Thermal Measurements of Icy Lunar Regolith Simulant

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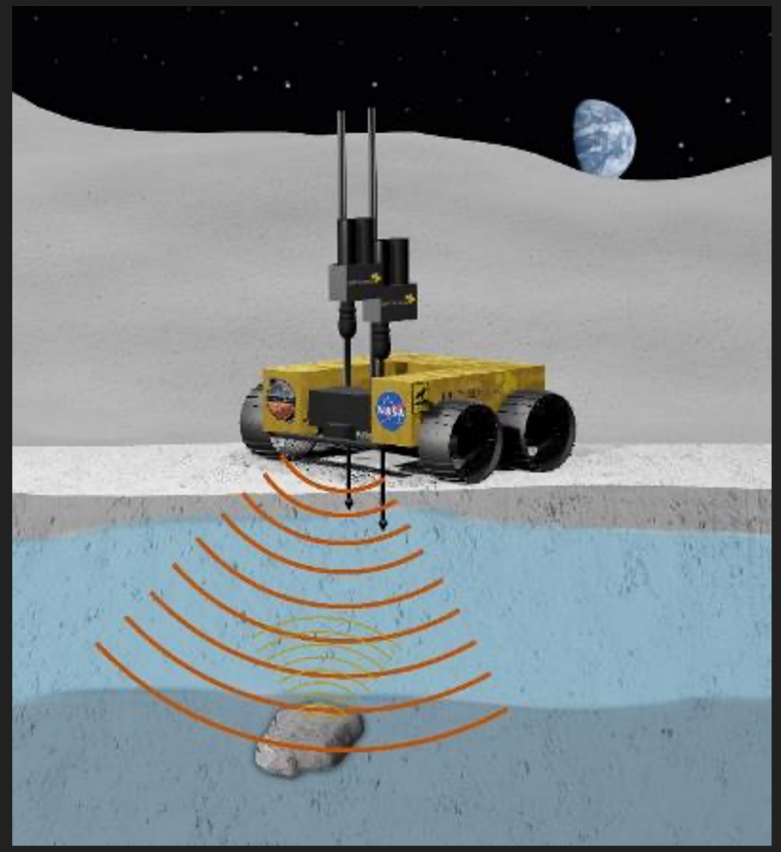
SPACE RESOURCES ROUNDTABLE

PHCP Project Introduction

Space Resources Roundtable

Percussive Hot Cone Penetrometer and Ground Penetrating Radar

- GPR
  - Location of larger ice deposits
- Geotechnical Data
  - Cone surface pressure & load
  - Impact loads
  - Measurement of depth displacement
- Thermal Data
  - Vertical and lateral quantification of volatiles
  - Properties of desiccated regolith



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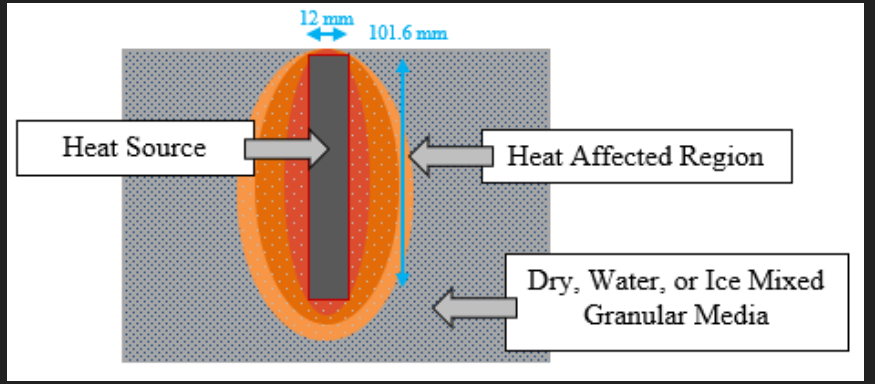
PHCP Thermal Measurement Objectives

Space Resources Roundtable

Atmospheric Testing

- Determine size of heat affected zone
- Thermal properties of various wt.% mixed water and ice samples
- Experimental data for thermal model
- Develop a method of correlating data with wt.% of ice

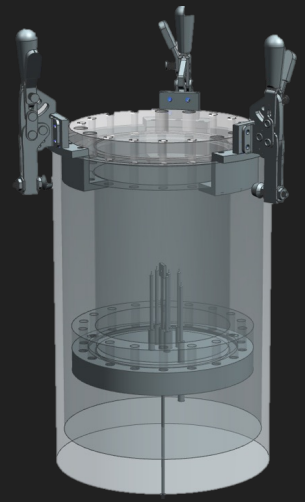


Atmospheric Testing

Vacuum Testing

- Test thermal cone designs at medium vacuum
- Analyze thermal property differences between atmospheric and vacuum
- Refine method of correlating data with wt.% of ice

Thermal Cone Vacuum Testing



Cryogenic Vacuum Volatiles Testing

Cryogenic Vacuum Volatiles Testing

- Thermal properties for various wt.% of LCROSS volatiles
- Experimental data correlating power and temperature measurements with wt.%

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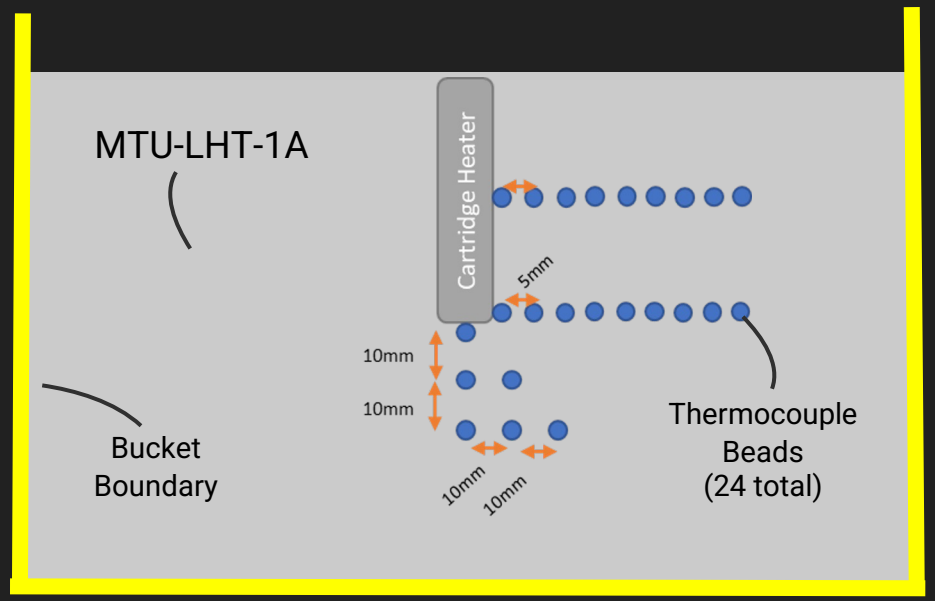
Atmospheric Test Setup

Space Resources Roundtable

Number of experimental tests conducted at three constant power levels for sample mixtures with specific weight percentages of water or ice

