Exploring and Using Lunar Polar Volatiles

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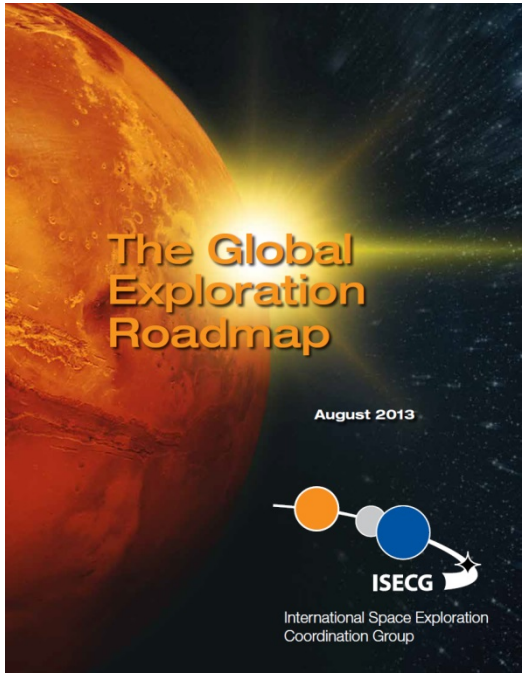
Annual Meeting of the Lunar Exploration Analysis Group
Columbia, Maryland
20 October 2015

What is ISECG?

- **The International Space Exploration Coordination Group (ISECG)**
  - Voluntary, non-binding international coordination forum and mechanism
  - Goal of strengthening both individual exploration programs as well as the collective efforts, working together to advance a long-range human space exploration strategy



- **Global Exploration Roadmap (GER)**
  - http://www.globalspaceexploration.org

- **Senior Agency Meeting (Oct. 8-9, 2015)**
  - "They also discussed the importance of **advancing knowledge and technologies for the use of local resources** on the Moon and Mars for the sake of the exploration missions. This is of great interest to several space agencies, which are, in coordination with the international science community and private entities, assessing sustainable exploration approaches utilising in-situ resources (**in particular lunar volatiles**). Space agencies are advancing continued collaboration with government and non-government entities in this area that will be documented in a public website."

Polar Volatiles Coordination

- **Formed small team of ISECG participating agency representatives to coordinate activities associated with exploring and using lunar polar volatiles**

  CSA (Vicky Hipkin, Martin Picard)
  DLR (Norbert Henn, Oliver Angerer)
  ESA (Bernhard Hufenbach, James Carpenter)
  JAXA (Naoki Sato, Takeshi Hoshino)
  NASA (Nantel Suzuki, John Gruener)
  Roscosmos (Georgy Karabadzhak)

- **Goal: Establish an internationally-coordinated effort to address scientific knowledge gaps and exploration capability gaps related to lunar water ice and other polar volatiles**

- **Engage the lunar exploration and scientific communities**
  - Presence and discussions at science conferences
    - Lunar and Planetary Science Conference
    - International Symposium on Moon 2020-2030, Dec. 15-16, 2015, Noordwijk, The Netherlands
    - Microsymposium 57: Polar Volatiles on the Moon & Mercury, Mar. 19-20, 2016
  - Presence and discussions at engineering conferences (e.g., PTMSS/SRR)
    - Planetary & Terrestrial Mining Science Symposium/Space Resource Roundtable
  - Participate with 'Friends of Lunar Volatiles', chaired by Dana Hurley

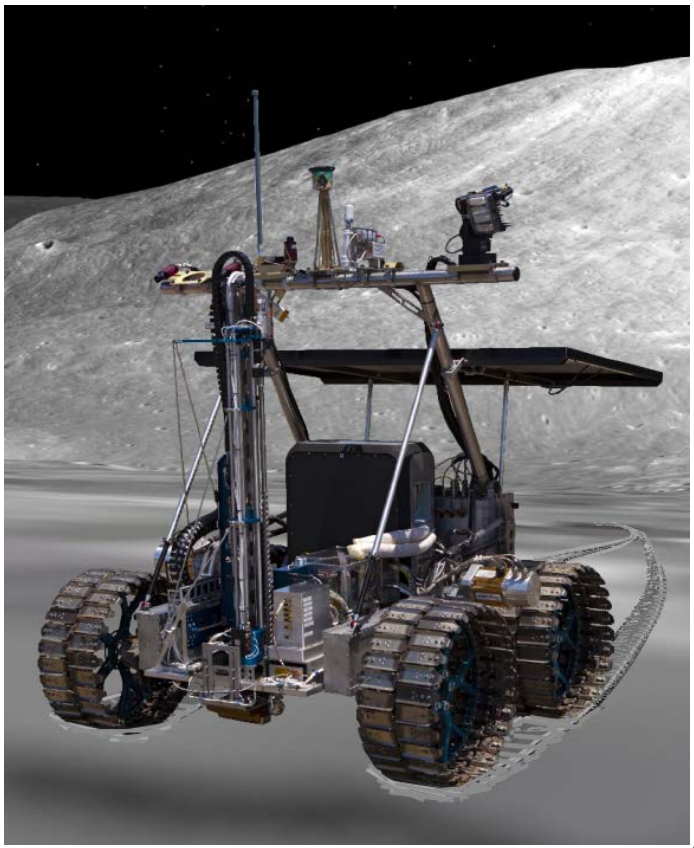
Why Lunar Polar Volatiles?

