THE IMPORTANCE AND FEASIBILITY OF IN SITU MARTIAN AEOLIAN AND METEOROLOGICAL INVESTIGATIONS.

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The Need For In Situ Studies of Mars' Surface-Atmosphere Interactions: Aeolian (wind-driven) sand and dust significantly influence landscape evolution and climate across the solar system [1]. On Mars, atmospheric dust is a major climate driver and is lofted through poorly understood mechanisms, including dust devils and quasi-regular global-scale dust storms. As on the Earth, wind-transported sand is a major force in the dust emission process, as well as martian landform development, abrasion of surfaces, and creation of complex stratigraphies (Figure 1). On Saturn's moon Titan, sand produced from photochemical aerosols has formed vast dune fields. Even on comets, aeolian processes within a transient, very thin atmosphere appear to have formed sand ripples.

Despite recognition that these surface-atmosphere interactions have profound effects on many planetary bodies, no aeolian-focused mission has ever flown. Experiments and models confined to Earth conditions leave critical questions unanswered, such as: How do micrometeorological processes drive diurnal, seasonal, and annual dust, sand, and volatile cycles both locally and globally? How does surface roughness influence threshold wind speeds for sediment transport under different atmospheric densities found throughout our solar system?

A key challenge is that aeolian and meteorological processes operate over a wide range of spatial and temporal scales, the smallest of which we have only observed on Earth. On Earth, numerical modeling integrates laboratory studies (grain-to-meter and <hours scales) with field investigations (m-to-km and min-to-seasons scales) to facilitate the extension of smaller scale aeolian processes into a global context. For other planets, we must rely on untested extrapolations from Earth-based knowledge and laboratory measurements to represent processes such as saltation, dust lifting, turbulent boundary layer mixing, etc., which use highly uncertain assumptions and scaling laws. **Still missing are in situ, high-resolution, and high-frequency observations of aeolian and meteorological processes on another planetary body – analogous to terrestrial field studies.**

Mars is a prime target for developing an understanding of surface-atmosphere interactions on planetary bodies with low-density atmospheres because of its recognized wide-spread sediment transport and the strong role of dust on climate variability. In addition, decades of previous investment have yielded contextual information and relevant mission technologies.

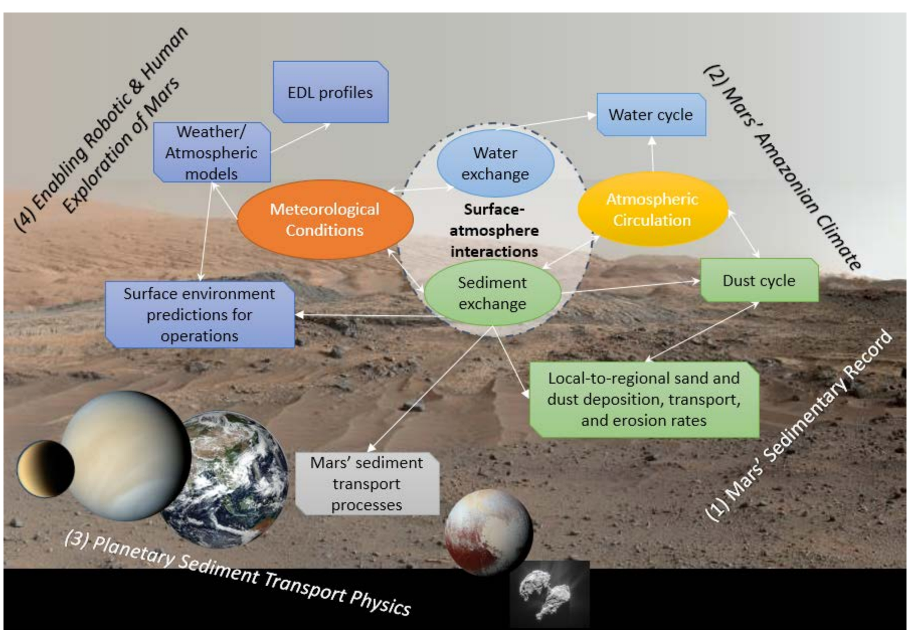

Figure 1: Many hypotheses addressing key Mars science questions hinge on unverified models of **surface-atmosphere interactions** (center), which are controlled by local meteorological and aeolian conditions/ processes (colored ovals). Studies in these areas connect to crucial gaps in our understanding of Mars' geologic and climate history [2,3], as well as to planetary sediment transport physics (at bottom are Titan, Venus, Earth, (Mars), Pluto, and comet 67P) and key information for engineering of future exploration efforts.

However, previous missions have yielded poor in situ datasets for these purposes as no dedicated sediment transport sensors were included and meteorological instruments were not well accommodated or designed to be part of a comprehensive aeolian/meteorological experiment.

