Subsurface Sampling and Sensing using Burrowing Moles

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Finding evidence for life on Mars will likely require accessing the subsurface since the Martian surface is both hostile to life and to preservation of biosignatures due to the cold dry conditions, the strong UV environment, and the presence of strong oxidants. Systems are needed to probe beneath the sun and oxidant baked surface of Mars and return samples to the surface for analysis or to bring the instrument sensing underground. Recognizing this need, the European Space Agency incorporated a small subsurface penetrometer or "Mole" onto the Beagle 2 Mars lander. Had the 2003 landing been successful, the Mole would have collected samples from 1-1.5 m depth and delivered them to an organic analysis instrument on the surface. The device called the Planetary Underground Tool (PLUTO), also measured soil mechanical and thermophysical properties. Constrained by the small mass and volume allowance of the Beagle lander, the PLUTO mole was a slender cylinder only 2 cm diameter and 28 cm long equipped with a small sampling device designed to collect samples and bring them to the surface for analysis by other instrument. The mass of the entire system including deployment mechanism and tether was 1/2 kg.

In addition to a mechanism for collecting subsurface samples, Moles can be used to carry a sensor package underground to make *in situ* measurements. The Mars Underground Mole (MUM) is a larger Mole based on the PLUTO design but incorporating light collection optics that interface to a fiber optic cable in the tether that transmits light to a combined stimulated emission Raman Spectrometer and Short Wave Infrared (SWIR) reflectance Spectrometer with sensitivity from 0.7 to 2.5 micrometers. This instrument is called the Dual Spectral Sensor and uses a Digital Array Scanning Interferometer as the sensor technology, a type of fourrier transform interferometer that uses fixed element prisms and thus is highly rugged compared to a Michaelson interferometer. Due to the size limitations of an on-Mole instrument compartment, and the availability of a tether, the sensor head, light sources, and control electronics for the instrument are on the surface. The DSS sensor is capable of sensing a wide range of minerals relevant to Mars Astrobiology objectives including hydrated minerals, clays, carbonates, sulfates, and ice. Additionally, Raman spectroscopy is effective for detecting organics. The MUM is designed to achieve a maximum depth of penetration of 5 m in Mars regolith and can be repeatedly deployed and retrieved. The ability to perform repeated sampling, combined with the low mass and power requirements, means that Moles could be incorporated into a rover mission as well as used on a stationary platform.

The Mole mechanism is a pointed slender cylinder that advances into soil by way of an internal sliding hammer mechanism. Part of the energy released by the spring-loaded hammer with each shock is transferred to the Mole casing and from there to the soil, resulting in penetration by displacing and compressing the surrounding soil. A backwards-directed impulse as a reaction to each forward shock is transferred via a suppressor mass against a second weaker spring allowing forward motion without requiring reactive forces provided by the lander. The Mole tip can be opened to collect soil samples. The Mole casing is tethered to a supporting mechanism that supplies power. Components supporting the Mole on the surface include a launch tube, tether reel and winch for pulling in tether, in addition to the tether itself.