Introduction to Extraterrestrial Drilling

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Jack Craft (Speaker)
craft@honeybeerobotics.com

Kris Zacny, PhD
zacny@honeybeerobotics.com

HONEYBEE ROBOTICS
Spacecraft Mechanisms Corporation

Honeybee Robotics Overview

Honeybee Develops Products & Technology for Advanced Robotic & Spacecraft Systems

Founded 1983, Privately Owned, Small Business

Aerospace, Defense and Commercial Industries

Systems to Components

End-to-End Capability

ISO9001 / AS9100 Certified

New York City, Denver, Pasadena

Client Focus · Teamwork · Continuous Improvement

Where you are, how you got there, and what you aim to do.

DRILLING THERE VS. DRILLING HERE

Where you are…

Local Environment

Atmospheric conditions (or lack thereof)

- Drilling fluids are impractical
  - Cuttings removal is a major concern
  - Heat dissipation is a major concern
- Some tried-and-true mechanisms need air to function properly

Gravity

- Low gravity means low downforce
- Microgravity means even less downforce

Regolith

- Local dust may be highly abrasive

…how you got there…

Packaging for Spaceflight

- System mass is highly constrained
- The drill must fit within the spacecraft’s launch envelope
- Power is constrained

…what you aim to do.

Mission Specific Constraints

The act of drilling may alter the target material.

- Forward contamination
- Cross contamination
- Alteration of morphology
- Loss of volatiles

Meeting the Challenges

Dry drilling

→ Mechanical or pneumatic cuttings transport

→ Duty cycling to manage heat buildup

Low available reaction loads

→ Low downforce, rotary percussion, penumatics

Mass/volume constraints

→ Spaceflight-specific designs, highly efficient mechanisms

Sensitive target materials

→ Contaminant-free materials

→ Contamination-reducing operating protocols

→ Duty cycling to manage heat buildup

History

WHERE WE’VE BEEN

History

Moon

- Apollo drive cores (Apollo 11-17)
- Apollo Lunar Surface Drill (Apollo 15-17)
- Soviet Lunar Drills (Luna 16, 20, 24)

Venus

- Soviet GZU (Venera 13, 14, Vega 1, 2)

Mars

- MER Rock Abrasion Tools
- Phoenix Icy Soil Acquisition Device
- MSL Powder Acquisition Drill System

