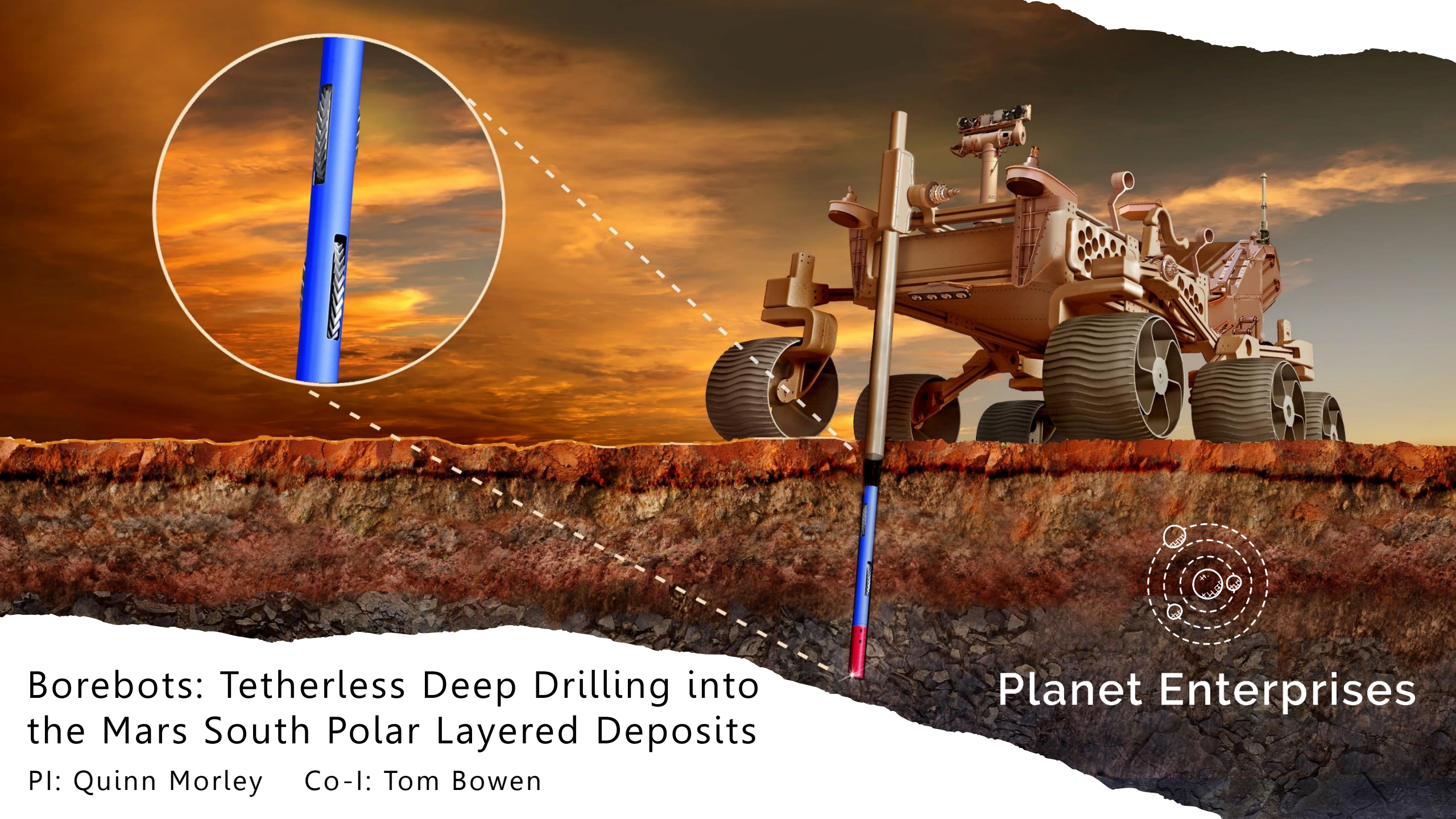


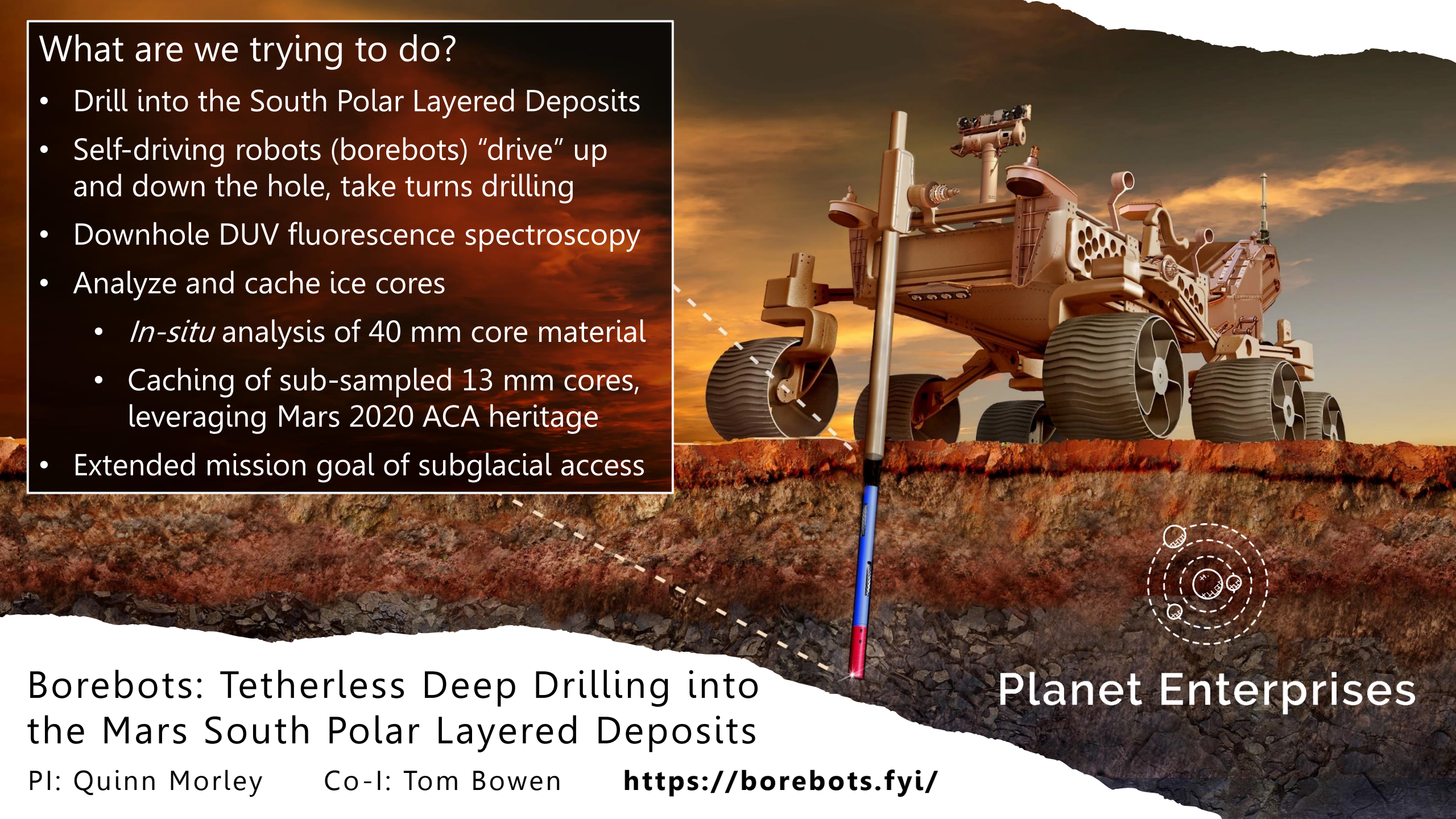
# Borebots: Tetherless Deep Drilling into the Mars South Polar Layered Deposits

PI: Quinn Morley  Co-I: Tom Bowen

Planet Enterprises

## What are we trying to do?

- Drill into the South Polar Layered Deposits
- Self-driving robots (borebots) “drive” up and down the hole, take turns drilling
- Downhole DUV fluorescence spectroscopy
- Analyze and cache ice cores
  - *In-situ* analysis of 40 mm core material
  - Caching of sub-sampled 13 mm cores, leveraging Mars 2020 ACA heritage
- Extended mission goal of subglacial access



