EXPLORATION FOR LUNAR POLAR VOLATILES: CONSIDERATIONS AND RECOMMENDATIONS*

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*Based on the report prepared for ESA under the umbrella of the Topical Team on Exploitation of Local Planetary Materials (TT-ELPM)

Building on the work of the Report of the LEAG Volatiles Specific Action Team, December 2014

- Review the unique environments at lunar poles and especially the likely presence of polar volatiles
- Considered the exploration of lunar polar volatiles through landers, rovers and sample return
- Consider possibility of additional (non-volatile) science opportunities of lunar polar exploration
- Charged by ESA with identifying emerging opportunities and recommendations in an European context

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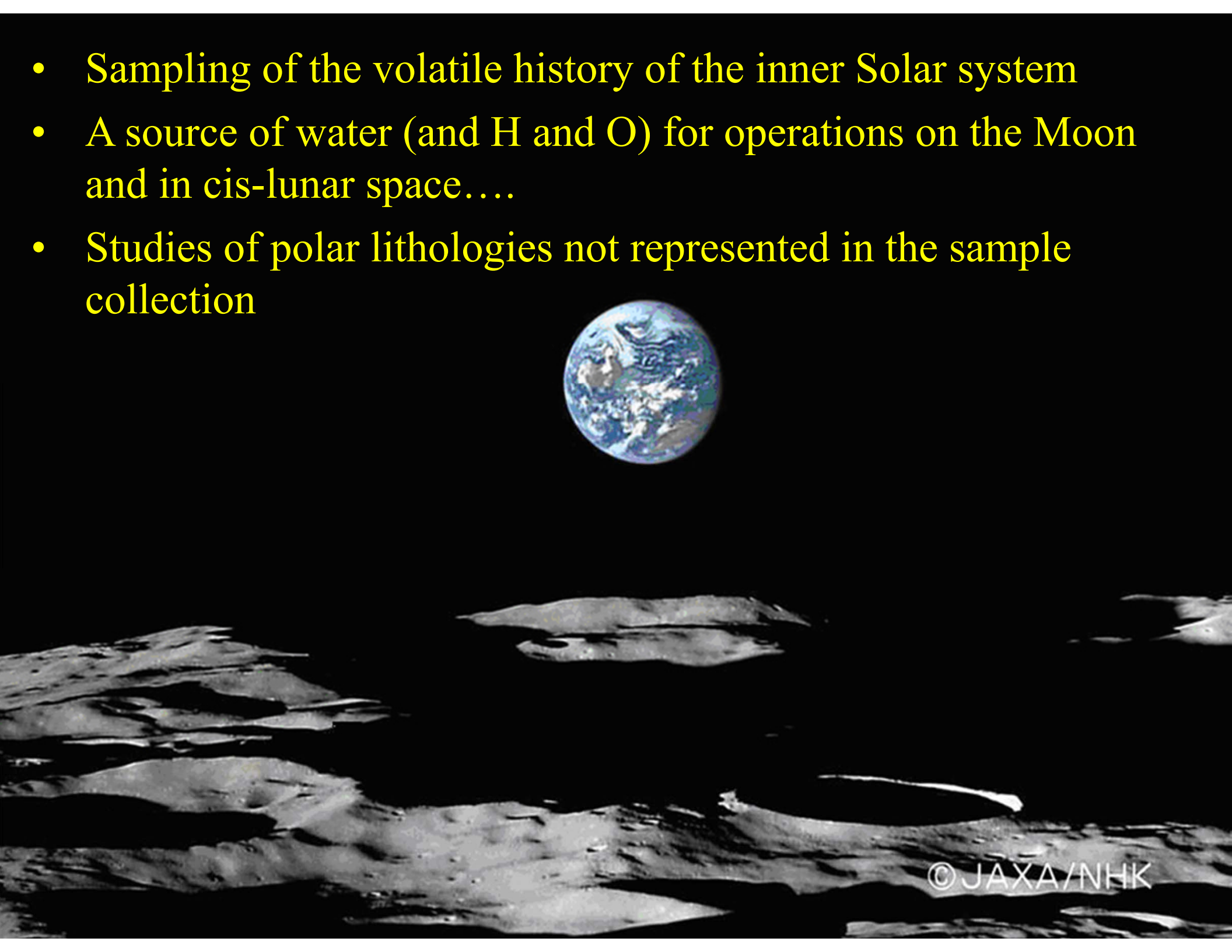
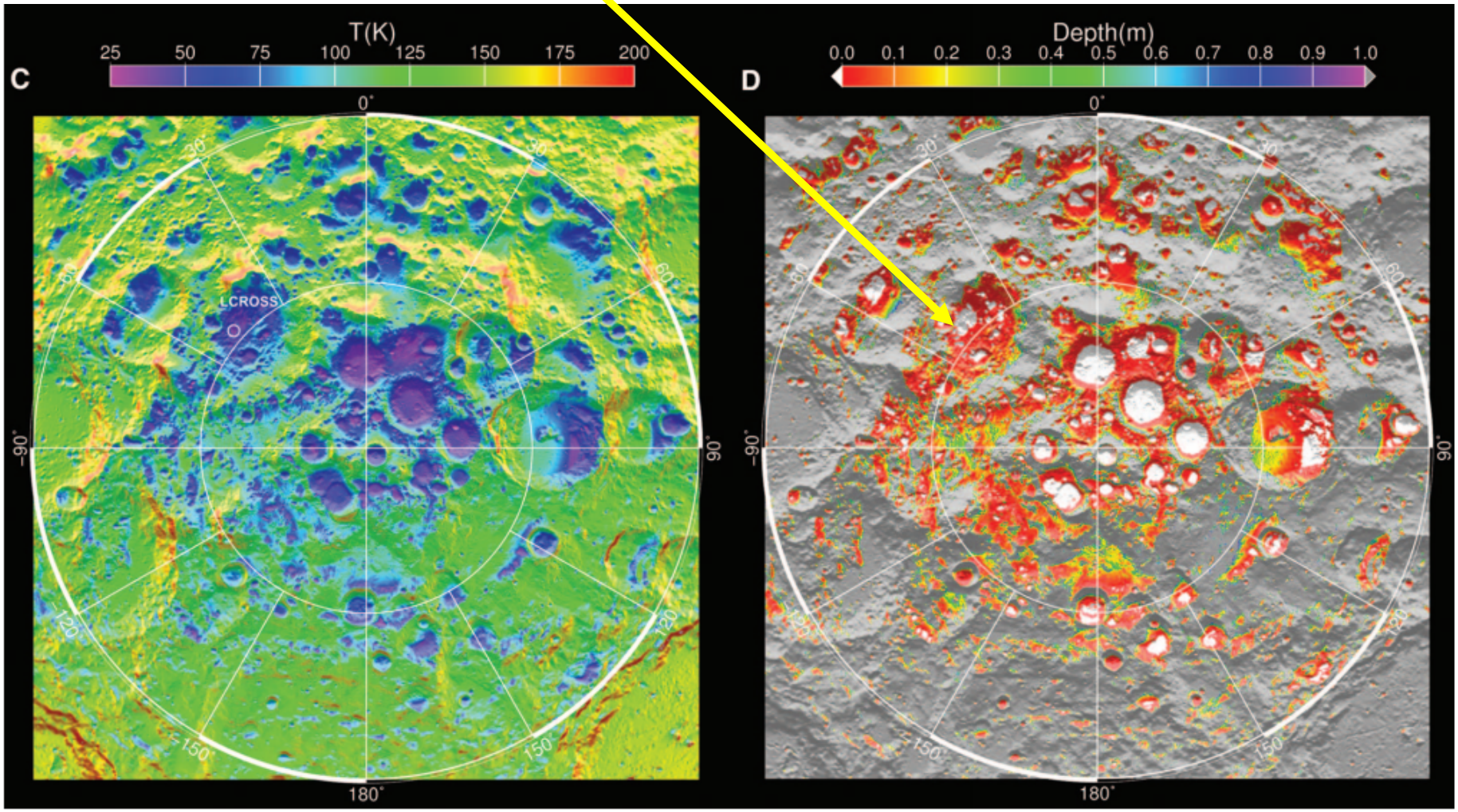
- Sampling of the volatile history of the inner Solar system
- A source of water (and H and O) for operations on the Moon and in cis-lunar space….
- Studies of polar lithologies not represented in the sample collection



Unique environments at lunar poles

LCROSS: 5.6 ± 2.9 wt% (Colaprete et al. 2010)
(90 kg m^{-3})



Images from Paige *et al.*, *Science*, 330, 479, 2010.

