Honeybee Robotics Planetary Sample Acquisition, Transfer and Processing Technologies

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Summary

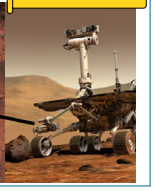
In the last decade, Honeybee Robotics Spacecraft Mechanism Corporation developed numerous sampling acquisition, processing and sample transport systems. These systems were built to meet specific requirements such as reaching certain depths, exhibiting certain levels of autonomy, acquiring samples of certain sizes and integrity (e.g. core vs. powder). Drills were built to operate at restricted power and Weight on Bit values and were tested either in the planetary analogs such as the Arctic, and/or laboratory, and/or environmental chambers and for this reason are at different Technology Readiness Levels (TRL).

RAT

The Rock Abrasion Tool (RAT) serves as the sample preparation device on the Mars Exploration Rover (MER) science payload. As an end-effector on the rover's robotic arm the RAT grinds a circular spot 45 mm in diameter and on the order of millimeters deep into a rock face with only 10 Watt of power to remove surface fines and weathered layers, preparing the rock for imaging and spectral observations.

Flight Hardware

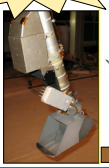
Surface Grinder



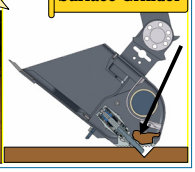
ISAD

Icy Soil Acquisition Device (ISAD), on the Mars 2007 Phoenix Lander consists of a scoop and a small cutting bit called RASP (see arrow), which will plunge into the icy soil. The ISAD is mounted at the end of an arm. As the RASP penetrates the surface, cuttings are thrown into the scoop's rear sampling chamber and are moved to the front chamber (using a series of robotic arm wrist articulations) where they can be imaged and transferred to instruments.

Flight Hardware



Surface Grinder



MiniCorer

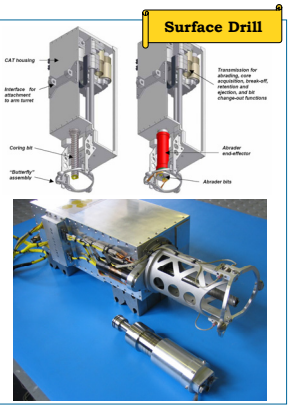
The Mini Corer: The Miniature Rock Coring and Rock Core Acquisition and Transfer System (Mini-Corer) was designed, built, and tested for the NASA's Mars Sample Return Athena Payload, scheduled for launch in 2003. It is a rover belly-mounted system and acquires rock cores for in-situ examination, and for caching for sample return. The Mini-Corer weighs 2.7 kg (not including pitch-translate system) and its dimensions are 29.8 cm x 14.51 cm x 9.64 cm.

Surface Drill

CAT

The Coring Abrading Tool (CAT): The integrated coring and abrading tool (CAT), is a hybrid of Honeybee's existing Rock Abrasion Tool (RAT) and Mini-Corer (MC) designs. The Rock Abrasion Tool is a TRL 9 instrument that is currently operating onboard of Mars Exploration Rovers. The CAT is an arm-mounted, stand-alone device, requiring no additional arm actuation once positioned and preloaded. This instrument is capable of autonomously acquiring, retaining and transferring 8 mm in diameter and up to 100 mm long cores of solid and unconsolidated material, abrading and brushing rock surfaces. Changing out bits and end-effectors to perform the coring/abrading operations is also done autonomously. The CAT weighs less than 4 kg, and can penetrate 100 MPa basalt rock with only 120 Newton of preload (Weight on Bit). The CAT was extensively tested in a vacuum chamber (under simulated Mars atmospheric conditions) and is currently at TRL 6.

Surface Drill



SATM Drill and Sniffer

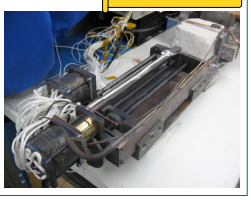
The Sample Acquisition and Transfer Mechanism (SATM) is a 1-meter class drill system that features sample handling abilities and sample return containers. A prototype was developed and tested to validate the performance requirements for the NASA ST/4 Champollion mission. The drill was designed to acquire 0.1-1 cc samples at 20 cm and at 1m depth with little cross-contamination.
The "Sniffer" drill concept can collect a sample at a known depth and heat it up inside the sample chamber with a semi-permeable ceramic heater until vapor is released. The vapor can then travel through a tube embedded in the non-rotating part of the drill to a mass spectrometer on the drill base.

1m Class Drill

Venus Drill

The High Temperature Motors and Drill: Most existing motors and actuators are not designed to survive in the harsh Venus environment (460 °C, 90 bar, CO2 atmosphere). In response, Honeybee developed two types of high temperature motors, a Switched Reluctance Motor and a Brushless DC Motor. A drilling system, actuated by two SRMs was tested in Venus conditions (temperature and CO2) for 20 hours. The current drill volume is 7 in x 4.5 in x 19 in with stroke of 10 in.