# Borebots: Tetherless Deep Drilling into the Mars South Polar Layered Deposits

PI: Quinn Morley  Co-I: Tom Bowen

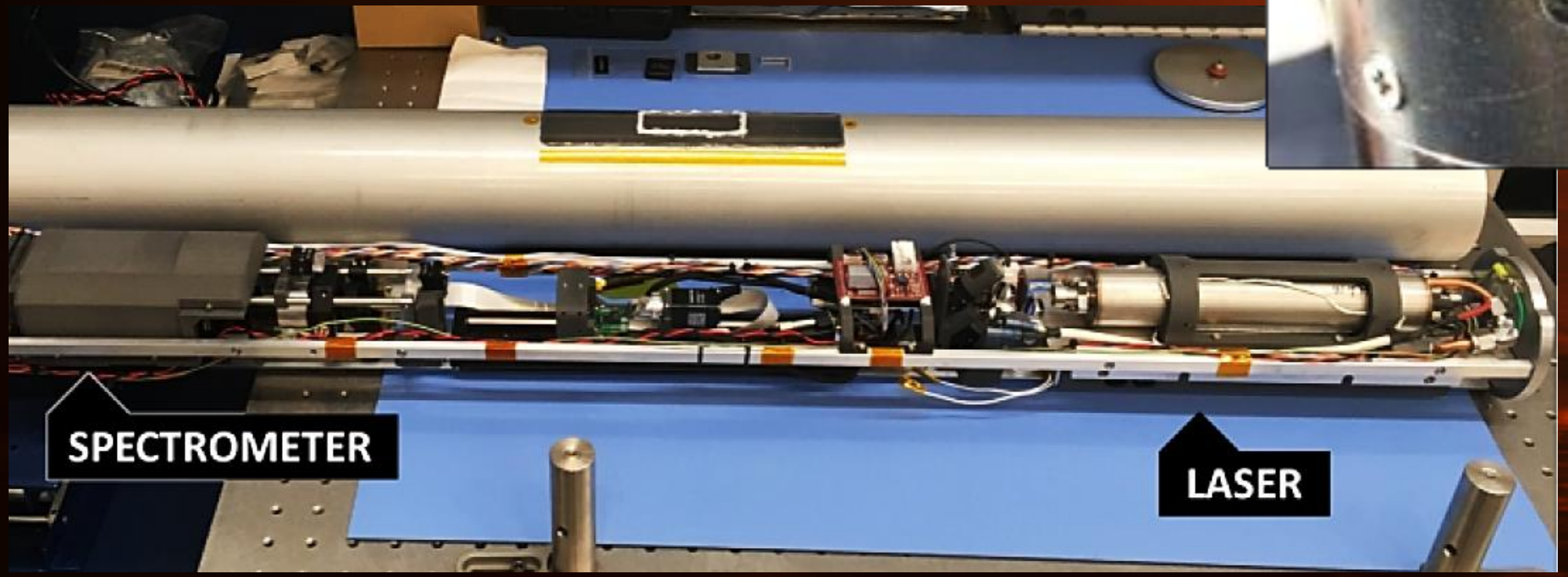
**https://borebots.fyi/**

Planet Enterprises

# Science Instruments

## Downhole Instruments

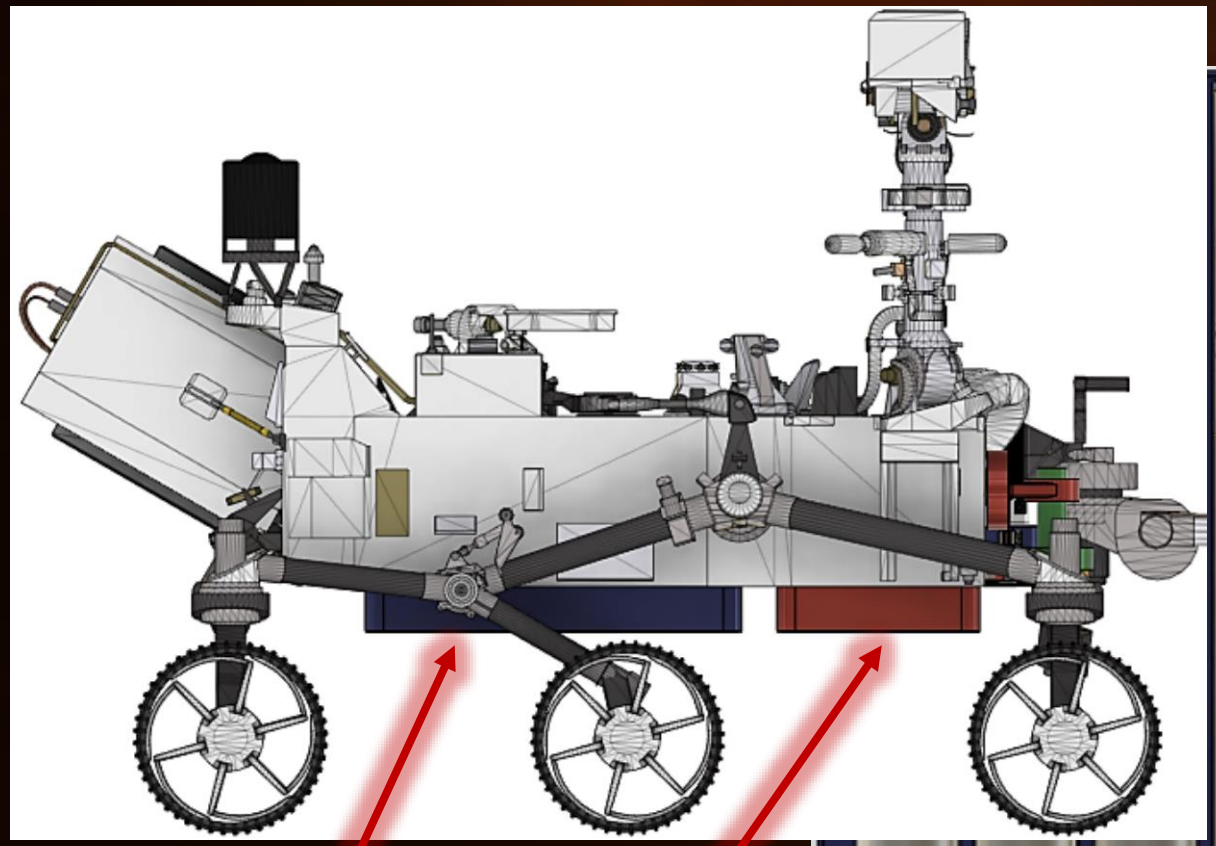
- Microscopic imager (white and UV light)
- WATSON Deep UV Fluorescence Mapping Spectrometer
  - Can detect, classify, and map the distribution of organic signatures embedded ice, on par with laboratory spectrometers. Add'l Raman capability.

