Deep-UV fluorescence and Raman instrumentation for organic detection in subsurface environments

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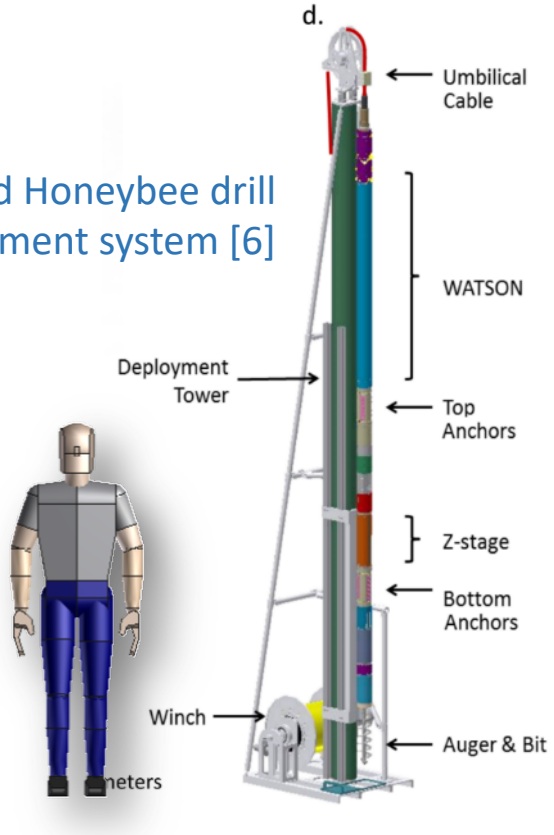
The WATSON project / NASA PSTAR

WATSON is intended for ice borehole mapping and organic detection, based on SHERLOC, the Mars 2020 deep UV Raman and fluorescence spectrometer [1].

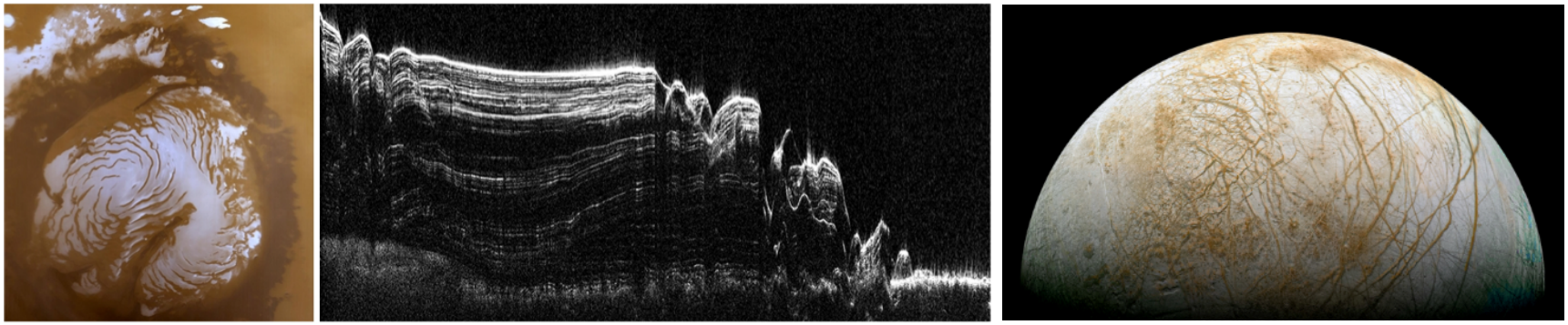
WATSON and Honeybee drill deployment system [6]



Science objectives

- Detect and characterize organic compounds/potential biosignatures, including microbes, in subsurface ice environments
- Determine the spatial distribution of organic material on the Greenland ice sheet at a depth of 100m
- Leverage high-TRL components to demonstrate the potential for future planetary missions