Near Surface

1-2 meters

Deep Drills

WHERE WE'RE HEADED

NanoDrills

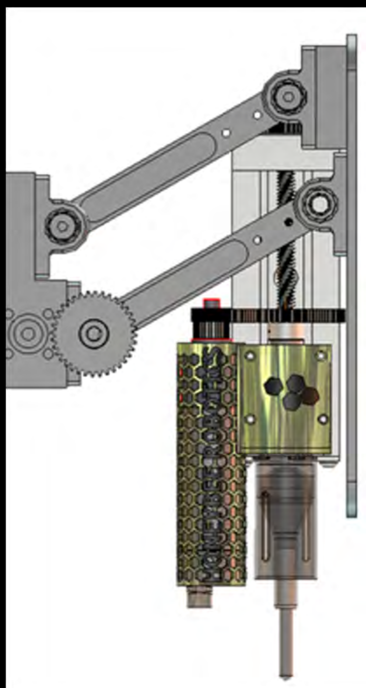
Sample Return

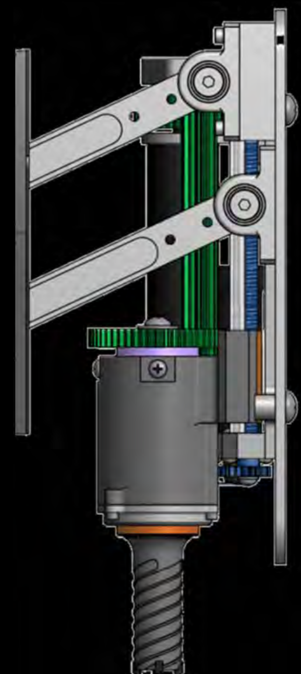
NEAR SURFACE

Near Surface – NanoDrills

Powder

Coring



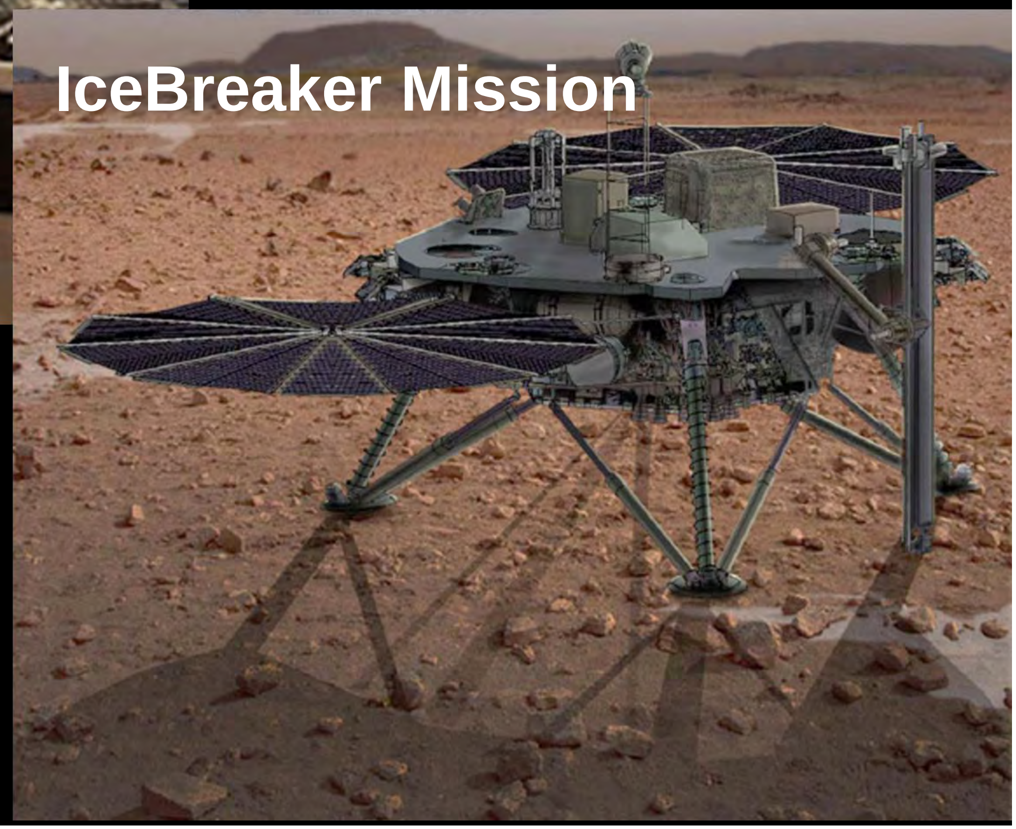


Near Surface – Sample Return

IceBreaker

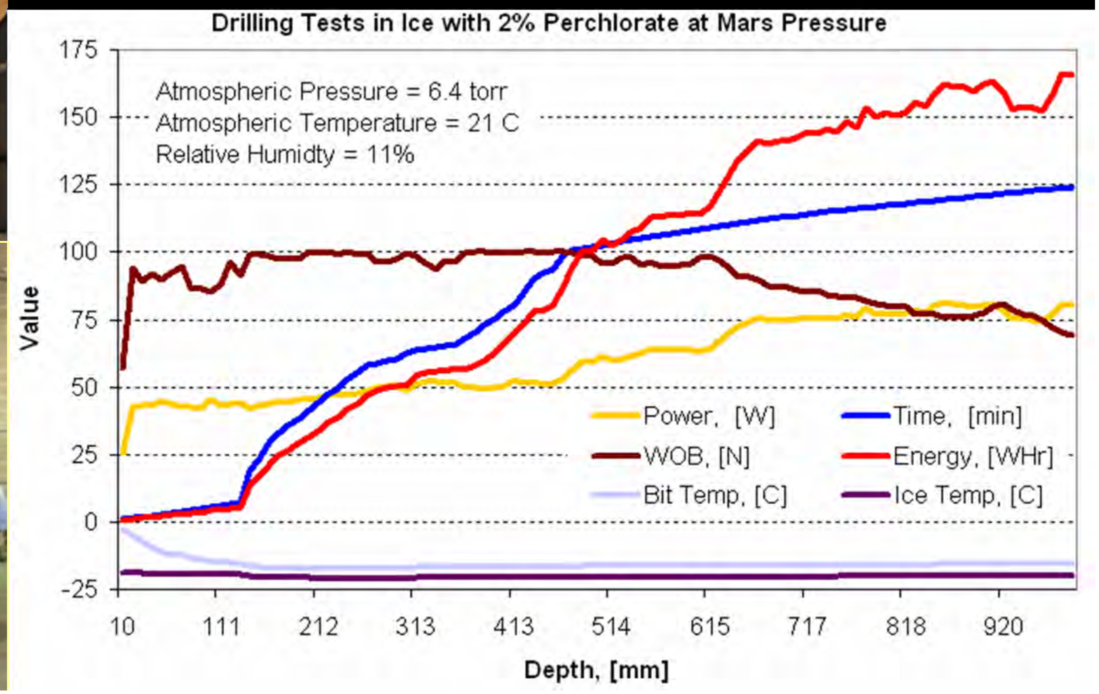
1-2 METER DRILLS

Mission Concept: Drill on a Lander



Test in Mars chamber

- 1m depth in 3.5m chamber
- Tests in
  - ice (w and w/out perchlorate)
  - icy-soil
  - rock
- Drilling at 1-1-100-100 level: 1m in 1 hr with 100 Watt and 100 Newton WOB



