Volatile Characterisation Instrumentation for ISRU applications

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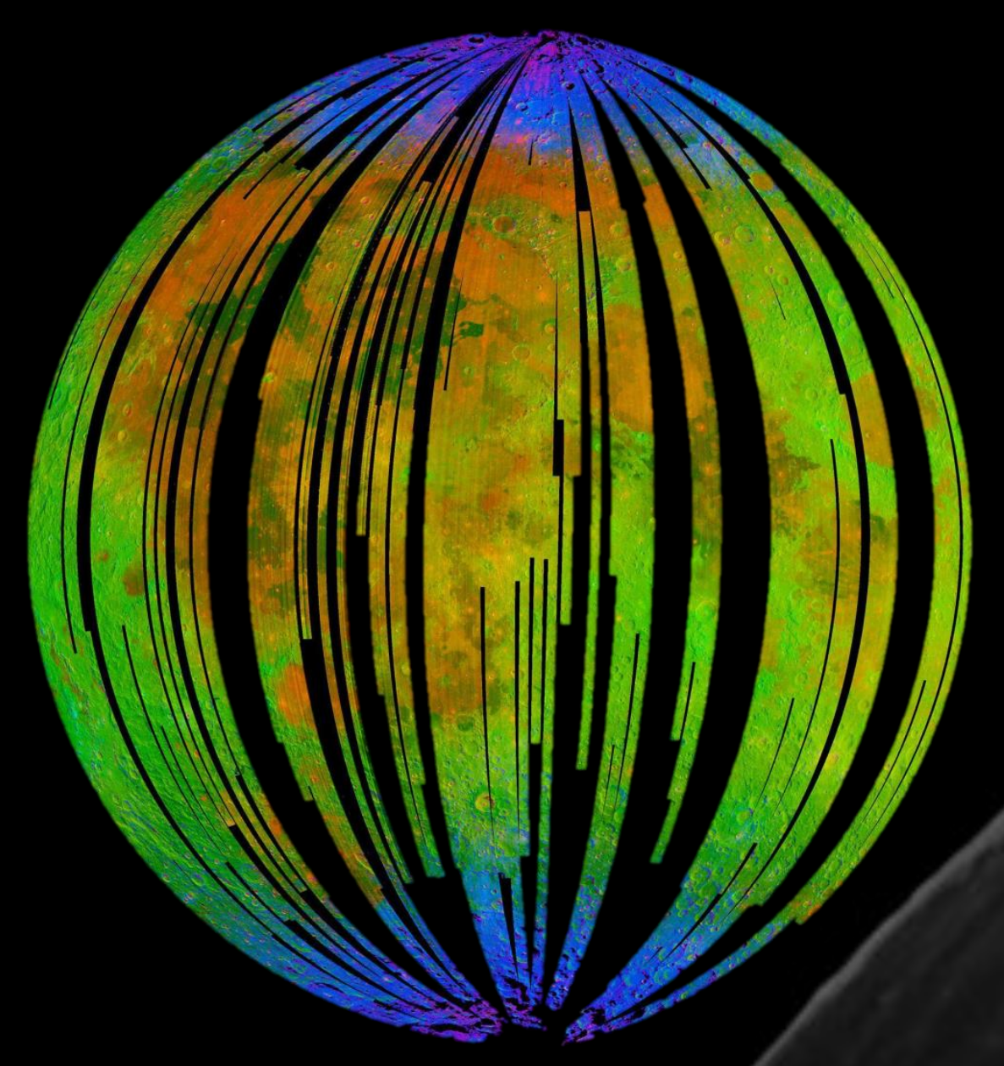
Volatile Characterisation instrumentation for ISRU applications

S. Sheridan[1] (simon.sheridan@open.ac.uk), A. D. Morse[1], S. J. Barber[1], Schwanethal[1] J. Biswas[2], P. Reiss[2], S., M. Reganaz[3], L. Richter[3]

[1]*The Open University, Milton Keynes, UK,* [2]Institute of Astronautics, Technical University of Munich, Germany. [3]OHB System AG, Germany.

