The Resource Prospecting Mission Drill

Kris Zacny, Honeybee Robotics

Gale Paulsen, Honeybee Robotics

Julie Kleinhenz, NASA Glenn Research Center

Jim Smith, NASA Kennedy Space Center

John Trautwein, NASA Kennedy Space Center

Jackie Quinn, NASA Kennedy Space Center

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HONEYBEE ROBOTICS
Spacecraft Mechanisms Corporation

Honeybee Robotics Spacecraft Mechanisms Corporation
398 W Washington Blvd., Suite 200, Pasadena, CA 91103
www.HoneybeeRobotics.com

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Background: The Resource Prospector (RP)

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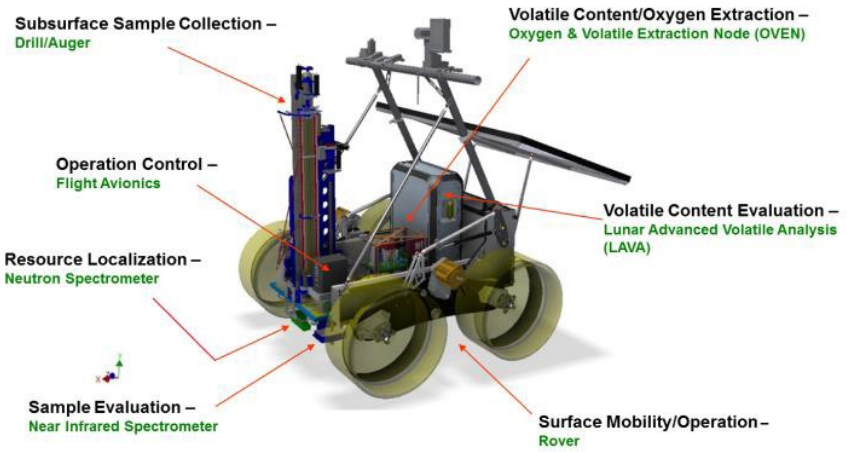
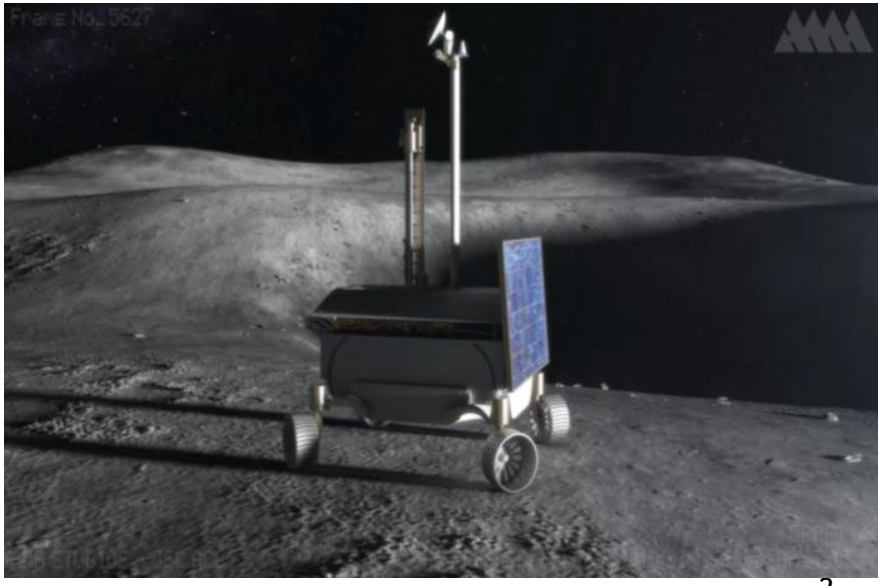
Goal:

- ISRU demo: Prospecting for volatiles, extraction of O2 from lunar regolith

Instruments:

1. The Neutron Spectrometer Subsystem (NSS)
   1. Localizing elevated H2 concentration
2. The Drill Subsystem
   1. Capture samples from up to 1 m
3. The Near InfraRed Volatiles Spectrometer Subsystem (NIRVSS)
   1. Characterize hydrocarbons, mineralogical context for the site, nature of water ice
4. The Oxygen and Volatile Extraction Node (OVEN) Subsystem
   1. Evolve the volatiles in sample by heating and transfer to LAVA
   2. Demo hydrogen reduction process (H2 reacts with iron oxide to produce water)
5. The Lunar Advanced Volatiles Analysis (LAVA) Subsystem
   1. quantities and species of volatiles via GC/MS
   2. Water Droplet Demonstration (WDD)





Andrews et al., 2014

The Drill Subsystem: Background

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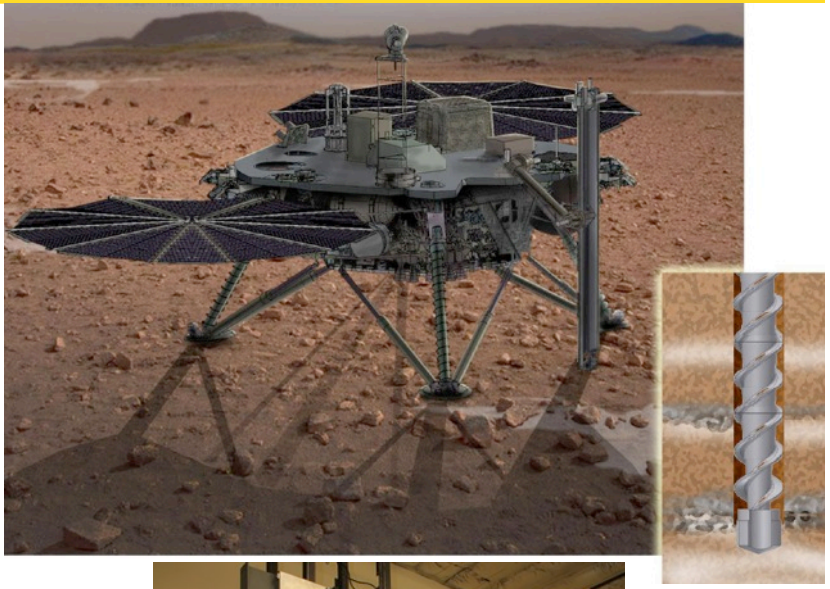
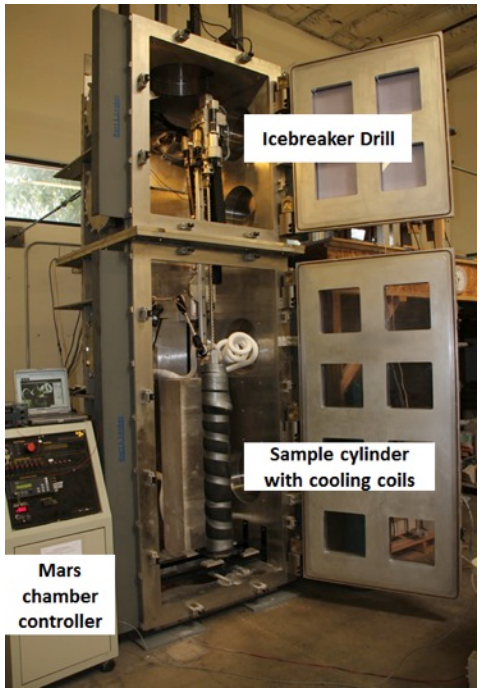
- **The Icebreaker drill**
  - Developed for acquisition of Ice/Ice Cemented Ground at the Mars Poles
  - 1 m depth, 10 kg
  - Tested in Antarctica, Arctic, Greenland
  - Tested in Mars Chamber
  - TRL 5/6
- **Goal:**
  - "Turn" Mars drill into Lunar drill
- **Mars vs Moon Drill**
  - Mars:
    - Planetary Protection
    - Perchlorate in Ice (freezing point depression)
    - Sticky Sample (Relative humidly up to 100%)
    - Full autonomy (long communication delay)
  - Moon
    - Extreme Temperatures (40K – 400K)
    - Hard Vacuum (Ice sublimation >106 K)
    - Teleop/supervised autonomy