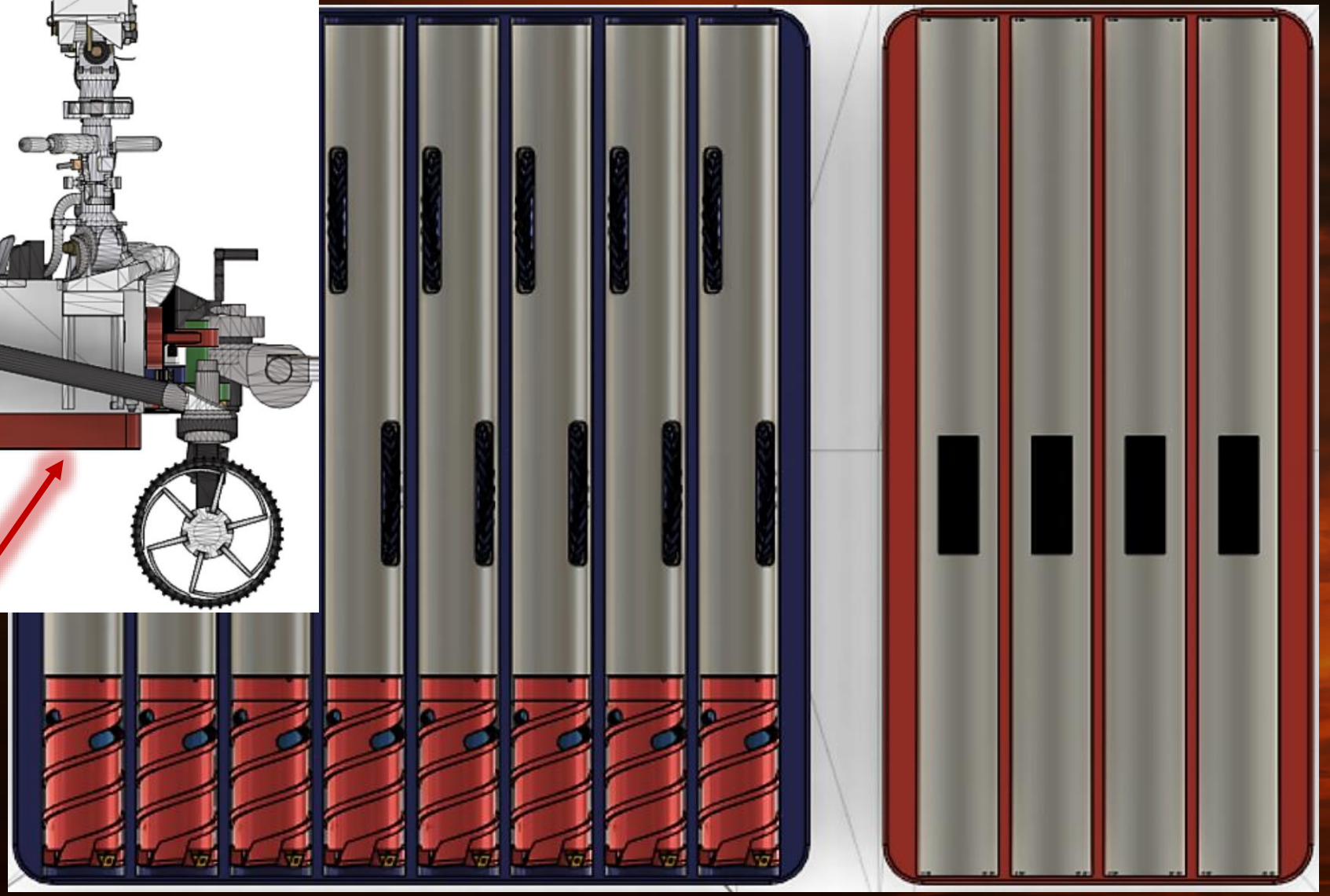



Zacny, K. et. al, 2016.
doi:10.1061/9780784479971.027

Eshelman, M. et. al, 2019.
doi:10.1089/ast.2018.1925

# Science Instruments

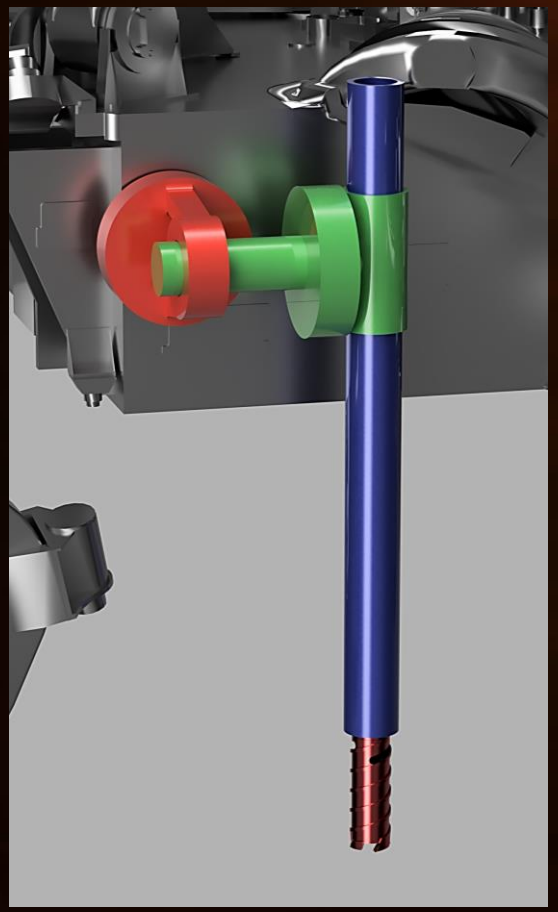


