

PLUTONS - PITS AND LUNAR LAVA TUBE EXPLORATION FOR PERMANENT SETTLEMENTS

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Summary: The ongoing PLUTONS (Pits and Lunar Lava Tube Exploration for Permanent Settlements) studies at USC to create graphic architectural concepts to explore and settle lunar lava tubes are presented.

Introduction: Most of the literature and proposals on lunar habitats to date have focused on lunar surface habitats and their evolution into permanent lunar surface settlements. Lunar lava tubes would offer several advantages over surface habitats, especially for building and servicing permanent settlements (**Fig. 1**).

Context: High resolution imagery from JAXA's Selene lunar orbiter have revealed naturally occurring breaches on lunar lava tubes. (Haruyama et al., 2009). These breaches were further confirmed by the Lunar Reconnaissance Orbiter. We call these naturally occurring lava tube roof breaches "skylights". We are now aware that there are plenty of these breaches all over the Moon and Mars. They appear to have been made by weak structure or caused by meteoritic impacts.

NASA's GRAIL mission (Zuber et al. 2013) pointed to a large distribution of subsurface cavities all over the mid latitudes and the intriguing lack of such features in the lunar polar regions.

Recent studies by P. Spudis et al. suggest shield volcanoes, and J. Melosh of Purdue has argued that lunar lava tubes are very sturdy structures. D. Kring of LPI also suggests that lunar lava tubes offer the next frontier for employing advanced technologies for exploration.

Approach: Recent studies and proposals to explore features like caves, pits and lava tubes (Whittaker 2012) have garnered interest, and teams from Caltech (Kerber et al. 2018), Michigan Tech University and USC have proposed using tethered robots to descend to the interior to explore these subsurface cavities. Analog exploration studies are ongoing in Iceland (Lee 2019), Hawaii (Rogers 2020) and around the globe.

Presentation: The PLUTONS project talk examines various aspects of exploring and settling lunar lava tubes. The focus is on creative concepts developed by the participants in the Spring 2024 ASTE527 Astro studio at USC.

Discussion: As an officer of the National Space Society and the Moon Village Association,

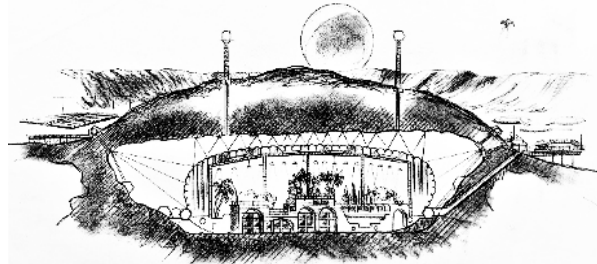


Figure 1: Concept for a Lunar Lava Tube Settlement. Lunar lava tubes may offer the potential to house permanent settlements, protected from the harsh surface environment and hazards. (M. Thangavelu)

it is good to remind that these space advocacy organizations' charter goes beyond those of the world's space agencies, and resonates with the NSS' *core philosophy for our species to become truly spacefaring; to live work and thrive in space and extraterrestrial settlements; to extend our reach and expand our sphere of activities outward into the solar system and beyond.*

Conclusion: It is long past time to boldly propose exciting and innovative lunar exploration missions. PLUTONS concept proposal offers ample opportunities to study exploration and potential lunar lava tube settlement opportunities.

Future Work: Versions of concept studies from the Spring 2024 PLUTONS studio will be presented at various conferences and meetings.

Acknowledgments: This ongoing work is being done in the graduate ASTE527 Astro Studio by the graduating class of astronautical engineering students in the VSoE, Dept. of Astronautical Engg.

References: Haruyama, J., et al. (2009). Possible lunar lava tube skylight observed by SELENE cameras. *Geophysical Research Letters*, 36(21); Kerber, L. (2018). Moon Diver: A Discovery Mission Concept for Understanding Planetary Flood Basalts. *AGU Fall Meeting Abstracts*, Vol. 2018, pp. P54D-09. Whittaker, W. (2012). Technologies enabling exploration of skylights, lava tubes and caves, No. HQ-E-DAA-TN63846. Lee, P. (2019). Habitability of lava tubes on the Moon and Mars: Lessons from Earth.