

Demonstration of Copper-Water Heat Pipes and HiK™ Plates on the International Space Station (ISS)

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Presentation Outline



- **Motivation**
- **Background**
- **ISS Flight APTx Experiment**
- **Results**
- **Conclusion**
- **Acknowledgment**



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- Copper/water heat pipes and HiK™ plates are very commonly used for thermal management of electronics equipment on earth.
- But have not been used in spacecraft thermal control applications due to the satellite industry's requirement that any device or system be successfully tested in a microgravity environment prior to adoption.
- ACT has achieved space flight heritage for its copper/water heat pipes and High Conductivity (HiK™) plates following the successful thermal testing on board the International Space Station (ISS).



ACT's Copper-Water Heat Pipes

■ Benefits:

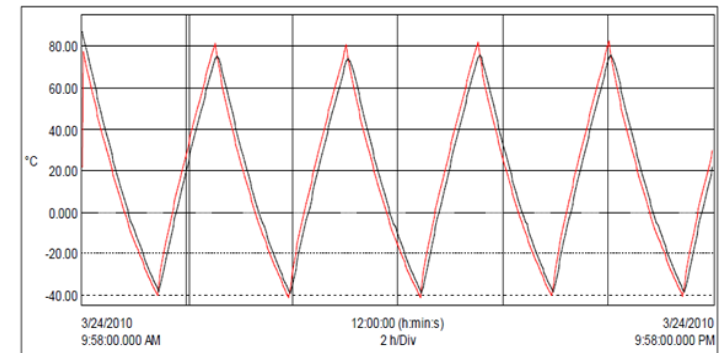
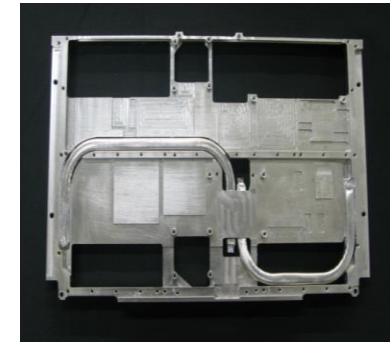
- Reliable, proven
- High performance
- Ground testable
- Easy integration
- Cost effective

■ ACT Capabilities

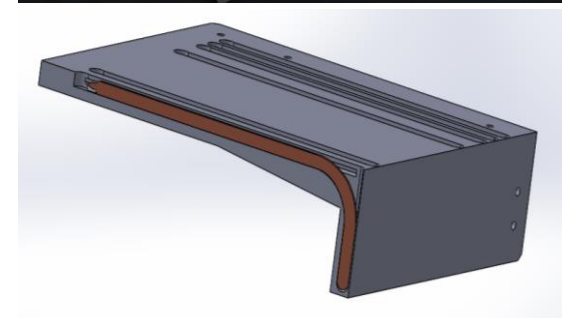
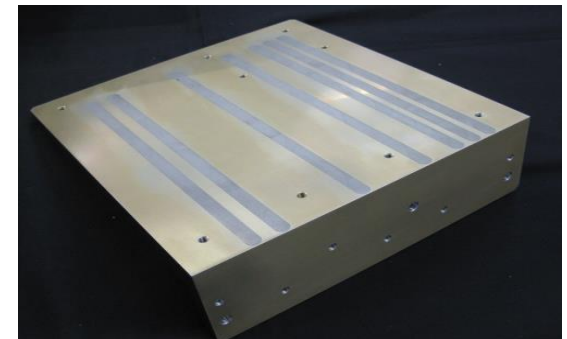
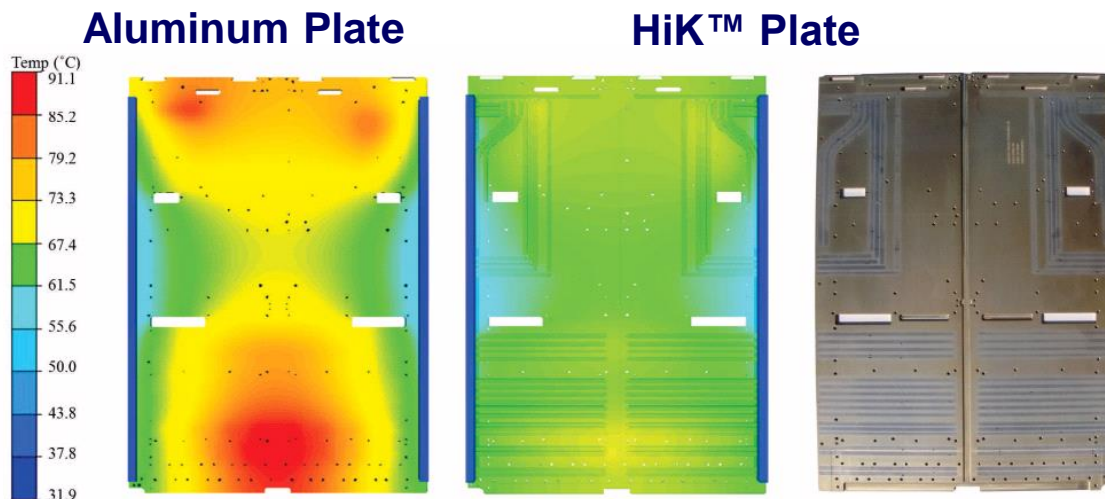
- Proven prototype & volume
- Demonstrated capacity > 250,000 per year

