1) - (3).

Copernicus crater: Copernicus crater (10N, 20W) is in the PKT region on the nearside. Pinet et al. [14] found that this crater has very complex and interesting geology. Analyses of recent data of the MI and the SP onboard the Japanese spacecraft "SELENE" and from the Moon Mineralogy Mapper (M3) imaging spectrometer onboard the Chandrayaan mission suggests the possibility that olivine, plagioclase, and impact melt coexist in Copernicus crater. The iSDT is currently conducting detailed investigations of this region.

Schrödinger basin: Schrödinger basin (75S, 126E) is located in the southern high latitude region on the farside. This basin near the SPA rim contains a wide range of mineralogies. For example, at the peak ring, there are areas with coexisting PAN and olivine [e.g., 15]. Basalt units have also been reported in this basin [e.g., 5], as well as a large area of pyroclastic deposits in the central eastern region of the basin. These pyroclastic deposits are particularly interesting because their glasses likely contain volatiles. Thus, the investigation of the lunar internally-derived volatiles will contribute to the understanding of the origin and evolution of the Moon. However, due to the size of Schrödinger, it is not possible to collect all these high priority samples during the initial HERACLES mission; although this would be possible during the proposed long traverse phase [2]. The results of detailed traverse planning in Schrödinger are presented in a companion abstract by Morse et al. [6]. Ongoing work by the iSDT includes using SELENE TC/MI/SP data to find areas with boulders from the PAN and olivine outcrops near the northern peak ring, and also detailed mapping of the interior crater-fill and peak-ring deposits.

Flamsteed region: The Flamsteed region (4S, 43W) is located in the PKT region on the nearside at low latitude. This area is reported to be a very young basalt unit (1.50 Ga [16], 2.54 Ga [17]). The youngest basalt in the Apollo sample and lunar meteorites collection is about 3.0 Ga old [e.g., 18]. Therefore, such a young sample would be unique and would help improving the accuracy of the lunar crater chronology. Detailed analyses of the chemical composition make it possible to obtain knowledge about the magmatic activity of this young lunar area.

Future work: The iSDT is now working on the prioritization of the science themes and is evaluating landing site candidates to be explored by the HERACLES mission. Furthermore, the iSDT will recommend a comprehensive suite of payload instruments to ensure that the specific science topics can be successfully accomplished.

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