Subsystem Testing and Results of the Planetary Volatiles Extractor (PVEx)

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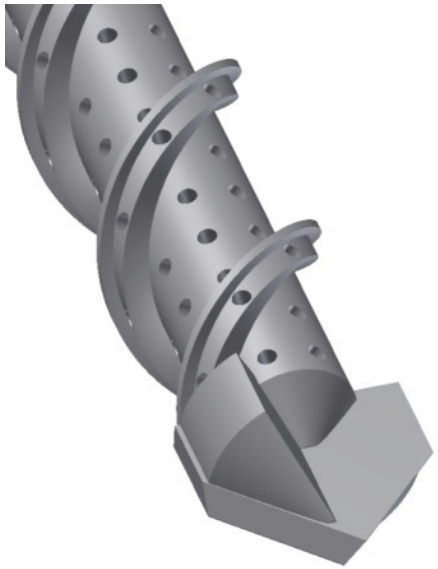
Agenda

- Volatile Extraction Architecture Trade
- Honeybee's TRL6 TRIDENT Drill
- Design Overview
- Test Results
- Future Work and Lessons Learned
- Acknowledgements

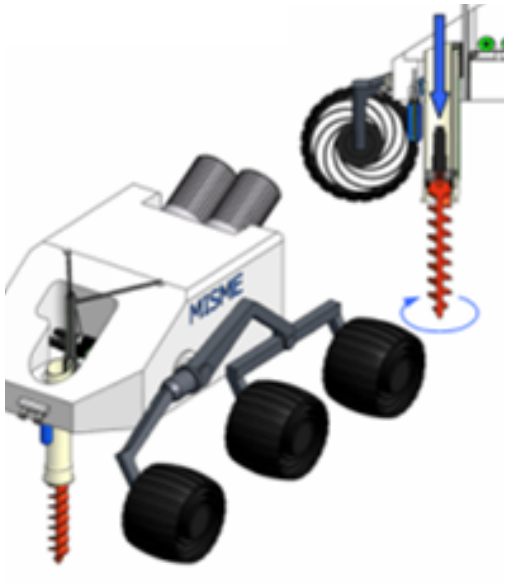
Volatile Extraction Options

- Trade was conducted on several architectures
- Coring proved to be the most efficiency in **water extraction** and **excavation energy** among architectures studied
- Conductive heating suitable for delivering heat to icy soil

