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A 'European response' to the recent Lunar Exploration and Analysis Group (LEAG) Volatiles Specific Action Team (VSAT) report on lunar volatiles – A report of advisory team under the umbrella of the ESA's Topical Team on Exploitation of Local Planetary Materials (TT-ELPM)

Meeting venue and date: VU University Amsterdam, April 23-24 2015

Attendees: Mahesh Anand (chair), Sebastien Besse (ESA), Neil Bowles (University of Oxford – via Skype), Ian Crawford (Birkbeck), Jessica Flahaut (VU University Amsterdam), Nicola Potts (Open University), Wim van Westrenen (VU University Amsterdam) and James Carpenter (ESA). Clive Neal (LEAG representative - via Skype).

Not present but part of advisory team: Marc Chaussidon (IPGP), Vincent Eke (Durham University), Harry Heisinger (Munster), Ralf Jaumann (DLR), Katherine Joy (University of Manchester), Zita Martins (Imperial College London)

Executive summary

This report should be read in conjunction with the LEAG VSAT report, as for sake of brevity not all findings of mutual agreement have been explicitly highlighted in this report. Overall the 'European' team concluded that it agrees with substantial parts of the LEAG VSAT report. However, the team has several additional comments/suggestions especially in the context of European interests and recent initiatives in lunar exploration (e.g. ESA-Roscosmos plans for a series of collaborative lunar missions).

Motivation:

This report was requested by ESA to support their discussions on an international lunar volatile strategy in the context of ISECG as well as ESA activities including cooperation with Russia on Luna-27 and Lunar Polar Sample Return (LPSR) missions.

In the following pages text in red font indicates excerpts from accompanying VSAT report that have been used as basis for our recommendations.

Introduction

VSAT – ….three lunar polar areas of significant extent that fulfill the VSAT charter to identify regions "where NASA and international / commercial partners could operate on the lunar surface in a cooperative manner to further understand the size, distribution, form, and resource potential of deposits of water ice and other volatiles."

We agree, but our recommendation is that additional work be carried out regarding landing sites taking into account an additional enlarged set of parameters (larger than the set used in the VSAT report). The VSAT report uses a relatively narrow set of constraints which in the context of polar volatile exploration could be expanded in our view. For example, the report did not consider landing in a PSR, nor did it incorporate sites that are partially shaded outside of PSR. In appendix one, we provide an initial additional study led by advisory team members Jessica Flahaut and Nicci Potts that illustrates some areas of interest that were not included in the VSAT report, but that could be of interest if an enlarged set of parameters is considered. Most notably, decreasing the H content threshold to >125 ppm increases the number of available sites in both the North and South Pole regions. Relaxing the direct-to-Earth and illumination constraints also results in a higher number of potential sites (including farside locations) in the North Pole region.

VSAT - These three areas, two near the south pole and one near the north pole, have combinations of hydrogen abundance and other relevant parameters that make them attractive candidates for detailed mission studies.

We recommend that these three sites and any additional promising locations are given due consideration for their science returns in terms of lunar science in addition to the volatiles aspect (especially exploring in detail the science questions that could be addressed by targeting northern polar sites).

VSAT - This finding is based on our conclusion that existing orbital data are sufficient to support near term landings.

The accuracy of this statement depends heavily on the aims and objectives of specific polar missions.

VSAT - However, significant uncertainties remain with regards to the distribution of volatiles at the 10 to 100m scales accessible to near-term missions.

This is an important point. However, because no landing missions to the poles have ever been undertaken, these uncertainties are not show stoppers.

Data and models are clear that volatiles are distributed unevenly at this scale and mission success scenarios should accommodate this likelihood.

We fully agree and this should be the starting point when designing any exploration mission for lunar polar volatiles.

We also found that a range of new orbital missions and science support activities could reduce this risk by improving both the empirical data upon which site selections are based upon, and the scientific understanding of polar volatile evolution. Regarding landed experiments, there are several key measurements--such as compositional variation and soil geotechnical and thermal properties--within the capabilities of small near-term missions that would greatly improve the understanding of polar volatiles; obtaining any of the needed quantities would benefit subsequent missions.

We fully agree with these statements.

From here on in this report, each heading corresponds to the one used in the accompanying VSAT report. Only a subset of headings from the VSAT report is covered underneath as in these cases we have some disagreements and/or have a European perspective.

Orbital Measurements Finding #1:

We agree that sufficient data are available to say that there are widespread areas of surface H content > 150 ppm. But given current knowledge and the uncertainties in abundance and heterogeneity there is no guarantee that a stationary lander will be able to sample a high-H reservoir. We recommend that future mission scenarios consider adding a mobility element, or target measurements (from orbit or using multiple landers targeting multiple locations) that tell us more about the required mobility. In addition, more modelling is required to assess (using an approach similar to Paige et al. 2010, for example) to assess preservation of ice/volatiles over a timescale of ~500 million years focusing on the effect of surface temperature.

