EXPLORING THE LUNAR SOUTH POLAR REGION AND FAR SIDE WITH HUMAN AND HUMAN-ASSISTED SAMPLE RETURN MISSIONS. D. A. Kring[1,2] [1]Center for Lunar Science and Exploration, USRA-Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX 77058 USA, [2]Solar System Exploration Research Virtual Institute (kring@lpi.usra.edu).

Introduction: There is broad international consensus that exploration of the Moon can address fundamentally important scientific questions (e.g., [1,2]) while providing a credible path that carries exploration beyond low-Earth orbit (e.g., [3]). Yet, we have never explored the lunar polar regions or the lunar far side with a lander, rover, or sample return mission. The polar regions and the far side remain luna incognita.

Intriguingly, orbital assets, supplementing the insights gained through the Apollo and Luna programs, indicate the Moon is the best and most accessible place in the Solar System to deduce processes associated with planetary accretion, differentiation, formation of primitive planetary crust, and impact modification of that crust.

One of the most comprehensive studies of lunar exploration objectives [1] outlined eight scientific concepts and thirty-five prioritized investigations. A series of summer studies, spanning five years, were conducted to identify every location on the lunar surface where those investigations could be addressed. The final summary of those studies [4] concluded that the majority of the objectives could be addressed in the South Pole-Aitken basin if exploration was limited to that region; that Schrödinger basin, which is within the South Pole-Aitken basin, is the scientifically-richest site; and that Amundsen crater, along the margin of the South Pole-Aitken basin, may be a better location to study volatiles than Shackelton crater.

Schrödinger Basin: This ~320 km diameter impact basin is the second youngest basin and the best preserved of its size. It is located in the modification zone of the South Pole-Aitken basin, the oldest recognizable basin on the Moon. A sample return mission to Schrödinger has the potential of determining the duration of the basin-forming epoch and testing the lunar cataclysm hypothesis [5,6], effectively addresssing the two highest science priorities of [1].

In addition, because the basin is so well preserved, it is a perfect target for discerning the geological processes of basin-size impacts.

Those processes uplifted material from great depth, producing a peak ring of crystalline massifs that expose lithologies that can be sampled to test the lunar magma ocean hypothesis. That material, when combined with material exposed in the basin walls and that survives as clasts within impact breccias, can be used to reconstruct a cross-section of the lunar crust. The Schrödinger impact melt can be used to derive the bulk composition of that crust.

Long after the impact melt had solidified, magmas rose through the basin and erupted on the basin floor, producing mare basalt flows and an immense pyroclastic vent. Both of those volcanic products can be used to probe the thermal evolution of the lunar interior.

The pyroclastic vent (Figure 1) is a potential in situ resource utilization (ISRU) target and, for that reason, was one of the sites observed during the human-precursor exploration phase of the Lunar Reconnaissance Orbiter mission. The vent may provide volatile deposits and fine-grained material that is easily excavated, transported, and processed for a sustainable exploration effort.

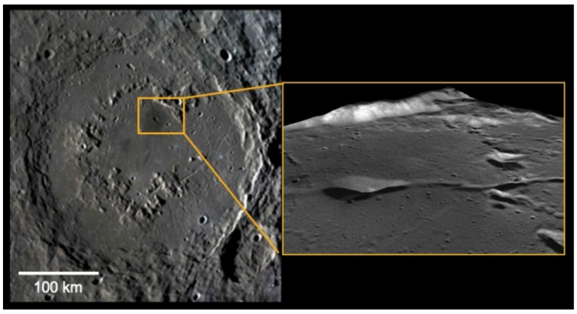

Figure 1: An immense pyroclastic vent on the floor of the Schrödinger basin that was targeted for its ISRU potential by the Exploration Systems Mission Directorate's portion of the Lunar Reconnaissance Orbiter mission.

Because Schrödinger is so well preserve and the diversity of geological processes so broad, a majority of the issues outlined in [1] can be addressed with sample return missions to/from this structure [4].

