RedWater at MTU:
Scaled Ice Melting Probe
Martian Environmental Testing for ISRU

George Johnson, Paul van Susante
M.E. Master's Student Researcher
georgejo@mtu.edu

HONEYBEE ROBOTICS

HUSKYWORKS
PLANETARY SURFACE TECHNOLOGY DEVELOPMENT LAB

SPACE RESOURCES ROUNDTABLE

RedWater Background

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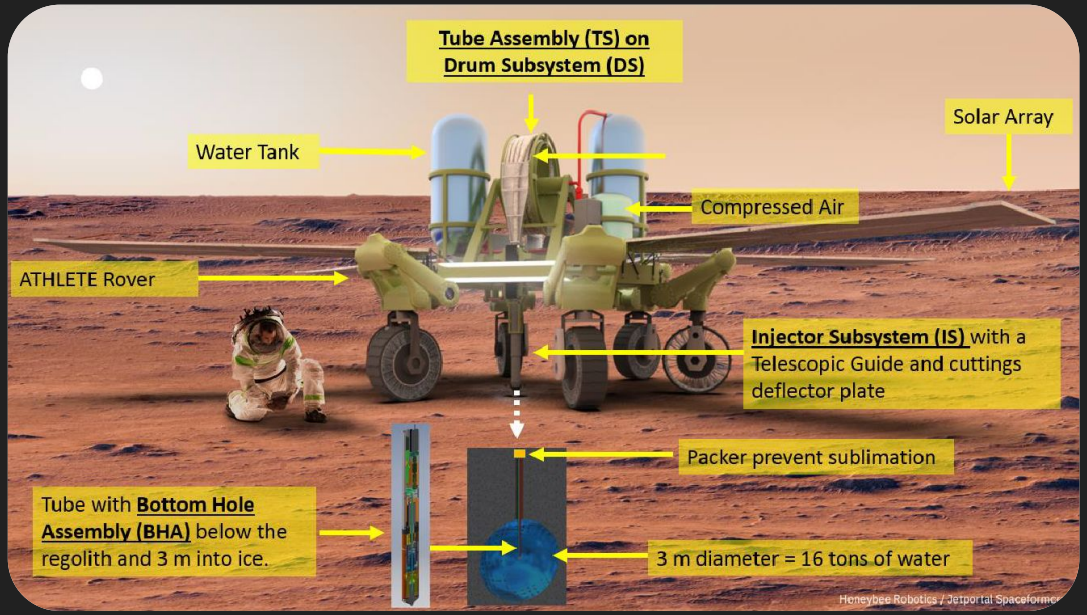
ISRU on Mars:

- ~1/3 of the Martian surface contains shallow ground ice
- SHARAD: Martian equatorial regions specifically the Arcadia & Utopia Planitia +

Honeybee Robotics' Method of Water Extraction:

- CT (Coiled Tubing)
- BHA (Bottom Hole Assembly)
- Rod Well (Rodriquez Well)



(Mellerowicz et al., 2022, Honeybee Robotics)

RedWater – MTU Scaled Probe Testing

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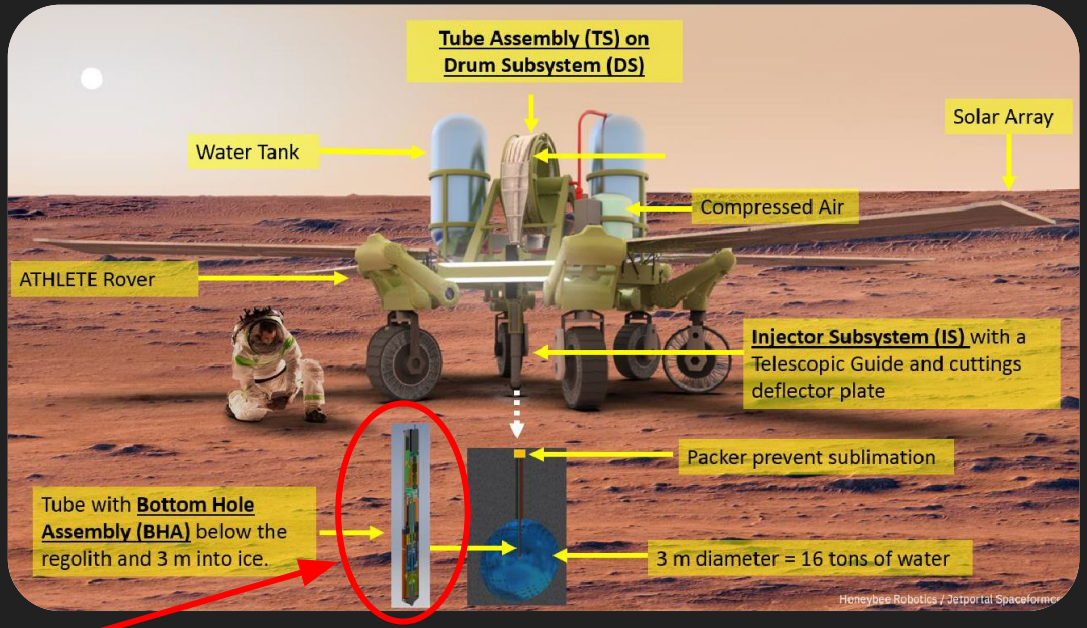
MTU Project Goal:

Provide a data set of a small scale probe's power efficiencies. Record observations of ice melting behavior under Martian atmospheric pressure. This data will be used to aid the thermal modeling of the RedWater drill simulations.



