Aluminum-Ammonia Heat Spreader for Lunar Surface Applications

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Presented By
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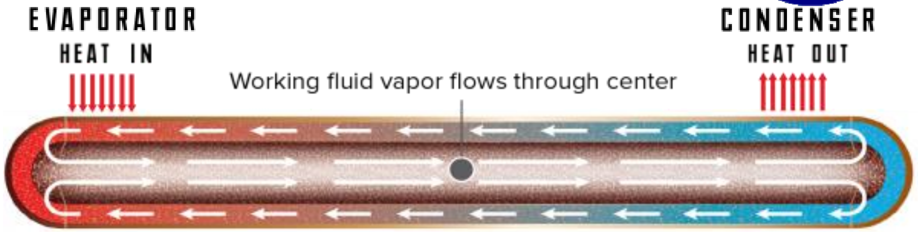
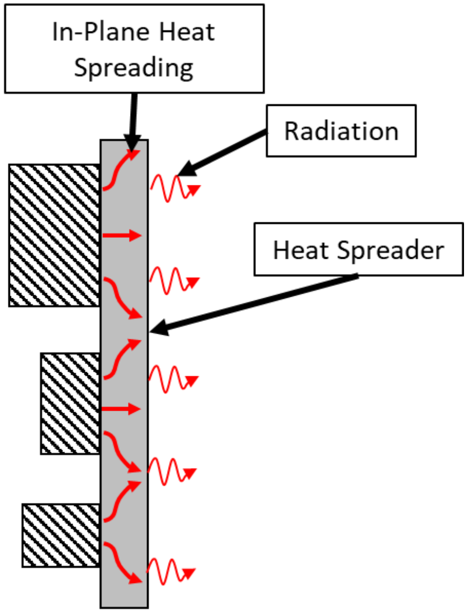
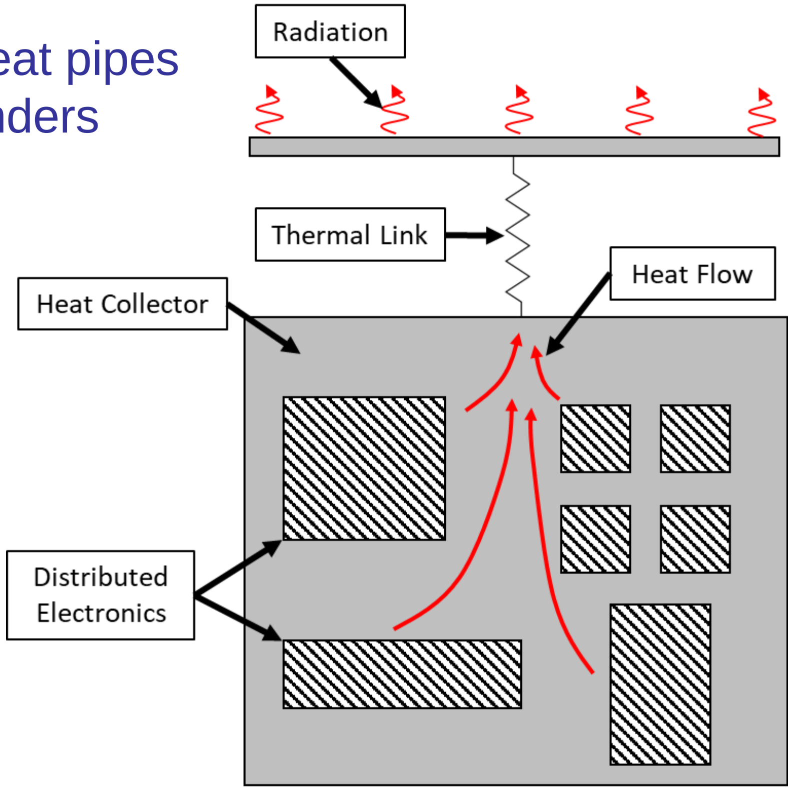
Heat Pipe-Based Thermal Management

- Heat pipes provide passive heat transfer
- Can be embedded in panels for heat spreading or collecting
- On the lunar surface the influence of gravity must be considered
- Vertically oriented surfaces are ideal for heat pipes but limit design and operation of rovers/landers