Sample Material and Volatile Composition	Constant Power Supplied		
	30 Watts	50 Watts	100 Watts
Dry, F-80	3	3	2
Wet 5 wt.%, F-80	1	1	1
Wet 10 wt.%, F-80	-	1	1
Frozen 5 wt.%, F-80	-	1	1
Frozen 10 wt.%, F-80	-	1	1
Dry, MTU-LHT-1A	1	1	1
Wet 1.5 wt.%, MTU-LHT-1A	1	1	1
Frozen 1.5 wt.%, MTU-LHT-1A	1	1	1
Wet 5 wt.%, MTU-LHT-1A	1	1	1
Frozen 5 wt.%, MTU-LHT-1A	1	1	1
Wet 7 wt.%, MTU-LHT-1A	1	1	1
Frozen 7 wt.%, MTU-LHT-1A	1	1	1
Wet 10 wt.%, MTU-LHT-1A	-	1	1
Frozen 10 wt.%, MTU-LHT-1A	-	1	1



Atmospheric Test Setup

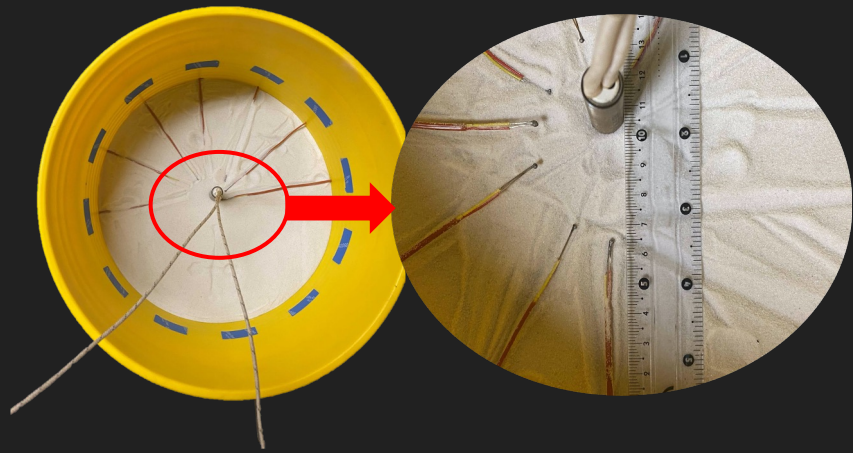
Used to determine the size of the heat affected zone and correlate weight percentage of water and ice under atmospheric conditions

Atmospheric Test Setup Procedure

Modified 5-gallon bucket

Spray specific wt.% of water in cement mixer with lunar simulant

Vibratory compaction or Consistent compressive compaction



Heater and relative thermocouple spacing

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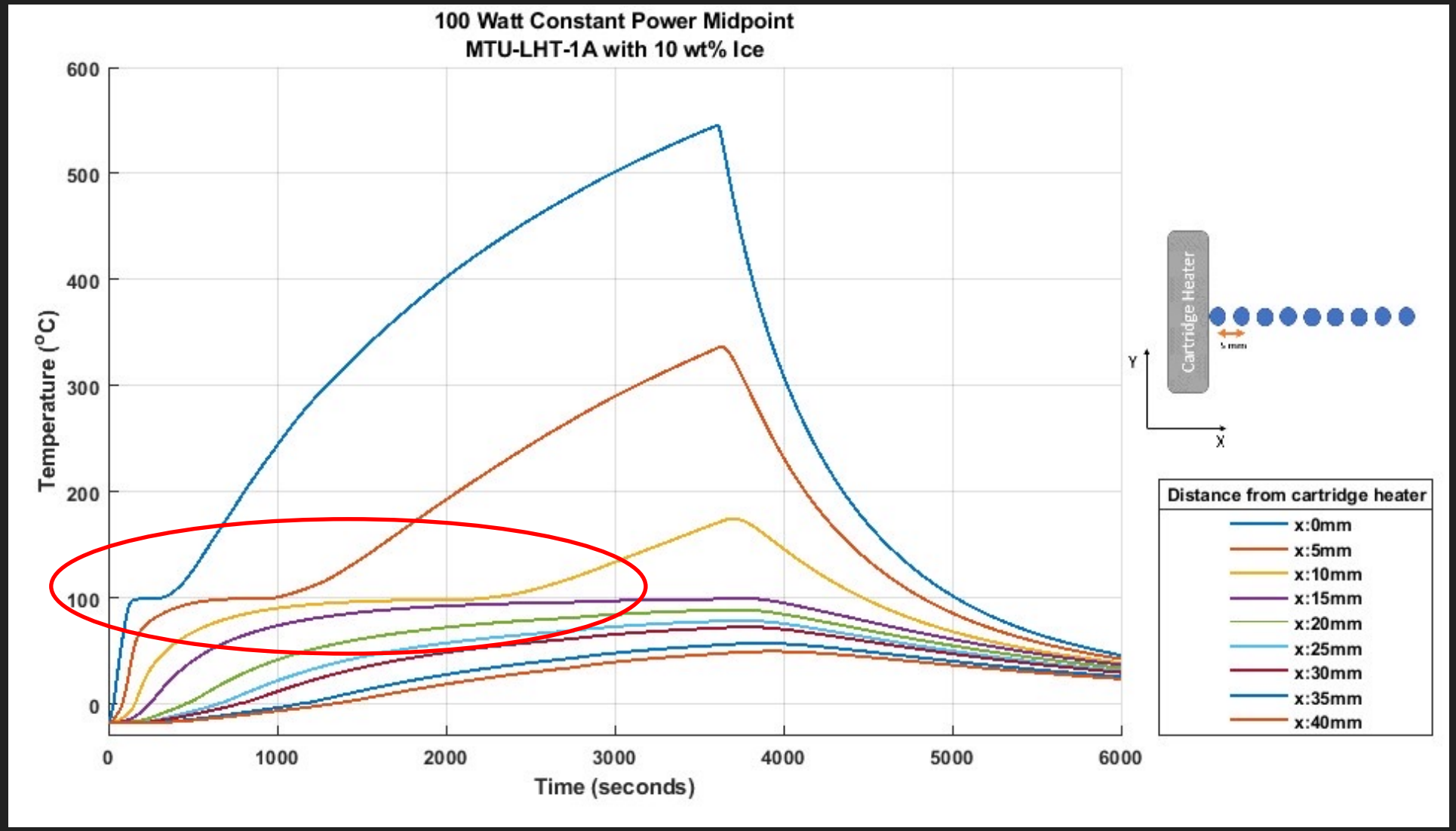
Atmospheric Test Results

