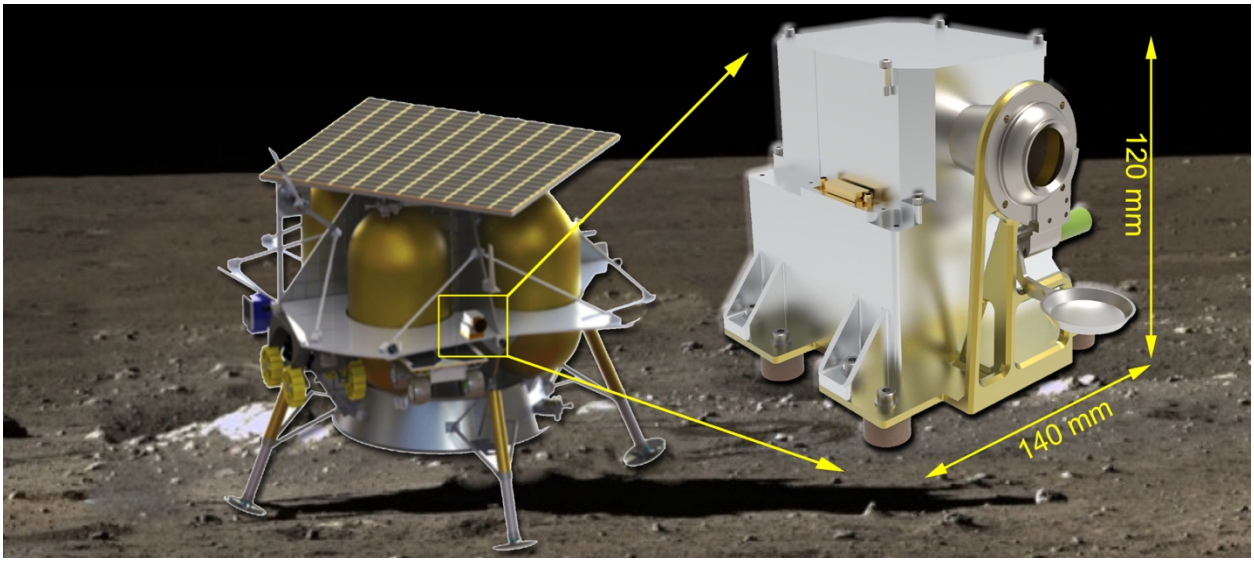
THE PEREGRINE ION TRAP MASS SPECTROMETER (PITMS): A CLPS-DELIVERED ION TRAP MASS SPECTROMETER FOR IN-SITU STUDIES OF THE LUNAR WATER CYCLE. B. A. Cohen[1], S. J. Barber[2], W. M. Farrell[1], A. D. Morse[2], S. Sheridan[2], N. M. Curran[1], M. Leese[2], C. Howe[3], P. Driggers[1], and R. Trautner[4]. [1]NASA Goddard Space Flight Center, Greenbelt MD (barbara.a.cohen@nasa.gov), [2]The Open University, Milton Keynes, UK, [3]STFC RAL Space, Harwell Campus, Didcot, UK, [4]ESA/ESTEC, Noordwijk, The Netherlands.

Introduction: The Peregrine Ion Trap Mass Spectrometer (PITMS) was selected for development and flight in the NASA Commercial Lunar Payload Services (CLPS) program. PITMS is a partnership between NASA Goddard, The Open University (OU), and ESA, to provide a payload manifested aboard the first flight of Astrobotic's Peregrine lunar lander. PITMS will consist of an ITMS sensor and front-end electronics, newly developed controller and power supply boards, and a GSFC wrapper. PITMS leverages the ESA PROSPECT development for the Russian Luna-27 mission and develops a standalone mass spectrometer suitable for small lunar landers. It will monitor the tenuous near-surface lunar exosphere in response to natural and artificial stimuli (e.g., diurnal temperature cycle, lander activities). Our investigation will provide measurements of the exosphere to significantly improve our knowledge of the abundance and behavior of volatiles on the Moon, linking the lunar surface to LADEE measurements, and informing future robotic and human mission design.

Lunar near-surface water: Landed mass spectrometers are uniquely positioned to assess the volatile components of the lunar regolith and exosphere and observe their behavior from dawn to dusk, addressing NASA science and exploration goals. The Moon has a tenuous atmosphere (exosphere) primarily made of neon, helium, and argon [1], molecular hydrogen [2], with smaller abundances of methane [3], sodium, and potassium [4]. Because of the rate at which atoms escape from the lunar atmosphere, there must be a continuous source of particles to maintain even a tenuous atmosphere. Characterizing lunar volatile reservoirs and evaluating their interrelations is a high priority for both lunar science and for exploration purposes, as water could represent a key resource for human utilization.

