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

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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!