**THE LUNAR WATER MISSION: A SMALL ORBITAL MISSION TO CHARACTERIZE THE WATER ON THE MOON'S SURFACE.** Charles A. Hibbitts[1], David T. Blewett[1], Pontus Brandt[1], Brenda Clyde[1], Barbara A. Cohen[2], John W. Dankanich[2], Rachel L. Klima[1], David J. Lawrence[1], Jeffrey B. Plescia[1], Jessica Sunshine[3], Joseph H. Westlake[1], [1]Johns Hopkins University Applied Physics Laboratory, Laurel, MD USA. (Karl.Hibbitts@jhuapl.edu); [2]Marshall Space Flight Center, Huntsville, AL, [3]University of Maryland, College Park, MD.

**Introduction:** The water ($H_2O$ and OH) on the Moon is of great scientific and exploration interest, but its chemistry, distribution, evolution, and abundance are poorly understood. We present a mission concept to answer many of the questions that are not only fundamental to the Moon but also applicable to other airless bodies, notably Mercury and asteroids. A small spacecraft orbital mission can potentially conduct Discovery-class science to understand fundamental questions regarding the origin and evolution of the water on the Moon and address exploration objectives by providing information on the physical nature, abundance and distribution of volatiles on the illuminated Moon and in Permanently Shadowed Regions (PSRs). This mission concept leverages rideshare launch opportunities, new propulsion technology, miniaturization of instrumentation, and improved communications. Specifically, an EELV Secondary Payload Adapter (ESPA)-class mission using solar-electric propulsion is potentially capable of an orbit unique design and a tailored instrument payload of imagers and particle detectors to characterize the surface and the solar wind input to answer questions related to the processes of formation, loss, evolution and sequestration of water on the Moon.

**Mission Objectives:** Better understanding volatiles in the inner solar system and specifically the Moon is a high-priority objective in the 2014 NASA Science Plan, the 2013-2022 Decadal Survey and has been the objective of several mission concepts. The Lunar Water Assessment, Transport, Evolution, and Resource (WATER) Mission concept is a <2 year, small spacecraft concept to unravel the complex processes responsible for the formation, loss, evolution, and sequestration of lunar water (OH and $H_2O$). The mission would address key questions including:

- How are volatile elements and compounds distributed, transported, and sequestered in near-surface environments on the surfaces of the Moon and Mercury? What fractions of volatiles were outgassed from those planets' interiors, and what fractions represent late meteoritic and cometary infall?
- What are the chemical and isotopic compositions of hydrogen-rich (possibly water ice) deposits in the lunar regolith?
- What are the inventories and distributions of volatile elements and compounds (species abundances and isotopic compositions) in the mantles and crusts of the inner planets?

The Lunar WATER Mission would answer these questions about volatiles on the Moon:

1. What is the origin of the water ice in the PSRs and how is it distributed spatially (in three dimensions)?
2. Is there $H_2O$ on the illuminated surface and if so, what is its source and how does it vary over space and