Some Considerations and Trades

Drilling Approaches

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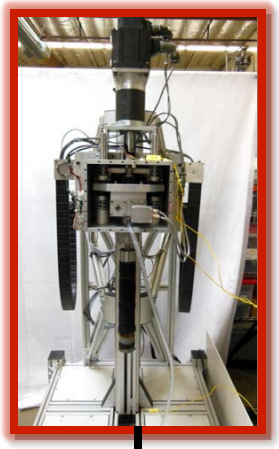
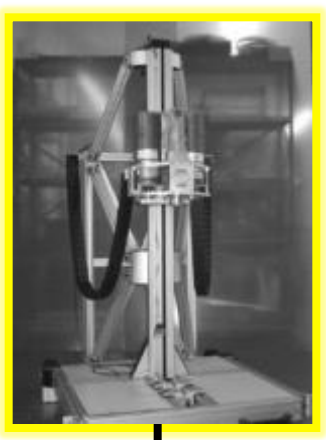
SONIC

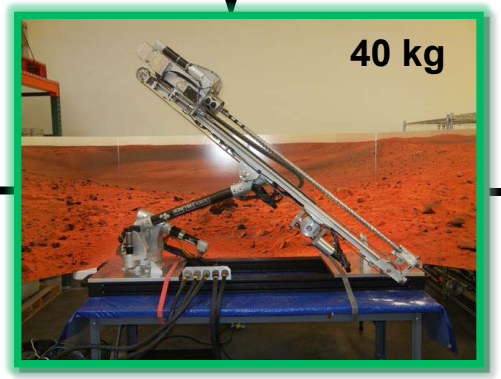


ULTRA SONIC

PERCUSSIVE



ROTARY



Final Selection:
ROTARY-PERCUSSIVE

Lander

Rover

Sampling Trades

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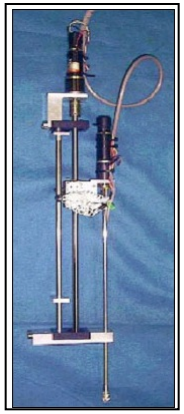
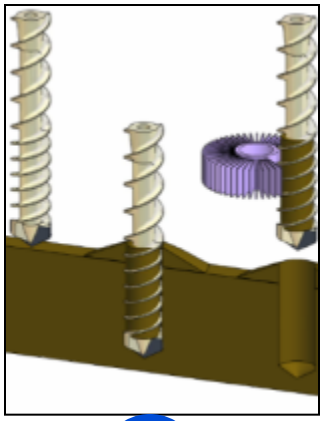
1. Embedded Sensor
Step 1: Drill
Step 2: Analyze