■ Qualification / Space Readiness

- Freeze/Thaw tolerant
- Shock/Vibe tolerant
- Flight hardware tested on the ISS



- **HiK™ plates have copper/water or copper/methanol heat pipes**
 - Flatten, solder in machined slots
 - Can withstand thousands of freeze/thaw cycles
 - Operate up to 12 inches against gravity (if water is used)
- **Effective thermal conductivity of 500 – 1200 W/m K for terrestrial applications, up to 2500 W/m K for spacecraft**
- **Identical dimensions, 22° C reduction in peak temperature measured**

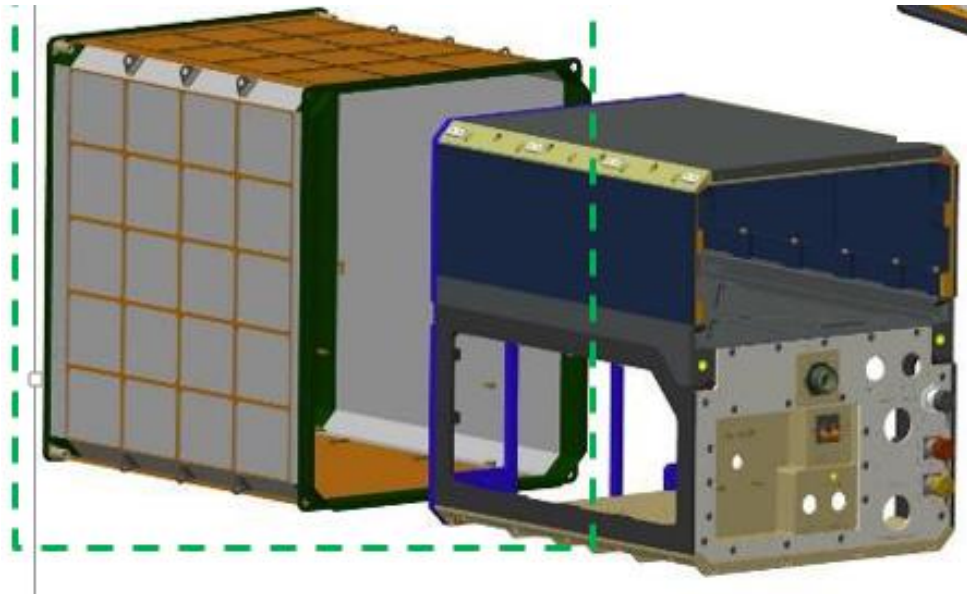


- NASA Marshall and NASA Johnson worked on an ISS flight experiment with components supplied by ACT.
- Experimental configuration – 2 experiments
 - Payload #1: VCHP with HiK™ plate – designed so that heat is delivered to the VCHP, whether or not the HiK™ plate works.
 - Payload #2: Separate HiK™ plate
- Envelope/Working Fluid Selection
 - Monel-Copper/water for VCHP
 - HiK™ plates with embedded copper/water heat pipes