10wt% Frozen Water &
MTU-LHT-1A @
Constant 100 Watts



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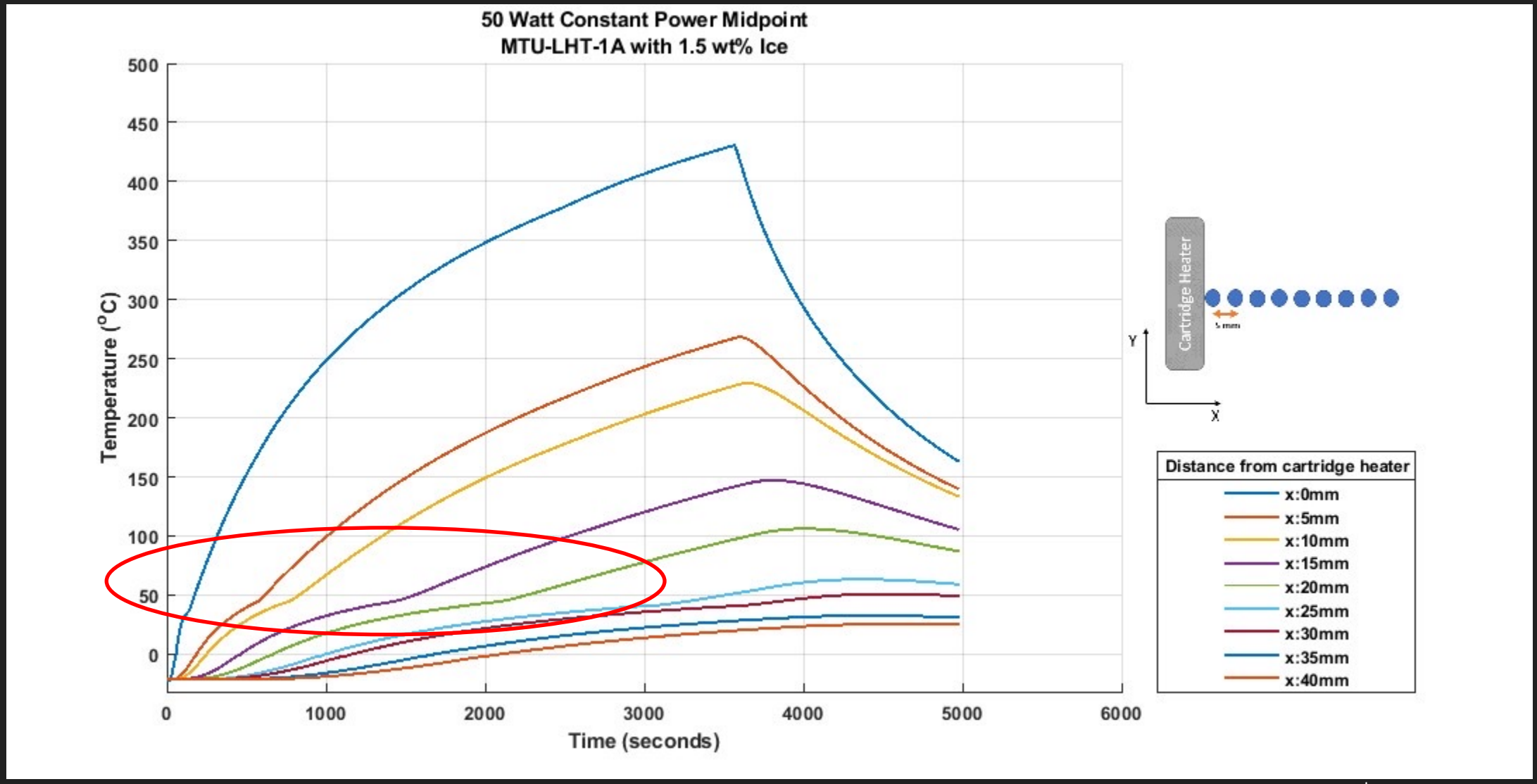
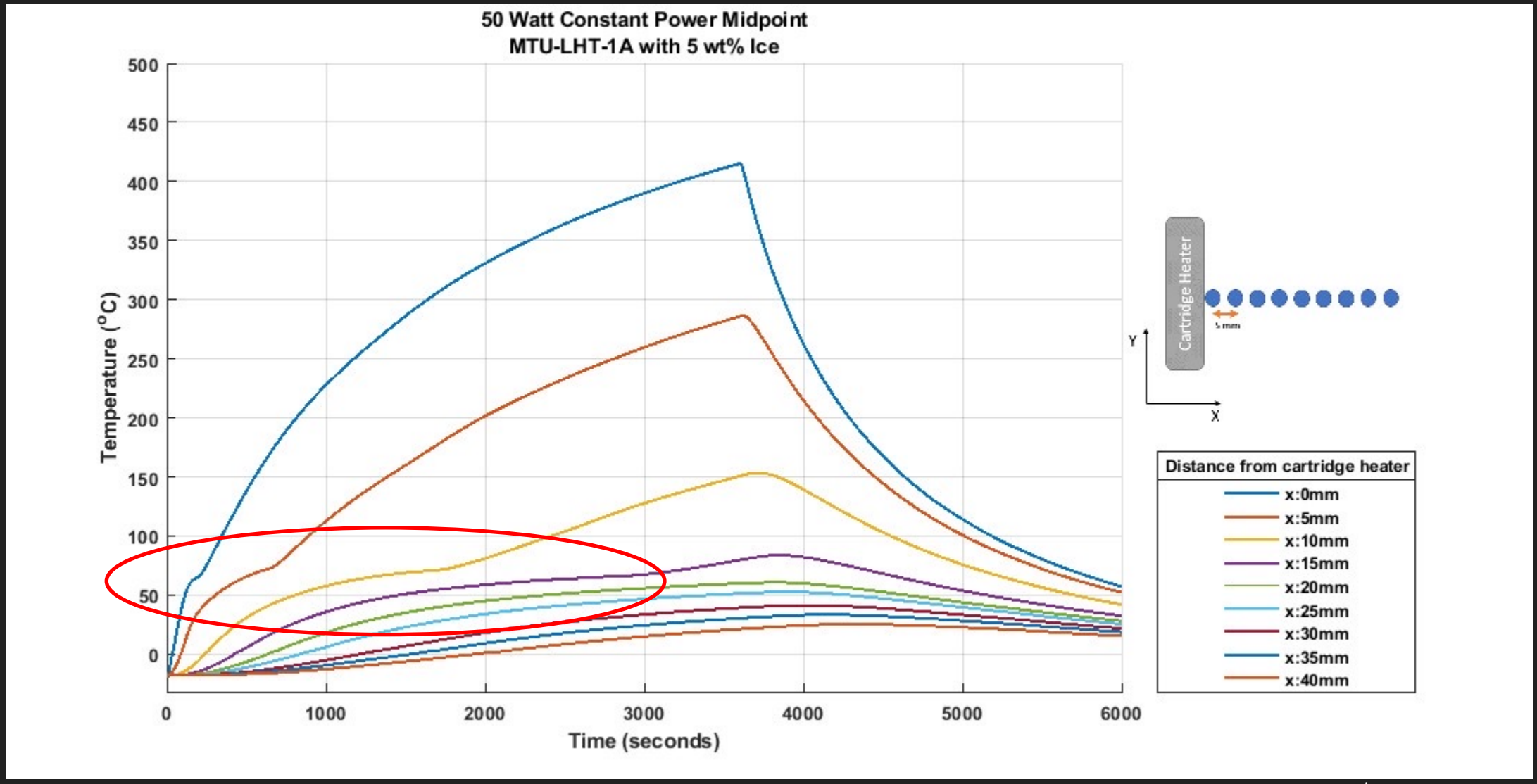
Atmospheric Test Results