2. Sniffer
Step 1: Drill
Step 2: Acquire Sample
Step 3: Analyze



3. Sampling Auger
Step 1: Drill
Step 2: Transfer Cuttings
Step 3: Analyze

4. Bit Sampler
Step 1: Drill
Step 2: Pull Out
Step 3: Transfer Cuttings
Step 4: Analyze

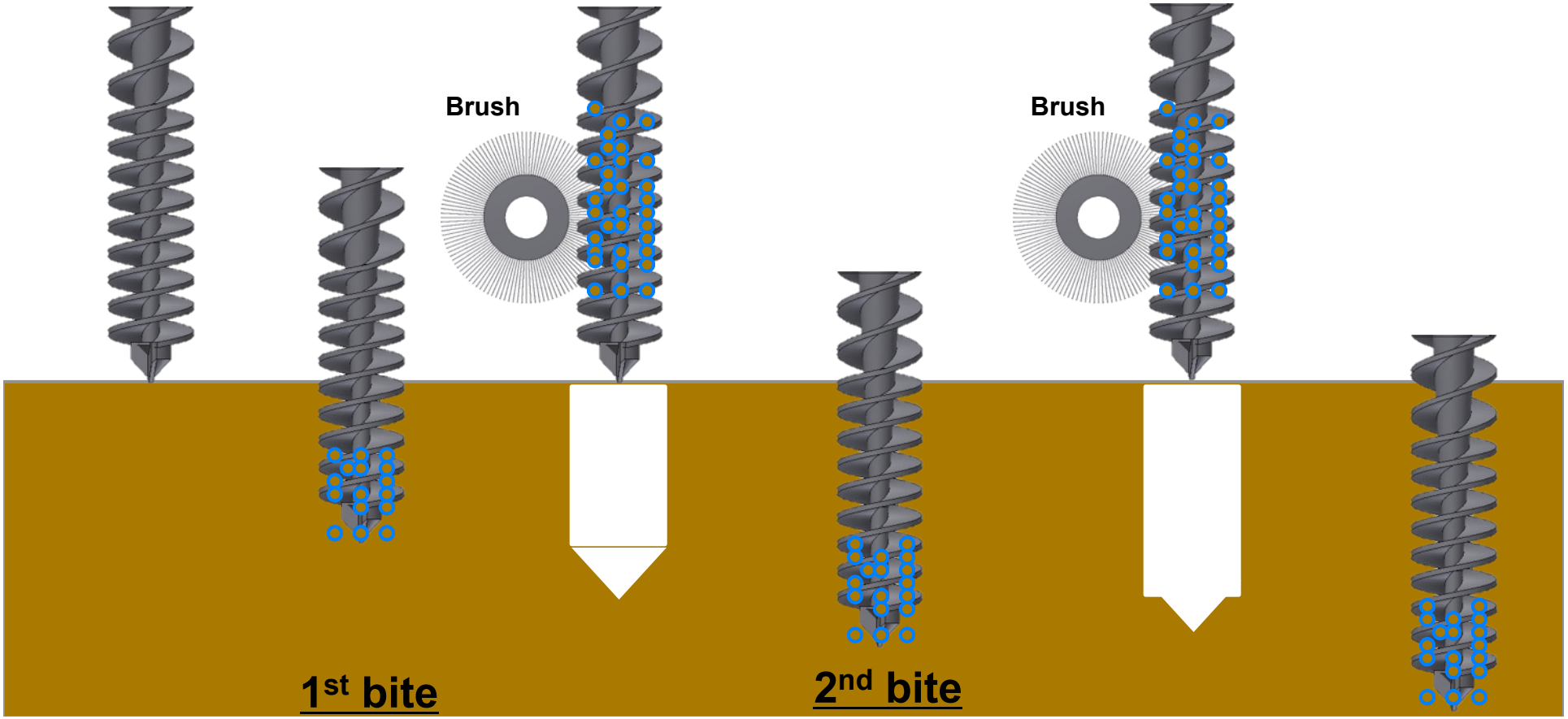
5. Core
Step 1: Drill
Step 2: Break-off core
Step 3: Capture Core
Step 4: Pull out
Step 5: Eject core
Step 6: Process core
Step 7: Analyze

