GPM Avionics Module Heat Pipes Design and Performance Test Results

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Outline

- Background
- Avionics Module Thermal Design
- Spacecraft Thermal Avionics and Battery (STAB) Test
- Test Profile
- Results
- Conclusions

BACKGROUND

Global Precipitation Measurement

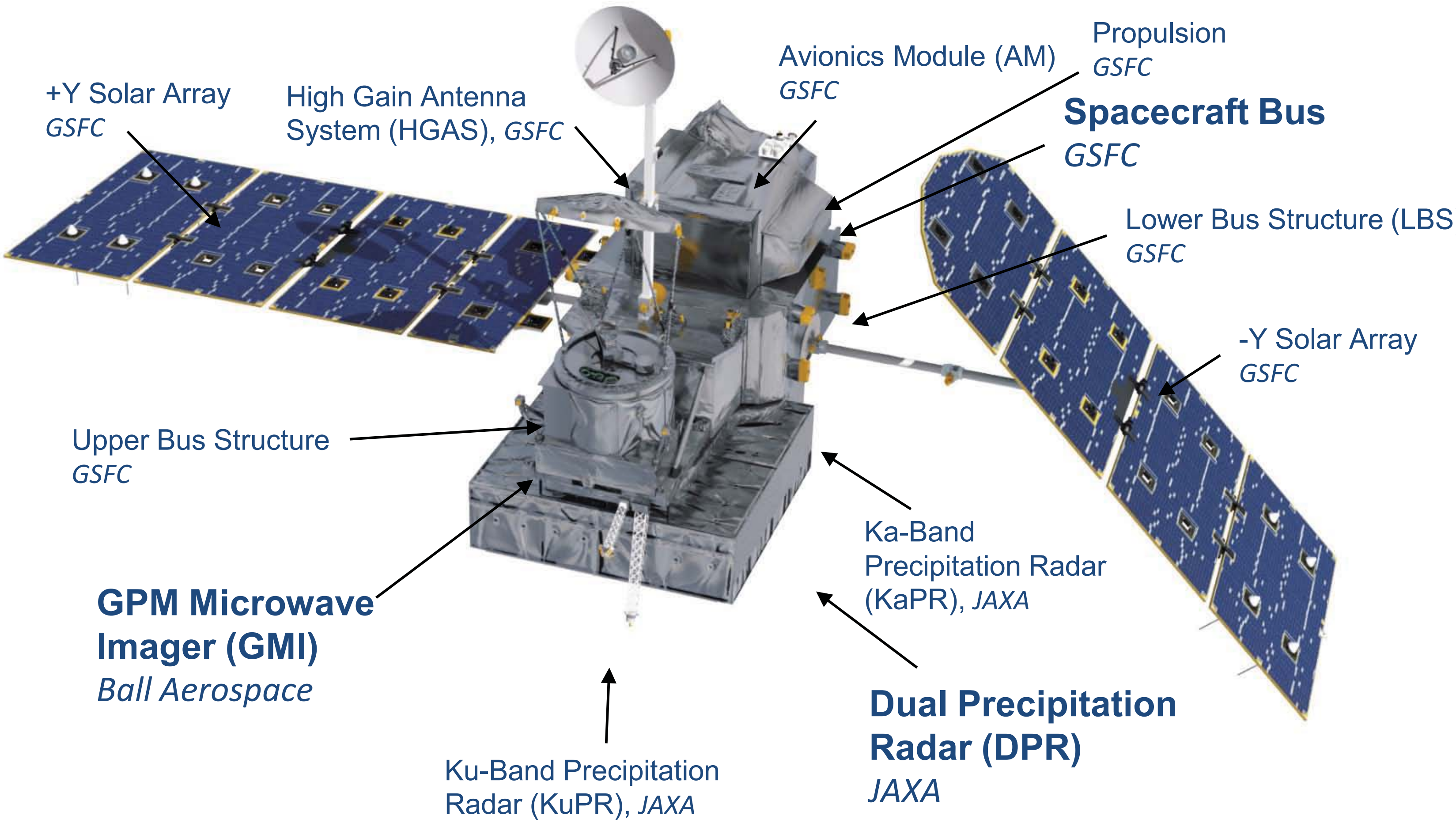
- GPM is a satellite constellation to study precipitation formed from a partnership between NASA and the Japanese Aerospace Exploration Agency (JAXA)
- The GPM Core Observatory, being developed and tested at GSFC, serves as a reference standard to unify precipitation measurements from the GPM satellite constellation
- The Core Observatory carries an advanced radar/radiometer system to measure precipitation from space

GPM Background, cont.

- The scientific data gained from GPM will benefit both NASA and JAXA by:
  - Advancing our understanding of Earth's water and energy cycle
  - Improving forecasts of extreme weather events
  - Extending our current capabilities in using accurate and timely precipitation information to benefit society

GPM Core Observatory

- The GPM Core Observatory consists of three major components:



Launch Date:
Early 2014

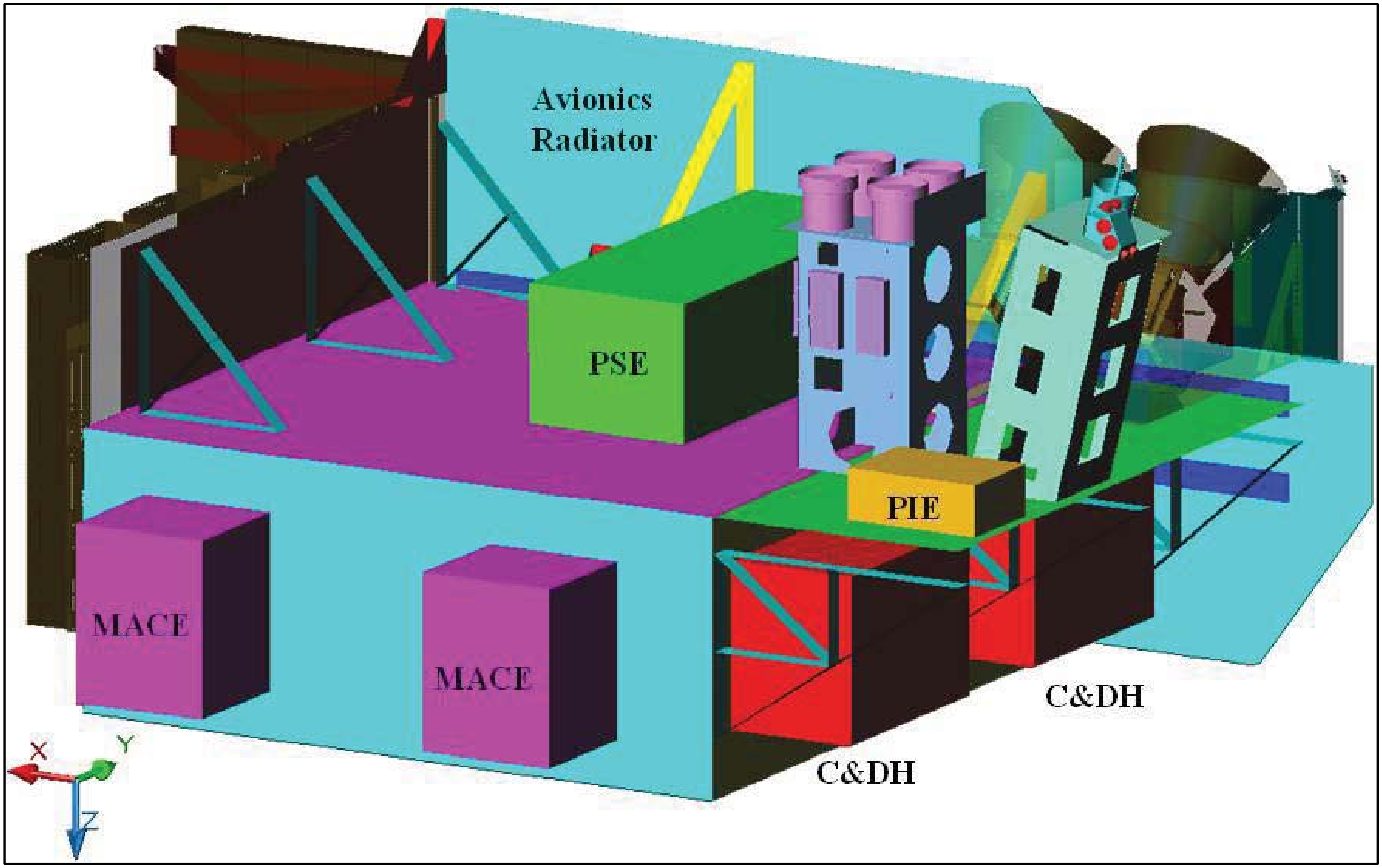
Launch Vehicle:
Mitsubishi Heavy Industries H-IIA (provided by JAXA)

AVIONICS MODULE THERMAL DESIGN

Avionics Module

Electronics Box	Number of Boxes	Thermal Control
Power System Electronics (PSE)	1	Two heat pipes transfer heat to radiator
Command and Data Handling (C & DH)	2	Two heat pipes transfer heat to radiator (shared with both boxes and with both MACE boxes)
Mechanism and Attitude Control Electronics (MACE)	2	Two heat pipes transfer heat to radiator (shared with both boxes and with both C&DH boxes)
Propulsion Interface Electronics (PIE)	1	Low heat dissipation, local thermal control (not discussed further)

GPM Avionics Module Thermal Model



Avionics Module Thermal Control

- A network of heat pipes are used for cooling the electronics boxes on the Avionics Module
- Two transport pipes cool the MACE and C&DH boxes (two boxes each, both pipes cool all four boxes)
- Two transport pipes cool the PSE
- All transport pipes connect to a honeycomb radiator which contains 13 embedded heat pipes
- The heat pipes and radiator were supplied by Advanced Cooling Technologies
  - The radiator was manufactured by MDA using heat pipes supplied by ACT
- Components were delivered to GSFC in the fall of 2010
- There are survival heaters on the condensers of the PSE heat pipes and on the radiator over the radiator spreader pipes that connect to the MACE/C&DH transport pipes