- **Sustainable, affordable human presence beyond LEO is a long-term goal of the GER**

- **Maintaining that presence may benefit significantly from use of local resources**
  - Limit cost and complexity of bringing all needed supplies from Earth
  - Most promising near-term uses are for life support systems and propellants

- **The Moon has many natural resources**
  - Sunlight
  - Solar Wind
  - High Ca and Al plagioclase
  - High Fe and Ti basalt
  - Pyroclastic deposits
  - Polar Volatiles

- **Polar water ice, a possible 'game changer'**
  - Water production possibly less complex
  - Water storage less complex than cryogenics
  - Measurements indicate a large abundance
  - Other volatiles and ices may also be beneficial
    - H_2S, NH_3, SO_2, C_2H_4, CO_2, CH_3,OH, CH_4, OH



Strategic Issues with Polar Volatile Exploration

- **What do we want to know and how do we find out?**
  - What are the key knowledge gaps, both scientific and resource related, to be answered?
  - What hypotheses can be developed and tested at the lunar surface to answer these questions?
  - What measurements could be applied to help formulate or test these hypotheses and support landing site selection for surface missions?
    - From orbit
    - Mobility
    - Drilling
    - Sample return
    - From the lunar surface
    - Permanently shadowed region (PSR) access
    - Sample analysis
  - What other science questions can be addressed at the poles and how does this affect landing site priority?
  - Which are the most significant regions of interest for making measurements?

Strategic Issues with Polar Volatiles Exploration

ISECG

How can we lower the cost?

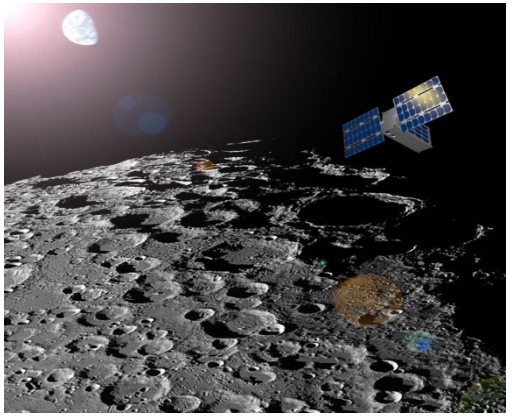
- Are there low cost innovative approaches that could be considered? (e.g. impactors, penetrators, cubesats, S/C end of life uses)
- How can the costs of access to the lunar surface be reduced?
  - Ride share
  - Procuring key mission elements as commercial services
  - Using smallsat and nanosat technologies
  - Utilizing common infrastructure/mission elements (e.g., power generation, thermal protection, communication relays, navigation beacons)
  - Utilizing existing assets from previous missions

How can we coordinate?

- Which is a better coordination approach to making measurements with several surface missions
  - All within a common region of interest?
  - Each to a different region of interest?
- How can common measurements and calibration standards etc. be utilised between missions to allow comparison of results and add value to individual data sets?
- What standards can be applied and what benefits would they bring?
  - Interfaces (e.g. mechanical, electrical, communication)
  - Propellant
  - Interchangeability of vehicle payload complements to maximize interoperability