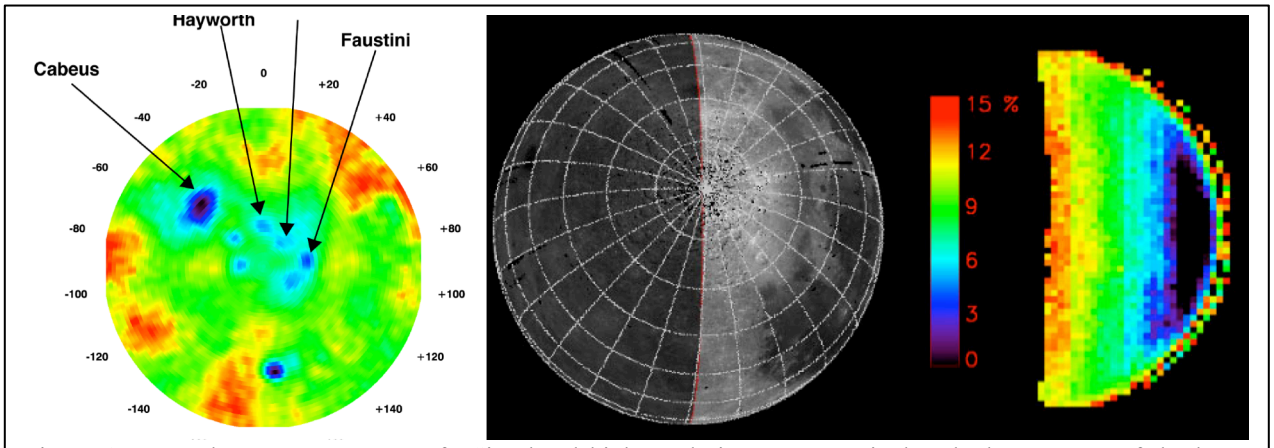


Figure 1. Example measurements. Left: Simulated high-resolution water equivalent hydrogen map of the lunar south pole possible from low perilune observations with a neutron spectrometer [1]. Right: Global map of water via the 3 μm absorber at the north pole at ~ 10 km/pixel from EPOXI [2].

time?

3. Does the OH on the illuminated surface have a solar wind origin? What are the evolution and loss mechanisms of this OH?

4. What are the compositional, temporal, and thermal dependencies in the distribution and relative abundance of both $H_2O$ and OH both outside and inside of PSRs?

**Mission Design:** Intrinsic to mission success is an orbit with a <10 km periapsis over either of the poles to map polar volatiles at high spatial resolution, and a high apoapsis of a few thousand kilometers to enable the characterization of global- and regional-scale volatile processes including measuring the solar-wind flux. Because low-altitude orbits are dynamically unstable, such an orbit requires continual corrections. Such corrections are efficiently enabled by Solar Electric Propulsion (SEP). The highly elliptical orbit is obtained after entering lunar orbit upon delivery to the Moon on a rideshare or independently entering from a geostationary transfer orbit (GTO) (Fig. 2).

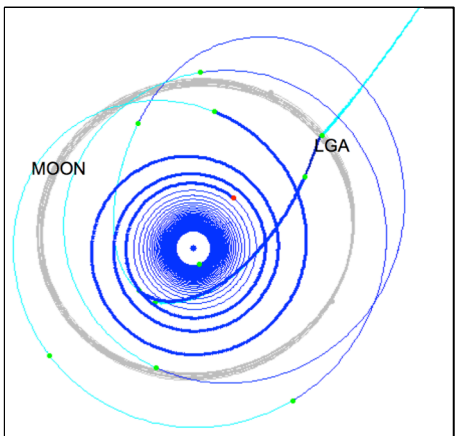


Figure 2. Orbit concept spiraling out from GEO to LGA. ~ 250 day. Not shown is weak lunar capture and spiraling down to lunar science orbit. ΔV<3000m/s.

**Measurements and Instrumentation:** Previous missions that measured lunar volatiles were dramatically limited in their investigation for multiple reasons. These include: 1) Not being able to obtain a global perspective of the Moon over a range of local times and 2) Not being able to observe inside the PSRs with the appropriate measurements at small enough spatial scales to characterize the water, geology, and temperature dependencies [e.g., 2,3,4]. A polar perilune will enable high-spatial-resolution measurements of polar volatiles via a neutron spectrometer [1] and either an IR multispectral imager augmented with an active source over a wider wavelength range than the Lunar Flashlight mission [5] or a multispectral UV imager to characterize the water ice at the surface within PSRs. At apolune, global information is obtained on the formation and loss mechanisms and evolution of OH and $H_2O$ on the illuminated surface using a Faraday cup to measure the solar-wind proton flux impinging on the surface, a neutral atom imager to understand the reflected portion of the solar wind, and the IR spectral imager in passive mode (Fig. 1) to investigate the OH and any $H_2O$ formed on the illuminated surface.

The neutron spectrometer could be a simplified version of a flight-qualified design used at Mercury [6]. The IR instrument design is simplified by the narrow wavelength range requirement of ~ 2 to ~ 4 μm,. The potential UV instrument is an imager derived from a flight-proven spectrometer, such as the MSX SSUSI instrument [7], which simplifies design while maximizing throughput and SNR. The Faraday cup solar wind detector and the Neutral Atom Imager (ENA) are both simple instruments with successful flight histories [8,9]. While this is an ambitious instrument suite for a small mission, it may be possible to optimize the science objectives with available mission resources to arrive at an ideal mission.

**Conclusions:** Understanding the origin, evolution, and exploration potential of volatiles over the illuminated Moon and within PSRs is a high priority objective for NASA that can potentially be accomplished with a ESPA or ESPA-grande class mission leveraging rideshare, SEP, and simple instrumentation.

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