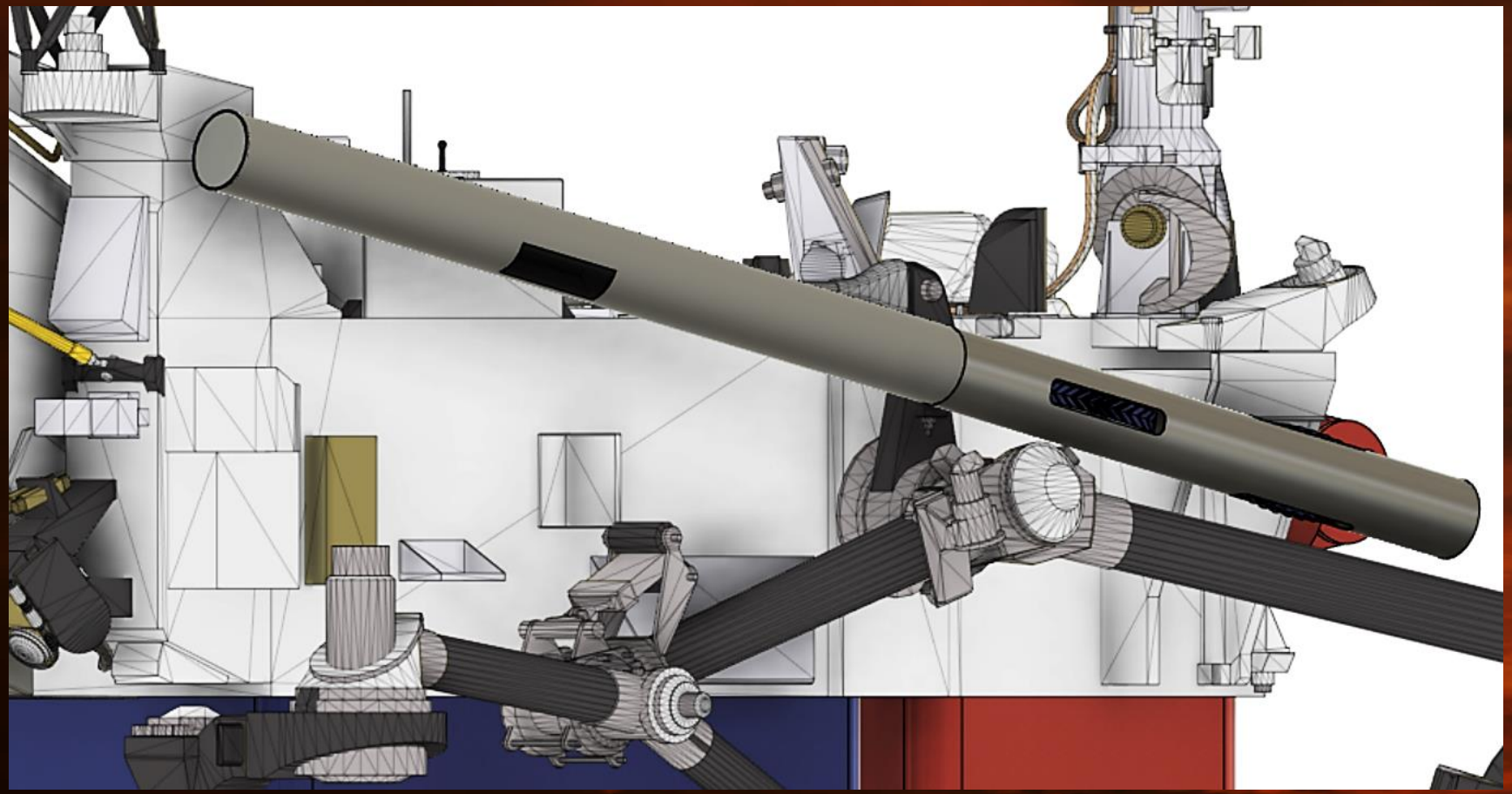


4” Borebots and WATSON stowage location under rover

# Science Instruments

## “WATSON-Bot” Arrangement and Stowage Between Uses



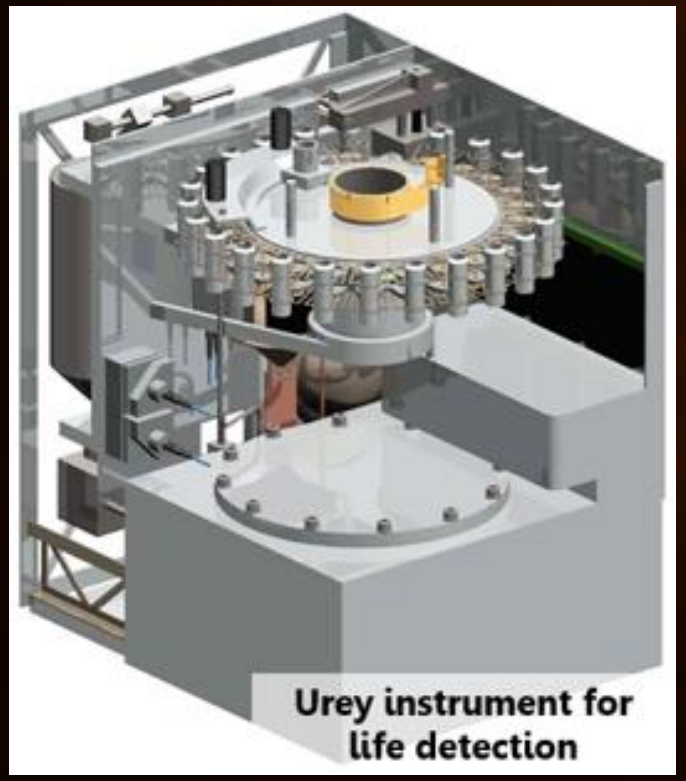


