12 ACTION ITEMS FOR OPTIMIZING HUMAN EXPLORATION & LUNAR SCIENCE IN THE NEXT 5 YEARS.

James W. Head[1] and David R. Scott[1]. [1]Department of Earth, Environmental and Planetary Sciences, Brown University, Providence, RI 02912 USA (james_head@brown.edu)

Introduction: The next five years of lunar science and exploration represent the beginning of a new era of human and robotic exploration of the Solar System, with an international armada of missions focused on the Moon, and missions addressing fundamental questions about our origin, evolution and our future. A major focus of this armada is exploration of the South Circumpolar Region (SCR) [1,2] with two major goals: 1) Assess the distribution, modes of occurrence, characteristics and abundance of polar volatile species, particularly water, and 2) obtain a representative sample of the Moon outside of the Apollo-Luna exploration region, with emphasis on obtaining a sample of South Pole-Aitken (SPA) Basin ejecta. Here we focus on the second goal, and outline 12 major themes and objectives for the next five years to optimize the chances for achieving this goal.

1) SCR is like Apollo 16, not like Apollo 15 and 17: Geologic goals and objectives at Apollo 15 and 17 were clear, very morphologically distinct, and assisted in traverse planning and mission operations. In contrast, the SCR is like Apollo 16 site geology: Astronauts Young and Duke quickly discovered that there were no highland volcanic plains, but instead the region was dominated by highland impact breccias of immediately unknown, and still today, uncertain provenance. Revisiting the Apollo 16 mission traverses and results will provide major insights into optimizing SCR exploration.

2) A Lot Has Happened Since the Formation of the SPA Basin: The SPA Basin is the oldest accepted impact basin, and thus SPA ejecta and related deposits have been subject to very significant destruction and reworking by over 4 Ga of impact cratering at all scales. Detailed geologic mapping [e.g., 3-4) is required to document the provenance of materials (redistribution by overlapping impact crater ejecta deposits) at any given point in the SCR, and to select landing sites and optimize scientific return.

3) Implications for Mobility: In order to ensure that a single impact crater ejecta deposit does not dominate the traverse region (minimizing science return), a minimum Apollo-style LRV capability (tens of km distance) is required.

4) Implications for Human-Robotic Partnerships: Because of the complexity of the SCR geology [1-4], and the subtlety of visible petrologic distinctions, ground-controlled roving robotic precursors, scouts and extrapolator missions (all with a full array of remote-sensing instruments) will be essential to scientific success.

5) Implications for Landing Site Selection: Due to the significant number of large craters (and thus extensive ejecta deposits) in the SCR, landing site selectin must incorporate detailed geologic mapping of overlapping ejecta deposits [1-3], as well as landing safety considerations, in order to optimize mission success.

6) Implications for Mission Planning, Systems Engineering and Systems Integration: Engineers, scientists and operations planning personal must work shoulder-to-shoulder to ensure the type of *science and engineering synergism* (SES) that evolved in Apollo, and that optimized mission scientific success.

7) Implications for Traverse Scientific Instrumentation: Due to the likelihood that virtually all samples will be impact breccias, sophisticated traverse and hand-held remote sensing instrumentation will be necessary to provide immediate detection of key minerals and geochemical signatures to enhance sample selection and triaging.

8) Implications for CONOPS: Traverse goals and objectives will not be as clear-cut as on Apollo 15 and 17, and will require intensive systems engineering integration efforts to optimize scientific return and real-time and inter/intra-EVA replanning.

9) Implications for Real-Time Science Support: Despite major advances in communications and video bandwidth, the optimal “situational awareness” will always be with the Astronauts on the ground [5]. This means that the Apollo ‘T3’ approach (Train ‘em, Trust ‘em, and Turn ‘em loose) should be the guideline for the real-time Ground Science Support Team and procedures should be developed for seamless updates and any real-time mid-course exploration corrections from ground-monitored remote sensing data or other updates.

10) Implications for Astronaut Training: The Apollo 16-like nature of the SCR means that a major pre-mission focus should be on intensive classroom, laboratory and field training of the Astronauts in lunar science and samples, sampling optimization procedures in impact-breccia-related terrains, and working shoulder-to-shoulder to ensure SES. Focus should be on 1) the optimization of hand-held real-time sample characterization procedures, 2) seamless updates from the ground on data collected remotely, 3) obtaining a representative sample, and 4) ensuring time and openness to unanticipated discoveries (e.g., and orange pyroclastic glass on Apollo 15 and 17).

11) Implication for Sample Return Mass: The complexity of the SCR geology means that mission success and scientific return will be determine post-mission, after the samples are unpacked and analyzed in terrestrial laboratories. Thus, sample return mass for each mission must have a minimum of Apollo J-Missions (Apollo 17: >110 kg).

12) Implications for Feed-Forward to Mars: Procedures for human and robotic exploration of the SCR must always consider what lessons can be learned to optimize human Mars exploration, where immediate communications are not possible. Chief among these lessons will be: 1) optimizing crew scientific training and independence during EVAs, and 2) focusing debriefing and exploration replanning into periods between EVAs.

Beyond the next five years, we are also researching the needs for human long-term and short-term camping habitats using synthetic biology and mycotecture [6] and integrating them into design structures and reference missions.

References: 1. Weber et al. (2020) LPSC 52 1261; 2. Head et al. (2021) NESF-ELS 292028; 3. Krasilnikov et al. (2021) LPSC 52 1428; 4. Krasilnikov et al. (2021) LPSC 52 1459; 5. Krikalev et al. (2010) Acta Astron. 66, 70; 6. Rothschild et al. (2021) LPSC 52 2687.