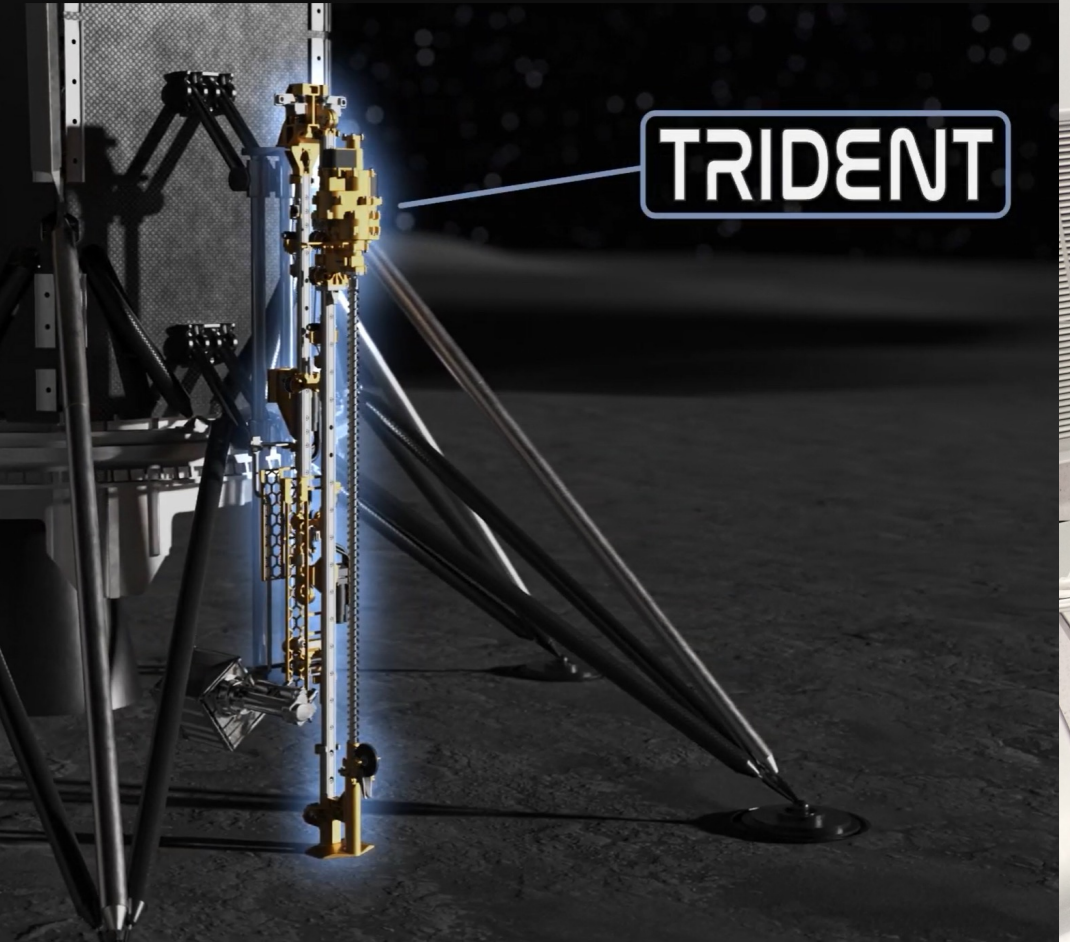

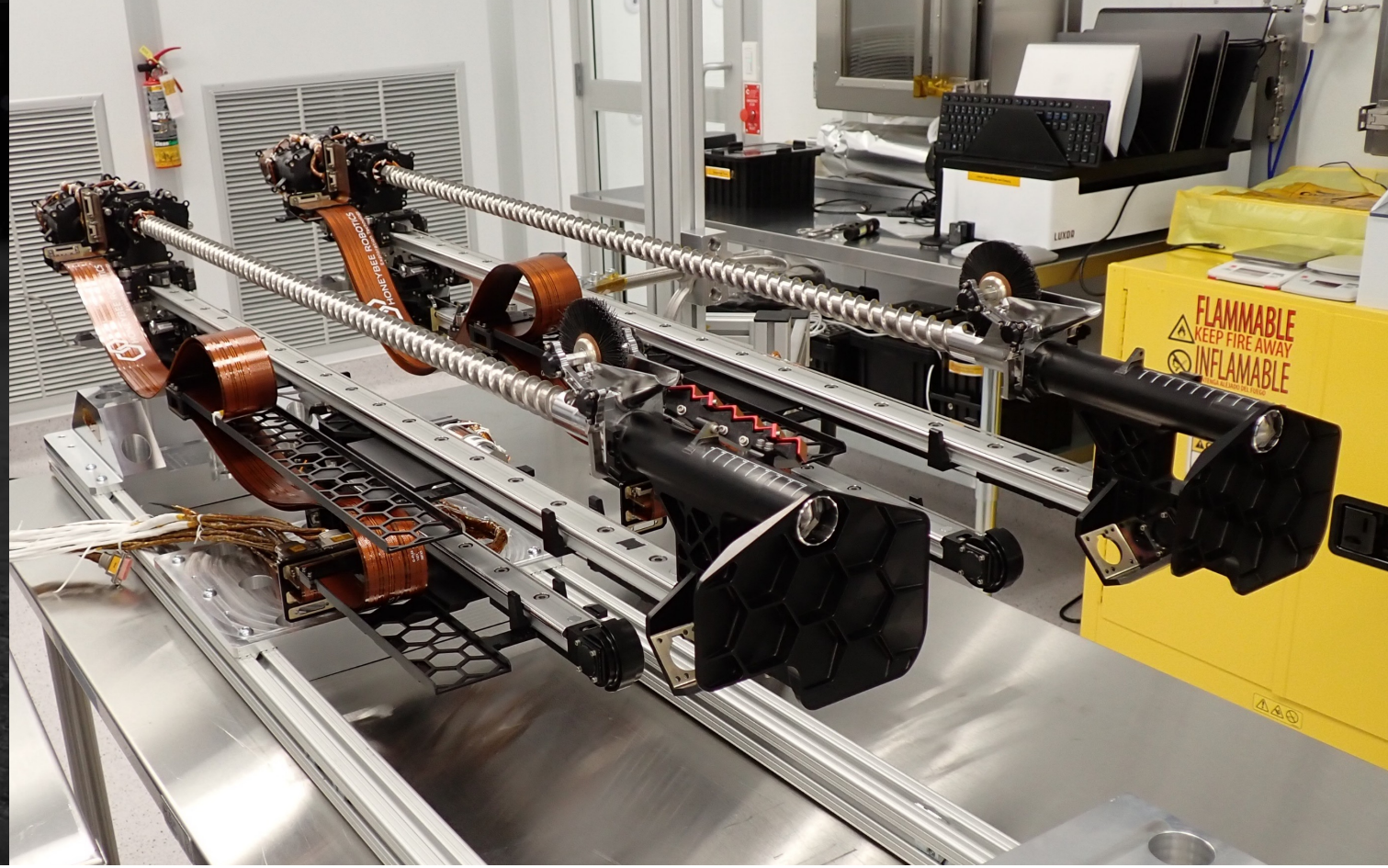

A Test Campaign to Baseline Flight Telemetry for the TRIDENT Lunar Drill on PRIME-1 and VIPER

