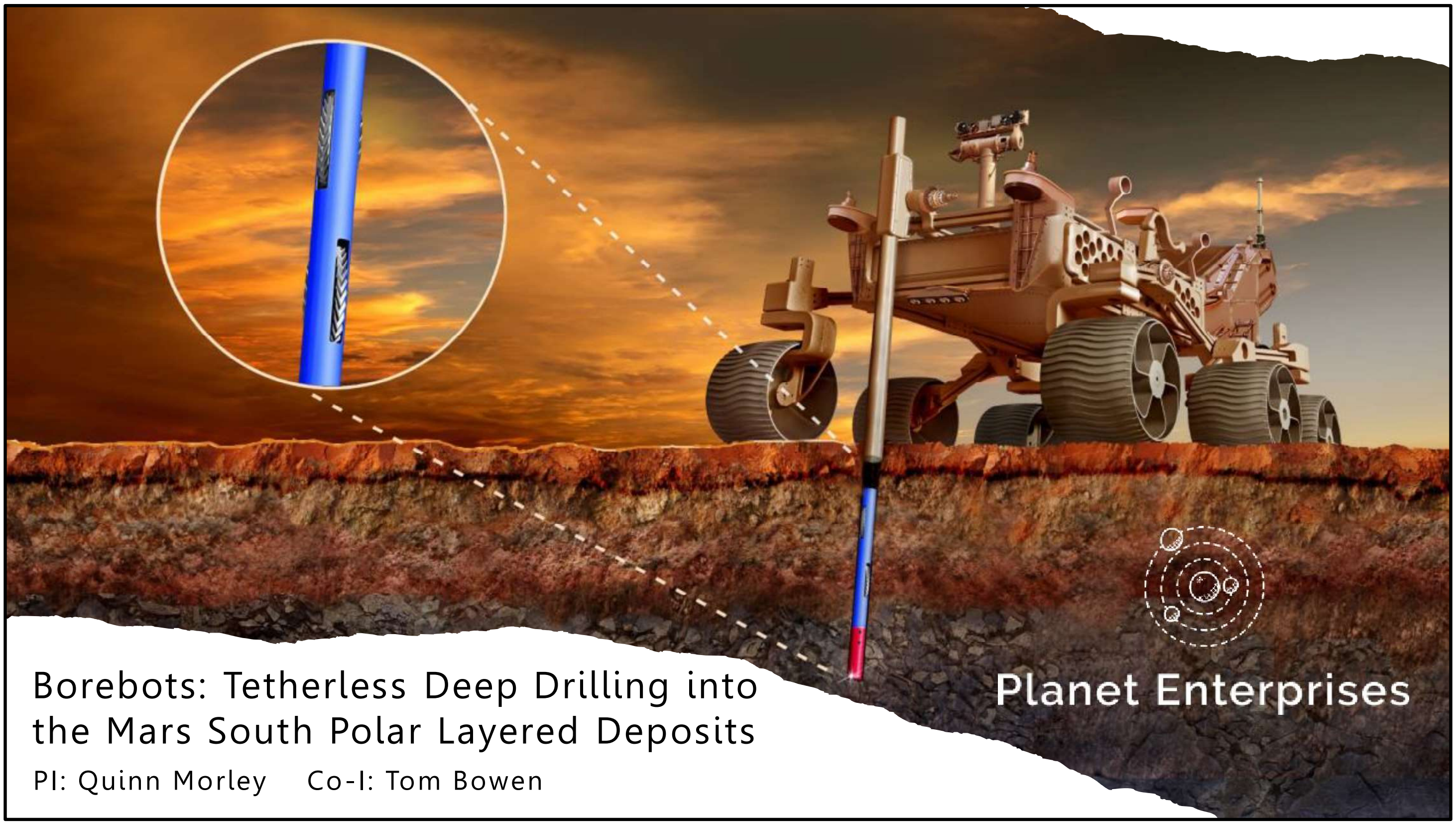
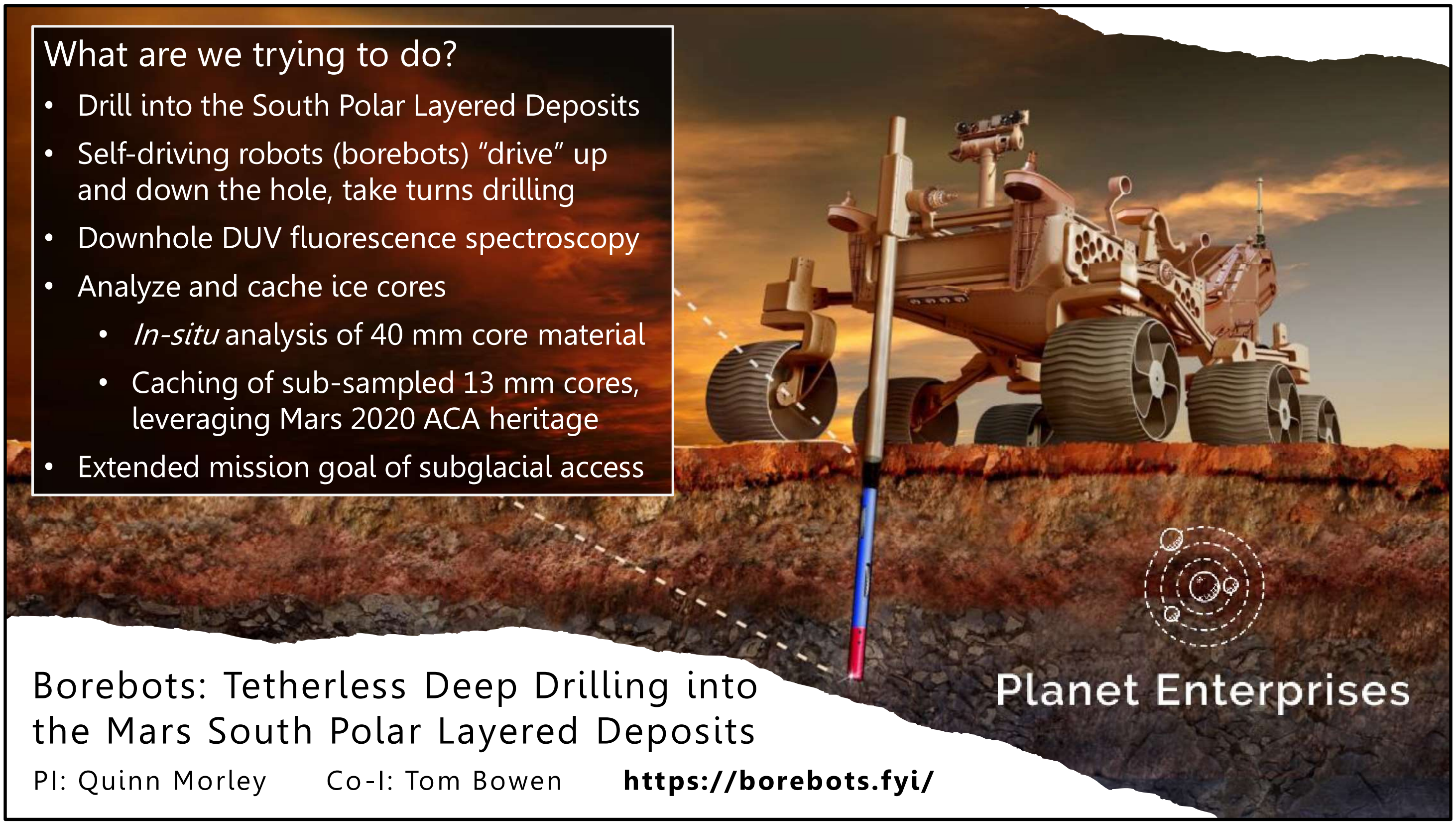


