Integrating Quench Modeling into the ICME Workflow

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Presentation Outline

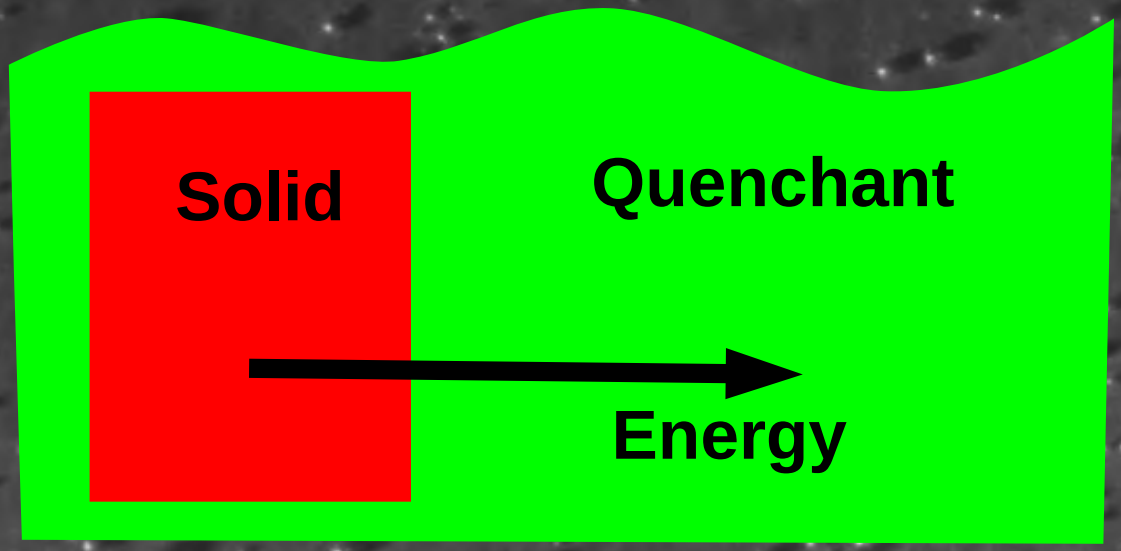
- ICME Link (Materials Engineering)
- Specific modeling type
- Approach for model development
- Experimental data collection
- Data collection procedure
- Review of experimental results
- Future model development

Materials Engineering

- Many factors are important to successfully design a material for a particular use
- Heat transfer can have an important impact
- Heat treating is especially important with metal alloys
- Quenching operations frequently used
- Quenchant with phase change during heat treatment is an important process
- Existing numerical models are not sufficient

What Type of Model?

- Heat transfer model
- Characterize energy movement
- Focus on surface heat flux rates

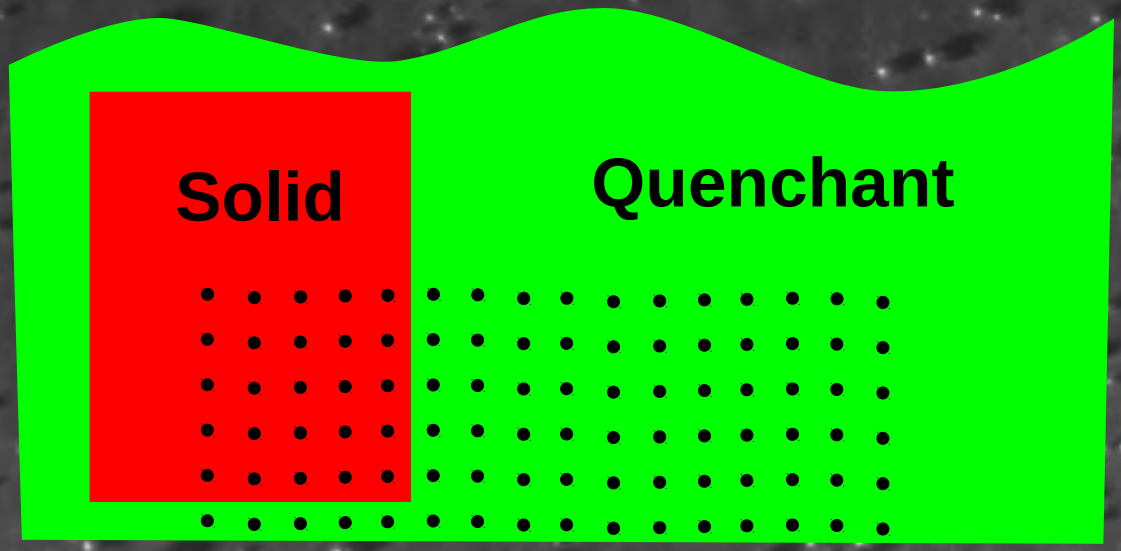


Model Access

- Computer Aided Engineering (CAE)
  - Path through commonly used tools
  - Leverage existing technologies
- High end work stations
  - “Reasonably” accessible computer hardware
  - Avoid super computer requirements

