NASA STEM

Flow Boiling in Micro-channel Experiment In Variable Gravity

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National Council of Space Grant Directors'
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Space Grant at New Mexico State University

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Presentation outline

- What is the NASA STEM project?
- The experiment and its purpose
- Concerns
- The work and conclusions from the design phase
- Methods
- The team

What is the NASA STEM project?

The NASA STEM Project is a student ran program funded by NASA and the Space Grant Consortium at NMSU; to encourage retention and further involvement of our developing STEM students.

Participants get hands on experience in the development of cutting edge research, while developing the tools necessary to be successful in their field.

Purpose of the experiment

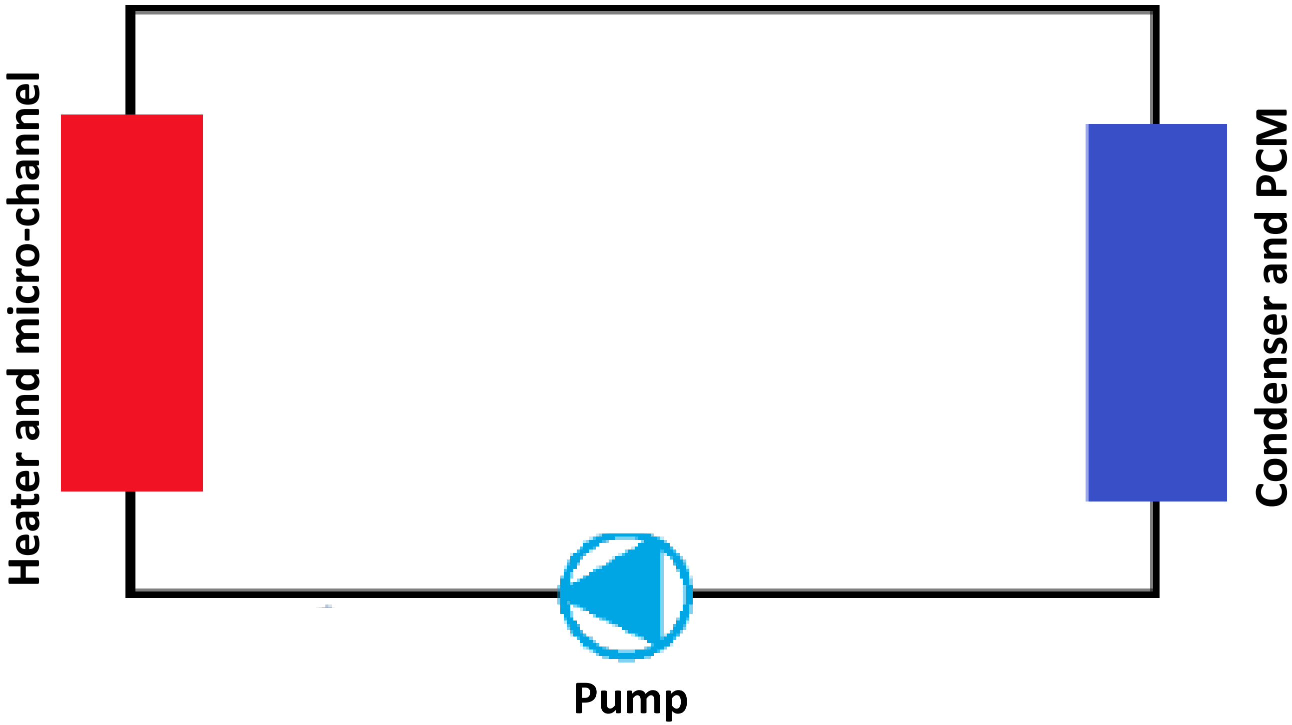
The understanding of flow boiling in varying gravity is crucial to space exploration. Due to a change in the effects of buoyancy on vapor, we experience limited surface area that is in contact with the heat transfer fluid in a hot channel. [1]

The effects of the channel size may impact the effectiveness of flow boiling and currently there is no literature on the effectiveness of flow boiling in a very small channel, (on the scale 5 mm). [2]

Our experiment will be within a channel that is 0.8 mm x 4 mm x 40 mm.