Atmospheric Test Results



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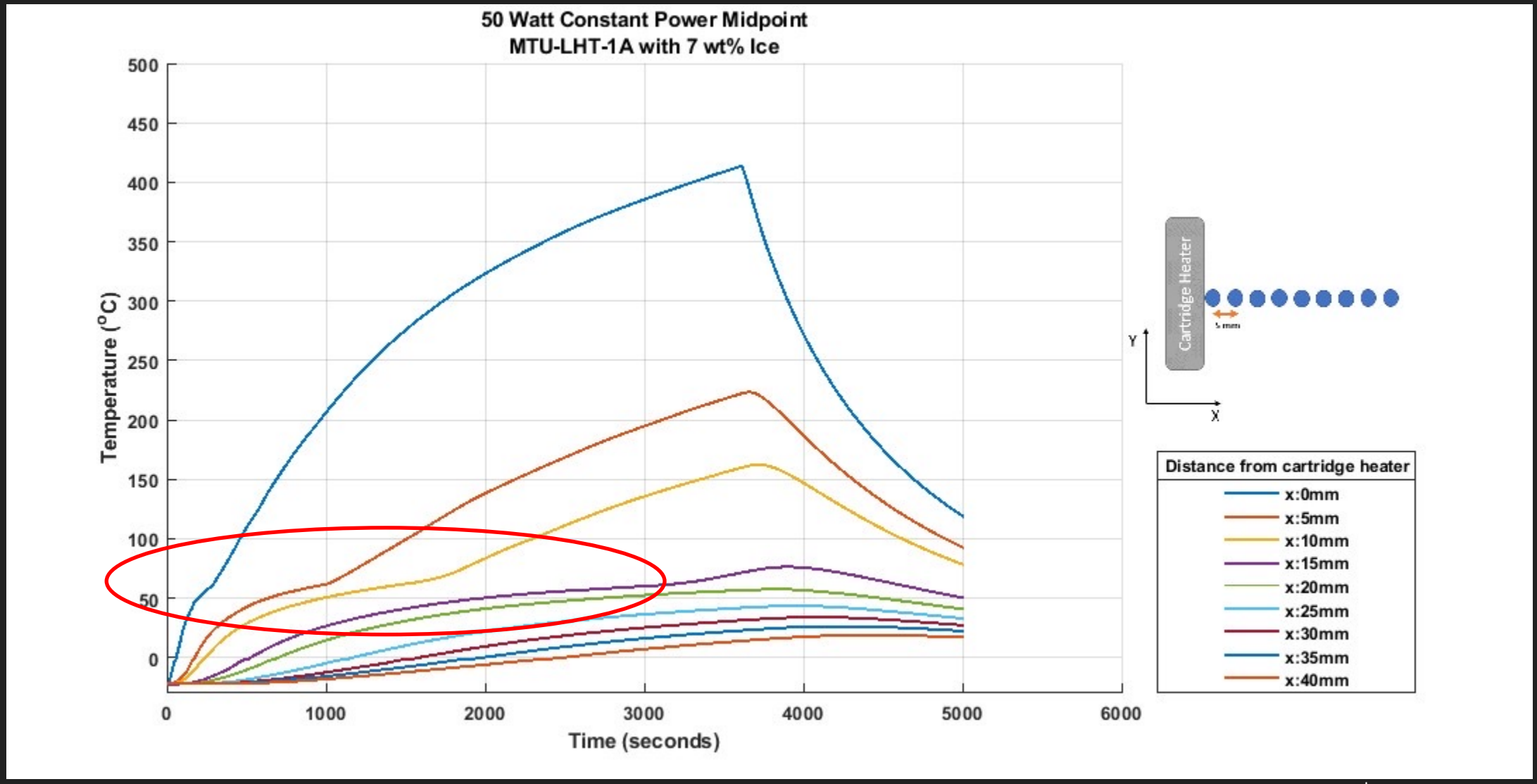