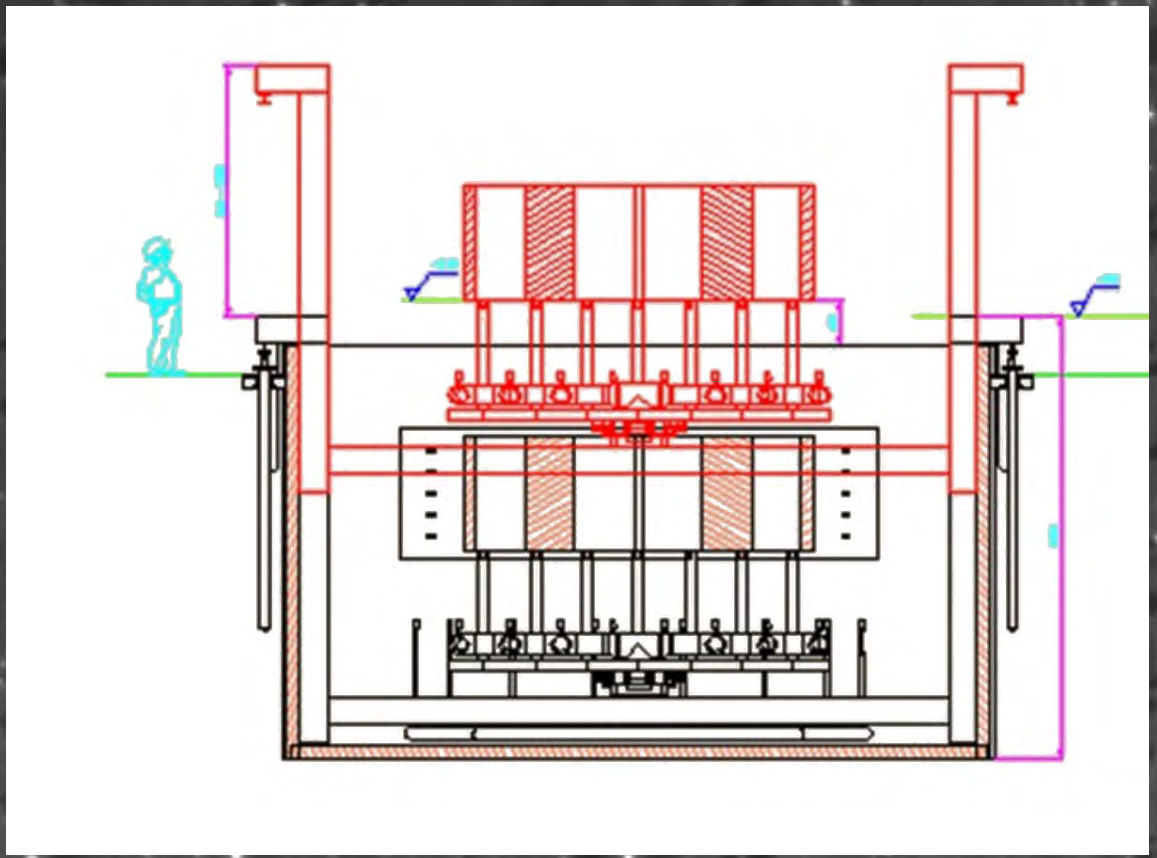
Computational Fluid Dynamics

- CFD
  - Collection of numerical techniques
  - Characterize fluid mechanics and heat transfer



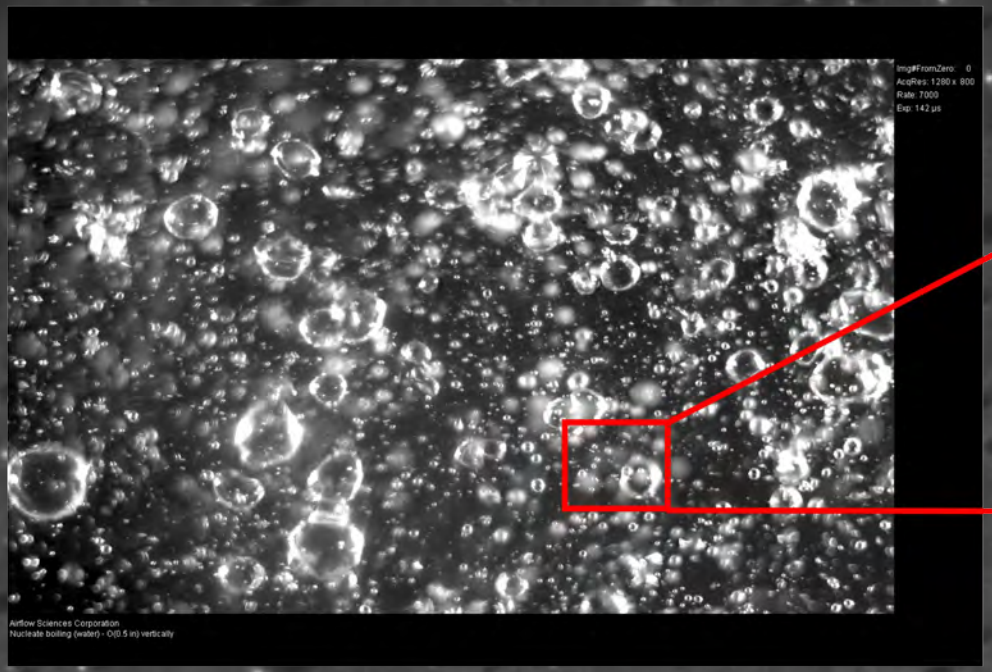
What Physics are Important?

