USE OF PRESSURIZED ROVERS IN SUPPORT OF PIT AND CAVE EXPLORATION ON THE MOON AND MARS

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Summary: Pressurized rovers are critical to supporting human cave exploration on the Moon and Mars by a) transporting caving equipment, b) serving as a reliable anchor, and c) providing a safe haven immediately outside the cave.

Introduction: Pits and caves are considered important targets in the future scientific exploration of the Moon and Mars [1]. Specific logistical and operational requirements for astronaut EVA (extra-vehicular activity) into pits and caves were investigated recently [2, 3]. In this study, we evaluate the potential role of pressurized rovers in supporting human pit and cave exploration on the Moon and Mars.

Approach: We draw from the recent studies of caving EVA, from the Apollo experience, and from planetary exploration analog experiences on Earth to identify rover requirements and functions.

Caving Equipment Transportation. Pit and cave exploration requires the availability of substantial caving and safety gear. Key items include rigging, safety lines, cables, ladders, lighting, portable power, communications system and relays, portable life support system (PLSS) supplies (*e.g.*, spare O_2 tanks), and more [3]. The large mass and bulk of this gear, estimated to range between hundreds of kilograms to potentially several metric tons, depending on the complexity of the caving operations, precludes its transportation on a small crewed vehicle such as the NASA Artemis LTV (Lunar Terrain Vehicle). Instead, a larger roving platform is required. The gear does not need to be pressurized, so a larger unpressurized roving platform would suffice.

Anchoring. Apollo astronauts had significant difficulties drilling on the Moon, as the lunar regolith was significantly more compact than expected, starting at shallow depths of just a few centimeters but especially below a depth of ~30 cm [4]. This resulted in drills jamming, components shearing off, and subsurface sampling failing. This Apollo experience suggests that creating robust surface anchors, a key requirement to enabling safe caving -in particular pit ingress and egress-, should not be reliant on regolith anchors.

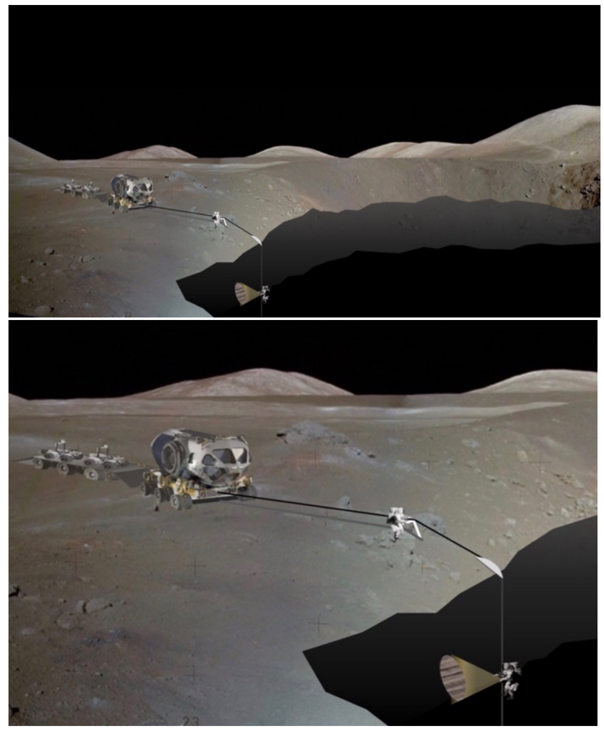

Figure 1. Pressurized Rover-Supported Cave Exploration*. An astronaut examines the vertical wall of a lunar pit while being lowered by another crewmember operating a winch anchored to a pressurized rover parked outside the cave.* ***Top:*** *General view.* ***Bottom:*** *Detail. Background landscape: NASA/Apollo 17/Shorty crater.*

Instead, a heavy vehicle positioned outside the cave entrance would provide, through ground friction, a reliable, robust, and mobile surface anchor.

Safe Haven. Caving EVAs will be inherently more risky than surface EVAs. While caves offer shelter against surface ionization radiation, micrometeoritic bombardment, and stark day-night temperature variations, they also present heightened risks compared to surface conditions, including confinement, darkness, loss of solar power, loss of communications, uneven surfaces, obstacles, rockfalls, tortuosity, and surbsurface operations. In spite of the anticipated extra caution to be applied in cave exploration, preparedness for emergency cave extraction and crew care is required. A pressurized habitable volume located immediately outside a pit or cave being explored would address this requirement, serving as a deep field safe haven analogous to a “base camp” in mountaineering or a hyperbaric chamber on deep diving ships.

Discussion. Combining the requirements for caving equipment transportation (a larger than LTV roving platform), anchoring (a heavy rover), and a safe haven (pressurized habitat), a pressurized rover provides a logical and ideal solution. A pressurized rover could transport the caving gear externally, on the vehicle itself or on a trailer; it would have amply sufficient mass to serve as an anchor; and it would provide a safe haven on site doubling as a medical evacuation vehicle.

Conclusion: This study identifies three fundamental uses of pressurized rovers in support of future human pit and cave exploration operations on the Moon and Mars: a) caving equipment transportation, b) anchoring; c) safe haven.

Future Work: Future work will include identifying specifics on how supporting caving affects the design of pressurized rovers, and investigating the proposed pressurized rover-based caving concept of operations at terrestrial analog sites.

Acknowledgments. A. Somani is supported by the US Air Force Academy Martinson Honors Program and by the Mars Institute; P. Lee by the SETI Institute, the Mars Institute, and NASA.

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