Component cooling in variable gravity environments
Next generation air craft
Future space missions

2-D diagram



Concerns

Limit changing environmental effects on the system

Structural

Increases and decreases in gravity
Centrifugal forces
Effects of change in pressure to the pump

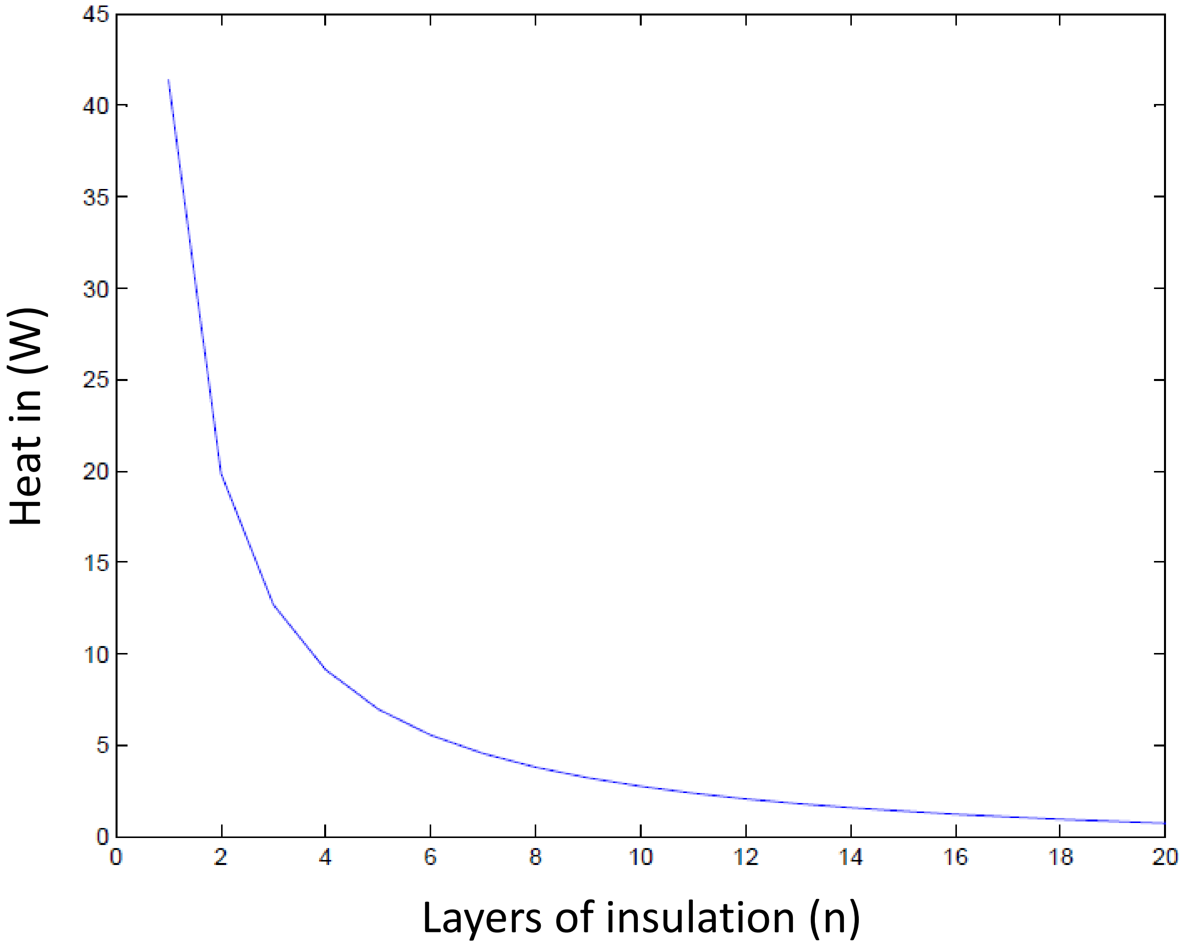
Thermal

Control external thermal effects to the system
Ensure phase change occurs

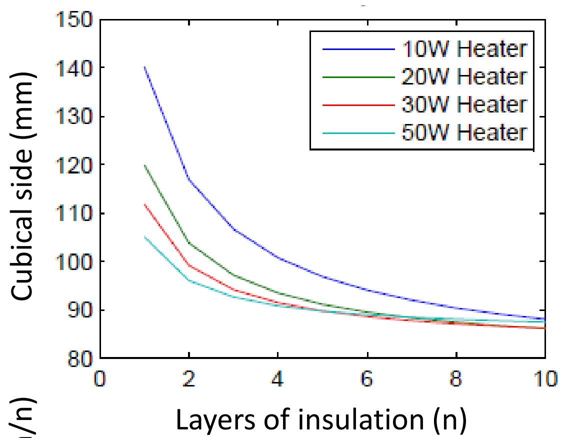
Electronic

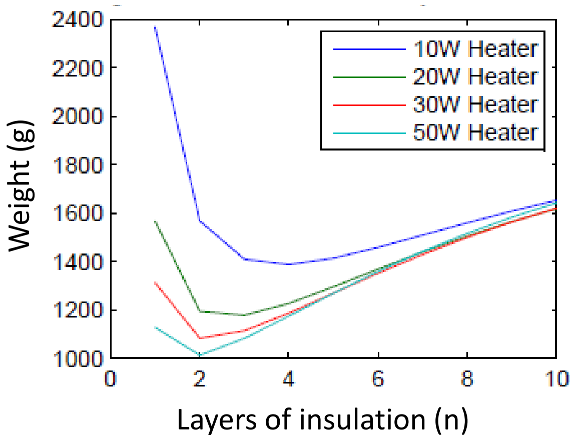