Searching for organics on icy/ocean worlds

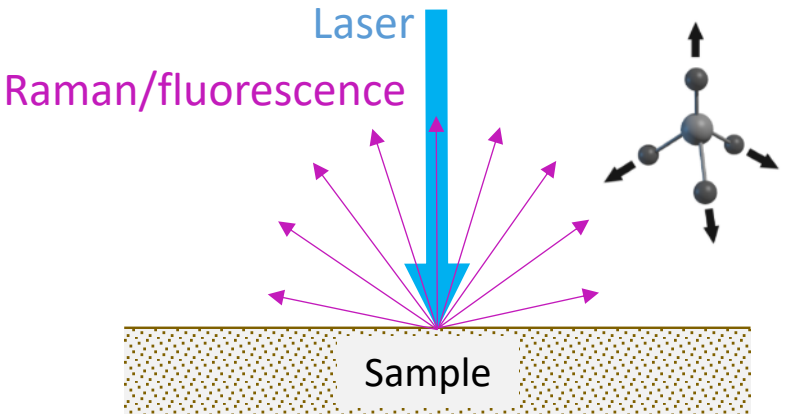


Left: north polar cap on Mars. Middle: Mars north polar ice cap cross section. Right: Europa
(Planetary Photojournal image PIA02800: NASA/JPL/MSSS, PIA13164: NASA/JPL-Caltech/ASI/UT, PIA19048: NASA/JPL-Caltech/SETI Institute).

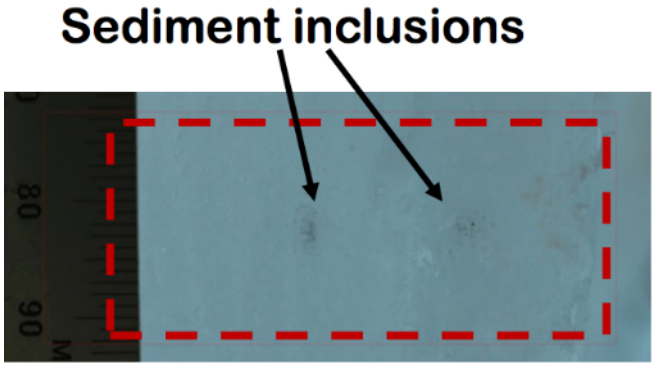
- Ice deposits provide an environment where chemical and biological signatures can be found
- Greenland and Antarctica have been found to contain organic material / microbes embedded in subsurface ice [2,3]
- In-situ organic and life-detection instruments are needed to enable future missions to these environments to search for organic material present

DUV Raman and fluorescence for organic detection

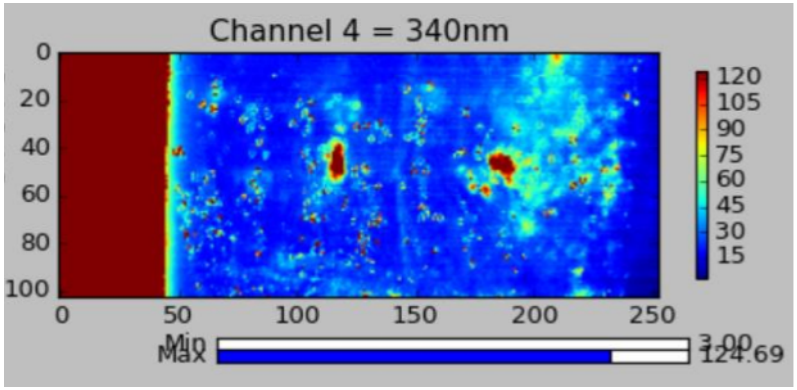
- Detect C=C, C=O, and other CHONPS bonds, fluorescence characteristic of aromatic organics and microbes
- Deep UV excitation results in pre-resonance/resonance in some organics, and Raman window free of fluorescence