1. Lunar volatiles

Recent years have seen a growing interest in lunar exploration, with most international space agencies planning to return humans to the surface of the Moon, and to establish a long-term presence. In Situ Resource Utilisation (ISRU) offers the opportunity to make use of locally available resources and to potentially reduce the costs associated with transporting materials such as water, hydrogen and oxygen to the lunar surface. The polar regions of the Moon have long been known to be possible traps for solar system volatiles due to the low temperature of permanently shadowed areas [1,2]. Recent remote sensing missions have established the presence of volatiles (including water) at the surface and shallow sub-surface at these Polar Regions making them targets for in-situ missions to determine their ground-truth volatile inventory.



Credit: M^3 / NASA / ISRO

Figure 1. False colour rendition of the global mineralogical observations conducted by M^3.

2. The LUVMI Rover platform

The Lunar Exploration Analysis Group (LEAG) Volatiles Specific Action Team (VSAT) findings state that there are enough uncertainties in the distribution of lunar volatiles from remote sensing techniques to imply that a non-mobile lander faces a significant risk of not finding volatiles or of "single data point" non-representative discoveries. To address the need for mobility, the Lunar Volatiles Mobile Instrumentation (LUVMI) [3,4] was developed (Figure 2).

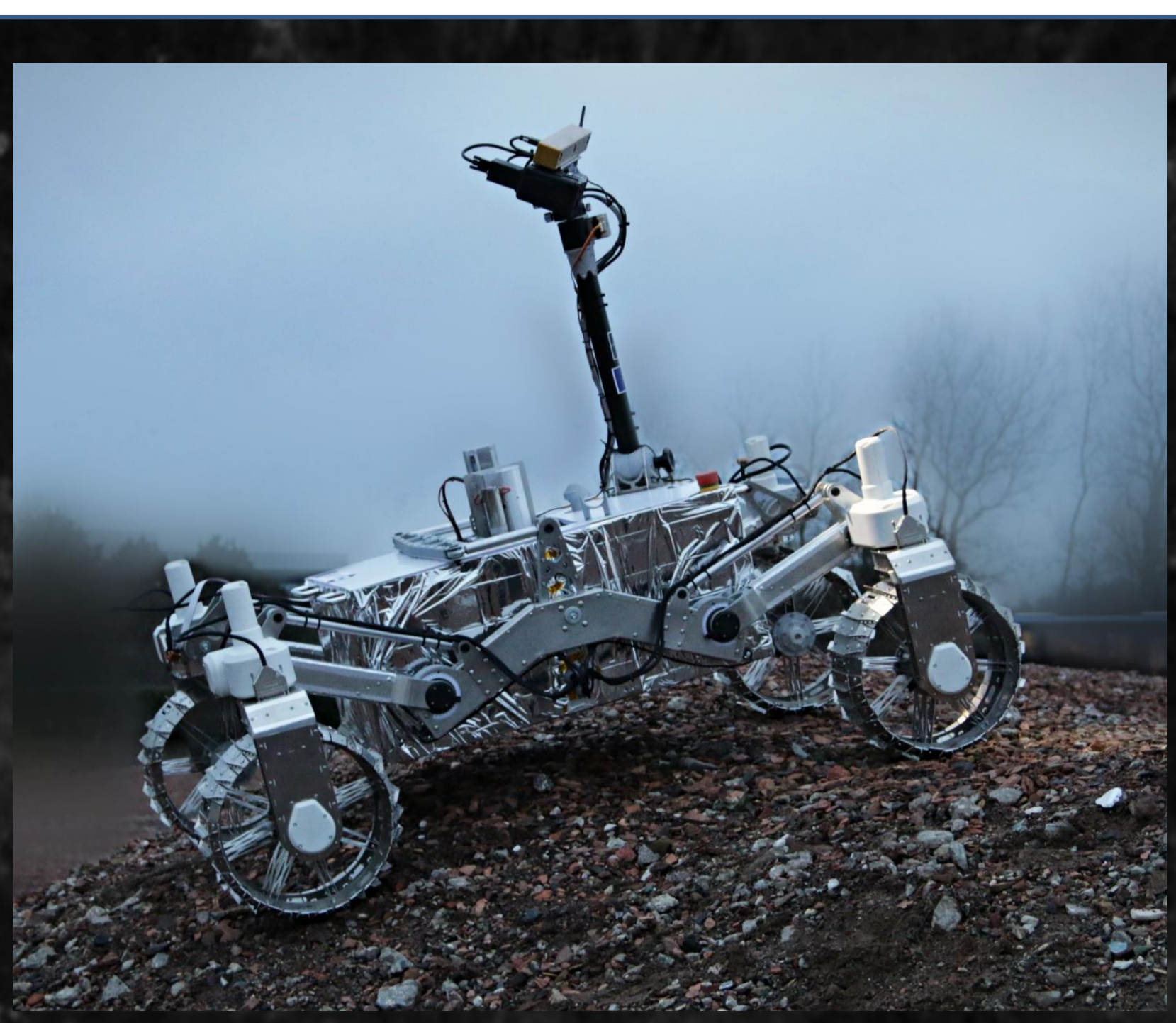


Figure 2. The LUVMI prototype rover during testing in December 2018

3. LUVMI Volatile extraction & characterisation

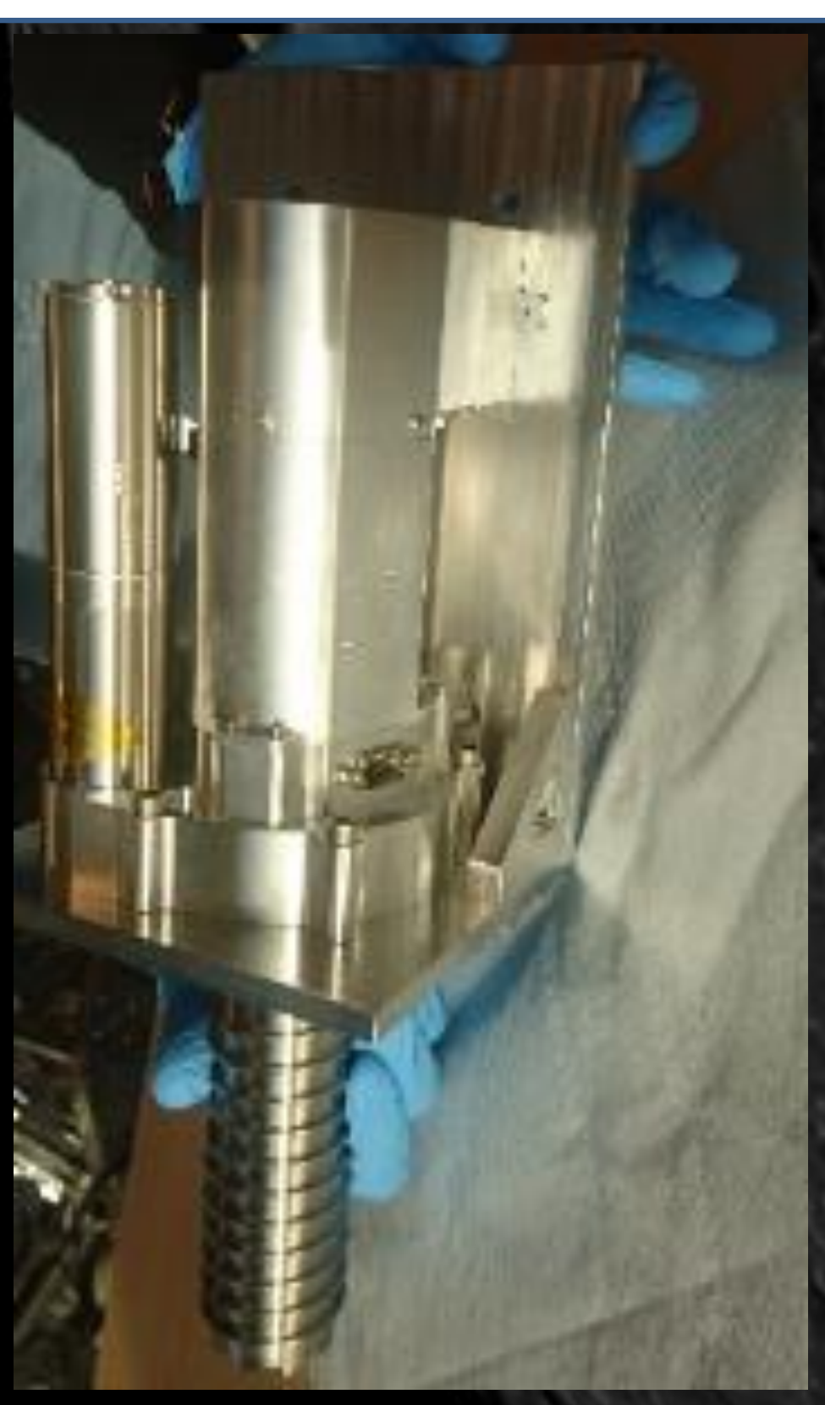


Figure 2. integrated VS & VA

The key LUVMI science package, comprising of the Volatiles Sampler (VS) and the Volatiles Analyser (VA) (Figure 3) was developed to address the current un-answered questions of what volatiles are present and the distribution on (and below) the lunar surface.

Extraction of Volatiles: The VS consists of a hollow rotating drill shell and heating rod to penetrate approximately 10 cm into the lunar regolith. A central heating rod heats regolith inside the drill shell to release bound volatiles.

Volatiles Analyser: The VA is an ion trap mass spectrometer based upon the Ptolemy [5,6] flight-proven instrument (Figure 2)

4. VA Mass Spectrometer Heritage

The Ptolemy Ion Trap Mass Spectrometer (ITMS) shown in Figure 4(a), returned the first in-situ volatile measurements from the surface of a comet in 2014. The Ptolemy ITMS is a mechanically simple structure that consists of a set of 3 electrodes to which a Radio Frequency (RF) field is applied such that ions may be trapped in stable orbits within the internal cavity. Manipulation of the RF field allows ions to be ejected in a controlled manner to generate a mass spectrum (Figure 4(b))