My name is Quinn Morley, I'm the PI for the Borebots project, and I'm also a senior in the Mechanical Engineering program at Washington State University.

I'm running two internet connections that are both shaky, so I'm hoping we can get through this without any issues. I'm going to turn off my webcam to help with that. **Anyone that wants it has my permission to record this.**

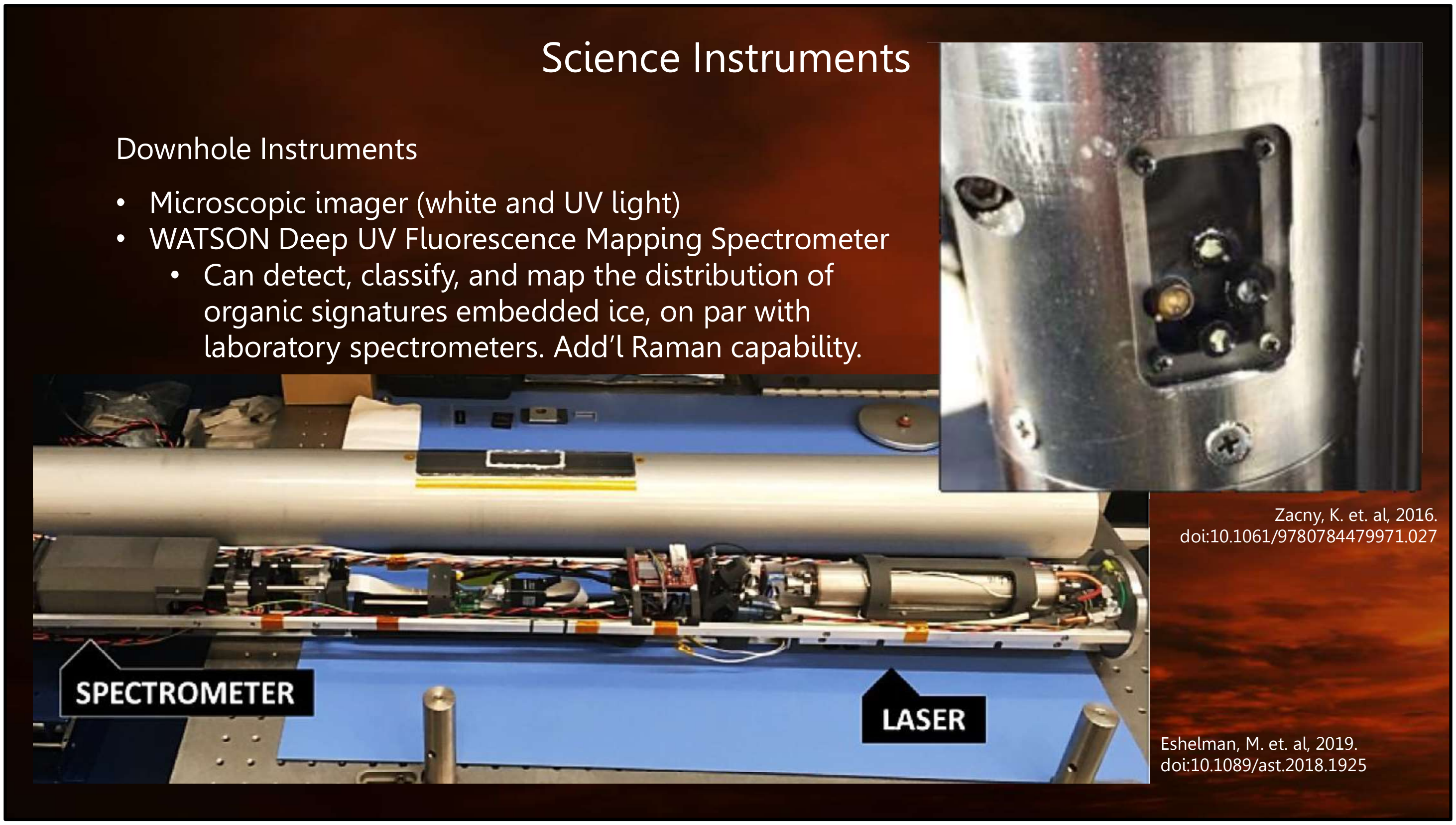
Turn off webcam!



