Considerations Related to Planning for the Exploration of the Martian Subsurface

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The Time to Start Exploring a New World: The Martian Subsurface

Access to the Martian subsurface, either through sounding or drilling, with exploration related to life & resources offers an unprecedented opportunity to explore a new world that so far has only been scratched. The quest for life and water inevitably leads into Mars' subsurface. MSL showed with one inch drills that the subsurface is chemically highly diverse and different from the surface. The technology is ready to enable diverse and affordable missions, from SmallSats fitting within ESPA class over Discovery & New Frontiers Classes, to Flagships. Exploring the subsurface will allow to (1) search directly for the "holy grail" of astrobiology—evidence of extinct and possibly even extant life on Mars—a journey started by the Viking landers more than four decades ago. It will also allow us to (2) detect and sample shallow ices & brines and possibly deep liquid water, (3) deliver sample cores to help complete our understanding of how the Martian climate, habitability, crust, and volatiles changed over time, and (4) allow to prepare for possible human exploration and find resources/ISRU—for which planning is lead by NASA and private space companies like SpaceX.

Why Mars Subsurface? For Life, Water, Resources & Climate

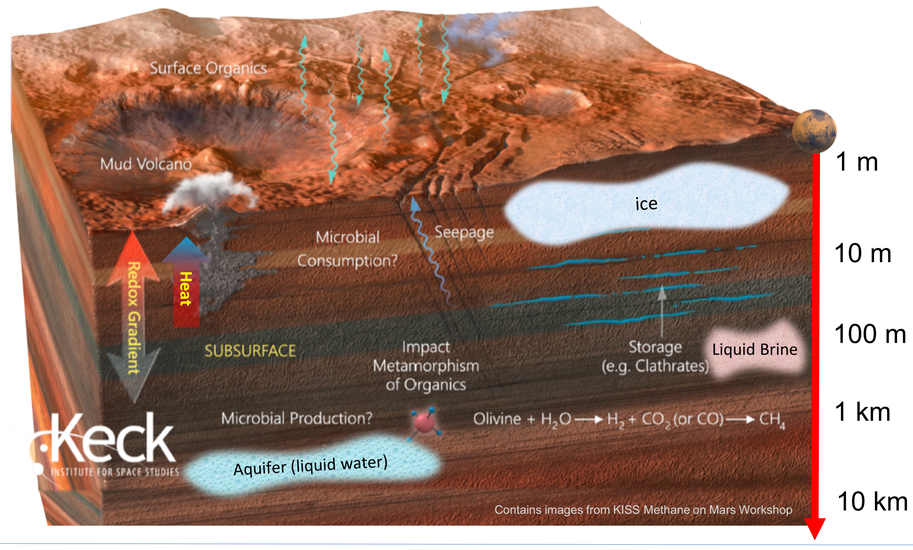
Because if we are looking for life and water, then there is no better place than the Martian subsurface.

- **Extinct life:** If life ever existed on Mars, then the longest living habitat was the Martian subsurface. It is also at greater depth (>1-5m) where the likelihood of biosignature preservation is greater due to shielding from radiation. (MEPAG Goal I)
- **Extant life:** If life still exists on Mars, then it is most likely to be found where liquid water exists. Brines could be liquid at shallower depth. Spectral evidence suggests brines on or close to the surface. Pure water aquifers are more likely to be below 1-10 km. (MEPAG Goal I)
- **Follow the water:** The subsurface is where liquid water was stable for the longest period in time, and where it might be still available in various forms and quantities. What are the water resources water (ice/liquid/thin films/pore filling/aquifers) in the Martian subsurface (MEPAG Goals I, II, IV)?
- **ISRU & humans:** The subsurface contains both valuable resources and hazards that must be explored for human missions. Technologies to access and handle such materials need to be developed. What are the resources in the Martian subsurface? Focus on water (ice/liquid) but also clathrates and other volatiles like CH_4 and O_2. (MEPAG Goal IV)
- **Climate & planet evolution:** How did the Martian climate and crust evolve over time? (MEPAG Goals II, III)