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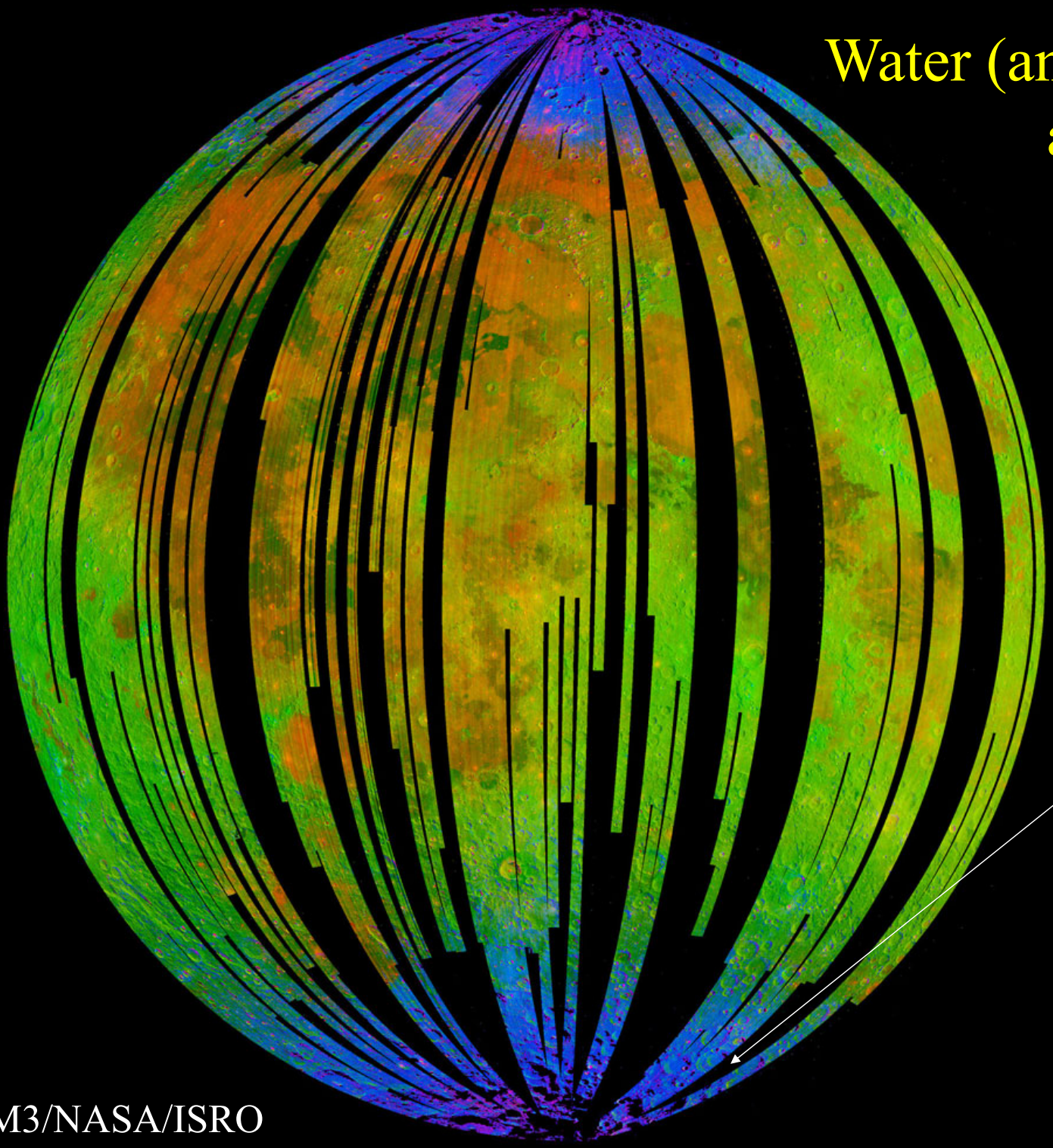


Water (and other volatiles) at high latitudes ?