We are trying to drill into the South Polar Layered Deposits with self-driving robots that “drive” up and down the borehole. Our Phase I results are very promising.

I’m not going to discuss the mechanical system of the borebot at all today, for those that are interested, we have some resources available on our website, just type borebots.fyi into your browser.

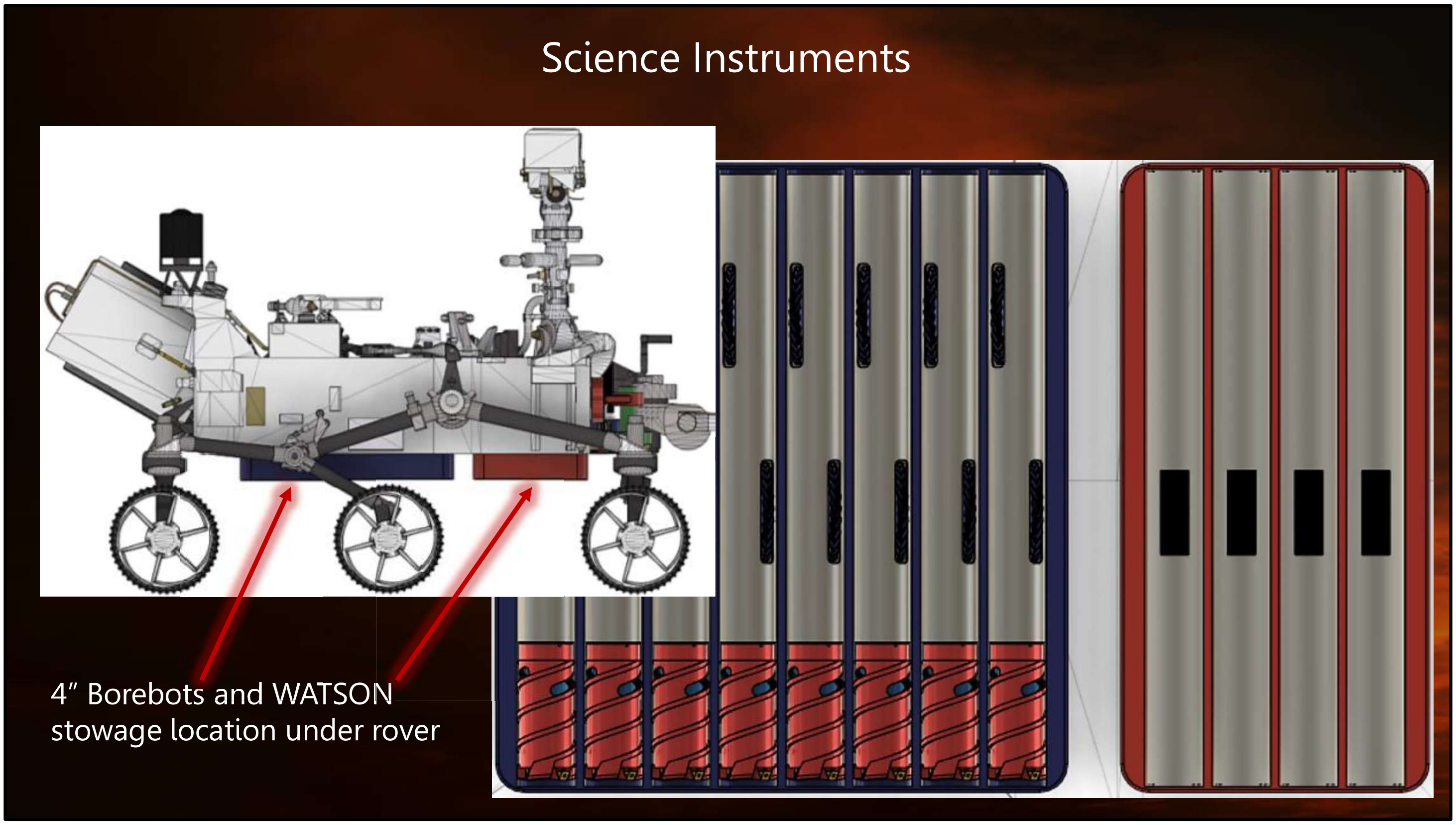
Turn off webcam!