Complexity

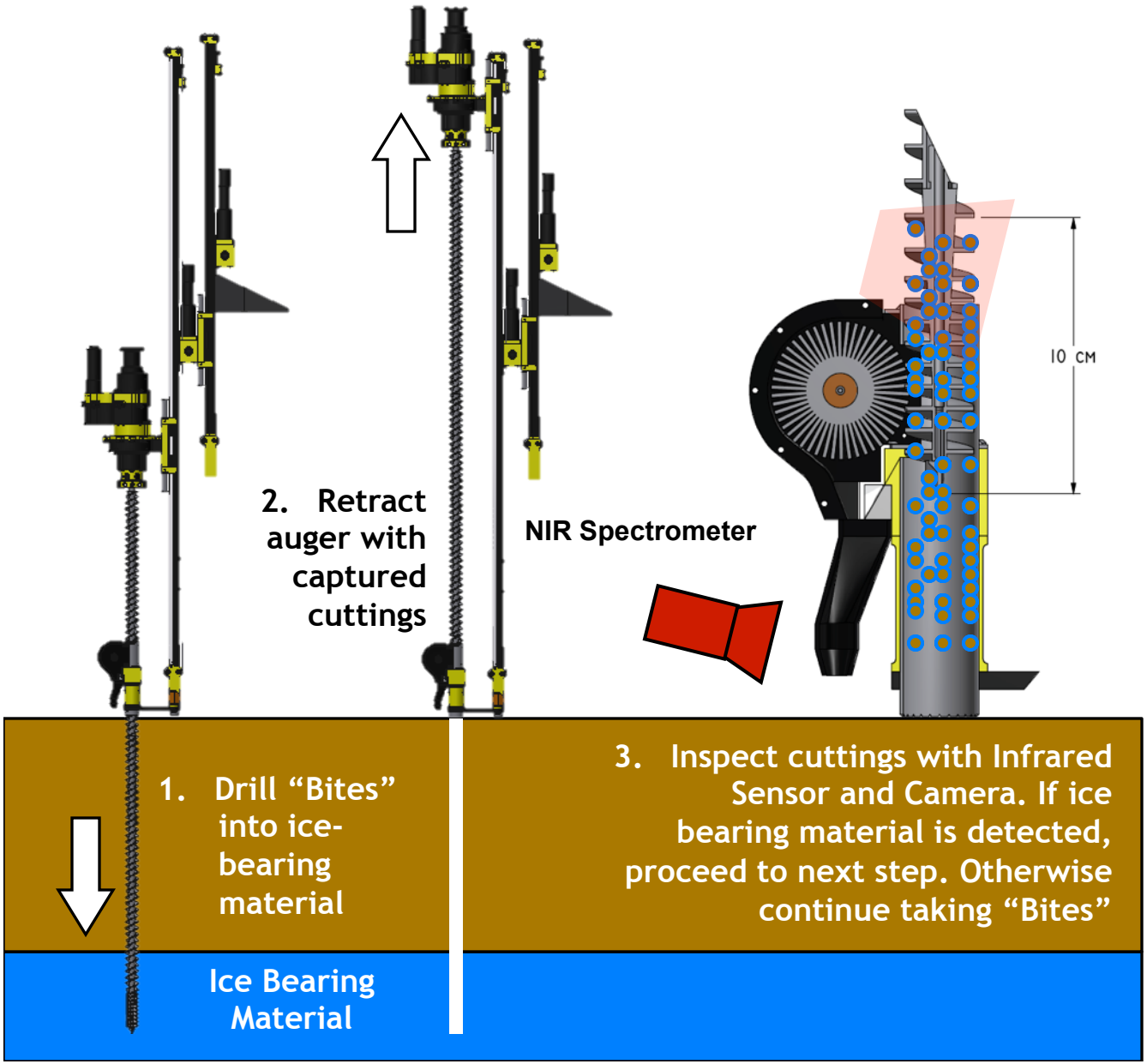
Science Payoff

“Bite” Sampling Concept

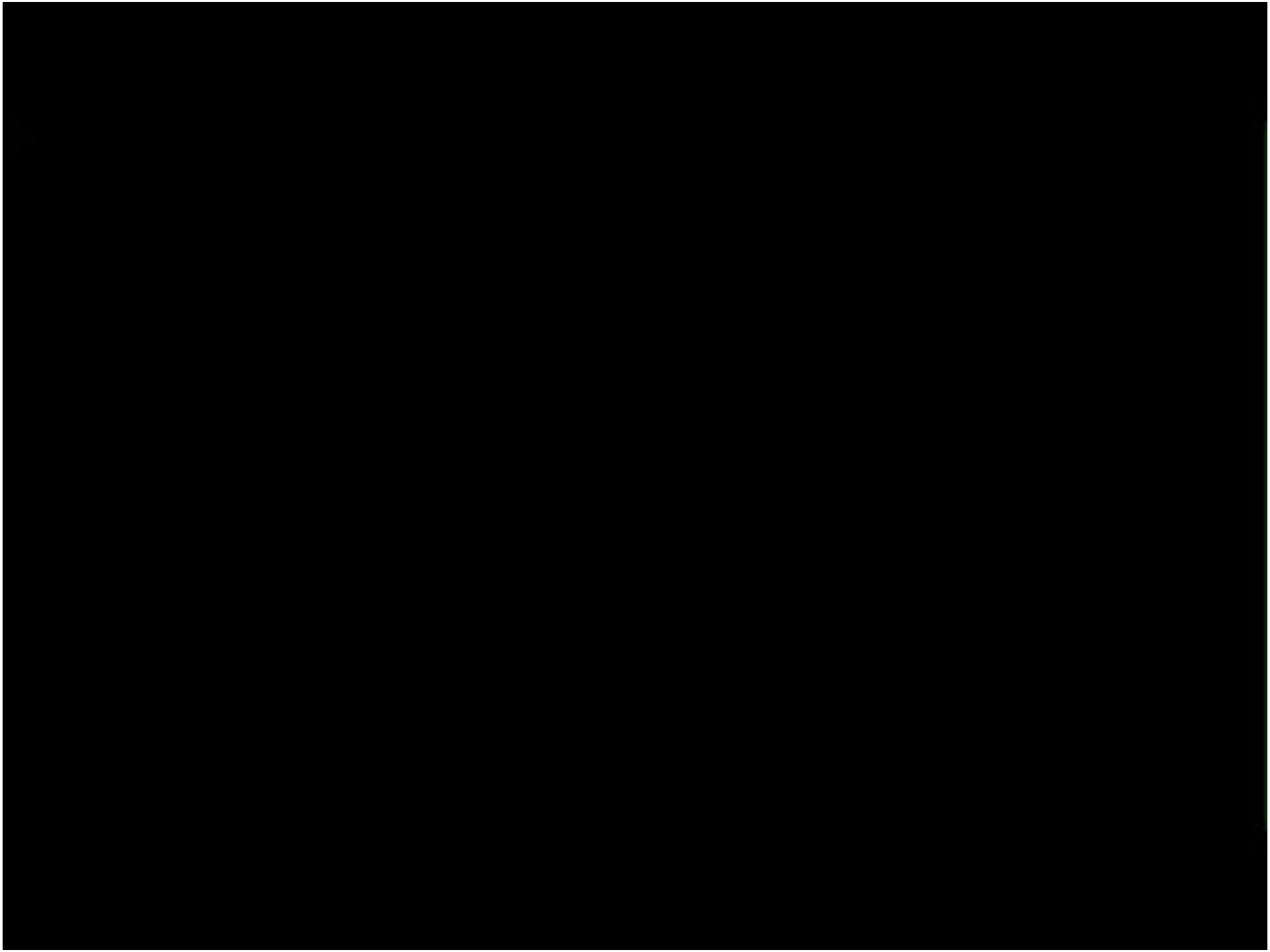
- Drill to 1 meter in short (~ 10 cm) “bites”
- Preserve stratigraphy in “bites”
- Lower risk (“graceful failure”) – if drill stuck at 60 cm, 5 bites done
- Time for analysis while drill in ‘safe’ place (above the hole)
- Time for subsurface to cool down



Implementation of "Bite" Sampling



4. Rotate and retract auger to deliver ice-bearing material still within sampling system



Lunar Chamber Demonstration

Tests at NASA GRC

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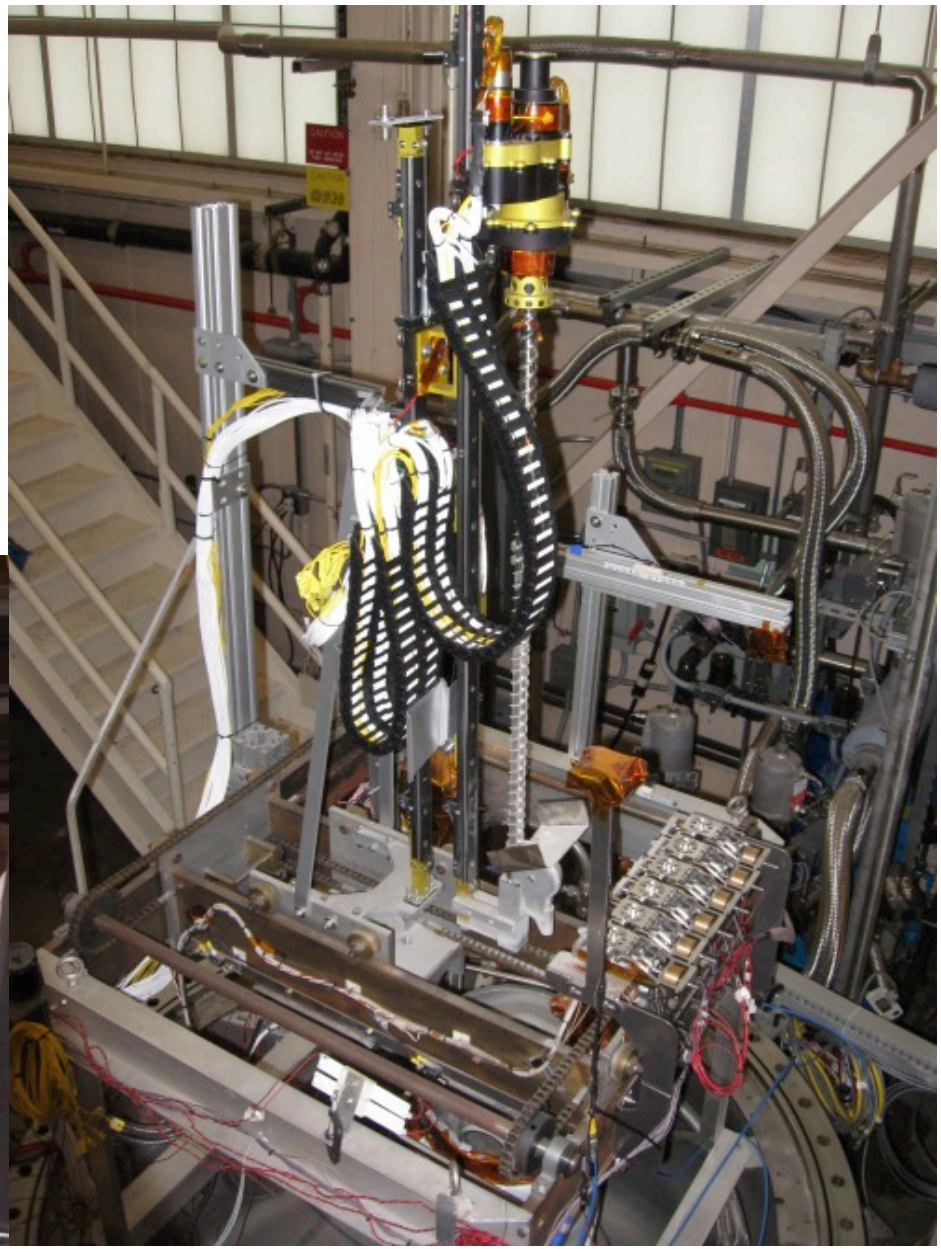
Background:

- Lunar chamber converted to 'dirty' chamber tests
- Soil:
  - NU-LHT-3M with 4-5 water wt%,
  - Vibratory compacted to ~1.5 g/cc
  - Temp: -140 C to - 90 C
- Chamber P: ~10^-6 torr
- Crucible T: -85 C to - 50 C (+10 C)

Goal:

1. Capture sample from 40 - 50 cm
2. Deliver to crucible
3. Seal



Setting up

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Sample Bin

Drill Assembly

LN2 Shroud

Top Lid

Cameras

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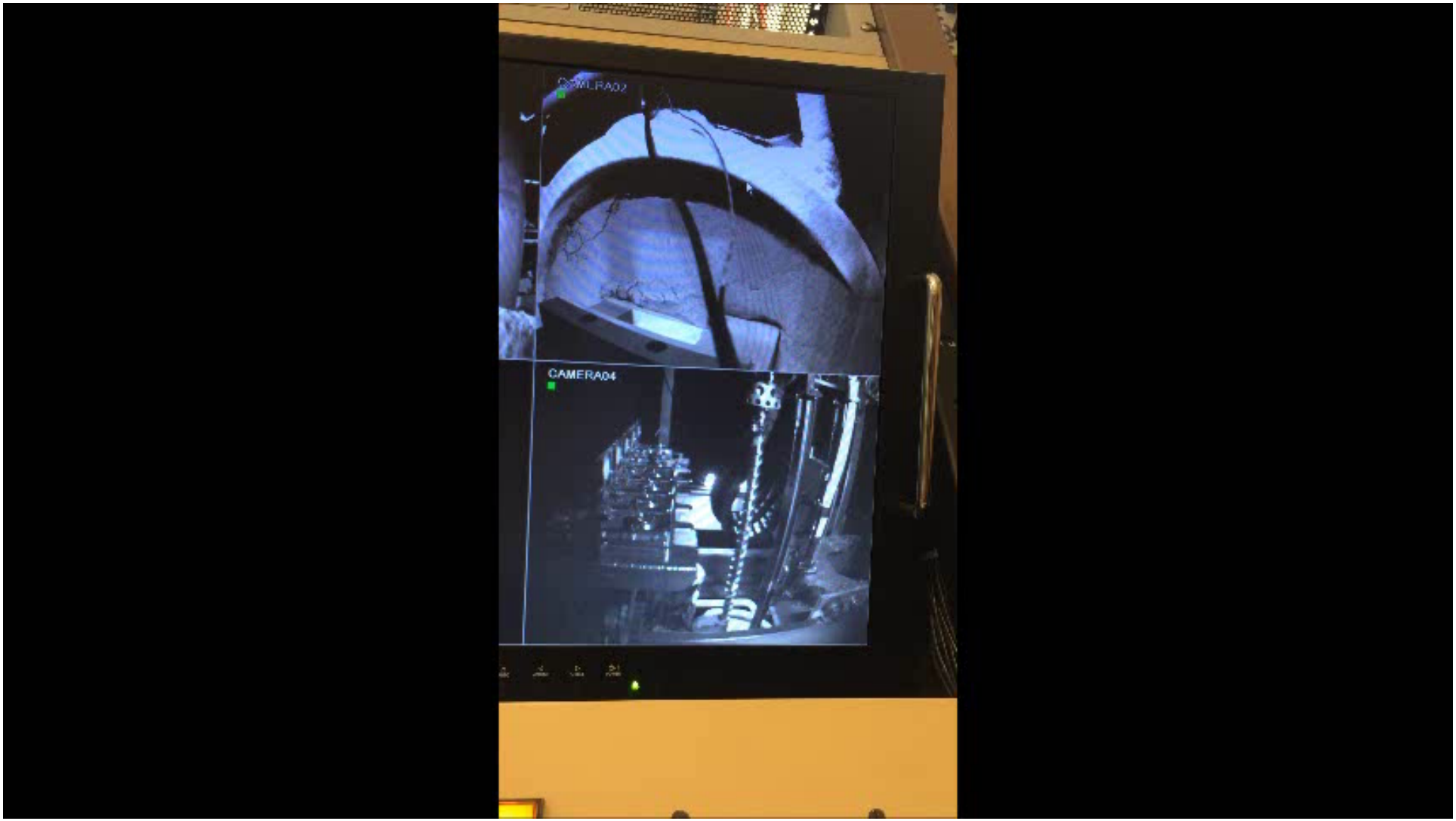
Seek-Drill-Dump-Close

