ASSESSING MARTIAN CAVE EXPLORATION FOR THE NEXT DECADAL SURVEY. A. A. Fraeman[1], J. C. Castillo[1], E. J. Wyatt[1], S. A. Chien[1], S. J. Herzig[1], J. L. Gao[1], M. Troesch[1], T. Stegun Vaquero[1], W. B. Walsh[1], K. V. Belov[1], K. L. Mitchell[1], J. Lazio[1], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA (abigail.a.fraeman@jpl.nasa.gov).

Introduction: Mars cave exploration is a topic of growing interest in the planetary science community as well as for human exploration. Hundreds of Martian candidate cave-related features have been identified in orbital datasets, most commonly associated with lava tubes [1]. Caves offer stable physio-chemical environments, may trap volatiles, enhance secondary mineral precipitation and microbial growth, are expected to preserve biosignatures, and provide record of past climate [eg. 2, 3]. Investigation of petrological sequences on skylight and cave walls can provide critical constraints on lava temperature and cooling history, leading to insights into Martian magmatic processes and differentiation. Caves are also believed to offer stable, radiation-shielding environment and potential to act as volatile traps, which will be important in future human missions [4].

Science Definition and Links to MEPAG Goals: Building on previous studies, we identified that a future mission to Martian caves should provide reconnaissance both for scientific and human exploration. Key science objectives for this pathfinder mission would be to map the cave geometry, determine traversability challenges, document the cave environment, and map the compositional and lithological diversity of the cave materials, including looking for volatiles, and organics.

Cave exploration would support MEPAG high level science objectives (IB) to determine if environments with high potential for current habitability and expression of biosignatures contain evidence of extant life, (IIIA) document the geologic record preserved in the crust and interpret the processes that have created that record, and (IVB) obtain knowledge of Mars sufficient to design and implement a human mission to the Martian surface with acceptable cost, risk, and performance.

Information needed to mature concept for decadal survey: The science goals should drive mission design, instruments and resource requirements. A payload could leverage recent or emerging miniaturized instrument developed for CubeSat-class deep space missions because of the mild radiation and thermal environment expected in caves. Here we focus on what is needed to understand how a reconnaissance mission might be carried out with a constellation of small (10s kg) platforms.

Mission architecture challenges: Managing the resulting complex design space, and performing associated trade studies to find well-balanced solutions, requires appropriate computational methods and tools to support mission designers and systems engineers in their decision-making processes. We are developing tools to study heterogeneous architectures where responsibilities (science, telecom) are distributed among assets. Our study includes trade-offs between potential power sources, homogeneity and heterogeneity of the assets, as well as distribution of science instruments to optimize cost and achieved benefit.

Telecommunication Challenges: The cave environment presents a significant challenge in maintaining reliable communications. Moving close to a cave wall or operating in small caves could all lead to substantial challenges for communication. In the most extreme case, two mobile assets could be in direct line of sight yet unable to communicate. This concept represents a perfect example for the application of disruption tolerant network (DTN) technologies. In order to allow a deeper analysis of these challenges, we have launched an effort to develop the capability for measuring and characterizing radio signal propagation at much higher fidelity in order to make sound design decision for in-cave communications.

Coordinated Autonomy: Novel operational concepts will be required, which are expected to include higher levels of autonomy and frequent communication among assets for autonomous coordination. A few different exploration strategies are being investigated for autonomous multi-rover cave exploration. The Dynamic Zonal Relay Algorithm spreads out the rovers along the length of the cave such that each rover investigates a specific area of the cave while maintaining communication distance to the neighboring rovers. The Sneakernet Relay Algorithm is an extension of the Dynamic Zonal Relay Algorithm where the rovers move beyond the communication range to neighboring rovers, allowing for data acquisition deeper in the cave. The Scout Observation Algorithm works on the premise that there are multiple scouting rovers and a single more capable science rover.

Summary: Advanced design of a Martian cave exploration concept has highlighted the need for novel approaches to communication and science acquisition. We note that these approaches may also be highly relevant to additional future Martian mission studies that utilize networks of assets to explore a single surface site.

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