Make sure our devices will work throughout the experiment
Battery Power

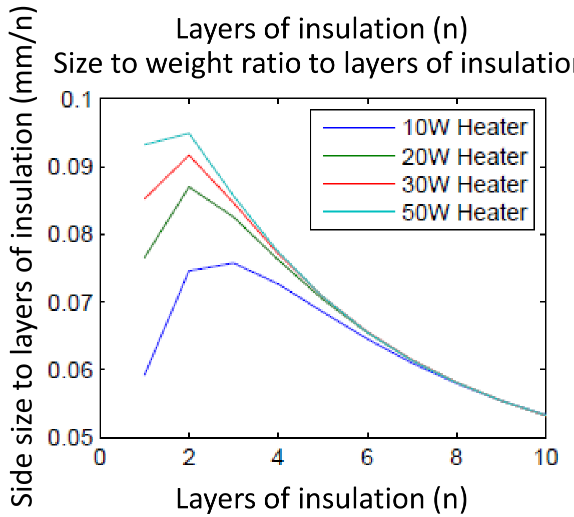
Heat transfer analysis



System analysis







Please Enter for which layer you would like info for: 6

At 6 Layers of insulation

Skeletal Structure OD: 188.00 mm (estimate)
Skeletal Structure Height: 173.50 mm (estimate)

10Watt Heater:
Total Trip Energy: 18636.68 joules
PCM = 648.73 grams
PCM Cubic Box side: 94.04 mm
PCM + Insulation Weight: 1457.43 grams

