Drill for Acquisition of Complex Organics (DrACO) for Dragonfly Mission, K. Zacny[1], G. Paulsen[1], L. Thomas[1], R. Margulieux[1], J. Spring[1], R. Wei[1], G. Adams[1], D. Yu[1], J. Bailey[1], P. Ng[1], A. Hames[1], R. Lorenz[2], E. Turtle[2], D. Wegel[3], M. Trainer[3], S. Krimchansky[3], [1]Honeybee Robotics, [2]Johns Hopkins Applied Physics Laboratory, [3]NASA Goddard Space Flight Center.

Introduction: Drill for Acquisition of Complex Organics (DrACO) is a sample acquisition and delivery system for the Dragonfly New Frontiers mission to explore Titan [1, 2]. The goal of the mission is to assess Titan's habitability and investigate its prebiotic chemistry.

Dragonfly is MMRTG powered octocopter lander, that will perform numerous vertical takeoffs and landings to pre-scouted locations. At each site, Dragonfly will have the option to use DrACO sampling system to analyze Titan surface material. Selected in June 2019, Dragonfly is scheduled to launch in 2027 and arrive on the Titan surface in 2034.

The primary goal of DrACO is to capture Titan material from up to 6 cm deep and deliver it to Dragonfly Mass Spectrometer (DraMS). DraMS operates in two measurement modes: Laser Desorption Mass Spectrometer (LDMS) and Gas Chromatograph Mass Spectrometer (GCMS), and each has dedicated cups. In the latest configuration, there are 40 LDMS cups and 18 LDMS cups.

The required sample volume for each cup is less than 0.5 mL, i.e., the size of an aspirin pill. Metering out such a small volume has been the major challenge. DrACO is designed to drill 50 holes and deliver 1 LDMS and 2 GCMS samples per hole. The increase in sample temperature during the acquisition and delivery operation, should be less than <20 °C.

DrACO: The DrACO sampling system within the Dragonfly lander is shown in Figure 1. DrACO consists of four major subsystems: The Sample Acquisition Drills (SAD), the Pneumatic Transport System (PTS), the Sample Delivery Carousel (SDC), and associated Avionics.

Material is suctioned directly through a hollow drill bit, and pneumatically conveyed in a fast-moving stream of cryogenic ambient Titan air to minimize temperature rise, reducing risk of sample alteration, or fouling of the transport system. In contrast to traditional sample transfer systems, the DrACO pneumatic architecture is gravity agnostic [3, 4]. The end-to-end system features two redundant sampling drills (SADs) and two redundant suction blowers in a "cross-strapped" configuration: either drill can deliver sample to either LDMS or GCMS cups using either blower.

Pneumatic approach has several advantages: (1) The delivery point can be at a distance from the drill, because the connecting tube can be routed around the vehicle. (2) Sample temperature remains cold during transfer because the transport medium is 94K Titan air. (3) Sample transfer does not rely on gravity, a strong advantage if moving cohesive material. (4) Cross-contamination is significantly reduced by running air through the pneumatic lines prior to and after sample transfer. (5) Risk of clogging is minimized because sample remains in motion until captured by the LDMS and GCMS sample cups or exhausted outside the lander. (6) sample capture can be achieved numerous ways to optimize metering.

This approach to sample collection and delivery solved the most difficult problem DrACO faced: delivering of a small volume of sample into a tiny cup at

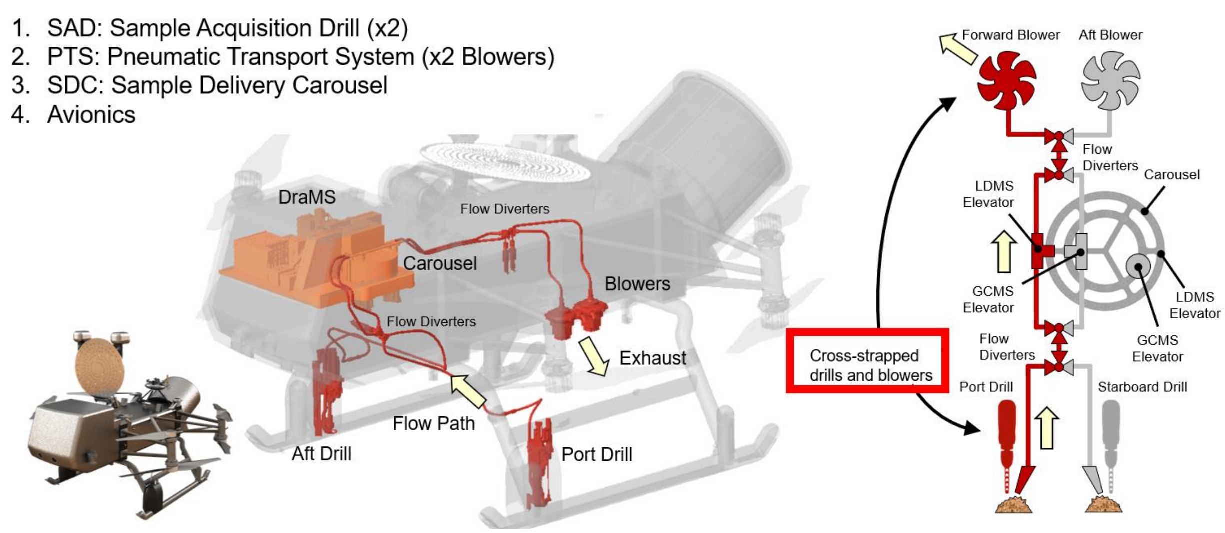

Figure 1. Configuration of DrACO.

some distance from the surface. No other approach would be able to achieve that within the constrained placed on the DrACO system.

