LOW COST, LOW POWER, PASSIVE MUON TELESCOPE FOR INTERROGATING MARTIAN SUB-SURFACE.
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Introduction: While there are multiple potential targets on the Martian surface, (such as Martian volcanoes, ice core mounds known as pingos, and a variety of other geological targets with surface expression) whose interior composition is of great scientific interest, the high spatial resolution of muon tomography, recently demonstrated on Earth [1] (Figure 1) makes the technique particularly suited for the discovery and delineation of Martian caverns, the most likely planetary environment for biological activity. Developing the technology now would position it favorably for a surface mission in the 2018-2024 time period to explore Martian regions with previously-identified potential trace gas sources, especially if they are associated with caverns, lava tubes or hydrothermal vents.

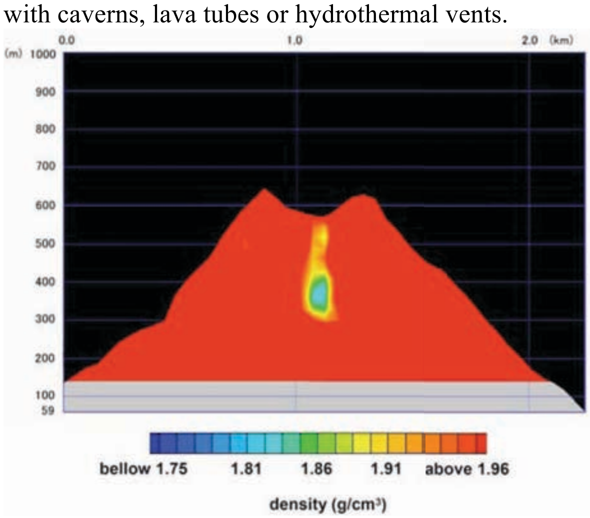

Figure 1: An example of the unprecedented resolving power of muon radiography - Density profile of a terrestrial volcano obtained with secondary cosmic ray muons [1].

A main goal of NASA's Planetary Science Decadal Survey is the study of fundamental processes on planetary bodies as key to understanding the evolution of worlds within our Solar System, and in particular the determination of the evolution of the surface and interior of Mars. A key priority of the decadal survey and of NASA's Mars Exploration Program Analysis Group (MEPAG) [5] is the detection of subsurface habitats on Mars. It accordingly outlines the need for future analyses of samples collected from sites with the highest potential as subsurface habitats. MEPAG 2010 [5] strongly emphasizes the importance of detecting deep and shallow subsurface (past or present) habitable environments on Mars. The development of a muon radiography instrument capable of providing high-resolution images of the interior of geological structures on Mars specifically addresses the goals and priorities set forth in the Decadal Survey and MEPAG 2010.

Muon radiography is a technique that uses naturally occurring showers of muons (penetrating particles generated by cosmic rays) to image the interior of geological structures in much the same way as standard X-ray radiography. Unlike gamma rays and neutrons that penetrarate onle several meters of rock, muons may traverse through up to several kilometers of a geological target. Recent development and application of the technique to terrestrial volcanoes have demonstrated that a low-power, passive muon detector can peer deep into geological structures up to several kilometers in size, and provide unprecedentedly crisp density profile images of their interior [2-4]. Preliminary estimates of muon production on Mars indicate that the near horizontal Martian muon flux, a necessary condition for muon radiography, is as strong or stronger than that on Earth, making the technique suitable for geological exploration of Mars [6].

The muon telescope represents an entirely new class of instruments for planetary exploration, providing a wholly new type of measurement for the detection and delineation of potentially habitable subsurface environments, and for the interpretation of composition and evolutionary state of the Martian surface. Muon radiography is a proven, simple, low cost (muon detectors are routinely built in physics laboratories worldwide), and efficient technology that could detect subsurface radiation-shielded habitable environments such as lava tubes or caverns that would not be detectable by any other technique available today. Thanks to its low power and data rate demands, it could be integrated as a secondary instrument on future missions with minimal impact on primary mission operations. A mission that includes a muon detector could set the stage for a future mission to directly explore subsurface habitable environments Mars, as foreseen in the Planetary Science Decadal Survey.

Due to its operation as a passive instrument using perpetually present background cosmic ray radiation as source, its low power consumption, and its low data rates, a muon detector offers a new kind of instrument that operate as a scientifically invaluable secondary instrument capable of operation in a variety of settings with minimal impact on the missions primary instruments and operations. (Figure 2).

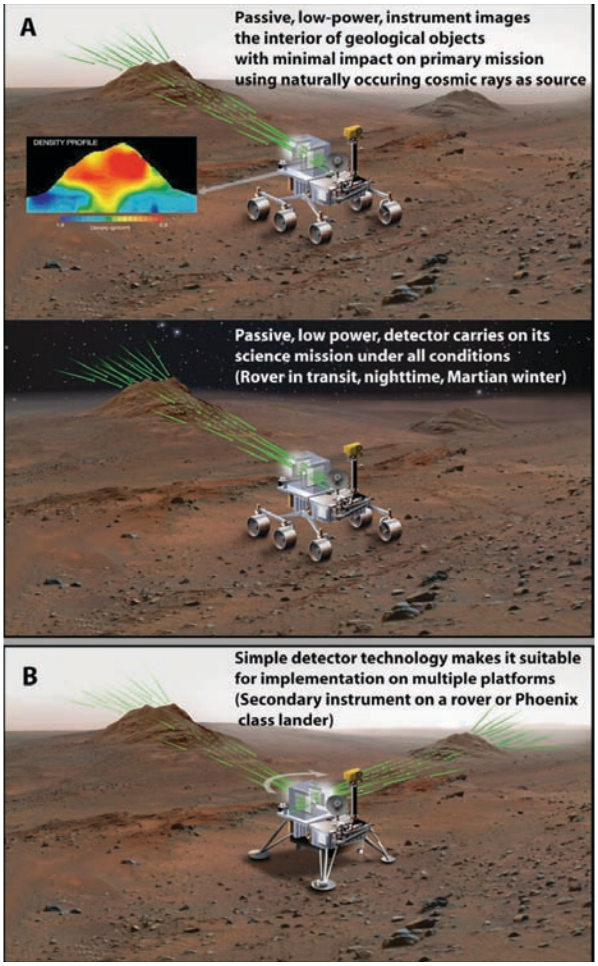

Figure 2: Operational concept. Muons generated by interactions of primary cosmic rays in the planet's atmosphere (green spheres) pass through a geologic object of interest, and are partially absorbed by the object. A passive muon detector composed of parallel scintillating plates on a lander or a rover records the tracks of the muons. The recorded tracks analyzed on site to determine the direction from which they entered the detector and the amount of energy absorbed by the target. The observations distilled into a density image of the geological target, much like an X-ray radiograph would, except using muons as a passive source of radiation. Two concepts are presented: (A) Muon radiography instrument mounted as a secondary instrument on a rover. (B) The instrument is mounted on a small Phoenix class lander observing multiple targets during the life of the mission.

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