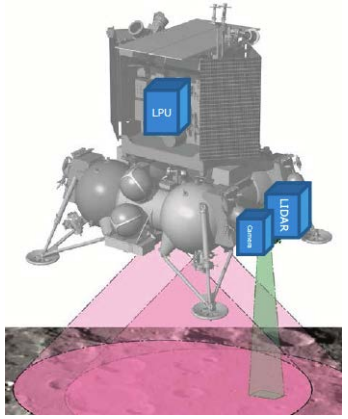
Recent Activities - NASA

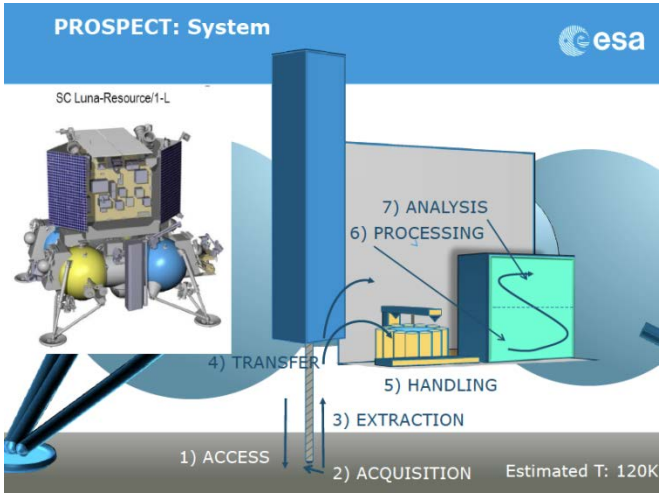
- **Resource Prospector**
  - Advanced Exploration Systems (AES) project
  - Instrumented rover
    - Neutron and Near-IR Spectrometers
    - Gas Chromatograph/Mass Spectrometer
- **Lunar Cubesat Orbital Missions**
  - To be launched on SLS Exploration Mission-1
  - Lunar Flashlight (JPL, MSFC)
    - 4-band point spectrometer
  - Lunar IceCube (Morehead State University)
    - IR spectrometer
  - Lunar Polar Hydrogen Mapper (Arizona State University)
    - 2 neutron spectrometers
- **Lunar CATALYST**
  - Astrobotic Technology
  - Masten Space Systems
  - Moon Express
- **Lunar Exploration Analysis Group (LEAG)**
  - Polar volatiles strategic action team
  - http://www.lpi.usra.edu/leag/reports.shtml

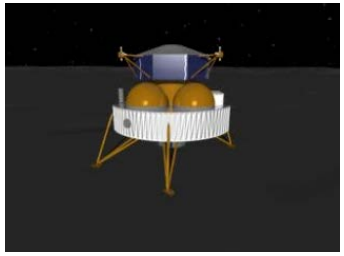


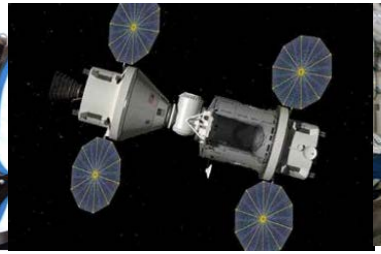
Recent Activities – ESA

- **ESA Collaborations with RSA Luna 27**
  - PILOT
    - Precision landing
    - Hazard avoidance
  - PROSPECT
    - Drilling down to 2 meters
    - Evolved Gas Analyser
- **ESA Human-Enhanced Robotic Architecture and Capability for Lunar Exploration and Science (HERACLES)**
  - Develop exploration technologies and capabilities
  - Perform science to enable human exploration
  - Stimulate economic expansion



