

## The importance of experimental facilities for Mars-analog research into aeolian processes

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### The goals of this white paper are:

1. to illustrate – and support broader awareness of – the importance of varied and accessible experimental facilities that enable Mars-analog research for understanding aeolian processes on Mars and other low-density planetary conditions,
2. a) to publicize a draft white paper summarizing the history and general importance of planetary aeolian facilities, and b) to solicit additional input to this white paper and community discussion of this topic.

**The importance of experimental facilities in aeolian research:** Aeolian geomorphology is pervasive on Mars and throughout the Solar System. Once described only with regard to larger planetary bodies with atmospheres (e.g., [1]), aeolian landforms are now interpreted in spacecraft images of smaller bodies with transient atmospheres or jets [2 and references therein]. Correct interpretation of the resulting landforms informs our understanding of planetary systems through, e.g.,:

- constraining models of surficial and atmospheric dynamics and effects of surface-atmosphere interaction,
- identifying local, regional, and global source-to-sink sediment pathways;
- revealing spatial differences in transported grain mineralogies,
- quantifying landscape evolution through abrasion;
- characterizing the effects of paleoclimates;
- constraining locations of likely organic material preservation and its accessibility by spacecraft; and
- indicating the potential forward contamination of terrestrial biota in a human mission.

Boundary layer wind tunnels simulate aeolian processes that include both suspended dust and saltating sand and produce aeolian landforms. The boundary layer is that portion of an atmosphere where airflow is dominantly controlled by interactions with the surface. Such wind tunnels have a well-established history of use in the terrestrial and planetary science communities [3]. Terrestrial boundary layer wind tunnels have been in use since the groundbreaking work of Bagnold [4], which laid the foundation for understanding such fundamental parameters as the threshold (minimum) wind speed required to entrain sediment. Building on this foundation has continued in other ambient wind tunnels around the world, such as at the Trent University in Canada [5], the Aarhus University in Denmark [6], and the Arizona State University in the United States [7], and is beginning at a new

20'-long wind tunnel at the University of California, Los Angeles [M. Day, pers. comm.]

**Planetary boundary layer wind tunnels:** Simulating planetary aeolian processes requires achieving both lower- and higher-than-terrestrial pressures. Low and high-pressure wind tunnels were developed at the NASA Ames Research Center in Mountain View, CA [see 2,3,7]. For Mars-analog research, a silo for testing structural issues and fuel tank sloshing problems of Atlas and Titan boosters under low pressure [8] was converted into the Planetary Aeolian Laboratory (PAL), which hosted the Mars Surface Wind Tunnel (MARSWIT) [9]. A suction wind tunnel, the MARSWIT (*Fig. 1*) was designed to simulate aeolian flow at pressures down to those on the Martian surface. For this purpose, the silo is pumped down to Mars surface pressures, while researchers monitor their experiments from the control room.

Following observations of likely aeolian landforms on Venus, the Venus Wind Tunnel (VWT) was also established in the PAL [10]. This high-pressure wind tunnel was a closed structure with a fan that pushed pressurized air through the test section. The test section was 1.22 m long with a test bed 18 cm wide, and viewing ports near the upwind and downwind ends through which observations were made.

With the interpretation of pervasive linear dunes in the tropics of Titan, the VWT was later refurbished as the Titan Wind Tunnel (TWT; *Fig. 2*) to simulate aeolian sediment entrainment on that largest satellite of Saturn [2].

**Other planetary aeolian experimental facilities:** Among other planetary aeolian experimental facilities, a Vortex Generator was built [11]. Originally housed at the NASA Ames PAL, this equipment (*Fig. 3*) enabled the creation of laboratory-scale dust devils under terrestrial and Mars-like pressures, for simulating dust devil processes on both planets [11,12].

Another planetary aeolian experiment device, the Venus simulator was a 6-cm wide and 80-cm-long tubular furnace equipped with heaters also originally housed at the PAL [13]. It was developed to evaluate the effects of grain impact under Venus analog conditions.

**Results of planetary aeolian experiments:** The results from these facilities illustrate their capacity to significantly inform our understanding of aeolian processes. The Venus simulator showed that particles can be abraded even with the very low impact velocities expected under Venus conditions [13, 14]. Vortex data, combined with field observations and modeling, have quantified the processes of dust lifting on

Earth and Mars [15]. Results from the low-pressure facility [MARSWIT] were used to quantify aspects of sediment transport processes, such as threshold wind speeds required to move sediments on Mars [16-18] and to model aeolian-type transport resulting from jetting on comets [19]. The high-pressure wind-tunnel provided data for modeling aeolian thresholds on Venus [20] and Titan [21].

**NASA Review of PAL:** A 2015 review of SMD planetary facilities included the PAL [22]. The findings included: unique capability to simulate various planetary conditions; relevance of the data to scientific and mission objectives; and efforts to solicit wider utilization and archive prior work. Weaknesses included: a very small user community, limited transparency, and limited capability to simulate all planetary conditions. Recommendations included: steps to broaden the user community; instituting improvements to the facility through committee; and mitigating risk of staff overturn.

**On-going improvements:** These findings have generally been acted upon. Workshops led by the limited community of users were held (e.g., at LPSC), and a User's manual is available, facilitating accessibility to these facilities [https://rpif.asu.edu/documents/PAL\_Proposers\_Guidebook\_2019\_v7.pdf]. The current user community now includes different researchers with several projects using the MARSWIT (K. Smith, pers. comm). At the same time, wind tunnel instrumentation and the means for making improvements to the facilities remains similar as in the past.

**Recommendations from this draft white paper:** Communications between Sept 2018 and March 2019 resulted in a draft white paper that seeks to encourage discusses specifically the PAL facilities in their current state and offers suggestions for improvements, including:

1. that NASA consider multi-year funding for the PAL;
2. that NASA consider additional funding additional funding to bring the instrumentation and capabilities of the NASA Planetary Aeolian Laboratory in line with instrumentation and capabilities found at other wind tunnel facilities;
3. that, given the possible limitations of the current facility, e.g., the structural limitations of the TWT, NASA conduct a feasibility study, to include a cost-benefit analysis, on building one or more new wind tunnels;
4. that NASA evaluate the prospects for locating and operating a NASA wind tunnel facility at an institution with more transparency, managerial engagement, and/or proximity to aeolian researchers, including an evaluation of whether the high- and low-pressure capabilities currently housed together in PAL should more effectively remain together or be housed in different facilities.

**Archiving aeolian data:** Beyond continued discussion of the recommendations of the draft white paper, next steps in addition to collecting these valuable data include compiling and archiving them [e.g., 23, 24]. We encourage past, present, and future experimentalists and field workers to contribute their aeolian data to public archives and would be happy to discuss means for making those contributions.

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