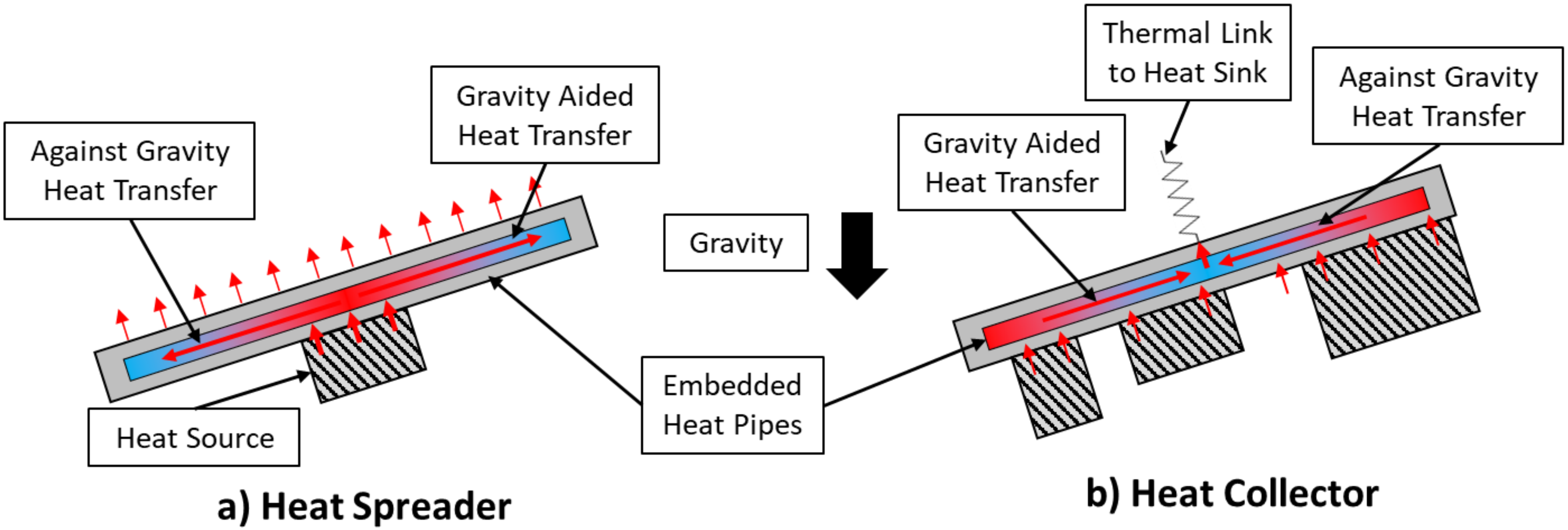
a) Heat Spreader



b) Heat Collector

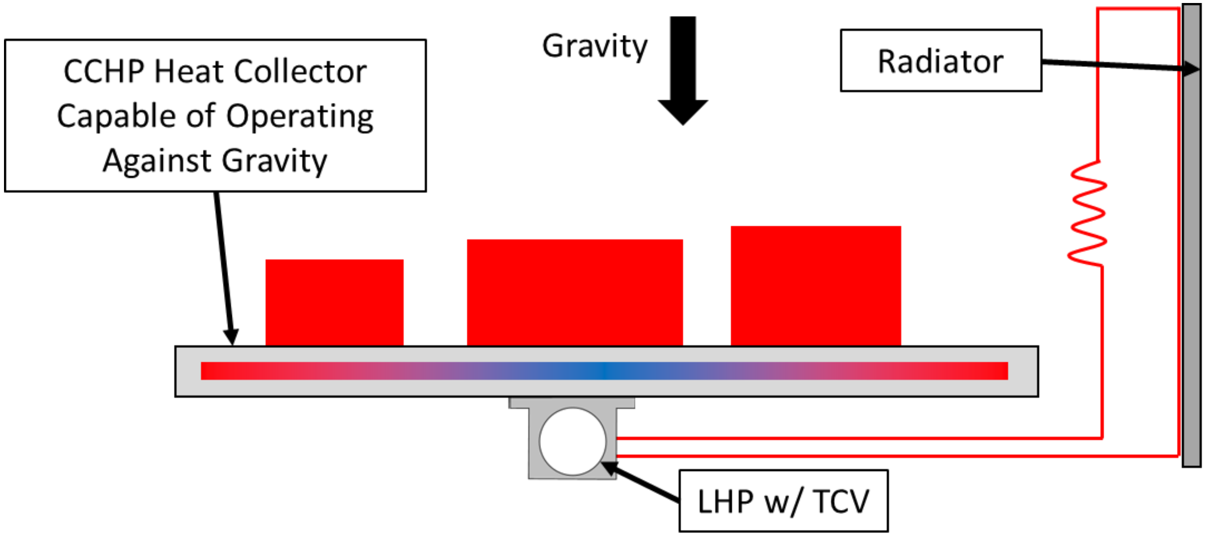
Heat Pipe-Based Thermal Management

- Nominally horizontal surfaces require wicked heat pipes capable of operating against gravity (cannot use grooved heat pipes)
- Actual orientation of heat pipes is unknown within a given range due to lunar terrain and/or dynamic motion (rovers)



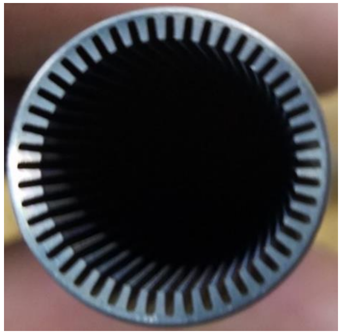
Thermal Management Architecture

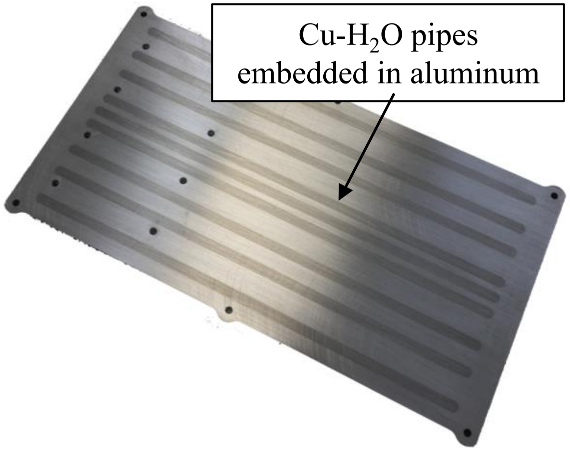
- As part of a NASA Sequential Phase II, ACT is developing several technologies for lunar surface missions with an emphasis on lunar night survival
- In partnership with Astrobotic, a lunar lander thermal management system mockup is being designed and fabricated for TVAC testing
- Lander electronics are mounted on a nominally horizontal surface
  - A panel of embedded heat pipes will carry heat to a Loop Heat Pipe (LHP) with Thermal Control Valve (TCV)
  - LHP w/ TCV provides a variable thermal link to the radiator with high turndown ratio
  - Due to the potential for unknown tilt angle the heat pipes must be capable of operating against gravity



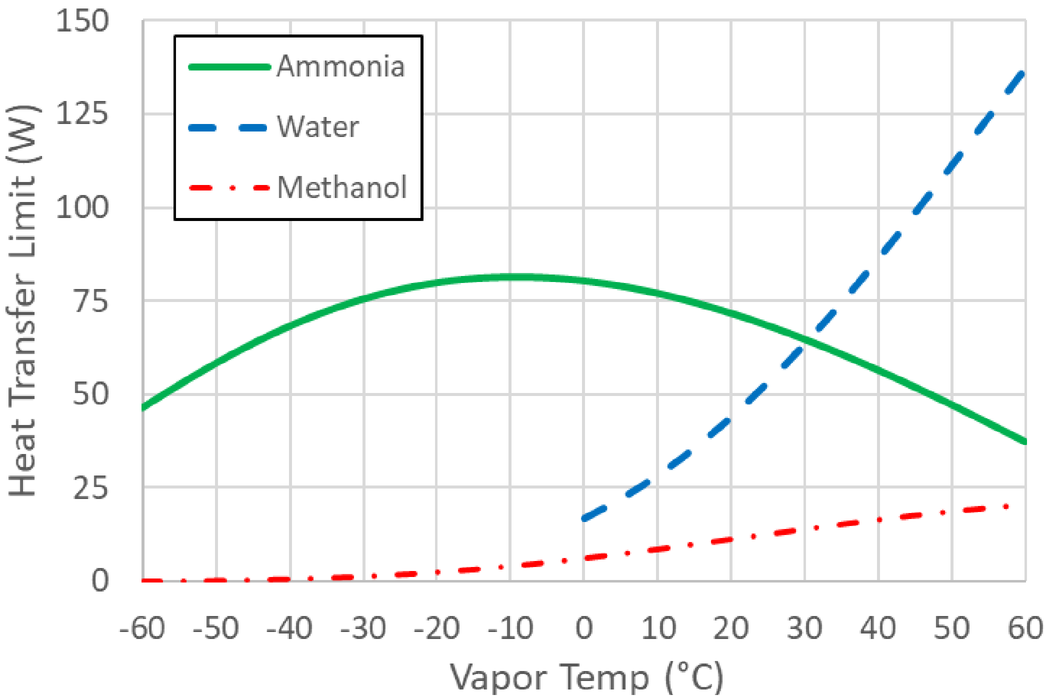
Heat Pipe Counter Gravity Options

- 3 common fluids for space heat pipes: Ammonia, water, and methanol
- Aluminum-ammonia grooved wick heat pipes are very common but not suitable for against-gravity operation
- Screen wicks can pump liquid against gravity