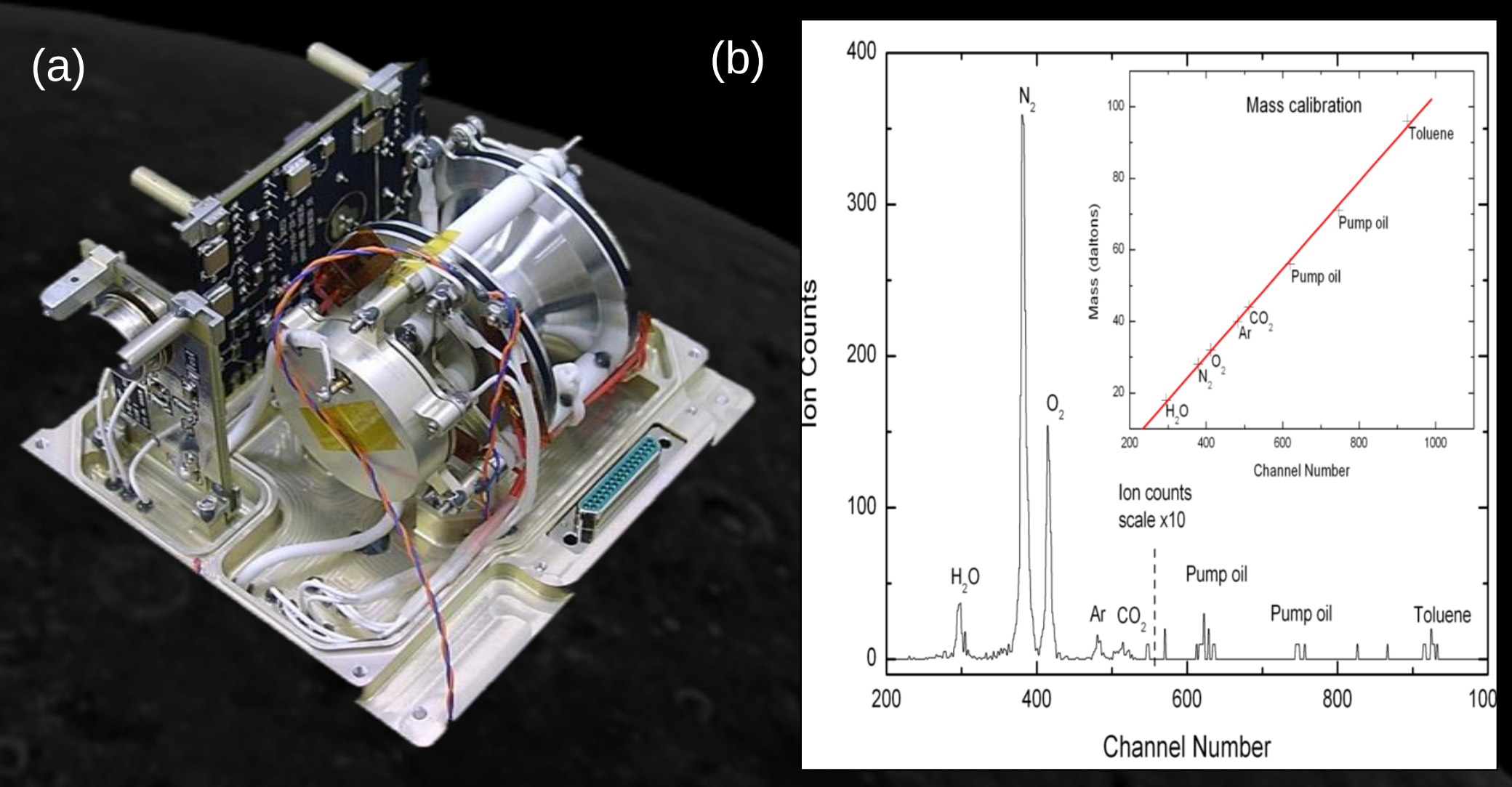


Figure 4 (a) The Ptolemy Ion Trap Mass Spectrometer instrument (b) typical mass spectra

5. The prototype VA ITMS MS

The prototype VA Mass Spectrometer that was developed during the LUVMI project is shown in Figure 5. This is a low mass, compact and mechanically simple device capable of rapid detection of masses in the range of 10 to 220 *m/z*,.

ISRU applications: capable of process control and product characterisation in the ISRU processing chain. Allows characterisation of ISRU feed-stock through detection of volatiles, including water that may be released during regolith heating and handling

Figure 5. LUVMI prototype VA mass spectrometer

6. The LUVMI-X miniature magnetic sector MS

In addition to the VA ITMS a miniature magnetic sector mass spectrometer is under development as part of the LUVMI-X follow on project. This instrument will be housed in a 1U volume and has a mass resolution that is sufficient to separate peaks for water as well as allowing measurement of hydrogen and its isotopes. Figure 6 shows a CAD model of the instrument. The miniature mass spectrometer Is capable of the following:

- process control - monitoring specific molecules of interest in an ISRU system
- prospecting for water and
- Measuring the hydrogen isotopic composition