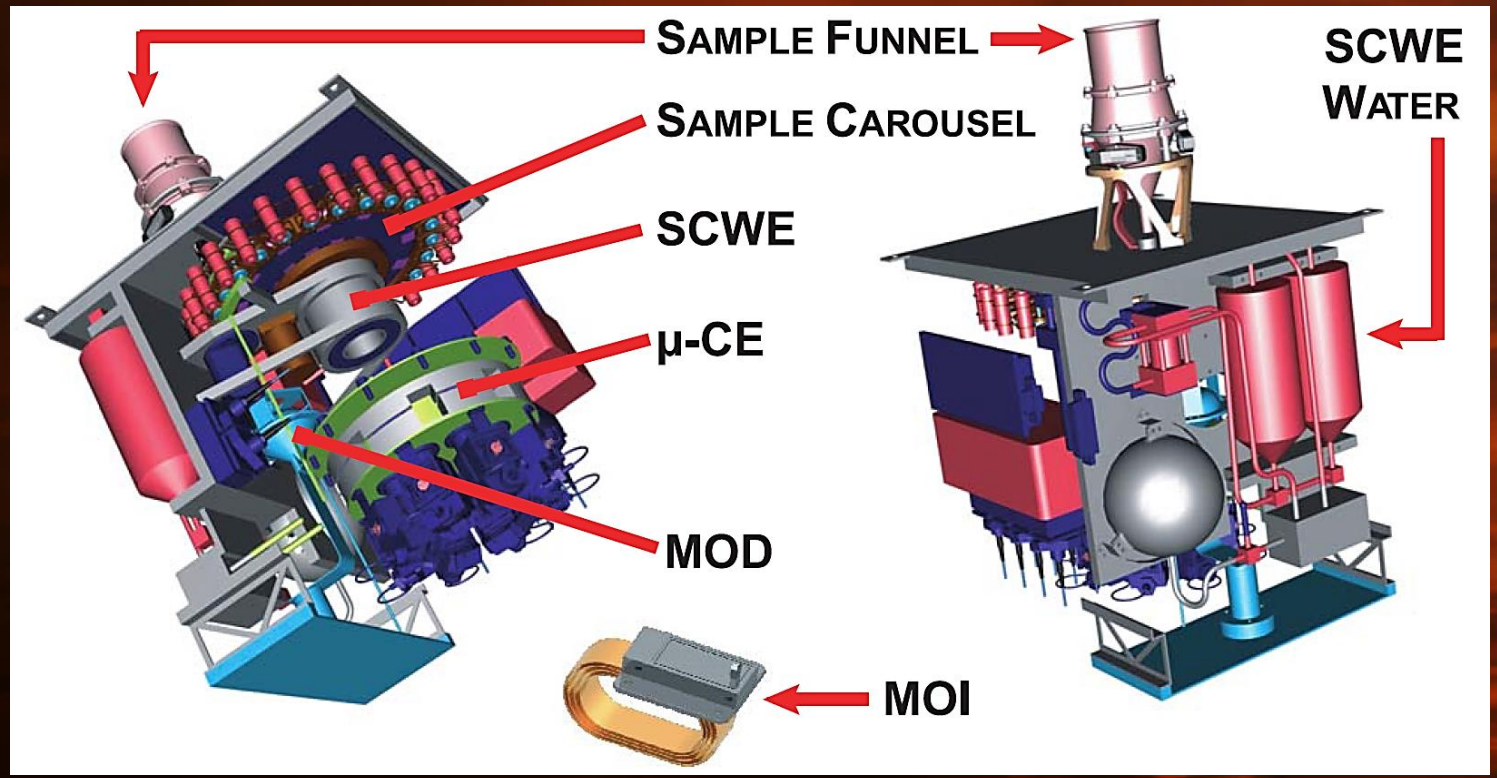
The deployment tube on front of the rover (shown left) can flip towards the outboard direction and store a WATSON-bot in a location above the right-hand rocker bogie.