(Mellerowicz et al., 2022, Honeybee Robotics)

Focus of research

Michigan Technological University

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Project Objectives & Requirements

- **Requirements**
  - Measure the power consumed to melt ice (-60° C) under Martian pressure (7 Torr)
  - Determine penetration rate relative to the energy consumed
  - Determine energy per unit volume of ice melted
  - Use a high-density heater in a small probe (1 to 5 inches in length)
  - Control or maintain the ice block temperatures (-60° C to -80° C)

- **How we planned to collect necessary data:**
  - Utilize an acrylic vacuum chamber to achieve Martian pressures (7 Torr)
  - Use liquid nitrogen cooled box to achieve -60 °C ice block temperatures.
  - Control a high-density 4” cartridge heater to heat various probes made of aluminum, copper, stainless steel, and titanium
  - Record the power consumed by the heater
  - Include a string potentiometer to record probe displacement

Vacuum Chamber Design Requirements

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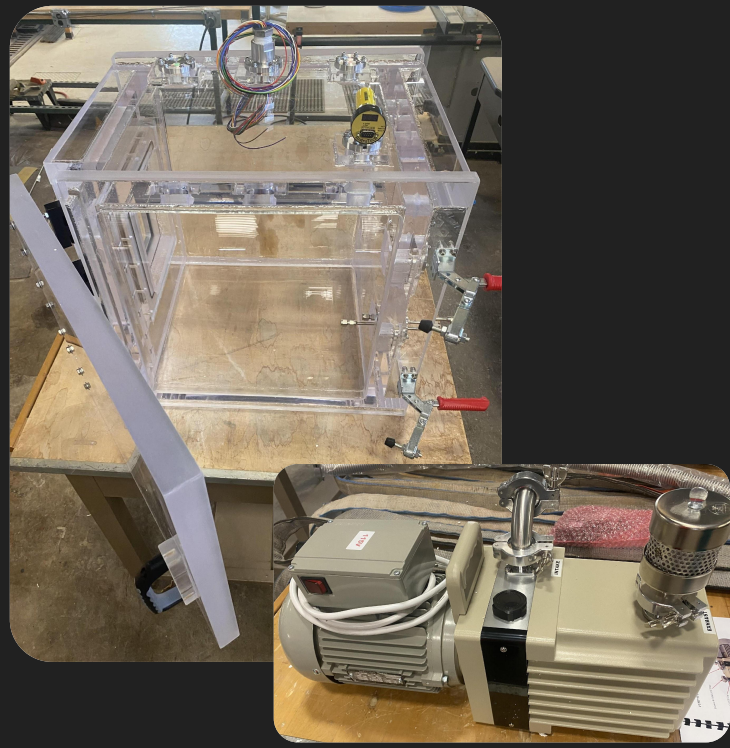
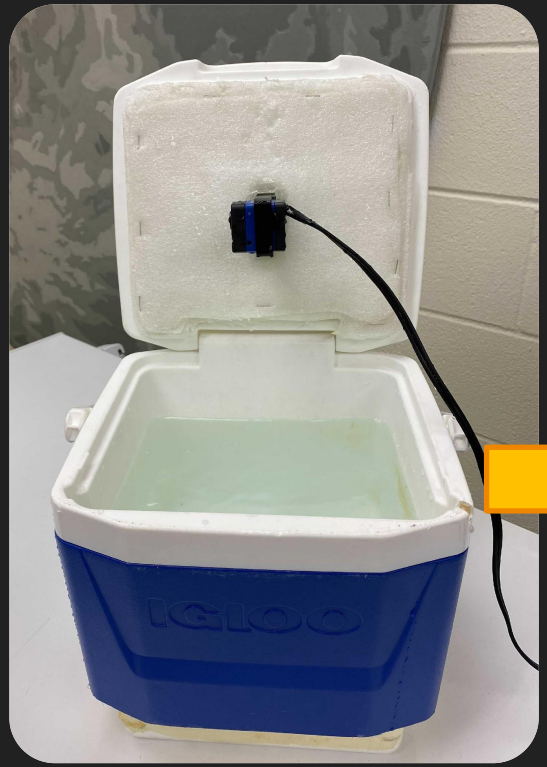
MTVAC – Acrylic Vacuum Chamber

- 18”x18”x18” interior dimensions
- (2) – 5 Type K Thermocouple Feedthroughs
- (1) – LN2 Feedthrough
- (1) – Digital Pressure Sensor
- (2) – Electrical Wire Feedthroughs
- (1) – Vent Valve Port
- (1) – Vacuum Pump Valve Port
- Oil Rotary High Vacuum Pump