Transport Heat Pipes

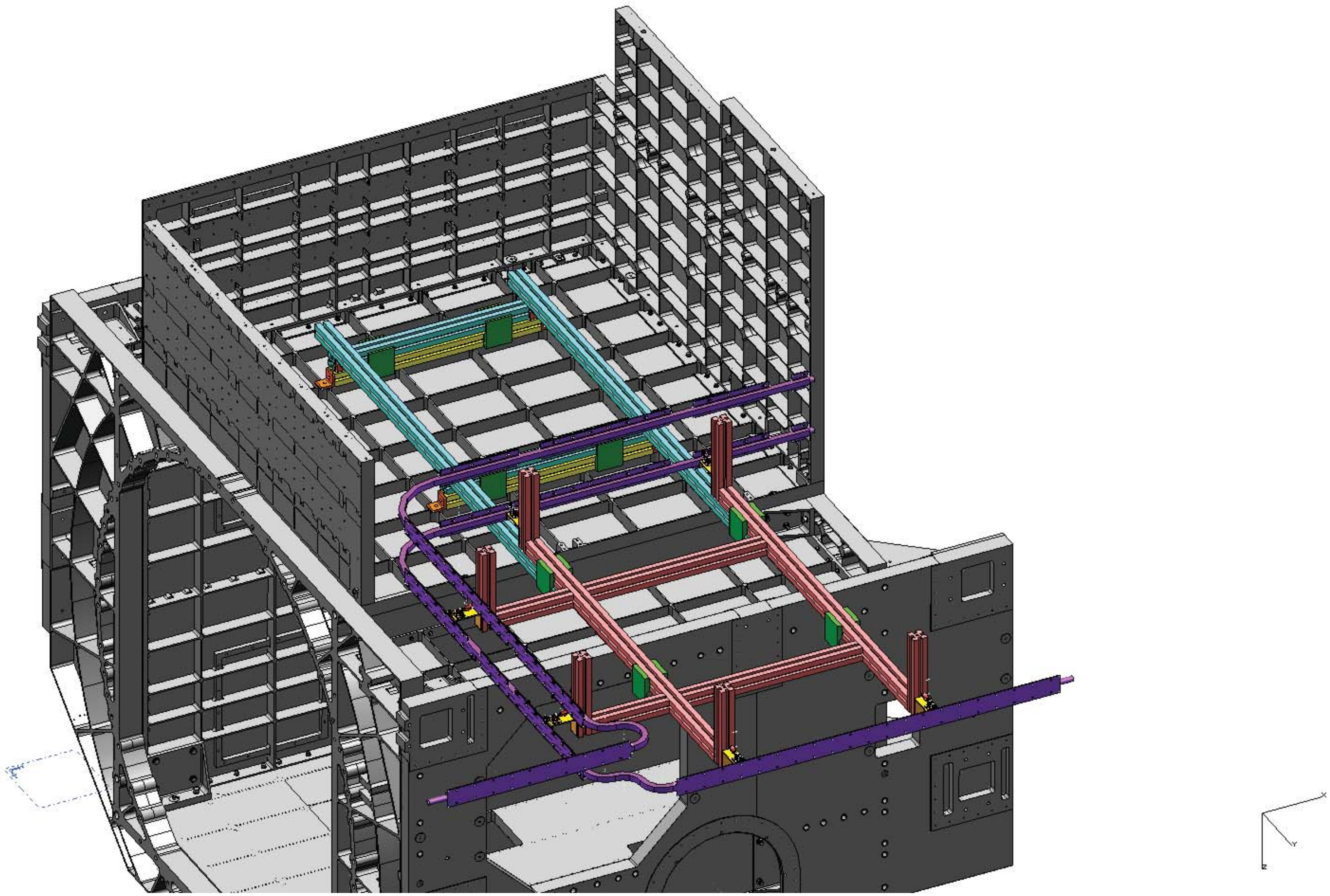
PSE pipe
(one shown)

MACE/C&DH
U-shaped
pipe

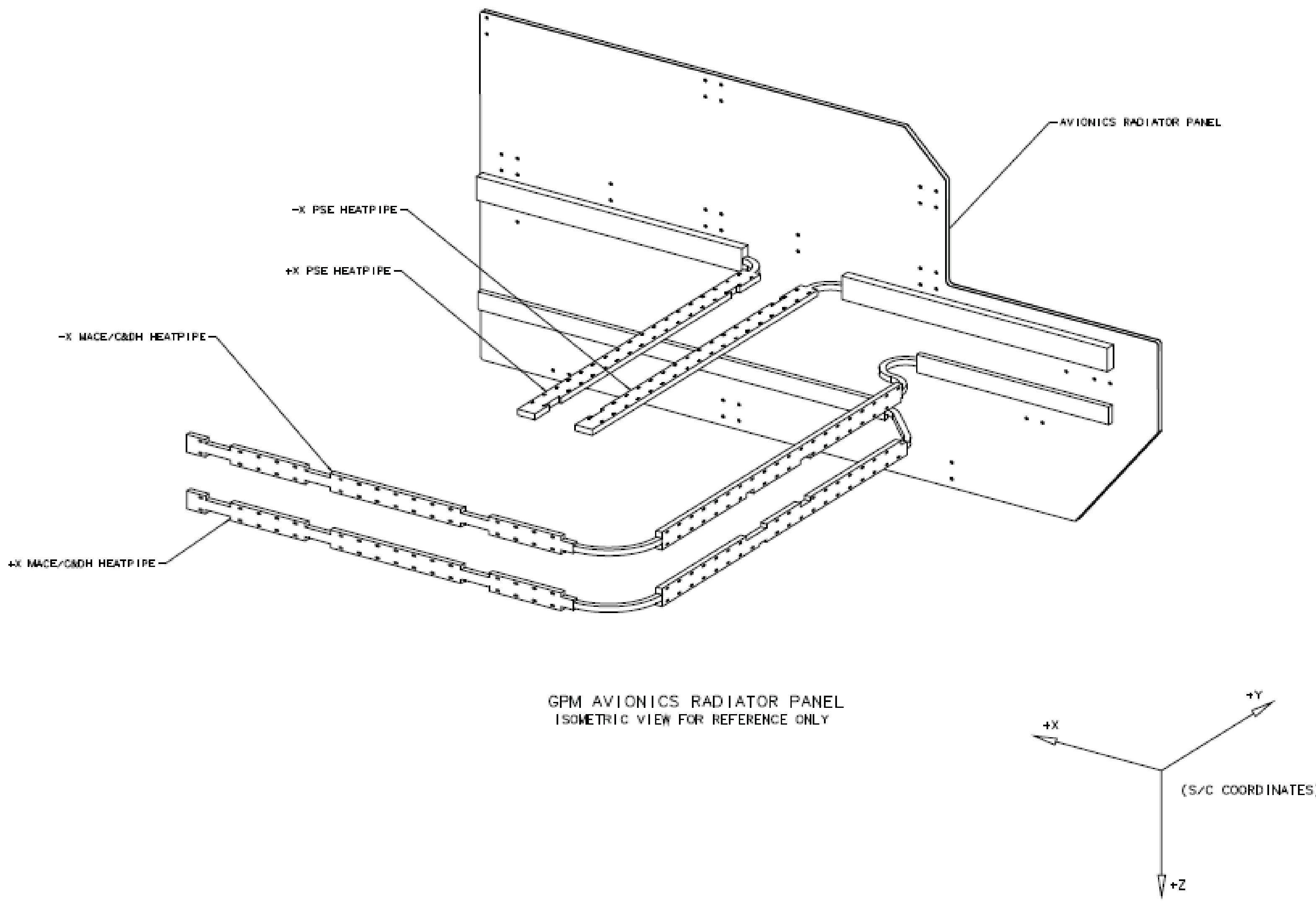
MACE/C&DH
S-shaped
pipe

Photo by ACT

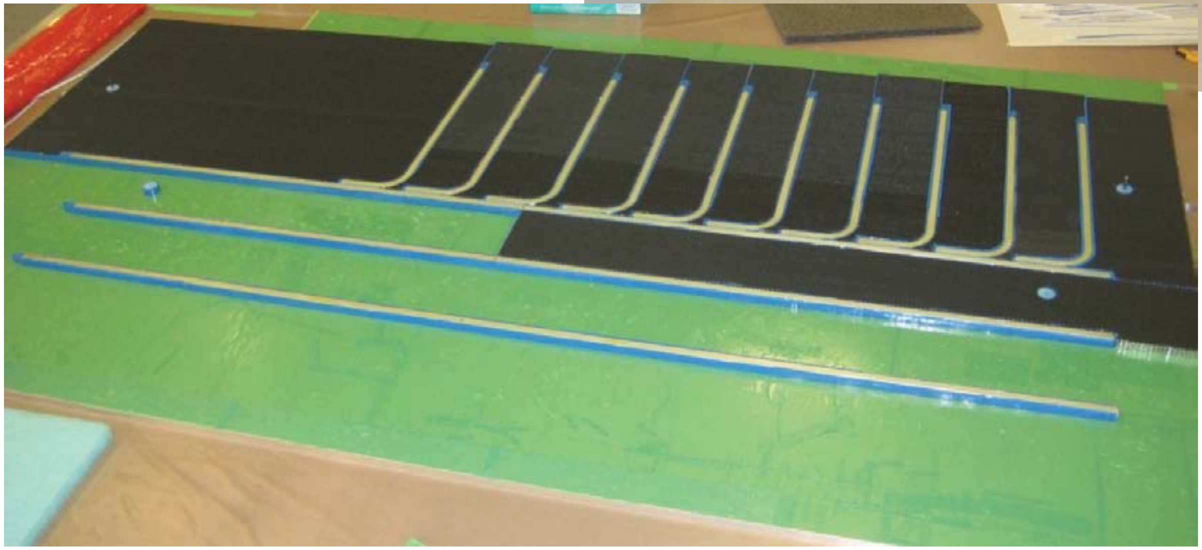
MACE/C&DH Transport Pipes on Installation Fixture