Spectral maps from raster-scanning laser preserve spatial context

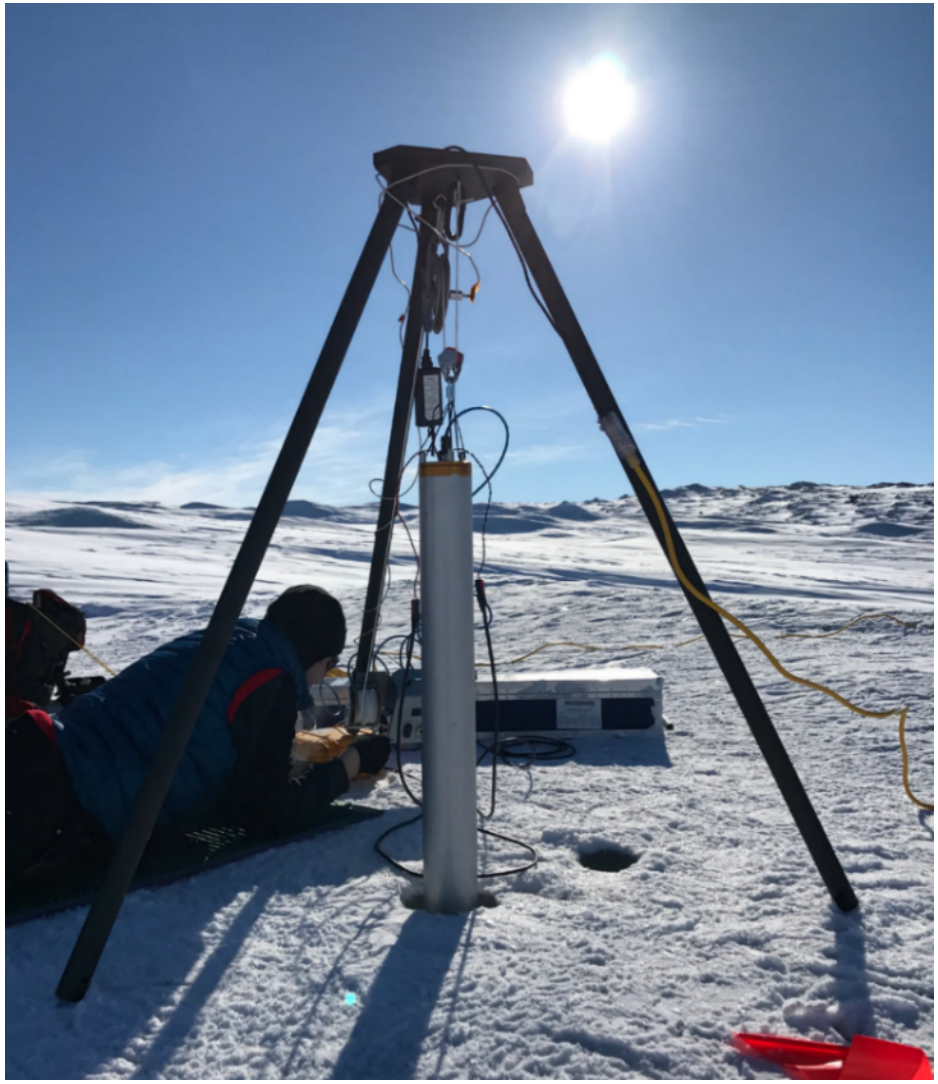


Visible context image



2017 Kangerlussuaq deployment

WATSON deployed in borehole



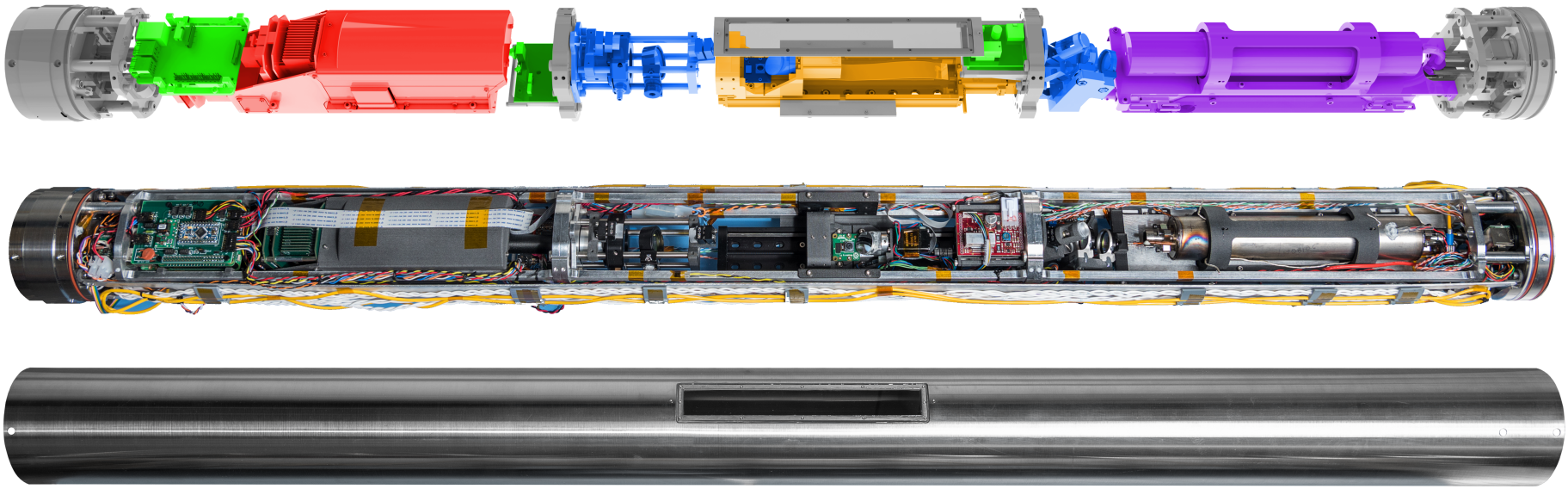