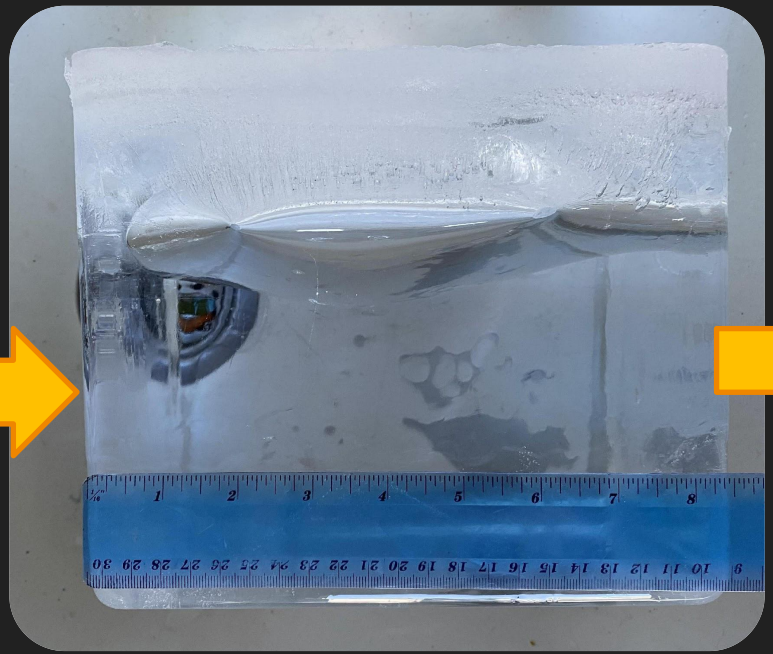


New Vacuum Chamber and Pump

Creating and Preparing Clear Ice



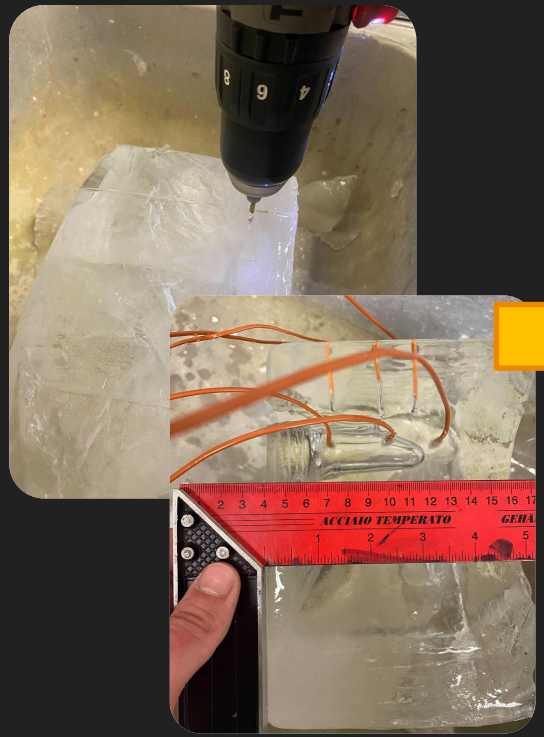
Modified Cooler and Water Pump



Clear Ice Block

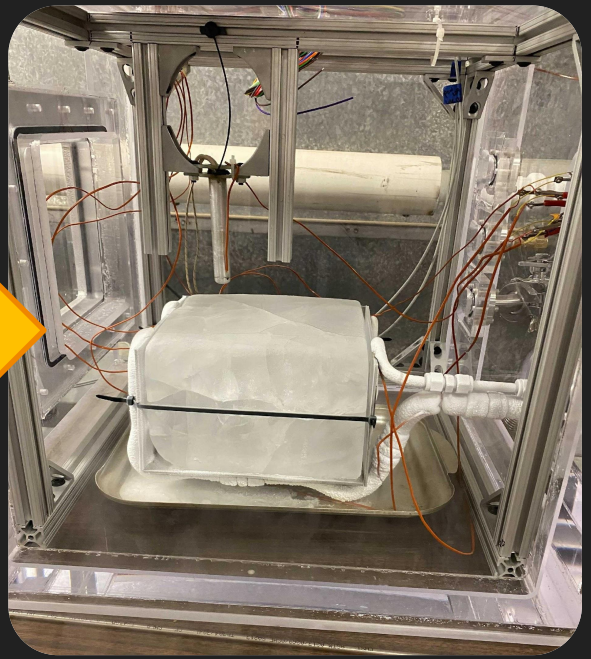