C. Pieters et al., Science, **326**, 568 (2009).

3μm absorption band: surficial OH, H_2O ≤800 ppm (≤1.3 kg m^{-3}). Vertical extent TBD

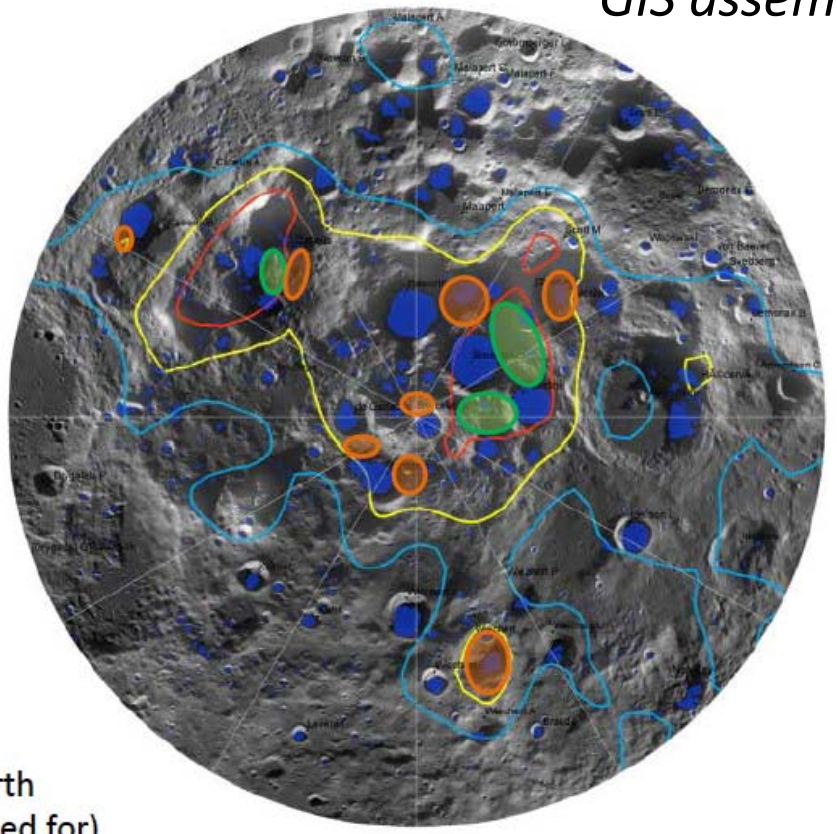
M3/NASA/ISRO

South Polar potential ROI

GIS assembled by Jessica Flahaut

ROI with **H>150**, slope<10 and avg. T<110

ROI with **150>H>125**, slope<10 and avg. T<110



(illumination and Earth visibility not accounted for)

WAC mosaic

<u>Additional step:</u>
Looking for potential sites that are close to (but not necessarily meeting) the VSAT threshold values but could be of higher scientific interest because of potential additional science.

- Between 80° and 90° latitude:
- 3 areas with H > 150 ppm
- 1 of these areas has avg. T > 110 K.
- Removing direct Earth communication/illumination constraints doesn't increase number of potential ROI.
- Reducing H to > 125 ppm increases number of potential ROI

