

SRR PTMSS 2016



Thermal Vacuum Testing of a Lunar Rated Sample Drill

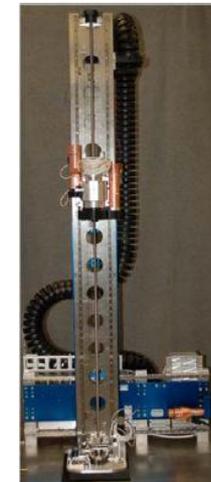
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Thermal Vacuum Testing of a Lunar Rated Sample Drill



DESTIN

- Low power, low mass, autonomous operation
- Drilling in consolidated and unconsolidated material
- Operational temperature -20C to +40C, storage -40C to +50C
- Vertical translation stage, rod handler, sample transfer receptacle
- Coring auger, auger and push tube
- DESTIN deployed on Neptec's Artemis Jr rover during analogue mission on slopes of Mauna Kea 2012



VDCU Project- toward a TRL6 Drill

- Design and build modified DESTIN drill for thermal-vacuum testing with moisture bearing lunar simulant
- Push tube, coring auger, auger tools
- Bit temperature sensor
- Lab rated avionics
- Assessment of volatile loss in drilling process

Thermal Vacuum Tolerances

- Reduction in differential CTE issues
- Mitigation of thermal cycling effects
- No lubricants
- Use of plastics – volatilization
- Lightweight, brushless motors: first lunar rated Maxon motor
- Temperature compensation for sensors
- System thermal management
- Start up in cryo conditions
- Vacuum welding
- Temperature effects on wiring harness



Thermal Vacuum Testing of a Lunar Rated Sample Drill



VDCU Tools

Push tube

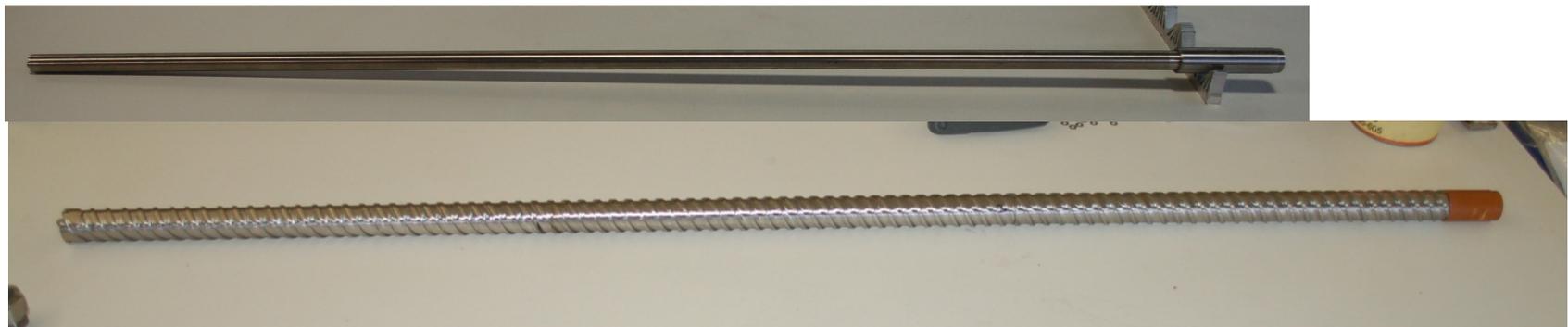
- drill and capture unconsolidated material (<2% frozen moisture)
- 1m depth
- 16.5mm diameter core

Coring Auger

- Drill and capture consolidated material
- 1m depth
- 16mm diameter core

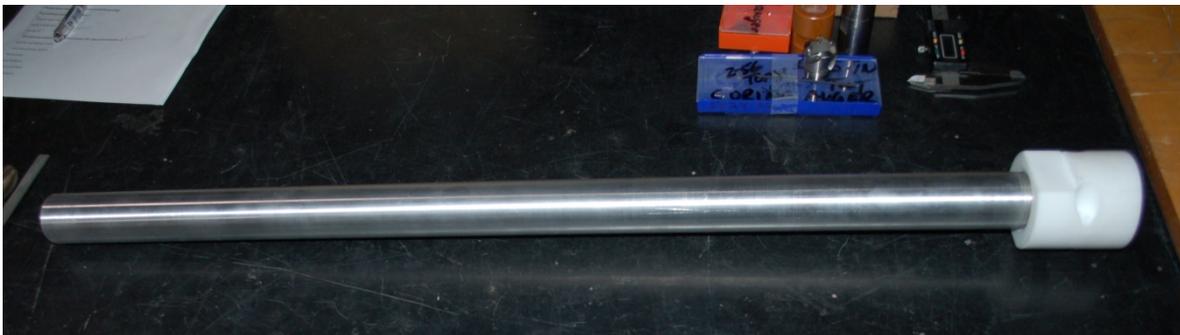
Auger

- Drill consolidated or unconsolidated material, cuttings augered to surface
- 0.5m depth
- 25 mm diameter
- Integral bit temperature sensor