Removal of Cloudy Ice Layer

Creating and Preparing Clear Ice



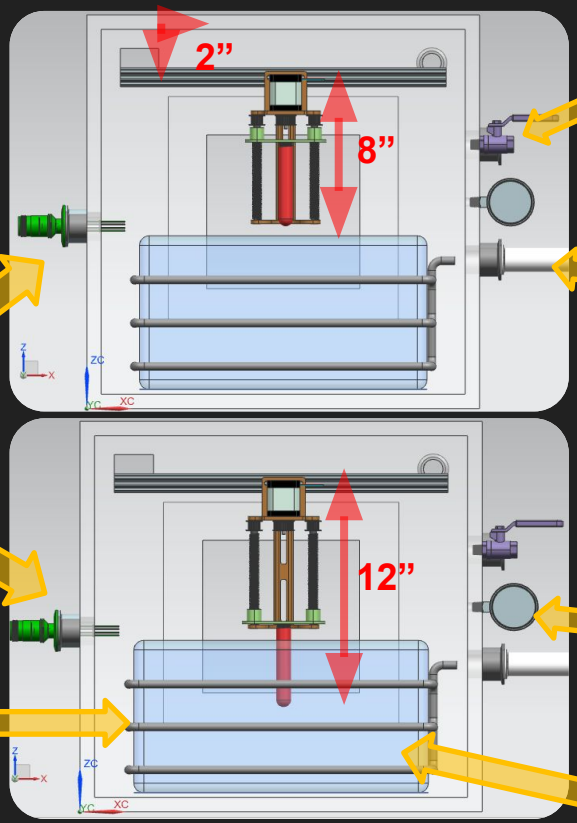
Melting and Drilling Ice Block

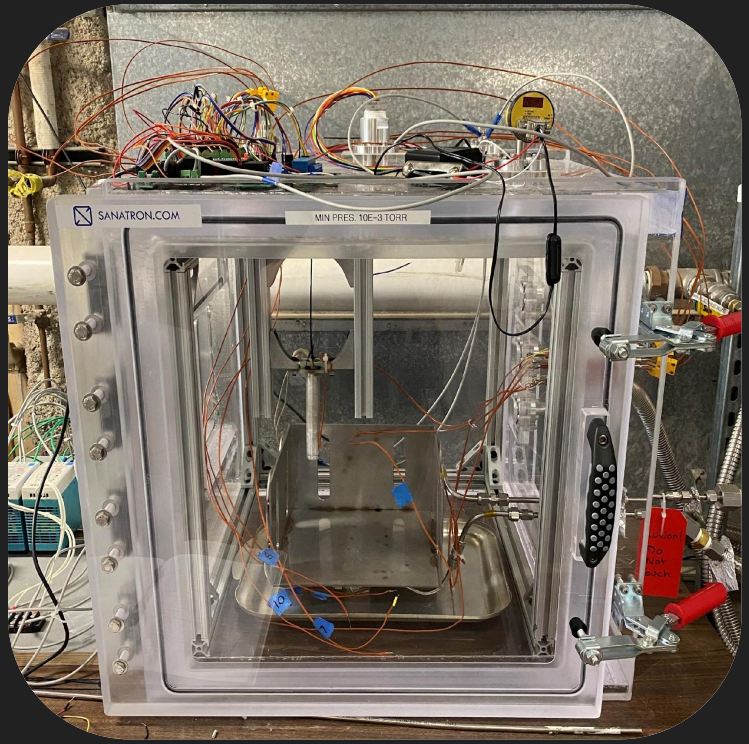
-80° C
Chest Freezer
(12 hours)



