NASA PLANETARY AEOLIAN LABORATORY: STATUS AND UPDATE. D. A. Williams and J. K. Smith[1], [1]Ronald Greeley Center for Planetary Studies, School of Earth & Space Exploration, Arizona State University, Box 871404, Tempe, Arizona 85287 (David.Williams@asu.edu).

Introduction: The Planetary Aeolian Laboratory (PAL), supported by NASA's Planetary Science Division, is a unique facility used primarily for conducting experiments and simulations of aeolian processes (windblown particles) under different planetary atmospheric environments, including Earth, Mars, and Saturn's moon Titan. Since the death of PAL founder Ronald Greeley in 2011, the PAL has been administered by PI David Williams (ASU) and has continued to serve the planetary science community including Martian and Titanian aeolian research. This presentation reviews the PAL facilities, their current capabilities, and how interested scientists can propose to NASA to use them.

What is PAL?: The PAL includes one of the nation's largest pressure chambers for conducting low-pressure research. The primary purpose of the PAL is to enable scientific research into aeolian processes under controlled laboratory conditions, and enable testing and calibration of spacecraft instruments and components for NASA's solar system missions, including those requiring a large volume simulated Martian atmospheric pressure. The PAL consists of: 1) the Mars Surface Wind Tunnel (MARSWIT) and 2) Titan Wind Tunnel (TWT) located in the Structural Dynamics Building (N-242) at the NASA Ames Research Center (ARC) in Mountain View, California and administered by Arizona State University (ASU). Also available (although not officially part of the PAL facilities) are: 3) an ambient pressure/temperature wind tunnel (ASUWIT) and 4) a vortex (dust devil) generator (ASUVG) on the Tempe campus of ASU, which is part of the ASU School of Earth and Space Exploration (SESE) and the Ronald Greeley Center for Planetary Studies. The TWT came online in June 2012. The *PAL Guidebook to Proposers* can be downloaded from this link: http://rpif.asu.edu/index.php/pal/.

Capabilities of PAL Facilities:

Mars Surface Wind Tunnel (MARSWIT). Put into operation at ARC in 1976, MARSWIT is used to investigate the physics of particle entrainment by the wind under terrestrial and Martian conditions, conduct flow-field modeling experiments to assess wind erosion and deposition on scales ranging from small rocks to landforms (scaled) such as craters, and to test spacecraft instruments and other components under Martian atmospheric conditions. MARSWIT is a 13-m long open-circuit boundary-layer wind tunnel within a large environmental chamber that operates at atmospheric pressures ranging from 1 bar to 5 millibars at speeds as high as 100 m/sec (currently down 30% because of ongoing repairs to Ames vacuum system). The chamber has an inside height of 30 m and an inside volume of 13,000 cubic meters. PAL draws its vacuum from the Thermal Physics Facilities' Steam Vacuum System and can be evacuated to Mars analog pressure (4 torr) in about 45 minutes. Due to the high cost to operate the vacuum system an agreement was struck in which PAL draws its vacuum almost exclusively as a ride-along with other NASA Ames projects/facilities. Aside from this agreement, reserved vacuum service is available provided sufficient funding is presented and there are no scheduling conflicts.

The MARSWIT instrumentation includes differential pressure transducers (Setra 239 and MKS 226A) linked to pitot tube apparatus for measuring free-stream wind velocities and deriving wind profiles. Pitot tube options include a singular pitot static and a vertical traversing pitot tube. These have a range of ±0.5 inches of a water column, or approximately 1.25 millibars. The MKS 226A specifies an accuracy of 0.30% of the instrument reading and a resolution of 0.01% of full scale. The Setra 239 specifies an accuracy of 0.14% of full scale. The Setra has been used in MARSWIT for many years and is reliable to measure velocities of 30-100 m/s at low pressure. The MKS is a new addition that will enable measurement of velocities below 30 m/s at low pressure. In addition, a Vaisala model DMP-248 dewpoint and temperature transmitter is used to monitor the temperature and relative humidity within the chamber. A DigiVac model 2L760 digital vacuum gauge measures the chamber pressure from Earth standard to the minimum allowable operating pressure (1 bar to 5 millibars) of the chamber. The MARSWIT is equipped with a high-speed (500k samples/second capability) analog-to-digital data acquisition system from National Instruments, Inc. Installed and operated on a dedicated computer, the system is capable of simultaneously measuring 64 analog channels, each of which can be independently accessed. The system is controlled by the National Instruments software package LabView™. This system allows for the simultaneous acquisition, analysis, and visualization of wind tunnel temperature, pressure, and velocity. Other analog and digital instruments can be incorporated to suit experimental requirements.