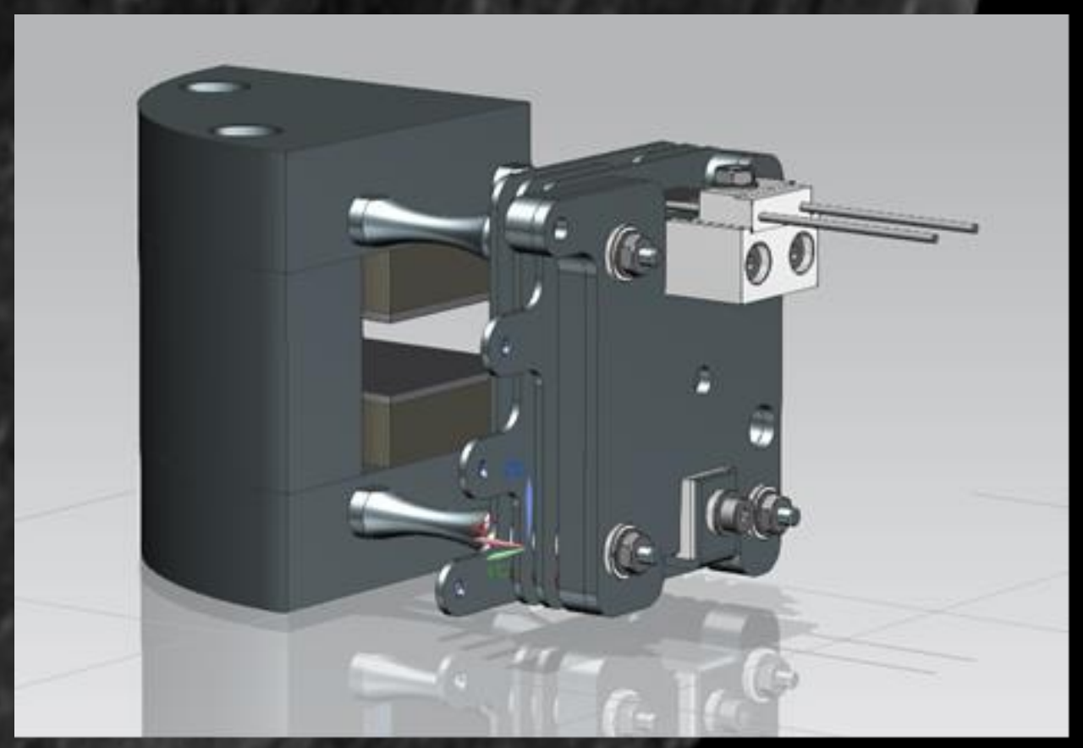


Figure 6. CAD model of the LUVMI-X miniature magnetic mass spectrometer

7. Results and summary

Results: Laboratory based analysis has demonstrated the ability of the VA ITMS instrument to characterise released volatiles from hydrated samples. A calibration using PFTBA is shown in (figure 6 (a) and (b)) demonstrating the ability to provide measurement over a mass range of of m/z 10 to 200.

The miniaturised magnetic sector mass spectrometer that fits within a 1U volume has been designed and modelled with SIMION, shown in figure 6 (c) and (d).

Summary: The VA results demonstrate mass range of m/z 10 to 220 and offers the opportunity to be a high TRL addition to future ISRU demonstration plant for real-time process monitoring of released or generated gases. In addition, a low mass, high sensitivity 1U sized magnetic sector mass spectrometer offers the ability to perform in-situ ground truth DH measurements on liberated volatiles. Work will continue for the next 2.5 years under a new LUVMI-X grant