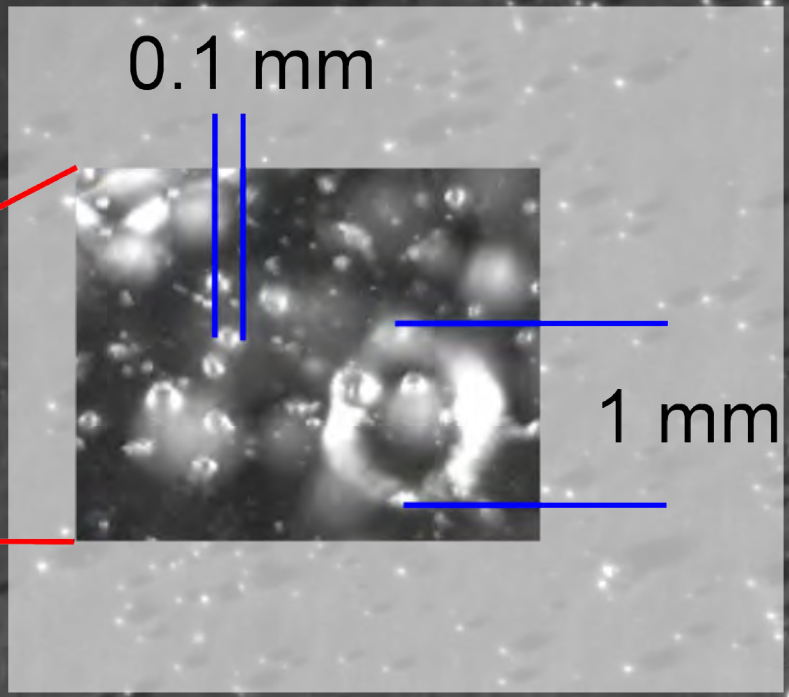
- Bulk fluid motion in quench tank
  - Large length scale



What Physics are Important?

- Surface Boiling
  - → Small length scale





Balancing Choices Made

- Resolve the quench tank bulk fluid motion
  - Propose general motion is not significantly impacted by local surface boiling. Especially when tank is agitated.
  - Propose using established “single phase” CFD techniques to characterize this motion.
- Vapor due to phase change only impacts surface heat transfer while on or near heat transfer surface.
  - Improve standard CFD heat transfer techniques

Overall Modeling Approach

- Leverage existing CFD technology
  - Methods work well for bulk fluid motion
  - Engineers are familiar with tools
  - Transient simulations of industrial equipment is common practice today
- Develop a new sub grid scale wall model
  - Similar to those currently used by turbulence models
  - Incorporate sub grid scale phase change physics into model

Wall Model Relationship

- Standard CFD convective heat transfer

$$q = h\left(T_{fluid} - T_{solid}\right)$$

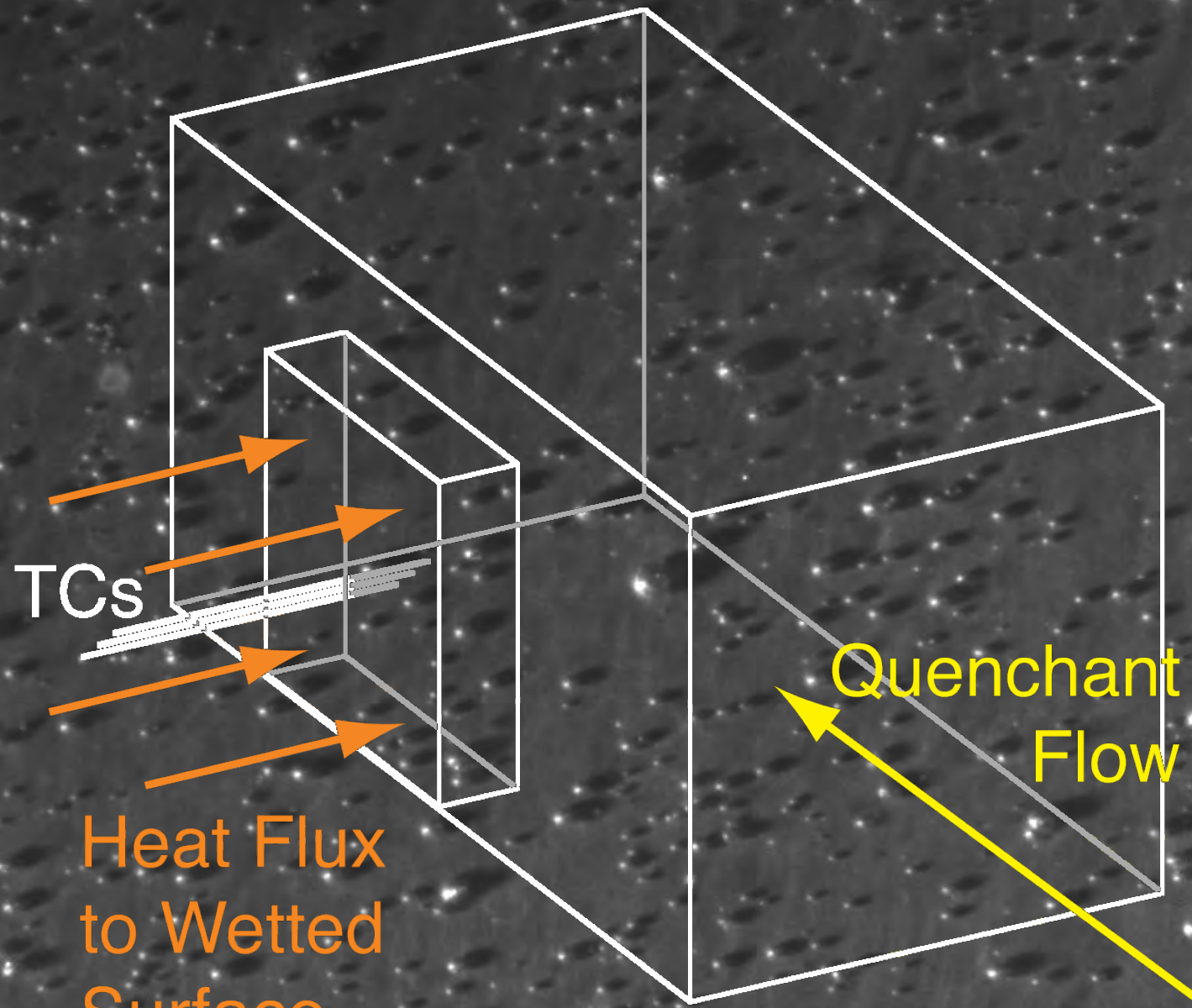
Needs to include physics for phase change (boiling)