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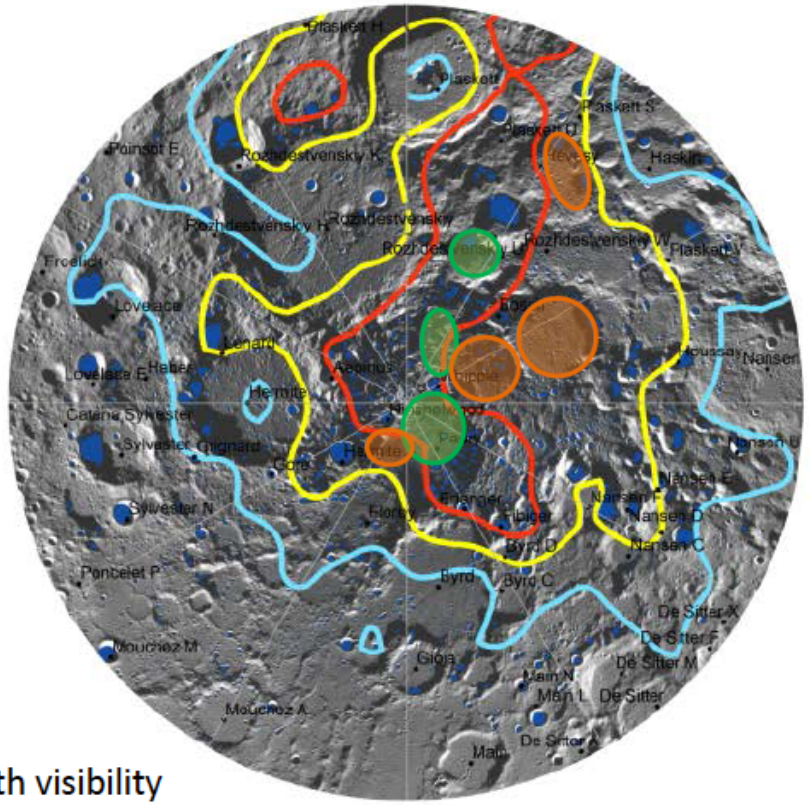
North Polar Potential ROI

GIS assembled by Jessica Flahaut

ROI with **H>150,** slope<10 and avg. T<110

ROI with **150>H>125,** slope<10 and avg. T<110



(illumination and Earth visibility are not accounted for)

WAC mosaic

<u>Additional step:</u>
Looking for potential sites where H-rich pockets exist below 80 deg. Latitude (e.g., Rozhdestvenskiy K crater, Plaskett crater, whose N wall is associated with a Kaguya pure anorthosite detection).

- Between 80° and 90° latitude:
- 3 areas with H > 150 ppm; in the VSAT report, 1 area was discarded and the other significantly reduced because of direct Earth communication/illumination constraints
- Lowering H to > 125 ppm or discarding the direct Earth communication criteria significantly increases the number of potential ROI
- High H abundance areas extents below 80° in latitude

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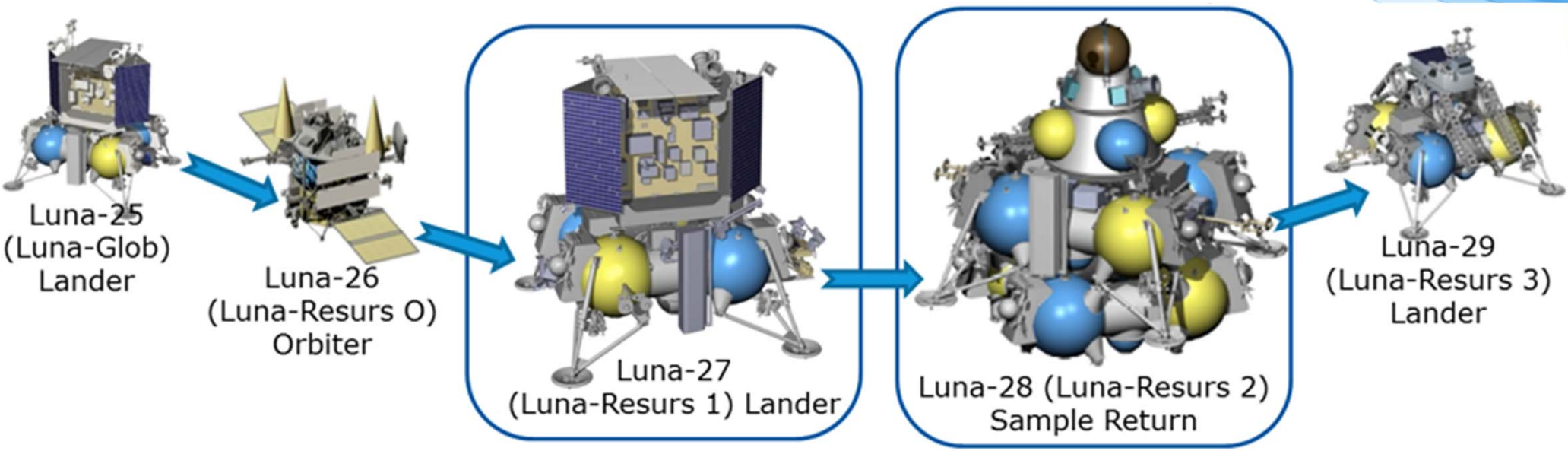
Emerging opportunities: the ESA/Roscosmos Cooperation