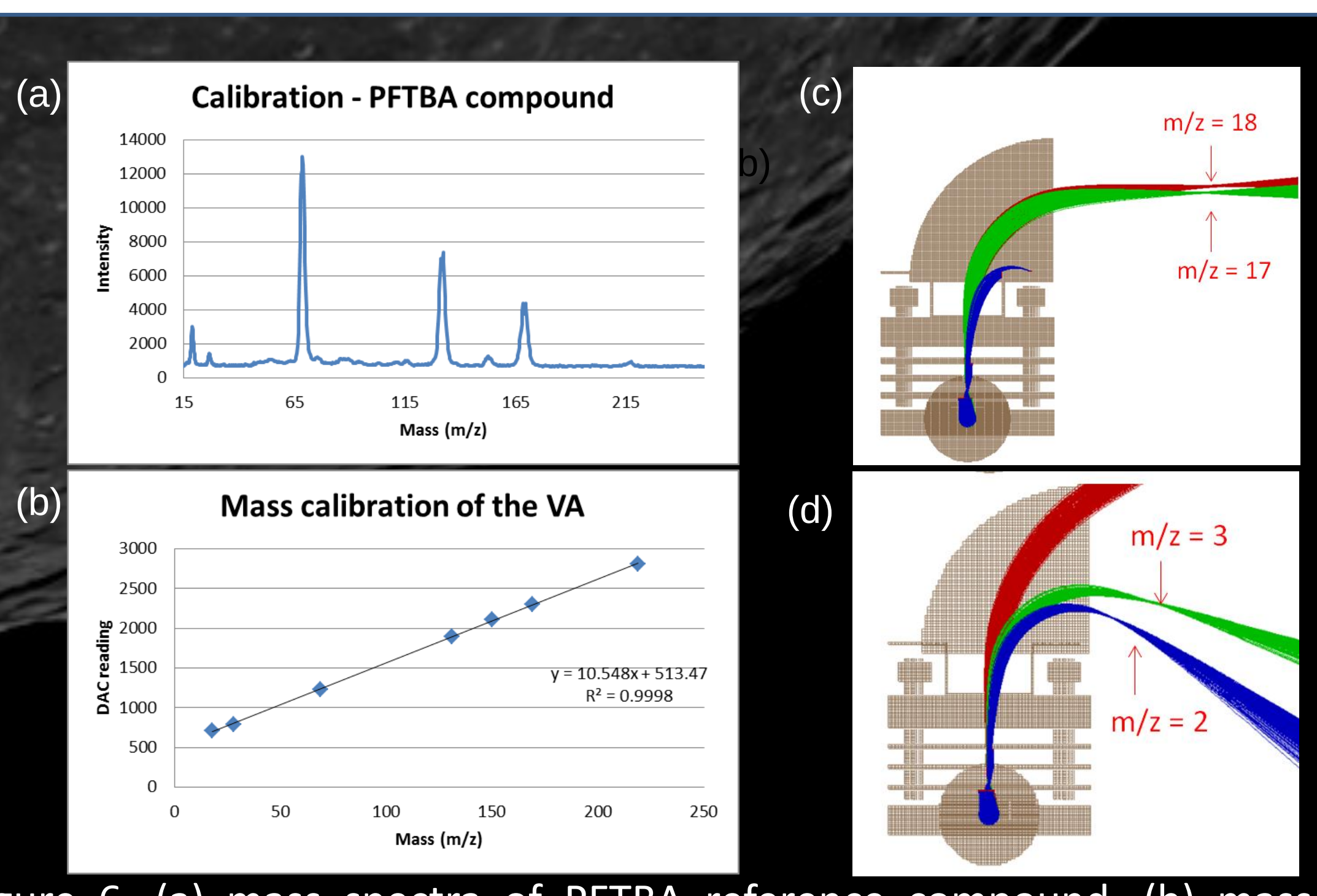


Figure 6. (a) mass spectra of PFTBA reference compound, (b) mass calibration and (c) volatile extraction from

8. References

[1] Paige et al. (2010) Science, 330, 6003, 479-482. [2] Vasavada et al., (1999) Icarus 141: 179-193.[3] Gancet J. et al. (2017) ASTRA 2017. [4] Biswas J. et al. (2017) ELS V. [5] Todd et al. (2007) Journal Of Mass Spectrometry. 42 (1):1-10. [6] Wright et al., (2007) Space Science Review. [7] Colaprete A. et al. (2010) Science, 330, 463-467.

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