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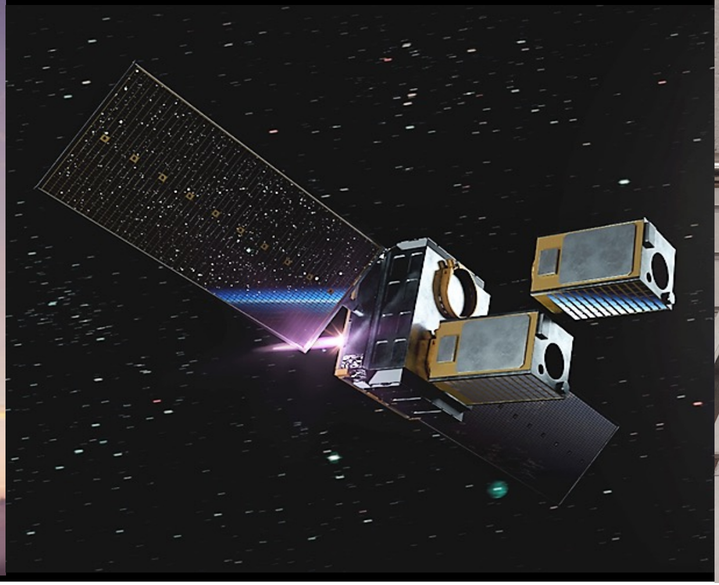

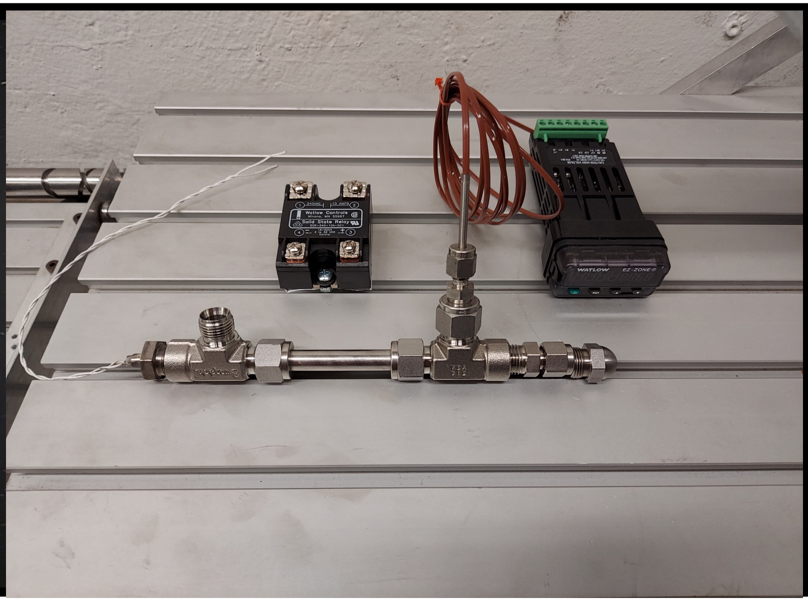

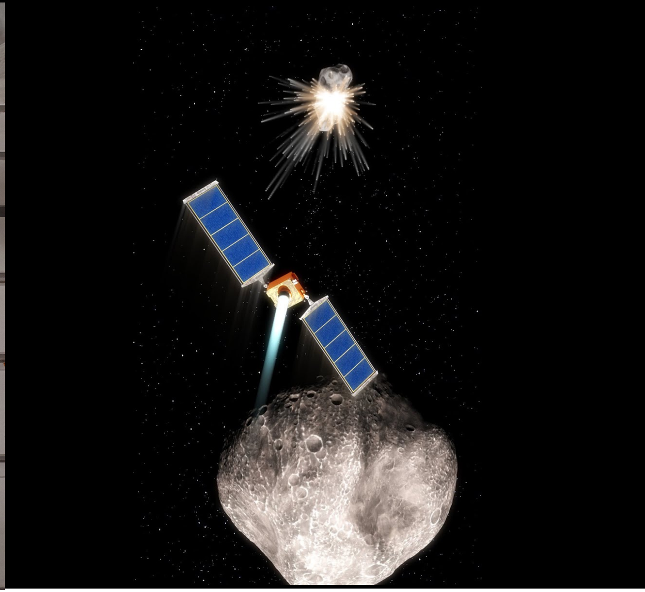

Resistojets for CubeSat Propulsion

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Presentation Outline

- Motivation
  - Where we fit in
- Objective
- Challenges
- Methods
- Current Status
- Discussion
- Takeaway