- Preparatory collaborative programme between ESA and Roscosmos.
- ESA planning to contribute PROSPECT and PILOT package (on Luna 27) - approved for Phase B in December 2014.
- Next mission in Russia's proposed sequence is for polar sample return (Luna 28).
- Sample return is mid-2020s but planning is at an early stage.
- Pre-phase A studies are happening for ESA contributions via European industry.

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Findings and Recommendations

- Concur with VSAT finding that existing orbital data are sufficient to support near term landings in lunar polar regions. However, significant uncertainties remain with regarding to the distribution of volatiles at the 10 to 100 m scales.

- Rover-enabled mobility (several 10s of m to several km) is key to assess inhomogeneous volatile distribution.

- Drilling (ideally >1m) required to assess vertical volatile distribution. But drill (or scoop) should be able to sample the uppermost cm or so.

- Additional work be carried out regarding landing sites taking into account an enlarged set of parameters (larger than the set used in the VSAT report, and including an assessment of measurements within PSRs).

- Important to measure the isotopic composition of volatile elements, both with respect to fundamental volatile science (e.g. origins) and with respect to assessing quantitatively potential landing-induced contamination of the surface materials.

- For landed experiments, several additional physical measurements--such as compositional variation and soil geotechnical and thermal properties would greatly improve the understanding of polar volatiles; obtaining any of the needed quantities would benefit subsequent missions.

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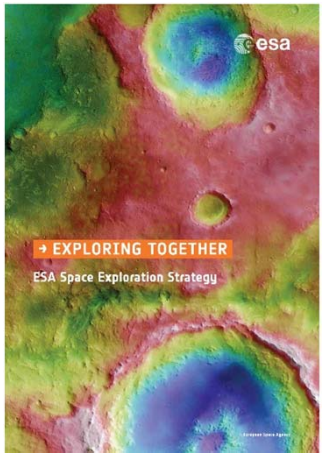
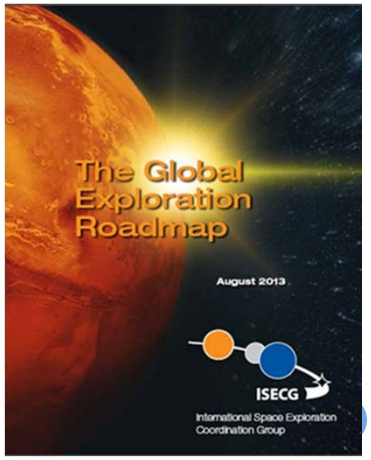
Recommendations (continued)

- Carefully targeted impact experiments (e.g. LCROSS-impact) should be encouraged, but we need to be aware of future contamination issues.
- High-angle impactors are especially valuable We recommend a lunar impact be considered as a disposal option in end of mission life scenarios for spacecraft on appropriate orbits (the decision by ESA not to impact Herschel into a PSR was a lost opportunity).
- Multiple small probes (nanosats, penetrators, etc) could make important contributions.
- ESA Lunar Exploration programme in collaboration with Russia/Roscosmos presents an excellent opportunity to explore lunar polar volatile deposits. These will lead to exceptional science return: addressing key questions on the source(s) of volatiles in the Earth-Moon system and in quantifying potential resources.
- Forms a key part of ESA's Exploration strategy and is fully consistent with the aims and objectives of the GER.





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