MARSVAC: ACTUATOR FREE REGOLITH SAMPLE RETURN MISSION FROM MARS. K. Zacny[1], L. Beegle[2], T. Onstott[3], R. Mueller[4], [1]Honeybee Robotics (zacny@honeybeerobotics.com); [2]NASA Jet Propulsion Laboratory; [3]Princeton University; [4]NASA Kennedy Space Center.

Introduction: The recent report issued by the International Mars Architecture for the Return of Samples (iMARS) Working Group [1] states that a "suite of 5 to 8 samples represent a reasonable compromise between scientific needs and mission constraints for MSR samples". Regolith, dust, and atmospheric gas represent 3 of the 8 sample types. These three types of samples answer 9 of the 11 science objectives, and can all be collected from a stationary platform greatly reduces the overall mission risk of potentially returning no scientific samples

Before we send humans to Mars, we need to bring martian samples back to earth for thorough scientific and toxicity analysis [2] . Bringing even a small sample back from Mars will be more beneficial than doing any type of in-situ analysis. In-situ investigations rely on instruments which, although highly capable within the mass and power constraints of spaceflight, cannot compare with a fully outfitted analytical laboratory.

Returning even a small sample from Mars for analysis on Earth can provide a more thorough understanding of samples than in-situ instruments can offer. A quick search reveals that the number of papers written about the SNC (~550) and ALH84001 (~400) Mars meteorites are much greater than those written about results from the MER rovers (~200). While this is a rough count, it indicates that in-situ missions are highly focused and constrained by the number of instruments that can be accommodated.

Risk of failure, and the mitigation measures in place, weigh heavily in the decision to fly a mission. The risk is generally linked to the number of actuators on the spacecraft and especially those that pose a single point of failure (i.e. have no redundancy). Hence many critical actuators or mechanisms have back ups (redundancy). Redundancy inevitably equates to higher mass and cost, which means less mass or budget for other instruments or subsystems.

Pneumatic Sampling of Regolith [2]: We are proposing a Mars Sample Return scheme whereby a sample of soil is acquired directly into a Mars Ascent Vehicle using a pneumatic system (Figure 1 and 2).

In the simplest scenario, we envisage one pneumatic tube to be embedded inside each of the 3 legs of the lander, for a total of 3 pneumatic tubes (It is also possible for the 3 tubes to be pushed into the regolith upon landing). With this type of deployment a level of redundancy is built into the system. For example, if one of the legs lands on a rock the other two pneumatic tubes in the other legs will still be functional. Upon landing, the legs will inevitably bury themselves into the Martian regolith. The tubes within each of the legs will then fill up with regolith. With one puff of gas we can then lift the soil enclosed within each tube to a sampling chamber onboard the Mars Ascent Vehicle. At the same time, an additional chamber can be opened to acquire atmospheric gas and dust. This MSR system will require: 1) one actuator to open/close a sampling chamber and 2) one valve to open the gas cylinder.

All mechanical systems for this sampling acquisition system exist. Valves and gas canisters have been flown for the past 50 years. The regolith sample can be either a primary sample or a contingency sample in case the primary sampling system (scoop etc.) fails.

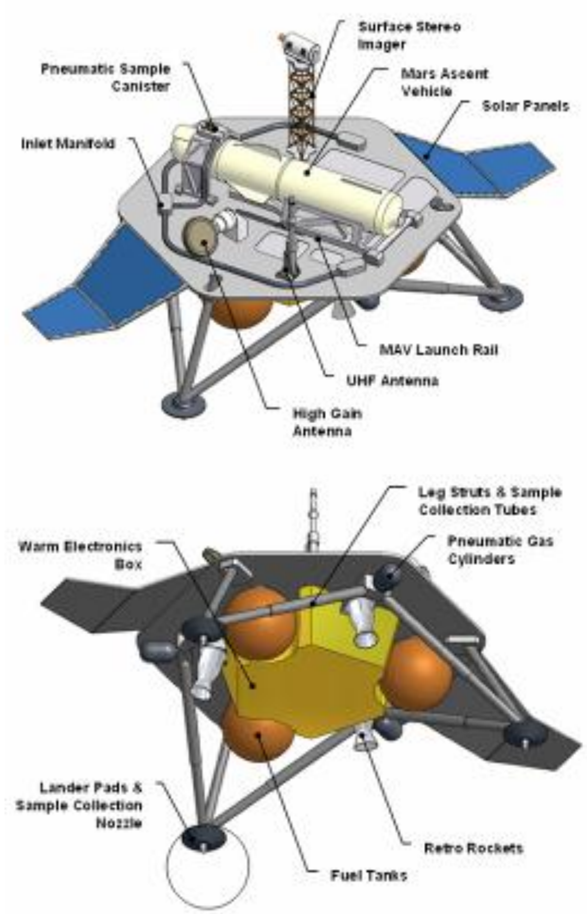

Figure 1. A schematic diagram showing components of the MarsVac: pneumatic sampling of regolith.