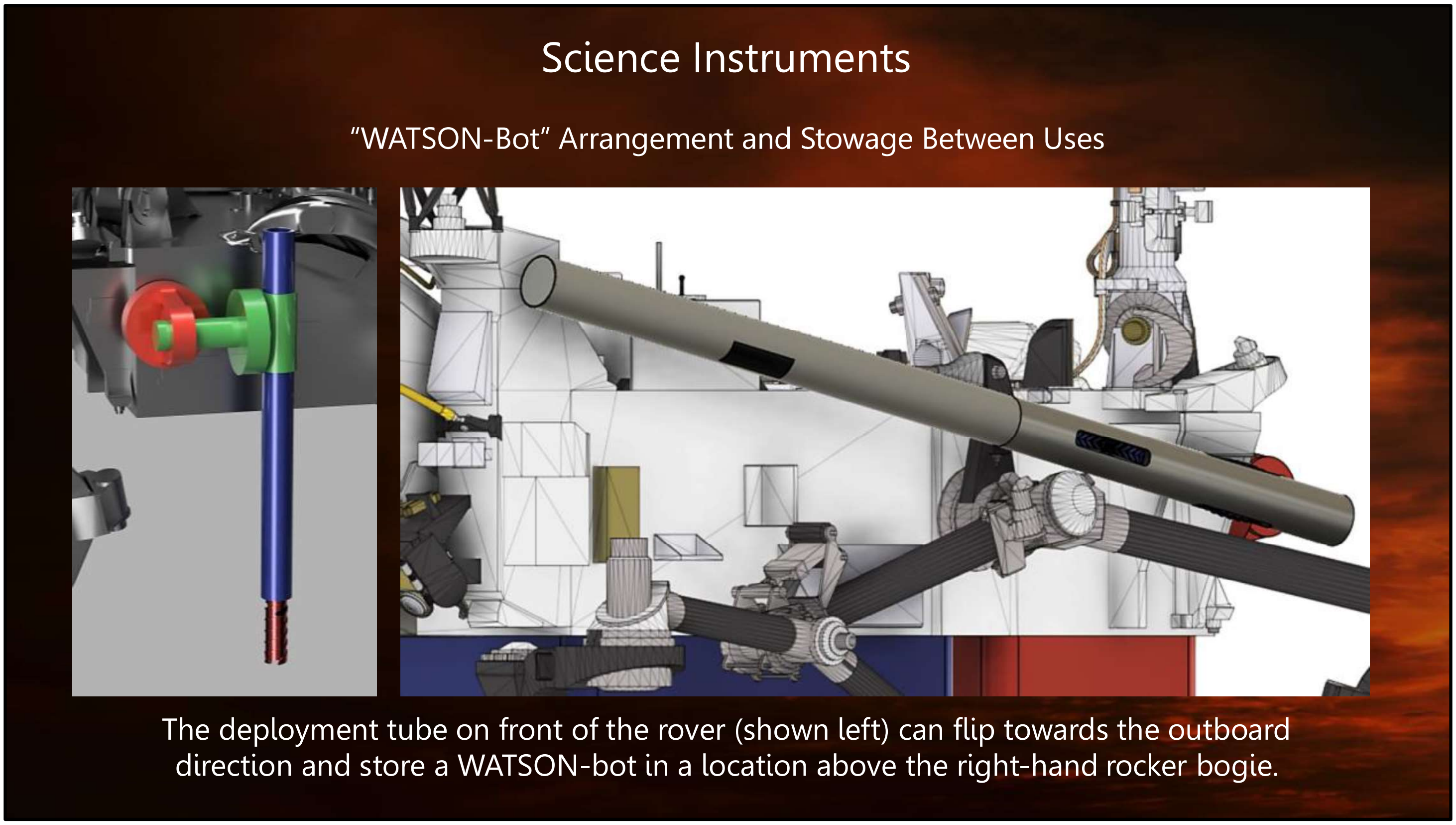
The most capable science instrument for our application, hands-down, is an instrument called WATSON.

This Deep UV Fluorescence Mapping Spectrometer can be attached to the front of a borebot and can be used in a passive scanning mode, or an active mapping mode. Raman spectra can also be collected. WATSON is about 4” / 10 cm in diameter, so it only fits on the bigger version of our borebot and requires a large lander and a robust handling system.

I would suggest everyone read about this instrument in Eshelman 2019. It’s fantastic.



Here is a stowage option for eight borebots and four downhole instruments, to provide some context. The aft stowage location is the same space that was used by the Mars Helicopter Ingenuity on Perseverance. The forward location is where the cover for the Sample Handling Assembly is, so our idea here was to hinge that cover instead of drop it on the ground, and we add our storage to it.