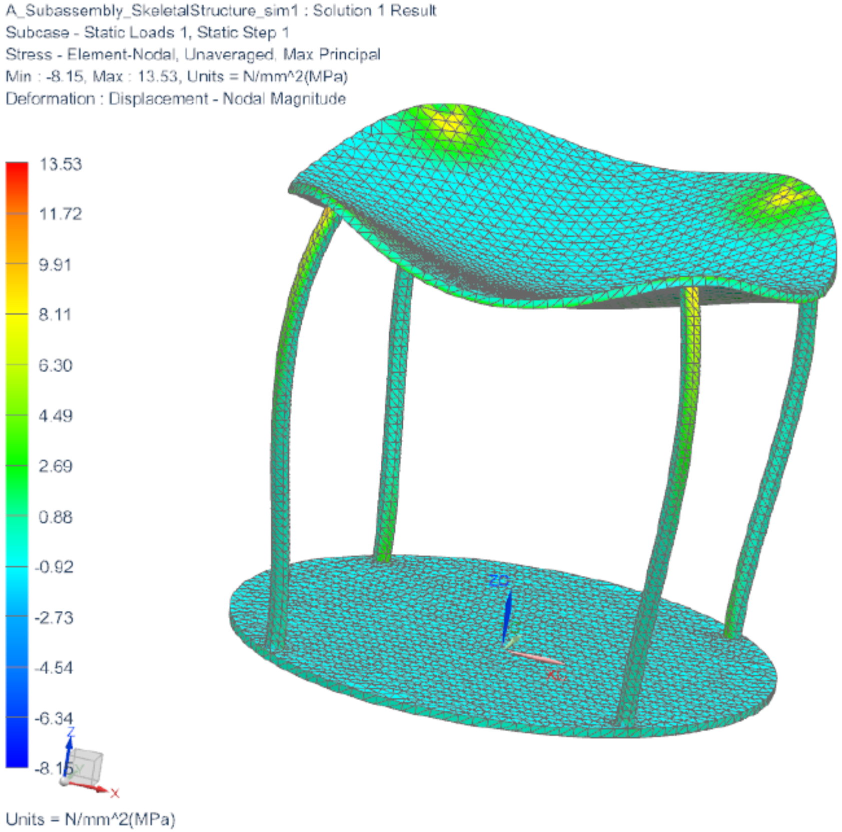
20Watt Heater:
Total Trip Energy: 30621.68 joules
PCM = 558.89 grams
PCM Cubic Box side: 89.48 mm
PCM + Insulation Weight: 1367.59 grams

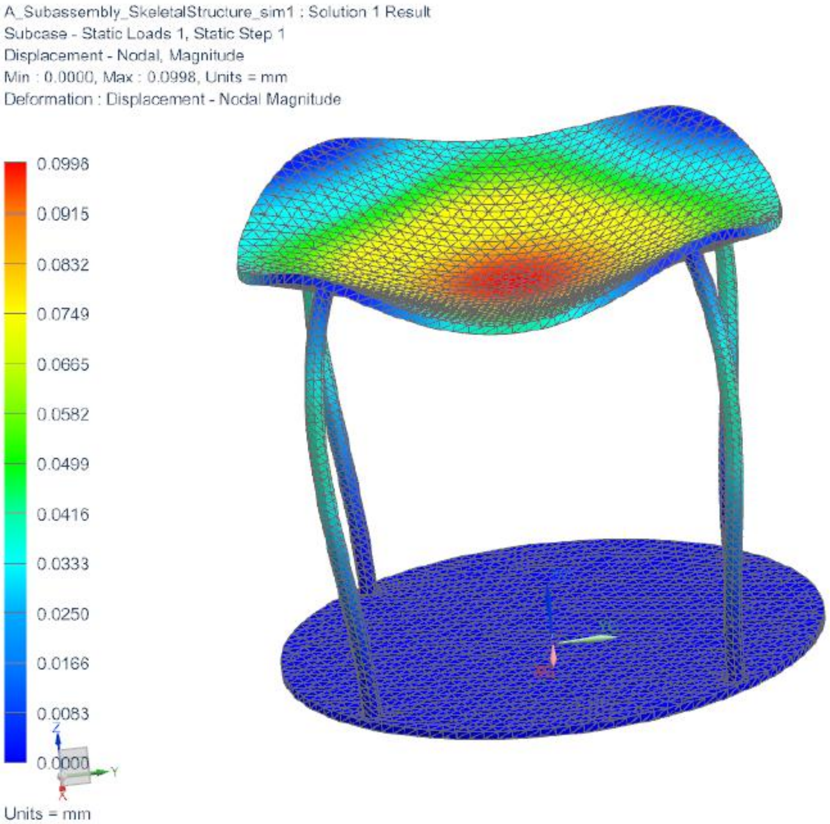
30Watt Heater:
Total Trip Energy: 42606.67 joules
PCM = 541.98 grams
PCM Cubic Box side: 88.57 mm
PCM + Insulation Weight: 1350.68 grams