Big Picture

Develop Green Propulsion System for 1-3U CubeSat

- Early CubeSats did not have propulsion systems
- Increased CubeSat activity increased demand for extended mission lifetimes and navigation
- Resistojets are simple engines that only require a heat source and control valves
- Interplanetary CubeSats with Resistojets could use water from asteroid regolith to extend their mission operations

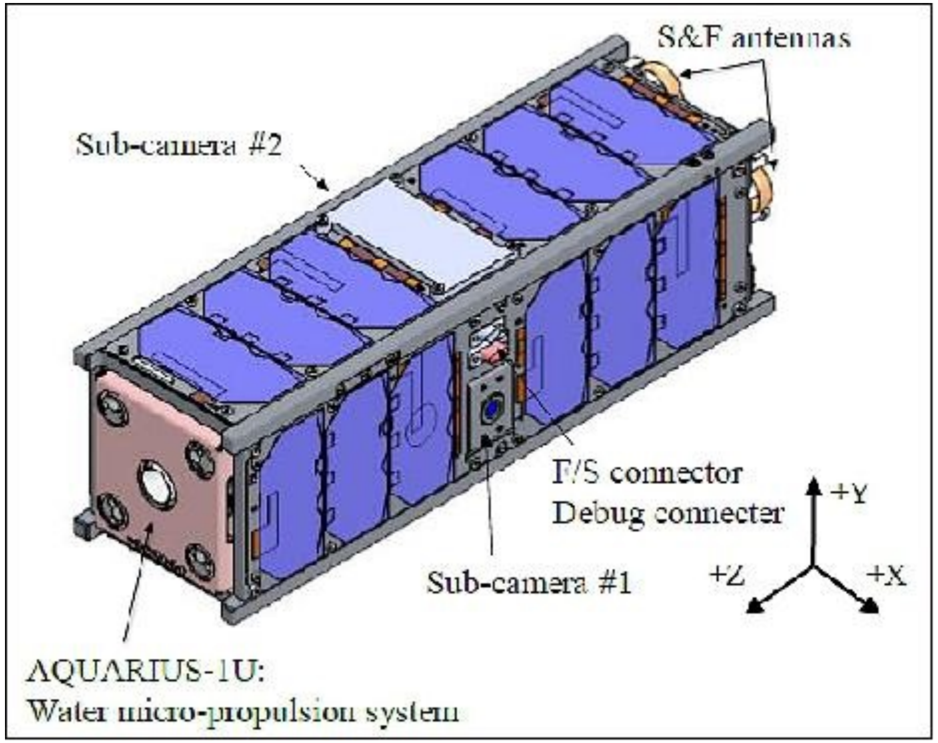
Objectives

Create a Thruster that is:

- Clean
- Cheap
- Simple in design

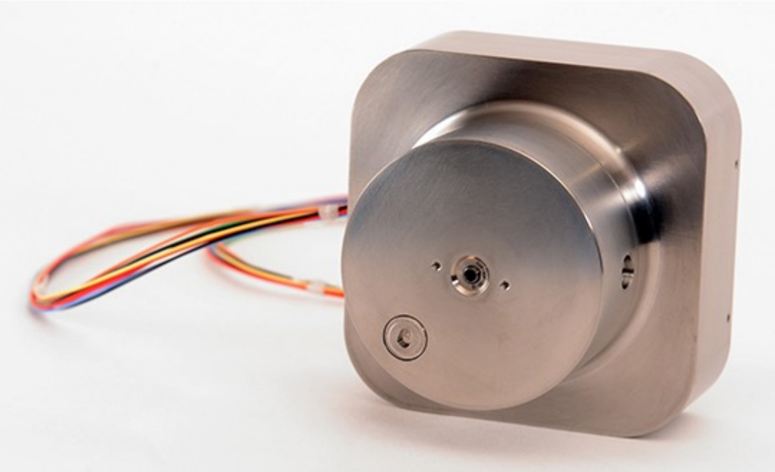
Solution:

- Resistojets are common and simple in design
- Water is clean and cheap

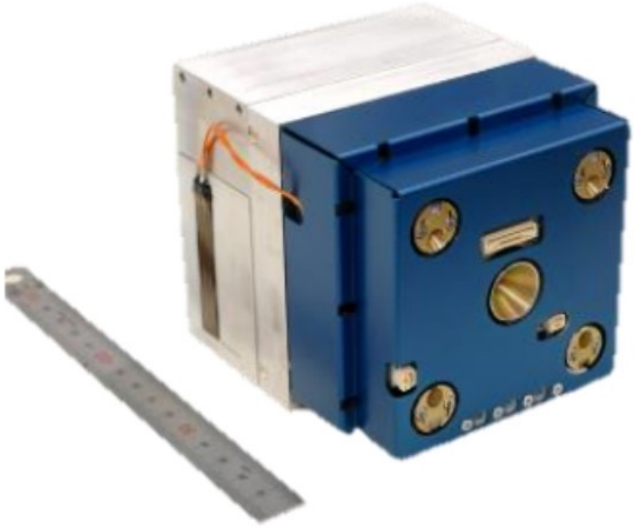


Current CubeSat Resistojets

CUA Resistojets simplify design by using refrigerants



AQT-D Resistojet successfully operated from ISS deployment in 2019



Challenges

- Steam is not an ideal gas (CEA code is not valid)
- Converging-diverging manufacturing difficulties (currently using a simple hole nozzle)
- Finding small parts was difficult
- Lead times of these parts extended the assembly timeline

CEA Code Analysis

- Major Finding: CEA relies on expelled gasses being an ideal gas
- Limiting Factor: Steam is not an ideal gas for temperatures below 748 Degrees Celsius (and pressures above 109 atm)

$$\frac{T}{T_c} < (\approx\ 2) \text{ and } (\approx\ 0.5) < \frac{P}{P_c} < (\approx\ 7)$$

- 500.0 C / 374.0 C = 1.337 (Fails)
- 1.97atm /217.7 atm = 0.009 (Does not Fail)

Analyzed research articles to obtain typical Resistojet values

A comparison of the UK-DMC Cubesat and the Optical Communications and Sensor Demonstration (OCSD) Cubesat

Parameters	OCSD Program	UK-DMC
Thrust (mN)	3.3	3.3
Specific impulse (s)	5	50
Power consumption (W)	9.57	10
Resistojet Volume (U)	Much less than 1U	N/A
Water Volume (cm^3)	26	5
Heating Temperature (C)	200	190
Operating Temperature (C)	45	35
Propellant Mass (g)	26	2.06
Nozzle Diameter (mm)	0.7	0.2
Opperating Pressure (atm)	1	N/A
Expansion Ratio	N/A	1

Gave us a starting point to determine our required Resistojet parameters

Initial Guess for a "Typical" Resistojet		Notes
Thrust (mN)	*3.3*	Decided on increasing to 30 mN
Specific impulse (s)	*27.5*	Dependent on Calculations
Power consumption (W)	*9.785*	
Resistojet Volume (U)	***1***	
Water Volume (mL)	*15.5*	
Heating Temperature (C)	***195***	
Operating Temperature (C)	*40*	
Propellant Mass (g)	*14.03*	For water: Carried Mass ~ Volume
Opperating Pressure (atm)	1	Determined that 2 bar is ideal