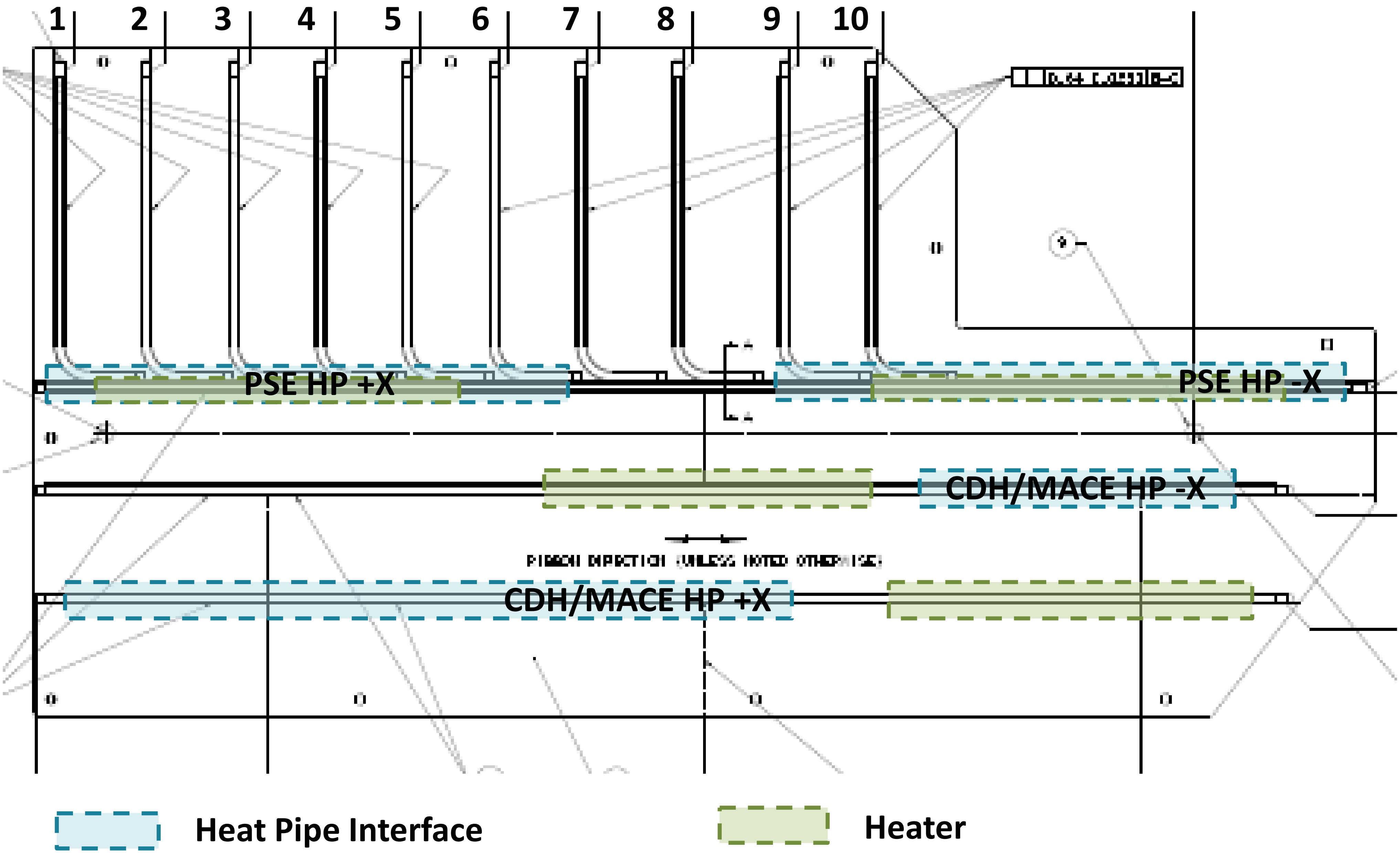
Avionics Transport Heat Pipes



Avionics Radiator Showing Embedded Heat Pipe Layout



Avionics Radiator (looking from back)



SPACECRAFT THERMAL AVIONICS AND BATTERY (STAB) TEST

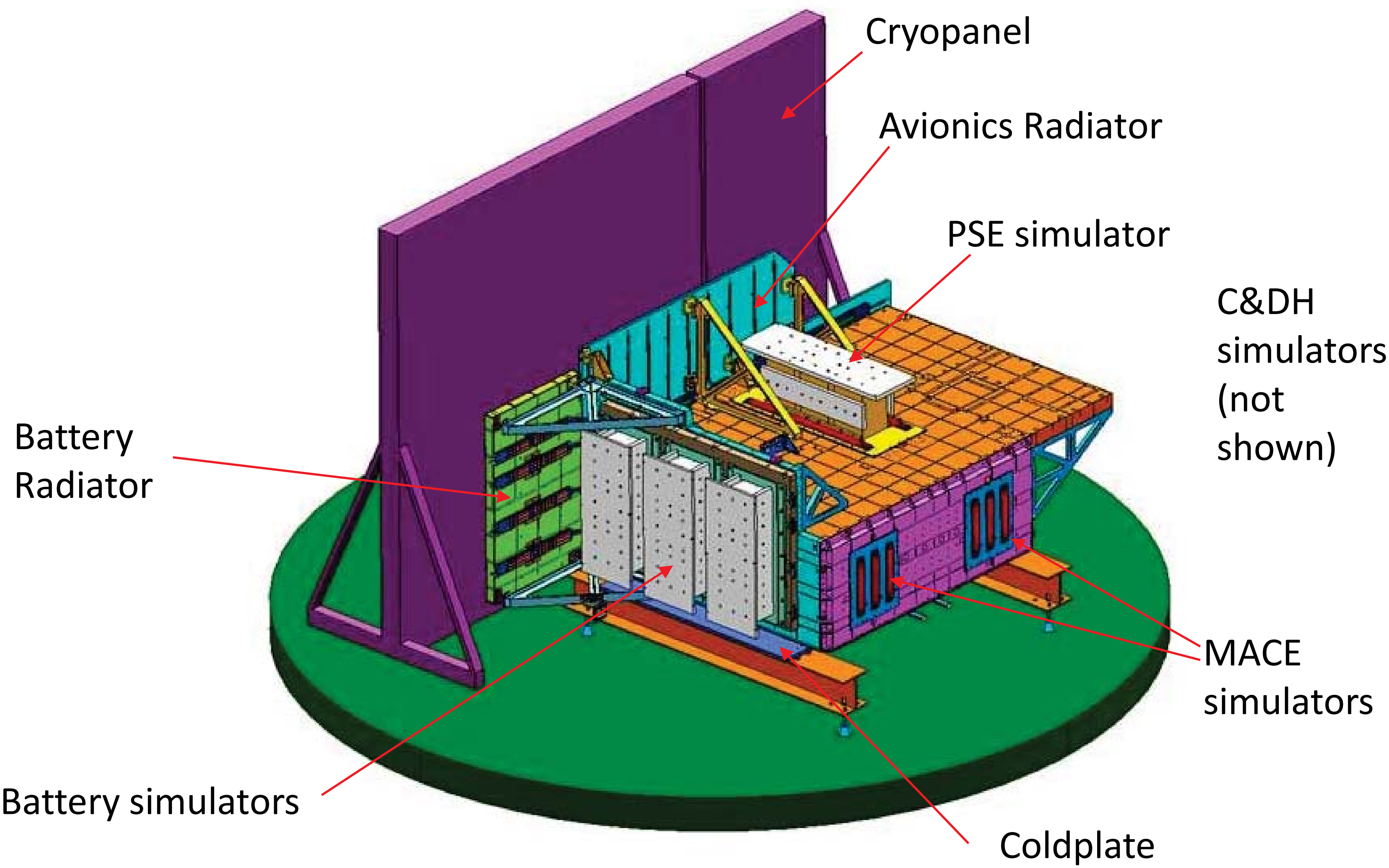
STAB Test Hardware

- Flight-like Avionics Module
- No Lower Bus Structure (LBS), simulated temperature/heat flows at the interface using a cold plate
- Baseplate simulators for MACE and C&DH Boxes with heaters to simulate power dissipation
  - Flight-like interface (NuSil)
- Mass simulators for PSE and Batteries with heaters to simulate power dissipation
  - Flight-like interface (NuSil for PSE, ChoTherm for batteries)
- Flight Avionics radiator and installation
  - Flight heaters installed
- Flight-spare Avionics heat pipes
  - Flight-like interfaces (NuSil at Avionics Module, eGraf at radiator)
- Flight Battery Thermal Control System assembly
  - Flight heat pipes
  - Flight heaters, thermostats, temperature sensors installed
  - Flight radiator with flight thermal hardware installed
- Heaters to simulate flight harness heating and any additional heating from the PIE, ST/SSIRU bracket, or GPS and OMNI towers
- Flight and Non-flight MLI
  - MLI used to close out Avionics Module and Battery assembly
  - Preliminary radiator closeout MLI, flight MLI on Avionics radiator backside
- Cryopanel simulating sink for battery and avionics radiators

