**PlanetVac: Regolith Mining Systems for CLPS Blue Ghost lander.** Kris Zacny[1], Zak Fitzgerald[1], Helen Jung[1], Vince Vendiola[1], Nate Borcyk[1], Roshan Misra[1], Mohammad Alattas[1], Ted Johnson[1], Krystine Carrington[2], Christopher Wohl[3], Rob Mueller[4], and Maria Banks[4], [1]Honeybee Robotics, Altadena, CA, zacny@honeybeerobotics.com, [2]UFO, LLC, [3]NASA Langley, [4]NASA KSC, [4]Smithsonian Inst, Washington, DC.

**Introduction:** PlanetVac is a revolutionary technology for acquiring and transferring regolith from almost any planetary body to instruments (for in situ analysis) or sample returned container (for sample return missions) [1-4]. PlanetVac uses a robust and dust tolerant pneumatic approach, similar to traditional pneumatic based powder delivery technologies used on Earth. The main difference is the sources of gas: PlanetVac uses a standalone gas canister to provide the working fluid (Figure 1).

The range of instrument types and mission goals has driven complexity of sample delivery approaches. Some instruments require 50 micrograms of sample delivered into small cups (GCMS), while others want a sample spread across a flat surface (Raman, LIBS, LDMS). In-Situ Resource Utilization missions would likely want larger quantities of specific relevant materials (e.g., fines that contain specific minerals). Some sample return missions want rocklets (for geochronology) while others may require 10 cc of representative regolith sample. PlanetVac is versatile and can be adapted to meet any of these requirements. The PlanetVac pneumatic approach is gravity agnostic (it can work in strong or no gravity field) and it works with non-cohesive or cohesive materials (the latter materials have been the most difficult to deal with on prior missions, especially in low gravitational fields).

**PlanetVac:** PlanetVac, in the baseline design, is attached to a footpad (or footpads if more than one PlanetVac is used) of a lander or deployed (e.g., using 5th leg/boom). It is connected to instruments or sample return containers via a pneumatic transfer hose. The exact location of the instruments and sample container is irrelevant since the transfer hose can be routed around other systems.

Figure 2 shows operation of PlanetVac. The gas jets inside the sampling head are pointed down to sweep and loft regolith into a transfer tube. The capture system separates the sample from the flow and delivers it to the instrument. Sample collection occurs in a matter of seconds after single valve opening command. As a result, total power draw is virtually nonexistent given the brief operation. In addition, no operator in the loop is required for collection.

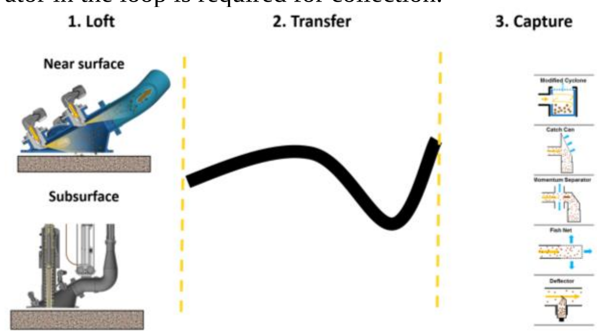


**Figure 2. PlanetVac sample acquisition and capture.**

The main advantage of the pneumatic transfer is that the point of acquisition and point of delivery can be anywhere on the spacecraft. Unlike scoops de-

| Parameters | Robotic arm and scoop | PlanetVac |
|---|---|---|
| |  |  |
| Mass, Volume, Power | High | Low |
| Cost, Complexity | High | Low |
| Sampling time | Hours – Days | Seconds |
| Relies on gravity | Yes | No |
| Works with sticky sample? | No | Yes |
| Can easily meter out? | No | Yes |
| Kinematic flexibility | No | Yes |
| | | |
| Ability to sample >1 location | Yes | No |
| Sample size | High | Small |

**Figure 1. PlanetVac vs Robotic Arm sample delivery.**

ployed by robotic arms which are constrained by kinematic position of the arm and the location of instruments, pneumatic transfer lines can instead be routed around potential obstacles. As such, sample acquisition hardware can be placed where it is best for sample acquisition, and instruments can be placed in the best location for performing analysis.

**Blue Ghost mission**: PlanetVac has been selected as part of the NASA Lunar Surface Instrument and Technology Payloads (LSITP) program to fly to the Moon's Mare Crisium in 2024 onboard Firefly Blue Ghost lander. It consists of four main systems: Sampling Head, Sorting System, Transfer Tube, and Avionics (Figure 3). Figure 4 shows inside view of the Sorting System. The system includes two chambers with a screen between them, and several material coupons to test regolith adhesion.