WATSON Block Diagram

Power / electronics
CPU, electronics, and power package

Spectrometer
Collects Raman and fluorescence emission

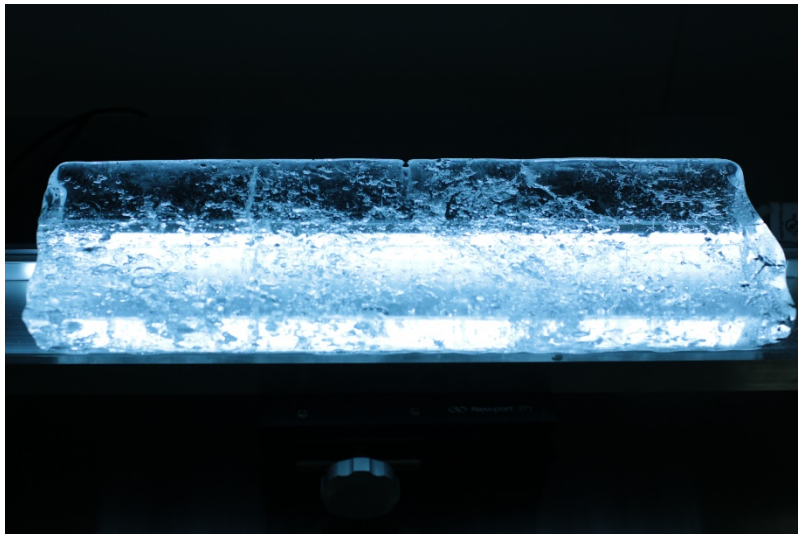
Motorized carriage
Rasters the laser across the sample surface