50Watt Heater:
Total Trip Energy: 66576.67 joules
PCM = 549.01 grams
PCM Cubic Box side: 88.95 mm
PCM + Insulation Weight: 1357.71 grams

Structural FEA

*** Exaggerated deformation in image, actual deformation is about the width of a human hair**





Viable thermal fluids

* Pressure about 1 atm (pump)
* Boiling point above 27 C (PCM)

Isobaric Properties for Ethane, 2,2-dichloro-1,1,1-trifluoro- (R123)

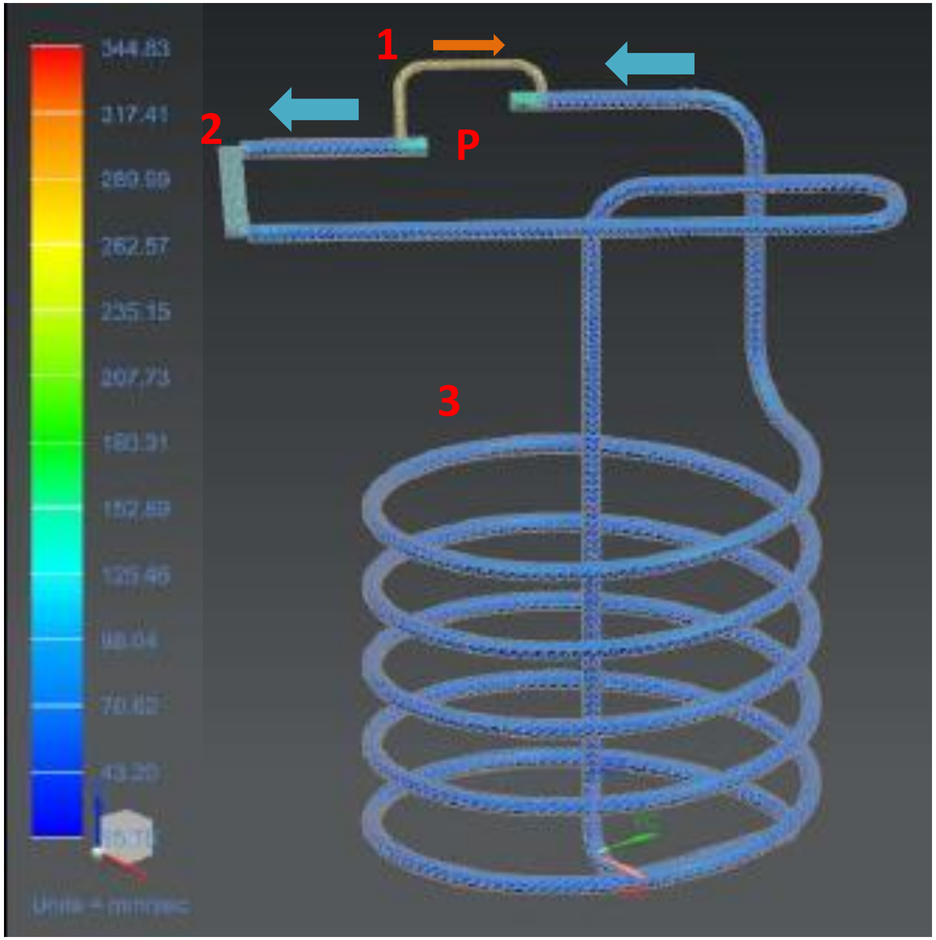
Temperature (C)	Pressure (MPa)	Density (kg/m3)	Volume (m3/kg)	Internal Energy (kJ/kg)	Enthalpy (kJ/kg)	Entropy (J/g*K)	Cv (J/g*K)	Cp (J/g*K)	Sound Spd. (m/s)	Joule-Thomson (K/MPa)	Viscosity (Pa*s)	Therm. Cond. (W/m*K)	Phase
31.300	0.11500	1447.6	0.00069078	231.51	231.59	1.1093	0.71088	1.0274	679.50	-0.30313	0.00038849	0.074683	liquid
31.361	0.11500	1447.5	0.00069085	231.58	231.66	1.1095	0.71094	1.0274	679.26	-0.30297	0.00038822	0.074666	liquid
31.361	0.11500	7.2897	0.13718	384.57	400.35	1.6635	0.63772	0.70735	128.97	36.664	1.0962e-05	0.0095581	vapor
31.400	0.11500	7.2886	0.13720	384.60	400.37	1.6635	0.63775	0.70738	128.98	36.647	1.0963e-05	0.0095604	vapor

