PRECISION LASER SENSING OF LUNAR POLAR VOLATILES. G. A. Neumann[1], E. Mazarico[1], X. Sun[1], A. N. Deutsch[2], and P. G. Lucey[3], [1]NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA. (email: gregory.a.neumann@nasa.gov), [2]Department of Earth, Environmental and Planetary Sciences, Brown University, Providence, RI 02912, USA.

Introduction: Resource utilization of hydrogen-bearing deposits will depend on precise knowledge of their abundance, depth of burial, composition, sources and sinks, and their operational accessibility. While it has long been known from neutron spectrometry that hydrogen exists at the poles of airless bodies such as Mercury and the Moon, in the latter case interpretation of radar and optical mapping has been challenging [1–3]. Debate persists as to the hydrogen's origin, mobility and chemical bonding. Sensitive methods to resolve these questions are now reaching technological maturation [4–5]. An in-house development of multi-wavelength lidar at Goddard and U. Hawaii, "Spectroscopic Infra-Red Reflectance Lidar" (SpIRRL) addresses contamination of passive spectroscopy by the competing effects of thermal emission and solar reflectance by means of a highly sensitive active measurement near 3 µm, where water absorbs strongly. Variations in 3 µm water band depth have been interpreted to be due to variation in water abundance. Reflectance measurements near 3 µm and supporting reference wavelengths can definitively answer the question of whether water detected by passive spectrometers moonwide is mobile by comparing day and night band depths which in turn constrains the supply of water to permanently shadowed regions at the poles. The 3-µm region is uniquely sensitive to the presence of all water bearing species and the instrument can characterize the abundance of water ice in permanent shadow down to the lunar background water abundance of about 100 parts per million, far below the abundance accessible to shorter wavelength measurements [5].

Geodetic Information:

The accessibility of volatiles for extraction will require knowledge of their position in relation to the lunar coordinate frame defined by laser retroreflectors and realized by altimetry and optical imaging so as to marshall the considerable assets required to make use of them. To this end, the importance of combining altimetry with spectrometry cannot be overstated. The proposed lidar can provide a global spatial coverage of the Moon every two weeks (half a lunar day) from polar orbits, providing abundant topographic crossover points and tiepoints. As shown for current [6] and previous [7] missions, altimetric ranges can support spacecraft orbit reconstruction accuracy at the 10-20 meter level, even in the absence of radio tracking. The time-of-flight data collected will thus be useful to geolocate the spectrometer data in the established LOLA-based lunar frame (including the data from other instruments onboard). Previous spectrometers such as M-cubed have required painstaking registration with imager mosaics and suffered from undetermined phase geometry (E. Malaret, personal communication).

Detection of sublimation lags overlying radar-bright water ice deposits: While reflectance anomalies are expected in regions of permanent shadow, one of the unknown aspects of lunar volatiles is burial and insulation by a more refractory volatile sublimation blanket composed of complex carbon compounds. If even small cometary impacts have recently carried volatiles to the Moon's cryosphere, they would deposit some amount of impure ice similar to the small-scale deposits inferred from 1064-nm laser reflectance at Mercury [8, 9]. The compounds are typically darker (< 0.05) than even mare regolith, but may be difficult to distinguish from other lithologies without a highly sensitive and optimized active lidar spectrometer. Experiments underway demonstrate the sensitivity of SpIRRL to water and other volatile species in a lunar regolith simulant under <170 K cryogenic conditions.

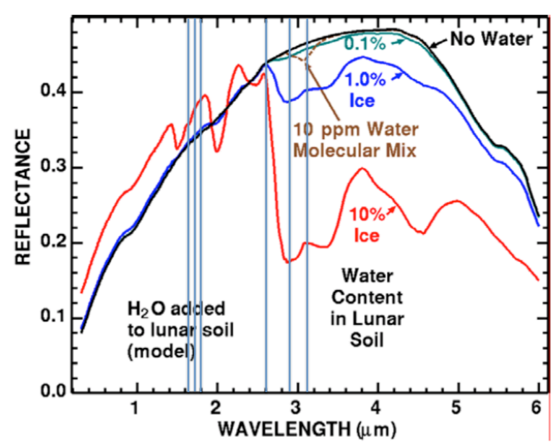

Figure 1. Radiative transfer models of spectral absorption at the 3-µm region which is sensitive to very small amounts of water in several forms [10].

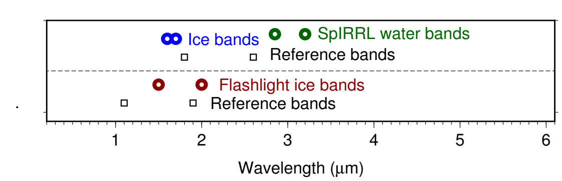

Figure 2. Multiple waveband measurement by SpIRRL as part of a lunar mission [11] suite of instruments vs. the proposed Lunar Flashlight [12].

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