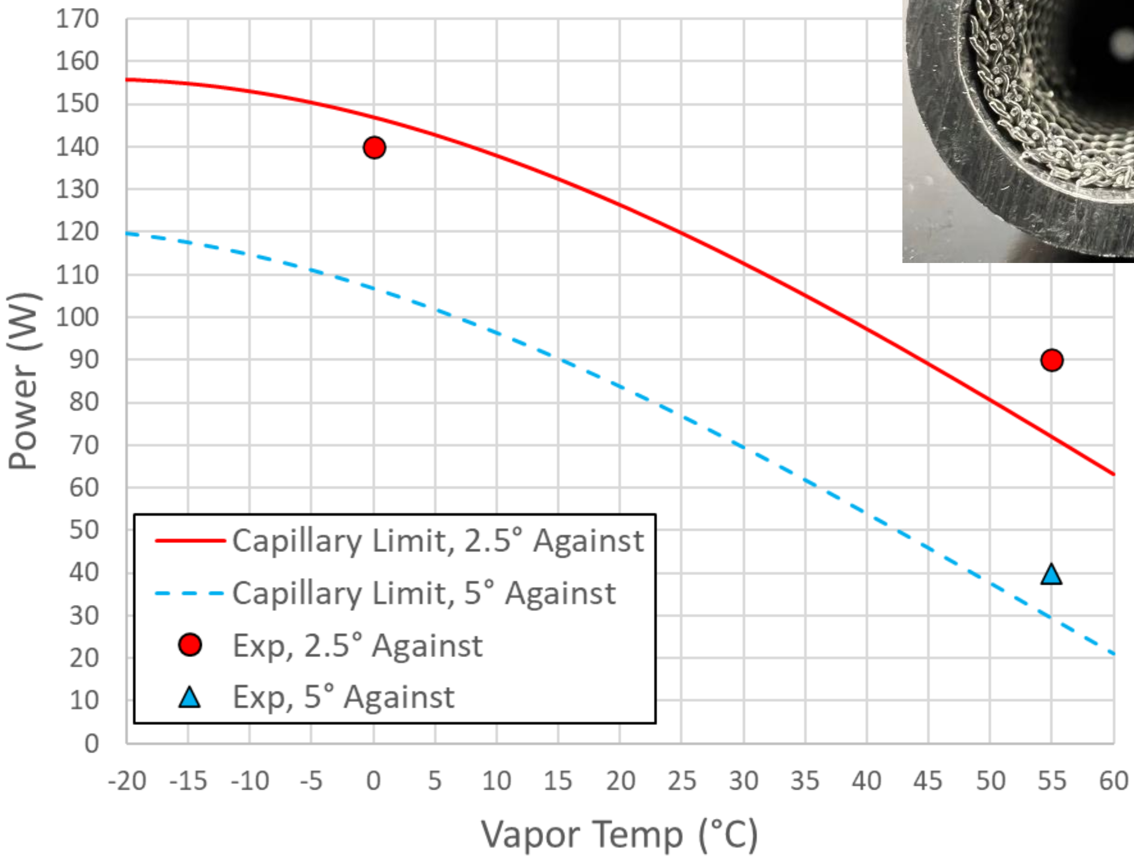


- Heat Transfer Predictions
  - Length = 305 mm
  - ID = 6.35 mm
  - 15° Against Gravity
  - Screen wick
- Water presents additional challenge due to freezing
- Aluminum-ammonia with screen wick is the clear winner



Aluminum-Ammonia Heat Pipe

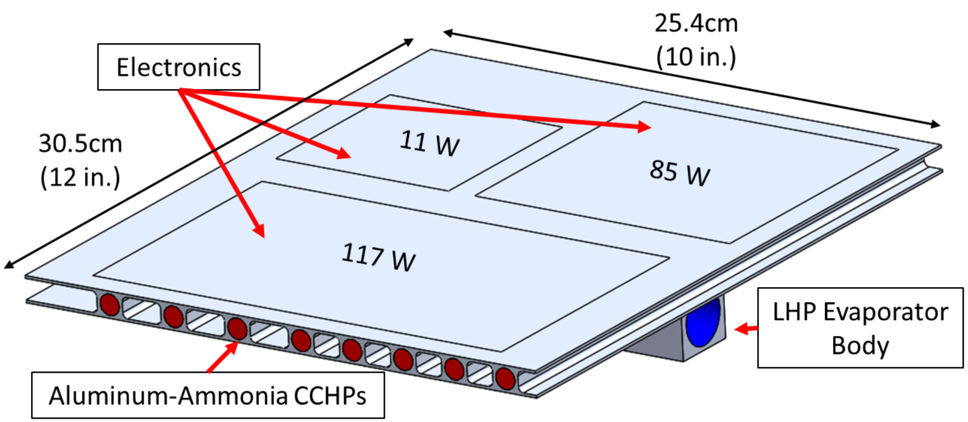
- Single aluminum-ammonia heat pipe with screen wick prototype was fabricated
  - Length = 305 mm
  - ID = 9.4 mm



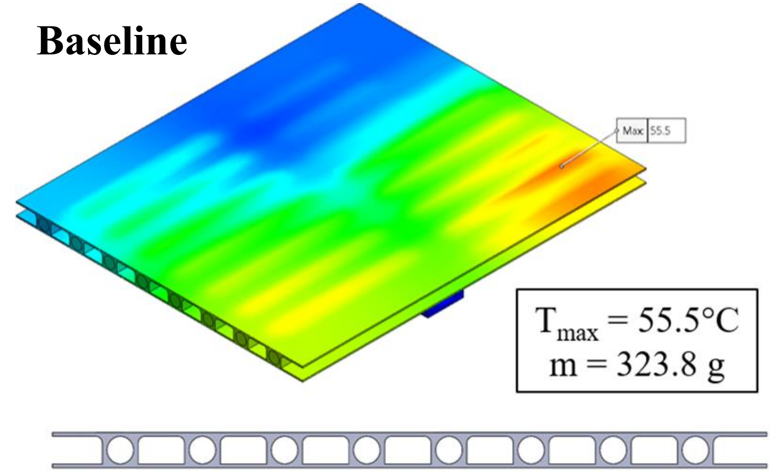
2.5° on Earth ≈ 15° on Moon
5.0° on Earth ≈ 30° on Moon