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HONEYBEE ROBOTICS

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TRIDENT Overview

One-meter rotary percussive drill

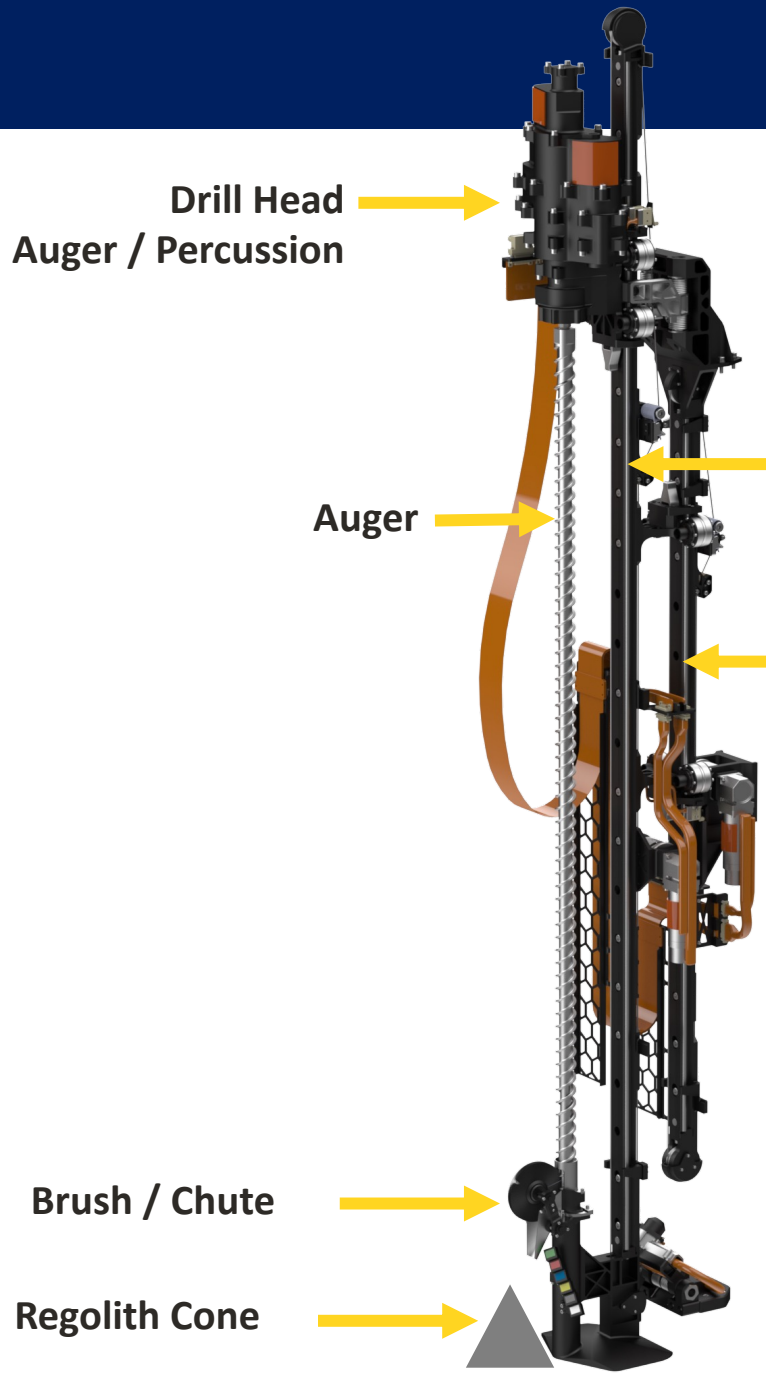
Bite sampling approach

Designed to be used with lander- or rover-mounted instruments to determine abundance of volatiles at lunar south pole

Drill itself is also as an instrument capable of making useful geotechnical measurements

Testing in known materials is instrumental in baselining TRIDENT telemetry → will enable us to better interpret data from the Moon!