Sample Acquisition Drill (SAD) consists of a Drill Head (Percussion/Rotation), Feed (Z) Stage, and a Drill Bit assembly, which includes Swivel (Figure 2). The Drill uses a rotary-percussive action to efficiently penetrate through the strongest Titan material. The rotation and percussion are driven by separate actuators, allowing for drilling flexibility using rotation with or without percussion.

As the drill bit cuts material, Titan air is pulled in via one of the two blowers (Figure 3). This cold air has several functions: keeping drill bit and formation cold, keeping sample cold, and delivering sample, via transfer tubes, into LDMS or GCMS cups. The openings in a drill bit are designed to exclude >1.5 mm particles that could foul the pneumatic system.

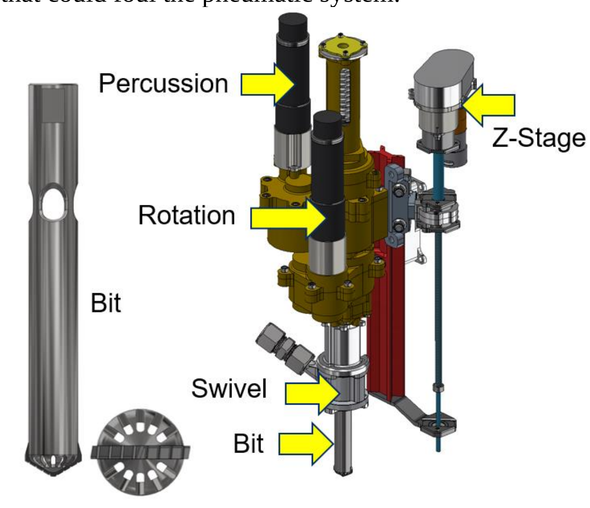

Figure 2. SAD with its major subsystems.

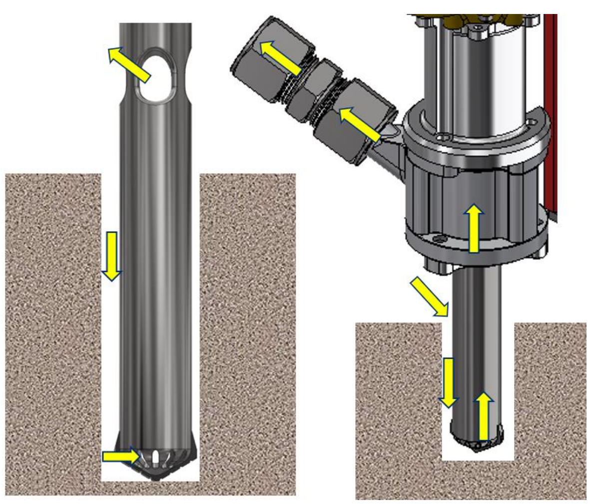

Figure 3. Direction of Titan air, which cleans the borehole and carries sample to cups.

Pneumatic Transfer System (PTS) operates on the same principle used in commercial vacuum cleaners: suction blowers rapidly convey sample from the surface to collection ports in the SDC [5, 6]. Titan's 94K air temperature, 4.4x higher air density, and 1/7th gravity result in pneumatic transport requiring less power than on Earth. Thus, lifting and transporting particles on Titan requires significantly lower power. The PTS uses a traditional centrifugal blower design, with impellers designed for Titan air.

Sample Delivery Carousel (SDC) has two rings that rotate together: the inner ring carries sample cups to feed GCMS and the outer ring cups that feed LDMS. LDMS and GCMS cups (Figure 4) collect solid particles from the moving airstream by redirecting them into the interior of the cup with a deflector plate that extends into the flow.

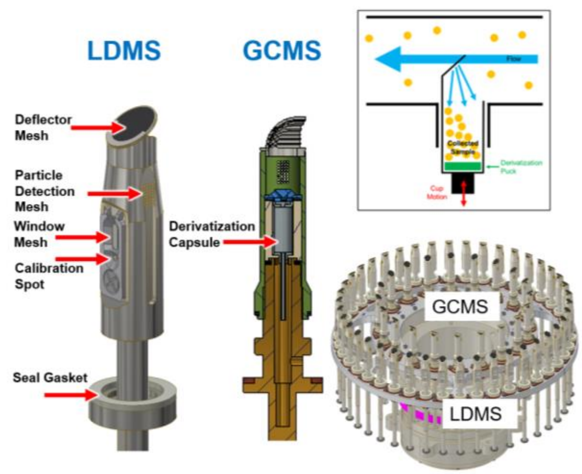

Figure 4. DrACO's LDMS and GCMS cups are designed for pneumatic capture.

Conclusions: The Phase A work resulted in DrACO architecture [7-10] that has been carried into Phase B without any major changes. Only the drill bit assembly had been modified to meet lower mass and power requirements and particle sensor has been added to the cups to indicate cup fill state condition.

The DrACO system is progressing through Phase B development, with anticipated Preliminary Design Reviews (PDR) scheduled for Q1 and Q2 of 2022.

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References: [1] Turtle et al., (2020), LPSC. [2] Zacny et al., (2017) LPSC. [3] Zacny et al. (2019), IEEE Aerospace Conf. [4] Lorenz et al. (2019) IPPW. [5] Rehnmark et al. (2018) IPPW, [6] Sparta et al., (2018) IPPW, [7] Sparta et al., (2019), [8] AbScConf. [9] Costa et al. (2019) AbSciConf. [10] Zacny et al., (2018) COSPAR.