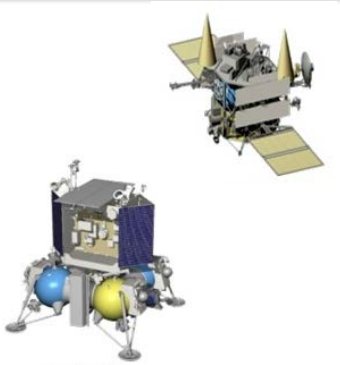


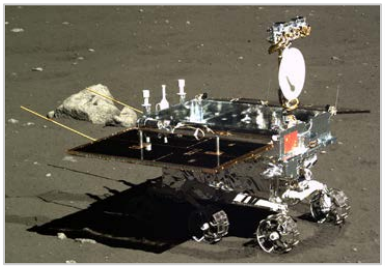


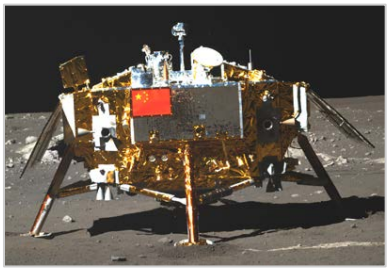


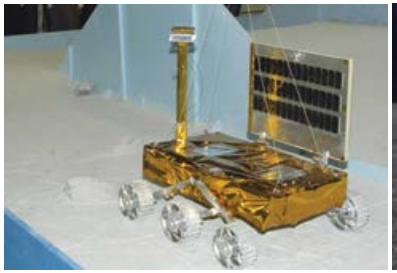
Recent Activities – Other Agencies

- **Russian Space Agency (RSA)**
  - Luna 25 (Luna-Glob) Polar Lander
  - Luna 26 (Luna-Resurs O) Orbiter
  - Luna 27 (Luna-Resurs 1)Polar Lander
- **Japan Aerospace Exploration Agency (JAXA)**
  - SELENE-2 polar lander study
  - Collaborating with NASA Resource Prospector
  - Smart Lander for Investigation Moon (SLIM)
- **China National Space Administration (CNSA)**
  - Chang'e 4 collaborations possible
  - Polar landing (or farside) possible
- **Canadian Space Agency (CSA)**
  - Lunar rovers (in development)
- **Korea Aerospace Research Institute (KARI)**
  - Lunar orbiter, lander, rover (in formulation)
- **Indian Space Research Organization (ISRO)**
  - Chandrayaan-2 (orbiter, lander, rover)





