TOWARD AN INTERNATIONAL LUNAR POLAR VOLATILES STRATEGY. J. E. Gruener[1], N. H. Suzuki[2], and J. D. Carpenter[3] [1]NASA Johnson Space Center (Mail Code KX111, 2101 NASA Parkway, Houston, Texas, 77058, john.e.gruener@nasa.gov) [2]NASA Headquarters (Mail Code CQ000, 300 E Street Southwest, Washington, DC, 20546, nantel.h.suzuki@nasa.gov) [3]ESA ESTEC (Keplerlaan 1, 2401 AZ, Noordwijk, The Netherlands, James.Carpenter@esa.int)

Introduction: Fourteen international space agencies are participating in the International Space Exploration Coordination Group (ISECG), working together to advance a long-range human space exploration strategy. The ISECG is a voluntary, non-binding international coordination mechanism through which individual agencies may exchange information regarding interests, objectives, and plans in space exploration with the goal of strengthening both individual exploration programs as well as the collective effort.

The ISECG has developed a Global Exploration Roadmap (GER) that reflects the coordinated international dialog and continued preparation for exploration beyond low-Earth orbit – beginning with the Moon and cis-lunar space, and continuing to near-Earth asteroids, and Mars [1]. Space agencies agree that human space exploration will be most successful as an international endeavor, given the challenges of these missions. The roadmap demonstrates how initial capabilities can enable a variety of missions in the lunar vicinity, responding to individual and common goals and objectives, while contributing to building partnerships required for sustainable human space exploration that delivers value to the public.

Use of Local Lunar Resources: In regards to exploration of the Moon, the initial missions and capabilities on the lunar surface will likely consist of small robotic missions limited in scale and mission duration, with everything needed for those missions delivered from Earth. However, when it comes to maintaining a longer-term human presence beyond low-Earth orbit, space agencies agree that the use of local resources could significantly benefit operations in the lunar vicinity, and possibly limit the cost and complexity of bringing all the needed supplies from Earth. The most promising uses for local resource utilization are in life support systems or as propellants.

For many years, the lunar regolith was seen as the primary source for both oxygen (chemically bound in lunar minerals and glasses) and hydrogen (implanted into the regolith by the solar wind). However, the recent discoveries of water on the Moon, particularly in polar regions, may lead to less complex methods to create life support consumables and propellants. To gain an understanding of whether lunar polar volatiles, such as water ice, could be developed and used in a cost effective and safe manner, it is necessary to understand more about the nature and distribution of the volatiles and operating in the lunar polar environment.

As the volatiles on the Moon are associated with the lunar regolith, new planetary mining technologies such as roving, prospecting, regolith excavation, resource processing, and product storage will be required. Technologies to operate in the lunar polar environment, such as power generation, communications, and thermal management will also need to be developed and tested.

Scientific Interest: Scientists have discussed the possibility of water ice existing in lunar polar regions since the early 1960s [2]. However, it wasn't until the 1990's that lunar orbiting spacraft began acquiring the data to support such a hypothesis. [3,4]. The Lunar Crater Observation and Sensing Satellite (LCROSS) provided direct evidence of the presence of water ice in a permanently-shadowed portion of Cabeus crater [5] in 2009. However, evidence of water ice in the lunar polar regions does not exhibit a spatial correlation with all permanently-shadowed areas on the Moon, as is suggested on Mercury [6]. Further spacecraft missions have shown that water exists on large portions of the lunar surface as a thin layer of surface-bound hydroxyl and/or water molecules [7,8,9], and could be a possible source of water for polar ice deposits. Understanding the quantity, distribution and form of lunar polar volatiles, including water ice, and pursuing the scientific questions regarding the creation, transport, delivery and accretion of water and water ice on the Moon are considered as strategic knowledge gaps by the ISECG.

International Strategy: The ISECG has begun an effort to develop a coordinated international lunar polar volatile strategy that is technically feasible, yet programmatically implementable. The strategy would follow an incremental phased approach, beginning with robotic prospecting to understand the nature and distribution of the polar volatiles through measurements on the lunar surface, and followed by robotic in situ resource utilization demonstrations (ISRU) to understand whether potential resources could be extracted and processed economically and safely.

Core Elements: Currently, there are three initial core elements to this strategy. 1.) Lunar Regions of Maximum interest - build a consensus among the international community for 'common regions' on the lunar surface to be collectively explored by a variety of

sequential, coordinated missions. The regions would be larger than a landing site for a single mission, perhaps areas as large as several tens of kilometers in extent, and possibly including highly illuminated peaks and permanently shadowed areas. 2.) Low Entrance Barriers - facilitate participation by space agencies, commercial entities, and universities by deployment of surface or orbital infrastructure assets that provide productivity-enhancing utility services within the specified region (i.e., power generation, thermal protection, communication) to allow for simpler, lower cost rovers or other surface systems; and collaborative development of instrument or surface system capabilities between participants. 3.) Common Standards – utilize standard interfaces (mechanical, electrical, communication) and standard propellants to optimize use of surface utility services, permit interchangeability of vehicle payload complements, and maximize interoperability. It would also be desirable to evaluate whether there are valuable common approaches and technologies to prospecting measurements and investigations, and to coordinating common instrumentation, calibration, measurements, methodologies and analysis, so to ensure a common interpretation of data from different areas on the lunar surface to maximize the overall science return.

References: [1] ISECG (2013) *http://www.nasa.gov/sites/default/files/files/GER-2013_Small.pdf.* [2] Watson K. et al. (*1961) J. of Geophys. Res*., 66, 1598-1600. [3] Nozette S et al. (1996) *Science*, 274, 1495-1498. [4] Feldman W.C. et al (2000) *J. of Geophys. Res*., 105, 4175-4195. [5] Colaprete A. et al. (2010) *Science*, 330, 463-468. [6] Chabot N.L. et al. (2013) *J. of Geophys. Res*., 118, 26-36. [7] Pieters C.M. et al. (2009) *Science*, 326, 568-572. [8] Sunshine J.M. et al (2009) *Science*, 326, 565-568. [9] Clark R.N. (2009) *Science*, 326, 562-564.