Laser and LPS
248.6 nm NeCu hollow-cathode laser



Core Analysis: Test on Low TOC Ice

WATSON at -10 C in MSU cold room

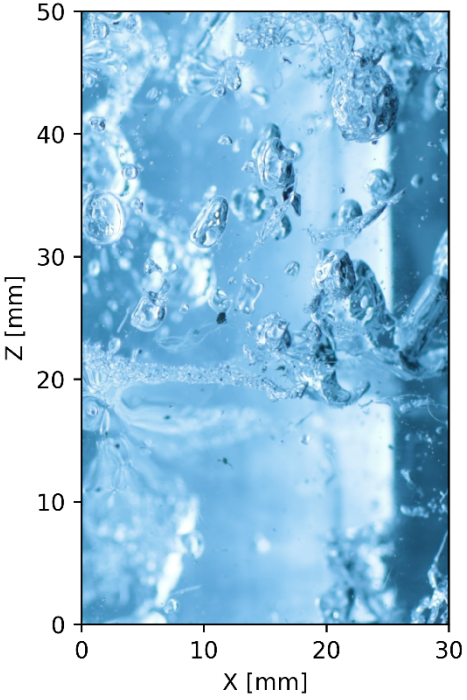


Ice core selected for scanning

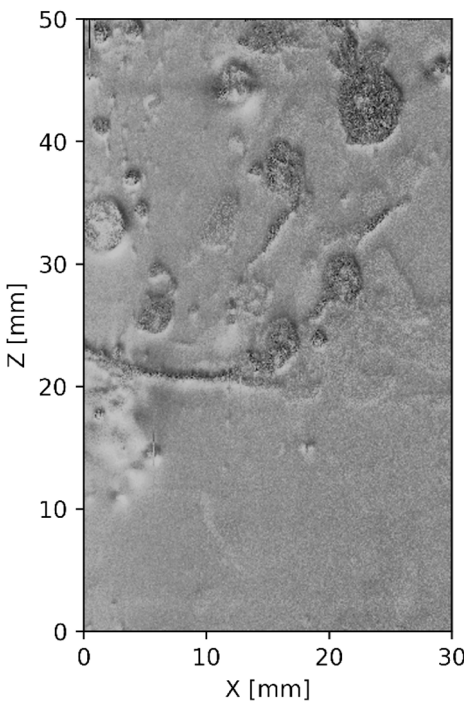
Objective: Determine what Raman and fluorescence signals WATSON can observe in natural ice ***(Low TOC ice: 50-200 ppb)***

IMAGING, RAMAN, FLUORESCENCE MAPS

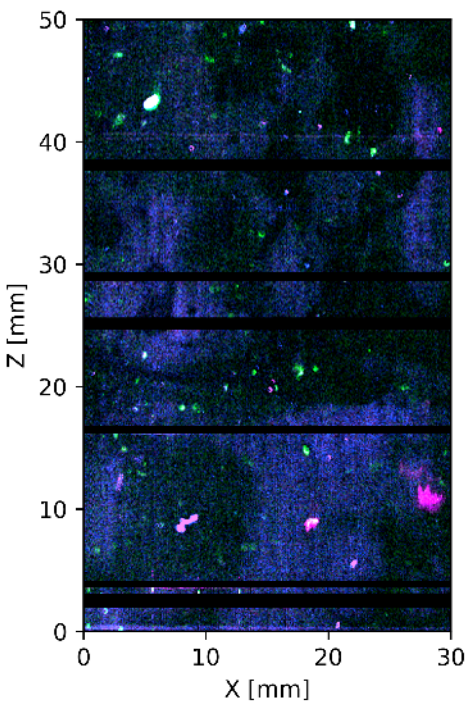
3 cm x 5 cm map, 100 um resolution, 1 pulse per point



