"Deep Trek: technology & mission concepts to explore the Martian subsurface habitability & life"

V. Stamenković (Vlada.Stamenkovic@jpl.nasa.gov), C. Edwards, N. Barba, M. Burgin, R. Grimm, K. Carpenter, P. McGarey, R. Manthena, M. Mischna, N. Lanza, J. Mustard, V. Orphan, K. Rogers, K. Zacny, B. Sherwood Lollar, B. Ménez, T. Spohn, A.-C. Plesa, J. Michalski, M. Osburn, P. Boston, K. Lynch, J. Tarnas, M.-S. Bell, J. Blank, K. Webster, T. Kieft, B. Sauterey, J. McDonnell, B. Sherwood-Lollar, J. Mustard, N. Smith, O. Warr et al.

1. Pitch: The goal of this white paper is to lay out the mission concepts, from SmallSats to New Frontiers-type, and existing instruments or technologies in near reach for taking on the exploration of the Martian subsurface with a focus on modern-day subsurface habitability and signs of subsurface life. We think that the answers to the driving questions that led us to Mars might be hiding beneath the wheels of our rovers and that it is time to explore this, as yet unknown, world. By doing so, we are embracing the recommendation to 'Go deep' by the National Academy of Sciences Committee on the Strategy for the Search for Life in the Universe from 2019. A companion paper, entitled "Deep Trek: exploring the modern-day subsurface habitability & life on Mars" is addressing the scientific motivation for taking on the exploration of the Martian subsurface with a focus on modern-day subsurface habitability and signs of subsurface life. We are standing at an exciting point in time, when we finally have the technological tools to start exploring one of the most promising targets for past and especially present life on Mars, the Martian subsurface. Join us for the beginning of this "Deep Trek".

2. Rationale: Today, the Martian surface is in many ways inhospitable to life for two main reasons: (1) on the Martian surface, liquid water and most brines are only metastable. The conditions needed to keep water liquid are, for the majority of the planet, generally at depths of several kilometers in the subsurface. Only salts such as perchlorates or soils with very low thermal conductivity can shift this depth, locally, closer to the surface but the extent of such salts on the surface and with depth is not clear. (2) Organics are being bombarded by oxidizing radicals and harsh radiation on the surface to a yet to be determined depth. These two points illustrate a trade-off between depth, modern-day habitability, and signatures of life: the first few meters could be too harmful for modern life to exist, freshwater at kilometers depth might offer high water activity needed by life, and brines could offer locally shallower liquid water but with a lower water activity.

Therefore, the quest to search for life in the solar system calls for exploring the Martian deep subsurface, which is likely the largest and longest-lived potentially habitable environment on Mars – possibly until present day.

In this white paper, we discuss the technology and mission concepts that would enable a start to the exploration of the Martian subsurface with a focus on quantifying the trades for modern-day subsurface habitability with depth, from shallow to deep, and searching for signs of extant subsurface life. The mission concepts discussed here vary in complexity from low-cost small spacecraft to New Frontiers-type mission concepts and Flagship mission designs.

This includes, for example, SmallSat concepts with landed electromagnetic sounders to characterize liquid groundwater or deployed gas sniffers to localize and constrain the biological potential of released trace gases. New Frontiers-type and Flagship mission concepts include the mission concept called VALKYRIE (Volatiles And Life: KeY Reconnaissance and In-situ Exploration).

VALKYRIE proposes to carry an electromagnetic sounder or equivalent to characterize liquid water inventories to kilometers depth, a deep drill to access the subsurface from 10-100 m, a heat probe sensor on the drill, and a surface biogeochemical analysis package with flexible complexity depending on mission class and degree of mobility, focusing on the variability with depth of the geochemical potential, nutrients, organics and signs of life.

