MARLI: MARs LIdar for global wind profiles from orbit. S.D. Guzewich[1,2], J. B. Abshire[1], M.D. Smith[1], H. Riris[1], X. Sun[1], B.M. Gentry[1], A. Yu[1], and G. R. Allan[3], [1]NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA, [2]CRESST/Universities Space Research Association, Columbia, MD 21046, USA (scott.d.guzewich@nasa.gov), [3]Sigma Space Corporation, Greenbelt, MD 20771, USA.

Introduction: The Mars Exploration Analysis Group's Next Orbiter Science Analysis Group (NEX-SAG) has recently identified atmospheric wind measurements as one of 5 top compelling science objectives for a future Mars orbiter [1]. To date, only isolated lander observations of martian winds exist.

Winds are the key variable to understand atmospheric transport and answer fundamental questions about the three primary cycles of the martian climate: CO_2, H_2O, and dust. However, the direct lack of observations and imprecise and indirect inferences from temperature observations leave many basic questions about the atmospheric circulation unanswered. In addition to addressing high priority science questions, direct orbital wind observations would help validate 3D general circulation models (GCMs) while also providing key input to atmospheric reanalyses.

The dust and CO_2 cycles on Mars are partially coupled and their influence on the atmospheric circulation modify the global wind field. Dust absorbs solar infrared radiation and its variable spatial distribution forces changes in the atmospheric temperature and wind fields. Thus it is important to simultaneously measure the height-resolved wind and dust profiles. MARLI provides a unique capability to observe these variables continuously, day and night, from a polar orbit that samples all local times during the mission.

LIDAR Measurement Approach: The MARLI lidar [2]is being designed to observe the atmosphere from a nominally circular polar orbit around Mars. The lidar measurement concept is shown in Figure 1. The instrument would be pointed ~30° off-nadir in a cross-track viewing direction. The lidar will continuously measure dust aerosol backscatter profiles, cross polarized backscatter profiles (for water ice aerosols), the component of the Doppler shift from wind profiles along the instrument's line-of-sight, and the range to the planet's surface. The present MARLI approach uses a Nd:YAG laser and makes measurements at 1064 nm [3] and its measurement types are shown in Figure 2. We are also exploring the feasibility of measuring vector-resolved winds using a dual-telescope approach

LIDAR Description: The laser backscatter from the Mars atmosphere is weak and is distributed in range and thus a highly sensitive lidar approach is necessary. The present MARLI approach measures the atmospheric characteristics along a single line-of-sight. The lidar uses a compact efficient ND:YAG laser with flight heritage, a low-mass receiver telescope and photon counting sensitive detectors.

The baseline design of MARLI utilizes a pulsed single-frequency diode-pumped Nd:YAG laser Its output pulses are wavelength stabilized near 1064 nm. The laser emits ~50 nsec wide pulses at a 1 kHz pulse rate. Nominally, the receiver uses a ~70 cm diameter telescope and splits the returned signal into 3 paths. One path is a cross-polarized channel to allow dust/ice discrimination. The other two paths are used to illuminate an etalon then are refocused onto detectors This part of the receiver is configured as a double-edge Doppler (optical frequency-shift) discriminator.

Our approach leverages new lidar components developed for NASA, including a single frequency laser from Fibertek and photon-sensitive HgCdTe detectors from DRS Technologies. Our targeted instsrument size is a ~80 cm cube, comparable to a medium-sized instrument such as the Mars Orbiter Laser Altimeter (MOLA). Nominal payload parameters are < 40 kg, < 90 W, and ~50 Kbits/sec. This approach leverages our work on measuring terrestrial winds and lidar technology supported by the NASA ESTO Instrument Incubator program.

Performance Estimates: Using measurement models developed as part of this project, we have calculated the expected performance of MARLI. The performance estimates are contigent on vertical bin depth and averaging time. The instrument will report measurements at a rate of ≥ 10 Hz. Assuming 2 km vertical bins and 40 second along-track averaging (~2° of latiude), our performance estimates are shown in Table 1.

