A Sample Sifter for the Proposed Icebreaker Mars Mission

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Introduction: The Icebreaker mission proposes to land at the site where the Phoenix mission discovered an environment that is habitable for life in recent times [1], and search for biomarkers of life. The subsurface ice is expected at shallow depth (<10 cm below the surface)[2]. By drilling up to 1 m depth into the icy material, Icebreaker plans to sample ice that was warm during past high obliquity periods. Samples are analyzed for organics and biomolecules.

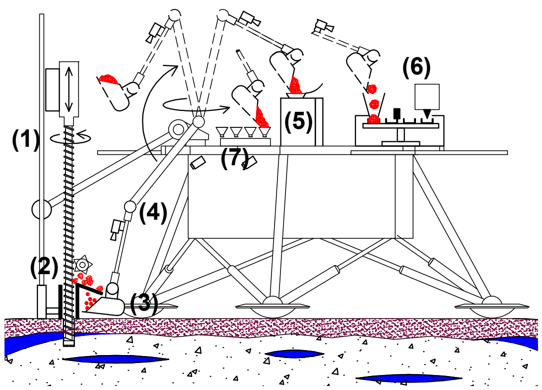

Figure 1: The Icebreaker Lander showing (1) Drill, (2) Drill screen, (3) ISAD based Scoop, (4) Robot Arm, (5) SOLID, (6)LDMS & Feeder, & (7) WCL.

The Icebreaker Lander (Figure 1) is similar to the current InSight mission Lander that was derived from the Phoenix and Mars Polar lander. Icebreaker carries a 1 meter rotary percussive drill [3] which augers to produce cuttings. These are captured by a scoop at the end of a robot arm and delivered to three analytical instruments: the Signs of LIfe Detector (SOLID) [4], the Laser Desorption Mass Spectrometer (LDMS) [5] and the Wet Chemistry Laboratory (WCL) [6].

We describe here a unique sifting scoop end effector developed and tested for possible inclusion in the proposed Icebreaker Mars mission. This device can receive icy samples of variable particle size and sieve the samples through a 1 mm grid while also slowly metering out the sifted samples.

Sample characteristics and instrument requirements: Cuttings of icy soils are expected to be much more sticky than the dry regolith, as was found with samples acquired from above and below the ice table during the Phoenix mission. Ice-cemented soils may have ice content ranging from 30% to 100% ice and the ice can sinter quickly to metal surfaces, resulting in very sticky characteristics. Icebreaker's instruments have stringent sample requirments: The SOLID Sample Processing Unit requires 0.5 – 2 cc volume of cuttings < 1 mm size. The WCL instrument requires 1 cc volume of < 2 mm sized cuttings. The WCL single use beakers were covered by a 2 mm grate filter which, during the Phoenix mission, either partly blocked or on one occassion fully blocked. The LDMS has no partical size restriction but requires the sample to be leveled to +/- 0.2 mm tolerance which is more easily achieved using small sized cuttings.

The Phoenix mission experience suggested any filtering mechanism be required to have an active device and not rely on a gravity feed principle, due to the stickiness of the icy material.

The Sifter Design: The Sifter as a Robot Arm end effector could: 1) capture cuttings brought up by the drill string; 2) store cuttings; 3) actively filter and meter out cuttings sifted to exclude >1 mm sized particles into the instruments; and 4) jettison over sized cuttings. The Sifter prototype (Figure 2) consists of an inlet funnel located over a feed mechanism, a rotary wire brush rotating at 30 rpm in a cylindrical chamber. The rotating brush operates similar to a metering pump, drawing in portions of cuttings from the inlet funnel and forcing them through a grate consisting of 1 mm wide slots cut into the the chamber base.

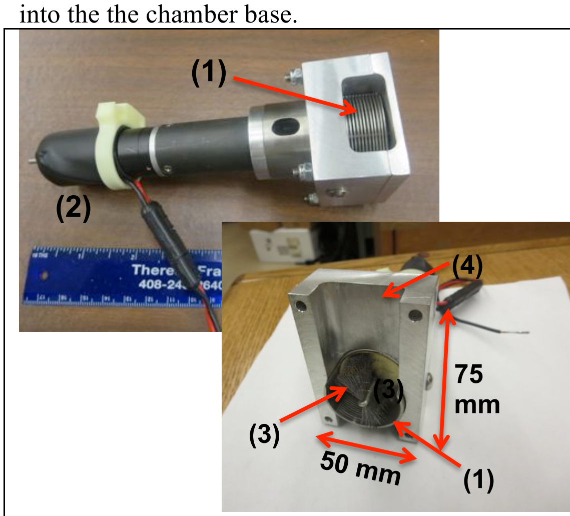

Figure 1: (Top) Sifter block viewed from underside showing (1) 1 mm grill and (2) Maxcon motor. (Bottom) front of Sifter with front plate removed showing (1) grill, (3) rotating wire brush, & (4) inlet

Cuttings are less likely to bridge and block a grate compared to a mesh. The over sized cuttings remain in the cylindrical brush chamber and are dumped by the Robot Arm by inverting the Sifter. When the brush is not rotating and positioned horizontally, sample will not fall through the inlet, so can be stored temporarily.

