Atmospheric/Surface Polarization Experiment at Nighttime (ASPEN)

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Instrument Description: The *ASPEN* instrument will be a multi-wavelength, altitude-resolved active near-infrared (NIR) instrument to measure the reflected intensity and polarization characteristics of backscattered radiation from planetary surfaces and atmospheres. The proposed instrument is ideally suited for a mission to Mars to investigate the nature and seasonal abundance of atmospheric dust and icy volatiles, provide insight into surface and cloud grain sizes and shapes, evaluate cloud particle microphysics and also provide atmospheric column content constituent chemistry during polar night and day.

Applications to Mars: By operating in the 1.43-1.67 m region, the active sensor will be sensitive to H_2O ice and vapor and CO_2 ice and vapor and dust. The *ASPEN* instrument capabilities include the following:

1. Global, night and day mapping of H_2O and CO_2 volatiles (ice and vapor) and dust storms,
2. Unambiguous discrimination of CO_2 from H_2O ice clouds, and
3. Multiwavelength polarization measurements to infer shape of ice and dust grains.

Our knowledge of the Martian polar regions is constrained by the current passive mode of instruments that have been put in orbit over the Martian poles. To date, technological constraints have dictated that remote sensing instruments on planetary science missions be passive or restricted to active sensing at limited, well understood wavelengths (e.g. 1.064m laser ranging with *MOLA* and 5/20MHz ground penetrating radar with *MARSIS/SHARAD*).

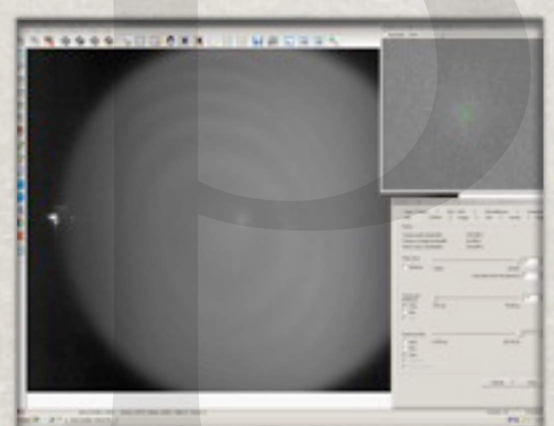
Science Questions: Previous instruments have given glimpses of cloud and surface ice activity on Mars, but no previous Martian orbital instrument has been able to achieve the following:

a.) Detect clouds up to 100km above the Martian surface during night and day;
b.) Discriminate between H_2O and CO_2 ice;
c.) Map cloud structure using lidar backscatter and depolarization;
d.) Map large grained (up to 30cm) CO_2 slab ice in the polar night [1];
e.) Determine whether H_2O ice in the southern polar trough system is due to cloud [4] or surface ice [5];
f.) Monitor 'cold spot' activity during the polar night and determine whether these enigmatic features are due to CO_2 clouds, precipitation, blizzards or surface ice [6];
g.) Monitor night and day geyser activity over the 'Cryptic Region' in southern spring and determine what amount of solar energy is required for them to be active [7];
h.) Uniquely identify cloud types and platelet/grain orientation, in order to confirm the presence of convective CO_2 cloud towers, a potentially critical part of the polar night dynamics and energy partitioning [8];
i.) Provide atmospheric column dust optical depths whenever the instrument is in operation [9,10].

Take Away Message: Our understanding of the sublimation of H_2O and CO_2 ice and related atmospheric changes is the result of recent studies of springtime recession using the *CRISM* instrument on MRO [1], the *THEMIS* instrument on Mars Odyssey [2] and the *TES* instrument on Mars Global Surveyor [3]. However, observations of the recession phenomena such as geysers and asymmetric retraction beg the key scientific question –

"what role does spatial and temporal deposition of ices during winter play in the annual CO_2 and H_2O cycles on Mars?"

***ASPEN* is designed as a response to this first order scientific question regarding Martian climate.**



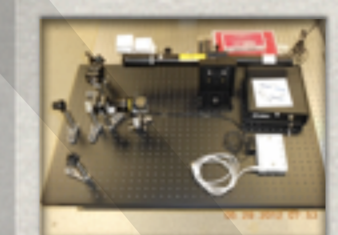
Terrestrial Analog Instrument: The *CALIOP* lidar onboard the CALIPSO spacecraft is a very similar instrument to the proposed *ASPEN* instrument. *CALIOP* operates a beam-doubled Ng-YAG laser at 0.532 and 1.064 microns and uses a mirror diameter of 1m. *CALIOP* has been used to investigate terrestrial dust optical depths [9,10], multi-layer vs. single layer cloud properties [11], ice water content [12] and particle orientations [13].