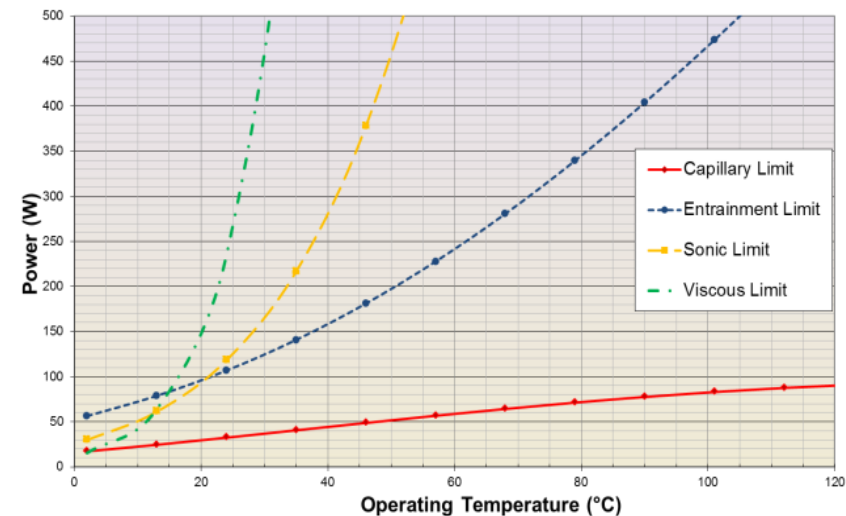
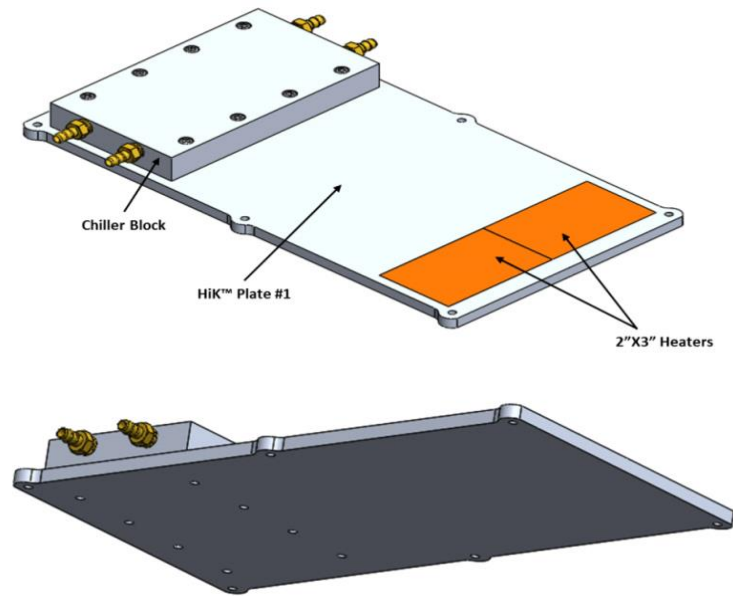


The International Space Station - (Photo: NASA)

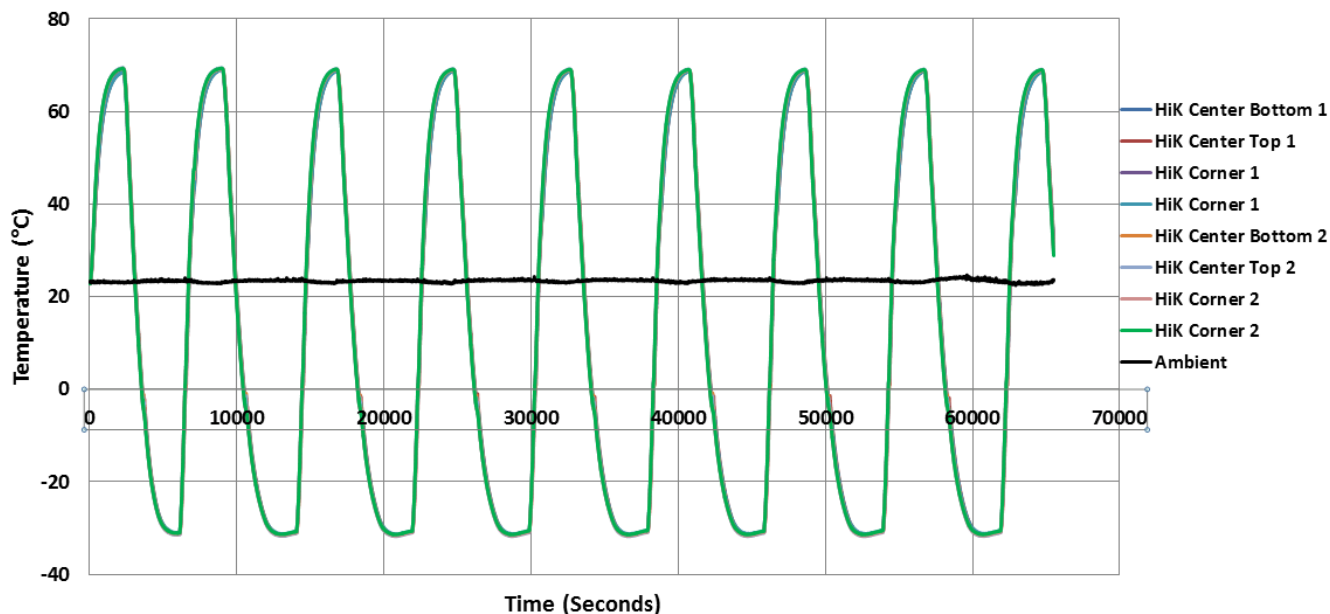
- The ISS test rack has a lower and an upper section.
 - The lower section has the a PCHX fluid loop from a previous PCM module test.
 - PCHX loop currently on the ISS, with duplicate loop on ground
 - The dimensions of the upper section, where our experiment would fit is 14" x 13.5" x 7.5" high