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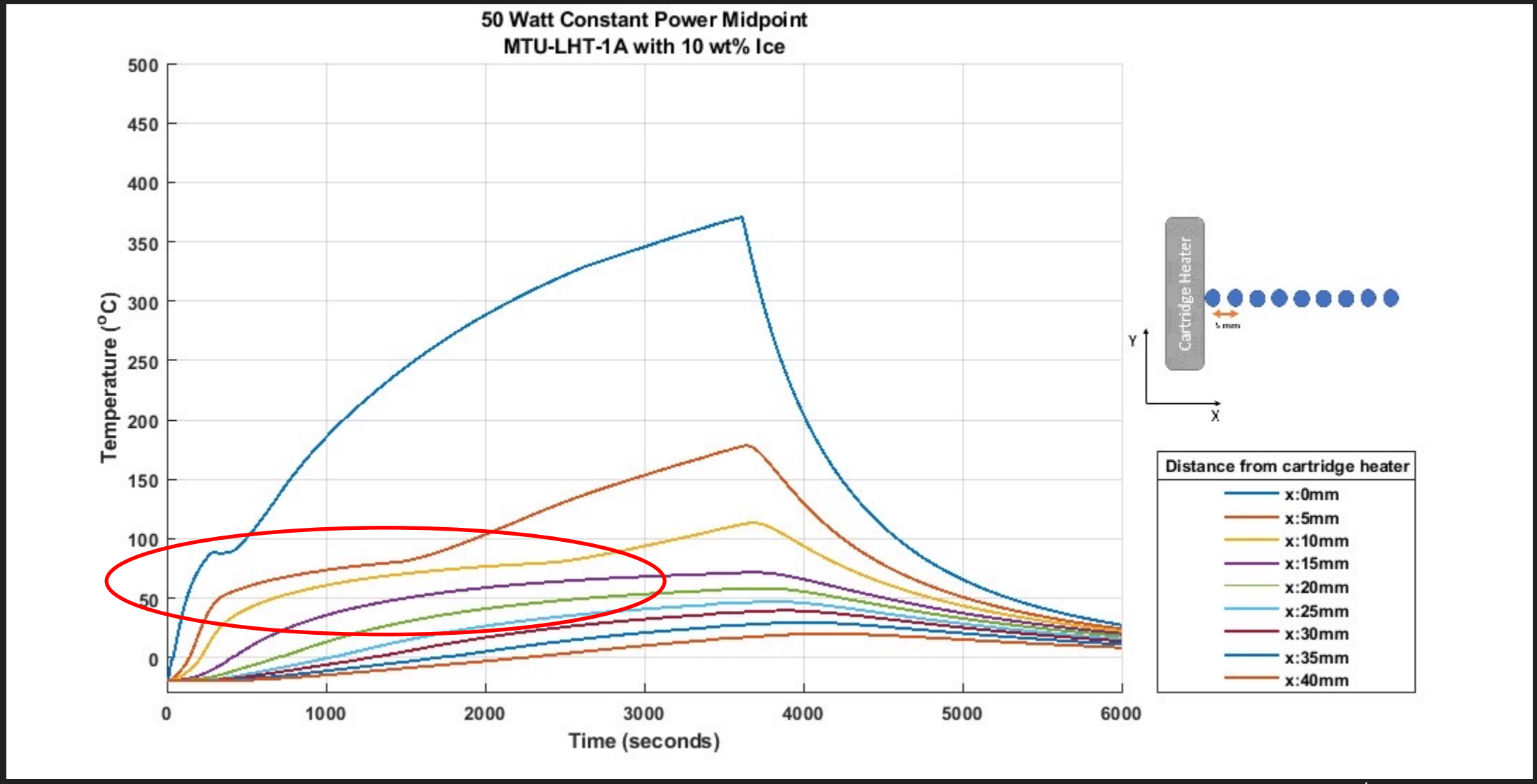
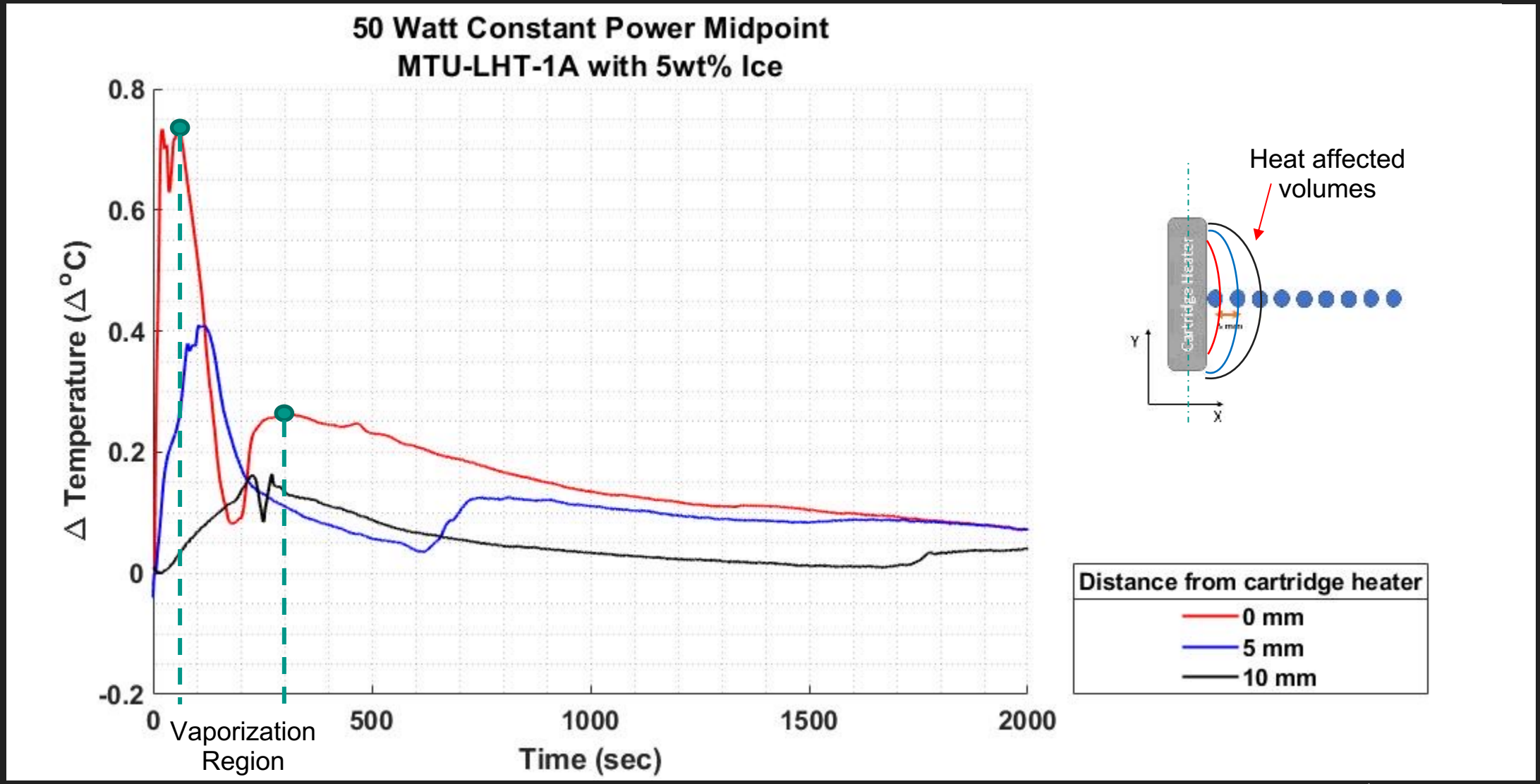


Atmospheric Data Analysis and wt.% Correlation



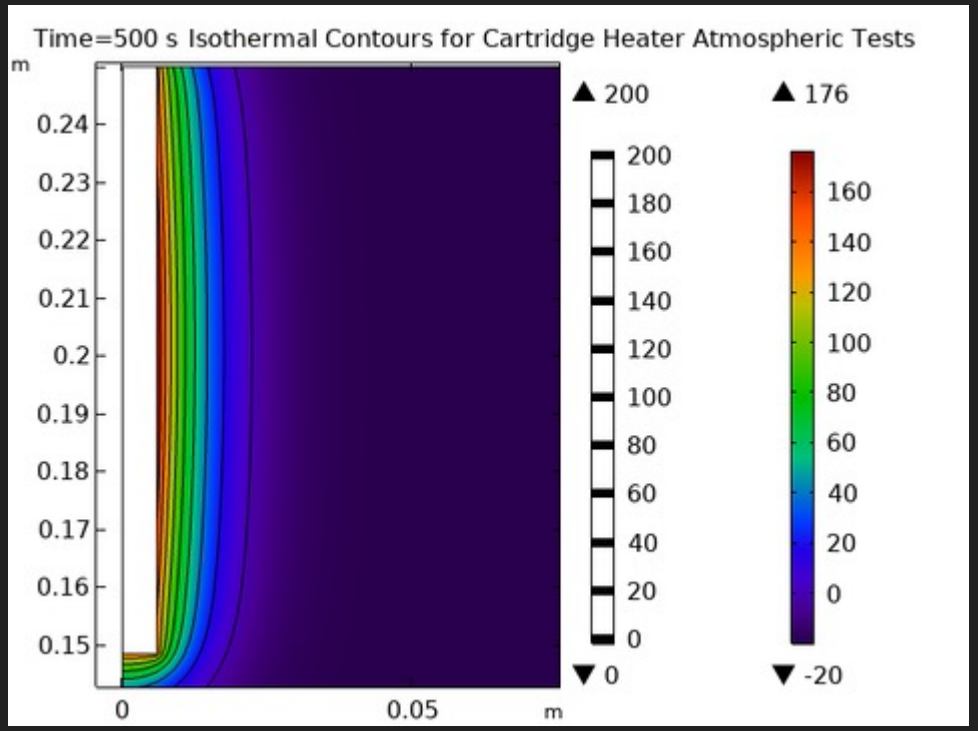
Atmospheric Data Analysis and wt.% Correlation

Knowns:

- Time duration of phase change & power supplied over that time
- Specific heat capacity of dry MTU-LHT-1A
- Volume and mass of dry or mixed regolith samples at each thermocouple location

Solving for:

- Energy input difference between dry and volatile mixed samples
- Weight percentage of volatile



Avg 2 mm volume	Avg 5 mm volume	Avg 10 mm volume
1.456 E-4 m^3	4.104 E-4 m^3	7.853 m^3