Antarctica Dry Valleys: Mars Analog

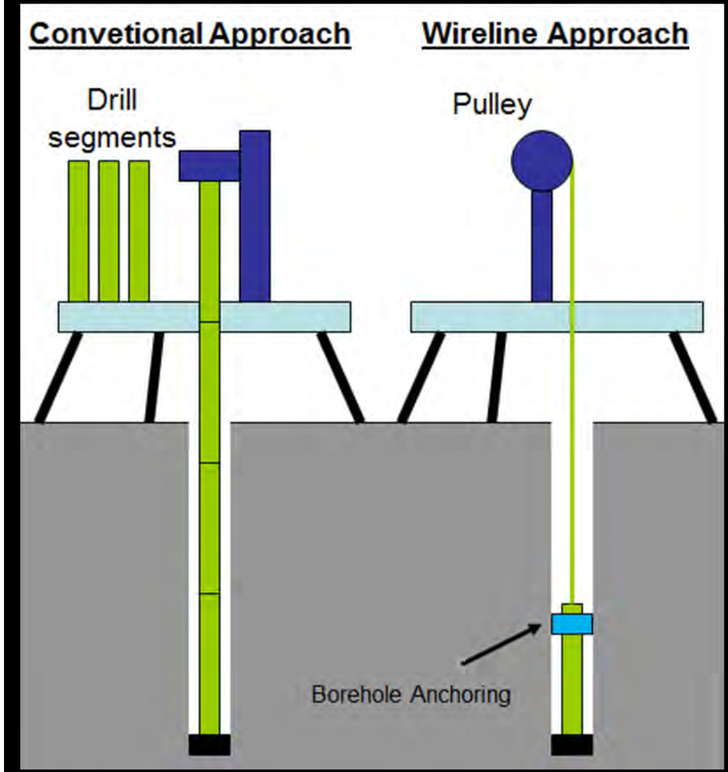
Ice cemented ground: 1m
Massive Ice: 2.5 m

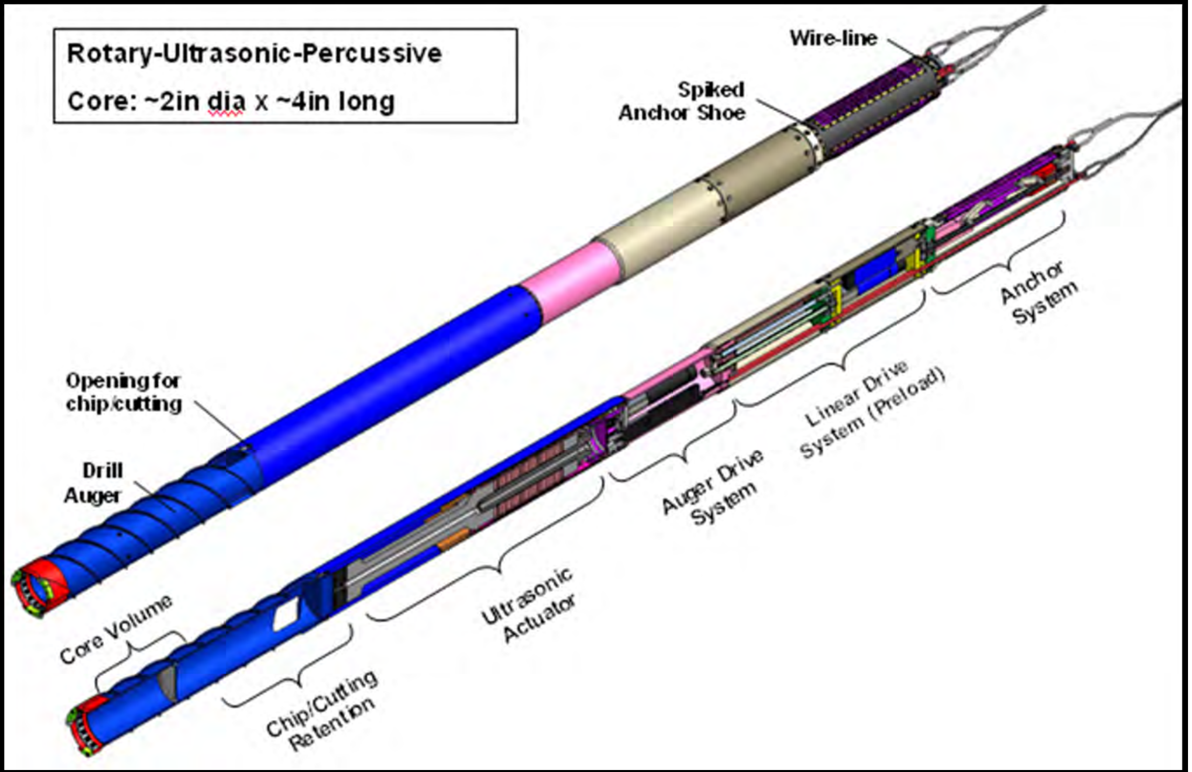
Drill Parameters:

- **Power: ~100 Watt**
- **Penetration Rate: 1 m/hr**
- **Weight on Bit: < 100 N**

DEEP DRILLS

Rotary-Ultrasonic Wireline Drill



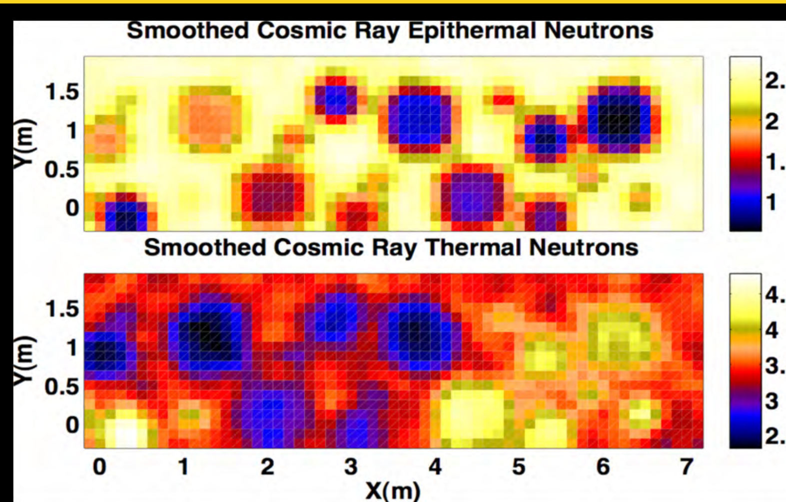


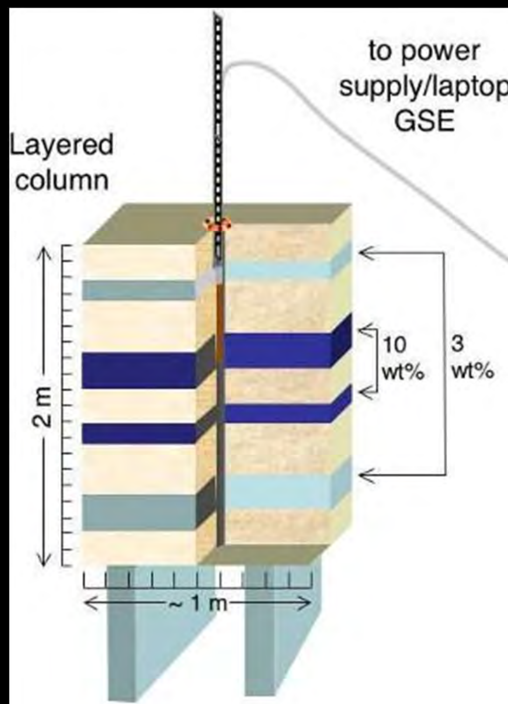
DRILLS AS INSTRUMENTS

