REBELS: Rapidly Excavated Borehole for Exploring Lunar Subsurface. J. Palmowski[1], K. Zacny[1], L. Stolov[1], K. Bywaters[1], [1]Honeybee Robotics, 2408 Lincoln Ave, Altadena, CA 91001 (kazacny@honeybeerobotics.com)

Introduction: The depth of lunar subsurface exploration has been limited to 3-meter thus far; this is the depth of the three lunar cores captured by Apollo 15, 16, and 17. Soviet Luna 24 sample return mission drilled to 2-meter, while Chang'e 5 drilled to 1-meter. Future missions such as PRIME1 and VIPER are limited to 1-meter depth. Understanding the stratigraphy on the 10-meter scale in the mid-latitude and polar regions would significantly enhance our understanding of the gardening as well as volatile distribution on the Moon.

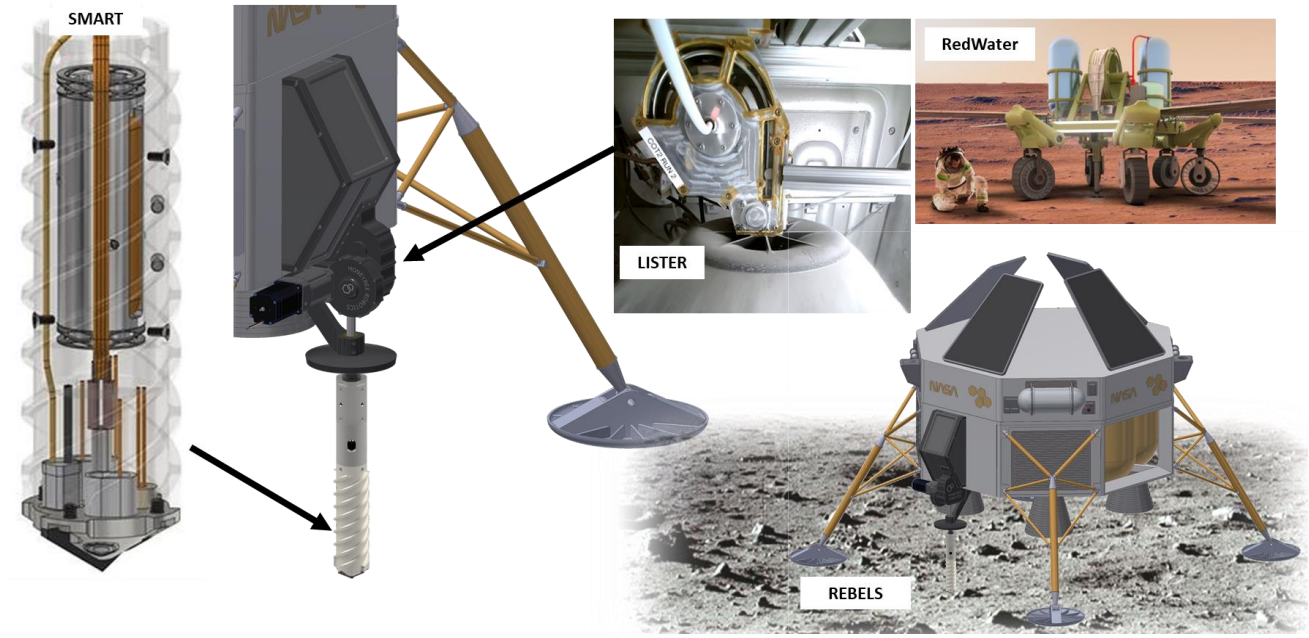

Figure 1. REBELS architecture

(REBELS) Rapidly Excavated Borehole for Exploring Lunar Subsurface: REBELS is a drilling and instrumentation system designed for penetrating >10 m below the lunar surface for in situ science investigation. The design leverages concepts from these existing Honeybee Robotics technologies:

- RedWater – a coiled-tube drilling system currently under development for penetrating 25 m below the surface of Mars [1].
- LISTER – a 3 m pneumatic drill scheduled to fly to the Moon in 2023 (Mare Crisium), and 2025 (Shodinger basin) [2].
- SMART – an instrumented drill under development for the RESOURCE project [3].

REBELS uses a coiled-tubing design similar to the one developed for RedWater and LISTER. The tube is reeled out from a drum while simultaneously re-formed into a straight tube using the Injector Subsystem. The tube contains the electrical harnessing for power and signals downhole, as well as the pneumatic lines required for clearing cuttings during drilling. Mounted to the end of the coiled-tubing is the Bottom Hole Assembly (BHA). The BHA consists of a Drilling Subsystem (motors, drill bit etc.) as well as a Sensing Subsystem with the following instruments:

- Near Infrared Spectrometer (NIR):
  - Volatiles, Mineralogy
- Neutron Spectrometer (NS):
  - Hydrogen (water)
- Temperature Sensor and Heater (TSH)
  - Temperature, Thermal conductivity → Heat flow
- Dielectric Spectroscopy Probe (DSP):
  - Electrical properties
- Camera:
  - Surface texture
- Drill telemetry
  - Subsurface strength, Water content (wt. %), Water-ice physical state

The primary advantage of REBELS is to bring the instruments to the sample – i.e., all the instruments in the BHA can be activated in real-time and collect subsurface data while drilling. In addition, the cuttings being pneumatically cleared out of the borehole can be collected and analyzed in real-time by surface-level instrumentation.

Future work: Various subsystems of REBELS are currently being developed to TRL ranging from 4 to 9 via various NASA projects. RedWater will achieve TRL6 in 2024, SMART will achieve TRL5 in 2023, and LISTER will achieve TRL9 in 2023.

Future work related to REBELS will include detailed engineering design that will constrain mass, volume, power, and development cost and schedule. As such, REBELS will be ready for future proposal opportunities or flight opportunities. Since the majority of technologies are at relatively high TRL, at this stage we envisage flight development timeline for REBELS to be within 24 months.

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References: [1] Palmowski, et al. (2021) Redwater: Extraction of Water from Mars' Ice Deposits. AIAA 2021-4038. [2] Nagihara et al. (2020) The Heat Flow Probe for the Commercial Lunar Payload Services Program of NASA. 51st Lunar and Planetary Science Conference [#1432]. [3] L. Stolov. (2022) SMART: Instrumented Drill for ISRU Investigations on the Moon [manuscript submitted for publication].