SMART: Instrumented Drill for ISRU Investigations on theMoon

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Ten Second Summary
SMART (Sensing, Measurement, Analysis, and Reconnaissance Tool) is the next generation drilling system for lunar in-situ resource utilization (ISRU) applications. Unlike TRIDENT, which uses the auger to move drill cuttings up to the surface for analysis, the SMART auger and bit assembly is integrated with instruments that can perform analysis in situ.

Science
The instruments on SMART are selected to characterize the lunar surface, search for water ice, and answer other scientific questions about the lunar poles. SMART also allows missions to make educated and expedient decisions as to whether downhole samples should be delivered to any rover mounted ISRU instruments (e.g., gas chromatograph mass spectrometer) for further analysis or processing.

List of instruments
1. Near infrared spectrometer for volatiles and mineralogical information
2. Neutron spectrometer for hydrogen detection
3. Dielectric spectroscopy probe for electrical properties
4. Temperature sensor and heater for thermal gradient and thermal conductivity measurements
5. Camera for visible light images and surface texture
6. Drill head and linear stage for regolith strength

System Overview
SMART consists of several major subsystems: an instrumented drill string, a slip ring and optical connector section, a rotary percussive drill head, a fiber optic rotary joint (FORJ), and a linear stage. The instrumented auger and bit contain a suite of sensors that characterize the drilled boreholes. The electrical and optical signals from the sensors are passed through the slip ring and FORJ sections to an avionics box. The rotary-percussive drill head provides the auger torque and percussion necessary to drill through lunar regolith. The linear stage assembly is a close copy of the TRIDENT linear stage and is used to provide preload and advance the drill into the subsurface.

Testing
To date, the drilling system on SMART has been successfully checked out in dry JSC-1a lunar simulants. Future testing will fully integrate the remaining instruments and their corresponding avionics and use water-doped lunar simulant.

Future Work
A prototype for SMART has been assembled with the goal of demonstrating instrument functionality and testing in a relevant lunar environment. SMART can be mounted to a lander/rover, or even be adapted as a handheld system for high grading on the lunar surface as part of the Artemis program. The drill-integrated instrument payload can also apply to other missions, such as >10-meter drilling systems called Rapidly Excavated Borehole for Exploring Lunar Subsurface (REBELS).

Table: TRL Description

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<th>Instrument</th>
<th>Existing technology</th>
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<tr>
<td>Drill-integrated NiS spectrometer</td>
<td>Mo, MSS</td>
<td>Part of ExoMars rover (ESA)</td>
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<tr>
<td>Neutron spectrometer</td>
<td>NSS, Intrepid</td>
<td>NSS flying in 2023 as part of VIPER, Intrepid flying on NASA CubeSat program (N5A Ames)</td>
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<td>Dielectric spectroscopy probe</td>
<td>Prove on AXEL rover system</td>
<td>Tested in Mojave desert (NASA JPL)</td>
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<td>Temperature sensor and heater</td>
<td>Heat flow probe on LISTER</td>
<td>Flying to the Moon in 2024 (HBR)</td>
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<td>Miniature camera head</td>
<td>ScoutCam 80 HD</td>
<td>Operated in orbit on NASA's Robotic Refueling Mission 3 in 2020 (ScoutCam)</td>
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<tr>
<td>Drilling system / Drill head</td>
<td>TRIDENT</td>
<td>Flying to the Moon as part of Prime1 and VIPER missions (HBR)</td>
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