AEOLUS: A MISSION TO OBSERVE THE THERMAL AND WIND ENVIRONMENT OF MARS
A. M. Cook\textsuperscript{1,2}, A. Colaprete\textsuperscript{1}, D. Mauro\textsuperscript{1,3}, J. Stupl\textsuperscript{1,3}, A.N. Nguyen\textsuperscript{1,2}, M. A. Kahre\textsuperscript{1}, R M. Haberle\textsuperscript{1}, A. Dono Perez\textsuperscript{1,2}, E. A. Uribe\textsuperscript{1,3}, K. N. Bonner\textsuperscript{1,2}, and S.V. Weston\textsuperscript{1,3}.

\textsuperscript{1}NASA Ames Research Center, Moffett Field, CA; \textsuperscript{2}Millennium Engineering and Integration, Moffett Field, CA; \textsuperscript{3}Stinger Ghaffarian Technologies, Moffett Field, CA.

Introduction: Aeolus is a mission concept to observe the thermal and wind environment of Mars, by measuring surface temperatures and Doppler shifts in atmospheric spectral lines. To date, direct measurements of Martian wind speeds have only been possible at the surface, only during daylight hours, and over small areas limited by rover traverse capabilities. From orbit, thermal measurements as well as still images of dust storms and dune migration have provided inputs to derive the latest datasets in Mars climate modeling. However, recent models (Figure 1) generated by Co-I Kahre of the Mars Climate Modeling Center at NASA Ames Research Center (ARC), demonstrate that model wind speeds derived from these indirect measurements may be in error by 50 to 100\%. For this reason, direct wind velocity measurements have been deemed “High Priority” by the Mars Exploration Program Analysis Group (MEPAG); measuring wind speeds and corresponding thermal data is vital to understanding the climate of Mars.

Aeolus will carry four miniaturized Spatial Heterodyne Spectrometers (SHS), coupled to two orthogonal viewing telescopes. These high-resolution near-infrared spectrometers will measure CO\textsubscript{2} (daytime absorption) and O\textsubscript{2} (day and night emission) lines in the Martian atmosphere. Doppler shifts in these lines can be measured during Martian day and night, resolving wind speeds with \textasciitilde 5 m/s precision. Orthogonal views allow the spectrometers to capture wind vectors (as opposed to only line of sight measurements) over all observation locations. Aeolus will also carry a heritage Mini Thermal Emission Spectrometer (MiniTES) to measure surface temperatures and CO\textsubscript{2}, H\textsubscript{2}O, and dust column abundances in nadir views. Finally, the Surface Radiometric Sensor Package (SuRSeP) will measure the surface for total reflected solar radiance, and low surface temperatures down to \textasciitilde 140K. These combined spectral and thermal measurements will provide a new understanding of the global energy balance, dust transport processes, and climate cycles in the Martian atmosphere. The Aeolus mission concept consists of a single satellite in a near-polar orbit, allowing it to pass over all local times, with the baseline mission observing all seasons of an entire Martian year (two Earth years).

The Aeolus mission concept is led by PI Anthony Colaprete and Deputy PI Amanda Cook, from Ames Research Center. The Aeolus Science Team is also based at ARC, where the Mars Climate Modeling Center supports a team of veteran Mars climate scientists, research staff, and students.

Science Objectives: The overarching goal of the mission is to provide empirical data for refining current climate models\textsuperscript{[1][5]} and for contributing to the understanding of Mars atmospheric phenomena that are not yet clearly understood. The first objective is to (1) produce a vertically resolved global wind speed map of Mars. Winds on Mars have never been direct-

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{Wind speeds derived from thermal measurements can be in error by up to 100\%. Contours show wind speeds in m/s. Solid lines are westerly winds, and dotted lines are easterly winds. (a) Global Climate Model simulated wind speeds. (b) wind speeds derived from thermal balance; (c) Difference between panels (a) and (b) shows that winds are not in balance with the thermal fields. Similarly, the actual winds on Mars are expected to be different from those derived from observed thermal fields. Source: Aeolus Co-I, M. Kahre.}
\end{figure}
ly measured, except for Viking\textsuperscript{[6]}, Pathfinder\textsuperscript{[7]}, and Phoenix\textsuperscript{[8]} surface point measurements. All other wind speeds have been derived from indirect thermal measurements or compositional variations in the atmosphere, and orbital imagery. Creating a global wind map would provide essential ground truth and corrections for the current Mars climate models. The last two objectives are to (2) Determine the global energy balance at Mars, and (3) Correlate wind speeds and surface temperatures with H\textsubscript{2}O, CO\textsubscript{2}, and dust (aerosol) column densities. To determine the thermal balance in the Martian atmosphere, the wind velocities will be correlated with surface temperatures, and dust, H\textsubscript{2}O, and CO\textsubscript{2} column abundances. This combination of measurements enables Aeolus to provide an essential dataset within the context of the three most influential factors determining Mars climate variability: temperatures, wind speeds, and atmospheric composition.

To measure wind speeds, Aeolus will measure Doppler line shifts for the O\textsubscript{2} and CO\textsubscript{2} lines detectable from the Mars atmosphere. O\textsubscript{2} primarily resides in the Martian troposphere (near 50-km altitude), while CO\textsubscript{2} exists at all altitudes. Measuring CO\textsubscript{2} absorption lines allows for more continuous altitude coverage for daytime measurements. Likewise, it is essential to include O\textsubscript{2} airglow emission measurements to capture wind speeds at night, since CO\textsubscript{2} is not observable in the night atmosphere. It is worth noting that no past or current orbiter missions have measured the Martian atmosphere at night. Thermal infrared and aerosol measurements of the surface will allow the Aeolus science team to correlate temperature gradients with wind speeds, and to assess the overall thermal balance in the Martian atmosphere.