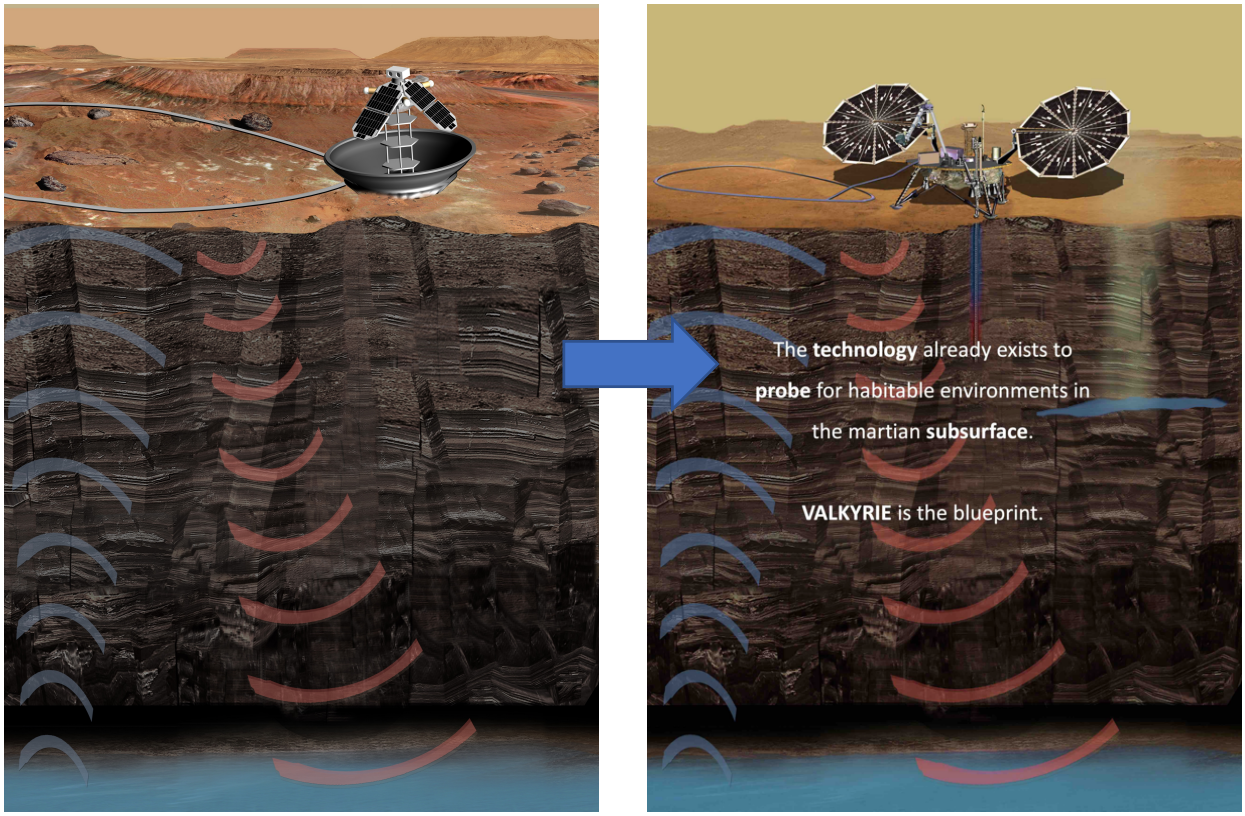

Figure 1: Exploration of the Martian subsurface with Smallsats to New Frontiers and Flagship mission concepts. SmallSats can bring liquid water sounders with trace gas sniffers. The VALKYRIE (Volatiles And Life: Key Reconnaissance & In-Situ Exploration) mission concept would allow more advanced and complete characterization of subsurface habitability.

3. Status of the white paper effort so far/planned schedule for its development: There already has been large community efforts in this field, from two white papers to the NAS in 2018 and ESA in 2019, a community paper in Nature Astronomy in 2019, a KECK KISS workshop in 2018, a NAI Workshop Without Walls in 2019 and two large AGU sessions (2018, 2019) amongst others.

4. The sort of involvement/collaboration we are seeking: We have lots of material to work with (see 3.) and are seeking additional co-authors, reviewers and co-signatories across the spectrum, from scientists to engineers.