Isobaric properties for Dodecafluoropentane

Temperature (C)	Pressure (MPa)	Density (kg/m3)	Volume (m3/kg)	Internal Energy (kJ/kg)	Enthalpy (kJ/kg)	Entropy (J/g*K)	Cv (J/g*K)	Cp (J/g*K)	Sound Spd. (m/s)	Joule-Thomson (K/MPa)	Viscosity (Pa*s)	Therm. Cond. (W/m*K)	Phase
33.100	0.11500	1585.2	0.00063083	3.5859	3.6584	0.011983	0.87329	1.0954	417.25	-0.17272	undefined	undefined	liquid
33.200	0.11500	1584.9	0.00063097	3.6954	3.7680	0.012341	0.87342	1.0956	416.95	-0.17234	undefined	undefined	liquid
33.218	0.11500	1584.8	0.00063100	3.7149	3.7874	0.012405	0.87345	1.0956	416.90	-0.17227	undefined	undefined	liquid
33.218	0.11500	13.867	0.072115	86.263	94.556	0.30868	0.81091	0.85178	90.107	23.096	undefined	undefined	vapor
33.300	0.11500	13.862	0.072140	86.330	94.626	0.30891	0.81101	0.85187	90.126	23.065	undefined	undefined	vapor

[5]

Flow loop CFD



With back flow pipe we were able to reduce the max velocity through micro-channel to be 195.66 mm/s

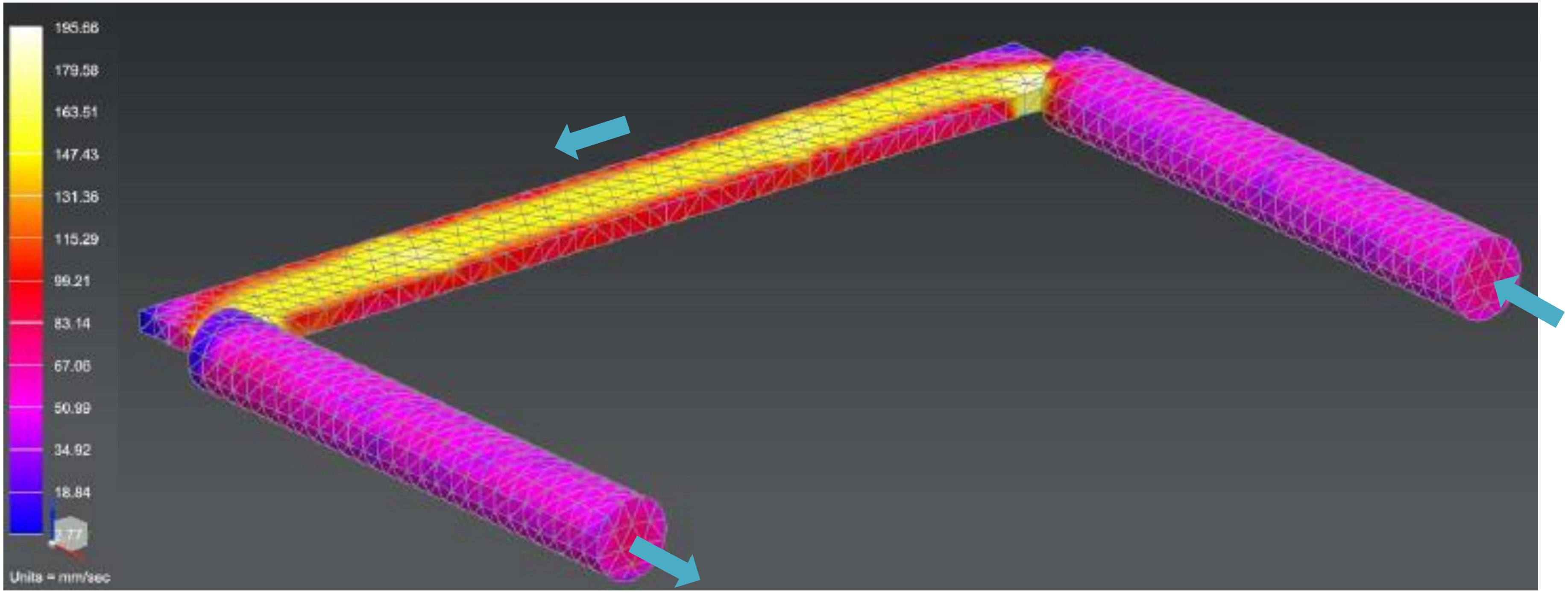
1) Back flow pipe
2) Micro-channel
3) Condenser coil