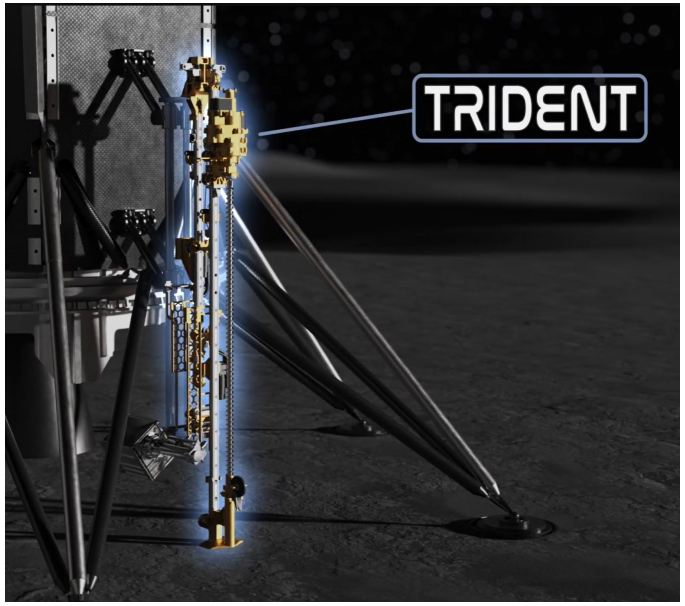
New avionics require a new baseline

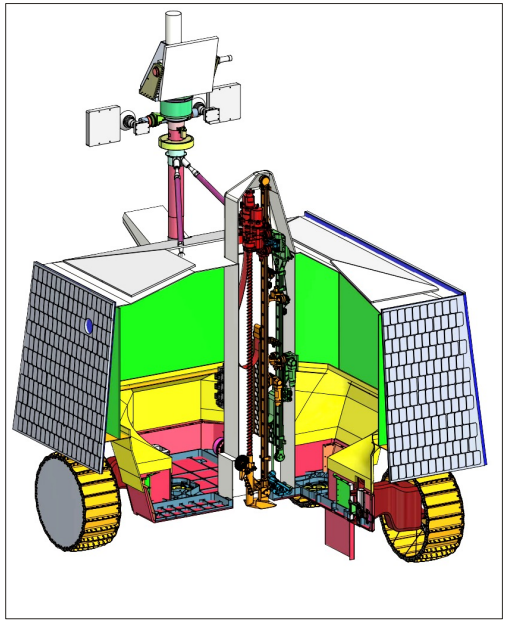


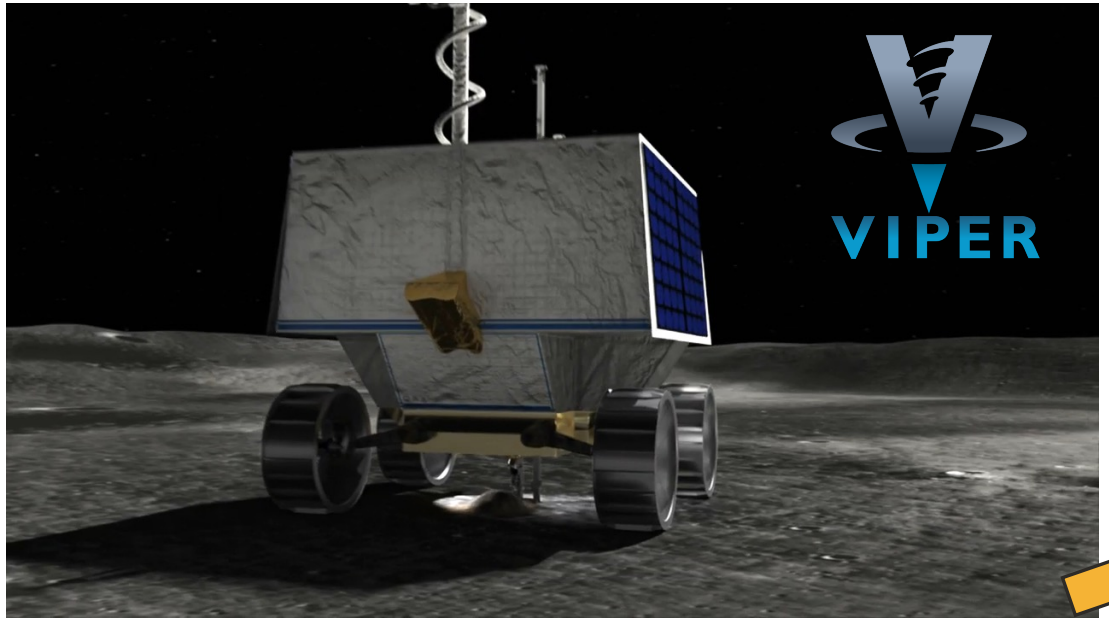
Avionics Box

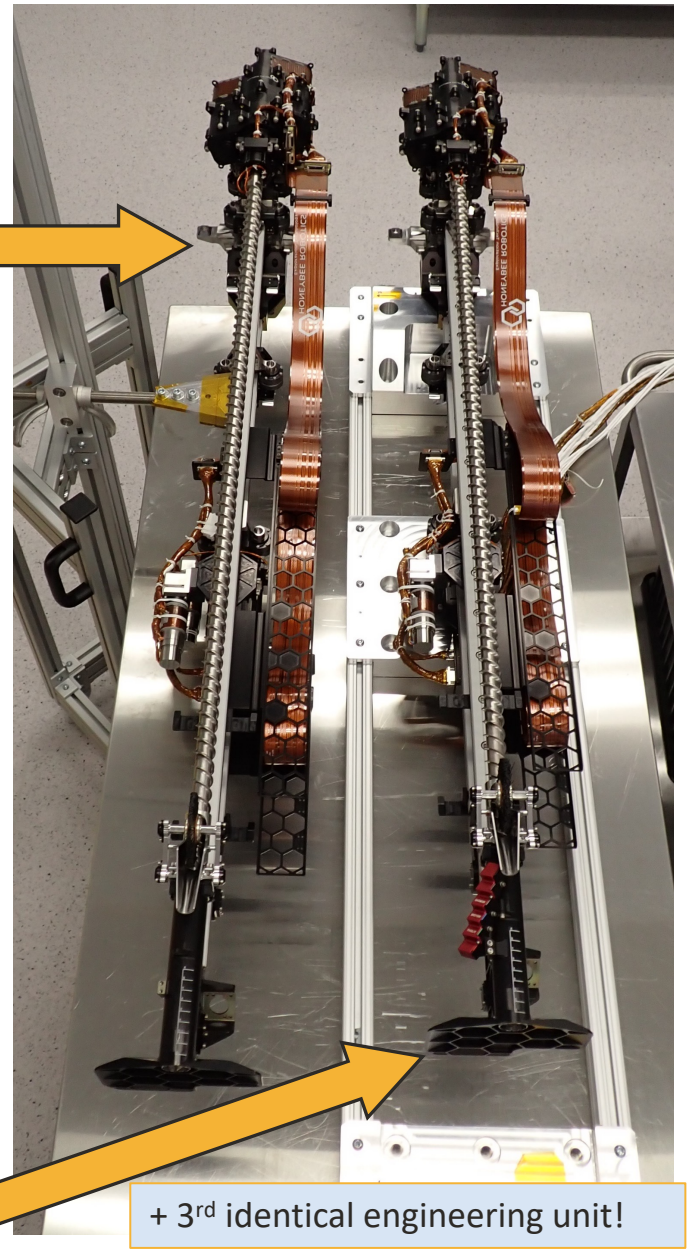
Upcoming Missions: PRIME-1 and VIPER

HONEYBEE ROBOTICS







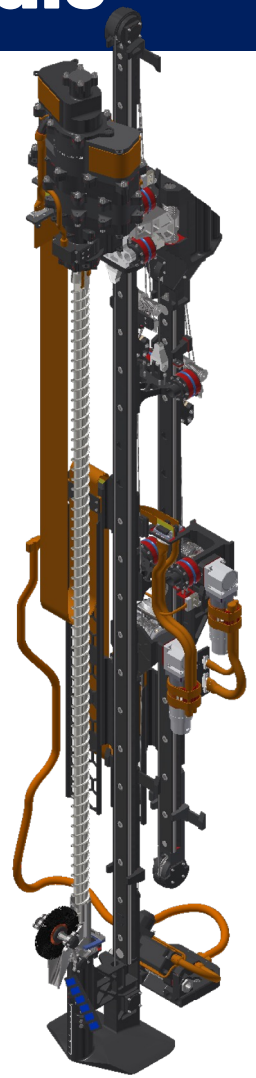


