COLLECTING IN SITU OBSERVATIONS OF METEOROLOGICAL AND AEOLIAN PROCESSES ON MARS (AND MAYBE OTHER BODIES). S. Diniega[1] (serina.diniega@jpl.nasa.gov), Brian Jackson[2], Alejandro Soto[3], Don Banfield[4], Christy Swann[5], Nathan Barba[1], Lou Giersch[1], [1]Jet Propulsion Laboratory, California Institute of Technology, [2]Boise State Univ., [3]Southwest Research Inst., [4]NASA Ames Research Center, [5]Naval Research Lab.

The need for planetary in situ observations: Aeolian (wind-driven) sand and dust are known to significantly influence landscape evolution and climate across the solar system (Figure 1) and could significantly impact future human exploration (e.g., biohazards, clogged seals, or interrupted operations), but many of the driving processes are not well-understood outside of Earth conditions [1-6]. Near-surface atmospheric dynamics will drive this activity, as well as feed into broader atmospheric and climate systems. For example, dust has been found to be a key driver in atmospheric modeling for Mars [5], and the large amounts of dust lofted on Mars (leading to regional/global dust storms) has been found to increase the loss of atmospheric water and hydrogen, potentially contributing to the significant change from a wet ancient Mars to the arid planet we see today [7]. But the rates and ways in which dust gets off the martian surface is not yet understood, leaving models and predictions difficult [5].

To validate and calibrate models describing the physical phenomenon, correlatable in-situ observations of both the surface activity and environment are needed. This in situ data, providing ground truth for the models, complements coarser-resolution orbit-based studies of wind-driven geomorphology, bedforms, and sediment transport [2-3] that connect to the broader systems. Furthermore, understanding how a specific planet's conditions affect the expression of a process guides our understanding of the fundamental (i.e., planet-agnostic) physics at work [4].

To optimize science advancement, observations of the environment and activity need to be acquired with high frequency and fidelity, at least when the activity is happening, so as to identify of trends and dynamic range over multiple scales (e.g., capturing diurnal and seasonal wind velocity patterns as well as the timing and magnitude of gusts). Contextual information is also needed so that results from the in-situ study can be extrapolated, via a model, to locations where detailed in-situ measurements have not been collected. Definition of the types of measurements that could be collected together (and potential instrument suites) has been well-developed through analogous terrestrial studies and community discussions [e.g., 8].

Current state of knowledge and capability for acquiring such observations: To date, Mars is the only planetary body where some in situ measurements of meteorology and aeolian activity have been acquired.

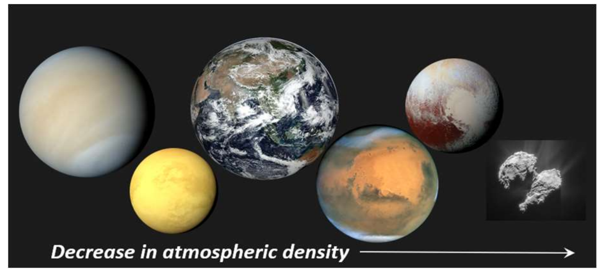

Figure 1. Solar system bodies where known or hypothesized aeolian features have been identified, in order of atmospheric density. From left: Venus, Titan, Earth, Mars, Pluto, comet 67P Churyumov-Gerasimenko. (Body diameters are not shown to scale.)

However, on previous Mars missions the relevant instruments were accommodated sub-optimally among other payload elements and thus did not yield the type of comprehensive, integrated, and detailed data needed to robustly test and guide models. Optimal, high-fidelity, and long-duration in situ investigations of aeolian processes outside of Earth have not yet been accomplished, due in part to technology limitations (described in [9] and also highlighted below).

However, recent advances in small lander design (especially to Mars), instruments, and operations designs make low-cost, low-risk, and high-value mission concepts appear feasible in the next decade [9]. Furthermore, many investigations of surface and atmospheric activity may work particularly well with small spacecraft designs, as the needed payload is small and landing site constraints yield large targets (i.e., the requirement is to land somewhere within a big windy field, rather than next to a specific outcrop). Numerous in situ measurements sites may also be a possibility, with multiple (identical?) spacecraft, not necessarily launched in close proximity [10].

Top challenges: With some of the small spacecraft mission concepts under development for in-situ investigation of meteorological and aeolian activity on Mars, these are some of the often-mentioned challenges, in rough order of priority:

- **Lower cost access to martian surface** with a small (5-10kg) science payload. One option is the SHIELD concept being developed at JPL [12] that could get to Mars via dedicated launch or as ride-along. For a specific platform, additional technical requirements would be imposed; e.g., with SHIELD, instruments would need to survive a hard-impact landing.

- **Collection of measurements over a vertical profile**, including wind, temperature, and other measurements, starting from the surface [6]. Such info is needed to constrain models of momentum and energy fluxes and estimate parameters in sand and dust transport models [3-5]. On Mars, some concepts focus on viewing the range ~0.5-2 m height [6], but higher into the planetary boundary layer would enable better connection to orbit-based observations of atmospheric systems. Options considered include a deployable boom (~2 m height) with several fixed sensors or a sensor that can move up/down, or a drone/balloon carrying sensors up tens of meters.
- **An operations scheme that enables sufficient frequency/fidelity observation of the dynamic environment**, including capture of transient peak/anomalous events (e.g., wind speed and direction distribution, including gusts, or dust devil passage). The scheme should also consider downlink limitations and mitigation strategies; options include onboard summarization of high-frequency measurements or identification of high-priority data, or autonomous environment responsive observation acquisition [9].
- **Survival and operations through extreme conditions**, especially considering thermal and power needs. Given the nature of the investigations, being able to collect measurements through dust storms and winter nights would be preferred.
- **One-time mobility within the landing platform** – although a meteorological investigation benefits from being stationary on the Mars surface (to observe daily and seasonal cycles in the same place), a one-time ability to optimally place/orient sensors within the landing environment (e.g., being able to face a wind or sediment sensor into the wind) would enhance science value of the observations. However, the optimal direction of measurement may change through normal meteorological cycles (e.g., winter and summer winds come from different directions), hence the lower priority.

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Table 1. A sample payload suite discussed in [9], thought to fit within current SHIELD [11] power, mass, and volume estimates, with measurements of interest.

Instrument	Collected measurements
Sonic Anemometer	• 3D wind speeds • Temperature estimates (based on observed speed of sound)
Laser dust velocimeter and anemometer	• 3D flux rate for transported sand and dust • Grain sizes within transport layer
Tunable Laser Spectrometer	Amount of CO_2, H_2O, and other trace atmospheric gas(es)
Saltation Sensor	Detection of size, height, and velocity of saltating grains
Flux radiometers	• Local energy balance • Ground temperature (with downward facing radiometer)
Cameras	• Environmental context • Identify and characterize meteorological phenomena, such as clouds and dust devils • Image grains on ground or lander to estimate size/shape and constrain variability and composition
Pressure Sensors	Surface pressure measurements, including during dust devils, etc.
Temperature Sensors	Near-surface thermal profile