Initial Passive Actuation Chamber Setup

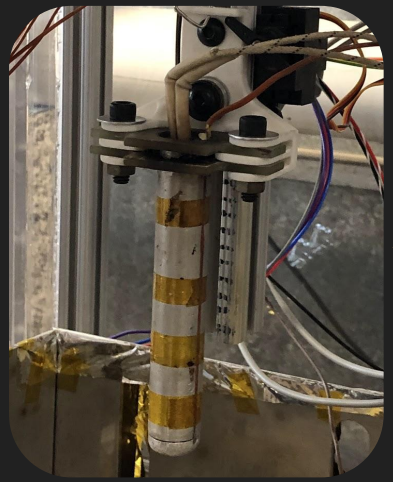
Designing & Building a Test Setup



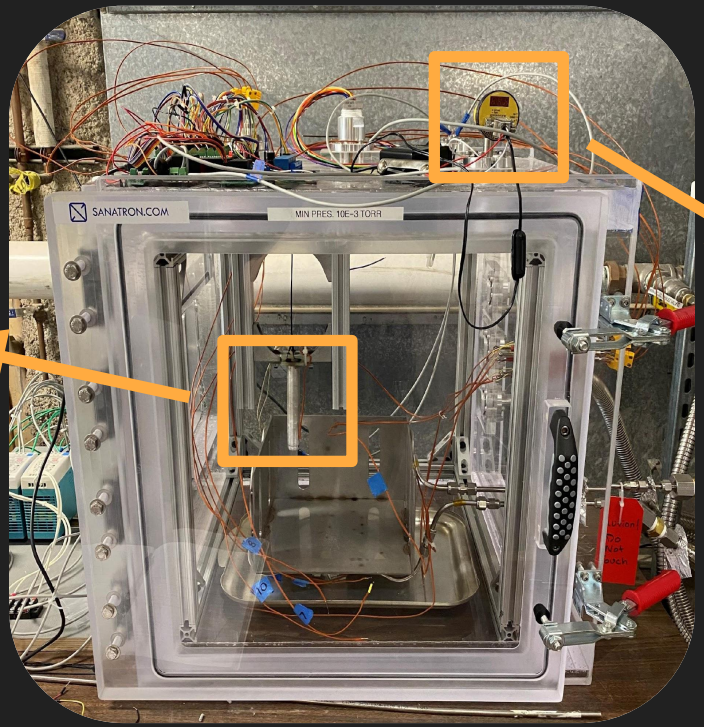


Initial Passive Actuation Chamber Setup

Passive Assembly & Setup Improvements



Updated Passive Actuation Assembly



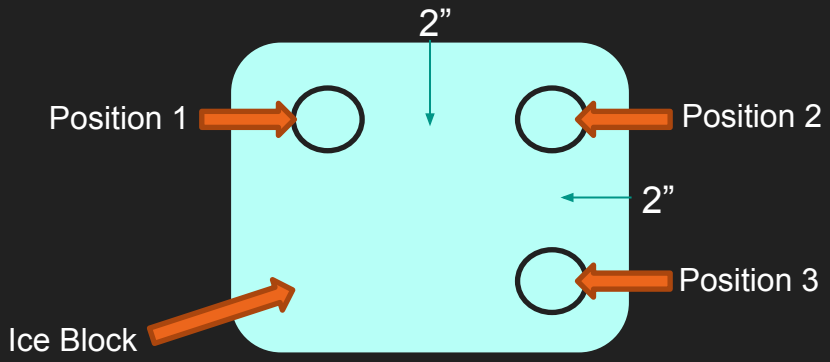
Vacuum Chamber Test Setup

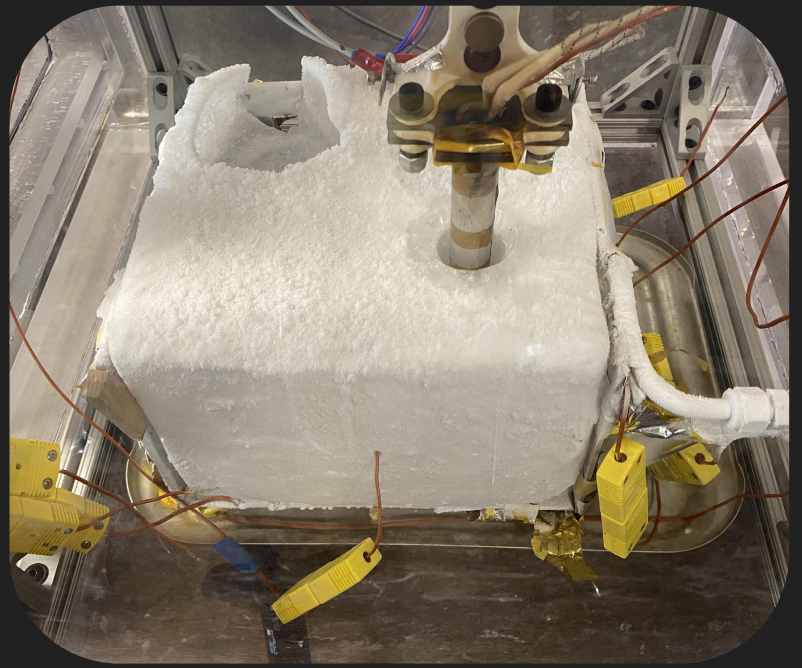
Replaced Pressure Gauge

Passive Assembly – Tests Conducted

Passive Actuation Test Matrix

	Ice Block		
	A	B	C
75 Watts	Pos. 2, T1	Pos. 3, T2	Pos. 1, T1
100 Watts	Pos. 3, T3	Pos. 1, T2	Pos. 2, T3
125 Watts	Pos. 1, T3	Pos. 2, T2	Pos. 3, T1



