Sampling the Ocean Worlds: Drilling and Pneumatic Transfer

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Introduction: Honeybee Robotics has developed an integrated sampling system for deployment to Titan that could be readily adapted for use on airless Ocean Worlds, like Europa. The system uses a drill to excavate material from the planetary subsurface and a blower to pneumatically transfer the cuttings to an onboard sample cup for analysis [1-6]. The prototype system has been tested in a cryogenic N_2 environment.

Background: Future missions to Ocean Worlds may search for evidence of past or extant biological activity or examine prebiotic chemistry; such missions would surely carry instruments that require samples of the planetary surface. The sampling system is thus critical to the success of these future missions.

A robust sampling system must handle a wide variety of materials (of different size, hardness, cohesiveness, etc.) while minimizing heat transfer and contamination of, and between, samples.

Design: The sampling system uses a centrifugal blower to generate gas flow and convey material (i.e. via pneumatic transport) from the surface to a collection chamber inside the spacecraft. This pneumatic system is fed by a custom rotary-percussive drill capable of generating small, transportable cuttings from a variety of simulants such as cryogenic ices, rocks, and soils that may be encountered on Ocean Worlds. The design of the drill is based on decades of drill design heritage dating back to Apollo lunar drills.

During sampling, fine-grained cuttings produced by the drill accumulate at the surface where the pneumatic inlet nozzle sucks them up at high speed. Once ingested, the sample is conveyed through tubing up to the spacecraft and is captured in a sample cup. The transportation takes only a fraction of a second. This approach not only minimizes heat transfer to the sample but also minimizes sample cross-contamination.

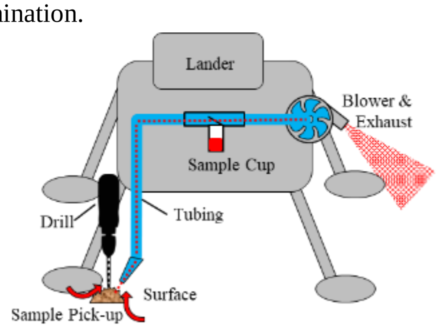

FIG. 1: SAMPLING SYSTEM LAYOUT FOR GENERIC TITAN LANDER.

Although this sampling system was designed for Titan, it could be adapted for airless Ocean Worlds by conveying sample using gas from a supply tank that is injected into a sealing shroud around the drill bit rather than the blower/inlet architecture.

Testing: From its inception, the design of the pneumatic system was guided by experimentation with Titan analogs at Earth ambient conditions. Simulants with wide-ranging mechanical properties were used to characterize performance and refine the design.

The prototype system was tested in a Titan-like environment (N_2 gas, 90°K) and successfully sampled Titan cryogenic simulants such as paraffin wax (evaporite analog), ammonia-water-Ice, water-Ice, and sand. This test validated the sampling concept with Ocean Worlds materials at cryogenic temperature by: drilling and creating fine cuttings, ingesting those particles, pneumatically transferring them through a tube, and finally capturing them in a sample cup.

Contamination testing of the pneumatic tubing was also performed with both rigid and flexible tubes. Results indicate ~2-3% max contamination for the sampling system.

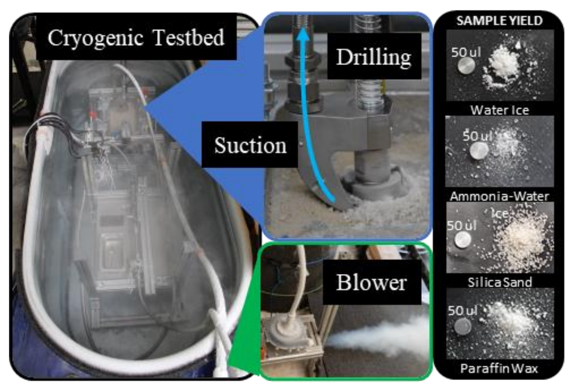

FIG. 2. SYSTEM TESTING IN CRYOGENIC N2 ENVIRONMENT.

Conclusion: Honeybee Robotics has designed and tested a sampling system for deployment to Titan that combines rotary-percussive drilling with pneumatic transport. The system has been tested in a relevant environment and shown to be an excellent means for sampling the Ocean Worlds.

References: [1] Rehnmark F. et al. (2018) 15th IPPW, [2] Sparta J. et al. (2018) 15th IPPW, [3] Sparta J. et al. (2018) ExOSS, [4] Zacny K. et al. (2018) 42nd COSPAR, [5] Zacny K. et al. (2019) IEEE Aero. Conf., [6] Zacny K. et al. (2014) IEEE Aero. Conf.