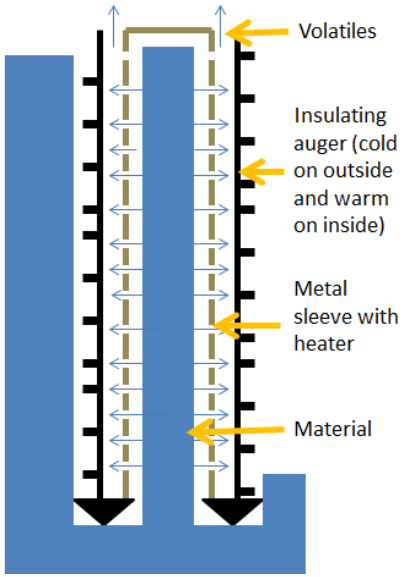
Sniffer



Auger

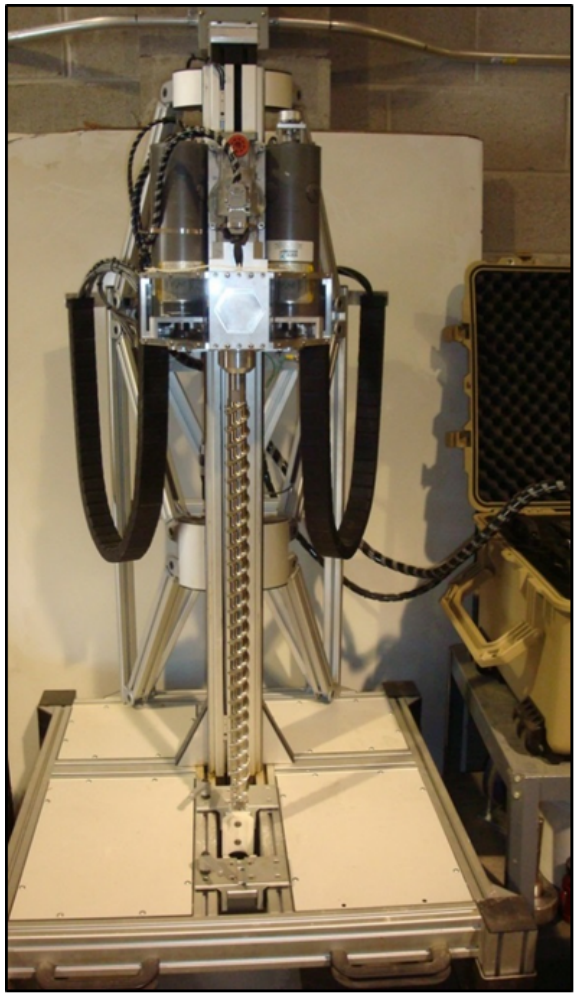


Corer

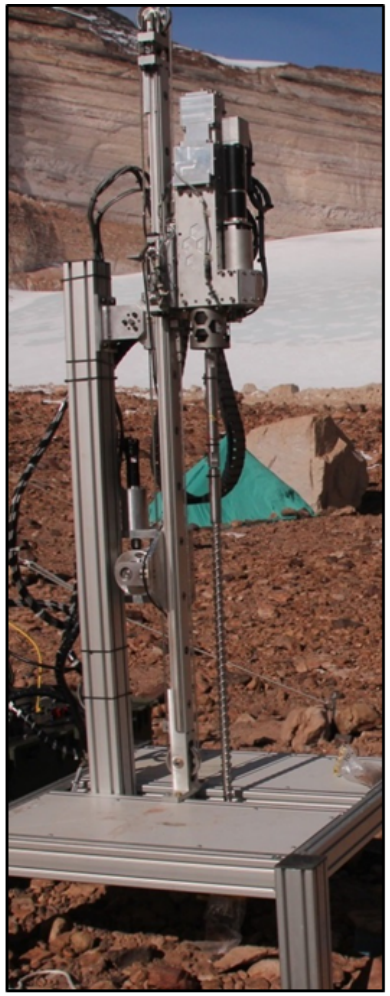


Corer architecture was selected for full-scale prototype

TRIDENT Evolution to TRL6

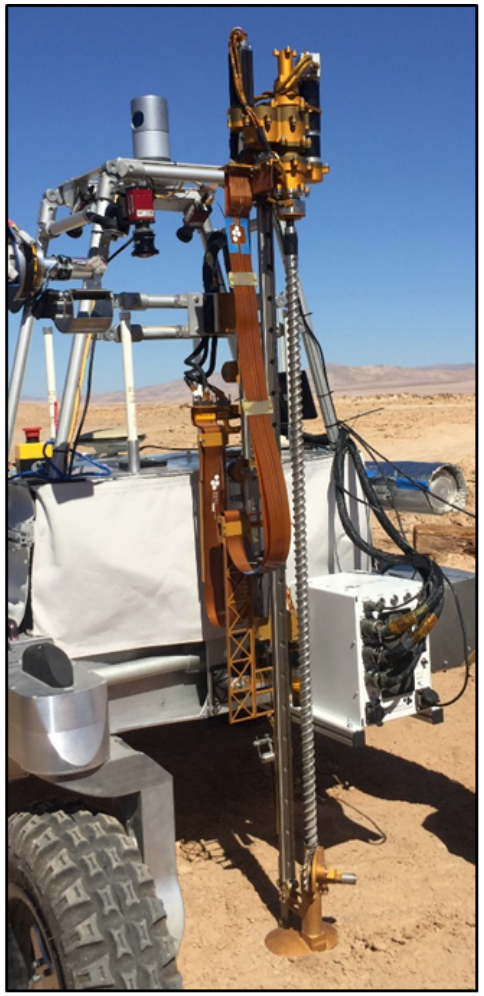


CRUX



IceBreaker

LITA / IB3 / RP15



RP ETU / ARADS

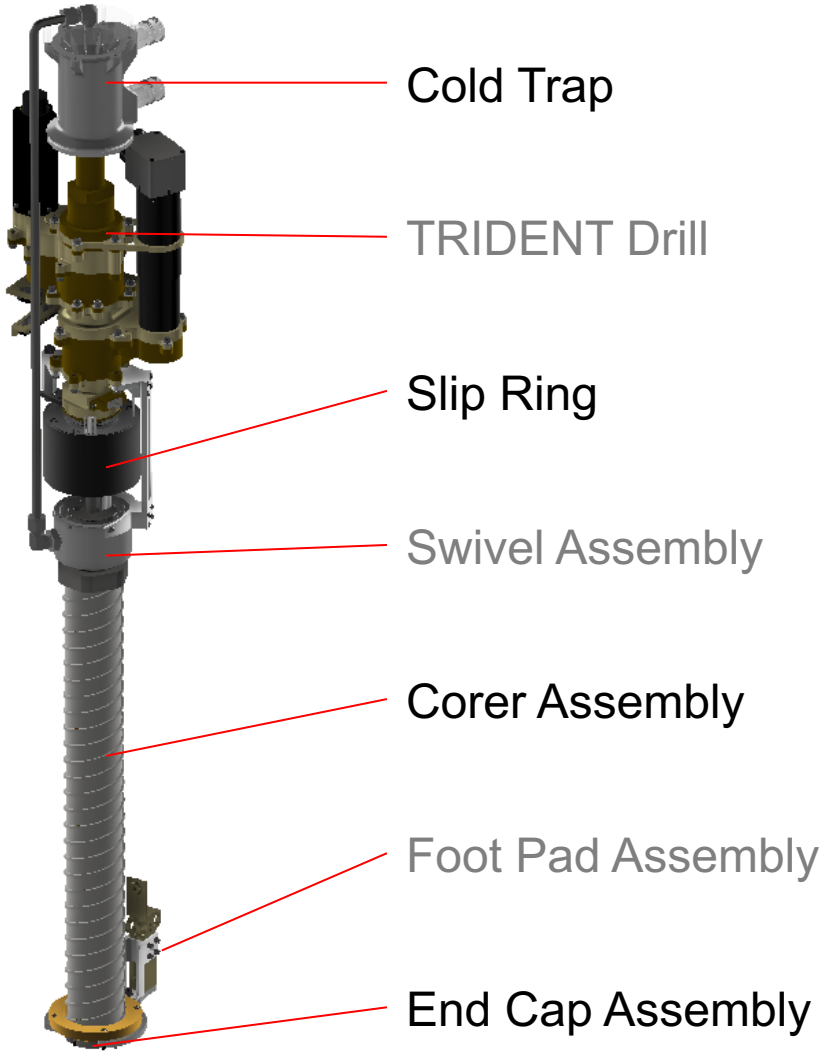
TRIDENT Drill

- “TRIDENT” = The Regolith and Ice Drill for Exploration of New Terrains
- One meter rotary-percussive drill for subsurface sampling, fully tested to TRL6
- Mechanism designed under the Resource Prospector mission to explore the permanently shadowed regions of the Aitken Basin at the lunar south pole