# 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.

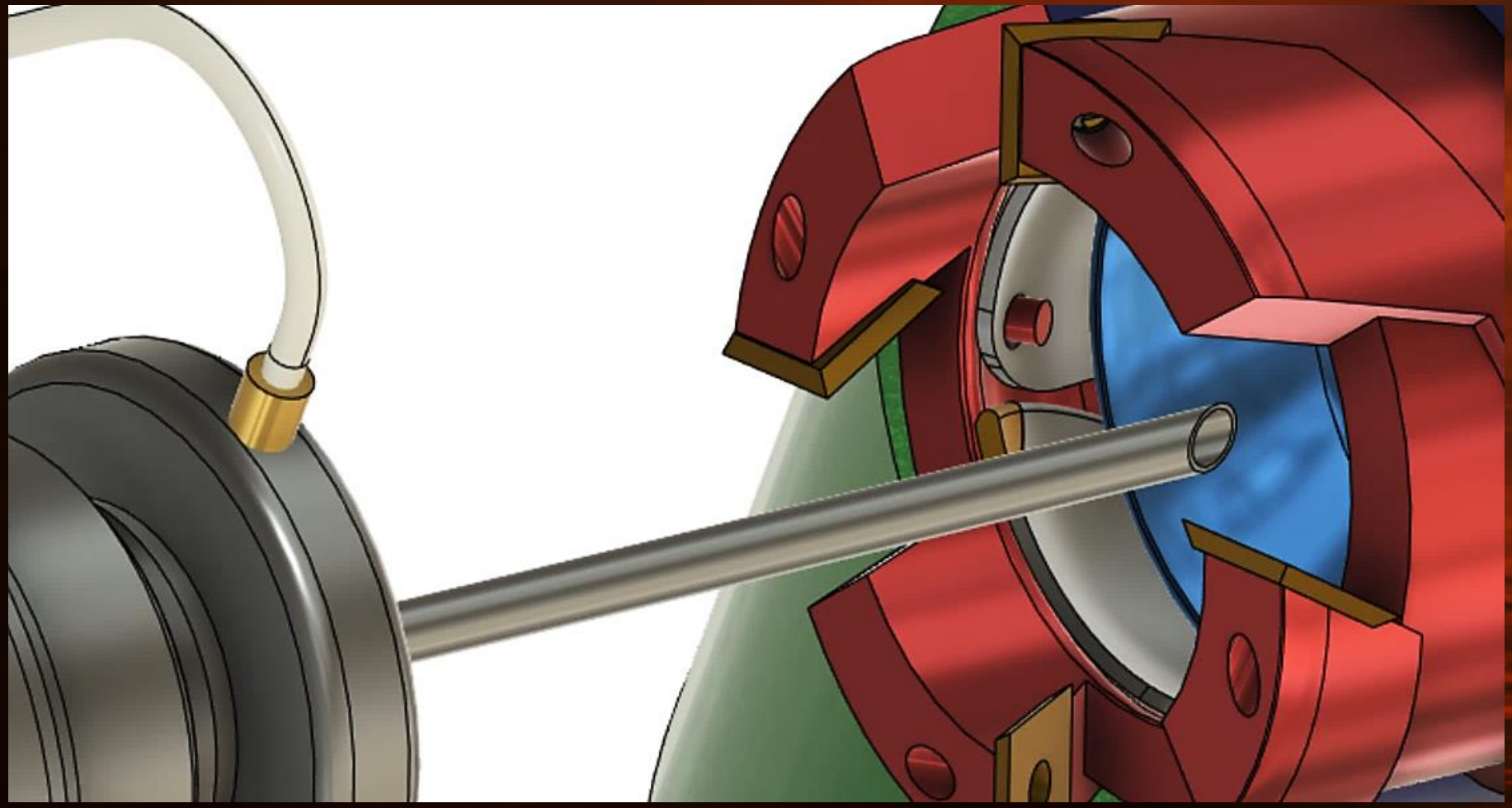



Aubrey, A., et. al. (2008). "The Urey Instrument: An Advanced In Situ Organic and Oxidant Detector for Mars Exploration." doi:10.1089/ast.2007.0169