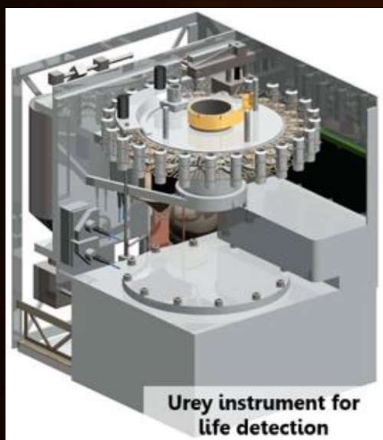


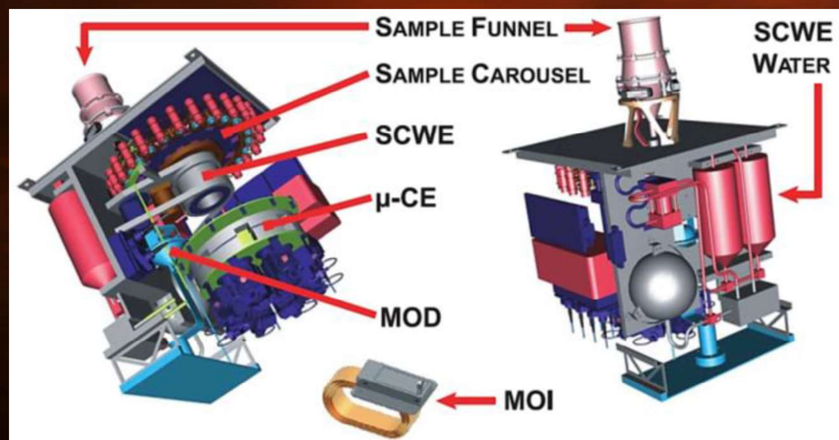
We move borebots around and deploy / extract them with a three-axis tube mounted to the front of the rover. At some point one of the borebots would have to be dedicated to the WATSON instrument, and it would only be used intermittently. Between uses it could be stowed on the side of the rover. This is a good option because the WATSON instrument is closer to the “warm end” of the rover.

Science Instruments

Rover Instruments

- In order to confirm (or further explore) findings made by WATSON, a physical sample processing suite is desired. The Urey instrument and the TEGA suite from the Phoenix lander can each fit in the MOXIE volume in the rover.





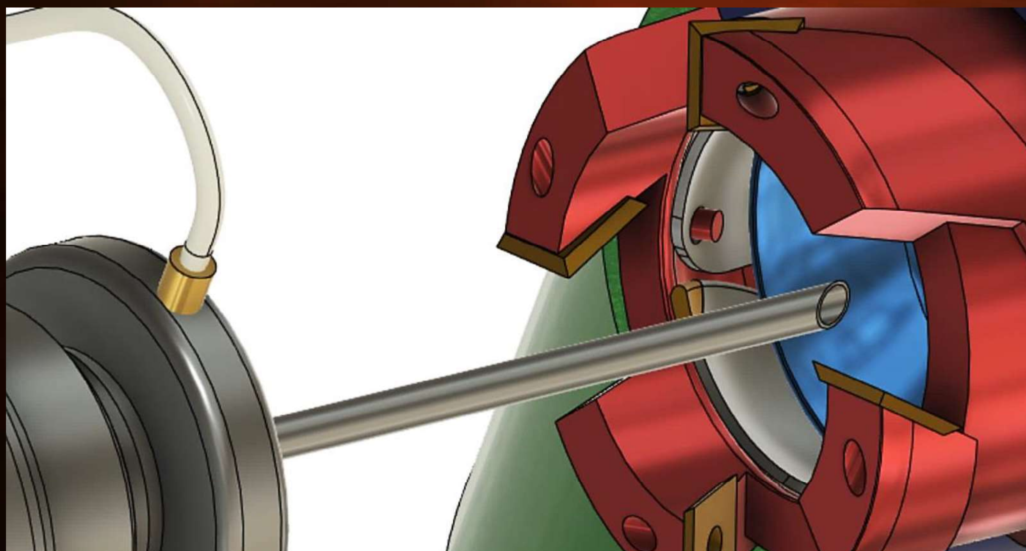
Aubrey, A., et. al. (2008). “The Urey Instrument: An Advanced In Situ Organic and Oxidant Detector for Mars Exploration.” doi:10.1089/ast.2007.0169

Either TEGA or the Urey Instrument could be incorporated into the body of the rover and still leave some room to spare. Both are designed to work with deck-mounted sample inlet ports. The SAM suite from the Mars Science Laboratory is far too large, since we are using the Mars 2020 Caching system.