+ 3rd identical engineering unit!

PRIME-1

Polar Resources Ice Mining Experiment-1

Fall 2023 Test Campaign Goals



Key VIPER Engineering Requirements

- Perform 1X life test (24 holes)
- Verify drilling speed (1 m hole in <2 hrs)
- Demonstrate stratigraphy resolution
- Provide power consumption estimates for various operations
- Testing to be done with engineering unit, identical to flight units

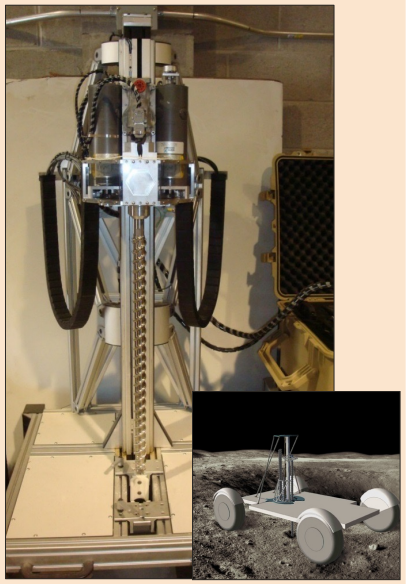
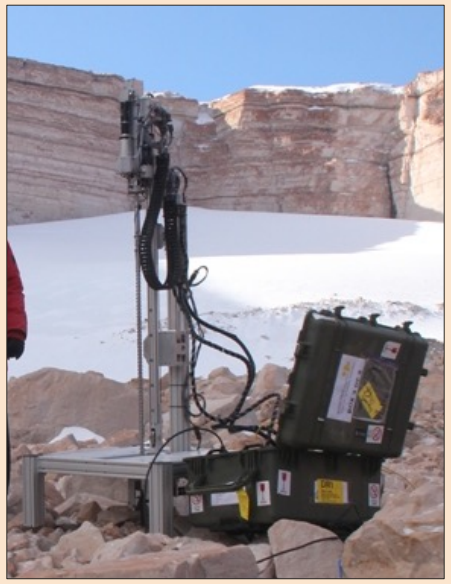
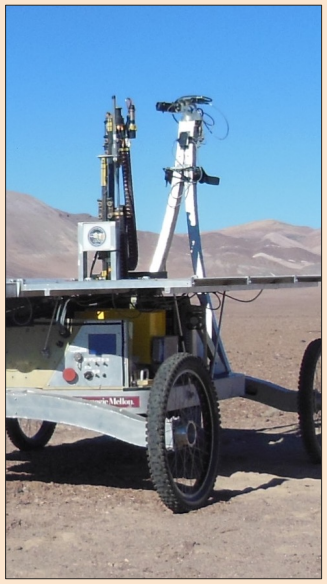
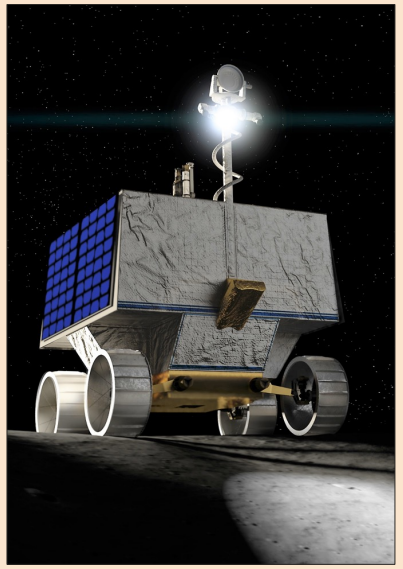
Additional Outcomes