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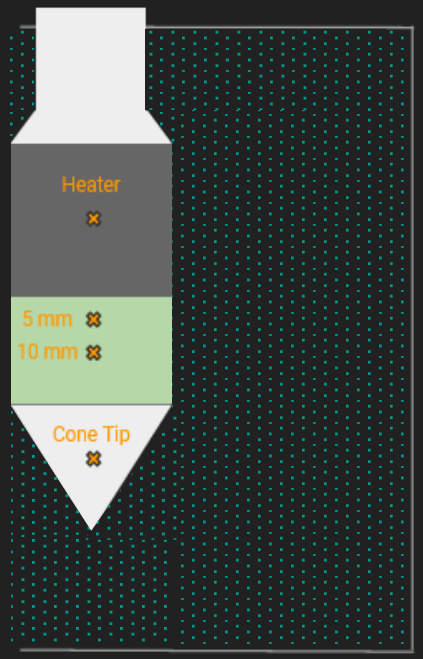
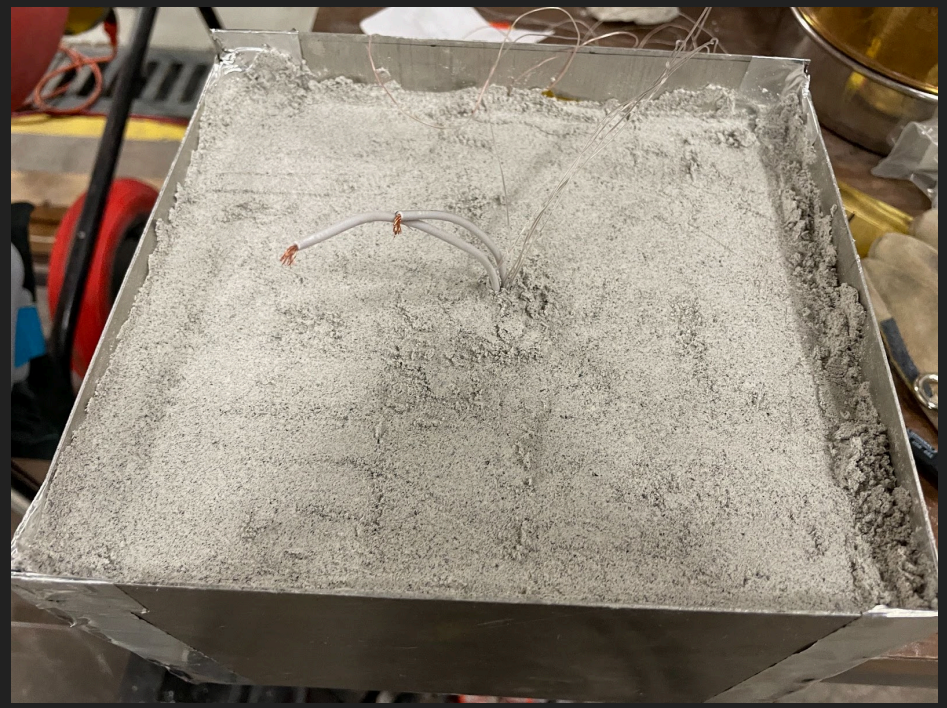
Thermal Cone Designs