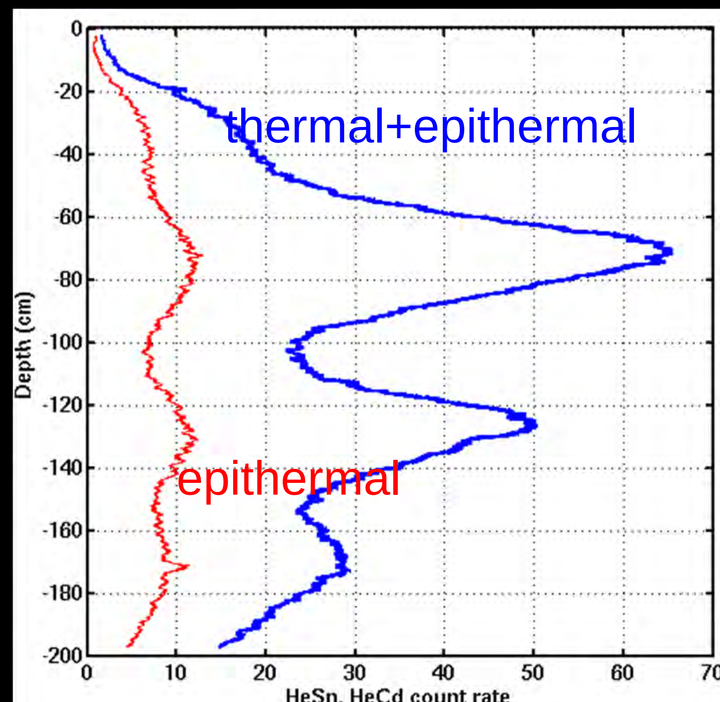
Drill Integrated Neutron Spectrometer

Neutron Spectrometer

- Hydrogen → Water
- Rover Based: H2-rich regions
- Drill based: Groundtruthing

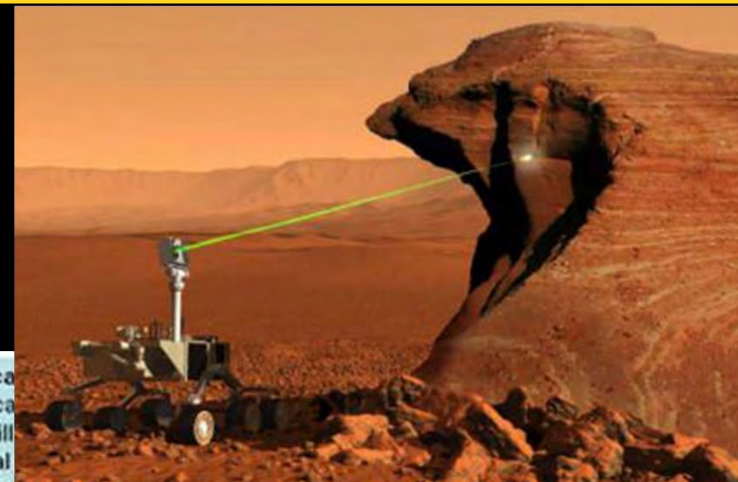


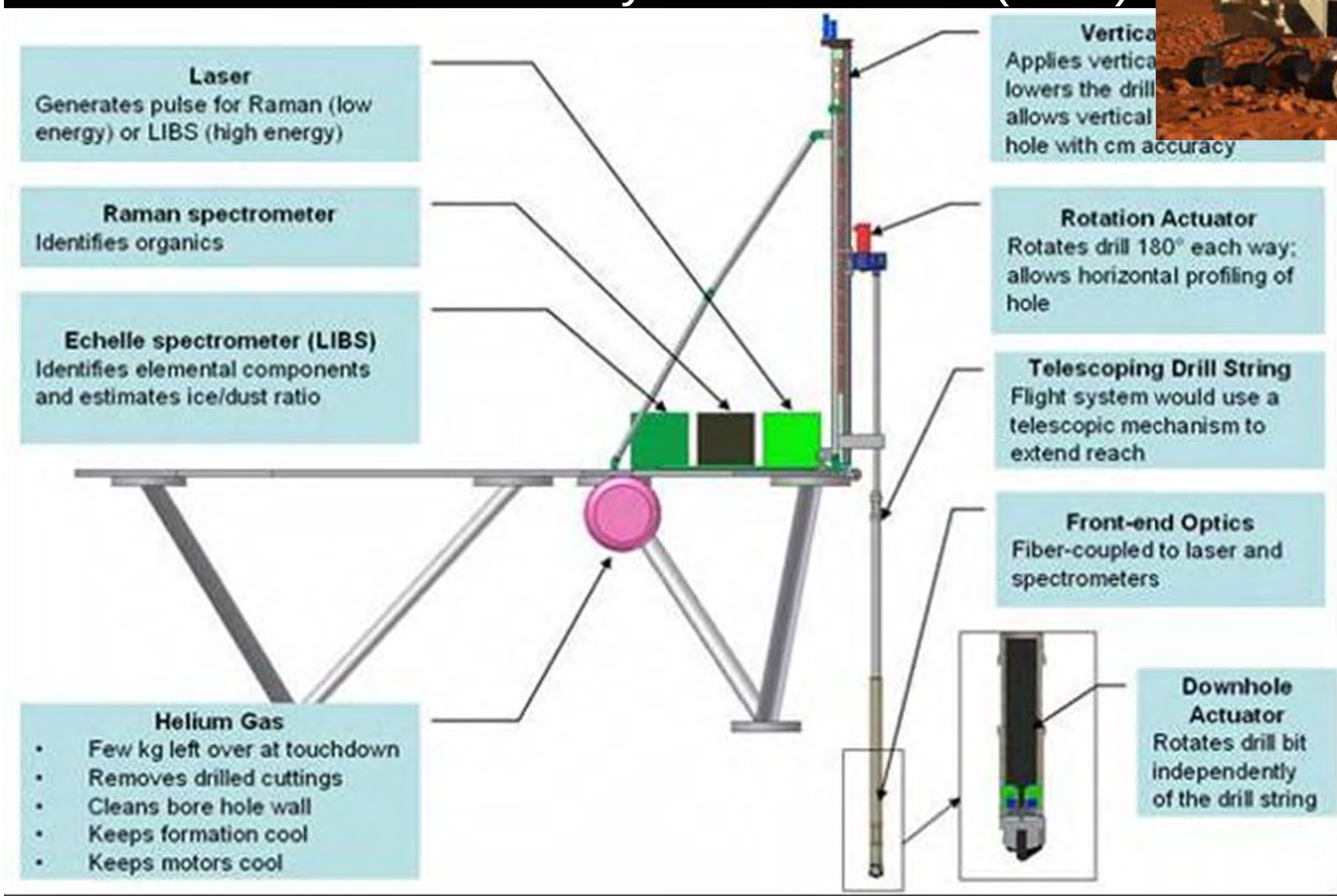


