Volatile Analysis by Pyrolysis of Regolith for Planetary Resource Exploration C.A. Malespin[1,2], D.P. Glavin[1], I.L. ten Kate[3], H. B. Franz[1,4], E. Mumm[5], S. Getty[1], A. Southard[1,2], and P. Mahaffy[1], [1]NASA Goddard Space Flight Center, 8800 Greenbelt Rd, Greenbelt, MD 20771, (charles.a.malespin@nasa.gov), [2]Universities Space Research Association, 10211 Wincopin Circle, Columbia, MD 21044, [3]Dept. of Earth Sciences, Faculty of Geosciences, Utrecht University, Budapestlaan 4, 3584 CD Utrecht, the Netherlands, [4]Center for Research and Exploration in Space Science and Technology, 5523 Research Park Drive, University of Maryland Baltimore County, Baltimore, MD 21228, [5]Honeybee Robotics, 460 34th Street, New York, NY 10001

Introduction: The extraction and identification of volatile resources that could be utilized by humans including water, oxygen, noble gases, and hydrocarbons on the Moon, Mars, and small planetary bodies will be critical for future long-term human exploration of these objects. Vacuum pyrolysis at elevated temperatures has been shown to be an efficient way to release volatiles trapped inside solid samples. In order to maximize the extraction of volatiles, including oxygen and noble gases from the breakdown of minerals, a pyrolysis temperature of 1300° C or higher is required, which greatly exceeds the maximum temperatures of current state-of-the-art flight pyrolysis instruments. Here we report on the recent optimization and field testing results of a high temperature pyrolysis oven and sample manipulation system coupled to a mass spectrometer instrument called Volatile Analysis by Pyrolysis of Regolith(VAPoR).VAPoR is capable of heating solid samples under vacuum to temperatures above 1300° C and determining the composition of volatiles released as a function of temperature. [1]

Instrument Description: The preliminary VAPoR flight instrument concept (Fig. 1) combines a sample carousel of up to six individually heated pyrolysis ovens with a reflectron time of flight mass spectrometer. [2]

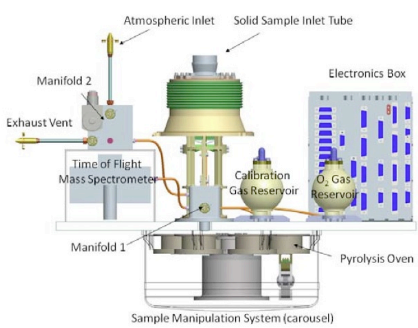

Figure 1. Cross sectional view of preliminary VAPoR flight instrument concept

The VAPoR gas processing system includes two gas manifolds, heated transfer lines, and two separate gas reservoirs containing calibration gas for the mass spectrometer and oxygen for combustion experiments. Powdered rock or soil samples collected from a rover or lander drill or scoop and delivered through the solid sample tube to one of the VAPoR ovens can then be heated by a controlled ramp from ambient to temperatures up to 1300° C to release the volatile constituents for direct measurement by the mass spectrometer.

Two independent units have been built and tested to understand the performance of the different instrument components. A laboratory breadboard was developed to test, optimize, and calibrate the reflectron time of flight mass spectrometer (TOF-MS) component of VAPoR inside a separate vacuum chamber. A separate portable field unit (Fig 2) consisting of a custom made pyrolysis oven coupled to a commercial RGA quadrupole mass spectrometer, vacuum manifold and turbomolecular pumping station, was built to demonstrate the feasibility of conducting vacuum pyrolysis evolved gas measurements in the field and has been discussed previously [3]

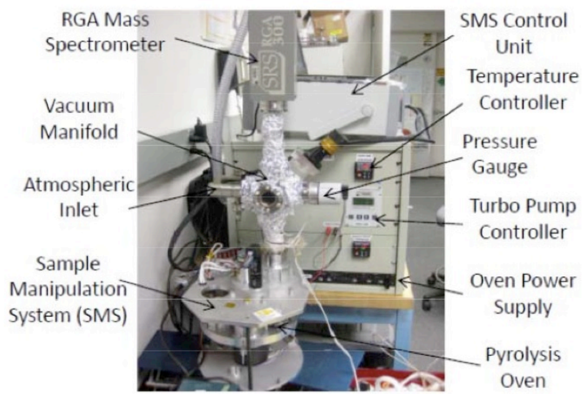

Figure 2. The VAPoR field instrument uses a new sample manipulation system and high temperature pyrolysis oven for evolved gas analysis of powdered solid samples.

Summary: Using the VAPoR instrument during NASA's 2011 Desert RATS field campaign at Black Lava Point, AZ and the 2012 MMAMA test in Apollo Valley, HI, we successfully demonstrated that high temperature vacuum pyrolysis of solid samples to temperatures exceeding 1300°C coupled with detection of volatiles by mass spectrometry can be used for the identification of resources including water and oxygen in surface samples. The inclusion of evolved gas analysis capability in the field and continued testing of instruments such as VAPoR in future field tests will be critical to the success of future robotic and human planetary resource exploration missions. The development of sample collection protocols designed to minimize or eliminate contamination from analyses such as those conducted by VAPoR are critical considerations for future space exploration architecture planning.

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References: [1] ten Kate, et al, Planetary and Space Sciences, Vol 58, Issue 7-8, pp 1007-1017 [2] Getty et al, Int. J. Mass. Spec, Vol 295, pp 124-132, 2010 [3] Glavin et al, Aerospace Conference, 2012 IEEE, pp 1-11