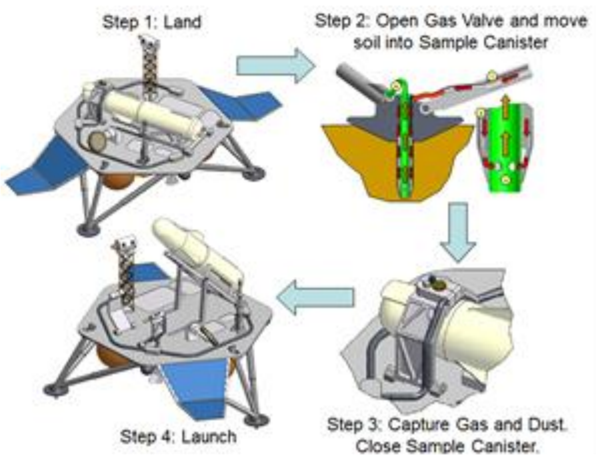

Figure 2. Summary of the 4 step Mars Sample Return Mission.

Regolith Sampling Procedures: Figure 3 illustrates the steps involved in acquiring a regolith sample.

1. Compressed gas cylinder releases a pulse of gas.
2. Gas travels down lander leg strut.
3. Gas is expelled through the lander leg pad nozzle into the regolith.
4. Regolith is pushed up the second leg strut towards the lander deck.
5. Regolith reaches the sample intake manifold where it combines with two other sample sources.
6. Regolith from all three lander pads is pushed up into the sample canister

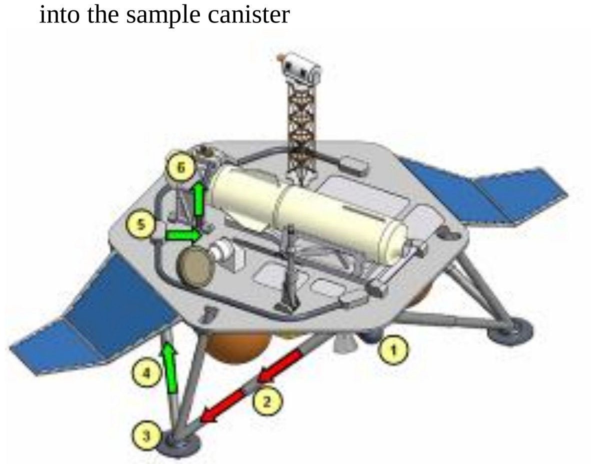

Figure 3: path of regolith from below the lander leg to a MAV sampling chamber.

Figure 4 illustrates the flow of gas and regolith. Red arrows denote the flow of gas, while green arrows show the path of regolith. The flow of gas and regolith would likely be as follows:

1. Gas flow down lander leg strut from gas cylinder.
2. Gas travels down outer tube of collection nozzle.
3. Gas passes through side holes in inner tube of collection nozzle, forcing regolith upwards.
4. Regolith takes the path of least resistance, moving up the inner tube, through the lander leg strut and up to the lander deck, where it is then collected.

Proof of Concept: In the most recent study we showed that it is possible to lift over 5000 grams of lunar soil with only 1 gram of gas at 10 psia [3]. All experiments were conducted inside a vacuum chamber with atmospheric pressures ranging from 1-5 torr (i.e. range of Martian pressures) and at 1G and 1/6th G. A canister with 20 gram of N_2 at 200 psi can easily fit inside the palm of a hand, with the gas in this canister being used to lift a few kilograms of regolith for sample collection [1].

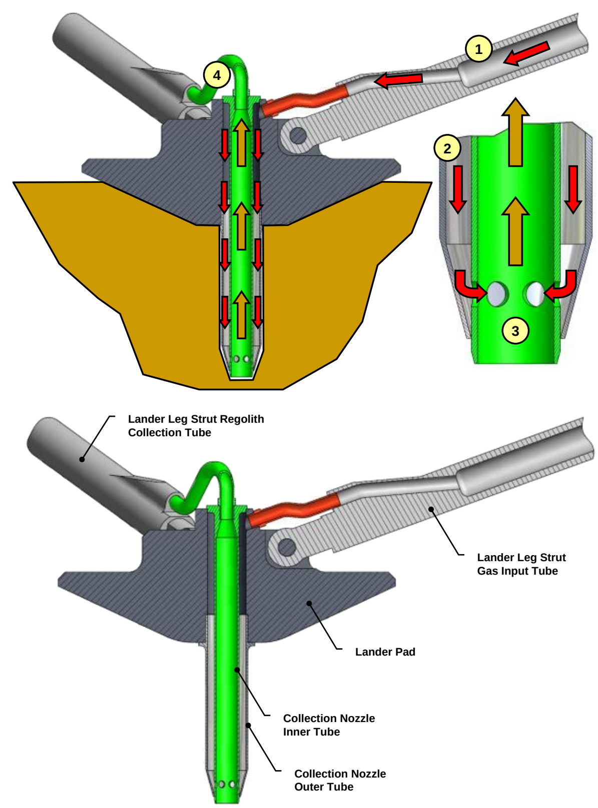

Figure 4. Lander Pad Collection Nozzle Concept and Flow of Gas and Regolith in Lander Pad Nozzle

References: [1] Borg et al., Science Priorities for Mars Sample Return, Astrobiology, Vol 8, No 3, 2008. [2] D. W. Beaty, et al. An Analysis of the Precursor Measurements of Mars Needed to Reduce the Risk of the First Human Mission to Mars. MEPAG/JPL Document CL#05-0381, 2005

[3] Zacny et al. (2010) Novel Method of Regolith Sample Return from Extraterrestrial Body Using a Puff of Gas, Paper #1082, IEEE Aerospace conference.