VENUS DRILL AND SAMPLE DELIVERY SYSTEM. K. Zacny[1], J. Hall[2], and VISAGE Team, [1]Honeybee Robotics (kazacny@honeybeerobotics.com), [2]NASA JPL.

Introduction: For over a decade, Honeybee Robotics and NASA JPL have been developing Venus technologies to enable surface missions and operations. Critical subsystem of these technologies include drilling and sample delivery. Venera 13, 14 and Vega 2 successfully demonstrated drilling and sample delivery to an XRF instrument from up to 3 cm depth. Drilling was performed using a 90 Watt rotary drill and sample delivery was done using a series of pyrotechnic actuators and pneumatic transfer. This heritage is non-existent though – blue prints are not available and engineers that design the systems have retired by now.

As part of the technology development that will enable analysis of Venus surface and subsurface, Honeybee Robotics and JPL developed high temperature actuators, drills, deployment systems, and sample delivery systems.

Venus drill: We developed a rotary-percussive rock sampling drill and high temperature (HT) electromagnetic actuator for a proposed mission to Venus known as VISAGE (Venus In Situ Atmospheric and Geochemical Explorer). The drill is powered by two brushless DC motors that have been characterized in dynamometer tests run at both room temperature and Venus surface temperature of ~462°C (Figure 1). Dynamometer test results are compared with performance estimates obtained using ANSYS Maxwell analysis software, demonstrating that losses at high temperature can be predicted with reasonable accuracy.

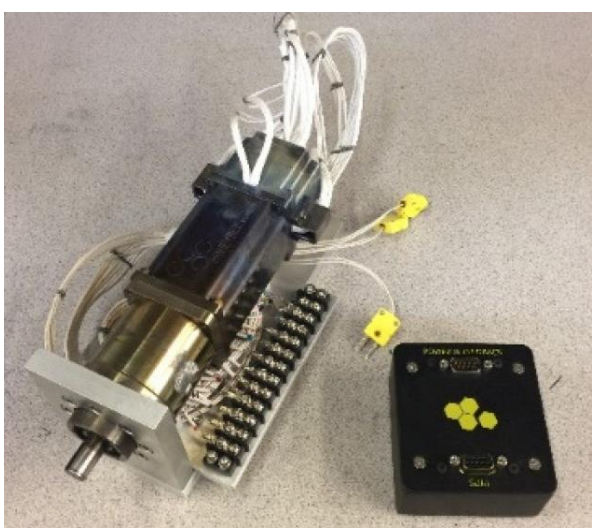

Figure 1. Venus actuator.

The Venus drill with its major subsystems is depicted in Figure 2 (the Deployment and Feed stages are not shown). The design includes a hollow drill stem extension through the bit and hammer drive assemblies up to the top of the drill body, where it will interface with the pneumatic sample transfer system. The sample will flow directly from the bit, through the hollow transfer tube into the rest of the sample transfer plumbing (not shown).

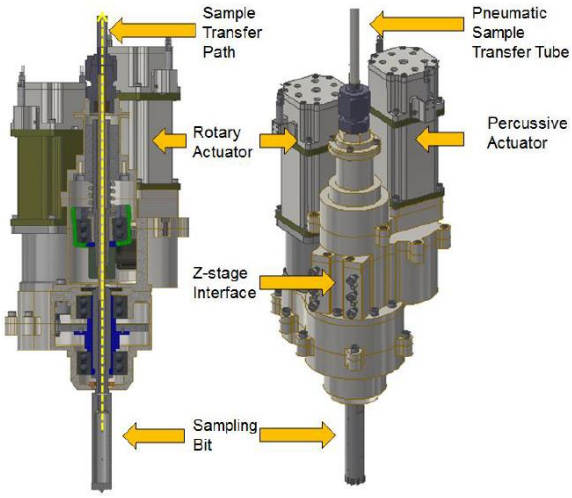

Figure 2. Schematics of Venus drill.

Drilling trials conducted in JPL's Venus Material Test Facility (VMTF) shown in Figure 3 have demonstrated the feasibility of sampling threshold strength Venus analog material within a time window compatible with the proposed VISAGE mission concept of operations.

The tests showed that the rate of penetration in 120 MPa Saddleback Basalt at Venus temperature and pressure was slower (3.8 mm per minute) than at Room Temperature (5.1 mm per minute). This has been attributed to the lower stiffness of the percussive spring (and, therefore, the percussive energy per blow) as well as increased electrical (i2R) losses at high temperature because of the higher resistance of the motor coils.

Additional tests have been conducted to demonstrate combined drilling with pneumatic sample delivery under Venus conditions. These tests used the Large Venus Test Chamber (LVTC) at JPL plus additional external hardware for the pneumatic transfer and airlock systems that would be located inside the Venus lander (Figure 4). These end-to-end tests successfully demonstrated all major steps in the complete sampling process: deployment of the drill to the surface, drilling, pneumatic transfer of the drill

cuttings to an airlock and movement inside the airlock of samples to a low pressure, low temperature location for scientific analysis.

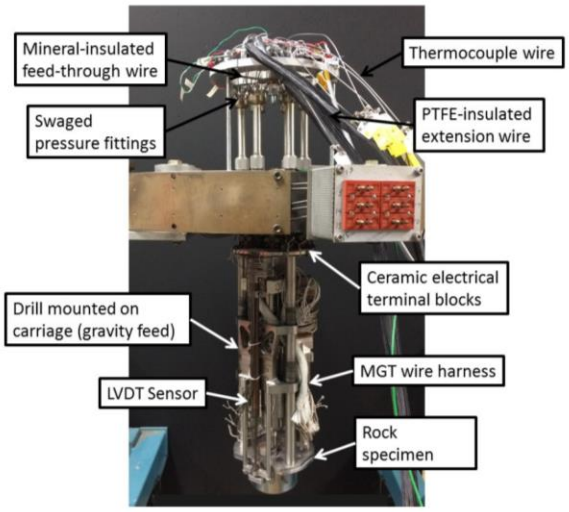

Figure 3. Venus drill prior to Venus chamber tests.

Figure 4. JPL Large Venus Test Chamber and associated pneumatic sample transfer equipment.

Conclusions: This work demonstrated that drilling and sample delivery under Venus conditions is feasible. Further development is required to improve the reliability and efficiency of the system prior to flight.

References: [1] Zacny et al., (2017), Development of Venus Drill, IEEE Aerospace Conference, [2] Rehnmark et al., (2018), Environmental Chamber Testing of the VISAGE Rock Sampling Drill for Venus Exploration. 44th Aerospace Mechanisms Symp., [3] Rehnmark et al., (2017), High Temperature Actuator and Sampling Drill for Venus Exploration, ESMATS.