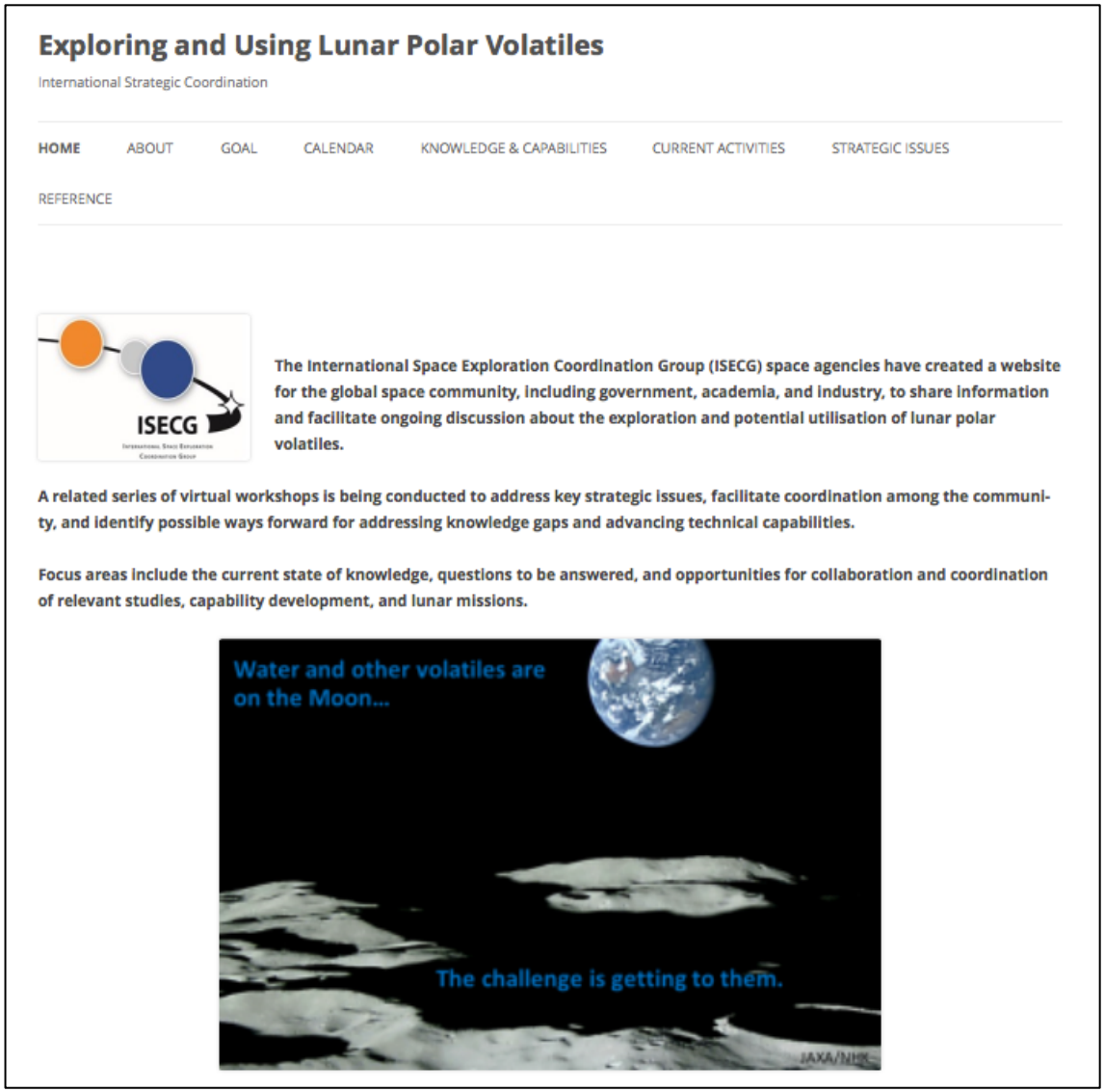




Lunar Polar Volatiles Website

http://lunarvolatiles.nasa.gov

- **Website goes live this Thursday**
- **Will be continually updated and refined**
- **Receptive to community inputs**
- **Send comments/inputs to:**
  - hq-lunar-volatiles@mail.nasa.gov



Lunar Polar Volatiles Virtual Workshops

- **A series of virtual workshops will be hosted by NASA SSERVI**
  - Adobe Connect (instructions on ISECG polar volatiles website)
  - Will be archived

ISECG Lunar Polar Volatiles Virtual Workshop #1:

Topic: Lunar Datasets
Wed, Nov 18, 2015 (0800 EST / 1400 CET / 2200 JST-KST)

Questions:
What remote sensing scientific instruments from lunar orbit or Earth have produced the most beneficial datasets to identify lunar polar volatiles deposits? What are the most promising scientific instruments for use on the lunar surface to refine our understanding of the abundance, distribution, composition, form, and accessibility of lunar polar volatile deposits?

Expected Outcome:
1. A better understanding of the datasets that are available to assess lunar polar volatile deposits.
2. A better understanding of the type of scientific instruments that should be used on lunar surface missions to prospect for lunar polar volatile deposits.
3. Progress in mission planning to address the ISECG lunar cold trap volatiles strategic knowledge gap (SKG).

Panelists:
Mahesh Anand – Chair, ESA Topical Team on Exploitation of Local Planetary Materials
Paul Lucey – Chair, LEAG Polar Volatiles Special Action Team
Igor Mitrofanov – Lunar scientist
Paul Spudis – Lunar scientist

Suggested Advance Reading:
-LEAG Lunar Volatiles Study (Dec 2014)
-European Response to LEAG study (Sep 2015)

Lunar Polar Volatiles Virtual Workshops

ISECG Lunar Polar Volatiles Virtual Workshop #2:

Topic: Where to Explore, and How
Wed, Dec 16, 2015 (0800 EST / 1400 CET / 2200 JST-KST)

Questions:
Based on current knowledge, what are the most promising Regions of Interest for lunar polar volatile resource prospecting? Given the unique polar environment (e.g. extreme temperatures; dynamic, low-angle sunlight and shadows; limited line-of-sight earth-communications, uncertain soil mechanics), how can lunar exploration systems and instrumentation be used to prospect, characterize, acquire, process, and utilize polar volatiles?

Expected Outcome: TBD

Panelists: TBD

ISECG Lunar Polar Volatiles Virtual Workshop #3:

