Caves as Planetary Analogs for GPS Denied, Low-Light Mapping and Navigation in Rugged Environments. W. E. King[1], M. R. Zanetti[1], E. G. Hayward[1], and K. A. Miller, [1]NASA Marshall Space Flight Center, 4600 Rideout Road, Huntsville, AL 35812, United States. (Contact: walter.e.king@nasa.gov)

Background: The Kinematic Navigation and Cartography Knapsack (KNaCK) team is developing tools that enable ultra-high resolution terrain mapping and navigation using mobile light detection and ranging (LiDAR) and simultaneous localization and mapping (SLAM) algorithms in fully GPS-denied and unilluminated environments [1, 2]. The backpack mounted LiDAR instrument under development by our team demonstrates the potential of mobile SLAM LiDAR for use in challenging surface environments such as steep walled craters and permanently shadowed regions as well as for lunar, planetary, and terrestrial cave exploration, study, and utilization [3].

Caves as Planetary Analogs: The lunar south pole has rugged and irregular terrain, difficult illumination conditions (extremely low angle of incidence sunlight), and no access to GPS. Lava tubes and subsurface voids on the Moon, Mars, and other planetary bodies will be similarly challenging. Terrestrial caves are excellent analogs for these conditions, providing a proving ground to refine technology for mapping and navigation on other worlds while advancing the State of the Art for terrestrial cave survey. The overburden above cave passages blocks ingress of both light and GPS signals. Highly irregular geometry challenges scan matching algorithms and frequent jostling of the instrument due to rugged and confined terrain interferes with the accuracy of dead reckoning based on inertial measurements. These conditions are similarly challenging to other lunar surface technologies. The responsible use of terrestrial caves as planetary analogs could benefit a wide array of technology development efforts.

Field Work: The KNaCK instrument was used to map two terrestrial caves: Three Caves in Huntsville, AL, and Lava River Cave, a lava tube in northern AZ. Data from Three Caves was collected in 6.5min, capturing a substantial portion of a maze-like complex with only a 370m traverse. Data from Lava River Cave was collected in 44min over 1100m. The maps produced contain 18.4M and 44.8M points, respectively, after post-processing.

Results: The accuracy of the Lava River Cave scan was compared to an existing survey of the cave produced by the Central Arizona Grotto (Fig.1). The LiDAR map is highly accurate at local scale, recording the morphology of the cave in cm-scale detail. However, there is notable drift from the survey at global scale. Continued testing in cave environments offers an opportunity to tune SLAM parameters and experiment with constraining solutions with other data sets (such as survey data or radio location stations).

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References: [1] Zanetti M. R. et al. (2022) LPSC LIII, Abstract #2660. [2] Miller K. A. et al. (2022) LPSC LIII, Abstract #2808 [3] King W. E. et al. (2023) IPCC IV, Abstract #1075.

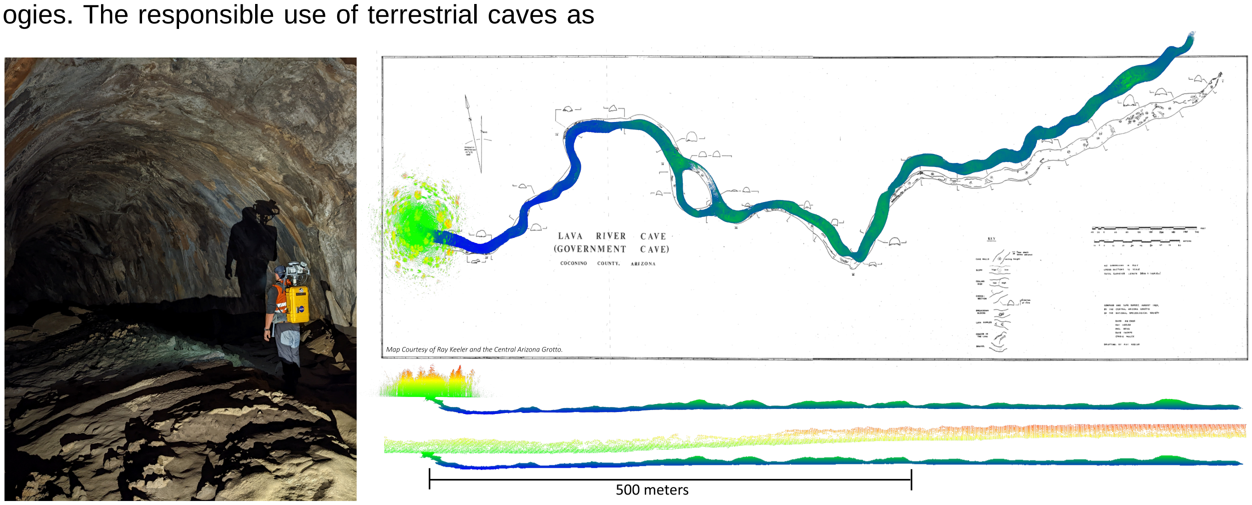

Figure 1. Lava River Cave: (left) scanning borehole passage, (top) LiDAR map overlaid with traditional cave map, (middle) profile view of LiDAR map, (bottom) NAIP Point Cloud DEM overlaid with LiDAR map.