MARS SURFACE WIND MEASUREMENTS USING AN ACOUSTIC ANEMOMETER. D. Banfield[1], R. W. Dissly[2], and S. C. R. Rafkin[3], [1]Cornell University, 420 Space Sciences, Ithaca, NY 14853, banfield@astro.cornell.edu, [2]Ball Aerospace, 1600 Commerce St., Boulder, CO 80301 rdissly@ball.com, [3]Southwest Research Institute, Boulder, CO 80302, rafkin@boulder.swri.edu

Introduction: The Mars exploration and science communities have specifically recognized the importance of measuring wind and turbulent fluxes within the lower atmosphere. The current MEPAG Science Goals Document lists understanding the structure and processes operating in the boundary layer as a high priority Climate Science Goal. Accurate wind measurement and prediction is critical for robust EDL design, and for planning surface operations. It is clear that improved measurement techniques are needed.

Science Benefits: Turbulence in the planetary boundary layer of terrestrial planet atmospheres is the primary mechanism by which energy, momentum, gases, and aerosols are exchanged between the surface and the atmosphere [1]. These exchanges are critical to understanding larger scale phenomena such as dust storms, synoptical scale weather, and the water cycle on regional scales. Direct measurements of these exchanges are not possible with the meteorological instrumentation previously deployed on Mars, but are in fact possible using sonic anemometry.

Aeolian activity is currently the dominant force shaping the surface of Mars, as it has likely been for the last billion or more years [2]. To quantify wind erosion, it is essential to quantify the momentum exchange (e.g., surface wind stress or friction velocity) between the surface and the atmosphere to determine saltation activity and dust lifting [3]. Again, this has proved nearly impossible to directly measure using previous martian wind sensors, but is indeed possible using sonic anemometry.

Reducing Risk for Future Missions: The surface of Mars is a hazardous place for spacecraft, both those attempting to reach or leave the surface, and for surface operations. Regional scale circulations play a large role in these hazards, and yet we have minimal data to constrain or even validate mesoscale models. There are several of these sophisticated atmospheric dynamical models (of great utility on Earth) that have been adapted to model Mars, but differ from one another in fundamental ways in terms of the predicted flows. Quite simply, we currently do not have atmospheric observations with sufficient coverage or accuracy to confidently model winds on Mars, which significantly affect EDL design. More extensive measurements are required to improve the models and mitigate these operational hazards. A fundamental component of those improved observations would be the much richer data set provided by a sonic anemometer measuring turbulent fluxes in the martian boundary layer.

Acoustic Anemometry: The gold-standard for terrestrial in-situ wind measurements is sonic, or acoustic, anemometry. Sonic anemometers are able to measure the 3-D wind vector and the air temperature in their sensing volume at rates greater than 20 Hz, with accuracies better than 10cm/s. Since sound is advected with the medium that carries it, the travel time difference for acoustic signals in opposite directions yields the wind speed along that vector. In addition, the travel time average for all directions yields the temperature (via the sound speed). The very high accuracy, very high sampling rate and 3-D, open sensing volume nature of the instrument all combine to allow this instrument to directly measure the turbulent eddies that advect past the instrument. This capability is the key enabling aspect of sonic anemometry that opens up the new science capabilities discussed above.

The challenge for adapting these terrestrial instruments for use on Mars is two-fold: the atmospheric density is so low at Mars that it is very difficult to generate and receive sound, and the CO2 atmosphere attenuates high frequency sounds waves much more strongly than does the N2 on Earth. To couple well to the thin Martian atmosphere, we use specialized acoustic transducers that are designed with very light electrically-driven membranes that can both produce and sense sound waves in the Mars environment with relatively high efficiency. We also utilize a pulse compres-

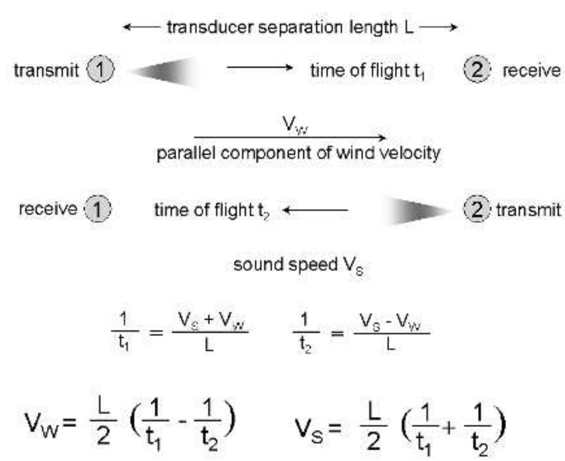

Figure 1. Diagram showing the principle of Acoustic Anemometry

sion signal processing technique to extract accurate sonic travel time information from relatively weak, noisy signals.

Anemometer Development Status: The Mars Acoustic Anemometer has been developed under the NASA PIDD Program to TRL 4, demonstrating excellent operational performance under relevant Mars atmospheric conditions. The form factor of the transducers has been optimized to be as small as possible while still yielding sufficient signal strength to perform the measurements with the desired repetition rate (>20 Hz) and accuracy (<5cm/s). The transducers have been tested from 0C to -135C, and performance was unaffected throughout these temperature swings. Wind-tunnel test of the instrument under realistic Martian conditions (CO_2, pressure & temperature) are planned in mid-June, 2012, in Aarhus, Denmark. This exercise will serve not only as a proof of the instrument under relevant martian conditions, pushing our development up to TRL5, but will also give us a calibration for the instrument under Martian conditions. The wind tunnel testing will be followed by a deployment of the instrument on a stratospheric balloon in September of 2012, maturing the complete instrument system to TRL 6.

Conclusions: Improved surface wind measurements on Mars are needed to increase our understanding of boundary layer and aeolian processes, and to increase the predictive capability for planning EDL and surface operations. New lines of inquiry into the nature of the processes at work in surface-atmosphere exchange at Mars are required for progress. The Mars Acoustic Anemometer is an example of a mature concept that can address these needs on future landed missions.

References:

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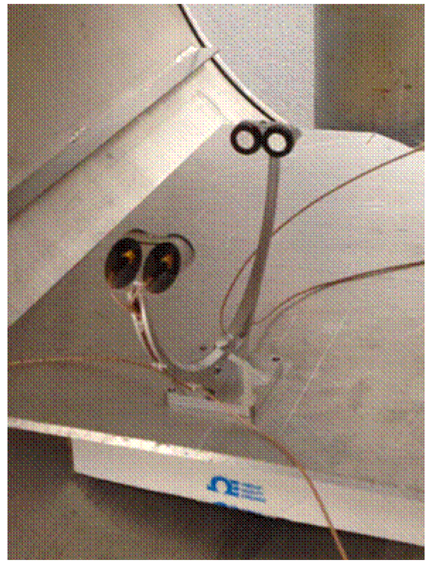

Figure 2. Mars Acoustic Anemometer in a test chamber at Ball Aerospace