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## The Lunar Volatile Resources Analysis Package

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**The Lunar Volatile Resources Analysis Package.** A. D. Morse<sup>1</sup>, S. J. Barber<sup>1</sup>, K. R. Dewar<sup>1</sup>, J. M. Pillinger<sup>1</sup>, S. Sheridan<sup>1</sup>, I. P. Wright<sup>1</sup>, E. K. Gibson<sup>2</sup>, J. A. Merrifield<sup>3</sup>, C. J. Howe<sup>4</sup>, L. J. Waugh<sup>5</sup> and C. T. Pillinger<sup>1</sup>,  
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**Introduction:** The presence and abundance of lunar volatiles is an important consideration for ISRU (In Situ Resource Utilisation) since this is likely to be a part of a strategy for supporting long term human exploration of the moon. The Lunar Volatile Resources Analysis Package (L-VRAP) is part of the provisional payload for the ESA European Lander [1] and aims to measure the abundance and chemical/isotopic composition of volatiles from regolith samples and the lunar exosphere.

**L-VRAP Concept:** The Package concept is based on instruments flown for other lander missions (e.g. GAP[2], TEGA[3], and Ptolemy[4]). Regolith samples are loaded into one of 24 ovens on a carousel whereupon the volatiles are extracted by either pyrolysis or combustion to temperatures of least 800°C. The abundance and chemical composition is determined by an ion trap mass spectrometer. The volatiles are then chemically processed to be suitable for isotopic analysis by a magnetic sector mass spectrometer. L-VRAP also contains reference gases of known chemical and isotopic composition to enable precise isotopic measurements. The CAD layout is shown in figures 1 and 2.

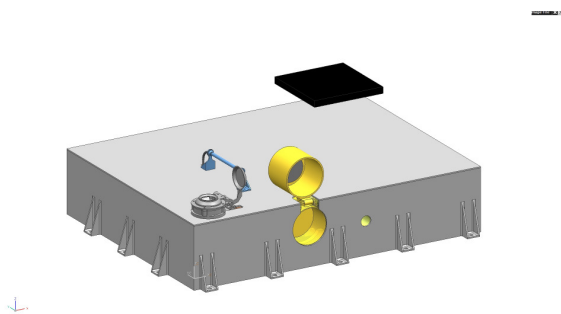


Figure 1. L-VRAP CAD model showing enclosure. Enclosure dimensions 460 mm × 350 mm, ht 97 mm

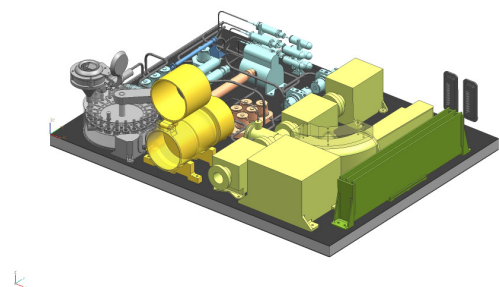


Figure 2 CAD model of the internal layout of L-VRAP. Subsystem details are listed opposite.

*Solid Sample Inlet.*

24 resistively heated ovens mounted on carousel  
 Sample size 50-100mg  
 Imager to estimate sample volume  
 Tapping station to seal sample

*Chemical Processing System.*

Valves and manifolds to control gases  
 Reagents and reactors to process volatiles  
 Reference gases H, C, N, O & noble gases  
 Reference gas mixture for ion trap MS

*Ion Trap Mass Spectrometer.*

Ring electrode  $r_0 = 8\text{mm}$ , 1MHz RF  
 Mass range 10 – 150 amu  
 Unit mass resolution  
 Electron multiplier detector  
 Frequency 1 mass spectrum/second

*Magnetic Sector Mass Spectrometer.*

6cm radius 90° magnetic sector  
 Mass range 2 – 150 amu  
 Mass resolution  $M/\Delta M = 65$   
 Triple Faraday cup detectors for C, N, O isotopes  
 Double Faraday cup detector for D/H isotopes  
 Electron multiplier detector for noble gases  
 Isotopic precision  $\pm 0.1\%$   $\mu\text{mol}$  samples,  $\pm 1\%$  nmol samples.

**Sample collection:** The Lunar Lander includes a robotic arm capable of scooping samples from up to 3.5m from the lander centre and to a nominal depth of 10cm. A timeline has been developed to analyse volatiles at various depths and locations as well as their variation over time and changing illumination conditions. The possible inclusion of a mobile payload element with a mole would allow a much larger range of samples to be acquired.

**Exosphere samples:** In addition to analysing volatiles released from regolith samples, L-VRAP can directly analyse the tenuous lunar exosphere by opening the mass spectrometers to the lunar environment. The ion trap MS can rapidly monitor the full mass range to detect transient events (e.g. during changes of illumination) whereas the magnetic sector MS has greater sensitivity can detect the less abundant volatiles. The housing for the Ion Trap MS also includes a material which passively traps the exosphere. Hence the exosphere can be collected over a long time scale during darkness.

**Contamination:** An important consideration for this study is the effects of contamination from the Lander. The landing sequence will use about 1000

kg of propellant, with a large fraction directed onto the landing site. Initial modeling indicates that uncontaminated samples will be accessible by the robotic arm at depths of several centimeters. Knowledge of the contamination composition and distribution will allow the identification of surface volatiles, either by subtracting the contamination or by identifying protected areas such as surface shielded by small rocks.

**References:** [1] Carpenter J. D. et al. (2012) *LPSC XLIII*, Abstract#1990. [2] Hoffmann J. H. et al. (2008) *J.Am.Soc.Mass Spectrom.* 19, 1377-1383. [3] Stewart et al. (2003) *J. Geophys Res.* Abstracts 5, 09489. [4] Morse A. D. et al. (2009) *In: Rosetta: ESA's mission to the origin of the solar system, 19.6*, 669-686.