THE TITAN WIND TUNNEL IN THE NASA PLANETARY AEOLIAN LABORATORY: FACILITY IMPROVEMENTS.

S. L. F. Sutton[1], D. M. Burr[1] , N. T. Bridges[2], J. K. Smith[3,4], S.M. Horst[5], X. Yu[5], J.F. Kok[6], F.A. Turney[6], J. R. Marshall[7], D. A. Williams[4], [1]University of Tennessee Knoxville, (ssteph34@utk.edu, dburr1@utk.edu), [2]JHU Applied Physics Laboratory, [3] NASA Ames Research Center, [4]Arizona State University, [5]Johns Hopkins University, [6]University of California, Los Angeles, [7]SETI Institute.

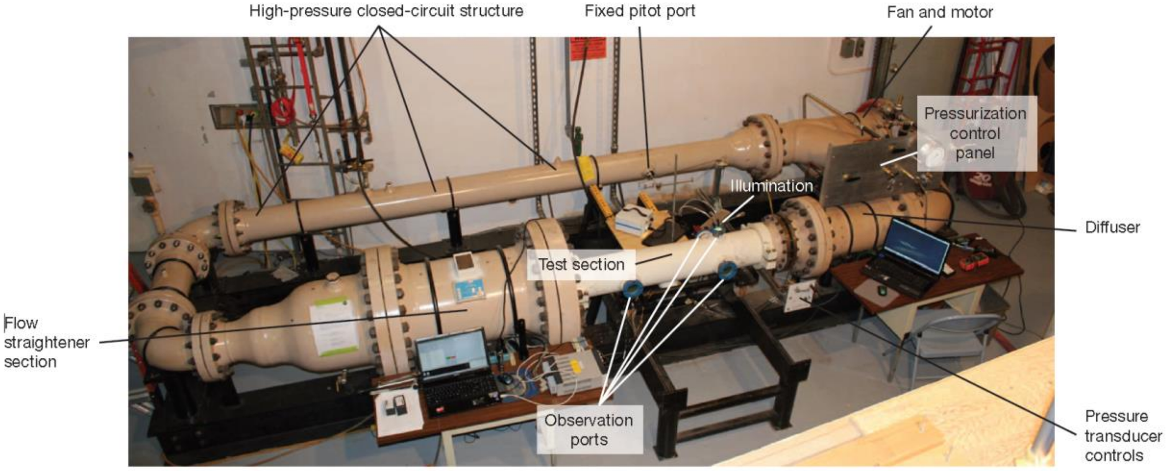

Figure 1: The high pressure Titan Wind Tunnel at the Planetary Aeolian Lab, NASA Ames Research Center, Mountain View, CA, USA. Flow is counter clockwise, test section is 1.2 m long and 0.20 m diameter (source [2]).

Introduction: The Titan Wind Tunnel (TWT; Fig. 1) is a community resource located in the NASA Ames Research Center Planetary Aeolian Laboratory [1]. A refurbishment of the 40-year-old Venus Wind Tunnel, this tunnel has been rebuilt, recertified to 20 bar, and fitted with new instrumentation (e.g. high-frequency, high-pressure transducers) for the investigation of threshold wind speeds and other aeolian parameters and processes on Titan [1,2]. The unique capability of this high-pressure wind tunnel allows simulation of wind conditions on Titan's surface with correct kinematic viscosity similitude, providing a window into Titan aeolian processes. On-going improvements and upgrades to the wind tunnel and its instrumentation are designed: 1) to facilitate its use by the community, 2) to provide more accurate and precise data, and 3) to expand the suite of measurements available. This abstract outlines some of these improvements and solicits input from the community on future instrumentation for this community resource.

Titan Wind Tunnel Improvements: Several improvements or new experimental configurations have recently been implemented or are planned.

Humidity sensor: As a significant factor in the strength of the interparticle force, humidity is a fundamental control on threshold [3,4]. The TWT is pressurized with air that is dried to a nominal dew point of -40° C during delivery to the TWT, where it is combined with the 1-bar air that the wind tunnel contains before pressurization. To measure relative humidity and temperature of the resultant pressurized air in the tunnel, we have recently installed a Vaisala HMT334 probe. The probe output shows that residual humidity in the tunnel may be lowered by successive pressurization and depressurization. On-going work is investigating the effects of humidity on threshold [5].

Fixed beds for investigating fluid entrainment: Consistent with past Venus Wind Tunnel work [6], our previous TWT work has used beds of loose sediment [2], which results in impacts from upwind that obfuscate any fluid entrainment. To better understand this entrainment we have created hybrid test beds to isolate fluid entrainment events by preventing saltation upwind of the downwind observation port. These hybrid test beds are covered with immobile particles affixed to the upwind portion of the bed, over which the boundary layer flow developed, but also contains a short 2-cm-long bed of loose particles, located at the downwind observation port (right-most port in Fig. 1), through which high-speed video is acquired. On-going work is using this new bed configuration to collect data for constraining numerical models of saltation [7].

Laser light sheet: Laser light sheets are increasingly common in aeolian wind tunnels [e.g., 8-10], as they isolate and strongly illuminate a single focal plane within the transport cloud allowing for observation of individual grain transport paths (e.g. Fig 2). Automated tracking of grain paths then allows for mathematical characterization of trajectories, both as statistical populations and as individuals [e.g., 10]. A laser light sheet system is currently being developed, for which a 1.6 W 450 nm wavelength laser would generate a 1.5 mm x

100 mm sheet via a Powell lens. At the same time, other possible laser systems are also being explored. Any light sheet would be projected through the illumination port on the top of the tunnel (Fig. 1) parallel with the airflow. High speed video would then be recorded normal to the light sheet (Fig. 3).