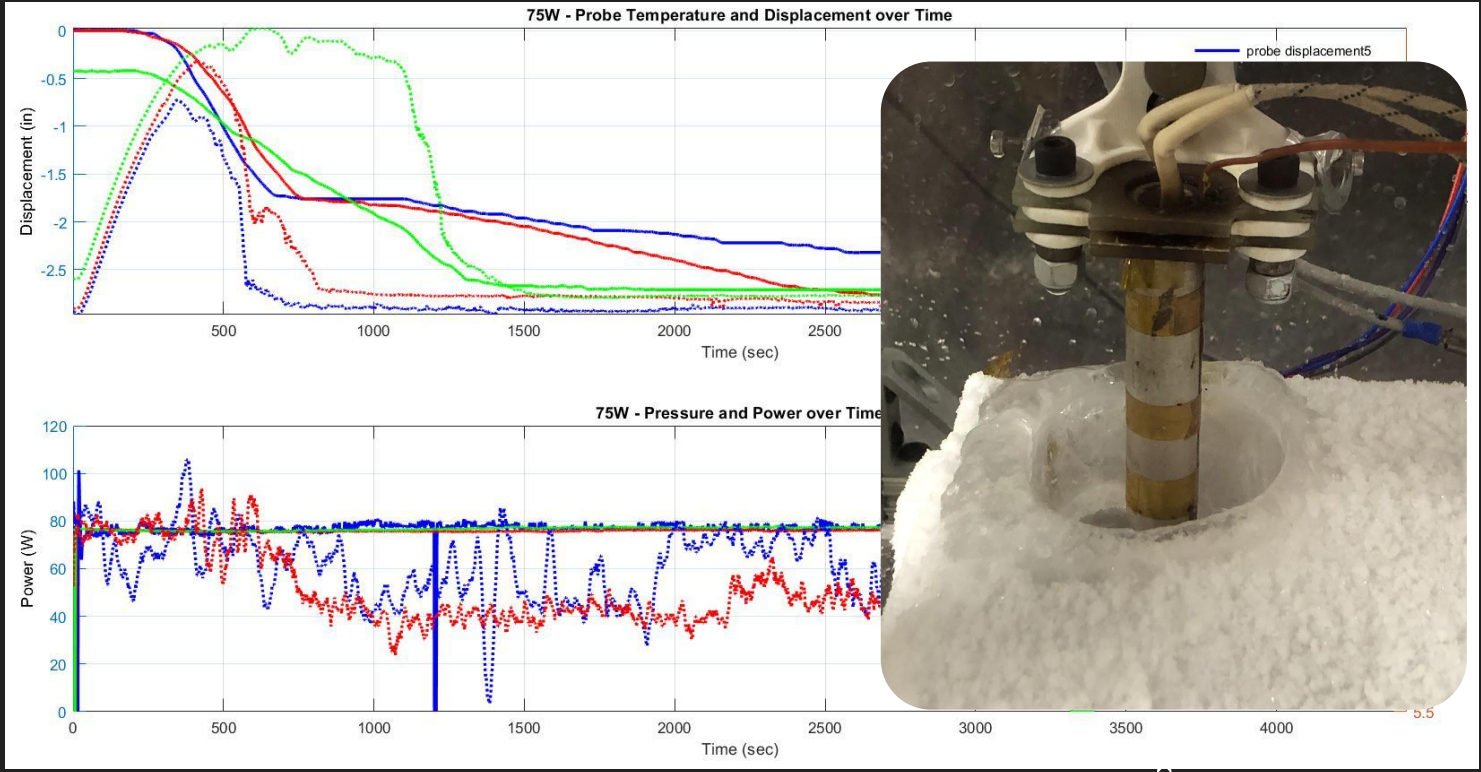


3rd 100W Passive Actuation Test, 7 Torr

Passive Assembly Results – 75W Data

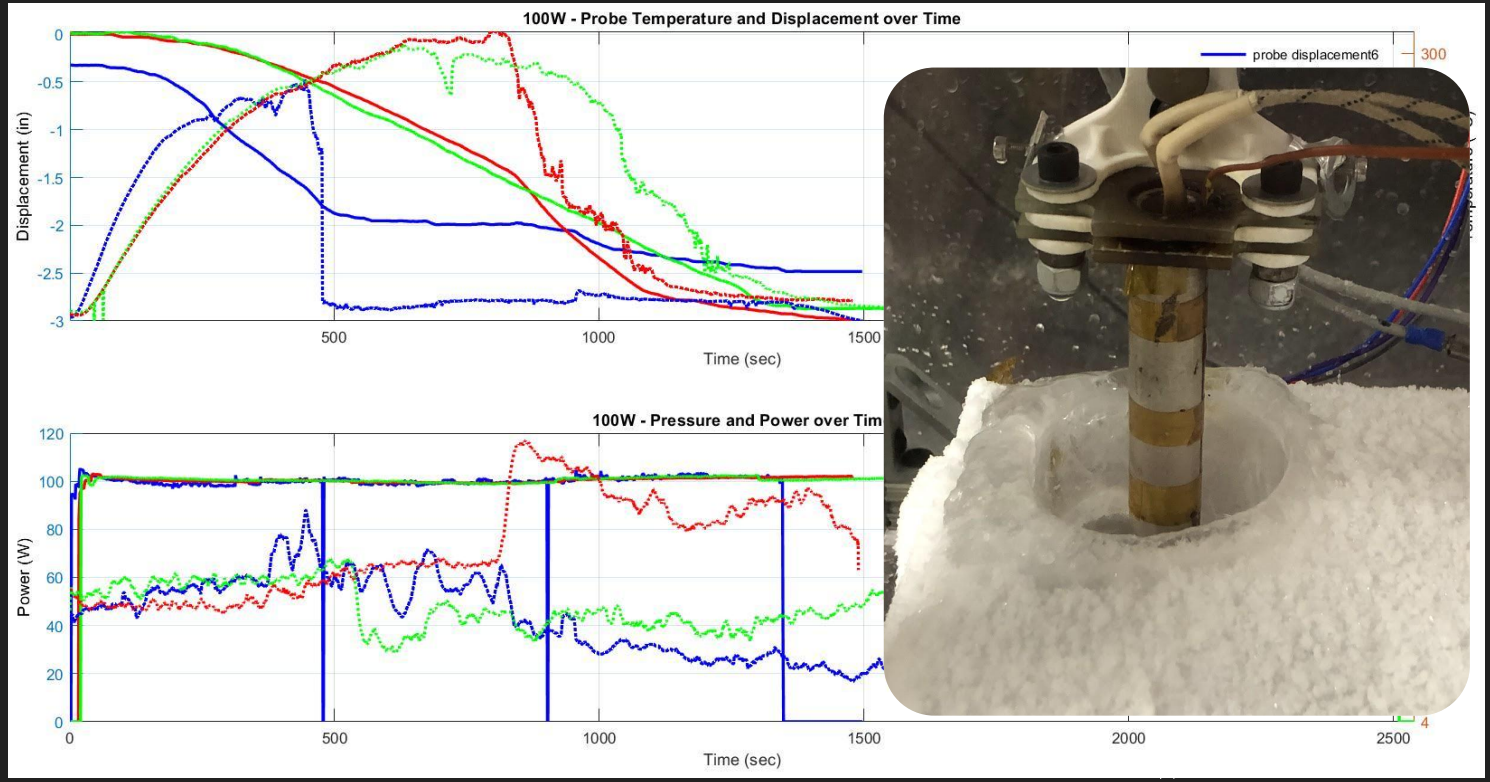
- *Large melt cavities*
- *Light boiling*
- *Rarely reached 3in depth*
- *Last test done with more sensitive pressure sensor*

Average Energy / Unit Volume:
1.25 kJ/cm^3
0.35 Wh/cm^3
*Misrepresentative Statistic.