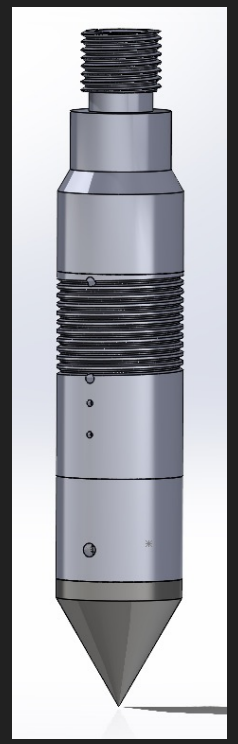


Thermal Cone
Vacuum Testing



Thermal Cone
Vacuum Test Setup

Aluminum Thermal
Cone mk1



Steel Thermal Cone
mk2

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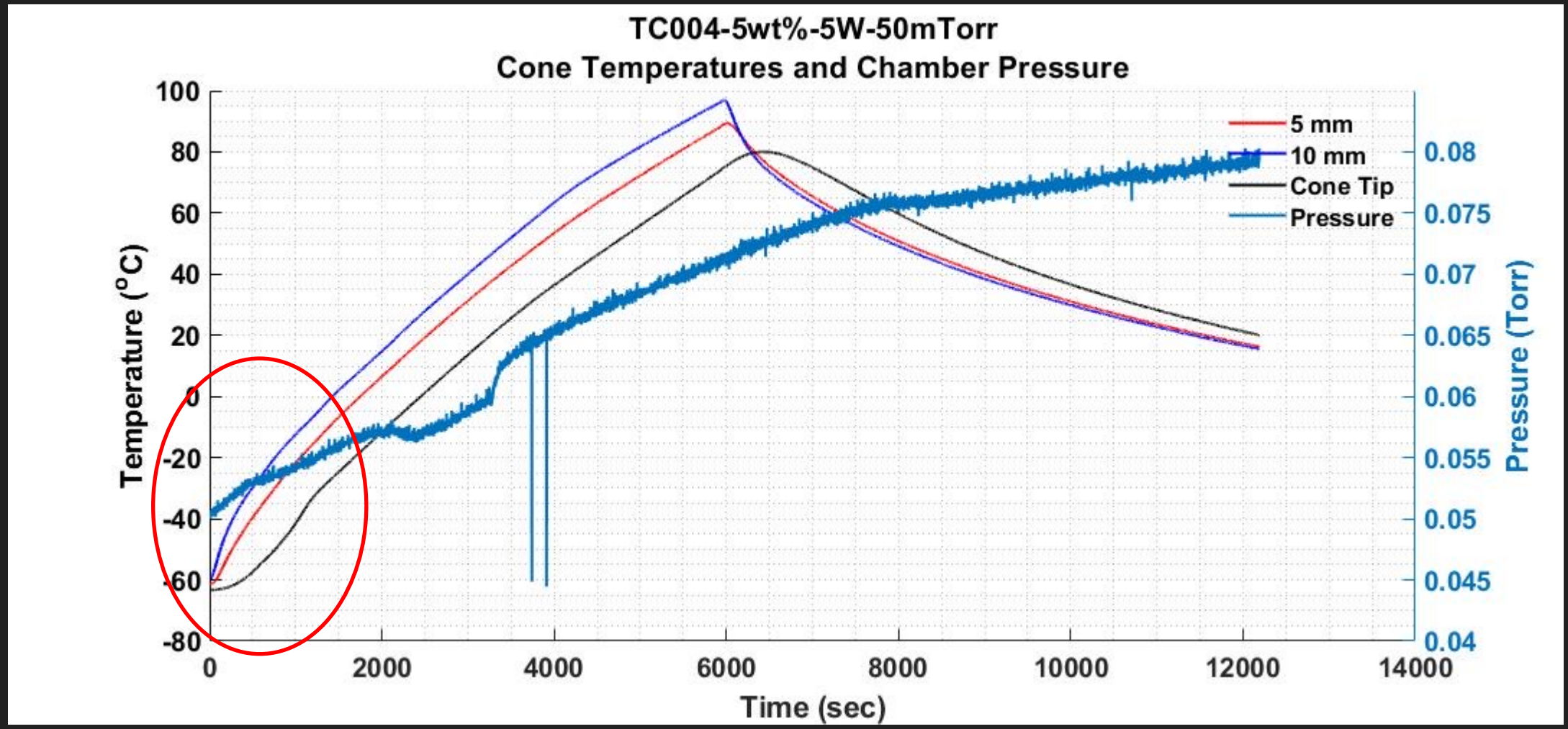
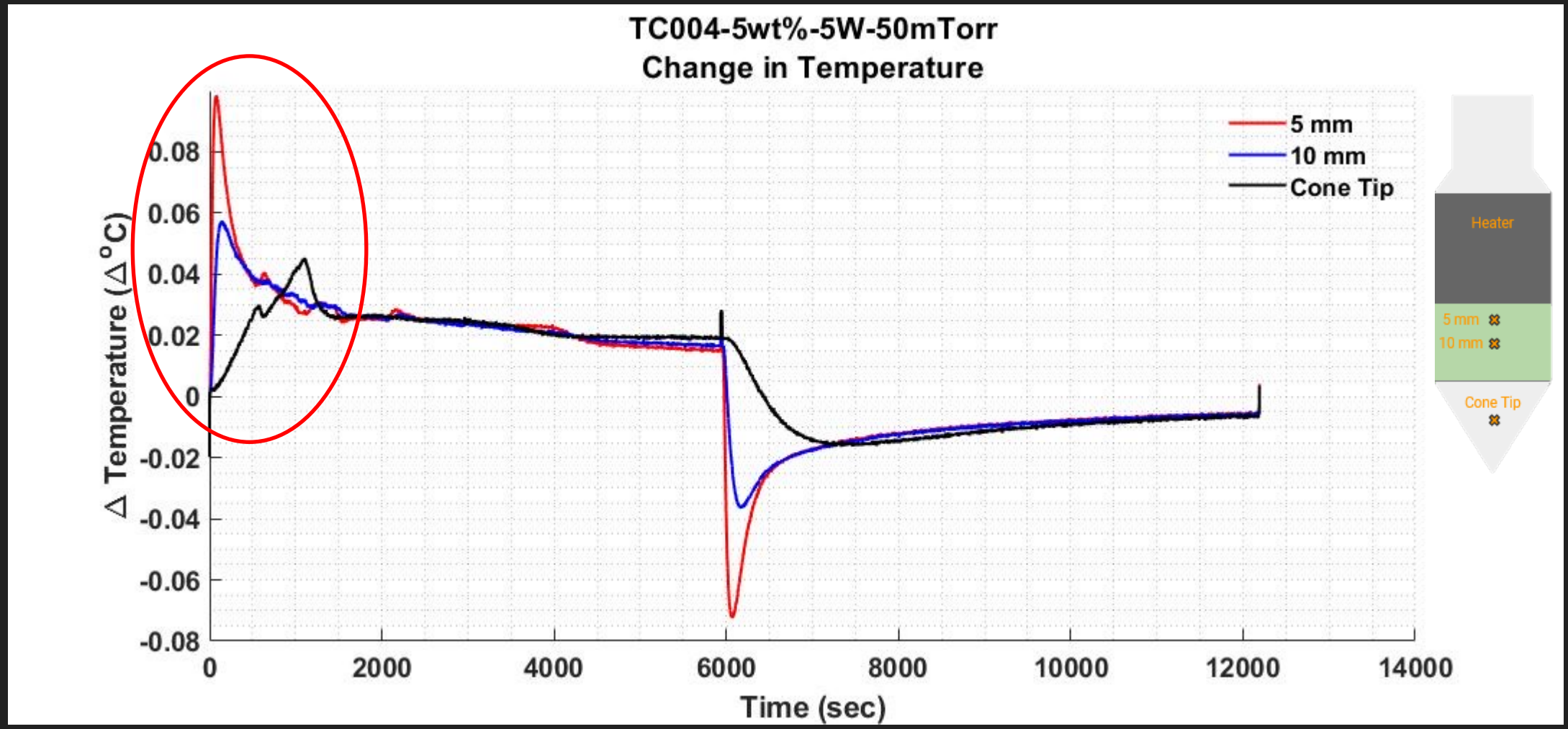
Thermal Cone Vacuum Test Results



* Discrete ice / snow particle inclusion

Thermal Cone Vacuum Test Results



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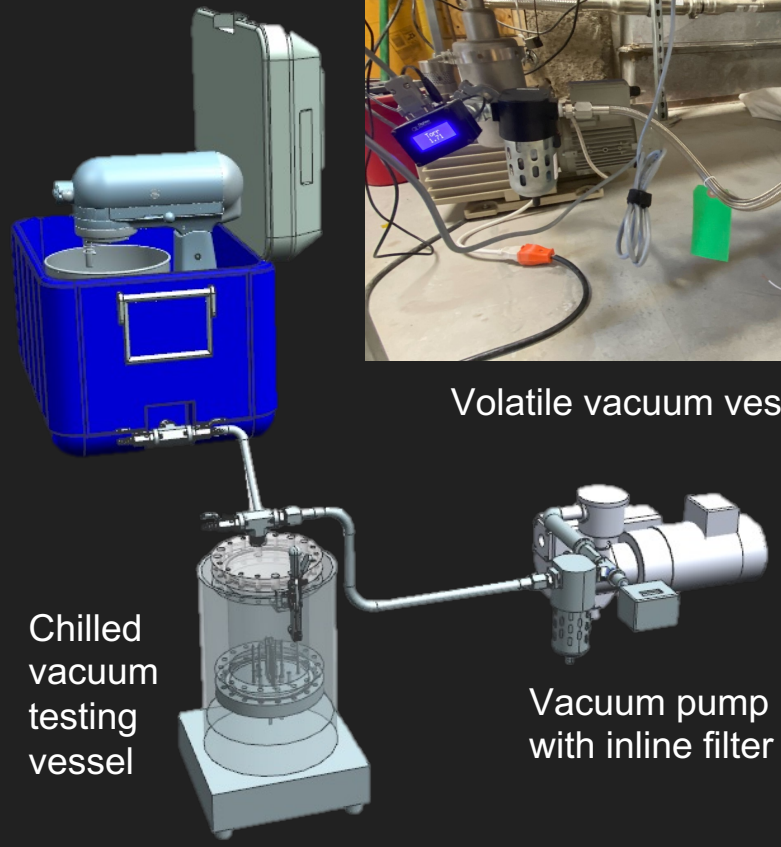
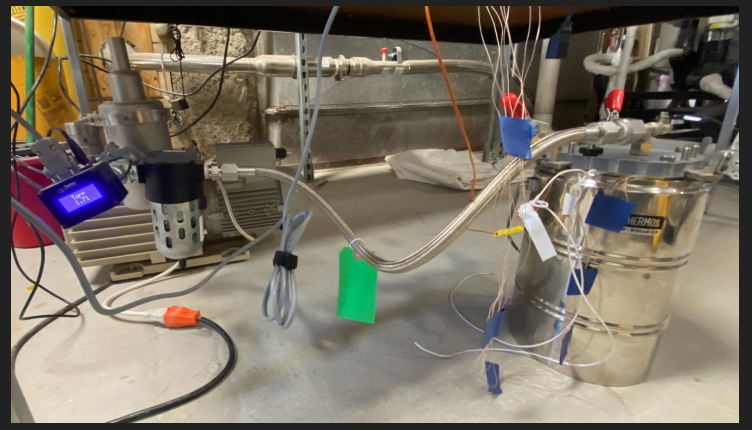
Cryogenic Vacuum Volatiles Thermal Measurement Test Setup