Experimental Approach

(Quasi-Steady State Flow Boiling)

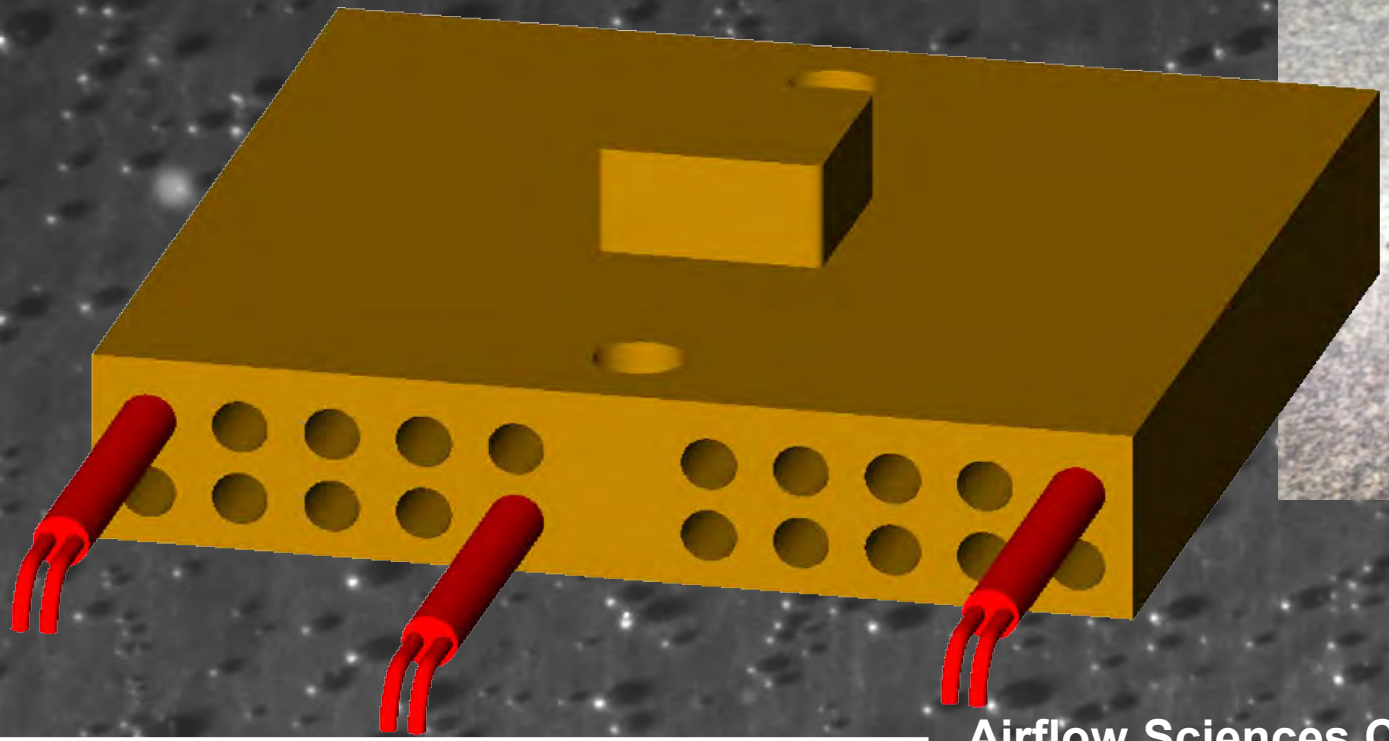
TCs to measure temperature and heat flux

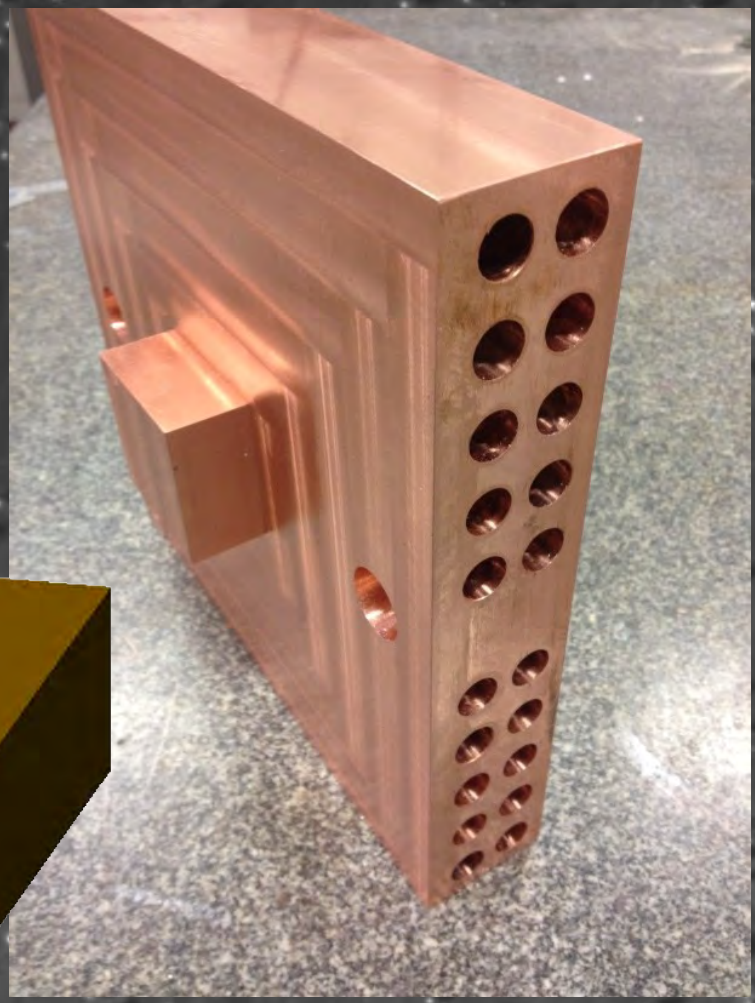
Reorient test section for different flow direction or surface normal