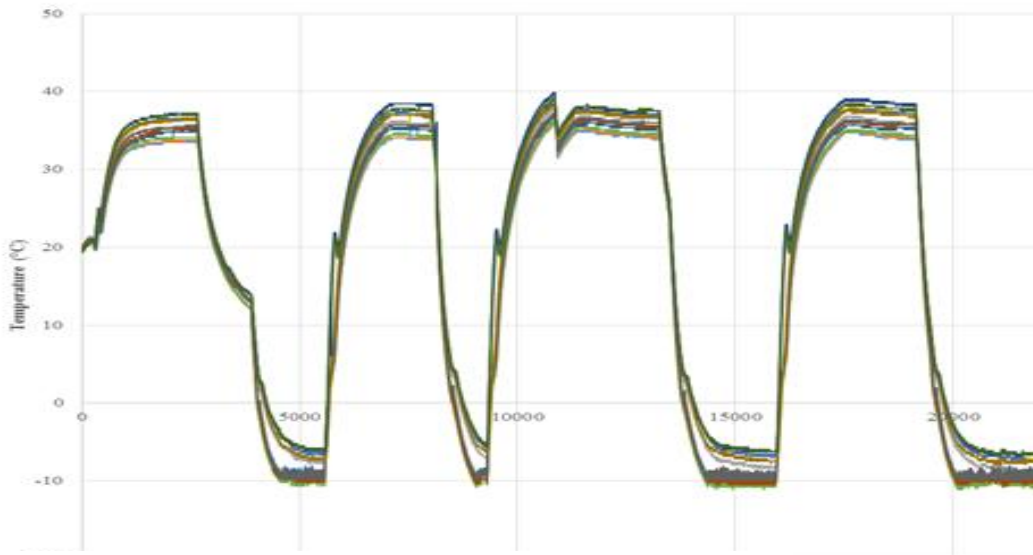
- Two 53W (2" x 3") silicon heaters will be used as a heat source on the top of the HiK™ plate.
- A chiller block was used to impose sink temperatures between -10 to 40° C
- Freeze/thaw testing was performed for the HiK™ plate on the ISS.
- Each HiK™ plate had 9 copper/water heat pipes. Each heat pipe can carry up to 65 W at 70 ° C before dryout due to the capillary limit



- Freeze thaw tests were conducted from temperature ranging from - 30 to + 70° C for two of the HiK™ plates.
- The plates were subjected to 15 freeze/thaw cycles.
- The embedded copper/water heat pipes can sustain these freeze/thaw cycles without damage.