- PVEx leverages the TRIDENT drill and integrates the PVEx architecture

Property	Specification
Auger Rate Max (RPM)	120
Auger Torque Cont. (Nm)	14.9
Auger Max Cont. Power Out (W)	187
Percuss Energy (JPB)	2.0
Percuss Rate Max (BPM)	1160
ZA Stroke (mm)	~1186
ZB Stroke (mm)	~800
Z Stage Output Force Cont. (N)	~508
Drill Head Mass (kg)	~4.64

Subsystem Overview

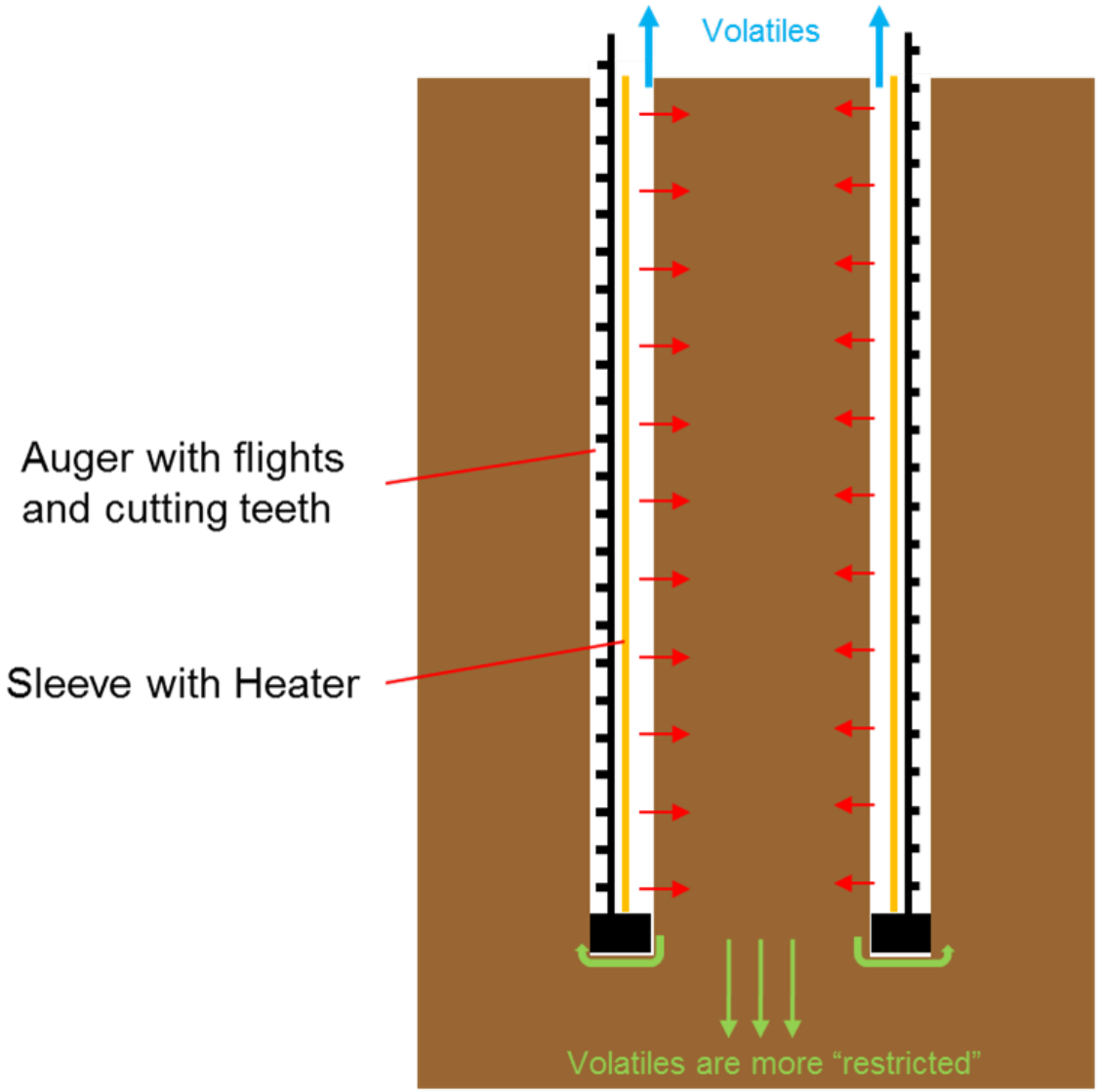
- “PVEx” = Planetary Volatiles Extractor
- 5 cm diameter by 0.5 meter long coring assembly integrated into TRIDENT Drill
- Performs well in dry and ice-cemented regolith
- Batch process which dumps dry regolith after extraction