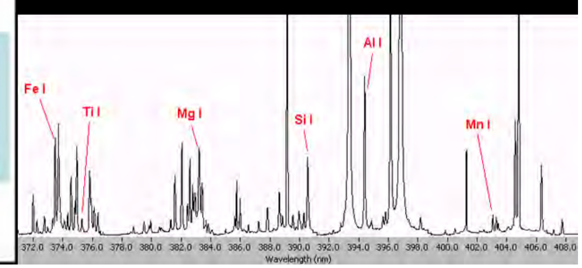


Drill Integrated Laser Induced Breakdown Spec

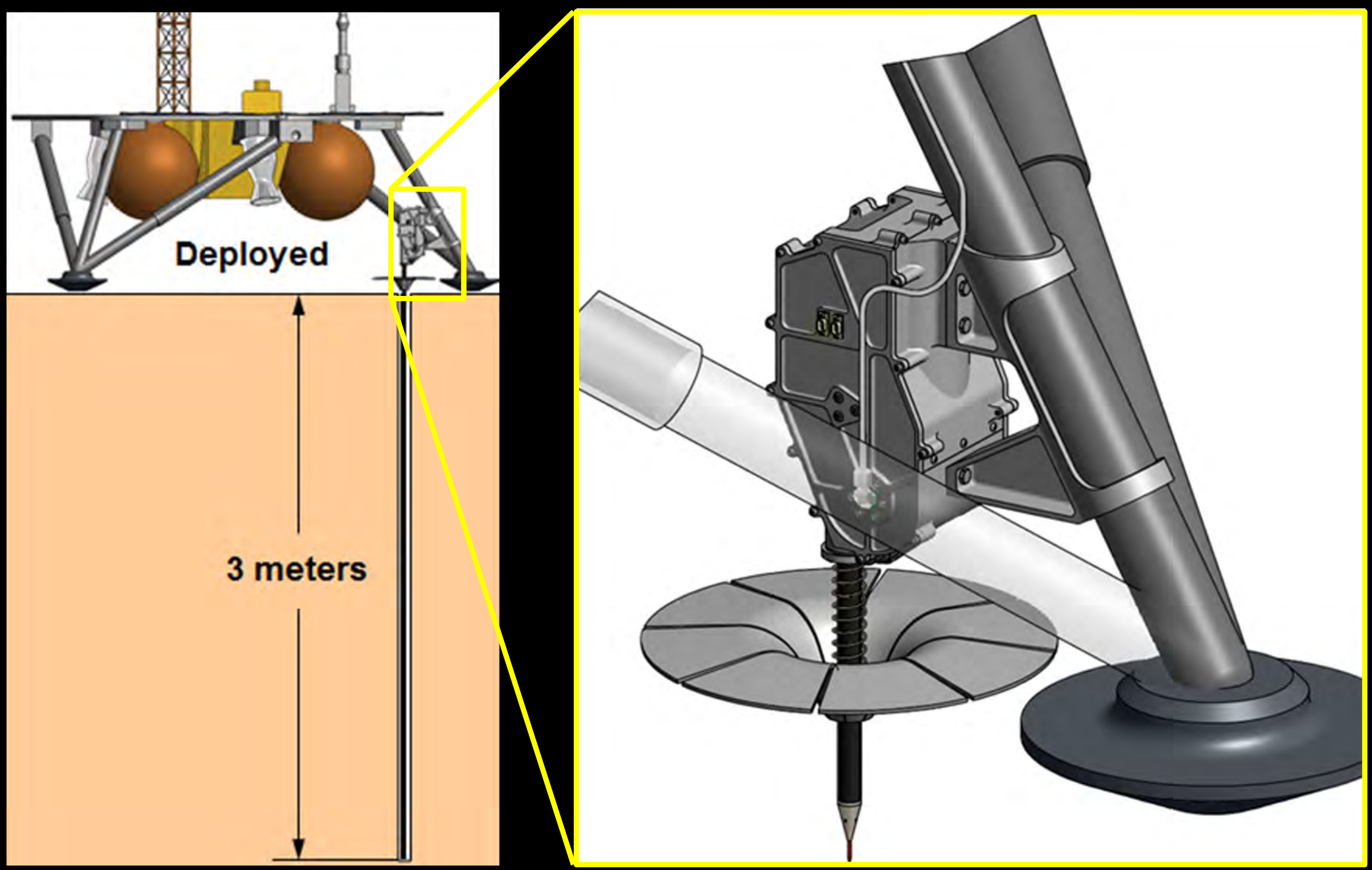
- Stand off 3D subsurface elemental composition
- Need laser and spectrometer
- More robust than X-ray Fluorescence (XRF)