Multiple spacecraft have observed water and hydroxyl in the lunar mid-latitudes as detected in the 2.8-micron absorption feature in the IR reflectance spectrum [5-9]. This surface reflectance feature may exhibit seasonal and possibly even diurnal variability. The LADEE Neutral Mass Spectrometer (NMS) and Ultraviolet Spectrometer (UVS) identified the primary atmospheric constituents at this altitude, their density, and variability [1, 4]. To date, water and OH have only been reported in the exosphere during meteor stream events by the LADEE NMS and UVS [10]. A definitive observation of exospheric water and OH released from the surface during nominal times remains elusive.

The only corresponding surface measurement was made by the Lunar Atmospheric Composition Experiment (LACE) on Apollo 17. LACE was a miniature magnetic deflection mass spectrometer deployed on the surface and oriented to intercept and measure the downward flux of gases. This instrument had a mass range of 1-110 amu and a sensitivity of 1 cps (~200 cm^{-3}), and operated for 9 months. LACE was routinely swamped by artifacts emanating from the nearby lunar module descent stage and other abandoned equipment during the



lunar daytime, but obtained firm detections of two species, argon and helium. Possible pre-sunrise detections of other species were obtained (see review in [11]), but only upper limits were determined for most of the volatile species of interest, including N_2, CO, CO_2, and CH_4; OH/H_2O was not determined due to the high backgrounds both inside and outside the instrument.

Lander Effects: Volatile compounds (including water) will be deposited onto the lunar surface by the lander itself. Observing the release of these vapor species over the lunar day will provide information on the properties of the regolith and the nature of the landing plume interaction with it, both important to future human activities. The exposed regolith is constantly being activated through bombardment by the solar wind and impactors, creating sites that bind volatile species such as water. Laboratory observations of water bound to lunar regolith shows a distribution of activation energies peaking near 0.7 eV, but with a high energy tail beyond 1 eV [12-14]. If *in situ* lunar regolith has the same properties, the water molecules will outgas from the surface over time as the surface is progressively warmed. If PITMS still senses considerable water surface outgassing near local noon (~400K), it implies that the surfaces contain sites with very high activation energy for water trapping, with values above 1.0 eV, as one might expect for mature highland samples. In this case, the surface is a potent sorption substrate. If, however, the local regolith has little outgassing at local noon, then this implies that *in-situ* exposed surfaces have outgassed at lower activation energies/lower temperatures. In this case, the surface may be a far less potent sorption substrates than environmentally dormant samples used in the lab, affecting our models of plume-originating water retention in the actual space environment.

Development & operation: PITMS consists of an ITMS built by OU in collaboration with RAL Space under contract by ESA, and a wrapper built by NASA GSFC that will integrate the ITMS with the Astrobotic lander. The ITMS has direct heritage from the Ptolemy mass spectrometer that made the first in situ measurements of volatiles and organics on comet 67P with the Rosetta lander, Philae [6]. It has a unit mass resolution up to an upper mass-to-charge (m/z) limit of 150 Da. Operating in a passive sampling mode, ambient gases enter PITMS through an aperture and diffuse around the mass analyzer cavity. They will be ionized through interaction with electrons emitted by a heated wire filament, and the resulting positively charged ions will be trapped in a radiofrequency field formed by application of suitable potentials to a set of three hyperbolic electrodes. Manipulation of the field facilitates the ejection of the ions into the electron multiplier detector in order of increasing m/z with amplitudes related to abundance. This passive technique was used during Rosetta's flyby of asteroid Lutetia [7] and at 67P during Philae's "bounce" after landing [6], achieving detection limits of around 1E-10 mbar, some five orders of magnitude better than that achieved by the LACE experiment.

GSFC will build the wrapper, consisting of a thermal base plate, a radiator, and a deployable dust cover, and conduct integration and test of the ITMS with the wrapper. The integrated PITMS payload and science investigation will be operated from GSFC. PITMS is manifested on the first flight of Astrobotic's Peregrine lander, which will fly as a co-manifested payload aboard the maiden flight of ULA's Vulcan Centaur vehicle in 2021. The lander is targeted for the Lacus Mortis basaltic lava plain in the northeastern part of the Moon, near an apparent skylight [15]. PITMS operations will commence soon after touchdown with the release of the dust cover. PITMS will continually scan at up to 10 Hz and integrate the mass spectra onboard if needed to build signal to noise. We expect to monitor the decay in the lunar exosphere from its post-landing peak, punctuated by any stimuli that create transient increase. PITMS observations will complement the descent plume characterization by SEAL [16].

Summary: PITMS will provide a modern measurement of OH/H_2O on the lunar surface, along with improved quantification of exospheric species of interest to both science and human exploration. This landed investigation would be useful anywhere on the Moon: equatorial siting would compare with LADEE, but polar would monitor migration of water molecules toward PSRs. Multiple measurements of the lunar atmosphere and surface-lander interactions would be valuable (including further builds of PITMS), particularly from multiple landing sites and during different seasons.

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