Heater Block

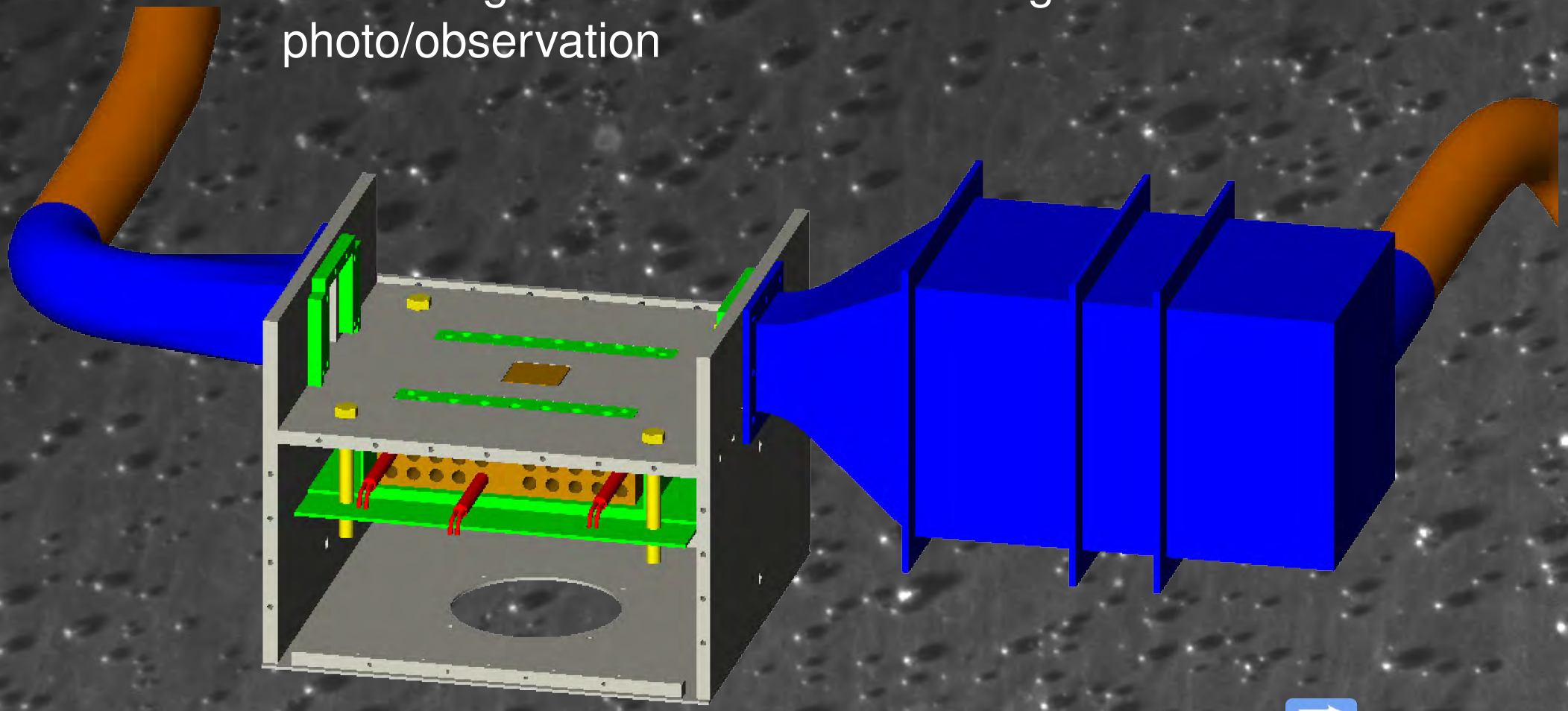
- Copper
- 20 cartridge heaters
- 9000 Watts total input
- TCs pass through back side