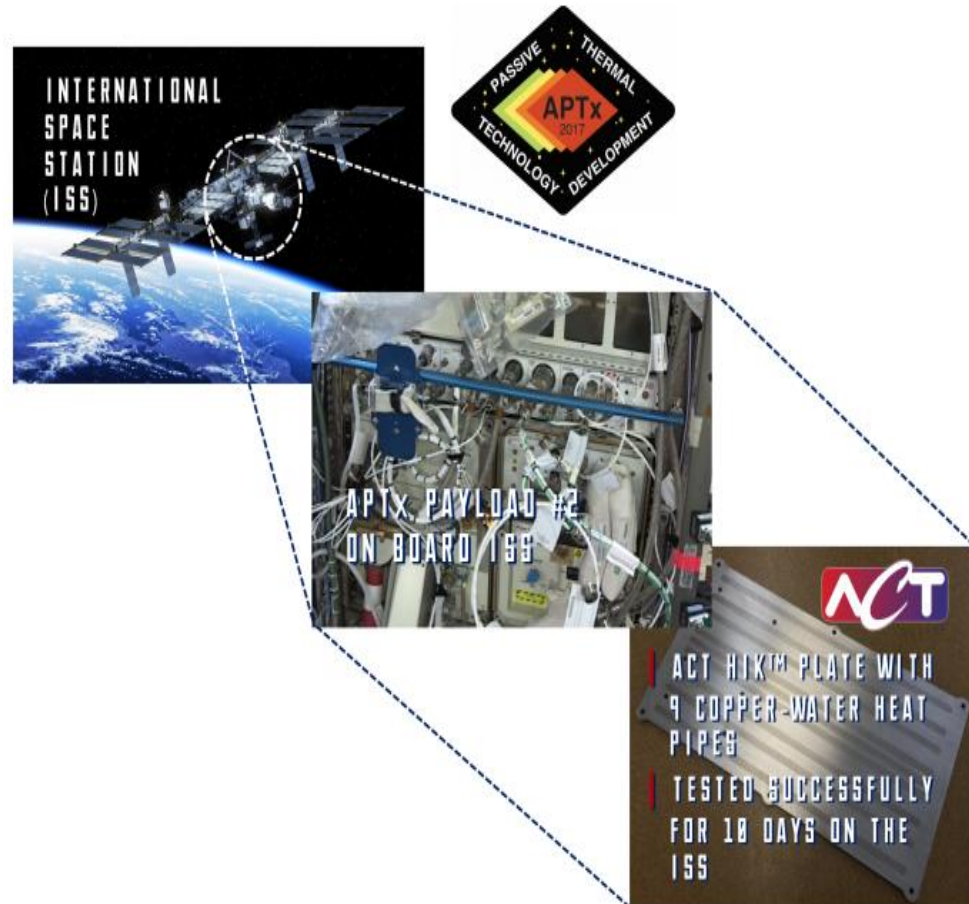
- Freeze/thaw testing was performed successfully for the HiK™ plate on orbit.
- The freeze/thaw tests were conducted for the HiK™ plate from temperature ranging from -10°C to approximately 40°C .
- Fourteen cycles of freeze-thaw and freeze-startup-thaw cycles were performed on orbit.



The assembled HiK™ plate integrated in Payload 2

■ The following was demonstrated during 10 days of testing on the ISS:

- Successful operation of the copper-water heat pipes and HiK™ plate.
- Ability of the copper-water heat pipes and HiK™ plate to survive multiple freeze/thaw cycles.
- Copper-water heat pipes can carry the required power.
- Copper-water heat pipes and HiK™ plate can start up from a frozen state.



- ACT Inc., NASA Marshall Space Flight Center and NASA Johnson Space Center, worked together to test HiK™ plates in the ISS microgravity environment.
- Two HiK™ aluminum base plates were designed, fabricated, and tested successfully in ground and on the ISS.
- The flight test verified the operation of the HiK™ plates with the embedded copper/water heat pipes in micro-gravity environment.

- In the ISS test for payload 2, the copper-water heat pipes were embedded in a HiK™ plate, and subject to a variety of thermal tests over a temperature range of -10 to 40 °C for a ten-day period.
- Results showed excellent agreement with both predictions and ground testing results.
- The HiK™ plate underwent 15 freeze-thaw cycles between -30 and 70 °C during ground testing, and an additional 14 freeze-thaw cycles during the ISS test.
- This flight test on-board ISS is an important step toward qualifying copper/water heat pipes as a passive thermal management solution in support of future human and robotic space exploration missions by NASA.



Acknowledgements



- The aerospace copper-water heat pipes and warm reservoir VCHP work was performed under the Advanced Passive Thermal eXperiment (APT_x) program which is a NASA Johnson Space Center (JSC) initiative and also funded by the ISS Technology Demonstration Office at NASA JSC.
- Mr. Angel Alvarez-Hernandez and Dr. Jeffery Farmer are the APT_x NASA's principal investigators.



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Questions?

Thank you for your attention!

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