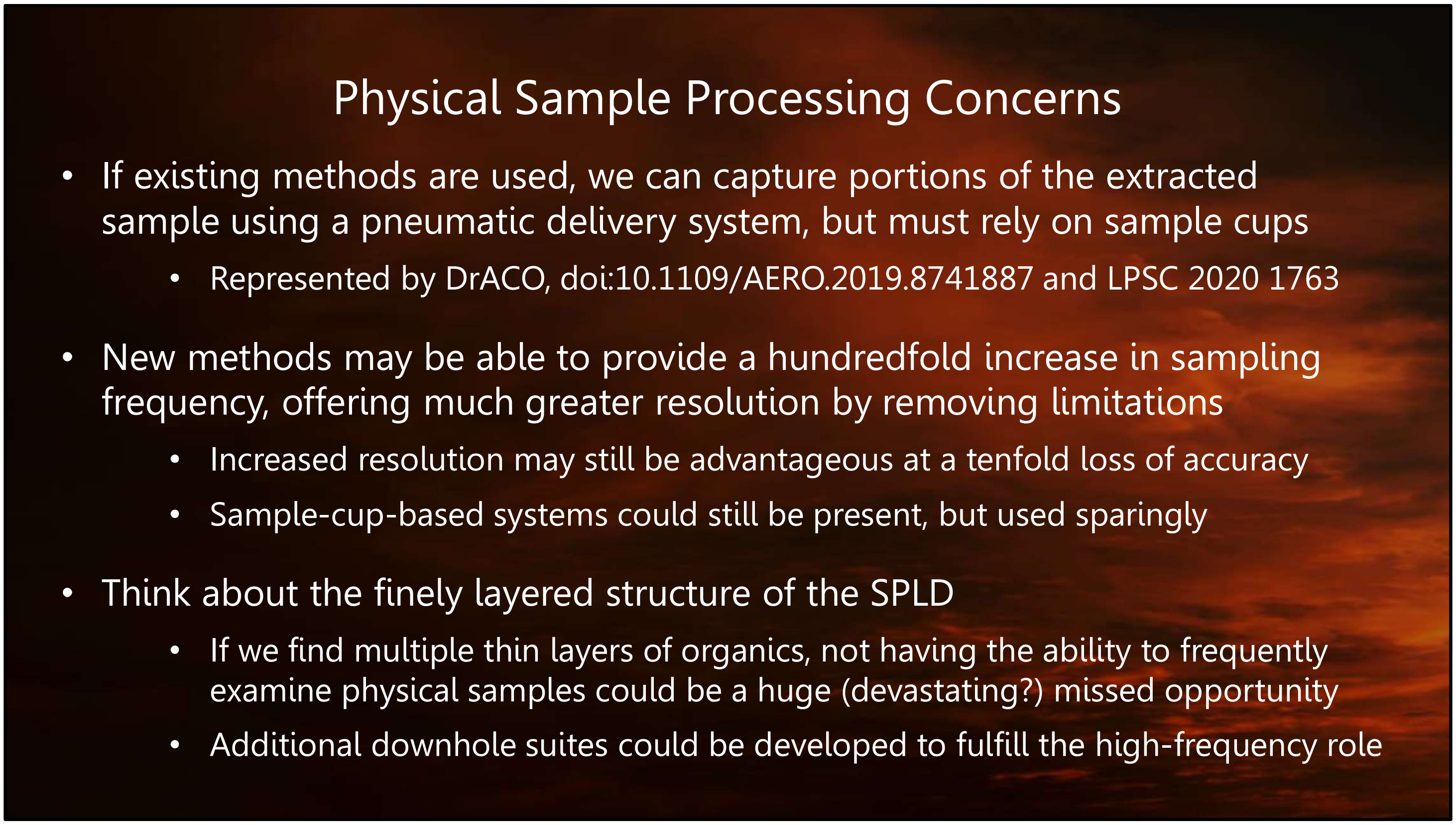
The overall idea:
- Mapping of organic signature distributions with the Raman UV Spectrometer
- Urey or TEGA for life detection / physical analysis of regions of interest
- Log the climate record with precision gas analysis (not currently part of Urey), or some other method of isotope ratio determination – we are open to any and all suggestions here. This is not my area of expertise, and I’d like to send our consultants in the right direction.

In-situ ice core analysis (in the drill head)

The potential to physically sample thousands of SPLD ice cores exists. We are focusing on ways to tie a "hot needle" instrument in with the science payload using a pneumatic sample handling system.



In addition to a sample inlet port on the rover deck, we can route ice core material to instruments pneumatically during the drill head cleaning process. There will already be chips and dust in the drill head, and more will be created while cleaning it out. To take this a bit further, we can have a dedicated tool for extracting material from the center of ice cores while they are still in the drill head – allowing access to a more pristine part of the sample. A hot needle could be one simple way to do this. The idea here is to use this needle method as an alternative to a full-on ice core melting station, which is how we extract climate records on Earth.



Back to the onboard instruments, we really want to be able to take a detection of organics to the “finish line” with the physical sample processing. We also want to focus on climate markers, because this can provide a global context to life detection science done elsewhere on Mars. These goals are easy to substantiate in a polar science drilling mission concept. The big problem here is the number of sample cups or ovens available. For example, TEGA can give us a very high-quality evolved gas analysis, but only has eight ovens. Urey is built from the ground up for life detection, including chirality analysis of trace biomarkers like amino acids and PAHs, but only has 24 sample cups.

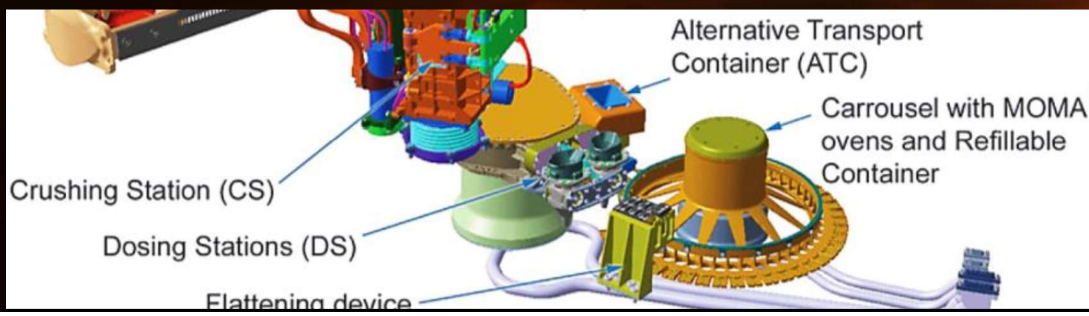
With the pneumatic system, we can capture portions of the extracted sample, but must rely on sample cups. See the DrACO system on DragonFly to see a high-TRL implementation.