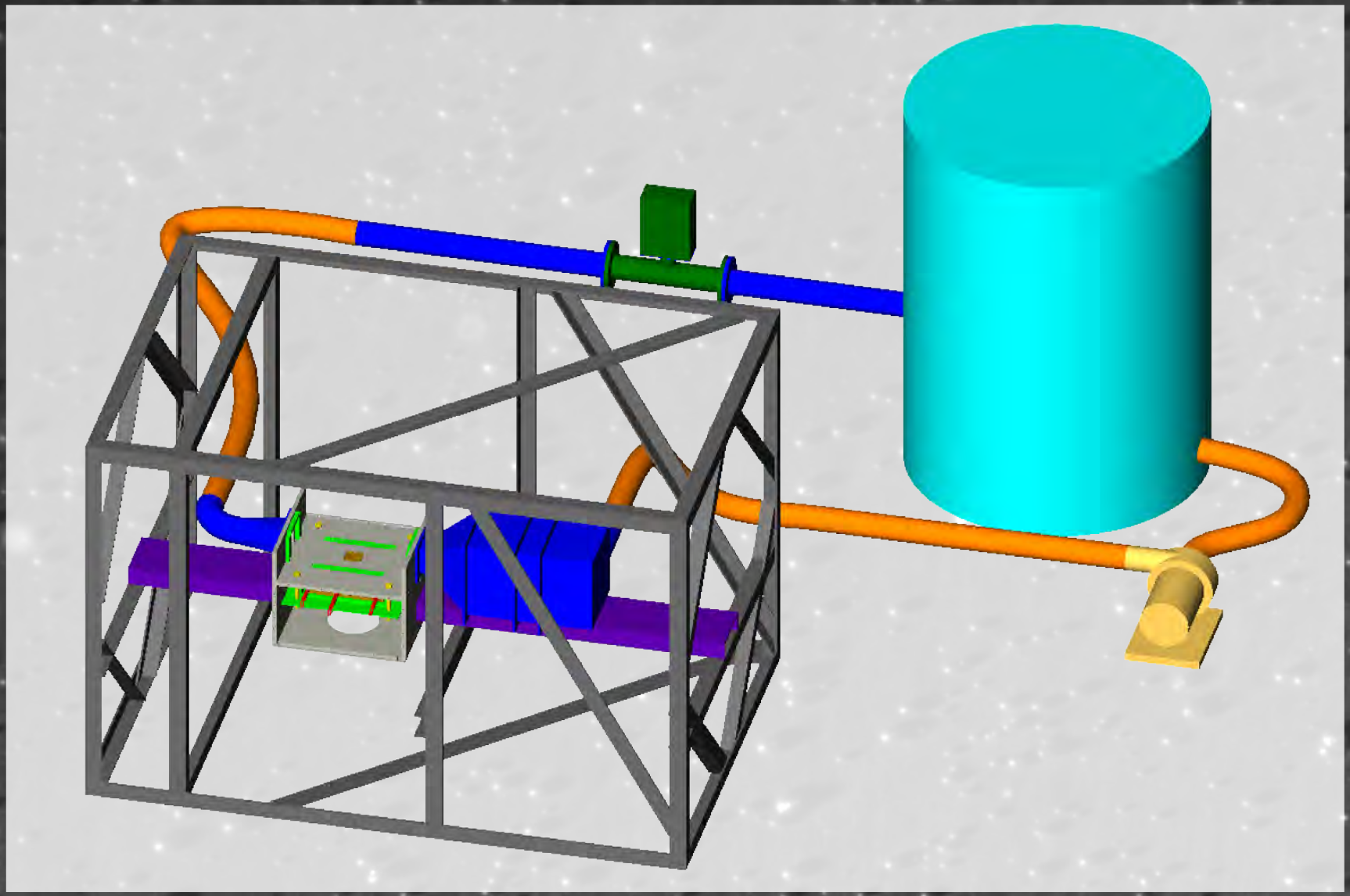


Heater Assembly Design

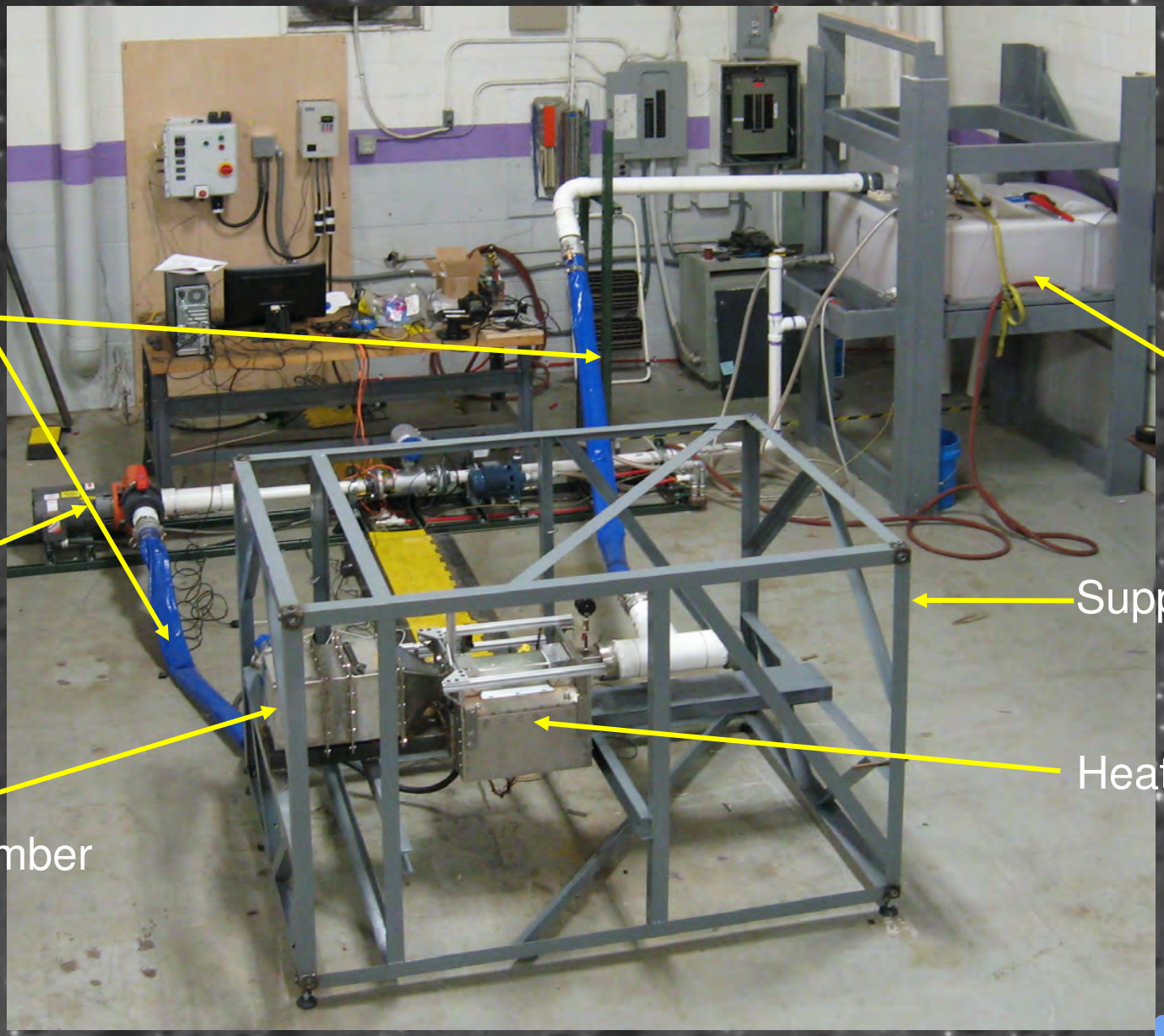
Settling chamber to provide good flow quality
Heated surface on side of test channel (omitted for clarity)
Remaining side of test channel are glass for photo/observation