Integrated ISRU architecture which combines excavation and volatile processing

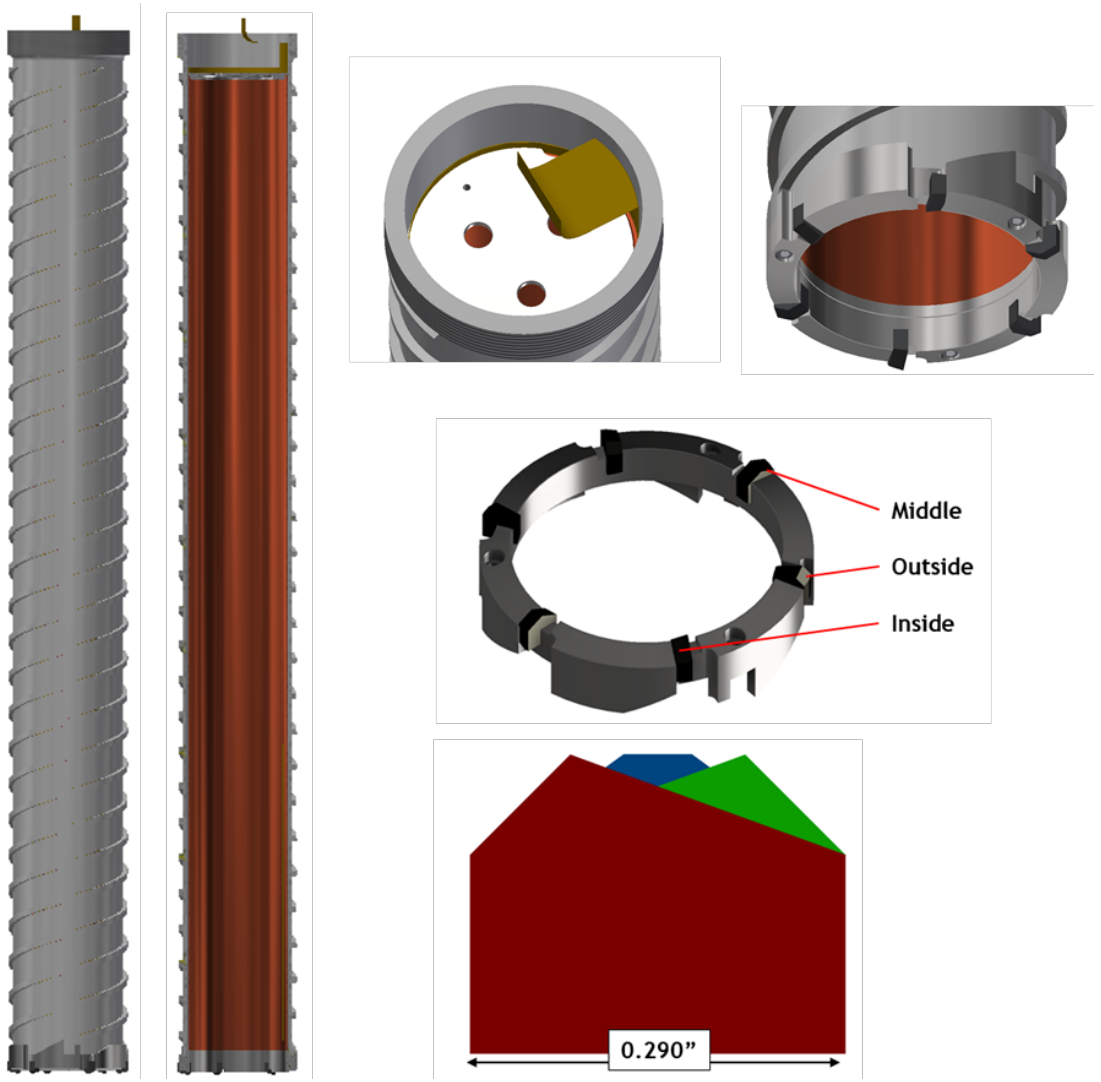
PVEx CONOPs

- After double walled corer reaches depth, heaters are activated
- Volatiles flow through the annular space created by the cutting teeth
- Volatiles are captured with Cold Trap (condenser)
- Drill is retracted and dry regolith is dumped