Heat Collector Design/Analysis

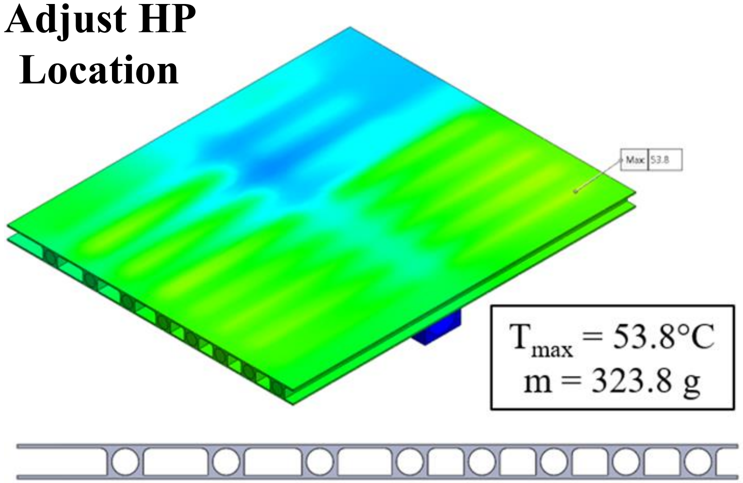
213W Total



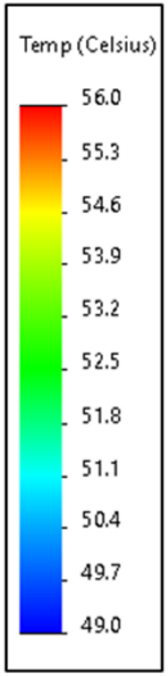
Baseline



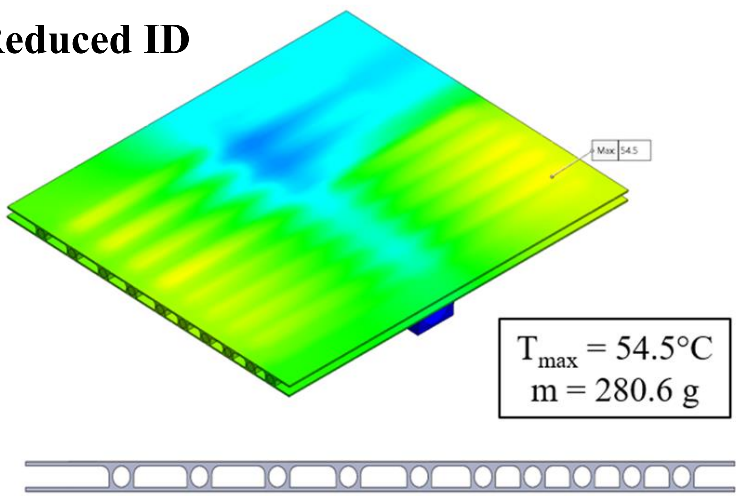
Adjust HP Location



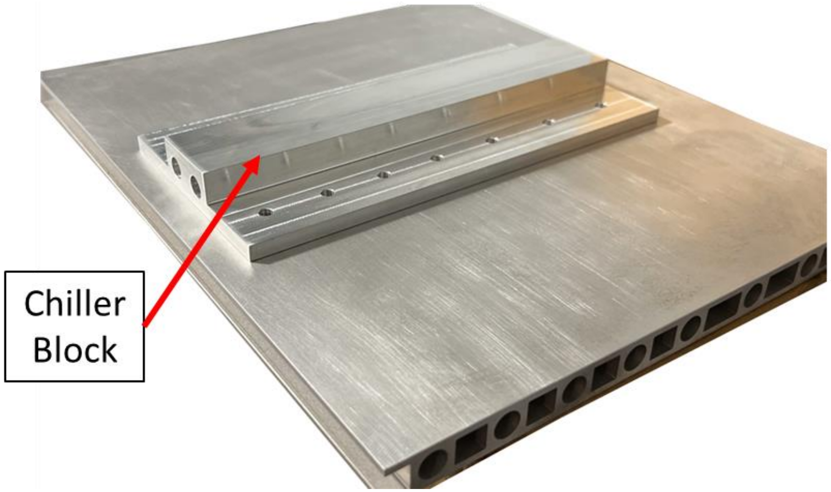
Design selected for manufacturing reasons