Passive Assembly Results – 100W Data

- *Reached 3” depth more consistently*
- *Cavities start small but expand*
- *Test 10 experienced pressure increase*
- *Last test done with more sensitive pressure sensor*

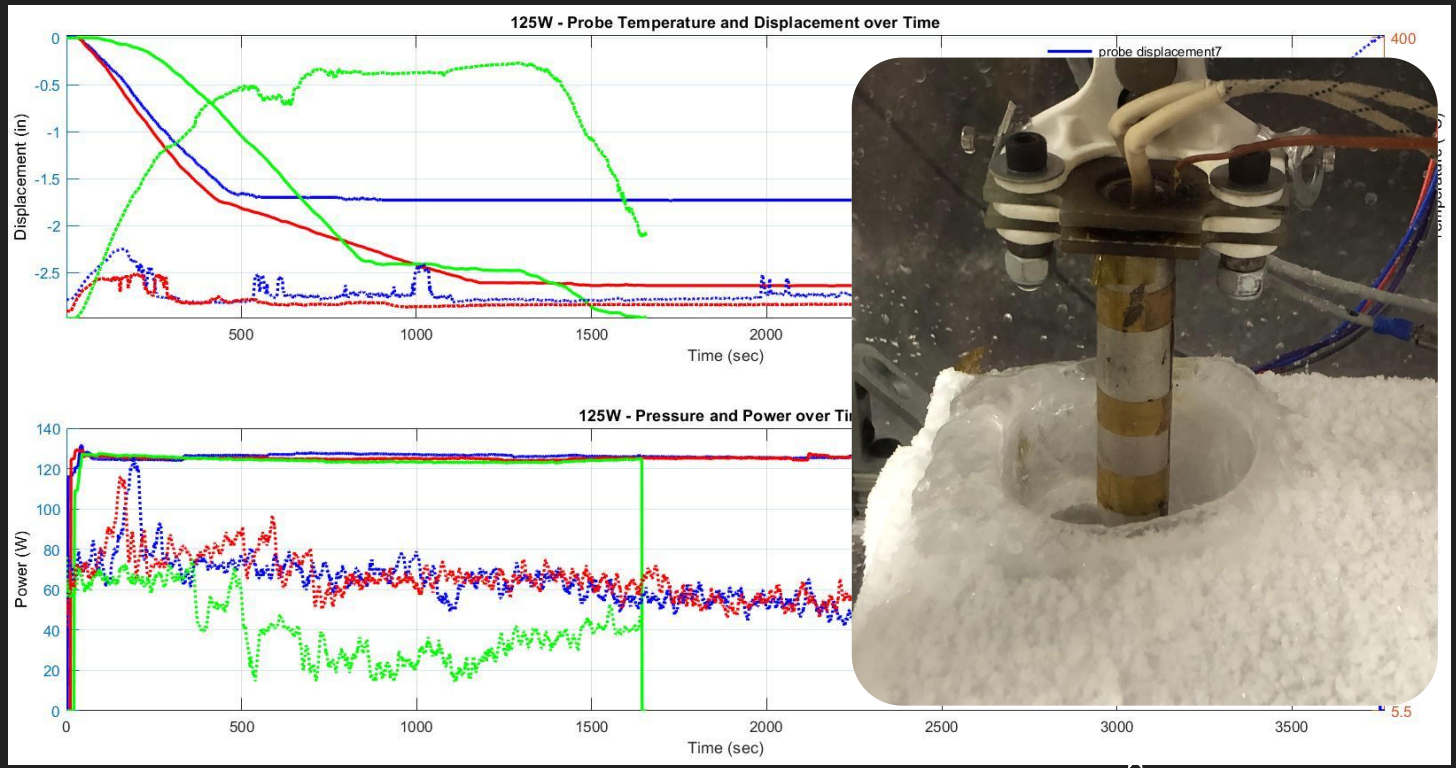


Average Energy / Unit Volume: 1.4 kJ/cm^3
0.39 Wh/cm^3
*Misrepresentative Statistic.

Passive Assembly Results – 125W Data

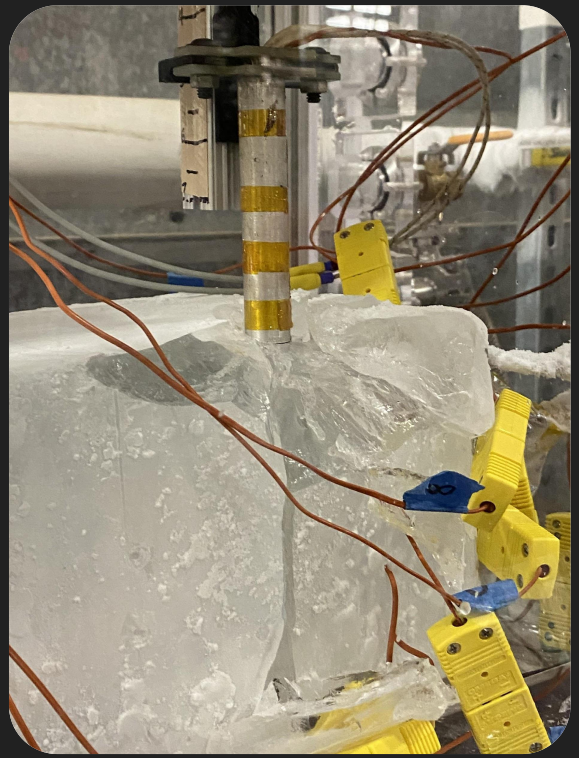
- *Lots of water pooling and boiling*
- *Large cavity diameters*
- *Sometimes hit 3in depth*
- *Last test done with more sensitive pressure sensor*