STAB Test Concept

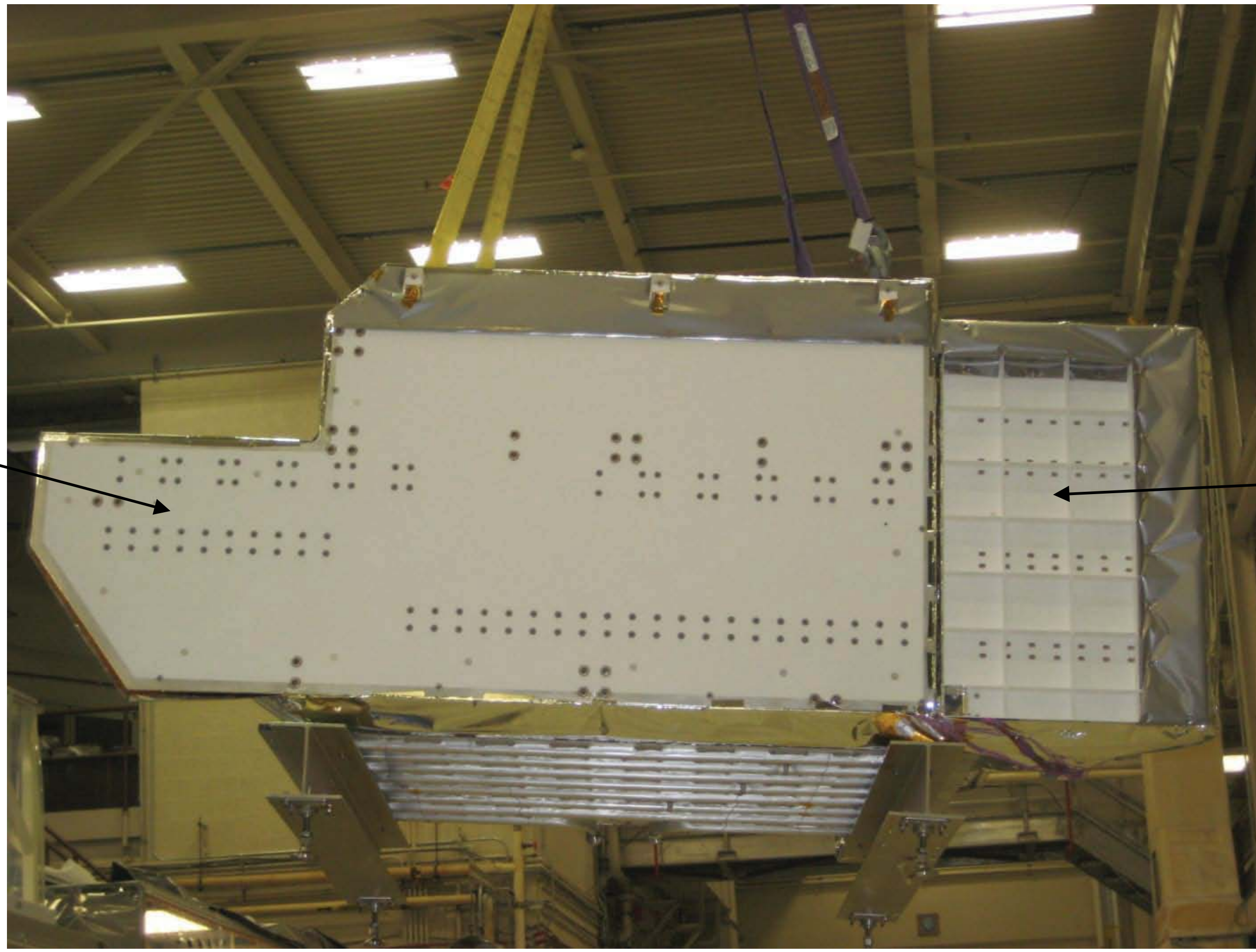
- Three thermal balance points:
  - Hot Beta 0
  - Cold Beta 0
  - Cold Beta 90 Nominal Operations
- Transient power simulation for batteries and PSE (Beta 0)
- Thermostat and survival heater check-outs

STAB TEST CONCEPT



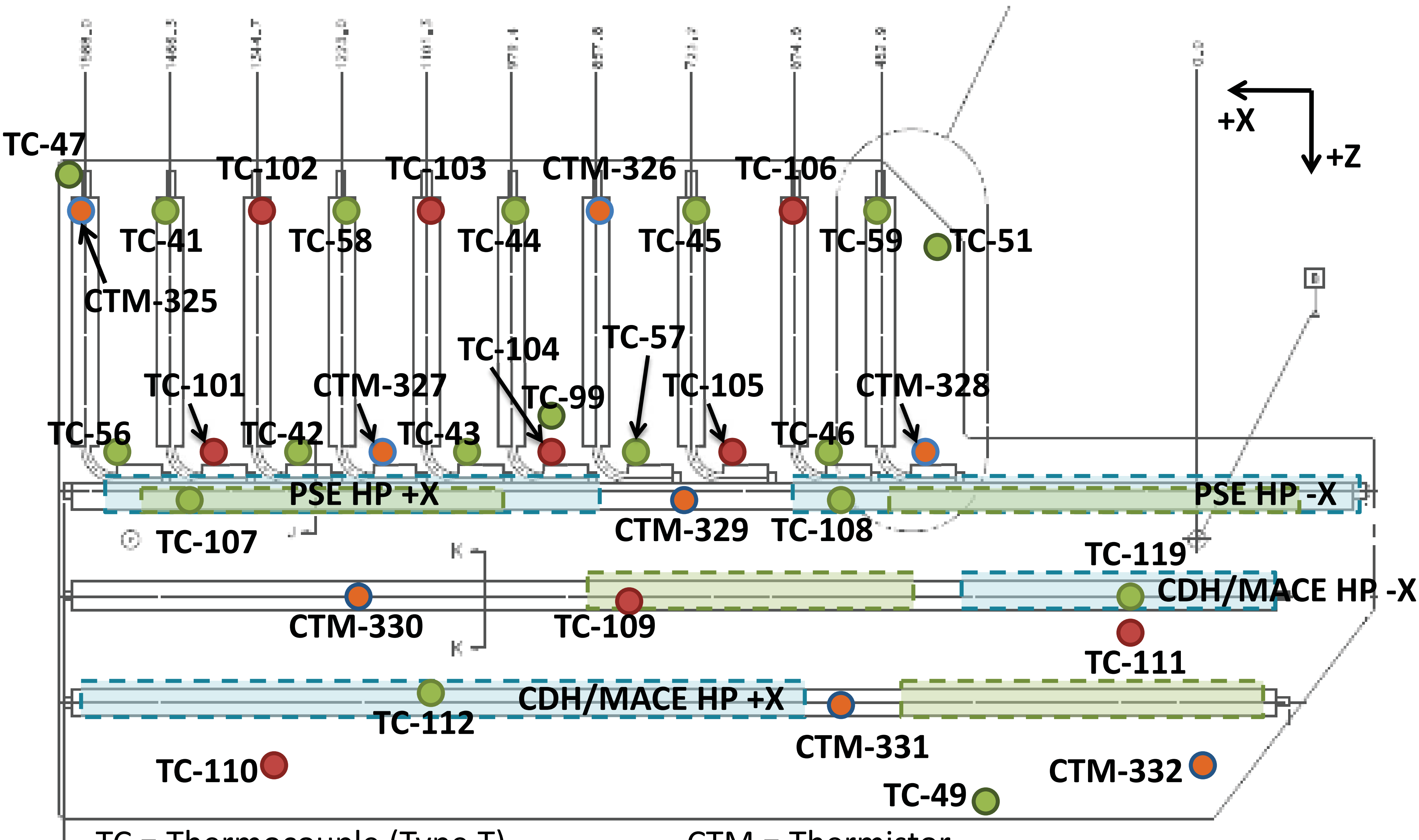
Test Assembly Being Removed from Chamber