# *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.



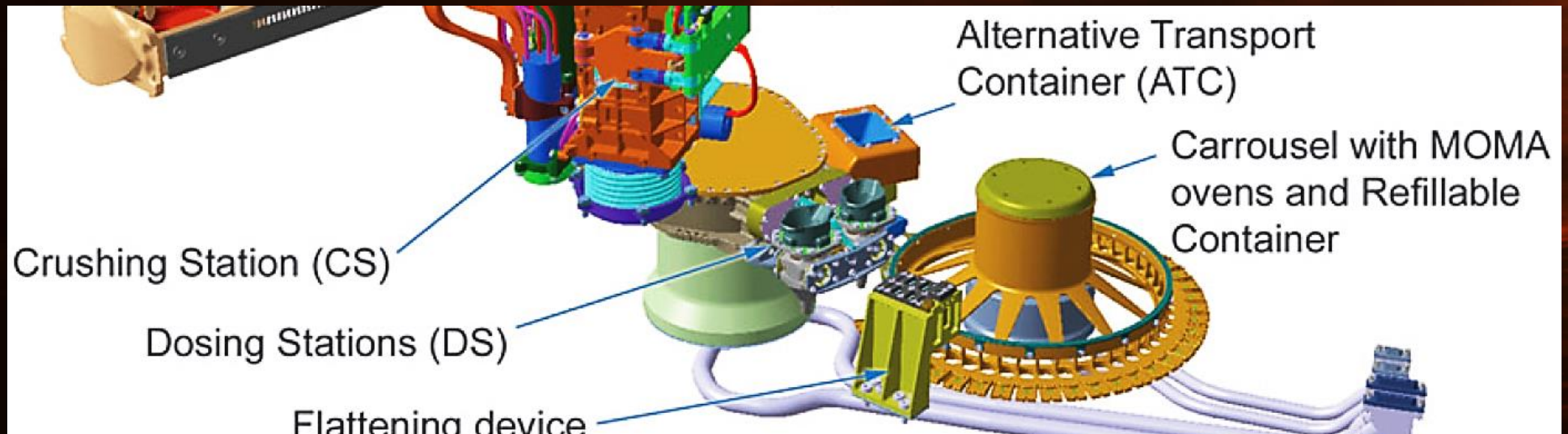
# Physical Sample Processing Concerns

- If existing methods are used, we can capture portions of the extracted sample using a pneumatic delivery system, but must rely on sample cups
    - Represented by DrACO, doi:10.1109/AERO.2019.8741887 and LPSC 2020 1763
- New methods may be able to provide a hundredfold increase in sampling frequency, offering much greater resolution by removing limitations
    - Increased resolution may still be advantageous at a tenfold loss of accuracy
    - Sample-cup-based systems could still be present, but used sparingly
- Think about the finely layered structure of the SPLD
    - If we find multiple thin layers of organics, not having the ability to frequently examine physical samples could be a huge (devastating?) missed opportunity
    - Additional downhole suites could be developed to fulfill the high-frequency role

# “Unlimited” Sample Processing Ideas

Make the sample cup carousels work for thousands of samples:

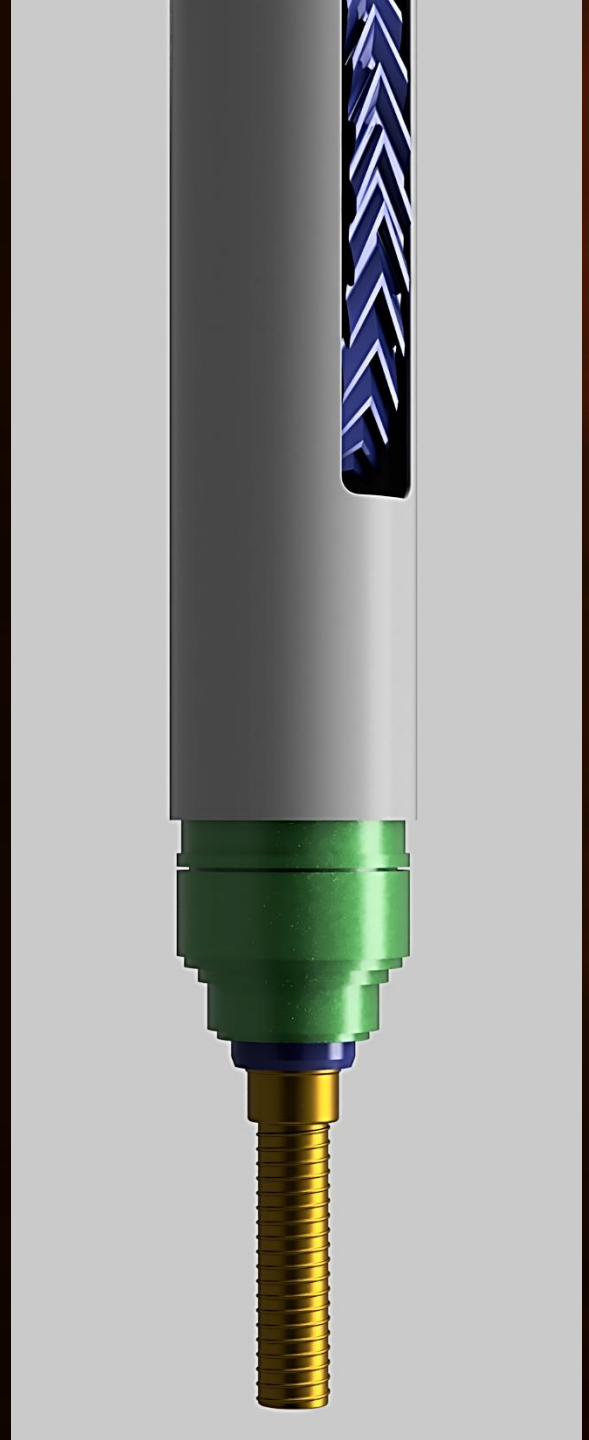
- Dispense some kind of plasticizer into the cup after each use, and bake
- Rinse with in-situ reagent (SPLD is 85% water ice on average)
- Apply statistical methods to control for contamination in reused cups
- Nested doll approach: cups could have disposable liners nested 10+ layers deep
- Remove a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