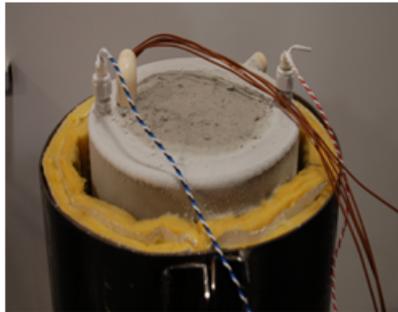


VDCU Volatile Capture

- Assessment of volatile loss due to sample formation and capture
- Passive capping mechanisms to mitigate volatile loss from sample within (or on for auger) tool
- Unique mechanisms for each tool
- Analysis performed post test



Lab Drill Tests



- Moisture added by weight to CHENOBI
- 0%, 2%, 5%, 7.5%, 100% moisture contents
- Compacted in test bed to appropriate compaction level
- Thermocouples inserted at various depths
- Test bed pre-frozen in upright freezer
- Bed inserted into LN2 cooling jacket and cooled to -150C prior to drilling
- VDCU mounted to frame above test bed
- Tool cooled with LN2 prior to and during drilling
- Drill backplane and head at ambient temperature

Tool Drilling Tests

Auger

- penetration to depth of unconsolidated CHENOBI, frozen consolidated with 2%, 5%, 7.5% moisture, ice
- Cuttings augered to surface and on tool flights when tool retracted

Coring auger

- penetration to depth of unconsolidated CHENOBI, frozen consolidated with 2%, 5% moisture
- Sample capture 50-60%

Push tube

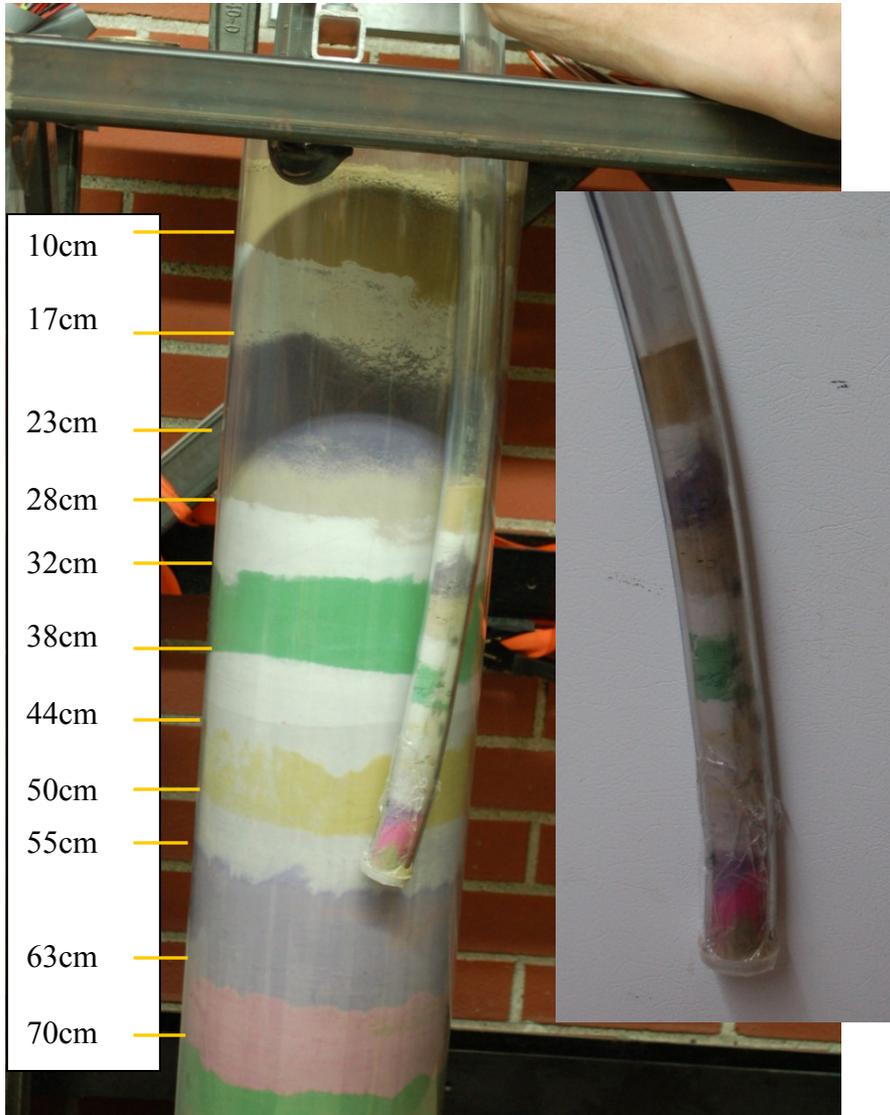
- Penetration and capture of unconsolidated sample (close to 100%)
- Penetration in consolidated 2% frozen moisture CHENOBI poor (20-50cm) but capture $\geq 80\%$