Heat Flow Probe



Questions & Discussion

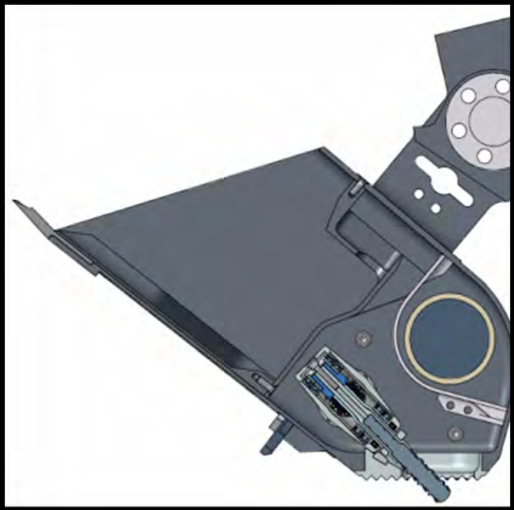
Thank you!

BACKUP SLIDES

Regolith Acquisition

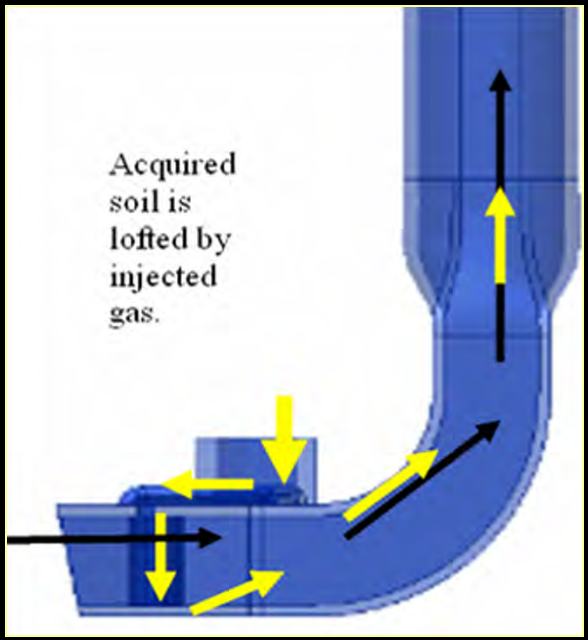
Phoenix: Scoop and RASP

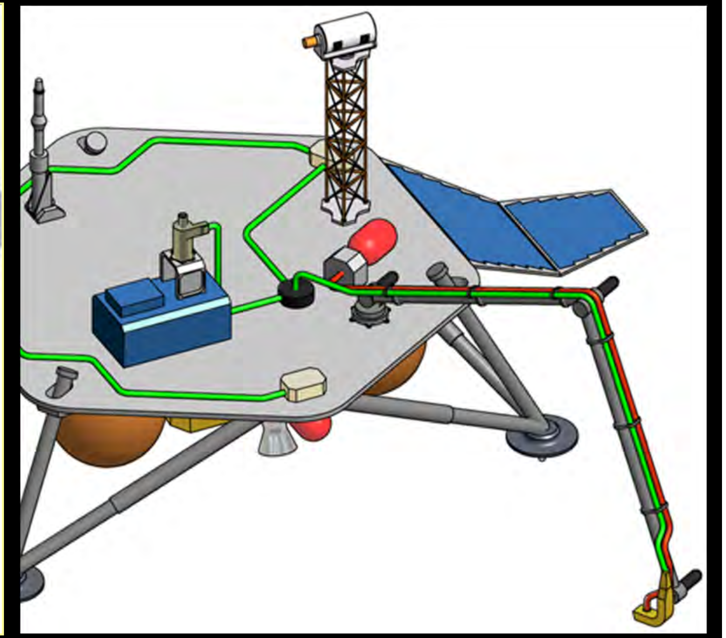
- First hardware to touch extraterrestrial ice
- Scoop removes loose layer
- RASP acquires permafrosted soil/ice



Pneumatic Scoop

- No moving parts
- End to end soil acquisition and delivery
- 1 g gas → 6000 g soil
- Can use He pressurant