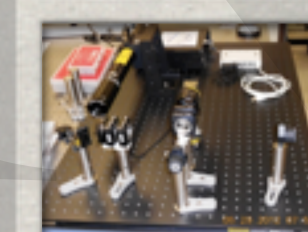
Preliminary radiometry calculations suggest that a spacecraft instrument could be 17kg (roughly half the weight of MOLA), with output power of 0.18W, (~half the output of MOLA) but with 10kHz pulse rate. It could operate with a power of 17W from the spacecraft, and would have a dish intermediate in size between *MOLA* and *CALIOP*.

NASA Requirements: The Mars Science community has recognized the need for an *ASPEN*-type instrument. The Second 2013 Mars Science Orbiter Science Analysis Group (MSO SAG) report stated that a "multibeam lidar" similar to *LOLA* on the Lunar Reconnaissance Orbiter and inheriting many aspects from the CALISPO lidar would "resolve optically dense atmospheric phenomena" and "significantly constrain seasonal mass budgets" and would be ideal for a "2013 MSO mission" [15]. The MSO SAG report also highlighted the need for Polar investigations, proposing a suite of observations for "P (Polar) type" observations.

A lidar instrument such as *ASPEN* was also recommended in the report on the 3rd International Workshop on Mars Polar Energy Balance and CO_2 Cycle [16] and has been emphasized as a future instrument priority in a white paper submitted to the Planetary Sciences Decadal Survey entitled 'Mars Polar Science for the Next Decade'.

Laboratory Precursor Instrument: Following recent funding of a NASA PGG proposal, we have commenced building a laboratory instrument called 'Coherent Backscattering LIDAR' (*CoBAL*) as a pre-cursor instrument to advance the Technical Readiness Level (TRL) of the *ASPEN* deign from TRL 1 to 3 (Figure 2). The instrument is in construction at Ball Aerospace in Boulder, CO and will become operational before the end of the year. The instrument will also be used to investigate the polarization properties of the cohenent backscattering phenomenon [17]. The effect will be observed on appropriate planetary analog materials (esp. CO_2 and H_2O ices) in order to lay the ground work for the *ASPEN* Martian instrument.





Future Work: We will be carrying out a range of experiments using the *CoBAL* instrument before the end of the year and will propose to the Planetary Instrument Definition and Development Program (PIDDP) a field instrument variation to lift the TRL of the instrument from 3 to 5, with the eventual goal of riding to Mars in the 2018-2021 timeframe, potentially as part of the MICADO Discovery class mission [18].

References: [1] Brown et al. (2009) *JGR* doi:10.1029/2009JE003333. [2] Titus et al. (2003) *Science* 299 1048-1051 [3] Kieffer and Titus (2001) *Icarus* 154 162-180 [4] Inada et al. (2007) *Icarus* 192 378-395 [5] Titus (2005) *GRL* doi:10.1029/2005GL024211 [6] Forget et al. 1995 *JGR* 100 21219-21234 [7] Kieffer (2006) *Nature* 442 793-796 [8] Colaprete et al. (2003) *JGR* doi://10.1029/2003JE002053 [9] Ma et al (2010) *JQSRT* 112, 338-345 [10] Lu et al (2010) *JQSRT* 112, 320-328 [11] Li et al (2010) *JQSRT* 112 361-375 [12] Heymsfield et al (2005) *GRL* doi:10.1029/2005GL022742 [13] Hu et al. (2009) *JAOT* 26 2293-2309 [14] Weimer et al (2007) *SPIE Proceedings* [15] Report from the 2013 MSO Second Science Analysis Group [16] Titus and Michaels (2009) *EOS Trans. AGU* 90 351 [17] Kuga and Ishimaru (1984) *JOSA* 1 831-835 [18] Titus et al. (2010) *LPSC* abs. #1151, Titus et al. (2012) *Mars Misson Concepts Workshop*