1m Class Drill



USDC Drill

The Ultrasonic/Sonic Driller/Corer (USDC) jointly developed the JPL and Cybersonics, Inc. addresses restrictions imposed by a limited Weight on Bit provided from a small lander or a robotic arm. The USDC requires only a very low axial force, thereby overcoming one of the major limitations of planetary sampling using conventional drills in low gravity environments. To reach a depth of 0.5-m in regolith, jointly Honeybee Robotics and JPL developed a sampler that combines a USDC mechanism and bit rotation. The objective was to produce an all-in-one type drill with the capability to acquire, retain, and transfer samples. The drill is currently being tested in analog formations.

1m Class Drill

SCSS

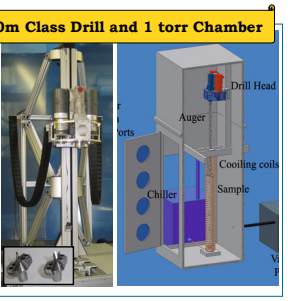
The Subsurface Coring Sampler System (SCSS) is a sample acquisition and transfer tool that can operate as both a drill and a coring device within the same borehole; it has the ability of acquiring consolidated and unconsolidated samples with the same bit.. It is capable of low power drilling in weak and strong targets up to 1 meter and acquiring multiple cores at required depth. The core size is 8mm in diameter and up to 4 cm long. By combining drilling, coring and sample handling in one unit, the drill provides great functionality for minimum power and mass.

1m Class Drill

CRUX Drill

The Construction and Resource Utilization Explorer (CRUX) drill is a test platform for testing drill bits, augers, and drilling modes (rotary, rotary percussive and percussive). This drill with a linear stroke of 1m, can produce 45 N-m of torque at a rotational speed of 200 rpm. A maximum downforce of 1000 N can be achieved. The drill platform was designed to accommodate a downhole neutron spectrometer, as well as temperature sensors, accelerometers, and electrical properties tester. Drill bits were tested in rocks and lunar regolith simulant. Mars chamber (under development) will be ~2.5 meters high with a 1m x 1m base and suitable for testing drills to at least 1m depth at ~1 torr pressure.

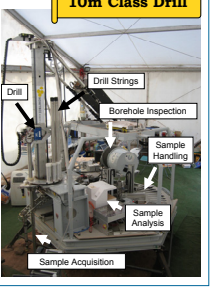
10m Class Drill and 1 torr Chamber



MARTE Drill

The MARTE drill: The Honeybee MARTE drill was part of the Mars Astrobiology Research and Technology Experiment (MARTE), which was a Mars research platform that has investigated robotic drilling to 10 meter depths. The MARTE drill is a highly automated 10 meter class drill system. The 10-axis system is designed for subsurface core capture, break off, recovery and hand-off as well as autonomous assembly and disassembly of drill strings. The drill produces rock cores 27 mm in diameter and 250 mm long while creating a 48 mm diameter borehole. A core hand-off sub-system delivers a core to a core clamp for sample preparation and delivery to scientific instruments. The drill strings interfaces allow for power and data transfer to embedded instruments. The system is designed to operate below 150 Watts average. The drill was field tested in limestone quarry and Rio Tinto, Spain and is at TRL 5-6.

10m Class Drill



DAME Drill

Drilling Automation for Mars Exploration drill is a 10 meter drill system designed to investigate methods of automated drilling and fault recovery. To achieve that, the drill includes seven sensors (e.g.a torque sensor to measure nit torque and a current sensor to measure total torque). A bit temperature sensor is also built into the lead drill string, and two current sensors are used to measure the current draw from the auger and Z axis motors. The drill can 'sense' its state and adjust drilling parameters or drilling sequence accordingly. It can also identify up to seven drilling faults and use pre-coded sequence to recover from them. The drill was deployed three times in the Arctic and is at TRL 4-5.

10m Class Drill

MeSH

The Mechanized Sample Handler (MeSH) is a miniature centralized sample preparation station that could be mounted on an MSL-class rover. It includes three main subsystems: a rock crusher, a sieving/shaking mechanism, and a portioning/distribution system. The MeSH is de-signed to receive a variety of sample types (loose regolith, pebbles and small rock cores), crush a sample and distribute powdered samples to a variety of instruments. MeSH's rock crusher uses attrition to reduce rock cores from a solid core to a very fine powder. The sieving/shaking mechanism sorts fine powder samples into two size categories, both targeted to be below 150 microns. The portioning/distribution system takes the sieved sample and makes an aliquot (small portion) of it, before it is passed off to instrument inlet ports.

Sample Crusher

SMS

The Sample Manipulation System (SMS) was developed for the Sample Analysis at Mars (SAM) Instrument aboard the Mars Science Laboratory (MSL). The SMS positions a sample from the sample inlet device to pyrolysis ovens. The main design driver is precise, autonomous manipulation of 74 sample cups to multiple interfaces. The SMS positions each sample cup below any interface to within 0.71 millimeters of true position and delivers up to 1330 Newton to create a hermetic seal between the sample cup and pyrolysis oven. The high sensitivity of the spectrometers require the SMS to be very clean and also capable of sealing the sample cups from the outside environment.

Flight Hardware

Sample Transfer