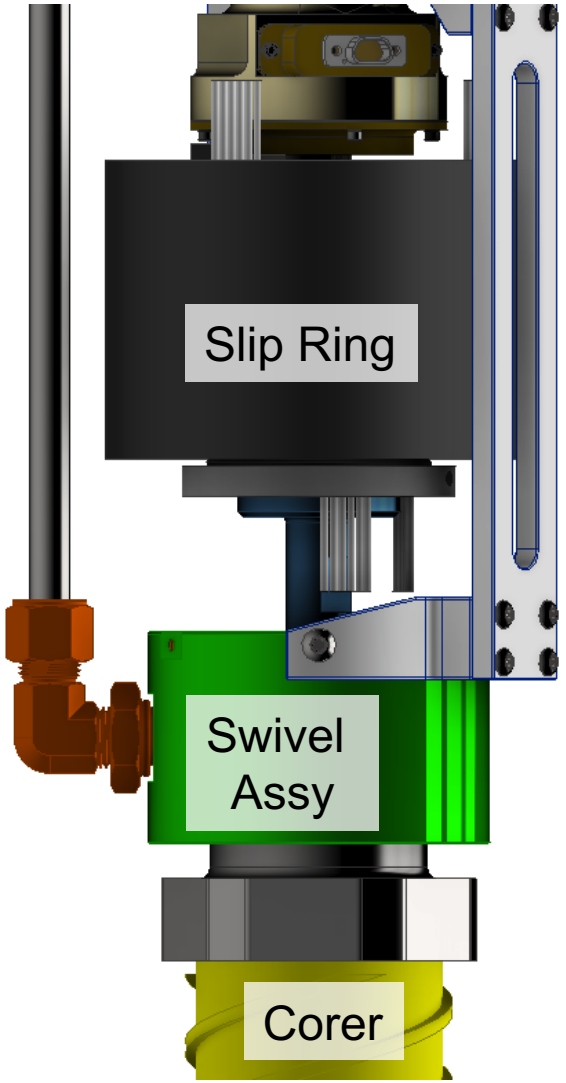
Corer and End Cap Assemblies

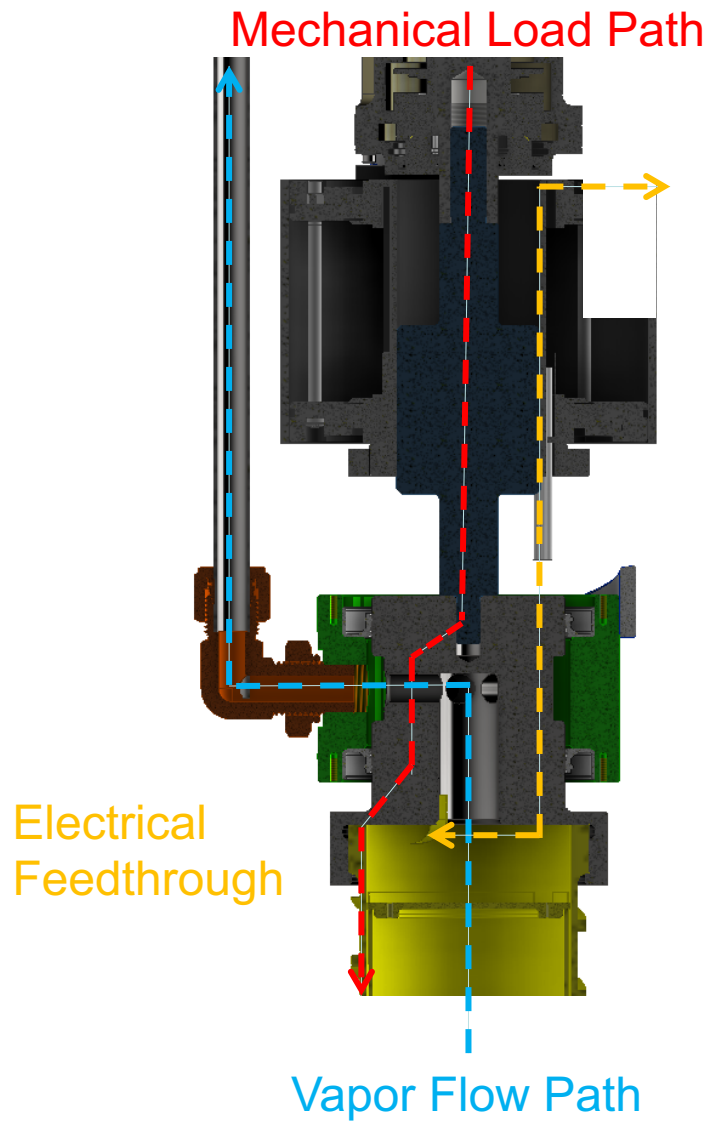
- 17-4 PH Stainless Steel Auger with Copper Sleeve insert
- Flex heaters are attached to Copper Sleeve (150W max)
- Stainless steel ends on ends of copper sleeve. Bottom transfers auger torque but not percussive path. Top acts as buffer plate
- End Cap is brazed with six Tungsten Carbide cutting teeth and attached to auger