Volatiles being considered for testing. Extracted from LCROSS data (Colaprete et al. 2010)

Volatile Species	Target Temperature (Tripple Point)
H_2O - Water	< 0 °C
CO_2 - Carbon Dioxide	< -56 °C
CH_4 - Methane	< -182 °C
C_2H_4 - Ethylene	< -169 °C
CH_3OH - Methanol	< -98 °C
SO_2 - Sulfur Dioxide	< -75 °C





Volatile vacuum vessel test setup

Cryogenic Vacuum Volatiles Thermal Measurement Test Setup

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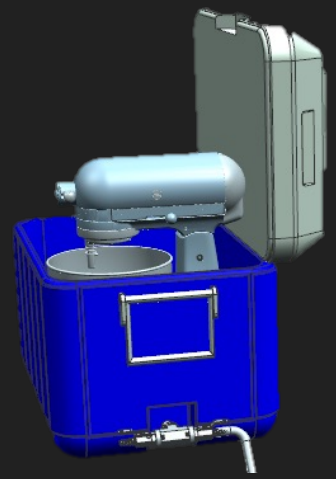


Chilled volatile mixing

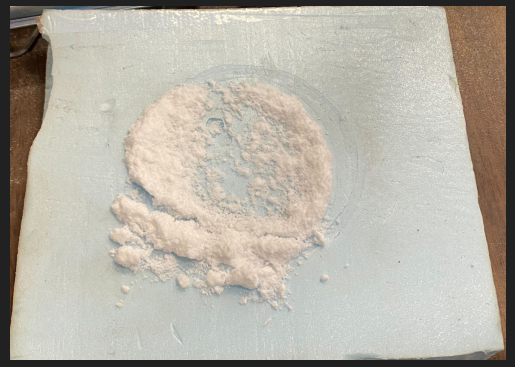
Insulated LN_2 bath box in fume hood

Volatile plunger and LN_2 box

Frozen volatile LN_2 cooled tube testing

LN_2 bath box

Plunger with nozzles for volatile deposition and compression rings for volatile snow collection



Frozen CO_2 snow collection

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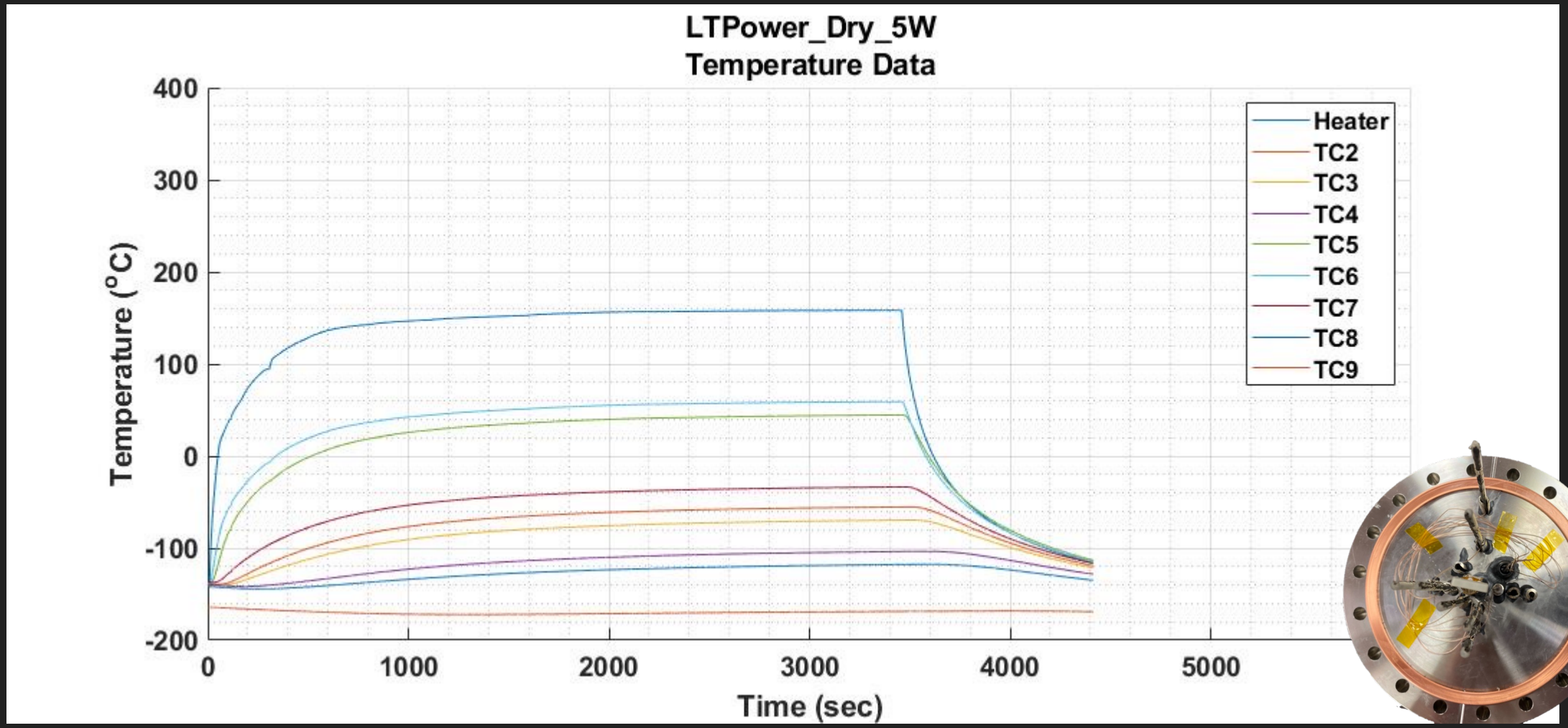
Cryogenic Vacuum Volatiles Test Results



Cryogenic Vacuum Volatiles Test Results

* Discrete ice / snow particle inclusion

Acknowledgements

PSTDL LuSTR Thermal Team

Dr. Paul van Susante
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Dr. Jeff Allen
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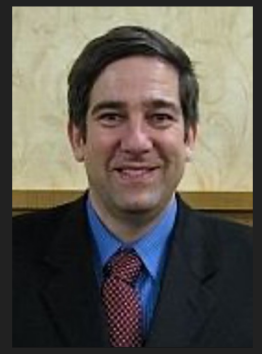

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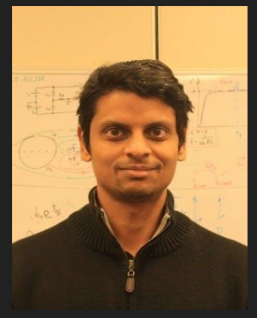

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