New Opportunities for Mars In Situ Investigations: New technology developments and lander concepts may enable delivery of small, focused payloads more cost-effectively to the martian surface (e.g., SHIELD [4]); such technologies could enable a complete aeolian/meteorological investigation. Multiple landers would enable simultaneous collection of distributed measurements to, for example, decouple spatial and temporal variability of meteorological conditions and sediment transport during passage of a storm front. Advances in miniaturization and data resolution of field instrumentation, along with a new JPL-developed concept for landing small payloads onto a planet's surface open a new paradigm for designing planetary aeolian and meteorological studies.

Mission concepts could involve compact landers, each with a deployable ~2 m-tall instrumented mast. These would collect vertical profiles of wind, dust/sand, heat, and water fluxes, along with meteorological measurements, providing concurrent in situ observations of surface-atmosphere exchange and environmental drivers. If a small number of landers were distributed within a large martian crater, their measurements could be connected via regional models of wind and sediment transport – analogous to field studies on Earth. If a lander also had upward-looking instruments, it could be paired with an orbiter that would allow for global and higher-altitude measurements of wind, aerosols, and/or water (ideally with overlap in altitude and time with lander-based measurements), generating global and full-atmospheric profile context that is directly matched with high-resolution in situ surface data (Figure 2).

Next steps: To further develop these types of mission concepts, discussions among planetary and terrestrial experts along with spacecraft engineers are essential to develop science investigations, instruments, and process modeling that drives spacecraft design, instrument accommodation, and mission operations. This type of integrated discussion – from early in the mission development process – is important to optimize instrument design and accommodation on the spacecraft. For example, critical open design questions that require many areas of expertise to answer are "With what height/vertical spacing within the turbulent boundary layer should instrument packages be deployed to determine when and how sediment is lofted?" and "How far from the lander body should sensors be placed to ensure there is no flow disturbance or thermal contamination?" We are pursuing collaboration opportunities that will bring both theory and practical expertise together to inform in-depth discussions of the state of technology and science within planetary aeolian and meteorological investigations.

This Presentation: At the 2020 Planetary Dunes workshop, we will outline a specific mission concept being developed with SHIELD engineers and instrument developers within the planetary and terrestrial aeolian/metereological communities, including our science objectives/traceability and identified key technical challenges. We also will outline a Planetary Decadal Survey white paper we are developing, that will describe the need for Mars in situ aeolian and meteorological measurements and the feasibility for achieving such measurements in the next decade (and will welcome comments and co-signatories).

References: [1] Diniega et al. (2017) *Aeolian Res.* 26, 5-27. [2] Diniega et al. (2019) *9th Mars Conf.* Ab. 6152. [3] Newman et al. (2019) *AGU Fall Meeting*, P33D-14. [4] Barba et al. (2019) *2019 IEEE Aerospace Conference*, 1-10.

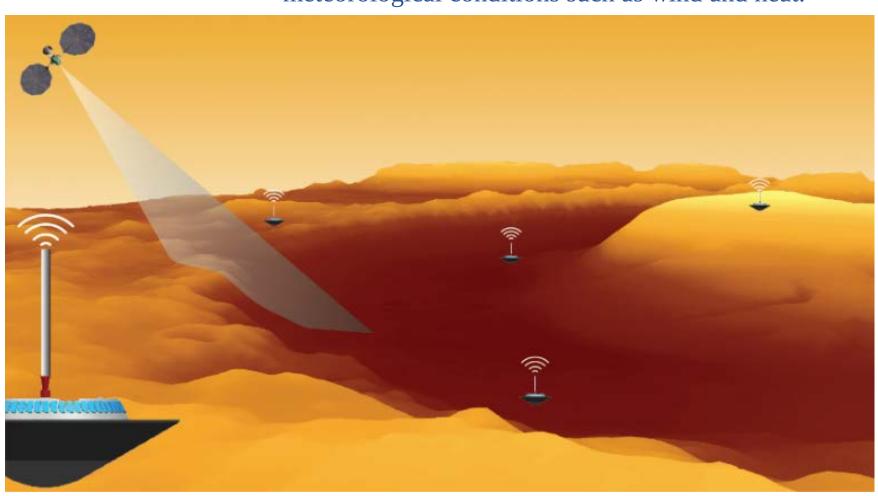

Figure 2: Schematic of a next-generation planetary aeolian and meteorological investigation (PAMI) mission concept, with ~5 landers distributed through a crater and a small orbiter, all with instruments aimed towards measuring sand, dust, and volatile fluxes at the surface and through the atmosphere, along with driving meteorological conditions such as wind and heat.