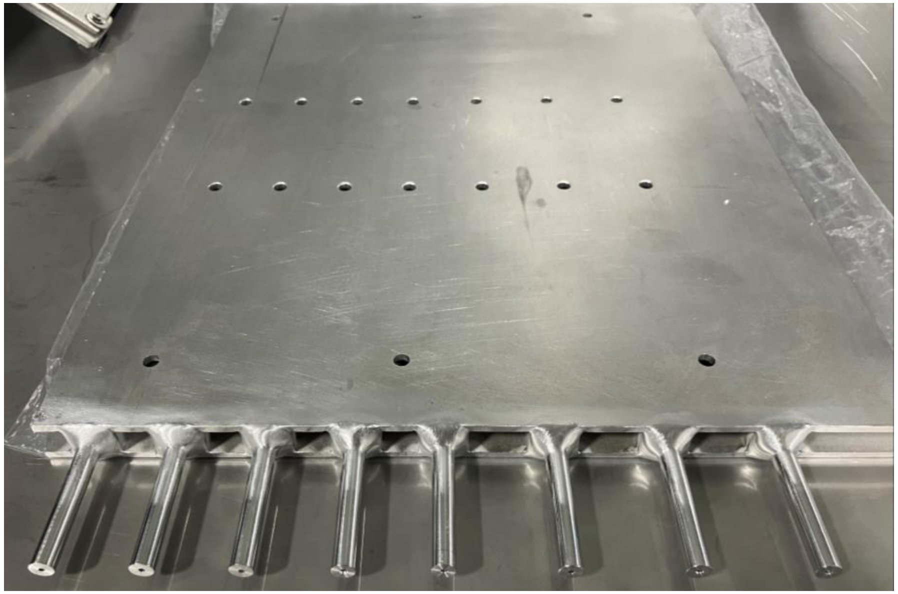


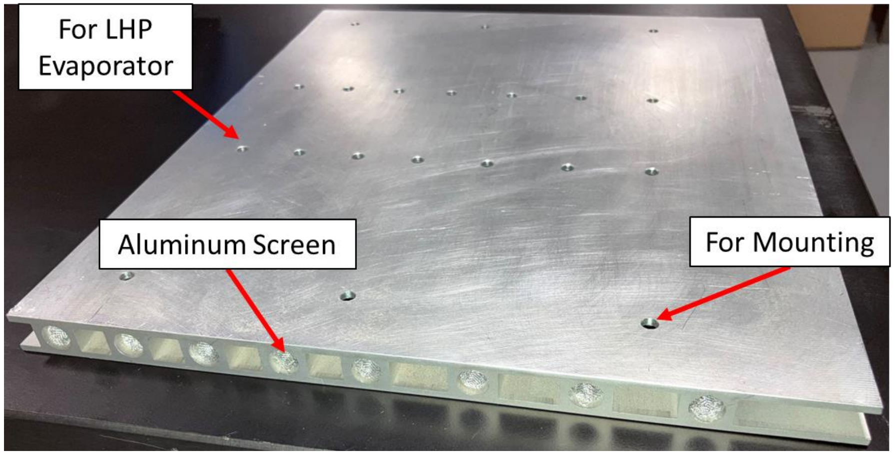
Reduced ID



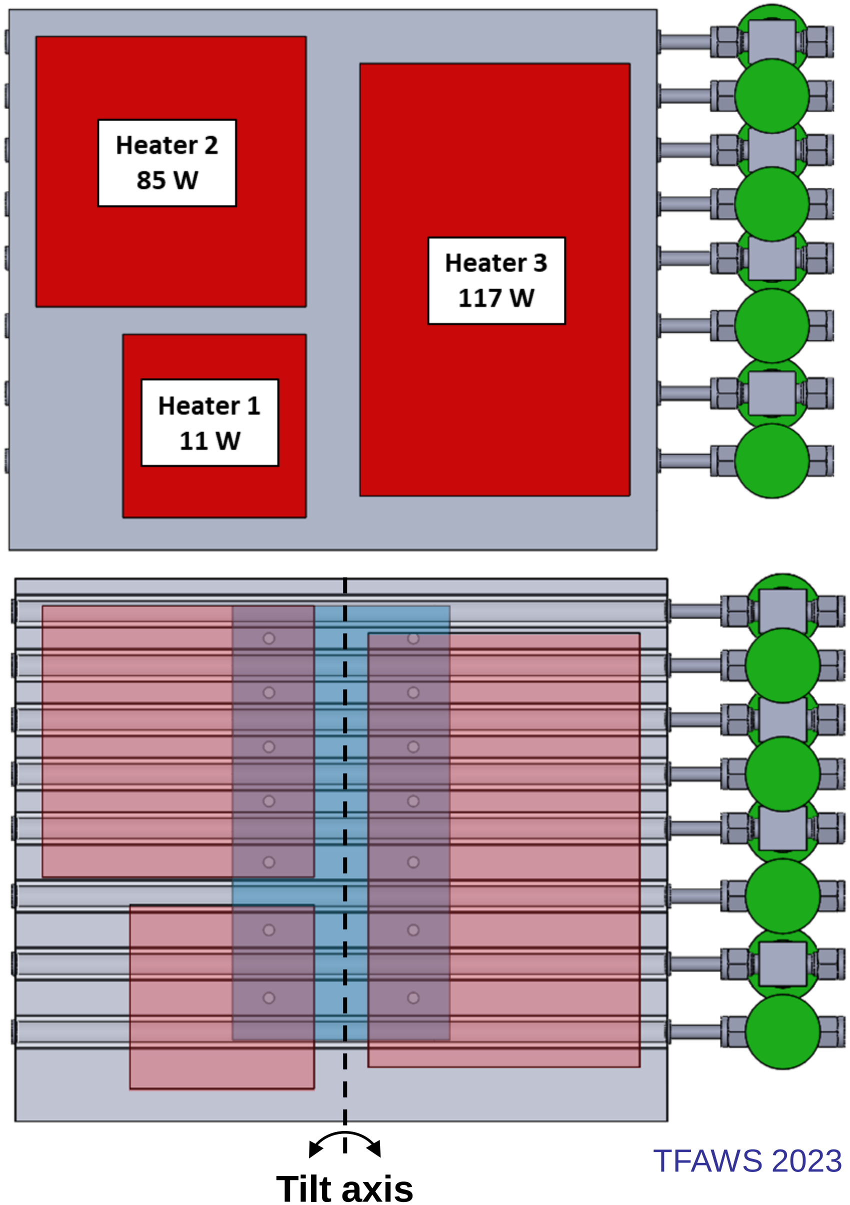
Heat Collector Fabrication

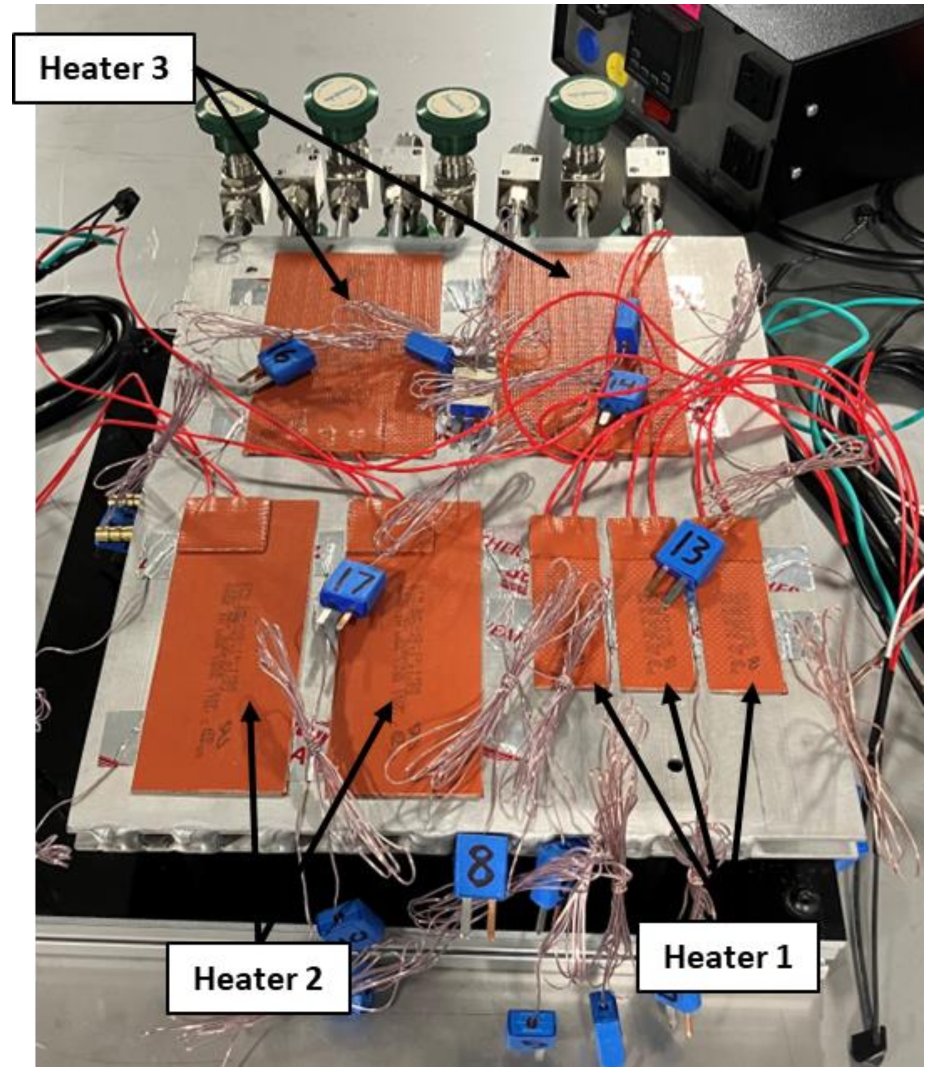




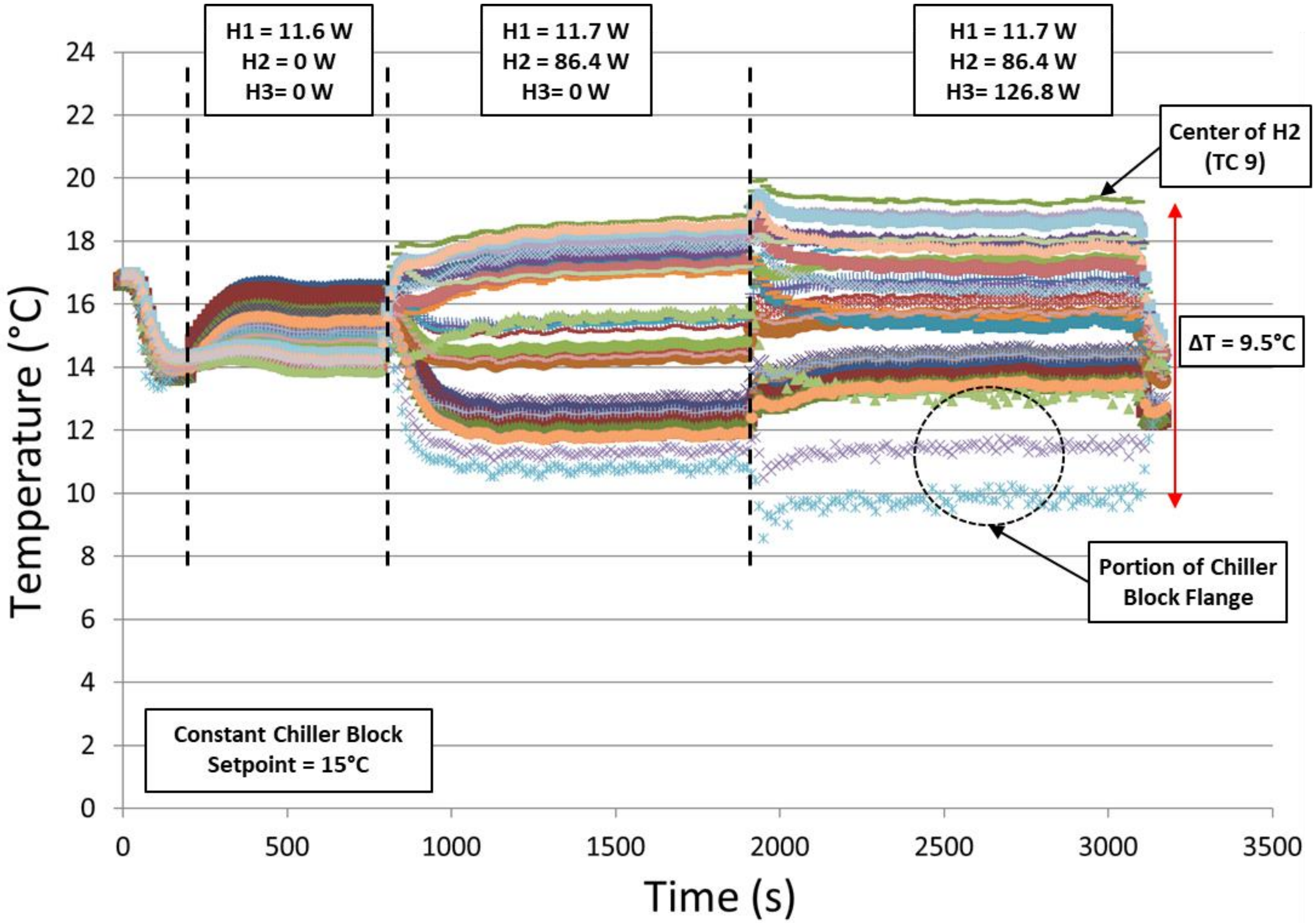


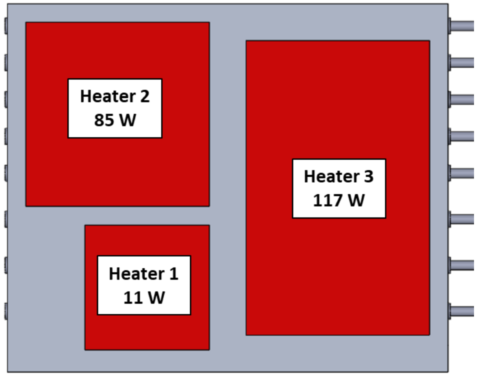
