MARLI: MARs LIdar for global climate measurements from orbit

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1. Summary

We are developing a multifunctional atmospheric lidar (MARLI) for Mars orbit. The lidar approach is to simultaneously measure atmospheric backscatter and depolarization profiles, wind profiles, and range from a near-polar circular orbit. These measurements address high priority needs for Mars as summarized in the 2011 Planetary Decadal Survey.

Although considerable progress has been made, knowledge of the present Mars atmosphere is limited by a lack of observations in several key areas including diurnal variations of aerosols and direct measurements of wind velocity. Both dust and water ice aerosols are pervasive in the Mars atmosphere. Dust interacts strongly with IR radiation causing large changes in the thermal structure and acting as a driver of atmospheric motions at all spatial scales. Water ice clouds play an important role in the water cycle altering the global transport of water vapor. The limited local time coverage of observations to date has shown large changes in the amount and vertical distribution of dust and ice aerosols and water vapor. However, existing observations do not allow the vertical distribution of the dust aerosols and ice to be characterized over the full diurnal cycle.

Winds on Mars play a fundamental role in climate and weather, yet basic questions still remain about the 3-D wind structure and how it changes with local time, location, and season. The winds transport water vapor, dust and ice aerosols, and mix all gaseous constituents. Winds are a primary player in all surface-atmosphere interactions. Wind velocities provide sensitive input and validation for Global Circulation Models (GCMs), and knowledge of winds is critical for the safety and precision of spacecraft entry, descent and landing (EDL). Despite the importance of winds on Mars, presently there are only a few direct observations of them, and indirect inferences are often imprecise. Because the Mars atmospheric dust cycles and CO_2 cycles are coupled, and because they both partially drive the wind fields, it is important to measure the dust, wind and CO_2 column simultaneously. It is ideal to measure them with the same instrument operating continuously, day and night, from a polar orbit, which is the basis of the MARLI approach.

2. Lidar Measurement approach

Our new lidar measurement concept is shown in Figure 1. MARLI is designed for a nominally circular polar Mars orbit. It is pointed typically 30-45 degrees from nadir in the cross-track direction, and the lidar continuously measures the aerosol backscatter profiles, the cross polarized (ice) backscatter profiles, the Doppler (horizontal) wind profiles, the range to the surface from space. The lidar wavelength is near 1533 nm and is stabilized off, but near, a CO_2 absorption line. The MARLI measurement types are illustrated in Figure 2.

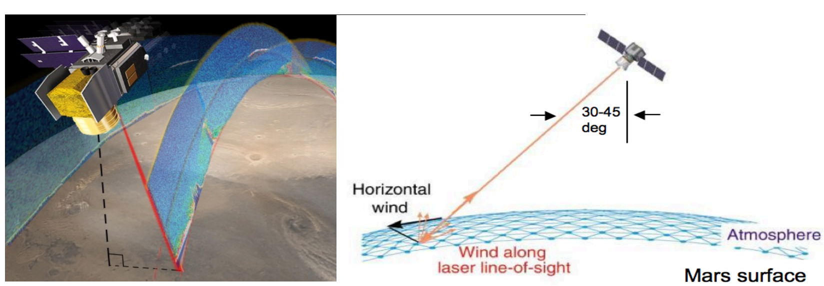

Figure 1. *(Left)* Mars Lidar measurement approach, which continuously measures the aerosol backscatter profiles, the cross polarized (ice) backscatter profiles, the Doppler (wind profiles), the column CO_2 absorption and the range to the scattering surface from orbit. *(Right)* Measurement orientation. Nominally the lidar is pointed cross-track at 30-45 deg off nadir, to measure the Doppler shift of the wind in the cross-track direction.

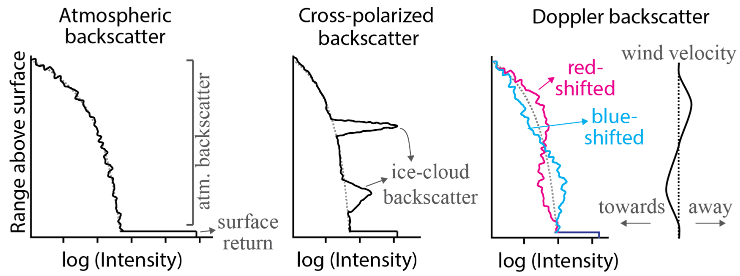

Figure 2. Illustrations of the MARLI measurements. *(Left)* Range (height) resolved aerosol backscatter profiles. The strong echo pulses reflected from the surface are used for the CO_2 column density measurements. *(Middle)* Profiles of cross-polarized backscatter, caused by clouds with ice-crystals.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

3. Lidar Description

The laser signal from the Mars atmosphere is weak and distributed, and its measurement requires a highly sensitive lidar approach. The key to maintaining compatibility for an orbital planetary mission is using a direct detection approach with efficient lasers, and a low-mass large area telescope, and photon-sensitive detectors. A simplified block diagram of the lidar is shown in Figure 3.

MARLI uses a pulsed fiber laser. It is small, efficient and wavelength tunable and operates near a single CO_2 line in the 1533 nm CO_2 band. Its output is chopped into pulses and amplified by several fiber amplifier stages. The receiver uses a ~70 cm diameter receiver telescope, and splits the received signal into 3 paths in the receiver. Each path uses a photon sensitive detector element in a small array. From these the primary measurements of height-resolved backscatter profiles, depolarization profiles, and wind velocity are determined.

Our approach builds on new lidar components developed for NASA and DoD, including laser power amplifier stages from Fibertek, and photon sensitive HgCdTe detectors from DRS-RSTA.

The targeted lidar size is ~80 cm cube, a medium sized instrument similar to our Mars Orbiter Laser Altimeter (MOLA). Nominal payload parameters are < 40 kg, < 65W, and ~ 50 Kbits/sec. The transmitter uses an efficient and compact wavelength tunable laser that operates on and near a single CO_2 line in the 1533 nm CO_2 band. The receiver uses a ~70 cm diameter receiver telescope and new highly sensitive HgCdTe detectors. This approach leverages in technologies from our ongoing work measuring CO_2 in the Earth's atmosphere supported by the NASA ESTO Instrument Incubator (IIP) program, and SBIR programs.

We have developed a measurement model and calculated the expected performance. The estimates depend on vertical bin depth and averaging time. The summary in Table 1 is based on averaging into 2 km bins vertically and for 40 seconds along track (~2 deg in latitude). The plan for this work for the Picasso program is to evaluate the performance of key components in lab tests, develop a lidar breadboard, and demonstrate atmospheric measurements under conditions that simulate measurements from space.

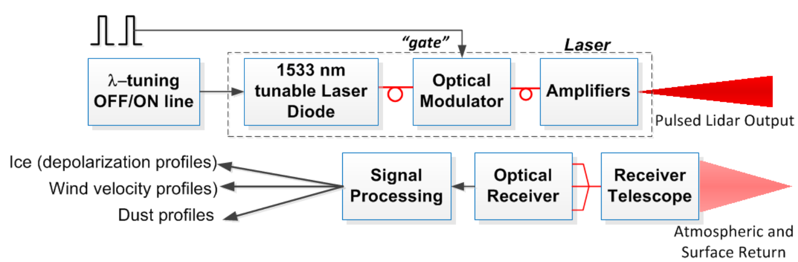

Figure 3. Block diagram of the MARLI lidar.

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