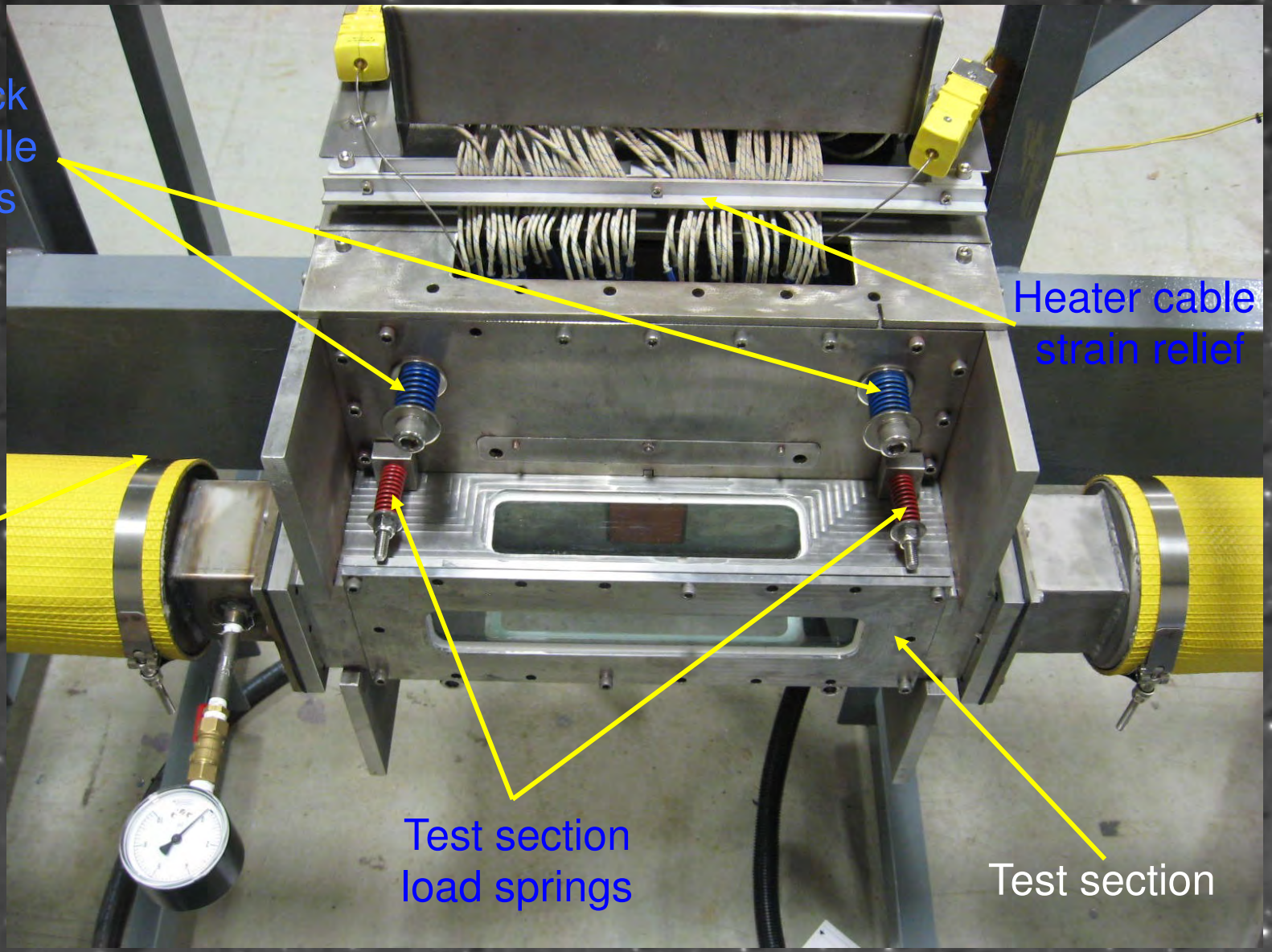
Full Test Fixture Layout



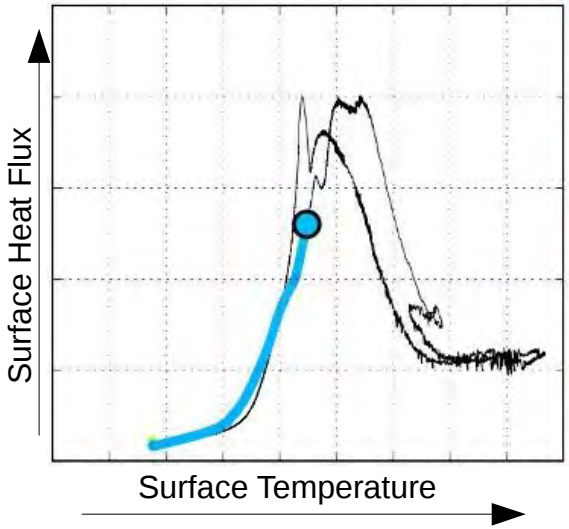
Test Fixture In Lab



Heater Assembly



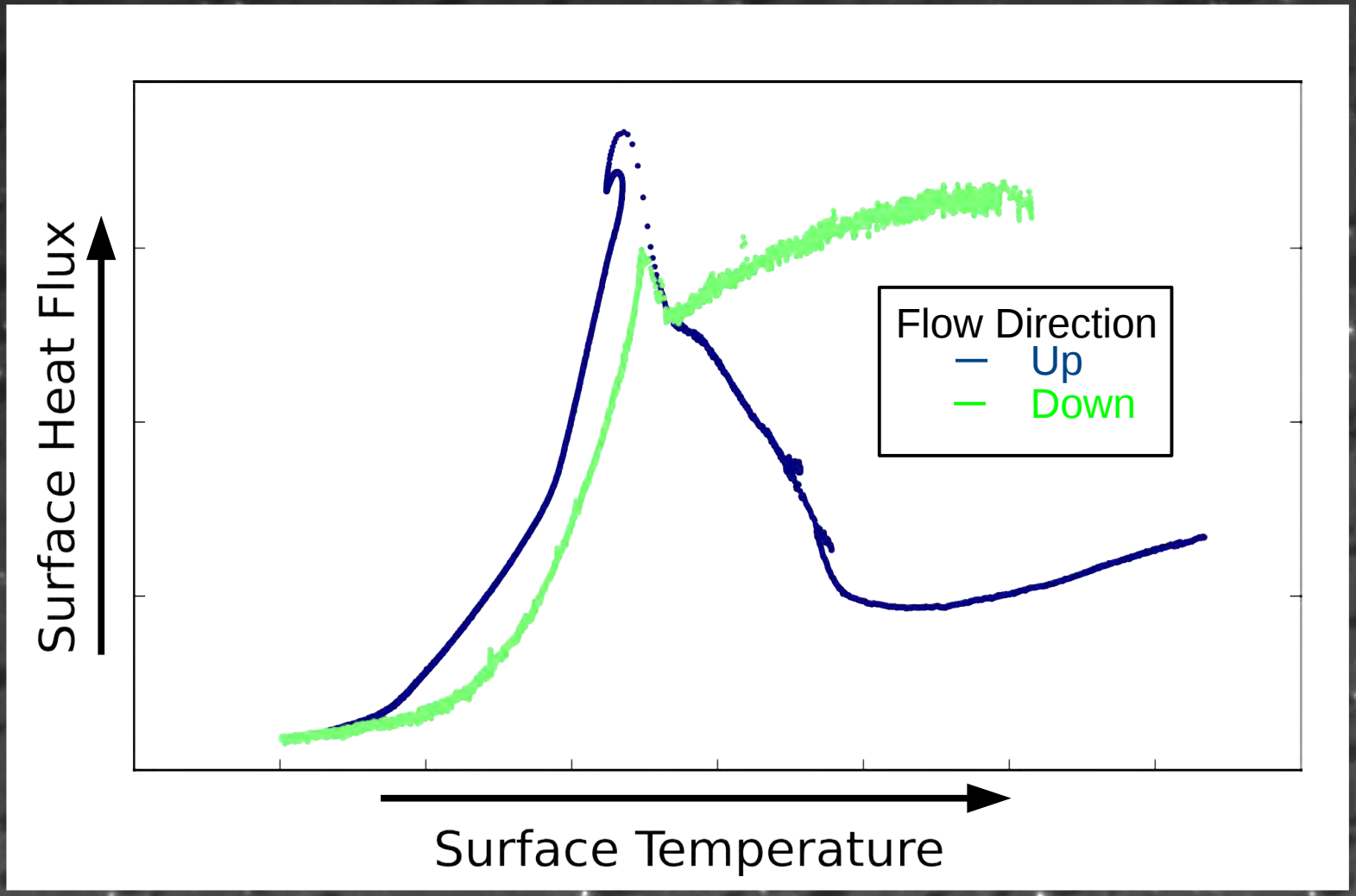
Experimental Data Collage

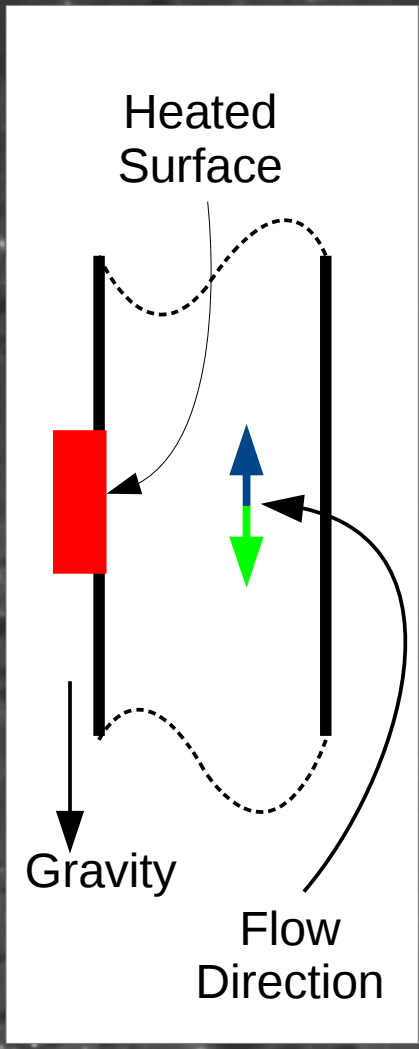


Bubbles

Heated Surface

Observed Heat Flux Variation





Future Work

- Finish collection of experimental data
- Compile physics based relationships to estimate heat transfer coefficient
- Implement relationship into a CFD environment
- Benchmark resulting simulation tool

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- Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the United States Air Force.