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HERACLES – Exploring the Moon in an International Context

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Abstract

The HERACLES (Human-Enhanced Robotic Architecture and Capability for Lunar Exploration Science) project is currently under study at ESA as a way to enable lunar science in an international context, in particular in collaboration with JAXA, CSA, while NASA and Russia participate as observers.

1. Introduction

HERACLES is designed to demonstrate key elements and capabilities for sustainable human exploration of the Moon and human-robotic exploration of Mars while maximizing opportunities for unprecedented scientific knowledge gain. To enable human lunar exploration, which is one of the four cornerstones of the European Exploration Envelope Program, it is planned to launch a sub-scale demonstration mission in the mid-2020's timeframe to test key components of lunar vehicles, including a lander, rover and ascent vehicle. ESA will coordinate and undertake the study of the ascent module, JAXA will study the lander, and CSA will investigate the rover element. In parallel, we are developing surface operational scenarios that reflect the input from the international lunar science community. This will include the selection and characterization of a potential landing site with a large scientific potential and return of lunar samples of high scientific value before conducting a long distance traverse that will provide further opportunities for science and exploration. The coordination of the planning of science opportunities is performed by the multi-agency HERACLES Science Working Group. This working group is also responsible for developing a mission science management plan to describe science team and science payload selection processes, and data and sample policies. In the next steps, we will engage the science communities of the study agencies and install an international HERACLES Science Definition Team (HSDT). The HSDT will generate a prioritized list of investigations and will provide input for landing site selection. In the initial phase of mission planning, the HERACLES study team developed a nominal scenario with Schrödinger basin as the reference landing site. On the basis of this preliminary study, Schrödinger basin might be a potential landing site that could satisfy may science objectives (Tab. 1) although other sites may also be considered.

2. Preliminary Mission Scenario

The current mission planning foresees a 70-day surface sample return mission, followed by a 1-year traverse encompassing one or more additional potential human exploration landing sites in the south pole region. We plan to return 25kg of samples, including the sample container. In 2017, the Science Working Group defined a set of mission science objectives in response to the ISECG Science White Paper (Tab. 1). A possible mission scenario to accomplish these objectives is shown in Fig. 1. The first HERACLES mission starts with the launch of a mid-sized launch vehicle (baseline Ariane 64) to lunar transfer orbit (LTO). The lunar desent element (LDE) main engine performs the lunar orbit insertion (LOI). In LLO, descent is preceded by a periselenium lowering manoeuvre and more tracking to initialise the LDE GNC for descent. It is assumed that the landing is to occur during daylight conditions During descent, the LDE controls the vehicle attitude to follow the descent profile to a high gate arrival ~1km above the lunar landing site. The part of the mission after High Gate Arrival is referred to as the final descent, and comprises of the reduction of remaining velocity and altitude. The final approach ends in a hovering phase, the goal of which is to precisely

Table 1: Initial HERACLES Science Objectives (unprioritised)	
Responding to ISECG Science Theme: Understanding our place in the universe	
S1	Constrain the impact chronology of the Earth-Moon system and test the cataclysm hypotheses by determining absolute ages for major impact events based on surface geological features
S2	Understand the Earth-moon impact flux by determining the abundance, composition and isotopic nature of impactor remnants in regoliths of various ages
S3	Enhance understanding of dynamic processes on airless bodies by measuring the processes of space weathering, solar wind and magnetosphere interactions and the exosphere
S4	Enhance understanding of the origin and evolution of the moon by determination of structural layering of the highland crust and mantle through in situ geophysical networks, and determination of compositional layering and solidification age through sample return
S5	Understand volcanic processes on the moon through obtaining eruption information, composition and age of silicic domes, scoria cones and holes and youngest and oldest mare material.
S6	Enhance understanding of cratering processes on the moon through study of impacts of different size, age and complexity
S7	Understand the origins of lunar volatiles trapped in ancient rock
S8	Understand solar and galactic evolution by measuring the abundance of cosmic ray generated isotopes in minerals of various exposure ages
S9	Contribute to understanding the origin of life and prebiotic chemistry through constraining Solar System Conditions when life first arose
Responding to ISECG Theme: Living and Working in Space	
L1	Determine the physical and chemical properties of dust and its toxicity
L2	Determine the composition and abundance of minerals in regolith as resources
L3	Identify the effects of exposure to the lunar radiation environment on DNA stability, mutation rates of exploration relevant microorganisms, including human cell analogues

acquire the reference altitude, to steer clear of any inacceptable terrain (rocks or steep slopes), to zero out any horizontal motion, and to perform main engine cut-off (MECO) for final ballistic descent to the surface. On the surface, the Rover egresses the LDE and starts the surface campaign. Initial exploration of the surface by the Rover is supported by ground control and time-tagged commanding until the crew arrives on the LOP-G. Once the crew is present, the crew-supported surface mobility operations will start. The rover then is commanded to drive, to perform sample collection and to transfer the sample container to the Lunar Ascent Element (LAE). The sample collection phase can take multiple lunar day-night cycles and ends with the deposition of the samples into the LAE. The LAE ascends into an initial orbit with the aposelenium at the altitude of the intermediate circular LLO and the periselenium high enough such that the initial orbit will not lead to an impact on the surface for at least two weeks. Eventually, the LAE initiates the transfer to the LOP-G. The sample container will be removed from the LAE by the LOP-G robotic arm. HERACLES's rover remains functional on the surface and is driven by ground-control along the planned traverse to demonstrate long-life, long-range surface mobility and exploration activities (in-situ investigations and sampling).

3. Summary

HERACLES is an exiting mission concept that enables Europe to gain access to the Moon and to play a leading role in the international exploration of the Moon. The concept is ambitious but offers enormous benefits particularly by the combination of human and robotic assets on the LOP-G. The mission will also allow excellent science from orbit, on the surface, and in terrestrial laboratories once the samples have been returned.

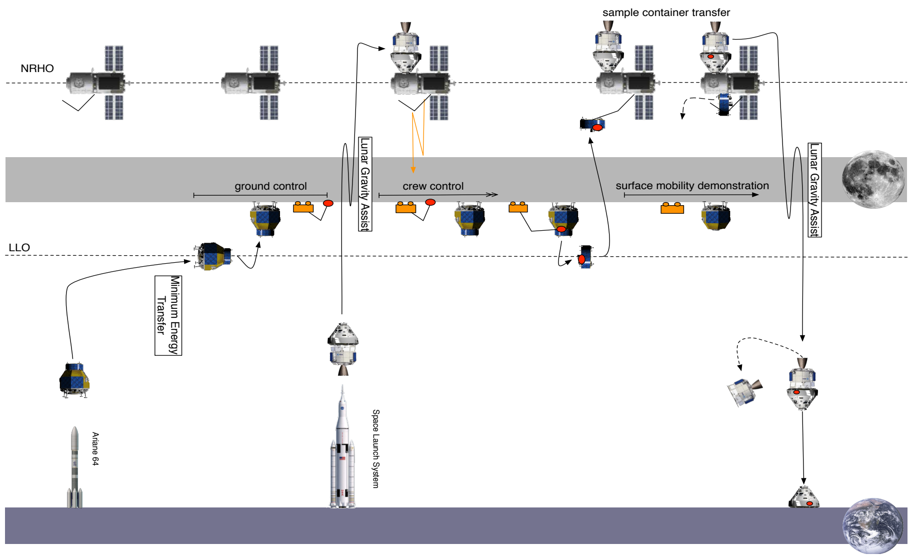

Fig 1: Baseline Mission Operations Scenario (left to right)