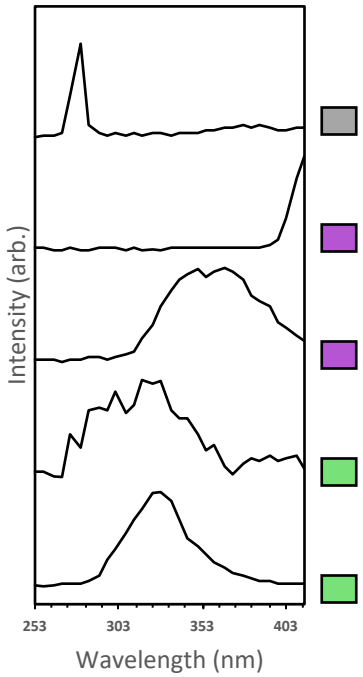
Context image



Raman water-ice band

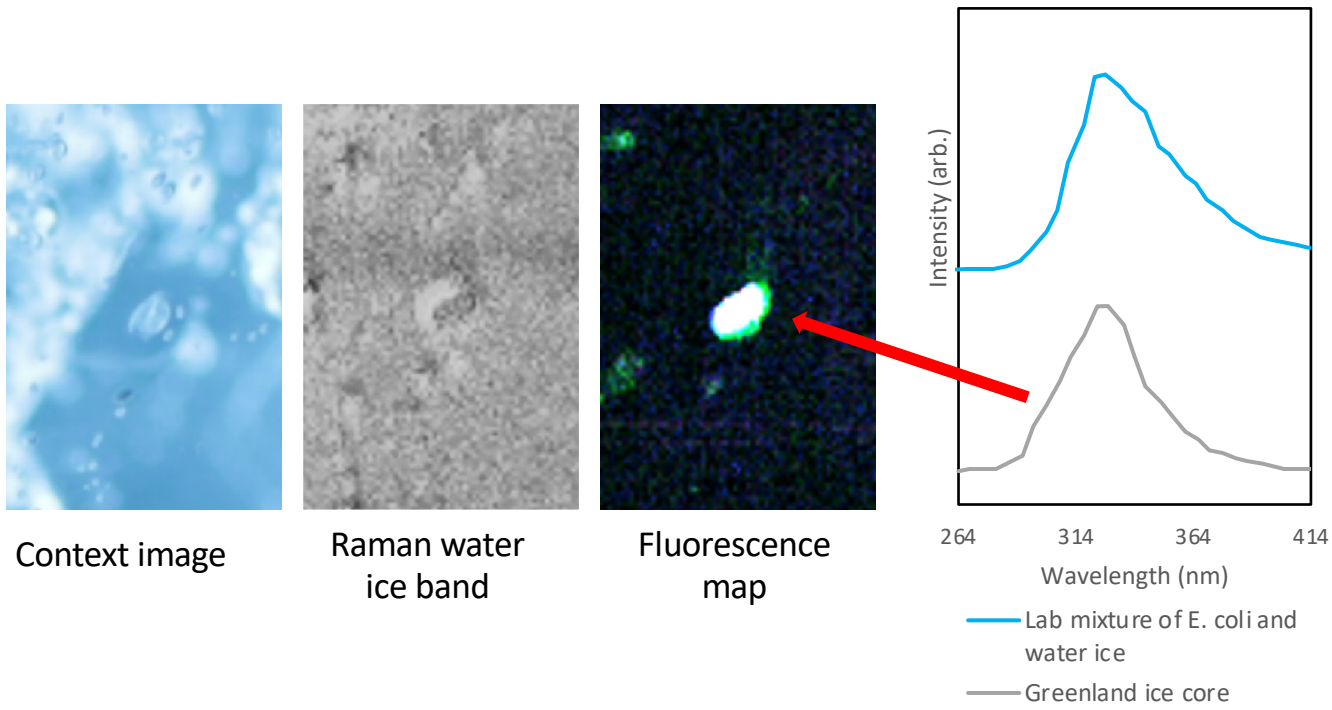


Fluorescence map



Spectral features corresponding to map colors

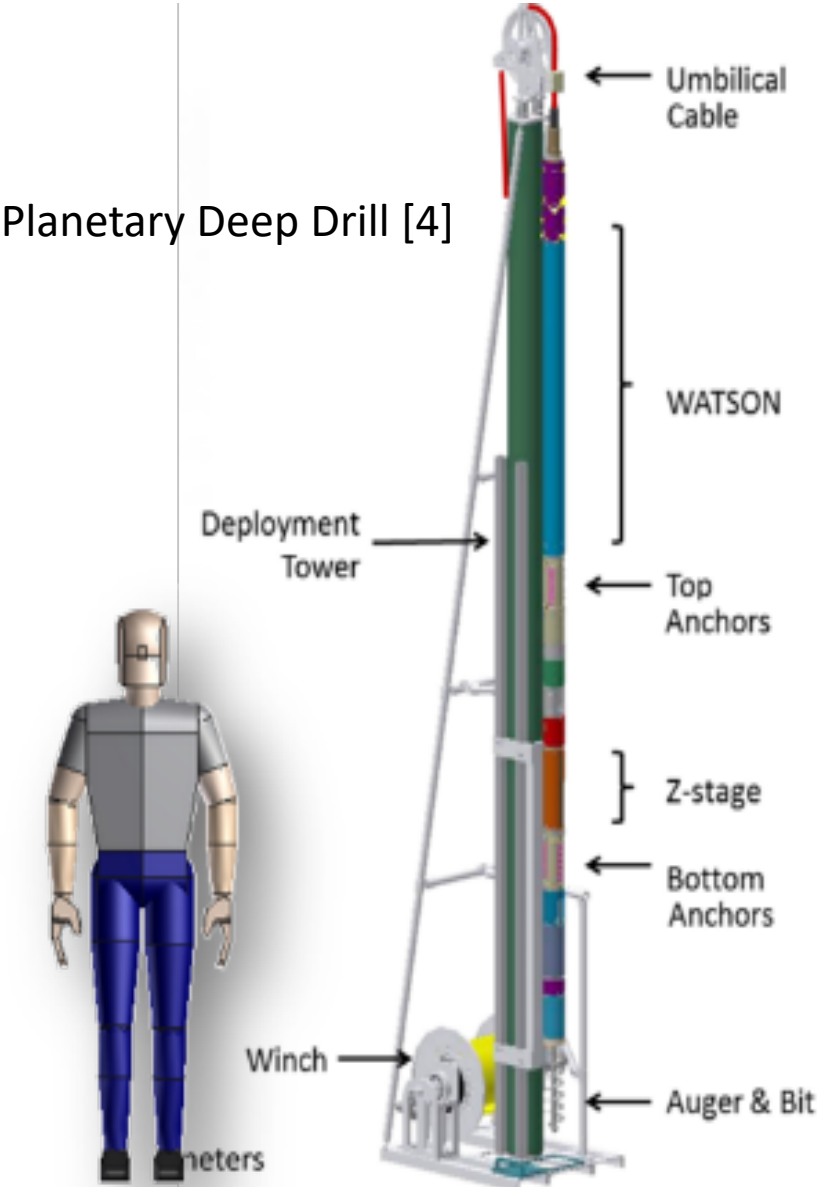
MICROBIAL-LIKE FLUORESCENCE IN ICE



- Detection of microbial-like fluorescence in a bubble at mm-scale depth in Greenland ice
- Bulk analysis shows low cell content at limits of the cell counting technique (~100 cells/mL), while WATSON observes the material in it's natural concentrated state