P represents the pump (not shown in figure)

Direction of fluid flow in backflow pipe in 1 G

Direction of fluid flow in 1 G

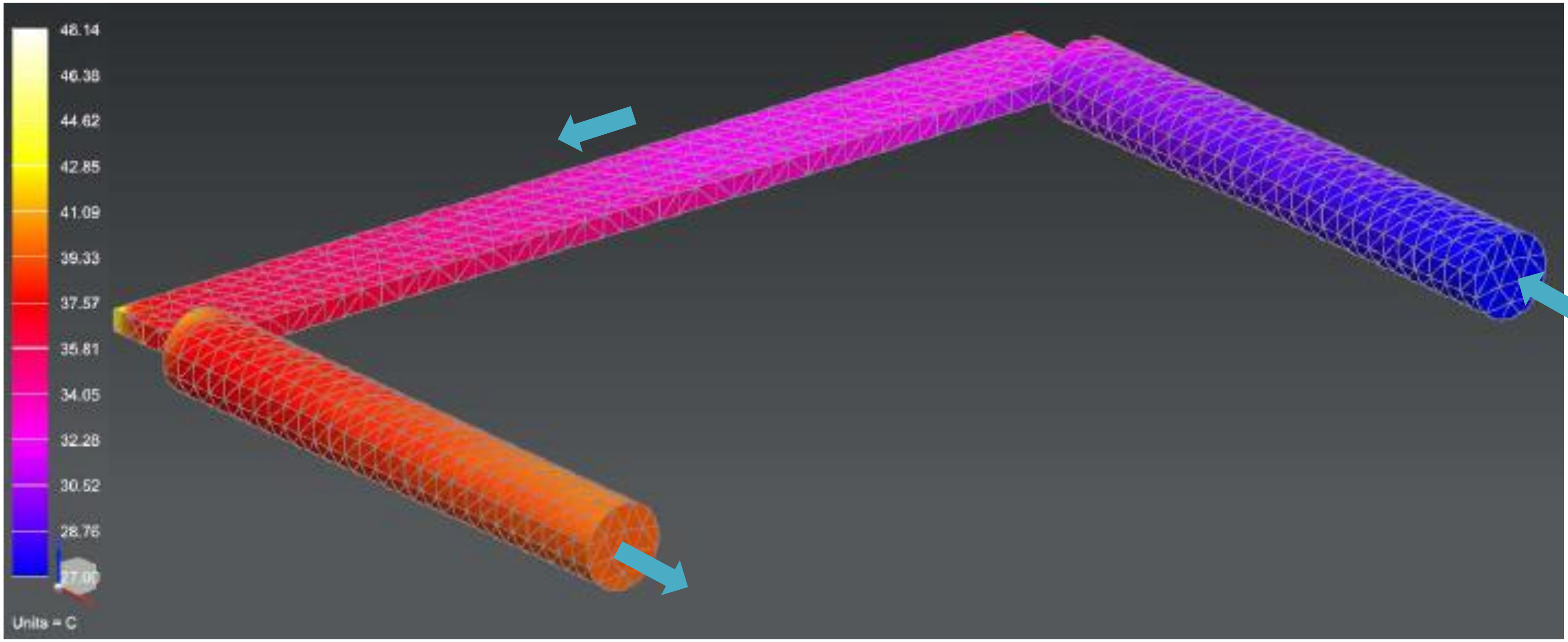
Microchannel CFD (velocity)