New (yet-to-be invented) methods may be able to enable a hundredfold increase in sampling frequency for us, offering much greater resolution by removing limitations. For example, the finely layered structure of the SPLD would take very well to frequent physical processing. It may be possible to create new downhole instruments to alleviate some of our concerns, but when it comes to examining preserved organic material – possibly containing dead and frozen lifeforms – it is hard to beat a physical instrument. The Urey Instrument is very strong in this context, but “as-is” it would have to be reserved for re-examining very significant findings by downhole instruments.

“Unlimited” Sample Processing Ideas

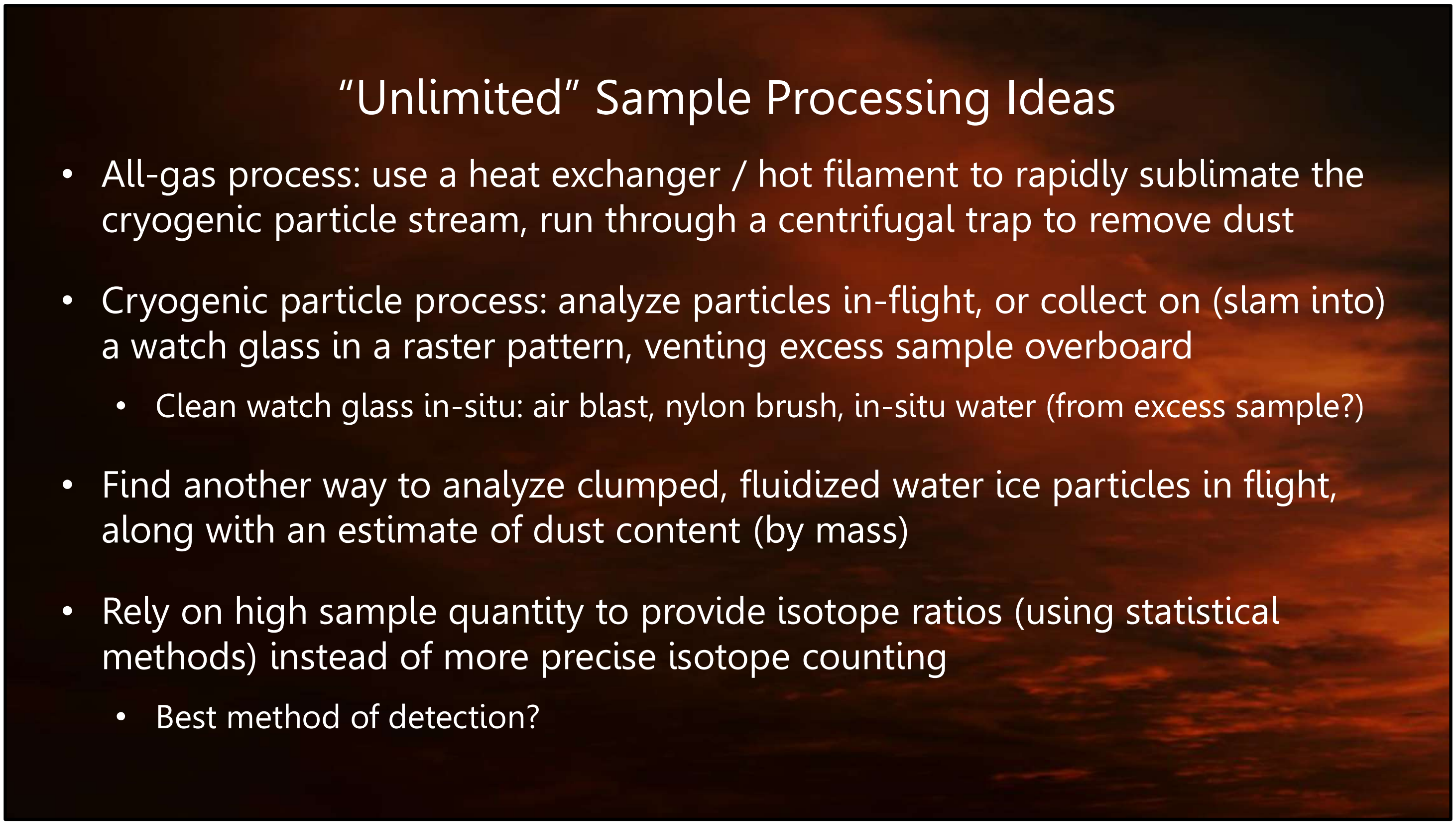
Make the sample cup carousels work for thousands of samples:

- Dispense some kind of plasticizer into the cup after each use, and bake
- Rinse with in-situ reagent (SPLD is 85% water ice on average)
- Apply statistical methods to control for contamination in reused cups
- Nested doll approach: cups could have disposable liners nested 10+ layers deep
- Remove a few cups from the carousel in favor of a cleanable watch glass station