Slip Ring and Swivel Assemblies

- Allow for mechanical, electrical, and vapor flow paths for the drill system
- Swivel housing is rigidly mounted to the drill to counter rotation of the swivel body
- Swivel Body is made from 17-4 PH Stainless Steel and must transfer percussive loads to the Corer Assembly
- Internal cavity between Swivel Body and Swivel Housing allows for vapor flow to a stationary tube and on to the Cold Trap



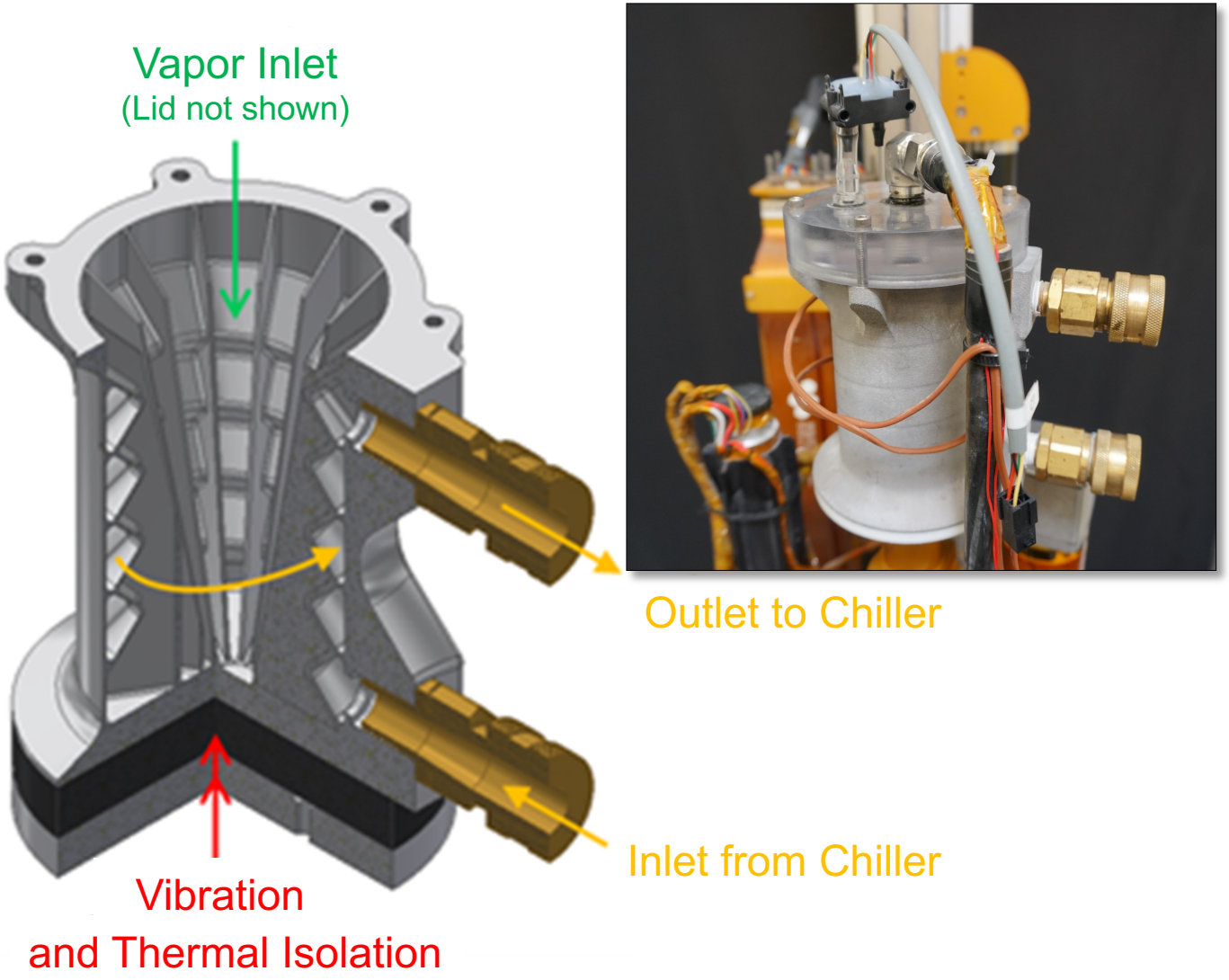


Cold Trap

- DMLS out of AlSi10Mg Aluminum

Thermal Conductivity >103 W/(m*^{o}C)