Avionics Radiator



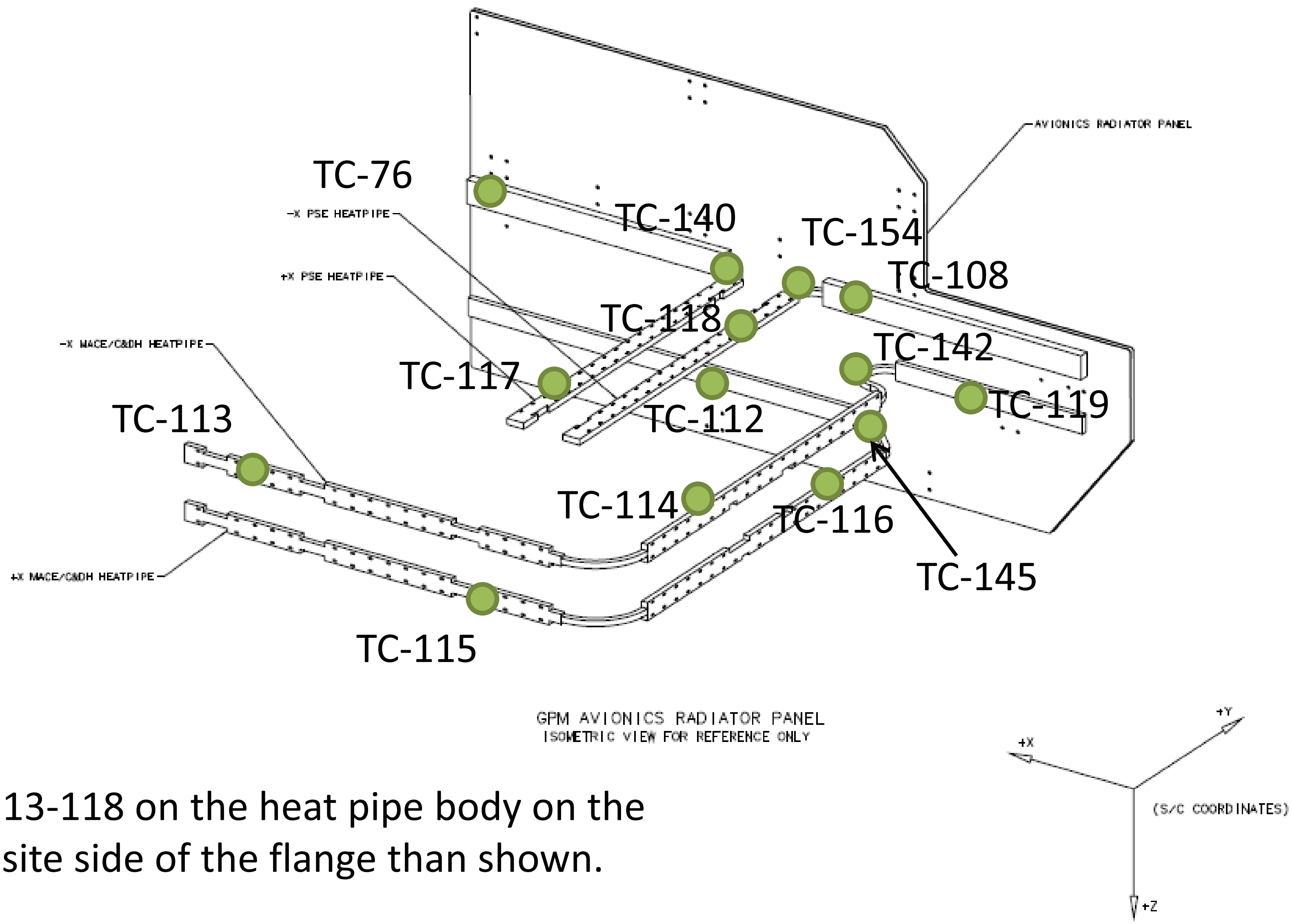
Battery Radiator

Avionics Radiator Temperature Sensors



TC = Thermocouple (Type T)   CTM = Thermistor

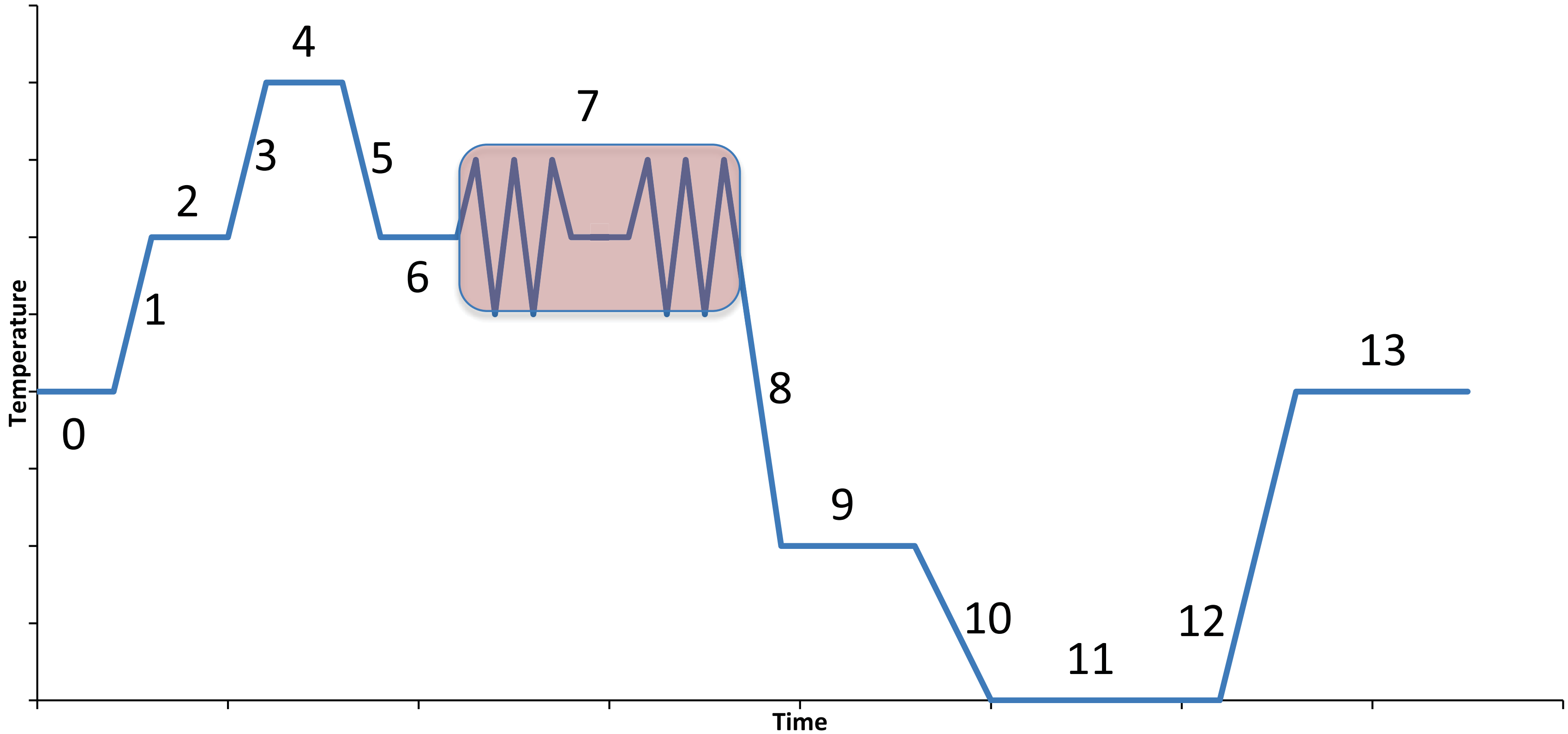
Avionics Transport Heat Pipe Thermocouples



TCs 113-118 on the heat pipe body on the opposite side of the flange than shown.

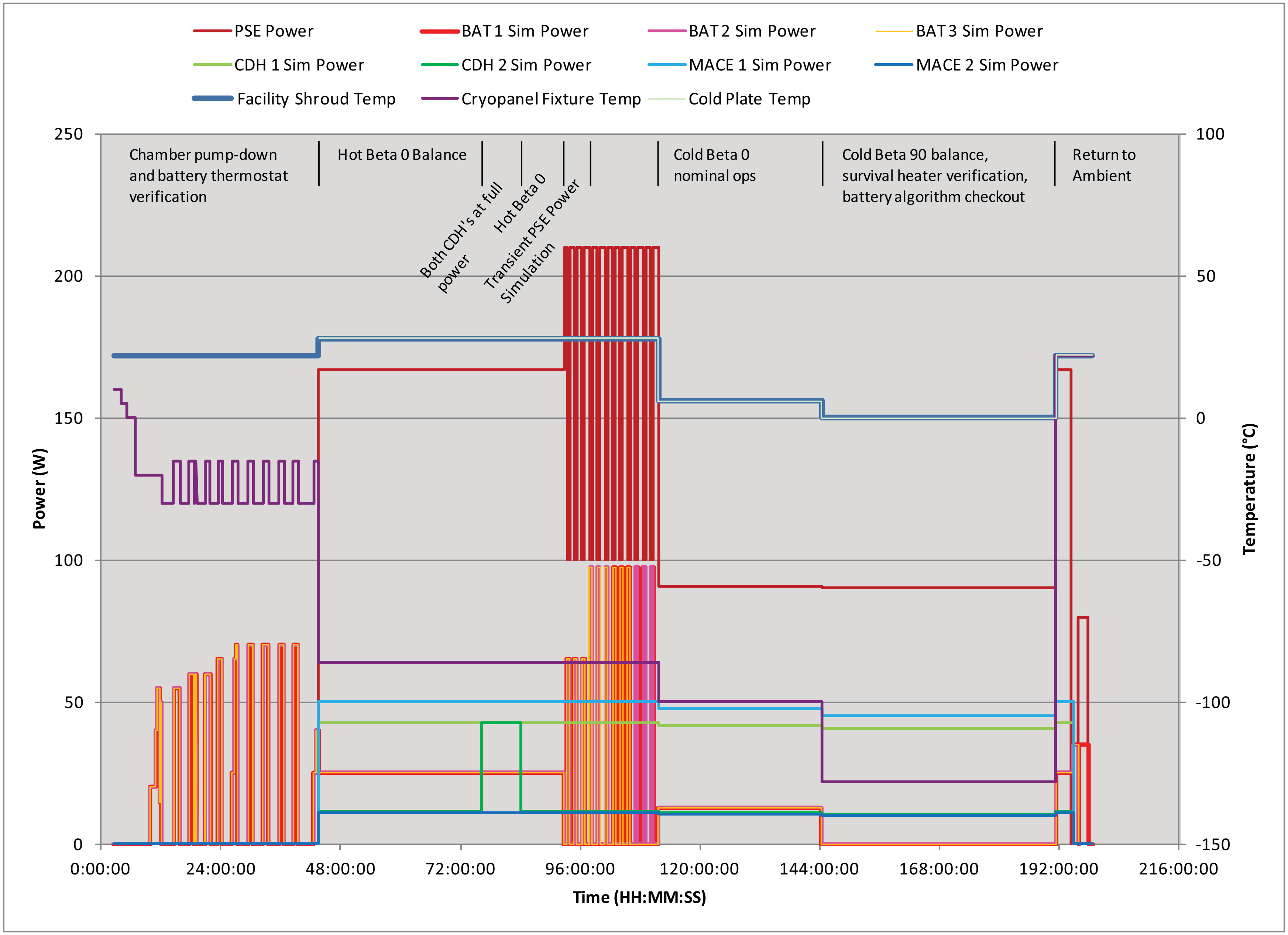
TEST PROFILE

Planned Test Profile



0. Test chamber checkout, pump down, battery thermostat verification
1. Transition to hot balance
2. Hot Beta 0 balance
3. Transition to CDH-1 & 2 to full power
4. Both CDHs to full power
5. Transition to Hot Beta 0
6. Hot Beta 0
7. Transient profile:
   a. Transient PSE power simulation
   b. Battery Failure checkout
8. Transition to cold Beta 0 nominal ops, nominal power balance
9. Cold Beta 0 nominal ops, nominal power balance
10. Transition to cold beta 90 balance
11. Cold beta 90 balance
    a. Avionics survival Heater checkout
    b. Battery Heater Control Algorithm Testing
12. Transition to ambient
13. Return to ambient

Actual Test Profile (requested)

