Lessons Learned for the 2019 Moon to Mars Ice & Prospecting Challenge

**Accessing the Ice / Penetration of Overburden**

- **What worked?**
  - Sleeves were helpful, but if using a drill sleeve, should be close to auger diameter to prevent sleeve from oscillating.
  - You need a drill/bit combination that is complimentary
  - High RPM helped get through the layers faster and monitoring the RPM helped differentiate the layers
  - Use something used by engineers
    - Specifically, a chuck that doesn’t slip
  - Just Rotation vs. Percussion and Rotation vs. Just Percussion? (this may be dependent on the bit)
    - Percussion didn’t work this year
    - Percussion with rotation works
    - Just rotation works
    - Each with the right work with the right bit and the right combo
  - Testing was very important
    - Testing worst case scenarios or getting more information about the layers/which materials to test would have helped with design
    - A 5-gallon bucket of concrete is a great testbed
      - Secure the concrete to the bucket with drywall screws so it doesn’t just start spinning
  - Reach out to industry for help!
    - Depends on who you ask
    - Bosch specifically was willing to share

- **What didn’t?**
  - Percussion alone didn’t work
  - A sleeve was useless this year
    - Loose layers would have made it useful
  - All-in-one custom bits were not a guarantee for success
    - Testing while prototyping was critical for successful bits
    - Downside is that if the bit fails you aren’t going to have a successful competition
      - It also adds more complexity to the design process

- **What would you do differently?**
  - More drilling area and more mobility around the work area
    - Encourage 3D Movement Machines
  - Differing “zones” of regolith
    - (EG: Half the box is Day 1, the other half the box is Day 2. Each side has different layers.)
  - Vary the layering over the competition?
    - Not universally popular
  - Better stabilize the drills

**Retrieving the Water/Water Extraction**

- **What worked?**
  - Use a Rodwell
  - Using closed loop thermal control
  - Cycling heat/water was better than constant heat
    - If you have large cavity in middle, be careful that you aren’t losing heat. Direct energy through contact heat and bring water up to as close to freezing as possible.
  - Use all available power for heating
Stock heaters (specifically cartridge heaters) limited by wattage limited our ability to melt ice
Combining multiple cartridge heaters was effective
- Heating from the bottom to the top was better
  - Heating near the top could have collapsed the hole

What would you do differently?
- On Earth, Rodwell is effective. But, it depends on having liquid water on Mars. Feasibility issues?
  - If we want teams to pull up ice chips, would need to be done in freezer
  - All-in-one tool head – possibility of re-freezing of drill head.
- Double-check for air leaks in the extraction process
- Getting ice chips might not be practical on Earth, but it may be more practical on Mars
- Challenge the teams to find the ice across a bigger area (outside for instance)
  - Recommended Blacksburg in the Winter.

Characterizing the Overburden

What worked?
- Cross-referencing data from multiple drill holes was useful
- Prioritizing specific data helps
  - “We focused on drilling to access for water because there were more points there”
- Taking notes while the drill was drilling made the difference

What didn’t?
- 3D Printed Parts are liable to snap...
- Trying to characterize the overburden, drill, and extract water all-in-one was really challenging
  - The challenge required using mechanical feedback to identify the layers, but that might not be the most effective method
  - Having a drill/heater in one (solving two problems at once) makes it easier, but also adds complexity.
  - Having foreknowledge (using a GPR for instance) could have helped
- Percussive drilling meant destroying the material and changing its properties
  - Made measuring the material difficult
  - Do you want the material properties to change? Does that make things harder?
- As soon as you add a PID loop you lose certainty over what you’re drilling through
  - Adding a control limited the usefulness of weight on bit measurements
  - It’s difficult to keep everything constant to measure the difference in the material
- If the sheath isn’t rotating, it has to be secure.
- Didn’t assume the concrete would be solid, but rather granular
  - Consider all possibilities in the future

What would you do differently?
- Change the weight on bit requirements to better match mining standards
- Clarify what you mean by hardness (how do you measure sand’s hardness?)
- Make challenge priorities (water collection vs digital cores) clear in the rubric
  - Alternatively make a baseline mission and allow the individual teams to prioritize a specific area (e.g. filtering, prospecting, etc…)
  - Tell the teams what they should optimize for
- If you weren’t time constrained, but were more heavily mass/volume constrained, how would that change things?