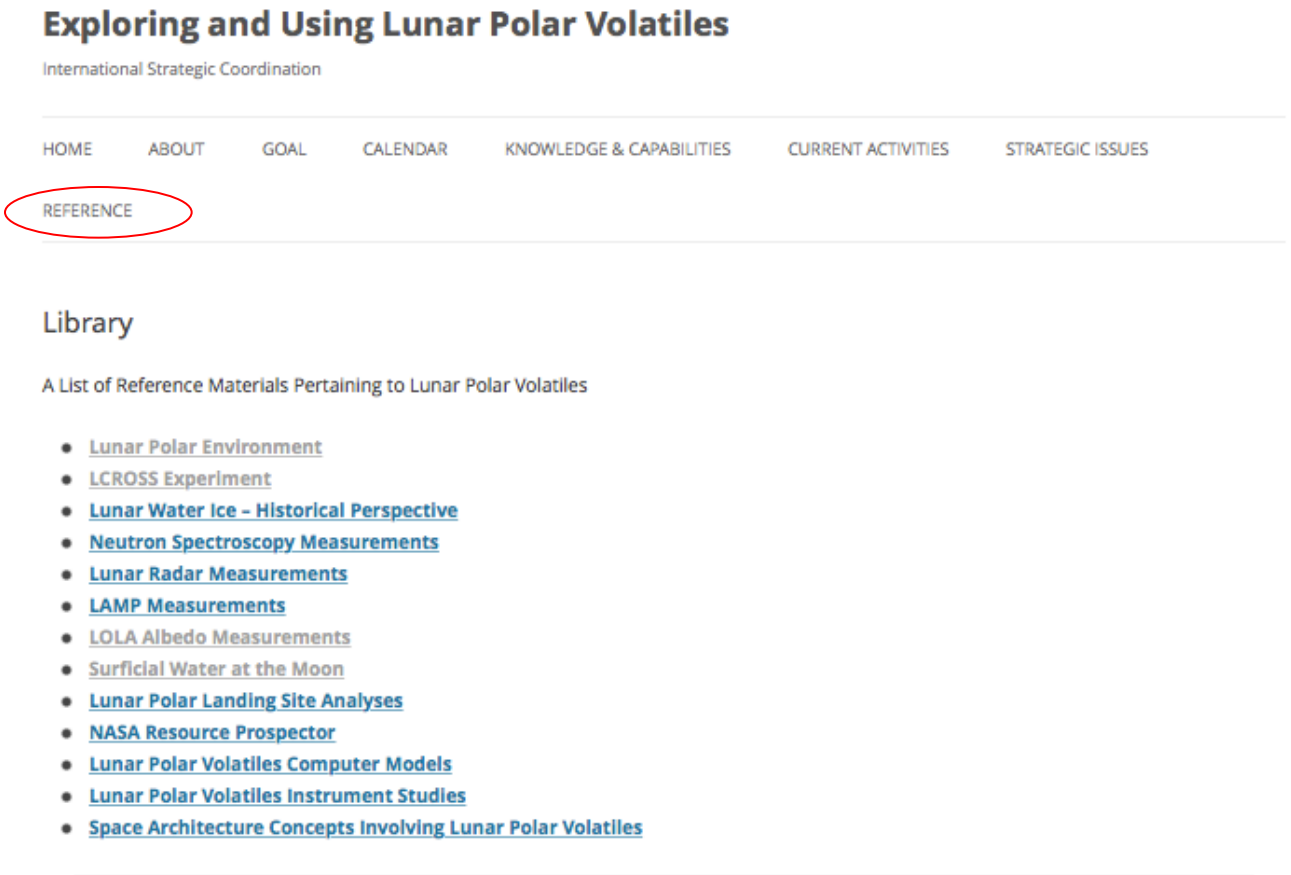
Topic: Maximizing Productivity, Minimizing Cost
Wed, Jan 20, 2016 (0800 EST / 1400 CET / 2200 JST-KST)

Questions:
What novel technologies or innovative operational approaches currently exist that enable productive, efficient polar volatile exploration, and what new ones need to be developed?

Expected Outcome: TBD

Panelists: TBD

Lunar Polar Volatiles Website References



Exploring and Using Lunar Polar Volatiles

International Strategic Coordination

HOME ABOUT GOAL CALENDAR KNOWLEDGE & CAPABILITIES CURRENT ACTIVITIES STRATEGIC ISSUES

REFERENCE

Library

A List of Reference Materials Pertaining to Lunar Polar Volatiles

- Lunar Polar Environment
- LCROSS Experiment
- Lunar Water Ice – Historical Perspective
- Neutron Spectroscopy Measurements
- Lunar Radar Measurements
- LAMP Measurements
- LOLA Albedo Measurements
- Surficial Water at the Moon
- Lunar Polar Landing Site Analyses
- NASA Resource Prospector
- Lunar Polar Volatiles Computer Models
- Lunar Polar Volatiles Instrument Studies
- Space Architecture Concepts Involving Lunar Polar Volatiles

Lunar Polar Environment

Bussey et al. (1999) Illumination conditions at the lunar south pole. Geophys Res Lett 26:1187-1190.
http://onlinelibrary.wiley.com/doi/10.1029/1999GL900213/full

Mazarico et al. (2011) Illumination conditions of the lunar polar regions using LOLA topography. Icarus 211:1066-1081.
http://www.sciencedirect.com/science/article/pii/S0019103510004203

The Lunar Polar Regions Today