- Cover edge cases in potential mechanical and thermal properties
  - Characterize auger thermal response
  - Characterize drill telemetry correlation to subsurface boundary layers and material strength
- Inform lunar operations and create “training data” for operators

TRIDENT flight avionics are different from development units. Until we run these tests, there will be no meaningful baseline / calibration curve against which we can compare lunar data

Development & Test History

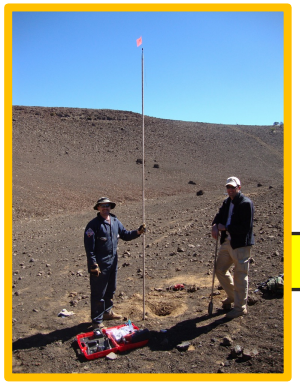
HONEYBEE ROBOTICS

Version:		CRUX ('05-'07)	Icebreaker ('08-'10)	LITA ('10-'13)	RP ('14-'18)	TRIDENT ('19-)
Image:						
TRL:		3	4	5	6	Lunar flight configuration!
Major Tech:		Rotary vs Rotary-Percussion	Cable-Pulley Z-stage Bite Sampling Hammer mechanism (Apollo)	Drill mass Avionics mass	Lunar-rating (P, T)	
Form-Fit-Function:		Function	Form-Function	Form-"Fit"-Function	Form-Fit-Function	
Tests	Chamber:	Mars	Mars	Mars	Lunar	
	Field:	Arctic	Arctic, Antarctica (Remote Ops)	Atacama, Arctic, Greenland	JSC Lunar Yard (rover) Atacama	
	Rover:	--	--	CMU Zoe	RP, KREX2	
	Vibe:	--	--	--	Vibe	

Field Testing

Nature offers “geological uncertainty” → ultimate hardware test
Operational experience is unparalleled → logistics around “doing stuff” in remote location is eye opening

Devon Island



Big Island

Atacama

Greenland

Houston

Dry Valleys

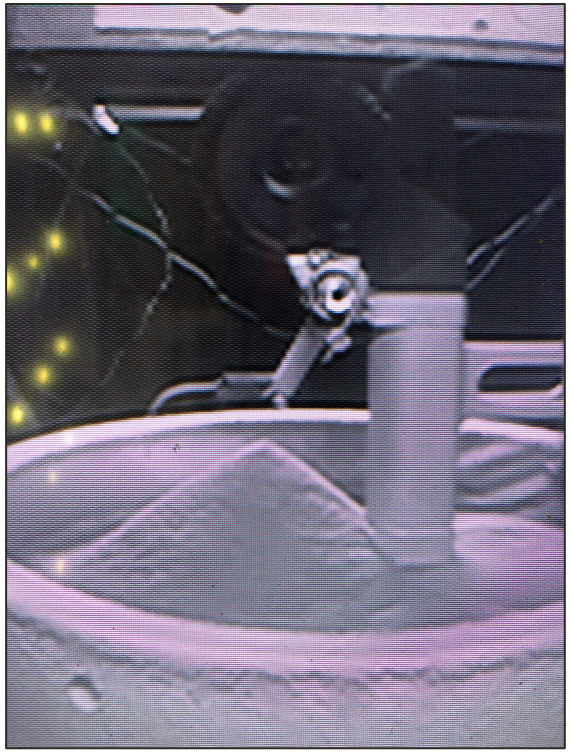
Notable Lab Testing: Integrated T-Vac at GRC