Max velocity in micro-channel
195.66 mm/s

Direction of fluid flow in 1 G

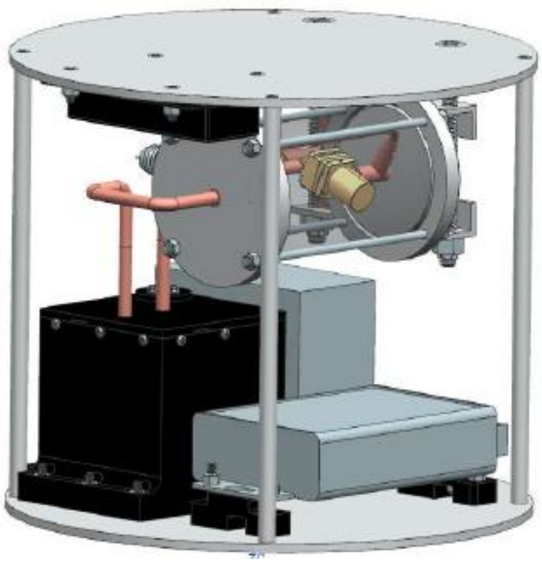
Microchannel CFD (temperature)

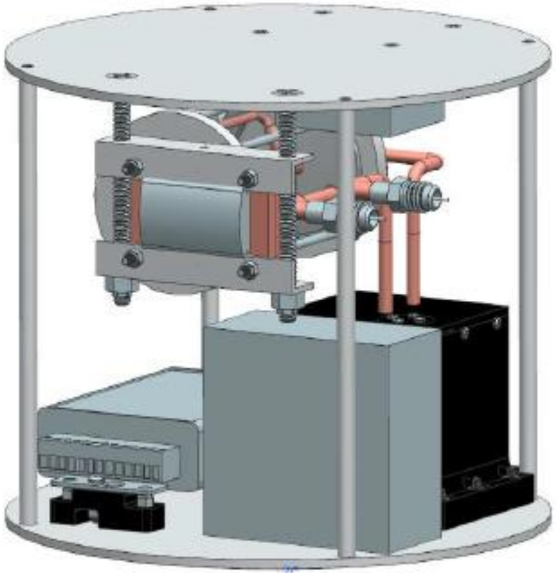


Max temp in fluid at 195.66
48.14 C

Direction of fluid flow in 1 G

3-D model





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Methods of data collection

Thermal DAQ

Accelerometer

Conclusion

- Better understand flow boiling through a micro-channel
- The changes in efficiency in varying gravity environments
- Determine force required to overcome film boiling in zero gravity (if possible)
- The effects of varying gravity on vaporized medium in a flow loop

The team

Mechanical Engineers

Philip Lane

Alvin Harvey

Kyle Edgerton

Angel Sanez

Civil Engineers

Sara Ruvalcaba

Chemical Engineers

Jessie Privett

Norann Calhoun

Electrical Engineers

Manda Mahender

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NASA

Dr. Kota

Dr. Stochaj

UpAerospace

Siemens

Mathworks

Resources

[1] Zhang H, Mudawar I, Flow boiling CHF in microgravity:
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[2] Baldassari C, Maeringo M, Flow boiling in microchannels and microgravity:
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