- Allow sufficient surface area for ice to deposit ice
- Chiller fluid is circulated around Cold Trap body
- Lid includes valving, pressure, and temperature sensors
- Experimentally collects a maximum of 33g of ice



Drill Performance

Tests were successfully conducted in various mediums:

- 5 MPa UCS Ice at -20C, Honeybee Walk-in Freezer
- 23 MPa UCS Texas Cordova Creme Limestone, STP
- 45 MPa UCS Indiana Limestone, STP
- 1.5g/cc NU-LHT-2M at 5% water by weight, 25C at 6 Torr

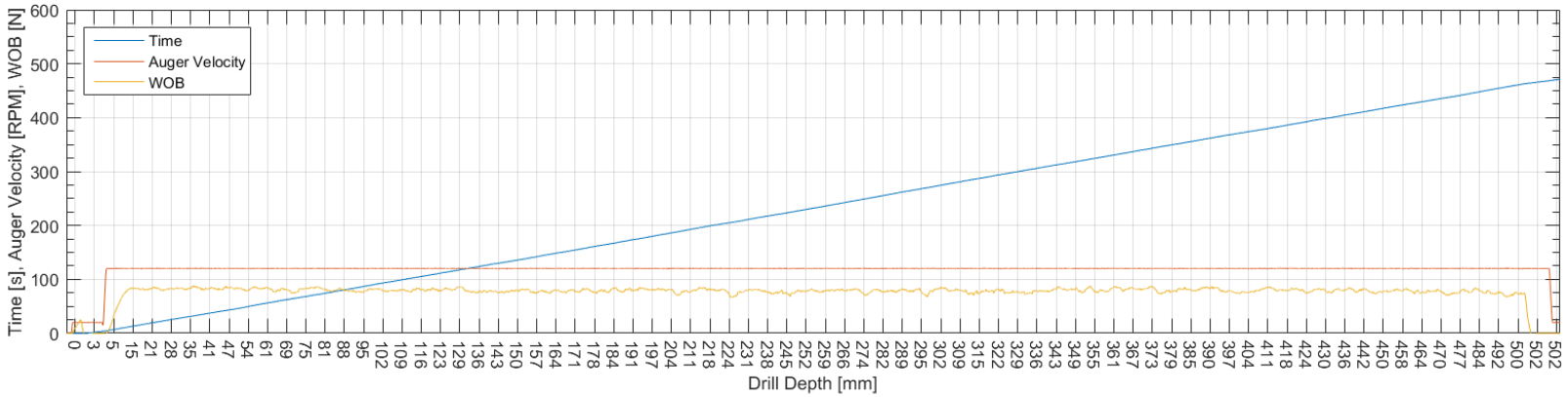
Drill Results

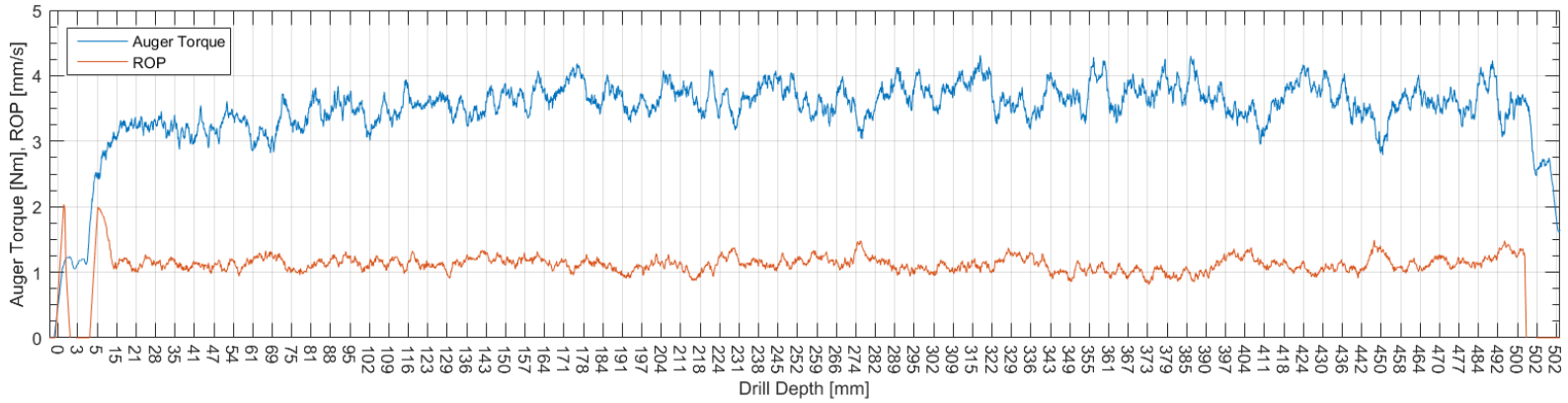
Drilling in -20C Ice (5MPa) with LITA

- Average ROP 1.1 mm/s
- Total Power: 105 W

  Auger: 25 W mechanical (41 W electric)