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Sample Integrity

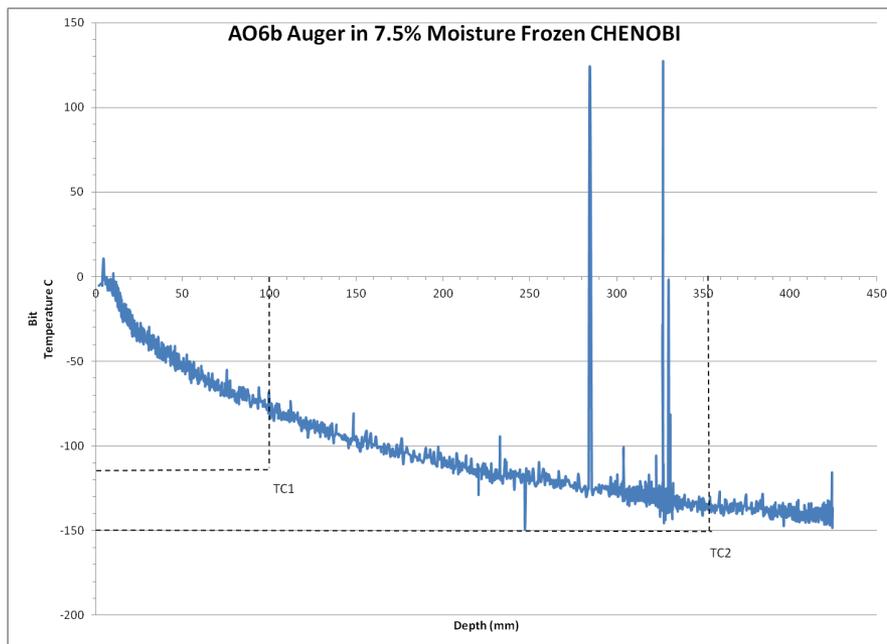


- Maintained with push tube and coring auger
- Sample colour corresponds to sample depth
- Auger cuttings augered to surface correlate only to depth of 20cm– mixing of cuttings on auger flights

Thermal Vacuum Testing of a Lunar Rated Sample Drill



Bit Temperature

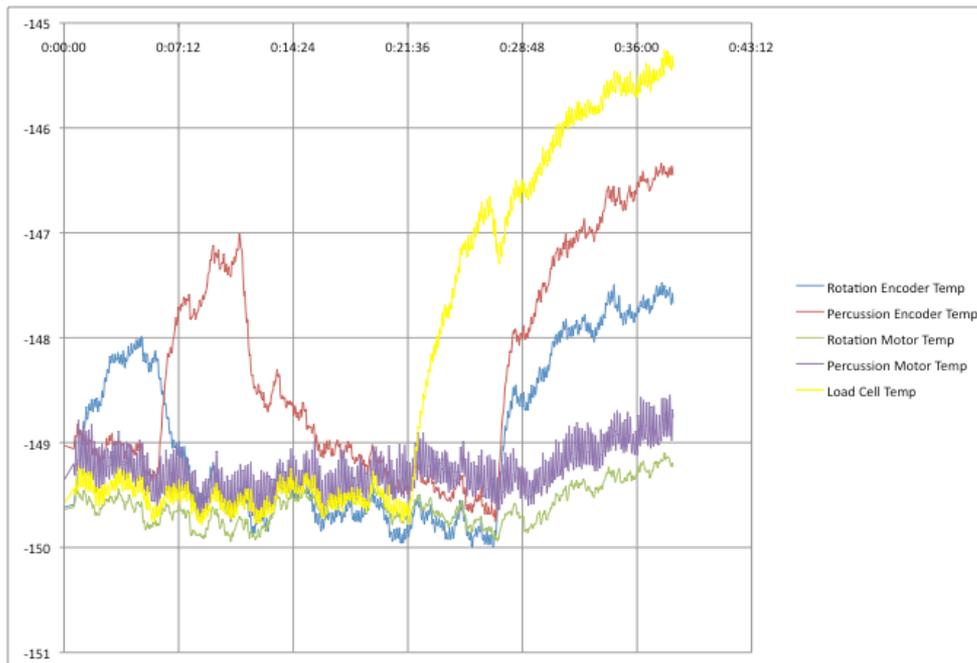


- Auger tool equipped with bit temperature sensor
- Good correlation with bed temperature
- Provides feedback on sample temperature for control of sample heating to mitigate volatile loss