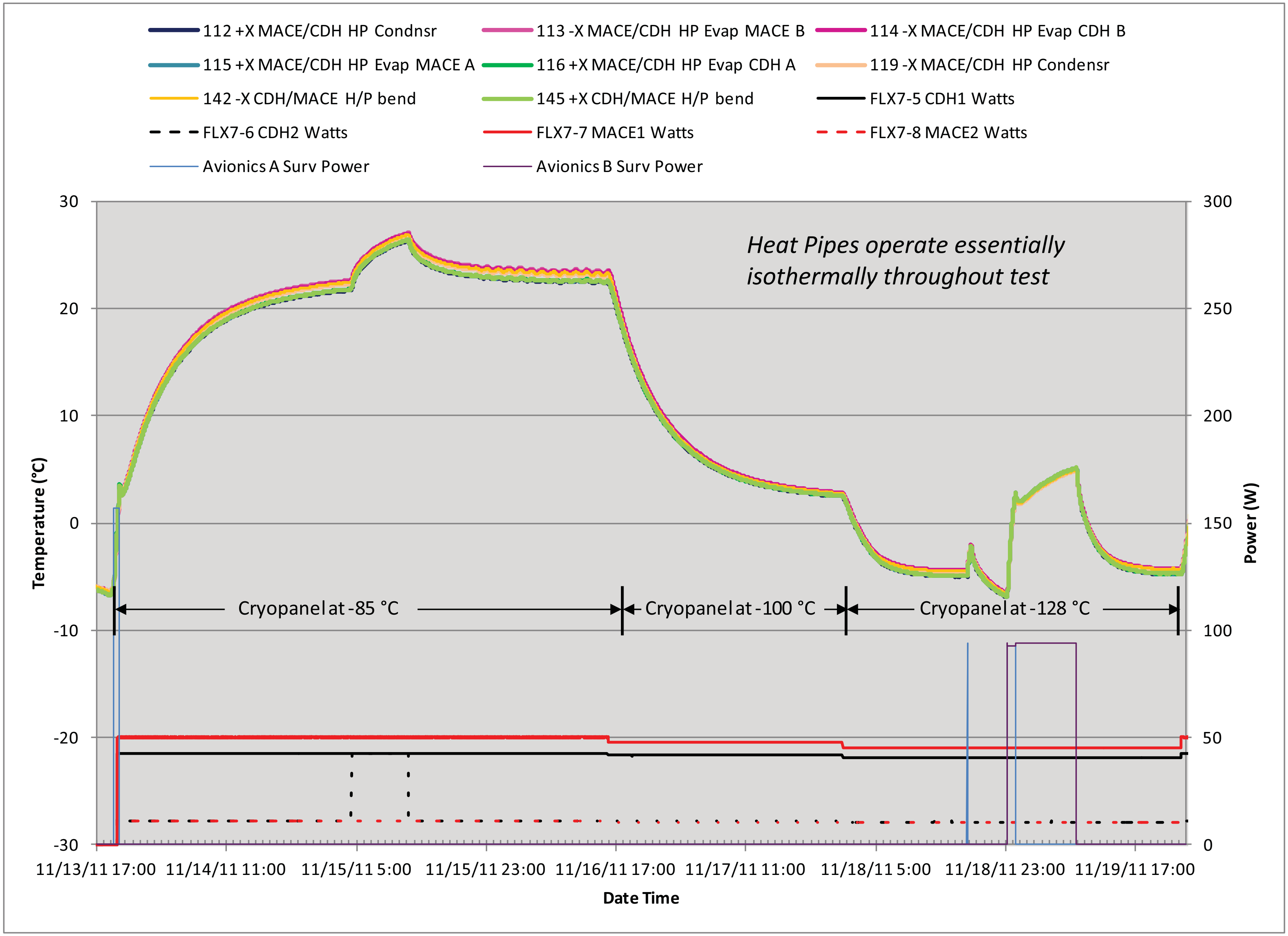


TEST RESULTS

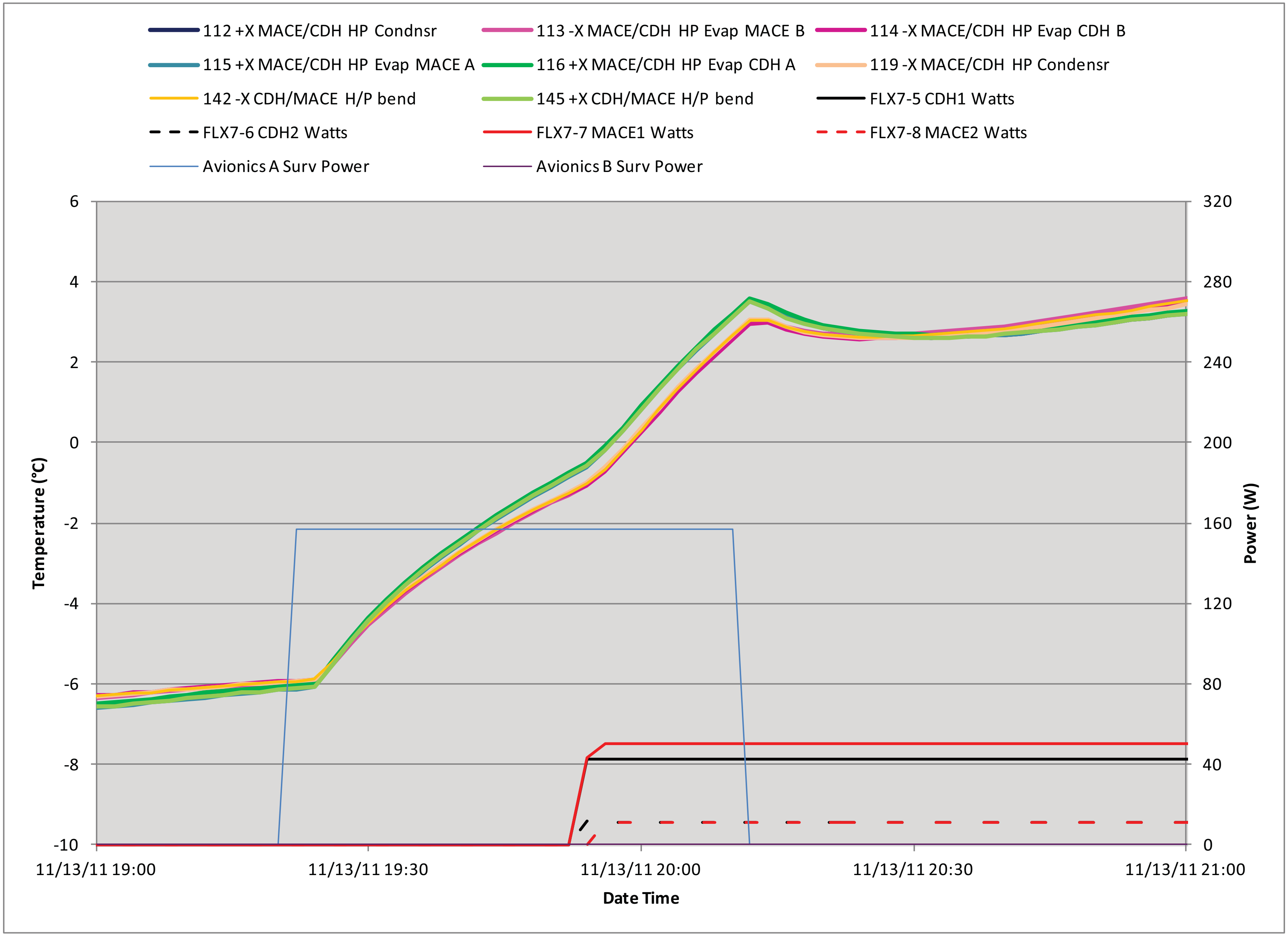
Results

- Transport pipes started as soon as power was applied and operated throughout test
  - Temperature data accuracy was not sufficient to allow calculation of conductances
- Very limited data is available for straight radiator pipes, but these appear to start immediately and operate throughout the test
- L-pipe radiator spreaders showed delayed start-up, some may not have started at all
  - This result was expected for these small heat pipes tested in reflux mode and is consistent with pre-delivery tests

