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The Deep Space Gateway can serve as the International Science Operations Center (DSG-ISOC) in Cis-Lunar Space (akin to McMurdo in Antarctica) for addressing fundamental scientific problems about the Moon and planets, and preparing for the human/robotic exploration of Mars and beyond. We envision the DSG to be a hub for facilitating the activities necessary to explore fundamental scientific problems in an integrated fashion, utilizing a broad strategy for the systematic exploration of the Solar System, calling on a wide range of technologies and accomplishing fundamental goals through potential international cooperation. Microsymposium 56, “Crust of the Moon: Insights Into Early Planetary Processes”, (http://www.planetary.brown.edu/html_pages/micro56.htm) identified a series of outstanding problems for future international human/robotic exploration of the Moon centered on: 1. Crustal geometry-physical structure; 2. Crustal Chemistry-mineralogy-petrology; 3. Exogenic crustal modification by impacts; 4. Chronology of crustal formation-evolution. Furthermore, the nature of mantle uplift and the possibility of sampling mantle in the uplifted material as well as determining the nature of basin impact melt processes (differentiated or undifferentiated) is critically important. Direct dating of impact melt and placing Orientale in the firm context of lunar chronology is also achievable. To illustrate the potential utility of the Deep Space Gateway ISOC, we are formulating a human/robotic exploration design reference campaign (DRC) to the 930 km Orientale impact basin (1,2), the most well preserved basin on the Moon. This DRC provides insight into all aspects of these fundamental questions.

Our design reference mission is a model for the exploration of the Moon and planets in the coming decades, and combines robotic exploration geophysics traverses operated radially from the basin interior, together with human exploration missions to the key sites that will provide data to address these questions. We outline six human exploration mission landing site targets: 1) Base of the Cordillera ring/Montes Rook Formation; 2) Base of the Outer Rook ring/Lacus Veris maria; 3) Inner Rook peak-ring massifs/Mauder Formation impact melt rough facies 1; 4) Mauder Formation impact melt sheet smooth facies; 5) Central melt sheet craters/Mare Orientale/Kopff crater; and 6) Mauder crater interior/ejecta. Our strategy for human/robotic exploration optimization from the DSG-ISOC centers on seven mission concept themes and is totally flexible relative to the important new results and significant discoveries that will be made from early DSG-ISOC-enabled science return in the next few years:

**Robotic Precursor Phase:**

I) **Precursor Robotic Missions** (What do we need to know before we send humans?);

II) **Context Robotic Missions** (What are the robotic mission requirements for final landing site selection and regional context for landing site results?);

**Human Surface Exploration Phase:**

III) **Infrastructure/Operations** (What specific robotic capabilities are required to optimize human scientific exploration performance? How can the DSG-ISOC implement/complement robotic capabilities);

IV) **Human Surface Exploration Phase** (Sorties to the key scientific exploration sites in the Orientale Basin for intensive scientific exploration with stay times up to 10-12 days and sample and data return back to the DSG-ISOC; practice feed-forward Mars exploration concepts);

V) **Interpolation Robotic Missions** (How do we use robotic missions to interpolate between human traverses);

VI) **Extrapolation Robotic Missions** (How do we use robotic missions to extrapolate beyond the human exploration radius);
VII) *Progeny Robotic Missions* (What targeted robotic successor missions might be sent to the region to follow up on discoveries during exploration and from post-campaign analysis?).

We use the targeted human exploration sites to illustrate how human exploration, complemented and assisted by robotic exploration, can provide insights into early planetary processes by exploring and characterizing the crust of the Moon. Our architecture provides insight into human/robotic exploration strategies for other lunar regions and other destinations on other planetary bodies such as Mars, all from DSG.

This international design reference mission approach will assist in identifying the key technologies, including laboratory, remote sensing and in situ that will be necessary to accomplish these fundamental and broad scientific goals in the DSG-ISOC time frame. It will also serve to form the partnerships and identify the opportunities and obstacles to international synergism. Human-Robotic partnerships in science and engineering synergism (SES), such as that exemplified by the NASA Solar System Exploration Virtual Institute (SSERVI), are absolutely essential to formulating and achieving these goals.

Fig. 1. Perspective view of topography of Orientale Basin. LRO LOLA data.


Fig. 2. The Orientale Basin from Lunar Orbiter, showing the rings and the Apollo and Luna equivalent landing site locations for the Orientale Basin.

Fig. 3. LRO LOLA Topography of the Orientale Basin.

Fig. 4. GRAIL Bouguer gravity map of Orientale Basin.

Fig. 5. Exploration Region of Interest 3 (ROI-3) for the origin of Inner Rock Mountains and Maunder Formation impact melt.