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Head Thermal Test

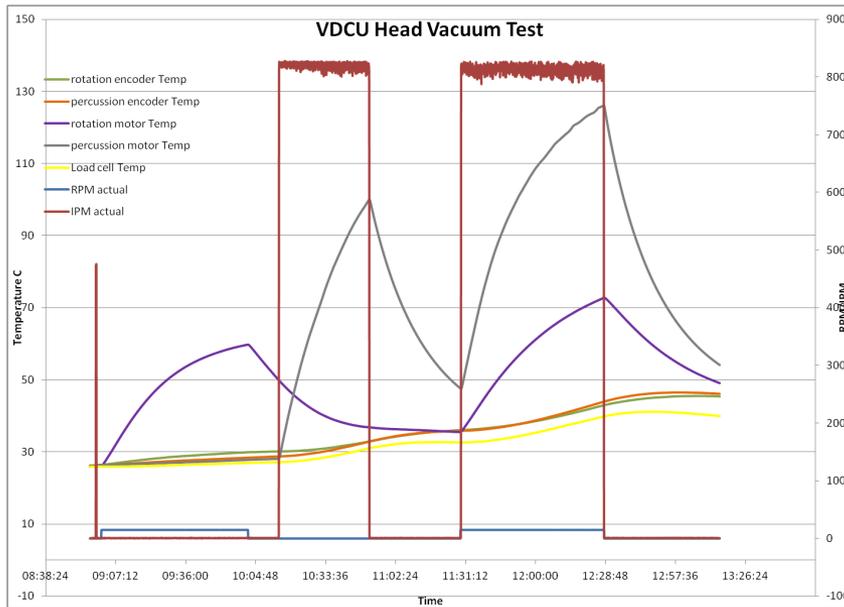


- Ensure survival at -150C
- ensure heaters could warm components during active cooling, within power limits

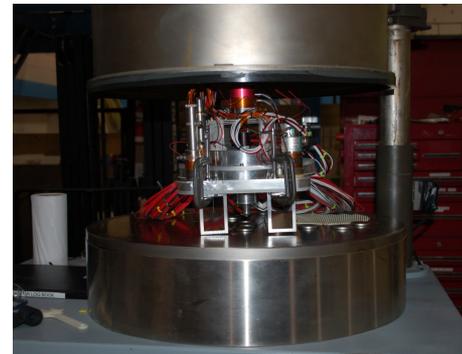
Thermal Vacuum Testing of a Lunar Rated Sample Drill



Head Vacuum Test



- Deltion vacuum chamber
- Drill head exposed to 10⁻² Torr
- System exercised
- No cooling, no heating
- Validated thermal management strategy



Thermal Vacuum Testing of a Lunar Rated Sample Drill



Thermal Vacuum Testing



- NASA Glen VF13 three week testing campaign
- Frozen 2% and 5% moisture CHENOBI test beds
- Drilling with each of the three tools
- Volatile capture mechanisms employed with last sample drilled with each tool
- Pressure $\leq 1 \times 10^{-5}$ Torr
- Cold wall 100K



Thermal Vacuum Testing of a Lunar Rated Sample Drill



Thermal Vacuum Testing: Results

- Demonstrated successful function of mechanical and electrical systems in thermal vacuum (100K, 1×10^{-5} Torr)
- Temperature monitoring near comminution zone
- Sample capture, cuttings to surface (coring auger, auger tools)
- Thrust 100N nominal
- Power consumption <60Watts average
- Standby power, all heaters active, <12Watts

Tool	Bed moisture (% by wt)	Time to full depth (min)
Auger	5	20
Coring auger	2	24
Coring auger	5	47
Push tube	2	45 (22cm depth only)

Thermal Vacuum Testing: Results

Volatile Retention

Tool	Volatile Retention %
Push tube capped	50
Coring auger no cap	63
Coring auger transferred	59
Coring auger capped	78
Auger cuttings transferred	0
Auger capped	14

Repeatability

- more than 26m depth drilled with VDCU
- Tools drilled an additional 14m using EBU2

Next Steps

- Improvements to coring auger bit to maximize sample capture
- Application of bit temperature sensor to coring auger
- Addition of other down the hole sensors
- Flight grade avionics
- Optimization of drilling energy and time through control strategy

Acknowledgements

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