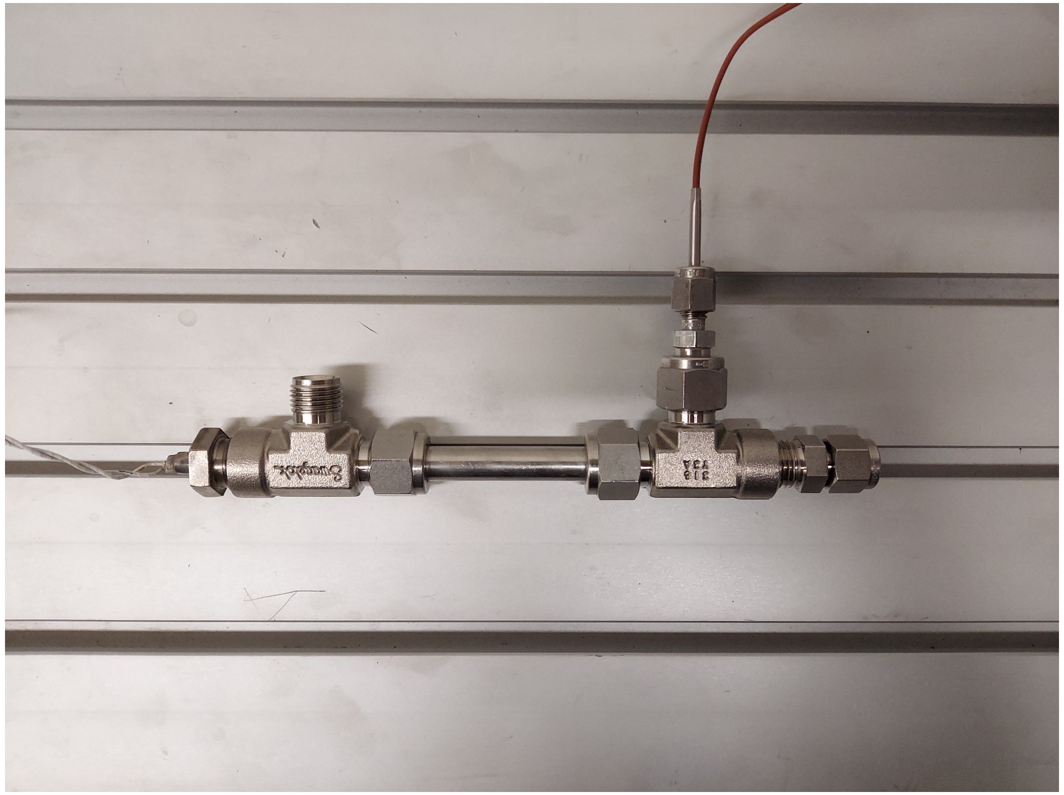
Experimental Sizing

Heater Section:

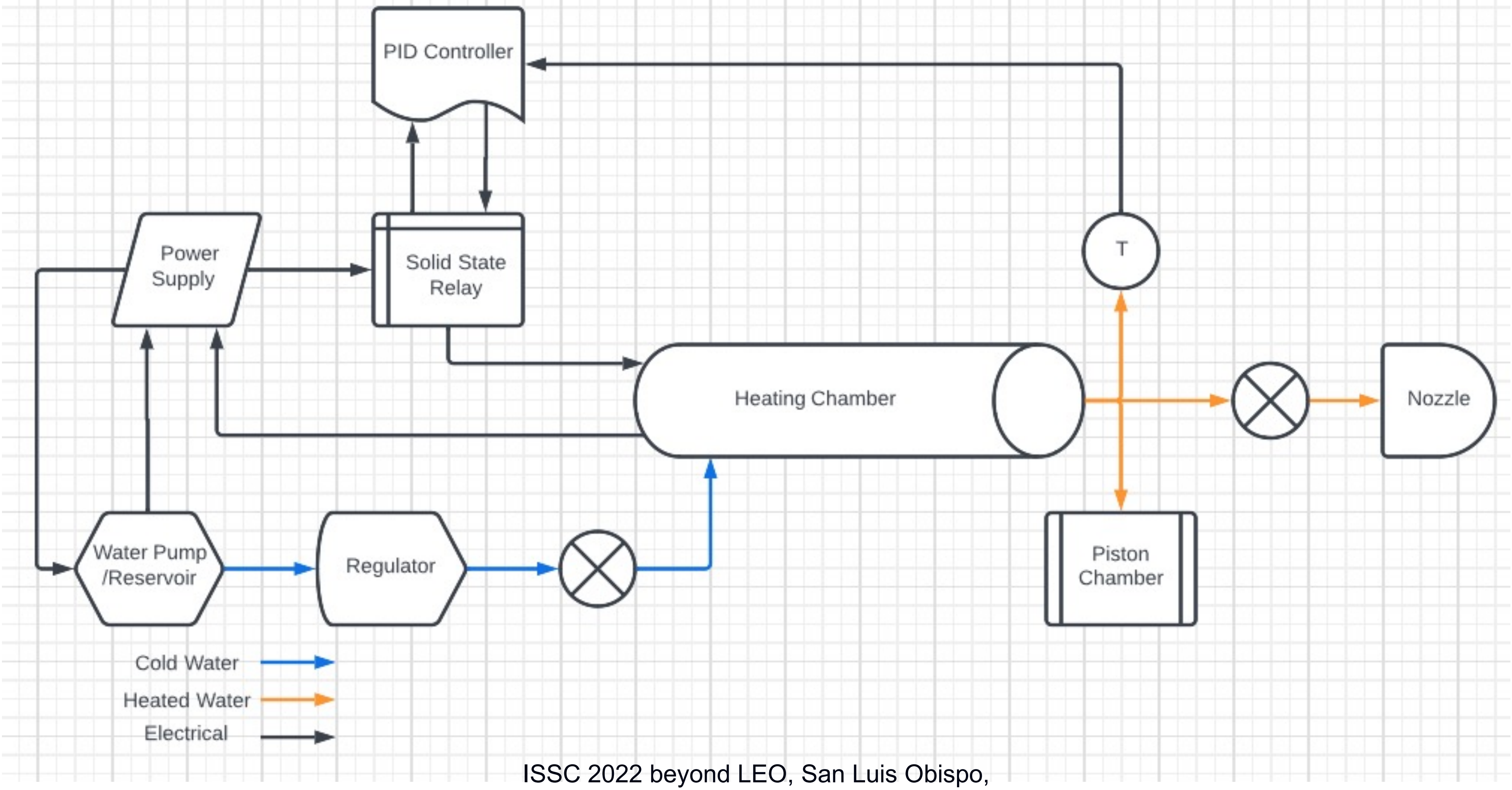
- Mass Flow Rate: 2.0 mL/min
- Temperature: 200 to 300 C
- Pressure: 2 to 4 bar

Feed Water Pump:

- Up to 6LPM
- Periodic Operation
  - Fill unit, self pressurizes upon heating, then expel in pulse