Other feed mechanisms were investigated and prototypes built and tested including a rotating trommel with flail, but the wire brush was the most successful enabling a positive force feed but is flexible to deal with hard oversized 5 mm "pebble" objects.

Testing: The sifter was first tested in a walk-in (-20 degree C) freezer where ice cuttings were manufactured by drilling into ice and ice/soil mixtures and deposited into the Sifter. The inlet and feed mechanism did not block.
It was also tested in Mars temperature and pressure conditions at the Honeybee Robotics workshop Mars chamber (Pasadena CA). The high TRL Icebreaker drill augering into Dry Valley Antarctic soil [7], consisting of 30% ice in Mars conditions was used to collect 62.5 cc of cuttings that were swept off the auger flights by a brush into the Sifter inlet. The sifter motor was then operated. Power was measured (Table 1) while operating dry and with sample. The sizes of the cuttings with and without passage through the sifter were measured (table 2) showing the effectiviness of the grate system. The Sifter metered out the filtered cuttings similar to a pepper grinder at a rate of 10 g/minute.

Table 1: Operation Current and Voltages

Operation	Current Amps	Voltage DC	Power (Max) W
Rotating dry	0.12 – 0.18	23.9	4.3
Sifting	0.25 – 0.54	23.9	13 W

Table 2: Size profile of Dry Valley cuttings (inc 30% ice)

Particle size (mm)	Cuttings Profile dropped in Sifter	Profile cuttings passed through Sifter grate
>2.8	1.7%	0.4 %
>2	2%	0.31%
>1.4	5.7%	1.9%
>0.7	6.4%	4.7%
<0.7	84.3%	92.8%

Results: The results show that the Sifter 1 mm slotted grate system did not exclude all particles > 1 mm as a small population of long flat particles appeared to pass through the grate by the rotary brush. Further investigation is required to determine whether the particles were manufactured during the process or native to the material. However the Icebreaker instruments can accept a small percentage of large particles. The delivery rate of 10 g/minute is somewhat slow, but could possibly be speedier if the brush were run faster than the 30 rpm operated in the test. Also there may be on the order of 20% flow rate error in this measurment as this quantity of cuttings was observed to fall into a collection plate prior to commencement of flow rate measurements through the sifter.

Finally the power measured showed fluctuations corresponding to the number of rotating brush blades brushing the cylindrical chamber walls. The maximum power of 13 W provides guidance on motor selection.

Future Possibilities: The Sifter core element (Figure 3) could be incorporated into a scoop to exclude large particles for future misisons. Further studies of this design are planned if Icebreaker is selected for flight. A sifter could be incorporated into a scoop design like the Honeybee Robotics ISAD scoop that was used on the Phoenix mission. The brush element could be located at the back/base of the scoop providing a mechanism to sift and meter out sample to instruments.

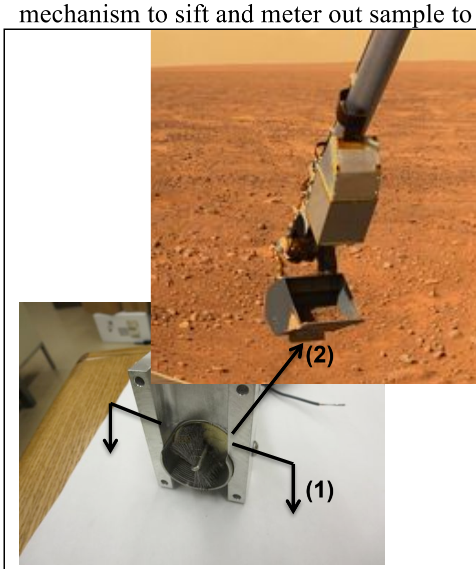

Figure 2: The ISAD-Sifter proposed for Icebreaker where the Sifter core element (1) is integrated into the base of the Phoenix scoop (ISAD) (2) for Icebreaker.

Conclusion: The Sifter is a simple sample filtering and metering system that has been demonstrated in Mars conditions to meter out filtered cuttings into instruments. Thus it is a candidate for application on the Icebreaker Mission, although other applications of this principle are possible.

References: [1] Zent, A. (2008) Icarus 196:385–408, [2] McKay C.P et al (2013) Astrobiology Vol 13, No 4, 334-352, [3] Paulsen, G. et al (2011) AIAA SPACE 2011 Conference & Exposition, American Institute of Aeronautics, [4] Parro, V. et al (2011) Astrobiology 11:15–28, [5] Brinckerhoff W. (2014) 45th LPSC, [6] Kounaves S.P. (2009) Journal of Geophysical Research Vol 114, [7] Dave A. (2013) Vol 13, No 4, 354-368