Speed x4

Seek-Drill-Dump-Close

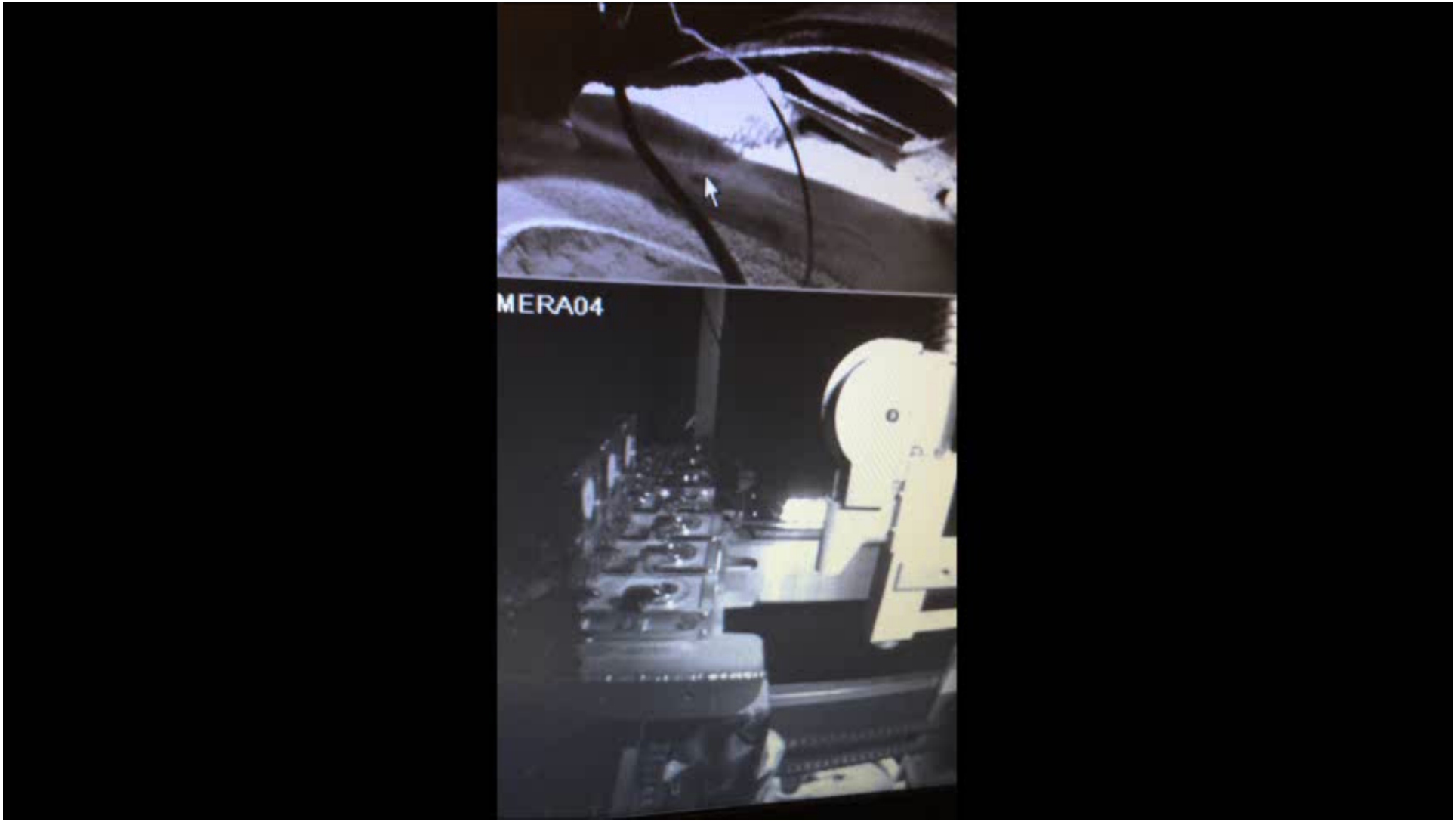


Speed x4

Seek-Drill-Dump-Close

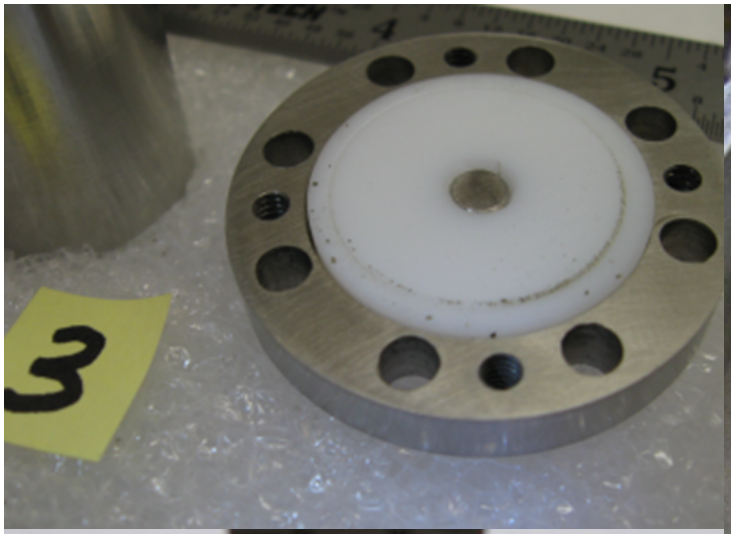
Speed x16

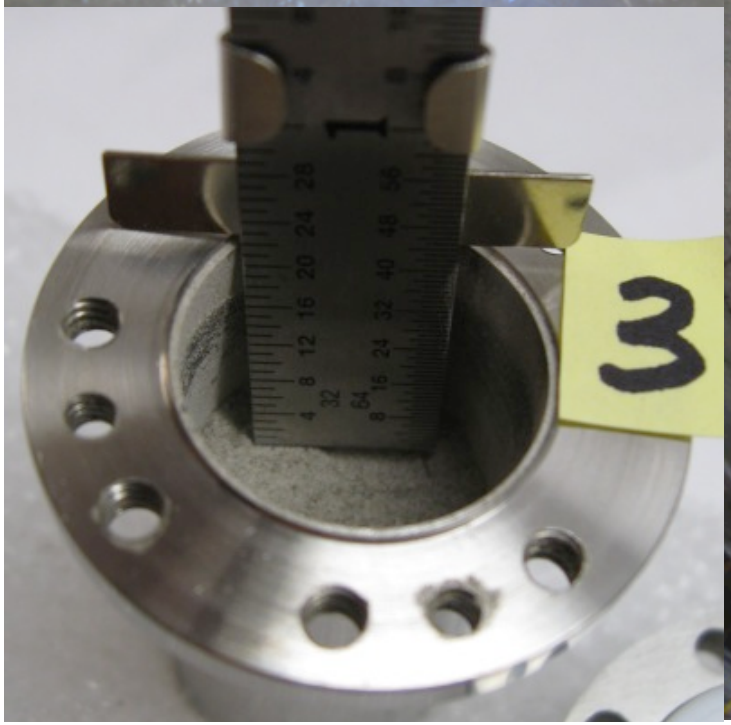
Seek-Drill-Dump-Close



Speed x1 (real time)