References:

[1] MEPAG: Chaired by B. Campbell and R. Zurek (2015), *Report from the Next Orbiter Science Analysis Group,* http://mepag.nasa.gov/reports.cfm

[2] J.B. Abshire, et al., MARLI: MARs LIdar for global climate measurements, 2014 International Planetary Measurement Conference. http://ssed.gsfc.nasa.gov/IPM/PDF/1057.pdf

[3] J.B. Abshire et al., MARLI, European Planetary Science Congress, http://meetingorganizer.copernicus.org/EPSC2015/EPSC2015-258.pdf

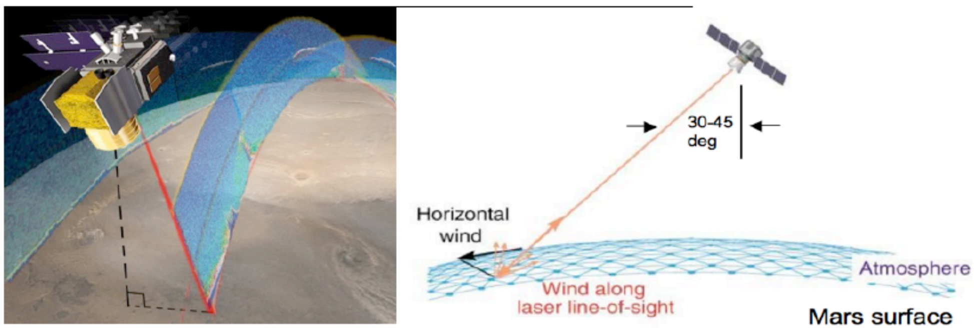

Figure 1. (Left) MARLI measurement approach, which continuously measures the aerosol backscatter profile, the cross-polarized (ice) backscatter profile, the Doppler (wind) profiles, the CO_2 column absorption (surface pressure), and the range to the scattering surface from orbit. (Right) Measurement orientation. Nominally, the lidar is pointed cross-track at ~30° off-nadir to measure the Doppler shift of the wind in the cross-track direction.

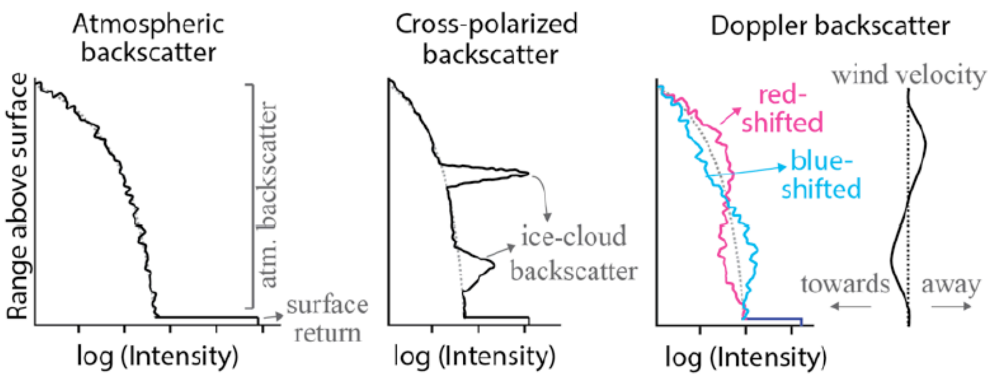

Figure 2. Illustrations of the MARLI measurements. (Left) Range (height) resolved aerosol backscatter profiles. The strong echo pulses reflected from the surface are used for the CO_2 column density measurements. (Middle) Profiles of cross-polarized backscatter, caused by clouds with ice-crystals. (Right) Height-resolved Doppler (wind) backscatter profiles as seen by the two detectors after passing through the double-edged filter. The horizontal wind profile (Far Right) is computed from the scaled ratio (difference/sum) from the detectors after the double-edge filter.

Table -1 Calculated MARLI performance

Parameter	*Surface*	*5 km*	*10 km*	*20 km*	*40 km*
Backscatter SNR	180	150	120	60	30
Wind horiz. velocity (m/sec)	1.2	1.4	1.8	3.5	~8
Range to surface (m)	<1	<1	<1	<1	<1