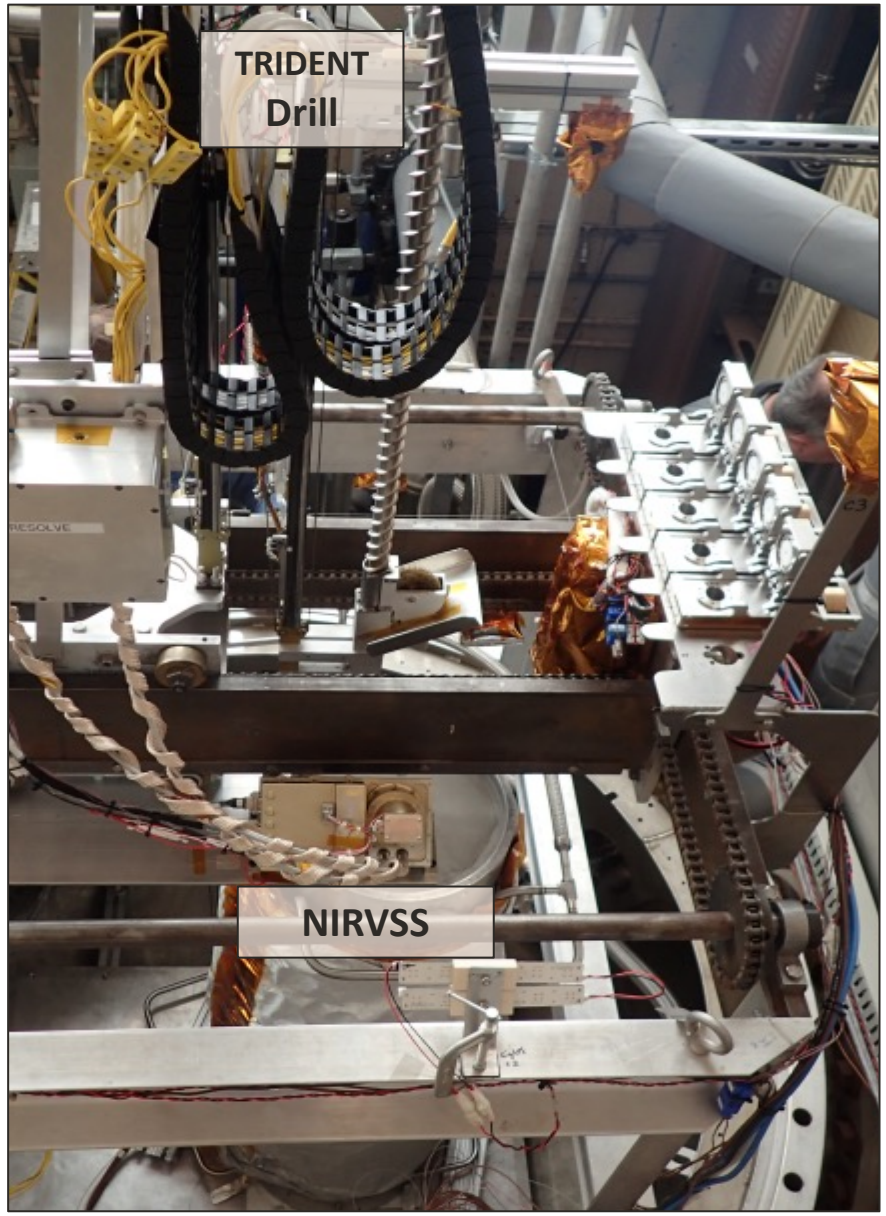
Integrated test with NIRVSS and MSOLO to validate drill ops

Drilled over 30 holes in controlled simulant bins

- Vacuum level: < 1 x 10^{-6} torr
- Regolith temp.: < -150C
- Simulant: NU-LHT-3M (dry, 2.5 wt. % H_2O, 5 wt. % H_2O)