Unexpected Challenges

What Worked?
On the first day, we created a list of instructions of everything that needed to be done and split that up between team. Helped team optimize and strategize what to do on Day 2

Table space was great

What didn’t?
- Double-check for vacuum leaks in your system
- Not knowing which doors we were supposed to use in the hangar.
- Tunnel vision comes when you get nerves. Don’t get caught up fixing one problem. Don’t forget basics in the middle of solving one problem.
- Placing special computational circuits where they will be vibrated the most is probably not a great idea
  - Consider the location of your parts and the vibration they will be subjected to
- Potential shipping methods may affect the integrity of the rig
  - The back of a UPS truck is a dangerous place for poorly packed instruments
  - Put your electronics in foam to dampen the effects of vibration
- Material properties change while you’re drilling
- Thermal expansion can affect the integrity of the bit
  - Copper specifically
    - Resin, hot glue, tape, nothing worked

What would you do differently?
- Perhaps place more emphasis on the unit testing during the midterm and integration testing for the final review
  - Make integration testing part of the video required
  - Video chat with the judges to demonstrate integration and allow them to pose questions
- Too much room along edges of bin. Drainage becomes a possibility. Or, overflow of water down the side of the bin.
  - This may not really have been the case, as seen during teardown.
- Run a full system check before starting an autonomous run
  - Build a check-list for what you need to do before starting an action
    - Split those responsibilities across the team before you get to the hangar
  - Don’t forget the basics when solving a problem
- Don’t trust NASA GFCI breakers.
  - Develop a standard test for GFCI sensitivity and response time
    - Provide an example of a commercial equivalent of what you might find in the center

The following were not discussed during the feedback session due to time constraints, but were recorded comments from teams directly prior to the feedback session.

Suggestions for 2020
- Offer Dinner for Monday Night
- Standardized electronics for teams
  - Many teams had to spend time on low level motion control
- Just go ahead and use basalt – let’s go worst-case-scenario
- Protolabs was AMAZING! More teams should have access
- Bosch/Dewalt Drill Sponsorship?
- Make the ice non-uniform (dirty ice)
- Full autonomy
- “Shipping” or payload dimension constraints
Below comment – “They did…”

- Encourage to show data in technical report, not just system overview.
- Post tech-demonstration debriefing with judges as a part of the technical presentation scoring
  - Poster session at the end?
- More info for onsite electrical set-up standards
  - GFCI requirement
  - Ground leakage
- Allow separation/modularity. Our original concept (+path-to=flight plan) included separating the drilling and extraction subsystems.
- Allow Movement! Have a larger area so teams can drive their drill to x location and have to show stabilization/operation.
  - Ice chest is small
- Consistent dimensions on ice chest/layer definitions
- It would be nice if we could work on our drills at night at the hangar
- More details on videos (mid-point and integration)
- Notify teams earlier!!! We were on winter break
- More funding for teams that travel farther

**Programmatic**

- We misunderstood what constitutes “autonomous.”
- Please bring back Jerry’s presentation on Tuesday
- Increase time limit on mid-point review video (+ more details)

**Onsite Competition**

- Fans?
- Sturdier platforms to stand on
- More outlets
- Do NOT reuse wood from previous years (too many holes!)
- Clarify where we are allowed to be in the building and which doors to use

**System Development Process**

- More support from sponsors and/or professional engineering firms
- Direct control of hand tools is better than driving the trigger!
- Test early and often. If you’re asking when to test, the answer is that you already should have started.
- Spend at least 2 weeks testing the fully functioning system.
- Start testing BEFORE being low on time.

**The Most Valuable Lesson**

- TEST, TEST, TEST!