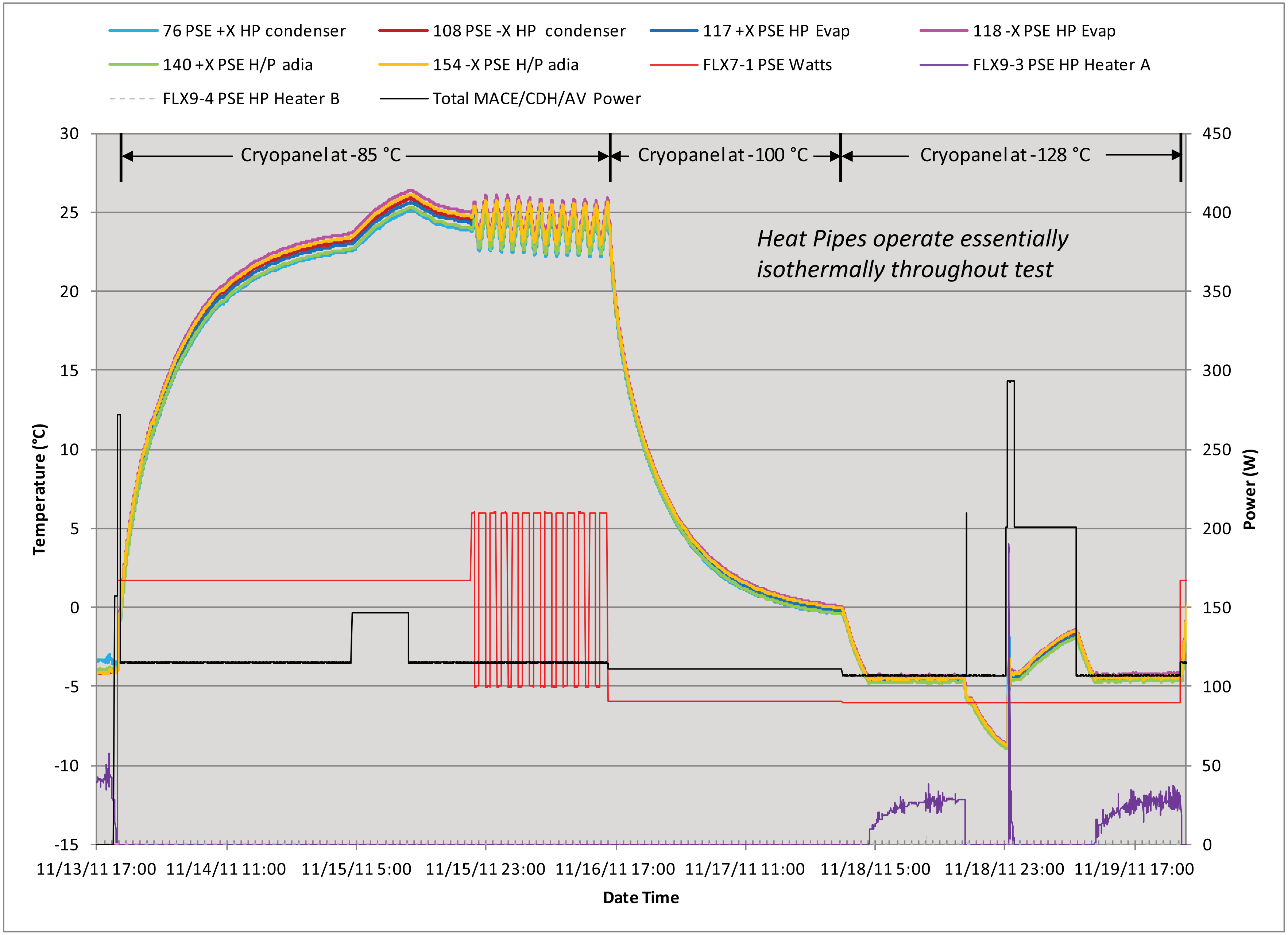
MACE/C&DH Transport Pipes



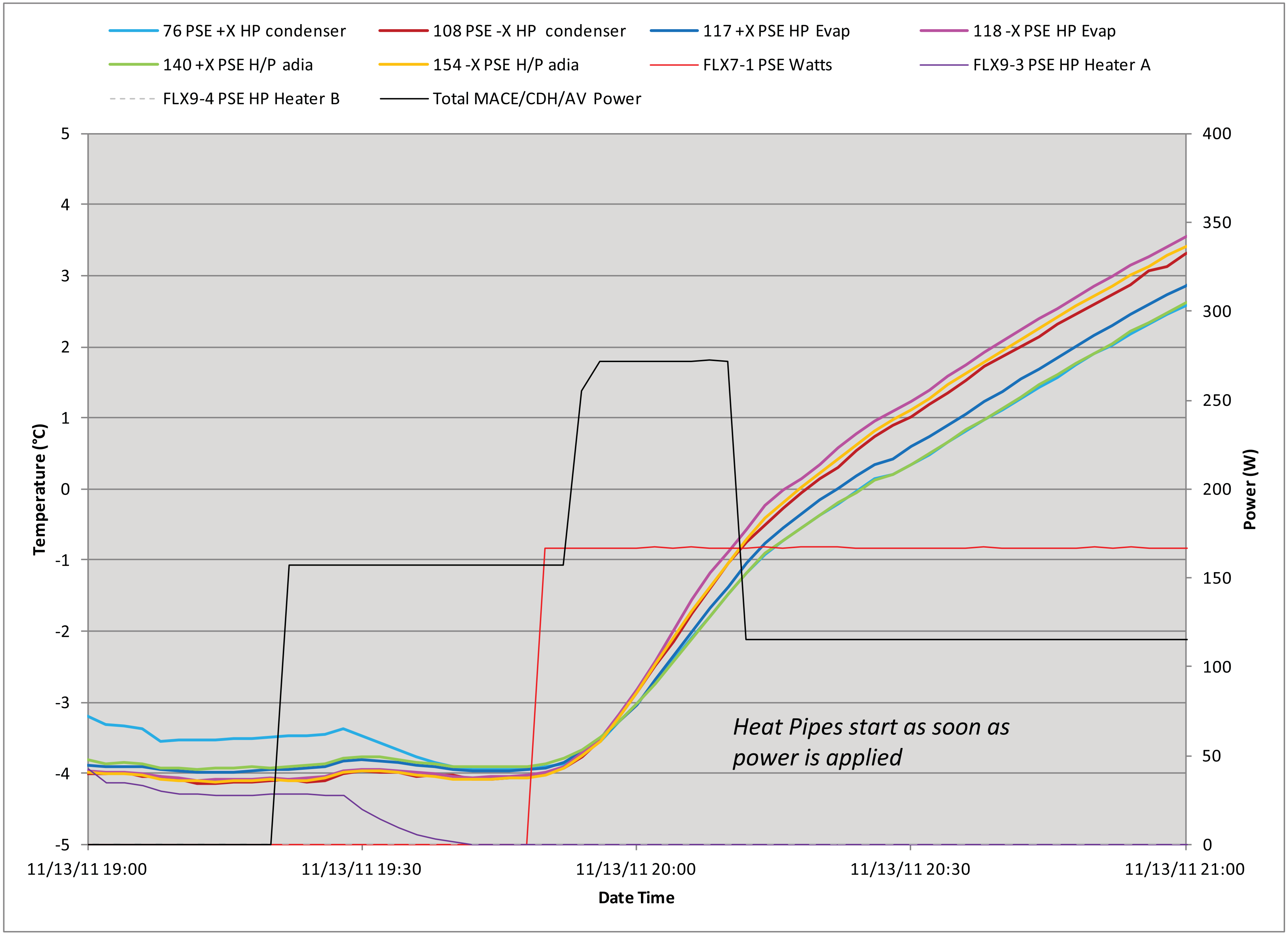
MACE/C&DH Transport Pipes Start-Up



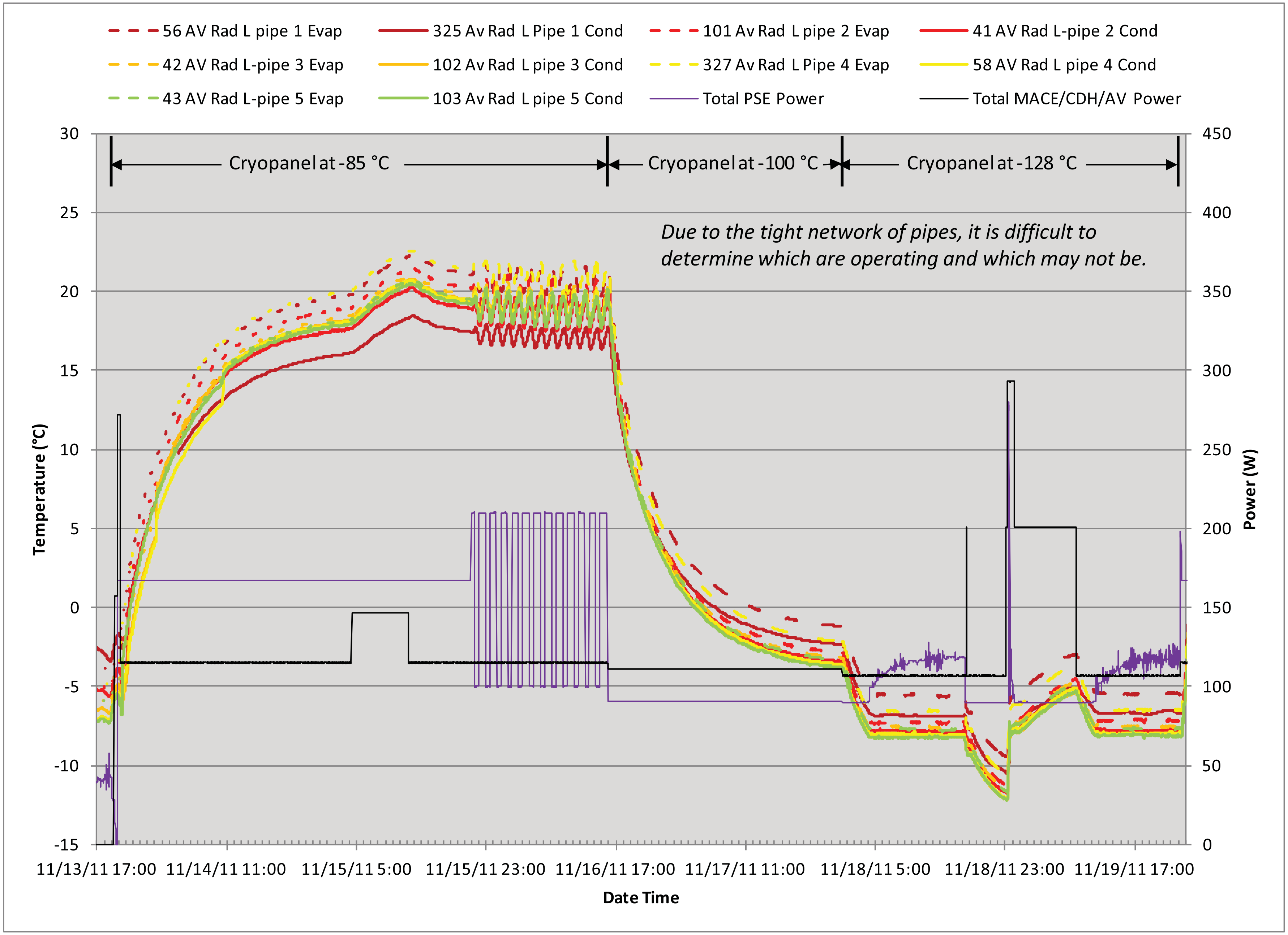
PSE Transport Pipes