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

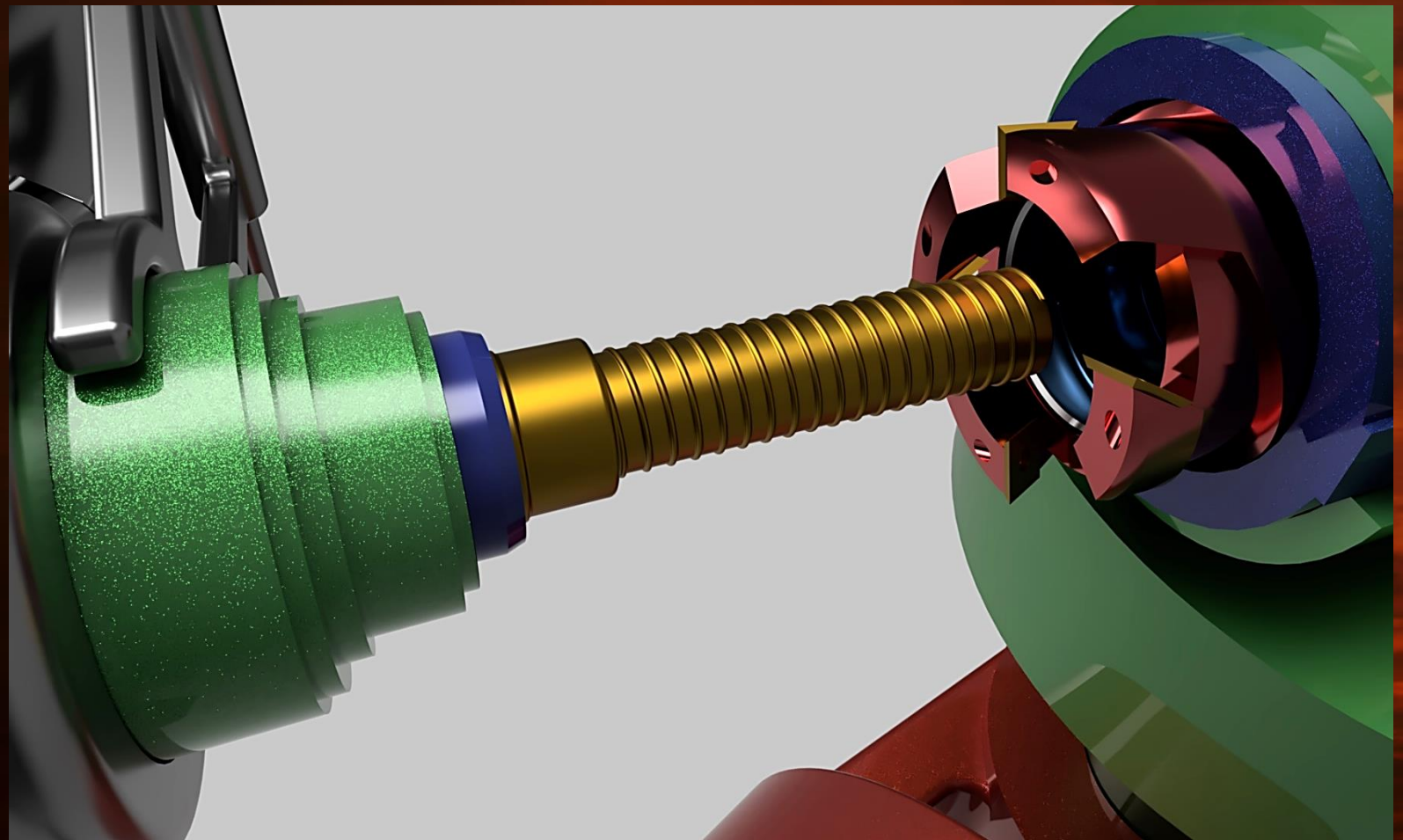
# “Unlimited” Sample Processing Ideas

- All-gas process: use a heat exchanger / hot filament to rapidly sublimate the cryogenic particle stream, run through a centrifugal trap to remove dust
- Cryogenic particle process: analyze particles in-flight, or collect on (slam into) a watch glass in a raster pattern, venting excess sample overboard
  - Clean watch glass in-situ: air blast, nylon brush, in-situ water (from excess sample?)
- Find another way to analyze clumped, fluidized water ice particles in flight, along with an estimate of dust content (by mass)
- Rely on high sample quantity to provide isotope ratios (using statistical methods) instead of more precise isotope counting
  - Best method of detection?



# Caching of Ice Cores

- The Perseverance Adaptive Caching Assembly (ACA) is used
- Sub-sampling: drill chuck actually fits on the end of the borebot
- Or, re-coring: turret corer (or chuck holder) can be moved to the rover deck to re-core the larger ice cores and extract a pristine core center



# Please Contact Us!

- Any sample-processing ideas are welcome / can help us plan future work
- Your feedback will help shape the work that we ask our science and robotics consultants to do, so early-stage feedback can pay dividends
- Our NIAC Phase I report is available at https://git.io/J9nhR
- We maintain a list of Borebots-related work at **https://borebots.fyi**
- Feel free to share with friends and colleagues!

Quinn Morley
Principal Investigator
quinn@quinnmorley.com

Tom Bowen
Co-Investigator
thomaswadebowen@gmail.com