Titan Wind Tunnel (TWT). The TWT [2] is a remodel of the Venus wind tunnel (operated 1981-1994), and became operational in June 2012. The TWT is a closed-circuit, pressurizable (currently to 15 bars) wind tunnel with an overall dimension of 6-m by 2.3-m. Included in the remodel were upgrades to a newer, higher performance motor, advanced motor controls, and new instrumentation. Overall tunnel pressure is determined by visual observation of a calibrated gauge (manufactured by Wika Instrument Corp., + or – 1psig) attached to the front of the tunnel instrument panel and a digital pressure gauge (Druck DPI 104) manufactured by General Electric. This instrument, in addition to providing a digital display for observation, delivers a signal to the data acquisition system for inclusion in the recordable data stream. The tunnel humidity and temperature are measured by a combination temperature humidity instrument (Vaisala HMT 334). Readings are visible by digital display and a signal voltage is deliverable to the data acquisition system. Differential pressure is measured (for flow velocity calculation) by two custom designed sensors (manufactured by Tavis Corp.). One of the units is designed to measure a wider range of differential pressure (0-0.75 inch H2O) and the other is more sensitive, measuring a narrower range (0-0.2 inch H2O). The units can be operated concurrently. The signal voltages from the sensors are sent to a data acquisition module (manufactured by Measurement Computing Corp.) and processed for interpretation by TracerDAQ software installed on a laptop computer. A test section is designed to allow the substitution of test plates. A test plate specifically designed for boundary layer profile work already exists and can be installed should the need arise.

ASU Wind Tunnel (ASUWIT). The ASUWIT consists of a 13.7-m long, 0.7 m high, 1.2 m wide open-circuit boundary-layer wind tunnel that operates under ambient temperature and pressure conditions and is capable of wind speeds of 30 m/sec.

ASU Vortex Generator (ASUVG). The ASUVG consists of a 0.5 m variable-speed fan mounted above a moveable table. A large board of pressure transducers is available and can be setup to collect wind pressure points in various areas of the test section. Currently the vortex generator's data is fed to a Windows PC running LabView™. The test section measures 1.2 x 1.2 m. The table can be adjusted in the X, Y and Z directions during experiments. The ASUVG has not been used for scientific experiments in over 5 years, and its last user (Lynn D.V. Neakrase) recommended a complete overhall before conducting future experiments.

How can I use the PAL Facilities: The PAL facilities are open to all NASA-funded researchers in aeolian studies. PAL researchers are currently funded by grants from NASA's Mars Fundamental Research (MFR) program, Outer Planets Research (OPR) program, and Planetary Data Archiving, Restoration, and Tools (PDART) program, and new proposals can be submitted to the Solar System Workings (SSW) program. SSW should be the primary R&A program to submit proposals to conduct laboratory studies with the PAL. However, new instrument development work and testing in the PAL could be included in proposals for the Planetary Instrument Concepts for the Advancement of Solar System Observations (PICASSO) or Maturation of Instruments for Solar System Exploration (MATISSE) programs. Currently rotor configurations for the Mars Helicopter accompanying the Mars 2020 rover are being texted in the PAL.

Although the PAL facilities are funded by PSD, there are still costs associated with the operation and maintenance of these facilities that must be encumbered by the user. Because the PAL facilities are administered by ASU, *you must budget for PAL operations in your proposal as a subcontract to Arizona State University.* The fixed daily cost to use the ASU facilities is $500/day, excluding materials, special equipment, and your travel costs. For non-sponsored (i.e., research not funded from the Solar Systems Workings program) projects, such as instrument development proposals or mission projects), NASA-Ames charges a pro-rated facility fee of $1,500/day for operations using the MARSWIT, where a pump down to Mars pressure is required. For use of the MARSWIT when a pumpdown is not required, or for use of the Titan Wind Tunnel (TWT), NASA Ames charges a pro-rated facility fee of $600/day. These charges can be justified in the ASU commitment letter sent by the PAL PI in your proposals. These funds would actually go to your home institution, and then NASA Ames would invoice you for these fees.

PAL Status: The PAL underwent a NASA Headquarters Review in Oct. 2015. Currently NASA plans to fund the PAL at its current level through FY 2018. When a new NASA Facilities Cooperative Agreement Annoucement of Opportunity is released, ASU will propose to continue administering the PAL for another 5-year cycle.

If you wish to use the PAL facilities, please contact PAL Director David A. Williams (David.Williams@asu.edu) at Arizona State University for more details and to schedule your work.

References:

[1] Greeley, R. and Iverson, J. D. (1985) *Wind as a Geologic Process,* Cambridge University Press, Cambridge, UK, 333 pp. [2] Burr, D.M., et al. (2015), The Titan Wind Tunnel, *Aeolian Research, 18*, 205-214.