Drill holes and crucible

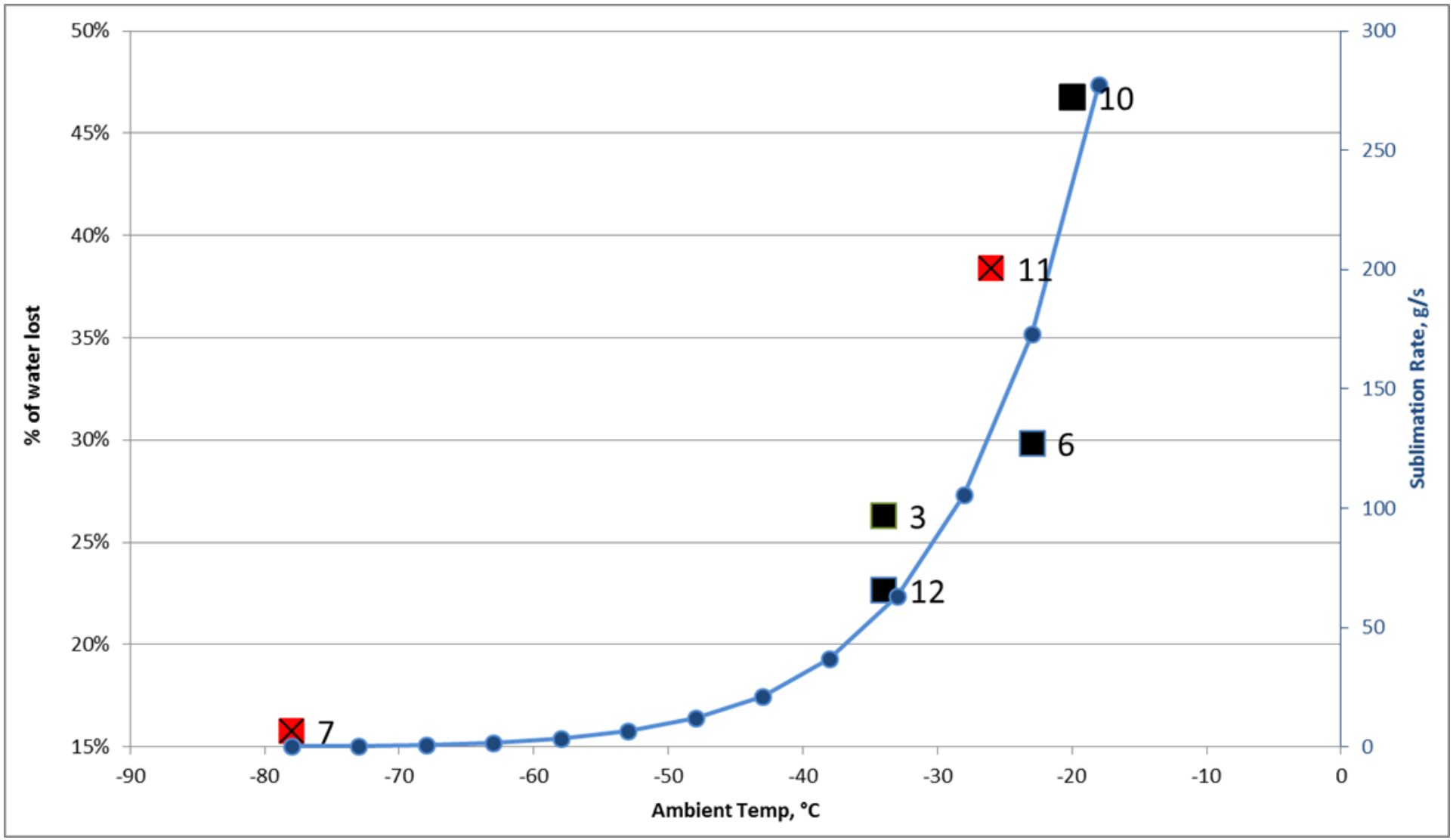




Results

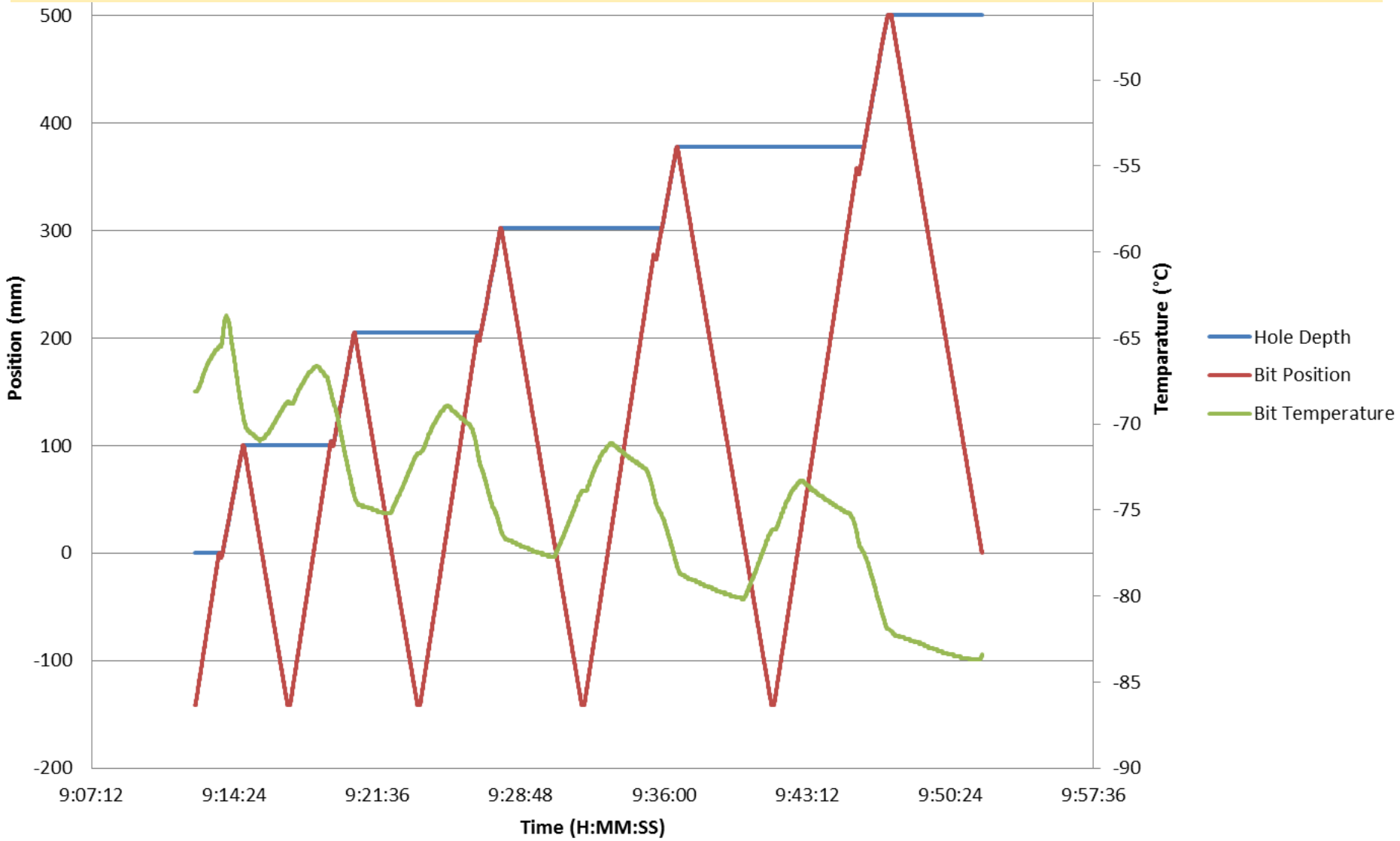
- **Water wt% = function(Temperature)**
  - Can preserve all water if T kept low