**Figure 3. PlanetVac consist of Sampling Head, Sample Sorting System, Transfer Tube (not shown), and Avionics.**

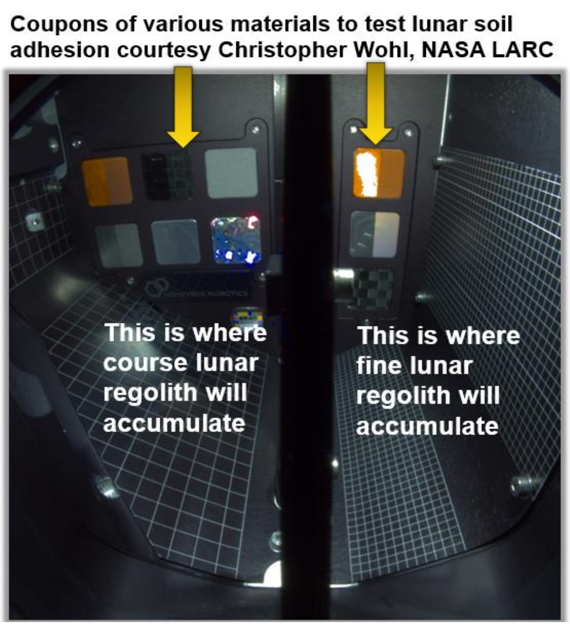


**Figure 4. Sorting System includes several coupons that will be used to determine dust adhesion.**

Figure 5 shows PlanetVac being deployed using a 5th leg (a boom) underneath the lander. Upon a command, the 5th leg will be deployed and it will actively preload PlanetVac against the surface. A burst of gas will be activated to aloft regolith into the Sorting System for inspection by a camera.

The system, in nominal operation, should require minutes to accomplish its baseline tests.

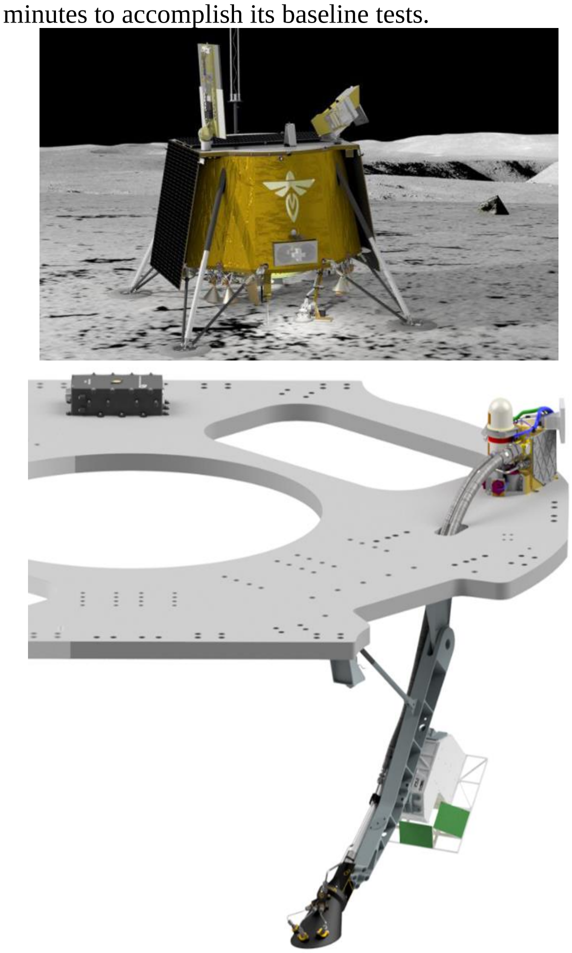

**Figure 5. PlanetVac will launch to the Moon as part of CLPS 19D. Shown is PlanetVac deployed by a boom (5th leg) on Firefly Blue Ghost lander.**

**References:** [1] Zacny et al., (2020) Pneumatic Sampler (P-Sampler) for the Martian Moons eXploration (MMX) Mission, IEEE Aerospace Conf. [2] Spring et al., (2019), PlanetVac Xodiac: Lander Foot Pad Integrated Planetary Sampling System, IEEE Aerospace Conf., [3] Zacny et al., (2019), Application of Pneumatics in Delivering Samples to Instruments on Planetary Missions, IEEE Aerospace Conf., [4] Zacny et al., (2-14), PlanetVac: Pneumatic Regolith Sampling System, IEEE Aerospace Conf.

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