  Percussion: 32 W mechanical (64 W electric)





Drilling with TRIDENT

Material		Indiana Limestone	NU-LHT-2M
UCS	MPa	45	~5
ROP	cm/min	1.80	5.81
Power	W	142	180

End-to-End Testing

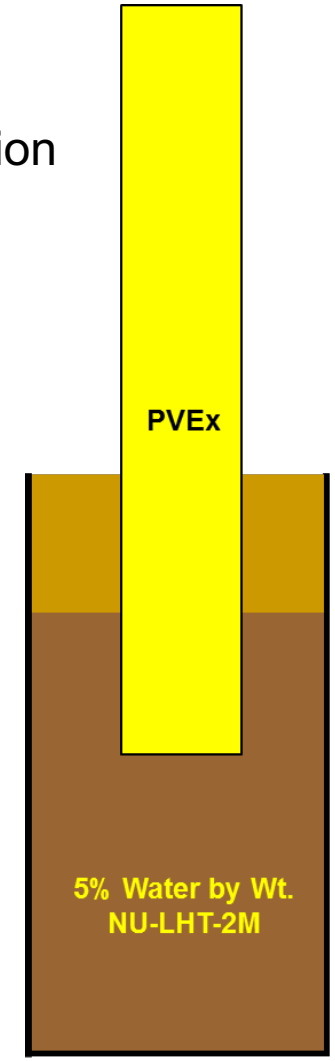
- Tests conducted at room temp and 6 Torr. Heating begins immediately after drilling
- Pressure in Cold Trap measured 0.1 to 0.3 Pa above chamber pressure
- 4.14.X tests were conducted in NU-LHT-2M at ~5% Water by Weight

Test #	Test Setup	Collection Efficiency
4.14.3	5% Water by Weight, 75W @ 2hr	7%
4.14.4	4% Water by Wt., Slow Heat	35%
4.14.5	6% Water by Wt., CT thawed mid-test	43%

Current Cold Trap is Limited in Volume

Volatile Delivery Demonstration

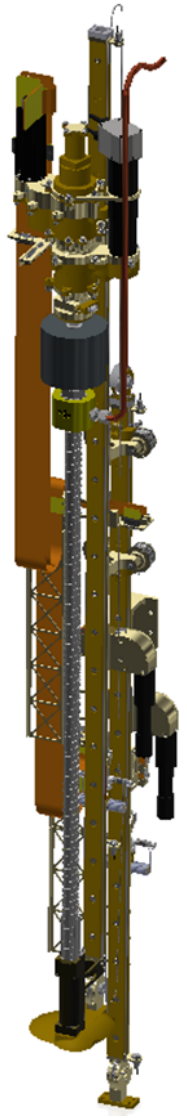
- PVEx can deliver volatiles directly to science instrumentation such as MSolo/Mass Spectrometer
- Can sample layers in “bites” – preserving stratigraphy and providing more accurate strength measurements of subsurface

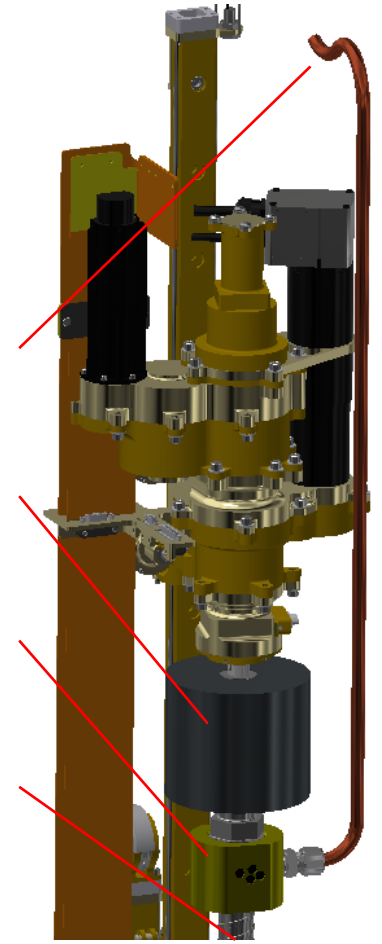


Visually demonstrated PVEx producing flow

Future Work and Lessons Learned

- Effect of vapor permeability through regolith as it dries still needs to be explored
- Continued work with various CONOPs to improve water collection efficiency
- Higher capacity Cold Trap in procurement
- A 1m long, 2.5 cm OD corer in development for direct delivery to science instrument





Acknowledgements

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Small Business Innovation Research / Small Business Technology Transfer

Questions

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