Heat Collector Final Prototype





Horizontal Orientation

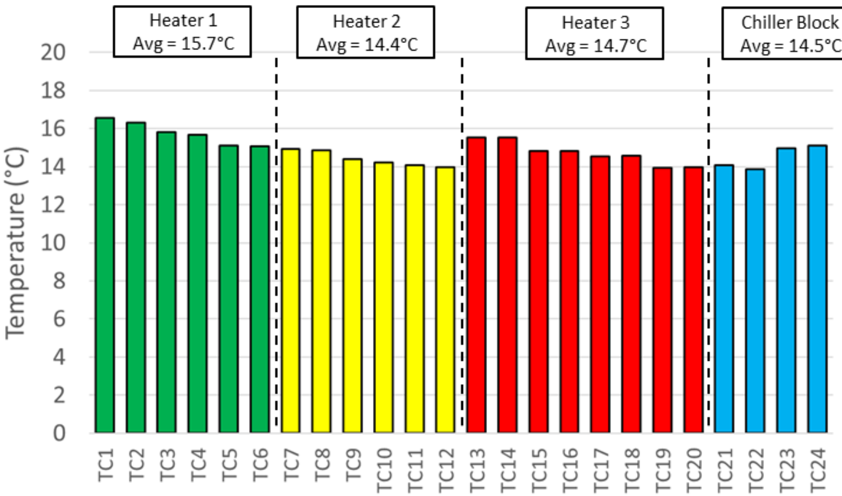




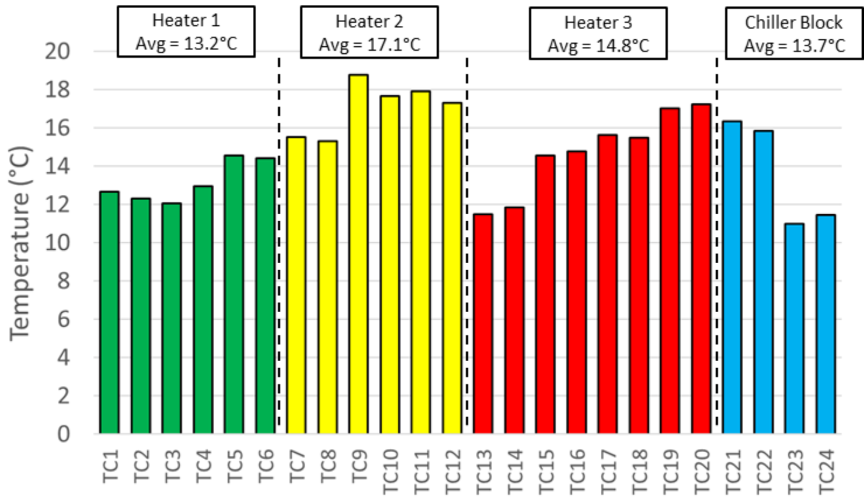
- 225W only 9.5C ΔT between hottest measured point on heated surface and coldest point measured on chiller block flange