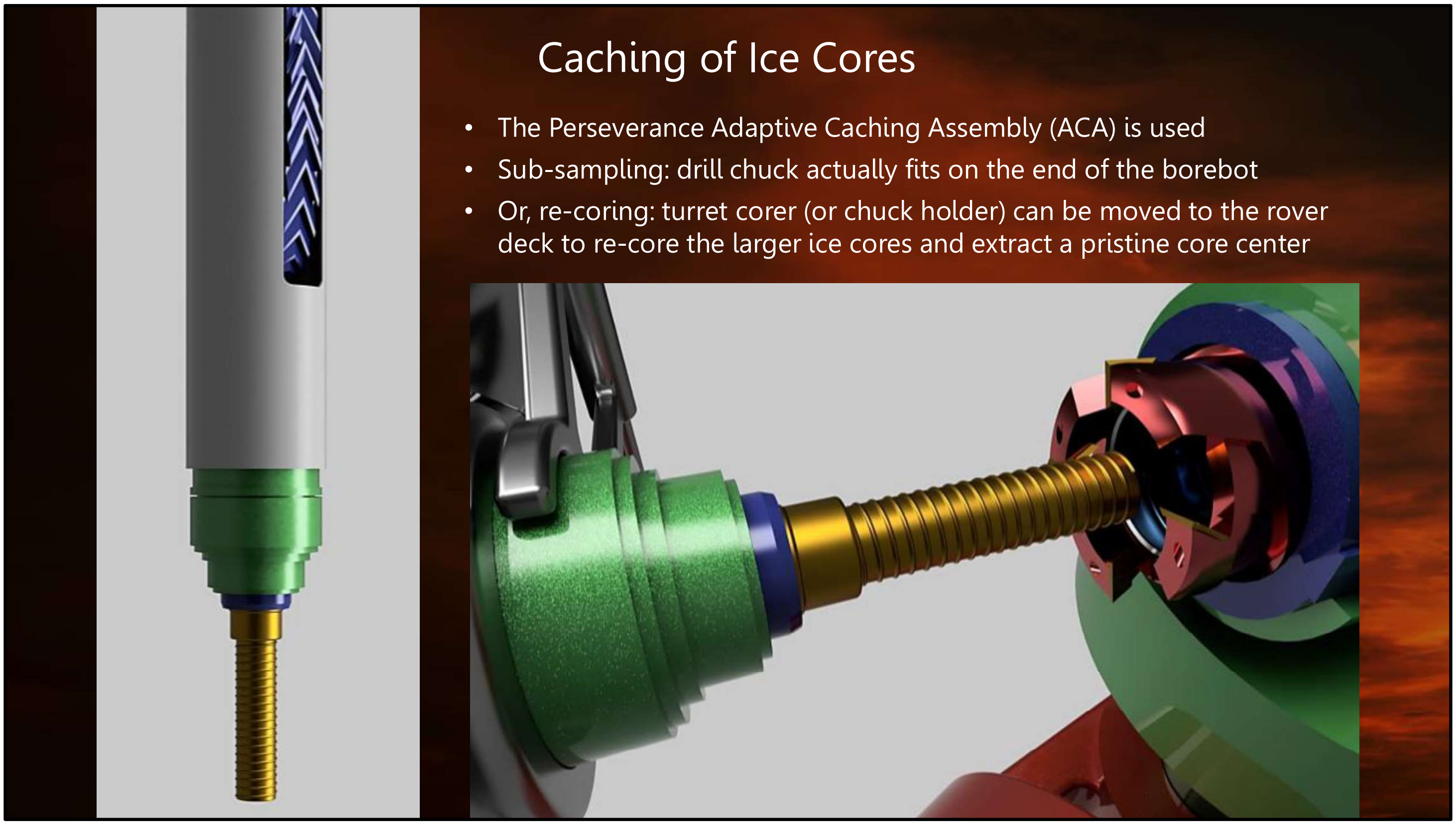
Vago, et al. 2017, doi:10.1089/ast.2016.1533

This slide is the result of some brainstorming we did during our Phase I work. The idea here is that even with its very robust carousel, we still aren’t even making a dent in the sampling frequency that we desire. Most of these ideas involve ways to reuse the cups without sacrificing the integrity of the process. Developing a cleanable watch-glass-type station is a way to stop relying on cups entirely, and lead to another idea on the next slide. I also saw something called a Refillable Container on the MOMA instrument from the Rosalind Franklin Rover, which can be loaded by the Alternative Transport Container if the dual-redundant sample metering system fails, and this would be a good starting point for a system that doesn’t use cups.



Here are a few more off-the-wall ideas, where we are trying to think of ways to use the pneumatic system without a carousel at all. With the hot needle extraction method, we can cook most of the volatiles during the extraction step itself. Or, perhaps with a larger needle and lower power setting we could retain some of the cryogenic material in the airstream. We are trying to avoid using a drill to extract material from the center of the core, because we looked at that early on as a way to capture core samples for the caching system, but we are moving away from that process. Still – if the goal is to make and ingest dust – a small, high-RPM drill may be able to help us with that.

Five count before next slide (caching) …



We can use the Adaptive Caching Assembly from the Perseverance rover nearly as-is. Since we are moving away from “re-coring,” we’ve been looking at attaching the chuck from the Mars 2020 turret corer directly to the front of a borebot. This is shown on the left. The idea is to drive all the way to the bottom of the borehole and take a core from the virgin substrate, and then resume normal drilling with the other borebots. We can get full-heritage on the chuck mechanism for the larger 4” borebots with this setup. It is possible to make the chuck fit on the smaller 64 mm borebots, but we would only retain partial heritage, and it would be difficult to add a percussor (for length and mass reasons), since the smaller borebots would normally be targeted at a smaller lander.

Thanks everyone, want to encourage you to please reach out to us if you have any ideas, or come up with anything that could help us during this workshop. It will really help us plan the work we do in the future.

Check out borebots.fyi to download our NIAC Phase I report, and also to find a link to our Mars Society presentation which covered more of the mechanical challenges that we've been dealing with. These slides are already posted there as well, I'll leave them up for a few weeks.

Q&A