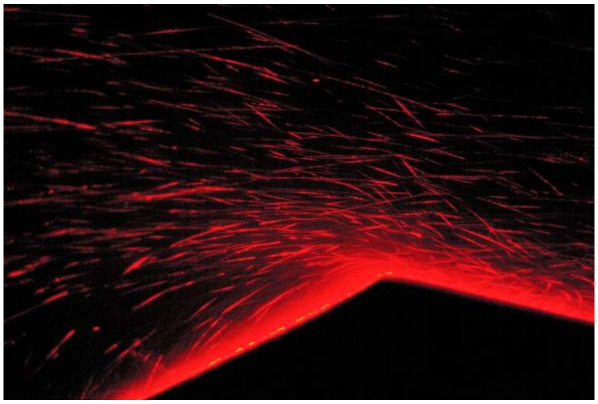

*Figure 2: Example of laser light sheet illumination of saltation over the brink of a dune (**Source: Dune Simulation Wind Tunnel, Univ. of Guelph and DRI**).*

Upon implementation of the laser light sheet, we will use it to continue investigating the effect of atmospheric density on entrainment processes. Numerical modeling predicts that fluid entrainment increases relative to impact entrainment with increasing atmospheric density [11]. This increase may be an effect of the lower threshold wind speeds, and thus reduced ejection velocities, leading to reduced impact speeds [12]. Also, the increased fluid drag at higher atmospheric densities results in more rapid vertical deceleration of the ascending grain, reducing both the magnitude and duration of exposure to accelerated wind speeds at greater heights above the bed [13]. Previous visual data analysis of high speed video showed the expected increase in fluid-to-impact entrainment events with pressure, but the magnitude of the fluid-to-impact entrainment ratio was an order of magnitude different from modeled results [14]. The laser-light sheet will be used to collect new high-speed video data for automated analysis to continue to investigate this question of how entrainment processes vary with pressure.

Other improvement: In addition to investigation-specific instrumentation, other improvements are continually implemented. Over the past year, improvements to the TWT have included: (a) relocation of the freestream reference pitot from a remote location away from the experimental sediments into the test section [1]; (b) the implementation of a second, more sensitive high-pressure / high-frequency transducer operating at a lower and more limited dynamic range [1], and (c) the capability to run both transducers concurrently.

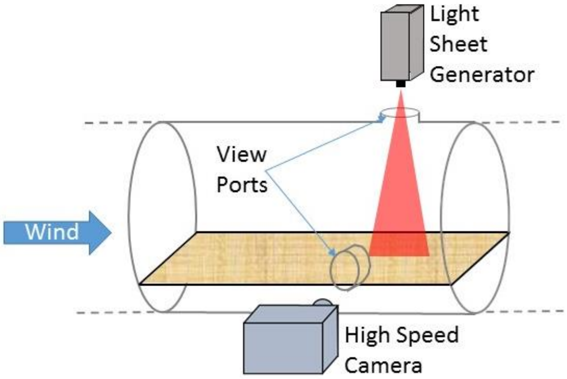

Figure 3: Sketch of possible particle tracking system for the TWT. A light sheet generator illuminates a narrow wind-aligned corridor in the tunnel centre for video capture of sediment trajectories.

Soliciting community input: The TWT represents a unique capability for investigating the aeolian processes that pervasively influenced the surface of Titan [15, 16]. It is the only facility in which high density winds can move sediment under controlled conditions, including correctly scaled high friction Reynolds number conditions applicable to past and present Titan climates. Proposed improvements include re-certification to ≥40 bars to simulate relevant atmospheric conditions at the surface of Venus and potentially to exo-planets.

References: [1] Burr D. M. *et al*. (2015) *Aeolian Res.* 205-214, 10.1016/j.aeolia.2015.07.008. [2] Burr D. M. *et al*., (2015) *Nat.* 517, 60-66, 10.1038/nature14088. [3] McKenna Neuman (2003) *Bound.-Lay. Met*. 108, 61-89, 10.1023/A:1023035201953. [4] McKenna Neuman, C. and Sanderson S. (2008) *JGR-ES* 113, F02S14, 10.1029/2007JF000780. [5] Yu et al. (2016) *LPSC XLVII*, Abs 2683, also Yu *et al*., (2017) *Manu. in prep*. [6] Greeley and Iverson (1985) *Wind as a geologic process: On Earth, Mars, Venus and Titan.* [7] Turney F. A. *et al*. (2016) *Am. Geophys. Union, EP53E-1019*. [8] Creyssels M. *et al*., (2009) *J. Fluid Mech.* 625, 47-74, 10.1017/S002211200800549. [9] Ho, T.D. *et al*. (2014) *Aeolian Res*. 12, 65-74 10.1016/j.aeolia.2013.11.004. [10] O'Brien P. and McKenna-Neuman C. (2016) *Aeolian Res.* 20, 126-138. 10.1016/j.aeolia.2015.11.005. [11] Kok J.F. (2010) *Geophys. Res. Lett.* 37, L12202, 10.1029/2010GL043646. [12] Iverson *et. al*.(1987) *Sedimentology, 34(4)*, 699-706, 10.1111/j.1365-3091.1987.tb00795.x. [13] Kok, J.F. *et al*. (2012) *Rep. Prog. Phys.* 75, 106901, 10.1088/0034-4885/75/10/106901. [14] Nield E. V. *et al*., (2016) *LPSC XLVII*, Abs. 1028. [15] Lorenz and Radebaugh (2009) *Geophys. Res. Lett. 36*, L03202, 10.1029/2008GL036850. [16] Lopes, *et al. Icarus 270*, 162-182, 10.1016/j.icarus.2015.11.034.