Regolith Acquisition

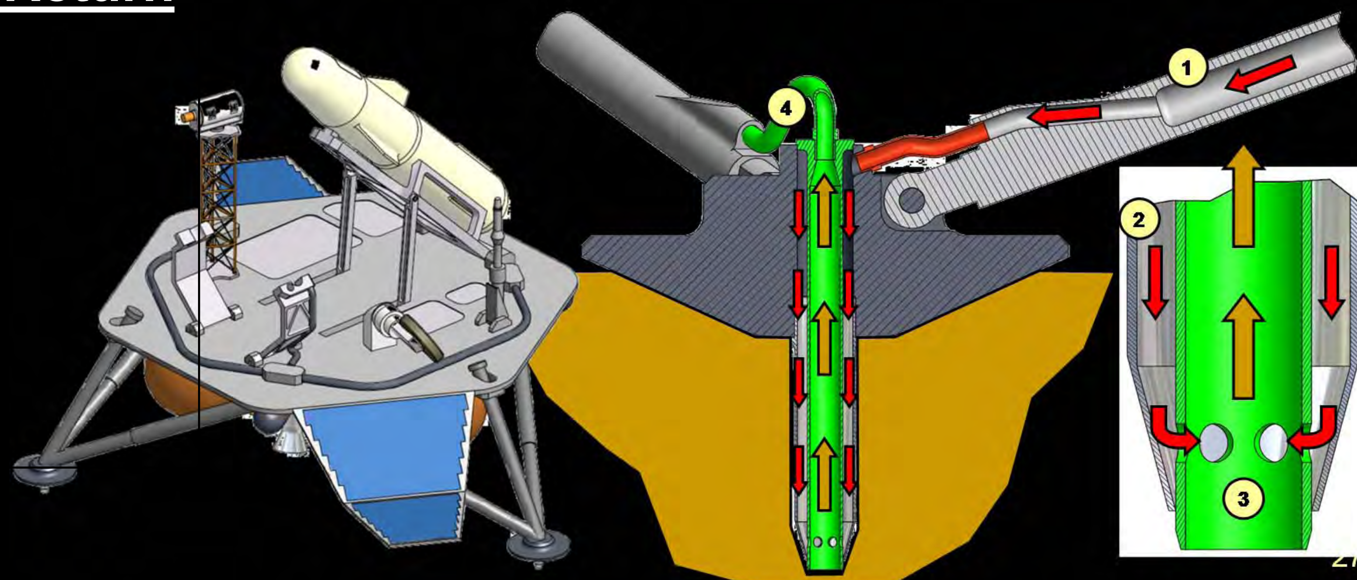
Rover based Sampler

- Rover drags/plows nozzle
- A puff of gas moves acquired soil into an instrument

Pneumatic Sample Return

Almost Passive:

1. open gas valve
2. close capsule



References

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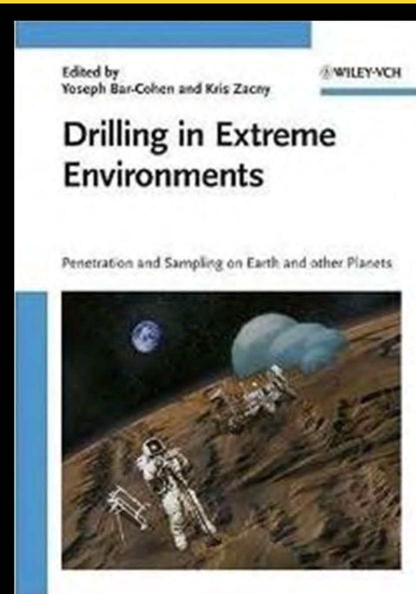
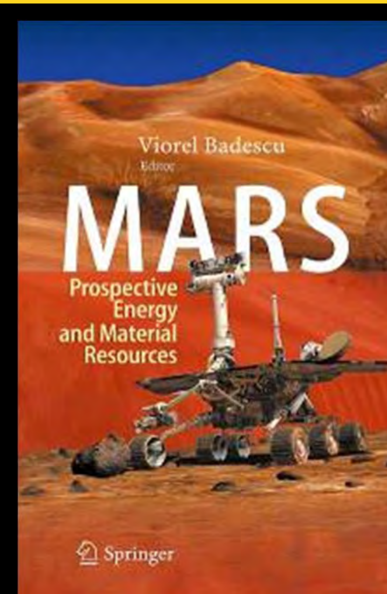
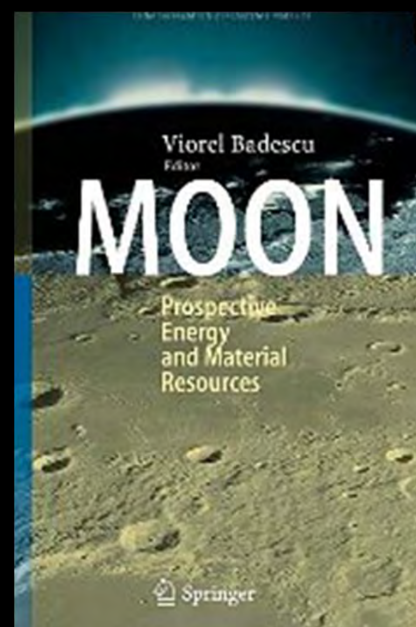
“Drilling and excavation for construction and in situ resource utilization,” Chapter 15 in V. Badescu (Ed.), <u>Mars: Prospective Energy and Material Resources</u>,

K. Zacny,

“Drilling and excavation for construction and in situ resource utilization,” Chapter 15 in V. Badescu (Ed.), <u>Moon: Prospective Energy and Material Resources</u>,







Asteroids