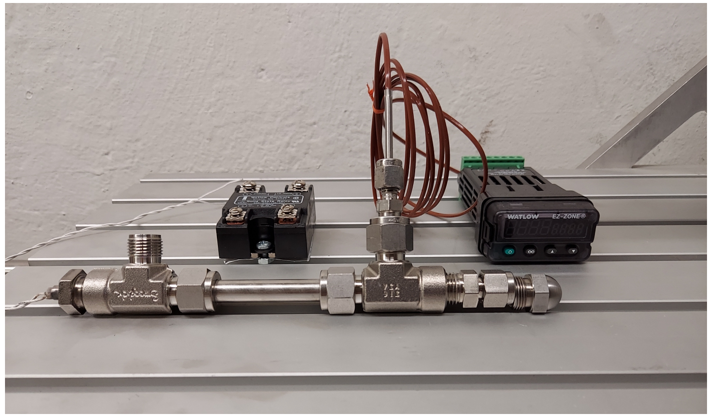


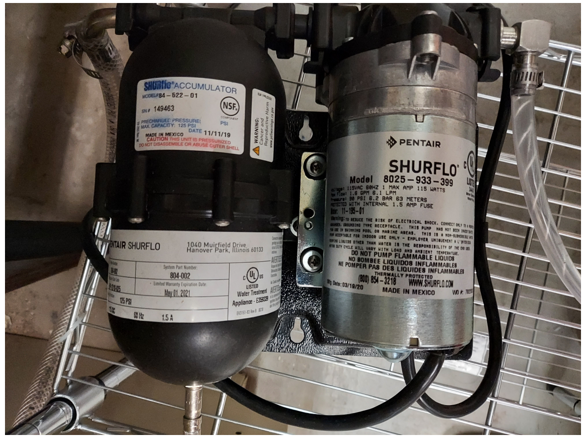
Process Flow Diagram



Purchased Design Components

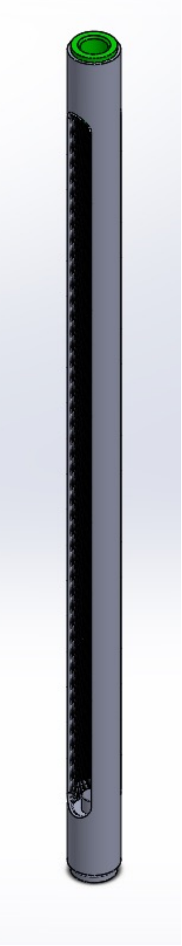
- Heater Assembly
  - ¼” 60V, 140W heater
  - 3/8” SS sheath
- PID heater & thermocouple
- Solid State Relay
- Feed Water Pump





Remaining Parts

- Power Supply (15 V)
- Expansion Relief Piston (Airpot 2KS95-3.0CP-ET)
- Solenoid Valve (Burkert 6013 136019)

Future Work

- Experimental verification of MATLAB data
- Converging-Diverging nozzle design and fabrication
- Vacuum Chamber testing
- Ice Plug buildup experimentation

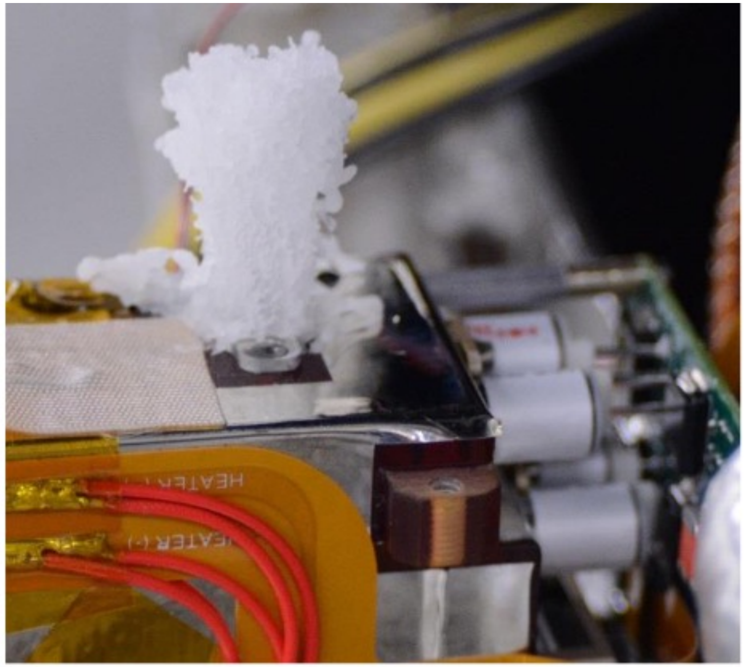


Figure 5: Ice plug buildup by the steam thruster firing in a vacuum.

Questions