Question for Clive: did LCROSS measure more or less H than expected from orbital measurements?

Yes, LCROSS measured more water than indicated by H abundance data (Paul Lucey, FOLV)

Orbital Measurements Finding #2:

We recommend that better mapping of hydrogen is required for both polar regions, in general, not just restricted to PSR. There are areas outside PSR that are at least as interesting scientifically as the PSR themselves. The 5 km scale seems to be linked to a specific mission idea that we could not judge. No, there was no specific mission idea. Paul Lucey (FOLV)

Orbital Measurements Finding #3:

We would reformulate this finding to state that orbital measurements cannot be made with the spatial resolution required to see the level of heterogeneity suggested by models of ice/hydrogen mobility. In other words a pathfinder landed mission, including preferably a mobile element (rover), is required to address spatial variations in the distribution of volatiles in lunar polar regions.

Orbital Measurements Finding #5:

We suggest rewording to state ‘impact experiments (e.g. LCROSS-impact) should be encouraged’, i.e. carefully planned impact experiments and not necessarily focussing on end-of-mission impacts that were not specifically planned. However, we anticipate two considerations that might be of interest to the wider community – fear of littering the Moon and fear of contaminating the source region of a future sample return mission.

However, we recommend that in certain scenarios the orbital trajectory of potential impactors may present a unique opportunity [e.g. Herschel]. In future missions with a suitable orbit we recommend a lunar impact stage is included in end of mission scenarios. In addition, which orbiter(s) are likely to be available at the end of mission could help considerations, as there will likely not be a companion spacecraft to make measurements of an impact plume.

Several small platforms / impactors could be very important as well but were not mentioned in the LEAG report.

Orbital Measurements Finding #7:

Apart from diurnal variations we should also consider longer timescales, but these require landed missions (multiple measurements, depth profiling etc).

Landed Measurements Finding #1:

We recommend adding a fourth item to the list: 'Mobility of volatiles and associated timescale(s)'

Landed Measurements Finding #2:

A rover traverse of several hundred meters to several kilometres is required. The minimum distance for ground truthing is 20 km. Minimum distance to confirm if there are volatiles present is likely to be ~1 km.

Landed Measurements Finding #3:

We would add the necessity of measuring the isotopic composition of volatile elements here. Both with respect to fundamental volatile science and with respect to assessing quantitatively potential landing-induced contamination of the surface materials.

Landed Measurements Finding #4:

Physical and thermal properties of polar regolith should be measured. The potential effect of some volatile compounds such as Hg and Na on instrument degradation should be quantified. It is not clear if that assessment has already been made.

Landed Measurements Finding #5:

This finding is really specific to PSRs, and some of the constraints could be somewhat relaxed if additional polar landing sites are considered. The team perceives that perhaps targeting PSR should be part of subsequent, not initial, missions focused on volatiles.

Landed Measurements Finding #6:

Recommend rewording to state that polar missions could benefit from persistent light. Alternative power sources (e.g. nuclear power source) could be considered for accessing PSRs.

Landed Measurements Finding #7:

We believe that there is a very strong case to be made for rover missions (see above).

Landed Measurements Finding #8:

We would like to stress that we consider these measurements ancillary – they are not show stoppers if they don't happen.

Regions of interest:

Seems to be biased towards US view – no landing in PSR considered, no partially shaded regions considered. We recommend developing European input to scientific value of different landing sites to compare/contrast with options presented in the VSAT report (Cabeus/Shoemaker/Peary). What would be regions of highest interest for polar volatiles? VSAT was necessarily relatively restricted given their remit but we should look beyond those constraints. As detailed in Appendix 1, we started a small activity to look at this.

Region of interest: Finding #2 is really essential, this is a top-level point and should be pushed forward in our assessment.

Compatibility of platforms with priority measurements matrix:

We recommend the following additions/modifications to the existing matrix shown on the final slide of the VSAT report:

- Tweak first row to state variability of LOCAL volatile distribution
- Surface sampling: should be 0-1 cm depth
- Chemical phase x static lander with drill (2,2) should be yellow
- Add a row: which volatiles are present? C-H-N-O-S
- Add another row: what is the chemical **form** of those volatiles (e.g. CH_4 or CO_2)
- Add another row: isotopic composition of these volatiles
- Add column on multiple small impactors/penetrators.

Original pointers from James (ESA):

(a) Do we endorse the LEAG report findings? - Yes

(b) Do we have additional comments? – Yes (see above)

(c) What are the key unknowns that need to be answered with regard to polar volatiles for both science and exploration? (see above)

(d) What hypotheses can be tested at the lunar surface to increase our understanding with respect to these unknowns? (covered)

(e) What are the highest priority measurements to be made from orbit and in-situ? (covered)

(f) Where are the most important locations to make these measurements? (covered)

(g) What approaches could be taken to make those measurements? (see above)

(h) What are the potential roles of: impactors, penetrators, stationary landers and rovers inside and outside of PSRs? (see above)