MARLI: MARs LIdar for global wind profiles and aerosol profiles from orbit

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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 wind observations from orbit 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 influences 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 orbit.

Lidar Measurement Approach: The MARLI lidar [2-3] 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 MARLI approach uses a pulsed single-frequency Nd:YAG laser, makes measurements at 1064 nm and its measurement types are shown in Figure 2. The MARLI definition work is being supported by the NASA Picasso Program.

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 height resolved atmospheric characteristics along a single line-of-sight. The lidar uses an efficient pulsed ND:YAG laser with flight heritage, a low-mass receiver telescope and photon-sensitive detectors.

The baseline design of MARLI, shown in Figure 3, 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. It is also feasible to measure vector-resolved wind profiles using a dual-telescope-receiver that shares the energy from a single laser.

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, < 90W, and ~50 Kbits/sec. This approach leverages our work on measuring terrestrial winds and lidar technology supported by the NASA ESTO IIP 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° latt.), the 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, 2015 European Planetary Science Congress (EPSC), http://meetingorganizer.copernicus.org/EPSC2015/EPSC2015-258.pdf

[3] S. D. Guzewich et al., MARLI, 2016 Lunar and Planetary Science Confernece (LPSC), http://www.hou.usra.edu/meetings/lpsc2016/pdf/1497.pdf

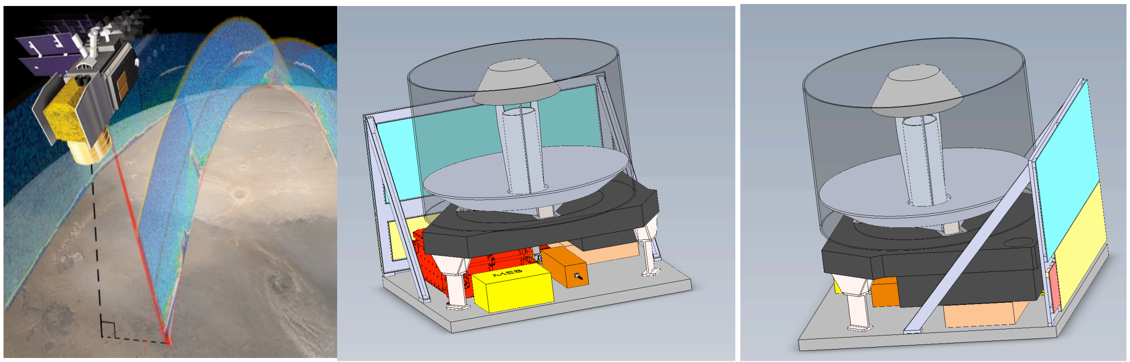

Figure 1. *(Left)* Mars lidar measurement approach, which continuously measures the aerosol backscatter profiles, the cross polarized (ice) backscatter profiles, the Doppler (wind profiles), and the range to the scattering surface from orbit.*)* Nominally the lidar is pointed cross-track at ~ 30 deg off nadir, to measure the Doppler shift of the wind in the cross-track direction. This sketch is for the single beam (cross track direction) approach. *(Middle and Right)* Drawings of the single beam (scalar measurement) version of MARLI from a recent instrument engineering study at NASA Goddard. In this concept the receiver telescope diameter is 80 cm, the laser box is in red, and the radiator panel is in blue and yellow.

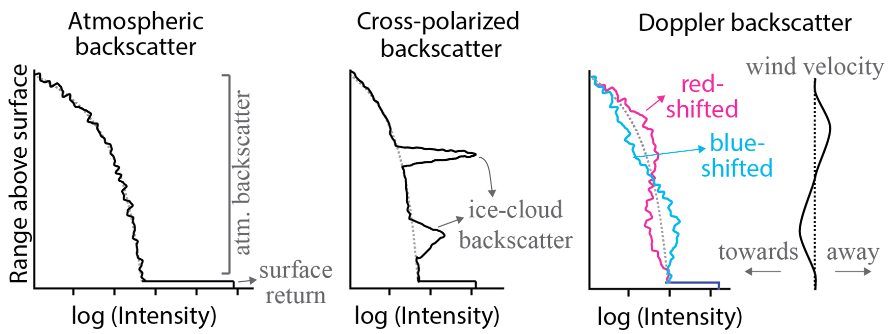

Figure 2. llustrations of the MARLI measurements. *(Left)* Range (height) resolved aerosol backscatter profiles.. *(Middle)* Profiles of cross-polarized backscatter, caused by clouds with ice-crystals. *(Right)* Height resolved Doppler (wind) backscatter profiles as seen by the two detectors after passing through the two etalons comprising the double-edge filter. The horizontal wind profile *(Far Right)* is computed from the ratio (difference/sum) from the detectors after the double-edge filter.

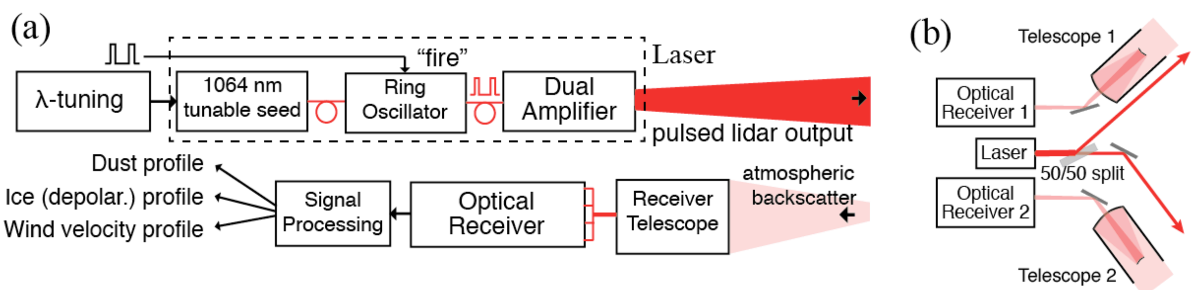

Figure 3 – *(Left -a)* Simplified block diagram of MARLI lidar for single beam (scalar) instrument configuration. *(Right –b)* Approach using a single laser and two identical receivers allow a vector measurement configuration.

Table -1 Summary of MARLI performance for Mars for the single beam configuration

Parameter	*Surface*	*5 km*	*10 km*	*20 km*	*30 km*
Backscatter SNR	400	350	300	170	80
Wind horiz. velocity (m/sec)	0.5	0.7	0.9	1.5	2.5
Range to surface (m)	<1	<1	<1	<1	<1