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Small Lidar for Profiling Water Vapor, Aerosols and Winds from Planetary Landers

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The planetary boundary layer (PBL) is the lowest layer of the atmosphere that interacts directly with the surface. For Mars and Titan, processes within the PBL are very important scientifically because they control the transfer of heat, momentum, dust, water, and other constituents between surface and atmospheric reservoirs. For Mars understanding these processes is critical for understanding the modern climate, including the stability and development of the polar caps how the regolith exchanges with the atmosphere how wind shapes the landscape how dust is lifted and transported and for being able to validate and improve general circulation models (GCMs). The PBL is also critical for operations since it is the environment in which landed missions must operate.

On Mars the PBL depth varies between roughly 1 and 10 km, depending on time of day, with the deepest layer occurring during the day when convective turbulence is greatest. The PBL is difficult to observe from orbit, and so detailed observations of it have been mostly limited to those just at the surface from landers. The lack of PBL observations has led to significant gaps of understanding in several key areas. These include diurnal variations of aerosols, water vapor and direct measurements of wind velocity, the combination of which provides information on the horizontal and vertical transport of water, dust, and other trace species and their exchange with the surface. The Mars atmosphere has complex interactions between its dust, water and CO_2 cycles. Because these quantities are interrelated and they partially drive the wind fields, it is important to measure the water vapor, aerosols, and winds simultaneously, ideally using a single instrument.

We are developing and plan to demonstrate a breadboard of small, highly capable atmospheric lidar to address these needs for a future lander on Mars or Titan. The lidar is designed to measure vertically-resolved profiles of water vapor by using a single frequency laser. The laser will be tuned onto and off strong isolated water vapor lines near 1911 nm. The vertical distribution of water vapor will be determined from the on- and off-line backscatter profiles via the differential absorption lidar (DIAL) technique. The same laser is used for measuring aerosol and wind profiles via the Doppler shift in the backscatter. The laser beam is linearly polarized and a cross polarized receiver allows separating the backscatter of water ice from dust. It emits two beams that are offset 30 deg from zenith and perpendicular to one another in azimuth, allowing directional wind profiles to be resolved. Both lidar measurement channels are otherwise identical and use common lens-type receiver telescopes.

These lidar measurements address important science needs that are traceable to Mars Exploration Program Analysis Group (MEPAG) science goals relating to climate, surface-atmosphere interactions, and preparing for human exploration. Our lidar will measure vertical profiles of water vapor, and dust and water ice aerosols and winds with km-scale vertical resolution from the surface to > 15 km altitude. These measurements will directly profile the full planetary boundary layer, which is key for understanding how water, dust, CO_2 and trace species exchange between surface and atmosphere. The lidar will provide observations of all quantities simultaneously.

Only one atmospheric lidar has been previously flown on a planetary lander. The lidar on the Phoenix Mars lander mission (Komguem et al., 2013) successfully measured aerosol backscatter profiles at 1064 nm and 532 nm as a function of altitude and time (Whiteway, et al., 2008). The lidar also measured cloud and ice scattering profiles and measured falling ice over the Phoenix Lander site (Whiteway, 2009).

Our lidar approach is designed to provide several important new capabilities. It will measure, for the first time, water vapor profiles from 100 m to 15 km, along with wind and aerosol profiles at 1911 nm. Our approach utilizes a highly sensitive HgCdTe avalanche photodiode detector as a key component of the lidar receiver. During the next 2 years of this project, our plan is to develop the remaining lidar components from TRL 2 to 4, and to use the breadboard lidar to demonstrate profile measurements of aerosols, water vapor and wind from the Mauna Kea Hawaii astronomy site

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