WATSON Drill Concept Overview

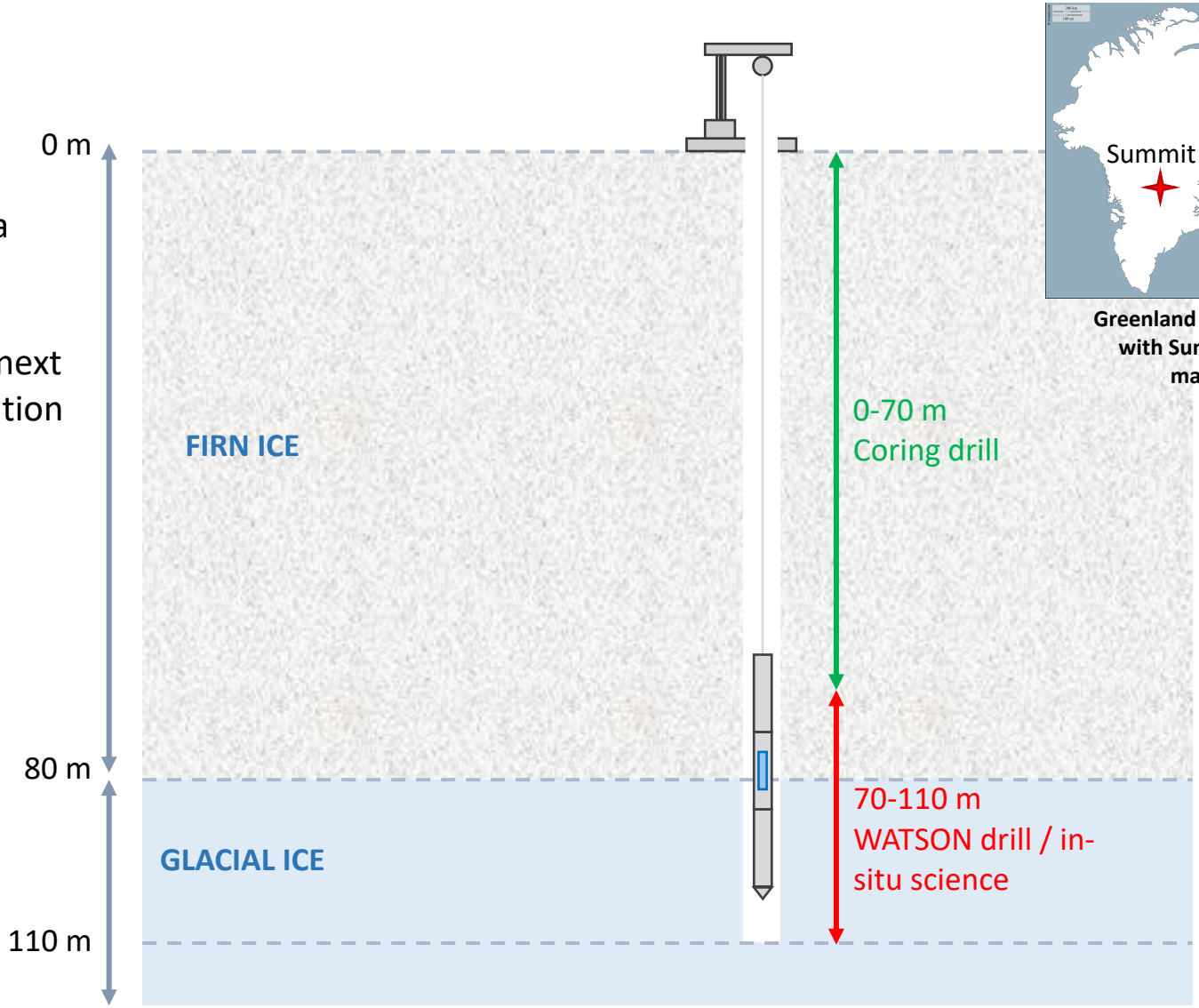
Honeybee Robotics Planetary Deep Drill [4]



ORT - Deployment to Plaster City, CA

JUNE 2019 – DEPLOYMENT TO SUMMIT, GREENLAND

- First 70 m drilled with a traditional drill
- WATSON drill used for next 30-40m, through transition zone into glacial ice



Acknowledgements

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[1] Beegle, L. W. et al. (2015) *IEEE, 90,* 1-11.
[2] Knowlton, C. et al. (2013) *Biology*, *2,* 206-232.
[3] R. Pappalardo and M. D. Coon (1996)
Lunar and Planetary Science, 27, 997.
[4] Zacny, K. et al. (2016) ASCE Earth and Space.