See Kleinhenz et al. 2015, AIAA SciTech



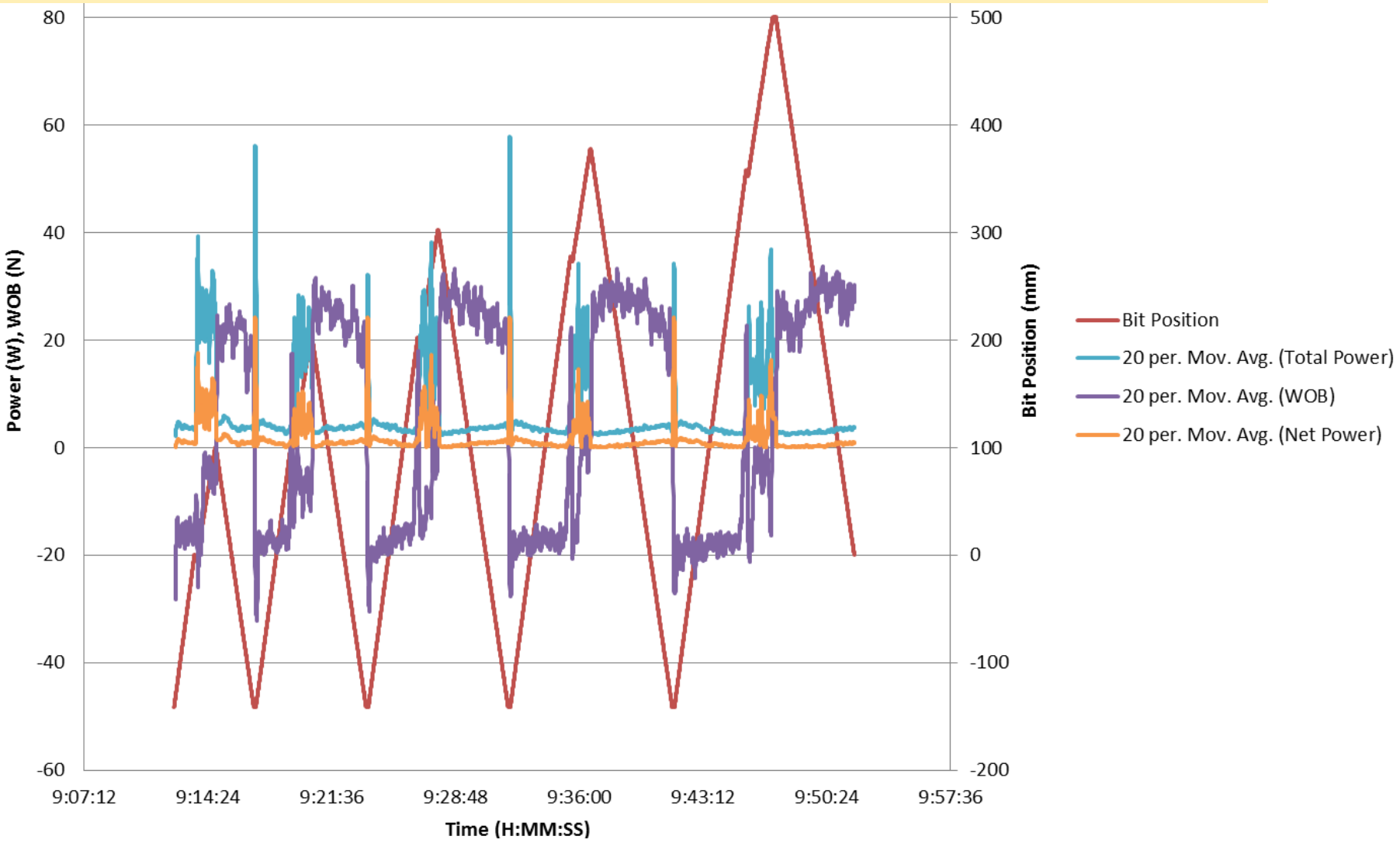
Drill Data

- Bit T was dropping during drilling because soil T was lower with depth
- Approx. 10 min to capture 10 cm “bite”



Drill Data

- Drilling Power ~20 Watt (percussion hardly ever used)
- Weight on Bit < 30 N
- Left drill in a hole for 45 min - no problem



Testing from the JSC RP Rover

Drill tests at JSC

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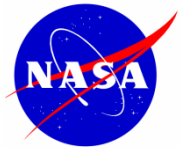
Acknowledgements



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- NASA ASTEP and ASTID
- NASA PIDDP
- NASA SBIR

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