Heat Collector Performance: Horizontal

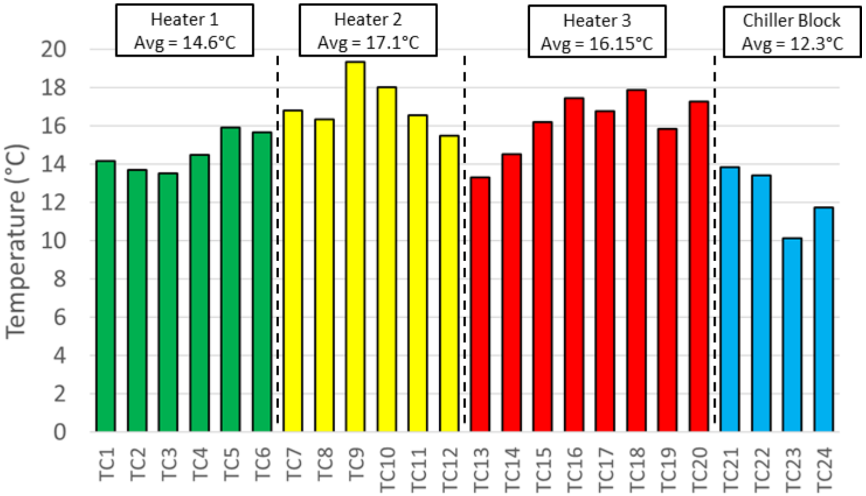
H1 On/ H2 and H3 Off

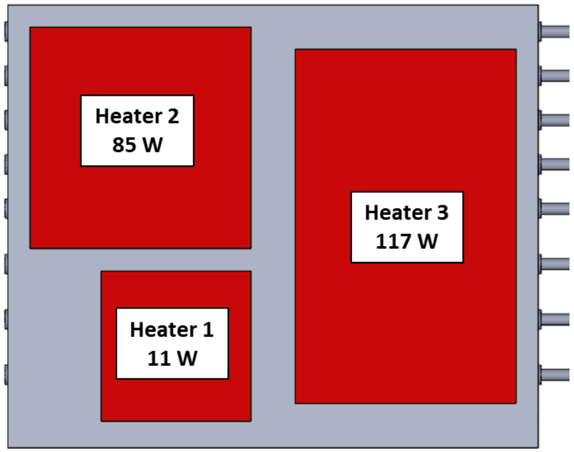


H1 and H2 On/ H3 Off



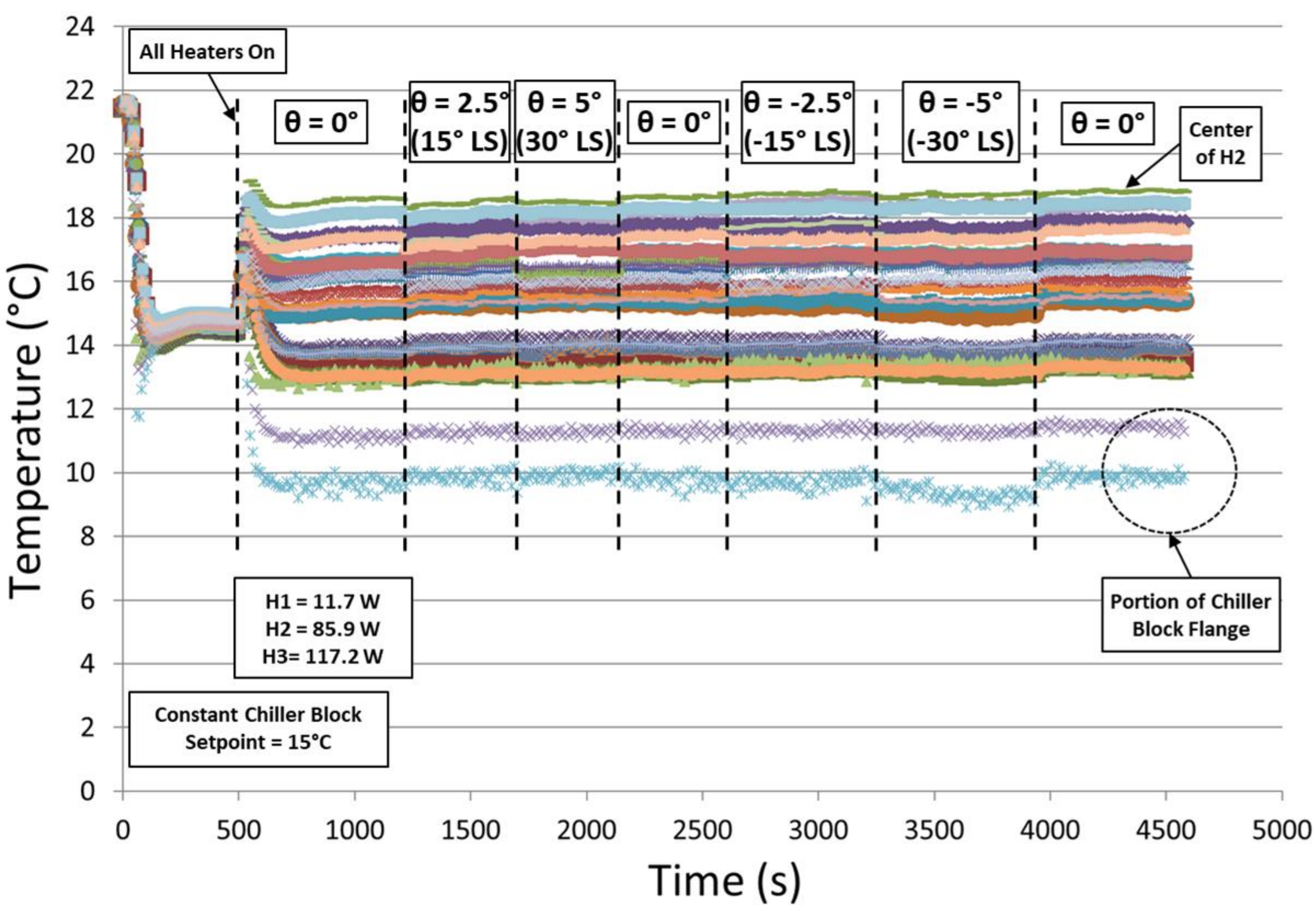
All Heaters On

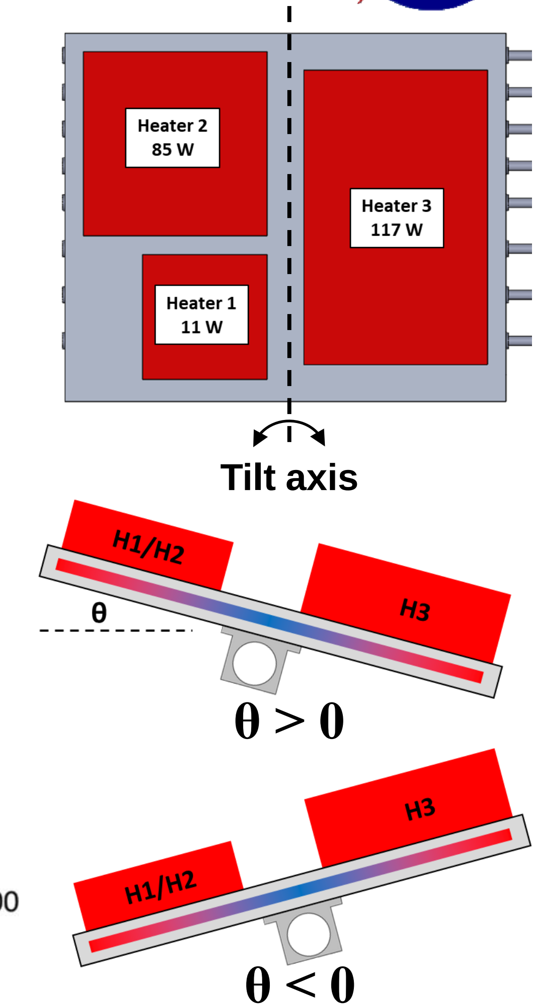




- Max ΔT on heated surface of only 6C at 225W

Heat Collector Performance: Tilted

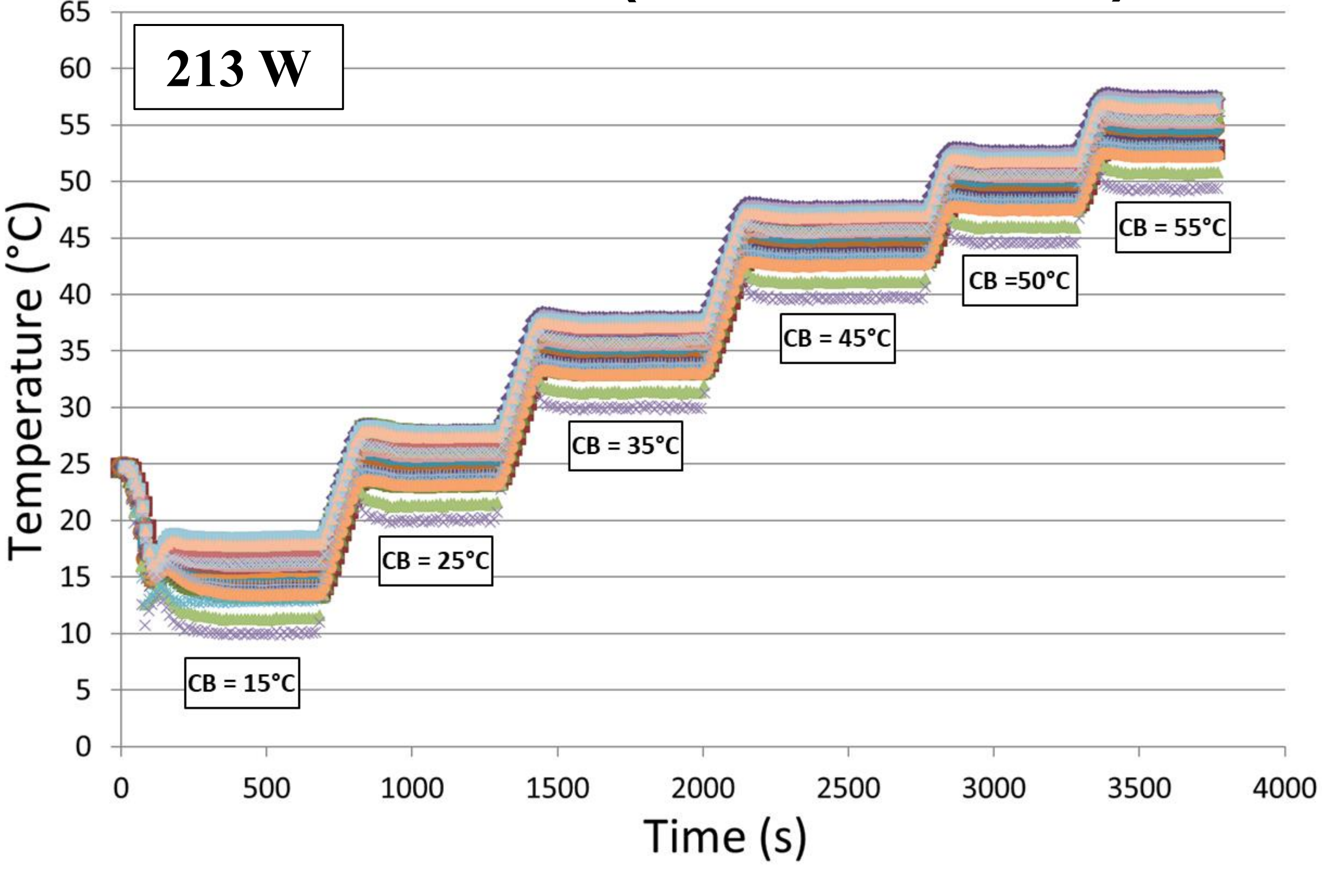


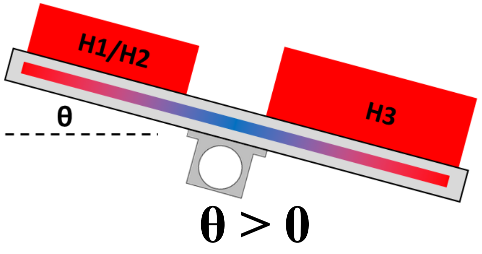


- Negligible effect of tilting up to ±5°
  - ±30° on the lunar surface

Heat Collector Performance: Tilted/High Temp

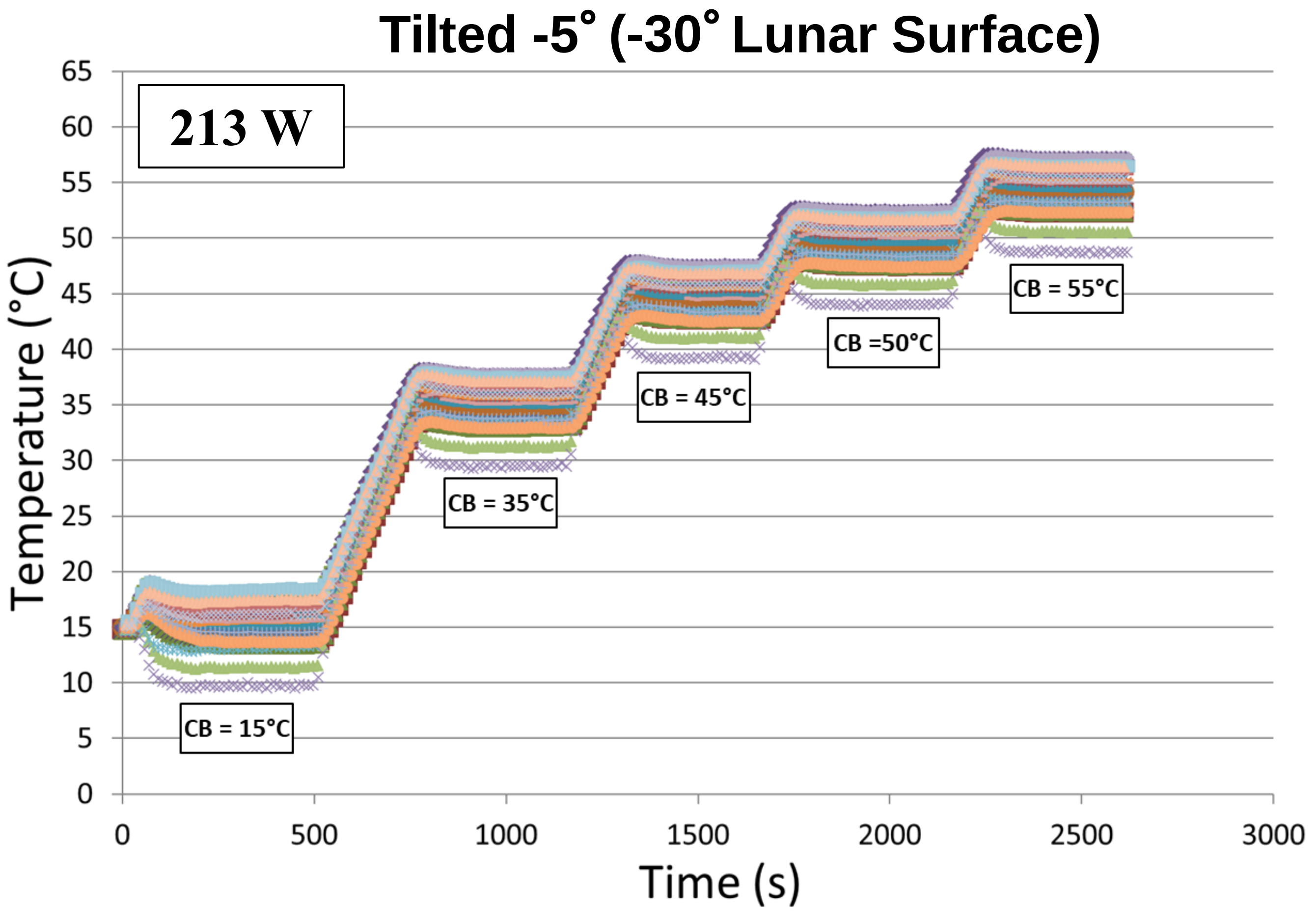
Tilted +5˚ (+30˚ Lunar Surface)

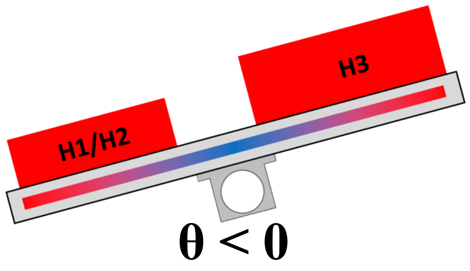




- Heat collector continues to operate at high temperature and maximum tilt of +5˚
  - Heat transfer limit for each pipe decreases at elevated temperature

Heat Collector Performance: Tilted/High Temp





- Heat collector continues to operate at high temperature and minimum tilt of -5˚
  - Heat transfer limit for each pipe decreases at elevated temperature

Conclusions

- A screen or sintered powder wick heat pipe is required if operation against gravity on the lunar surface is expected
- Aluminum-ammonia heat pipes are ideal for the typical temperature range of electronics and avoids freezing complications associated with water
- ACT successfully demonstrated the operation of a aluminum-ammonia screen wick heat pipe embedded panel capable of operating against gravity
- Next steps:
  - Replace chiller block with LHP evaporator and radiator panel
  - Test in ACT’s TVAC
  - Work with Astrobotic to modify setup for lunar night survival test in Astrobotic’s TVAC
    - Electronics boxes
    - Enclosure that provides thermal isolation

Test Setup for ACT TVAC