Studies have identified several landing sites and geologic stations for human sample return missions [5,7]. Studies have also identified several landing sites for human-assisted sample return missions [8-10]. In the latter context, a robotic asset on the surface would be coordinated with crew in an Orion vehicle in an orbit around the Earth-Moon L2 point [11] or in a distant regtrograde orbit.

Schrödinger basin is also a good location for the deployment of a low-frequency radio antenna to address astrophysical science objectives [11].

Amundsen Crater: If one instead focuses on the scientific and exploration issues associated with volatiles, then Amundsen Crater is an alternative location for sample return. Studies [12] suggest that all of the investigations of [1] associated with volatile elements in lunar polar regions can be conducted at this site.

Portions of the crater are on the nearside, providing the option of direct communications with

Earth, although access to far side stations might enhance the scientific return of any mission. Amundsen has a broad flat floor suitable for safe landings. It is also often illuminated, providing power to surface assets. Robotic or crewed rovers can drive into permanently shadowed regions (PSRs) to conduct analyses and collect samples in the coldest and potentially volatile-richest regions. Thermal gradients between a sunlit landing site and the PSRs allow for tests of transport and depositional mechanisms.

Also, a traverse across the basin floor will provide access to impact melt samples that can be used to determine the crater's age if returned to Earth and, thus, help calibrate impact flux rates to the Earth-Moon system. Moreover, if a traverse reaches the central peak, then samples of the deep crust can be analyzed and/or recovered.

Mission Options: To adequately address most lunar objectives of [1], sample return missions are required. The best results will be obtained by trained crews on the lunar surface. In the Constellation Program, those activities could have involved crews of four and at least one Lunar Electric Rover for mobility. A human-rated lander and rover, however, are no longer being developed, so alternative architectures involving integrated human and robotic systems are being developed.

Specifically, it may be possible for crew with a NASA Orion vehicle and ESA service module to tele-operate rovers on the surface (Figure 2) and/or provide a communication relay to mission control assets on Earth. In that type of scenario, samples could either be delivered by an ascent vehicle to the Orion spacecraft or, with a return capsule, directly to Earth. Both of these options are being examined in the context of missions to the Schrödinger basin and other areas within the South Pole-Aitken basin (e.g., [11,13]).

A sample return mission to Amundsen would also produce the great insights, but, in that case, meaningful in situ studies of volatiles are another option. Because volatile components can be manipulated with relatively low-temperature transformations, chemical abundances, molecular species, and isotopic measurements can be made on the lunar surface.

Conclusions: The diversity of geologic exposures in the Schrödinger basin provides several interesting mission scenarios and options for multiple sample return missions. If the focus was entirely on the issue of volatiles, then Amundsen crater is a good alternative landing site. Both would produce extraordinary science and provide an opportunity to develop capabilities that will sustain the exploration of space beyond low-Earth orbit.

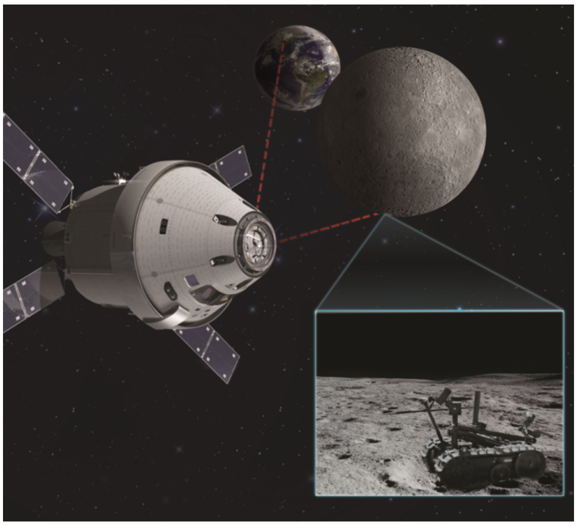

Figure 2: Illustration of the NASA Orion vehicle and ESA service module in the Earth-Moon L2 location above the lunar far side, from where crew can tele-operate a sample-collecting rover and maintain communications between surface assets and mission control on Earth.

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