Average Energy / Unit Volume: 1.2 kJ/cm^3
0.33 Wh/cm^3
*Misrepresentative Statistic.

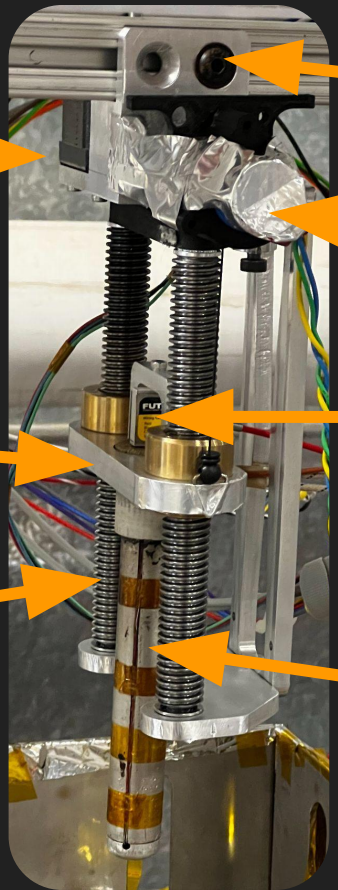


Passive Assembly - Lessons Learned

- High variability within each test
  - Number of cracks in the ice blocks
  - Melt behavior
  - Probe sliding and catching
- Video observation and data analysis is time intensive
  - Integrate a method of digitally recording probe displacement
- Unpredictable melt behavior between similar tests (constant power tests) probably due to the changes in chamber pressure



Active Actuation Assembly



Brushless DC Stepper Motor

Aluminum Support Structure

Acme Drive Screws

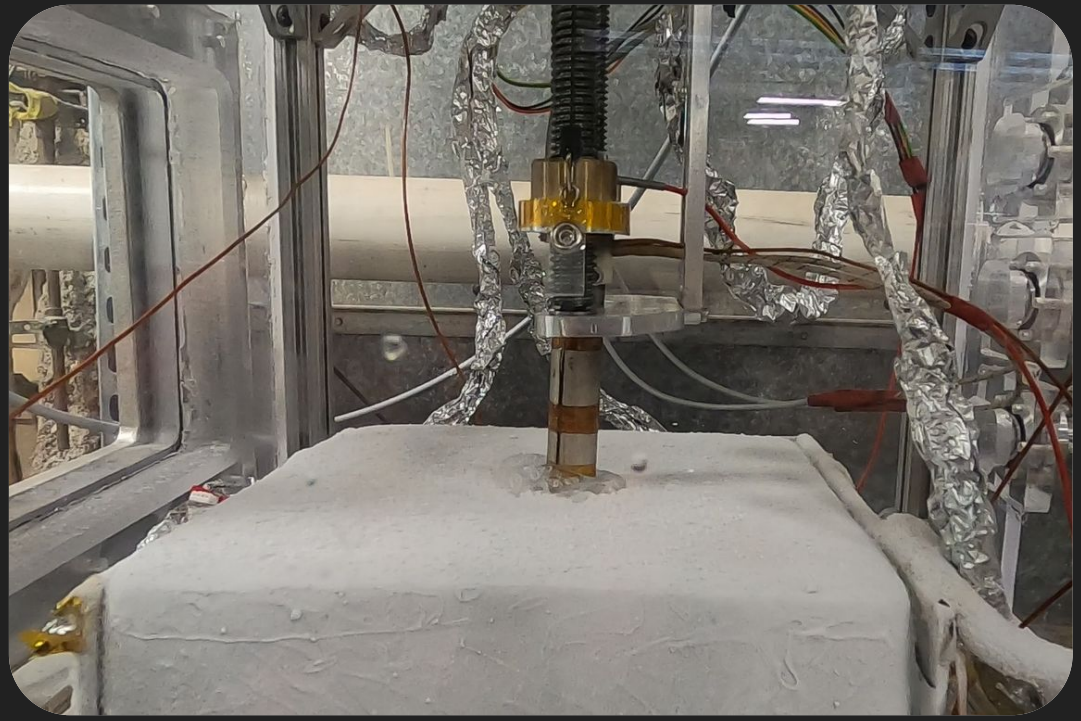
T-slot Mounting Bracket

Displacement Sensor

5-10 lb Load Cell & Alumina Ceramic with Vermiculite Attachment

Heater Probe

Integration and Initial Testing



First active actuation assembly test

- PID controlled weight on bit constant 5lb force
- String potentiometer recording probe displacement (in)
- K-type thermocouple recording probe tip temperature (°C)
- Brushless stepper motor driving lead screws

Acknowledgements

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