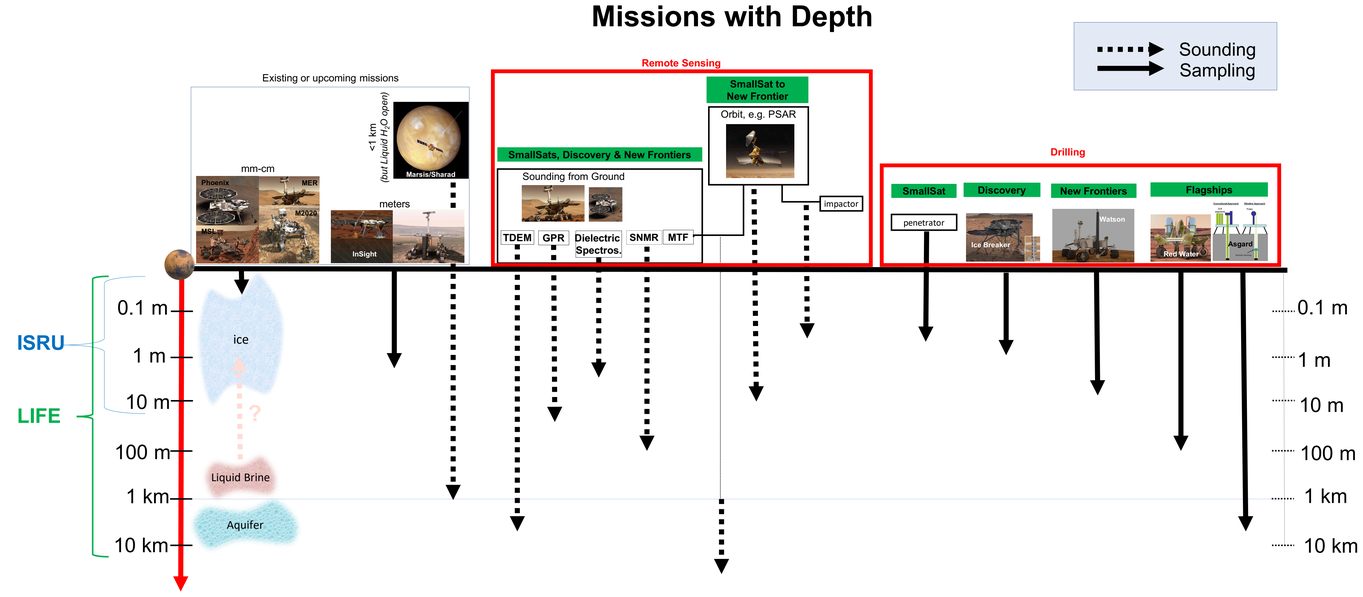
Why Now? Because…

- **It matters:** The Martian subsurface is the missing dimension of Mars exploration; and the place for life & water.
- **We can do it and do it affordably:** New technologies such as miniaturization, new materials, automation, data processing, sensor-driven adaptation, fault protection and recovery, CubeSat and SmallSat technology, SmallSat Bi-static radar (RAX/RainCube Combos), and 3D printing of engineering materials enable:
  - Small low-cost surface sounders for ice and water (SmallSat to Discovery Class).
  - Discovery Class and New Frontiers Class Drill missions to 1-10s of m.
  - Very Deep Drilling (100s of m to kms) for Flagship missions.
- **Commercial space exploration** targets Mars with the primary goal of human settlements. Before this can be done, we need to explore the resources and the hazards of the subsurface. Taking advantage of upcoming commercial sector interests and capabilities can be an important aspect of bringing these missions to fruition and reducing costs.
- **Cross-fertilization between Mars and Europa exploration/communities**: Subsurface exploration is key for Europa and other Ocean worlds. Mars subsurface exploration will benefit from Europa technology development and fertilize exchange between research on two very different worlds.
- **Back to the spirit of the Vikings and excite/engage the public:** A greater focus on life and a new unexplored dimension could massively enhance the public excitement for Mars in times where Europa is taking the lead.

Science with Depth



Missions with Depth



Science Objectives

- **Sounding**:
  - Map subsurface volatiles, focusing on H_2O, and the overburden over multiple spatial scales, from meters to multiple km, as it applies to the search for life and resources.
- **Chemical & Structural sampling as well as Ground truthing:**
  - Ground truth resources (focus on water (ice/liquid), secondary clathrates, other volatiles (e.g., CH_4)). Where and how much? Where is shallow ice equatorward of 50° latitude, how pure?
  - Measure in situ chemistry of shallow ices up to 50 m depth.
  - Measure chemistry of liquid brines and liquid water.
  - Get profiles of the D/H, $^{18}O/^{16}O$, carbonate content, organics, pH, volatiles, redox conditions, porosity, permeability, temperature, stratigraphy—unaffected by atmospheric processes or solar/cosmic radiation.
  - Evidence of life? Additionally, patterns of amino acids, macro-textual structure, sequencing.

MEPAG & NASA Goals Alignment

This initiative is highly aligned with MEPAG's goals, "Determining if Mars Ever Supported Life", "Understanding The Processes And History Of Climate On Mars", "Understanding the Origin and Evolution of Mars as a Geological System", and "Preparing for Human Exploration", which are tied to NASA's goals of scientific discovery, with the stated objective of understanding the Solar System, and exploration, with the objective of conducting human exploration in deep space.

So Far, Missions Have Physically Only Scratched the Surface

- Spirit and Opportunity used their Rock Abrasion Tool to get just millimeters below the weathering rind, while Curiosity's drill only extends this reach to ~ 5 cm. Mars2020 aims to reach ~ 6 cm.
- SHARAD & MARSIS have revealed subsurface ices, but the burial depth of those ices is poorly constrained and there is no ultimate answer related to liquid water, especially below 1 km, where it is expected to occur.
- InSight's HP^3 mole will reach depths of up to 5 m (in regolith) to measure heat flow. It will explore the deep large-scale structure but not the small-scale crustal regions that are relevant for life, resources, & climate.
- ESA's 2020 ExoMars rover will acquire drill samples from a depth of 2 m.

Mission Ideas: A Subsurface Fleet—From Small to Big

- **Sounding:**
  - Liquid water: Surface based Time Domain ElectroMagnetics (SmallSat to Discovery), Magnetic Transfer Function (Orbiter-Lander Configuration) (& Surface Nuclear Magnetic Resonance).
  - Ice mapping/characterization: Orbital (P)SAR, Surface Dielectric spectroscopy & Ground Penetrating Radar..
- **Drilling:**
  - 1-10m drill off the shelf (up to TRL 6) (Mars Ice Breaker, Trident, Marte, AMNH, Watson, Red Water).
  - 100 m capabilities near term for New Frontiers (Watson, Red Water).
  - Beyond 100 m under development but promising (can be MSL class, ASGARD).
- **Sounding and Drilling are complementary to each other. Should be done in parallel.**