This testbed and procedure will be largely replicated at Honeybee





T-Vac Facilities at Honeybee

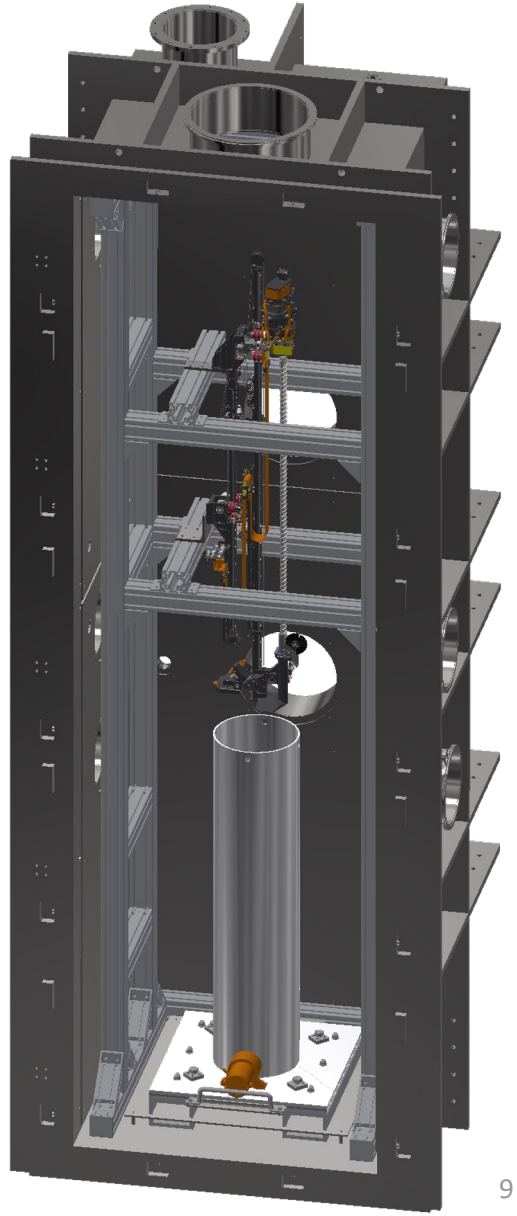
3 m tall lunar vacuum chamber

3X cylindrical simulant bins for regolith and icy regolith tests (same as GRC)

- Vibration motor for compacting regolith
- LN2 reservoir clamshell to bring bin to temperature in < 24 hrs

Walk-in freezer for icy regolith simulant preparation

Procedures adapted from GRC testing for simulant prep, assay, and loading

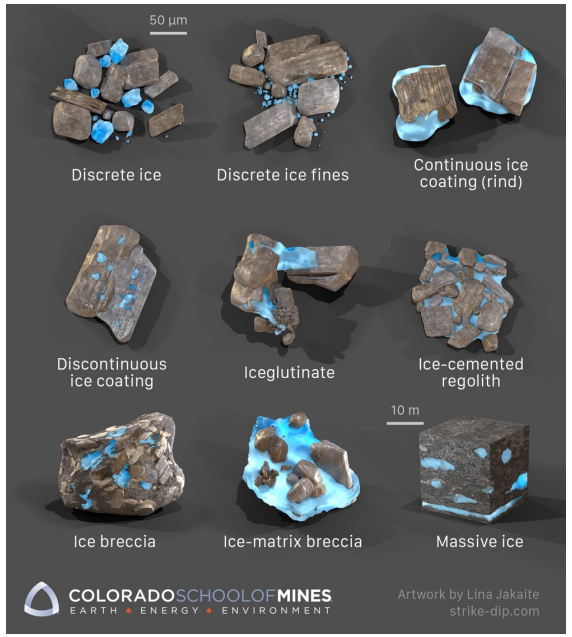


TRIDENT demonstration in a block of limestone (left) and 3D model of simulant bin in chamber for engineering test (right)

Test Matrix

TEST ID	SUBSTRATE	INCLUSIONS	% WT. H2O	PREP METHOD
1	Limestone	None	0%	--
2	Limestone	None	0%	--
3	NU-LHT-2M	None	0%	Vibratory compacted
4	NU-LHT-2M	None	0%	Vibratory compacted
5	NU-LHT-2M	None	12.0%	Ice cemented
6	NU-LHT-2M	None	8.5%	Ice cemented
7	NU-LHT-2M	None	5.6%	Ice cemented
8	NU-LHT-2M	None	2.7%	Ice cemented
9	Limestone	None	0%	--
10	NU-LHT-2M	None	12.0%	Discrete ice
11	NU-LHT-2M	None	8.5%	Discrete ice
12	NU-LHT-2M	None	5.6%	Discrete ice
13	NU-LHT-2M	None	2.7%	Discrete ice
14	NU-LHT-2M	Typ. Rock Dist.	0%	Vibratory compacted
15	NU-LHT-2M	Typ. Rock Dist.	5.6%	Compacted + ice cemented
16	Limestone	None	0%	--
17	NU-LHT-2M	Typ. Rock Dist.	5.6%	Compacted + discrete ice
18	Colored Plaster	None	0%	Colored layers separated by aluminum foil
19	TBD	--	--	--
20	TBD	--	--	--
21	TBD	--	--	--
22	TBD	--	--	--
23	TBD	--	--	--
24	Limestone	None	0%	--

Two textures of ice-regolith mixture tested with the same ice concentrations



Initial tests repeated to aid in tuning ops

Ice percentages based on LCROSS

Limestone repeated as a control for wear on the drill

Observe the effect of rocks on telemetry

Demonstrate that stratigraphy is preserved

Room to repeat tests or introduce "challenge cases"

HONEYBEE ROBOTICS