MARS CAVE EXPLORATION CONCEPT FOR SCIENCE AND HUMAN EXPLORATION.

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Introduction: Planetary cave exploration is a topic of growing interest in the planetary science community as well as for human exploration. More than 200 lunar and 2000 Martian cave-related features have been identified. Vents and fissures associated with water ice plumes on Saturnian, Jovian, and Neptunian moons also represent possible cave systems [1]. Lunar and Martian caves most commonly associated with lava tubes, although some have been proposed to be present in karstic sulfate terrain (Mars) and cryovolcanic features (outer planet moons). 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 [2, 3, 4]. 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 [5, 6]. Caves also represent potential environment for future human exploration: they are believed to offer stable, UV-shielding environment and potential to act as volatile traps [7].

Science Definition: Building on previous work, 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: (1) map the cave geometry (cave diameter/ceiling height from entrance to >100 m depth), (2) determine traversability challenges for future missions (boulder distribution, unconsolidated material), (3) document the cave environment (spatial and temporal variations in temperature and humidity and radiation), and (4) map the compositional and lithological diversity of the cave materials, in particular to characterize mineralogy and search for volatiles, and organics. These science goals led to identification of possible instruments and resource requirements. The payload leverages recent or emerging miniaturized instruments developed for CubeSat-class deep space missions. The mild radiation and thermal environment expected in caves justifies the use of CubeSat-class instruments while the multiple assets provide redundancy.

Subsurface Explorer Concept: Resource analysis so far suggests that the science of interest for a reconnaissance mission could be carried out with small (10s kg) platforms. Yet, intrinsic to their sizes, these platforms have limited resources, science capability, and lifetime. The situation is exacerbated in the case of the present concept where the only power source comes from batteries (radioisotope heating units were not deemed valuable in terms of anticipated cost and complexity). Novel operational concepts are required to compensate for limited power, which are expected to include higher levels of autonomy and frequent communication among spacecraft for autonomous coordination. Managing the 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. These will be addressed in more detail in the presentation. We have focused on utilizing a variety of assets and strategies to mitigate challenges related to communication and instrument operations while optimizing data acquisition and science data retrieval via an organized network. We studied 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. An important result from this study is that demanding telecommunication scenarios anticipated for this concept challenge the notion that cave exploration could be achieved with very small platforms (<1 kg) as has been suggested in the past [8, 9].

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