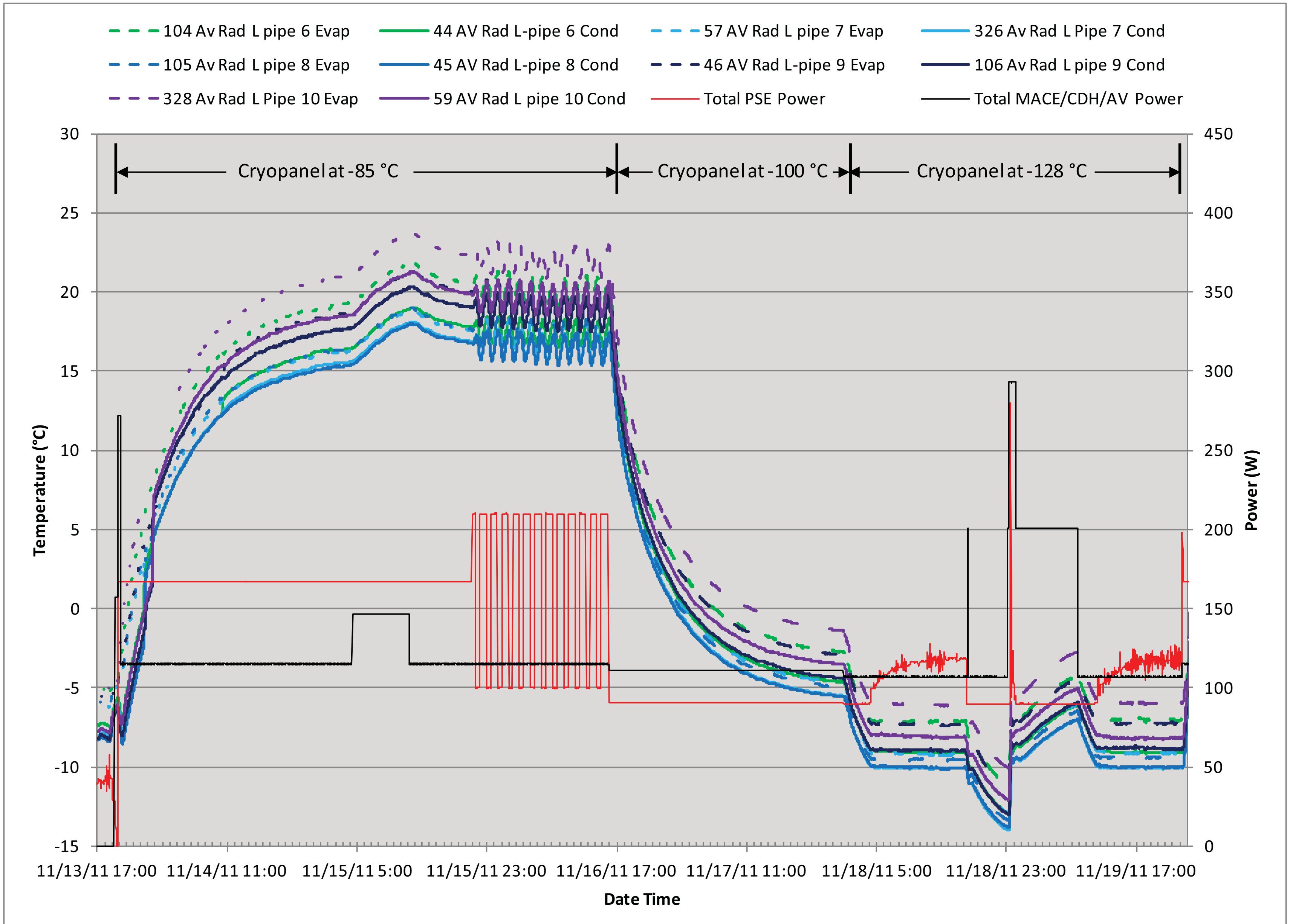
PSE Transport Pipes Start-Up



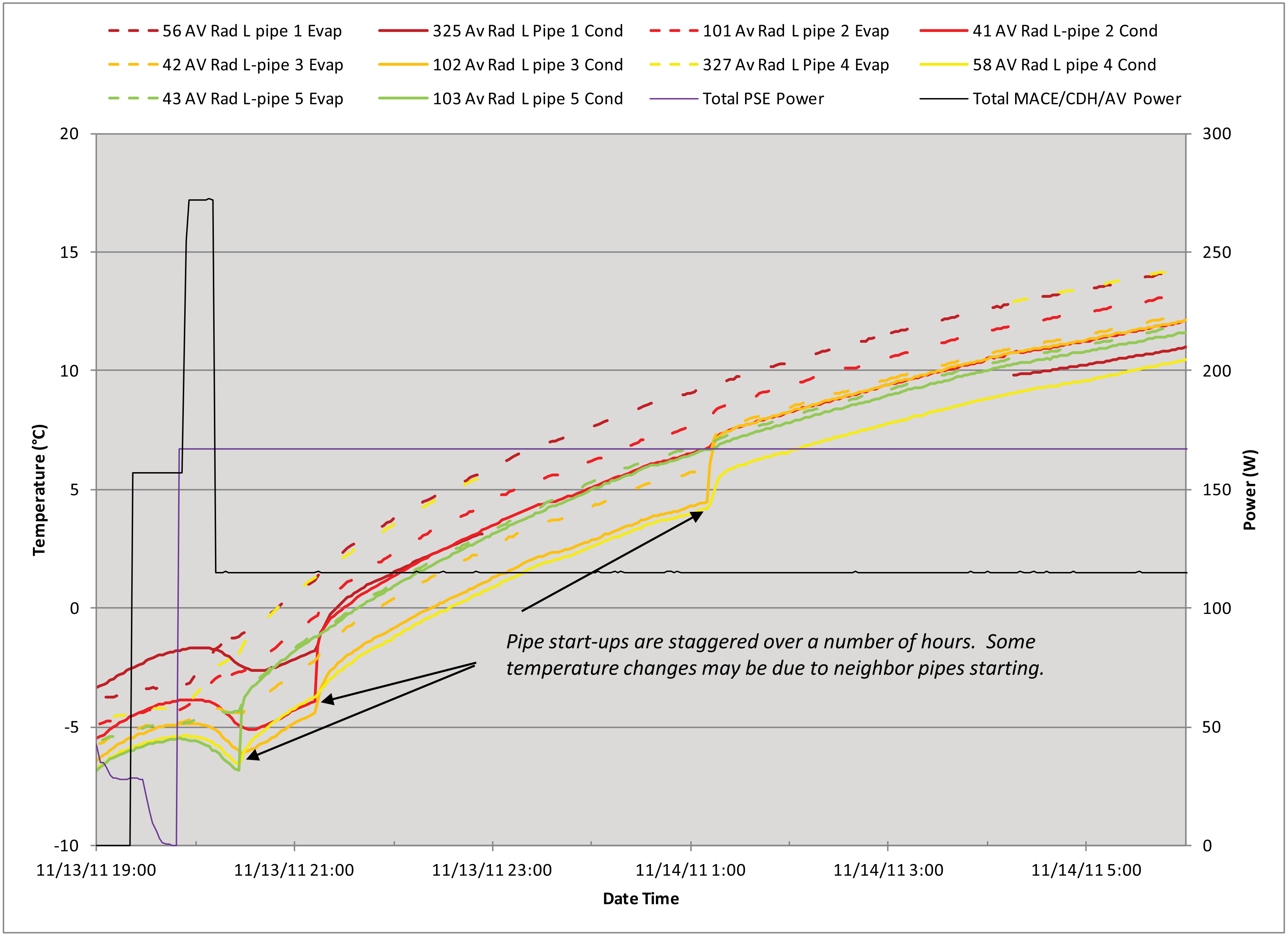
L-Shaped Spreader Pipes 1-5



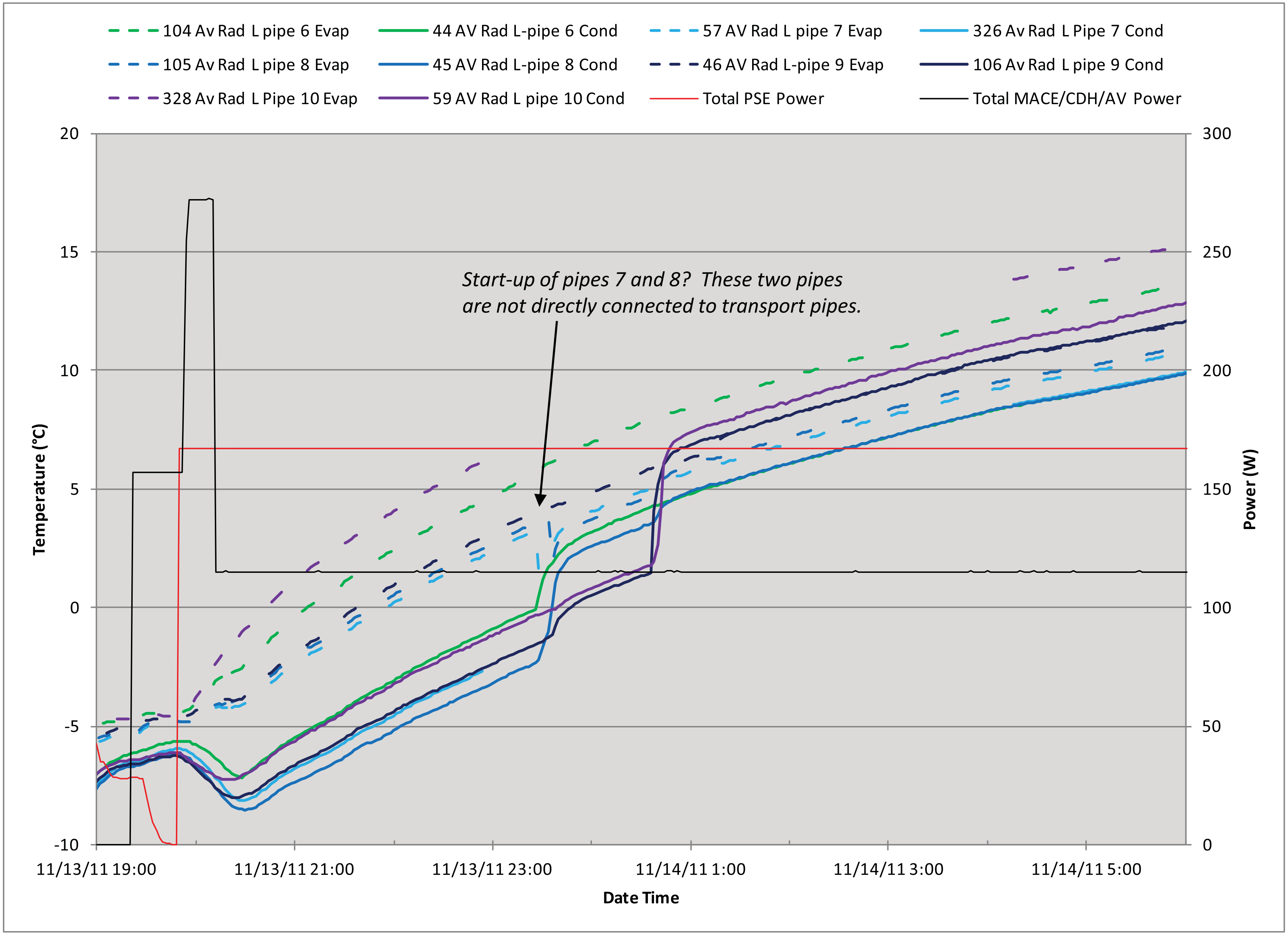
L-Shaped Spreader Pipes 6-10



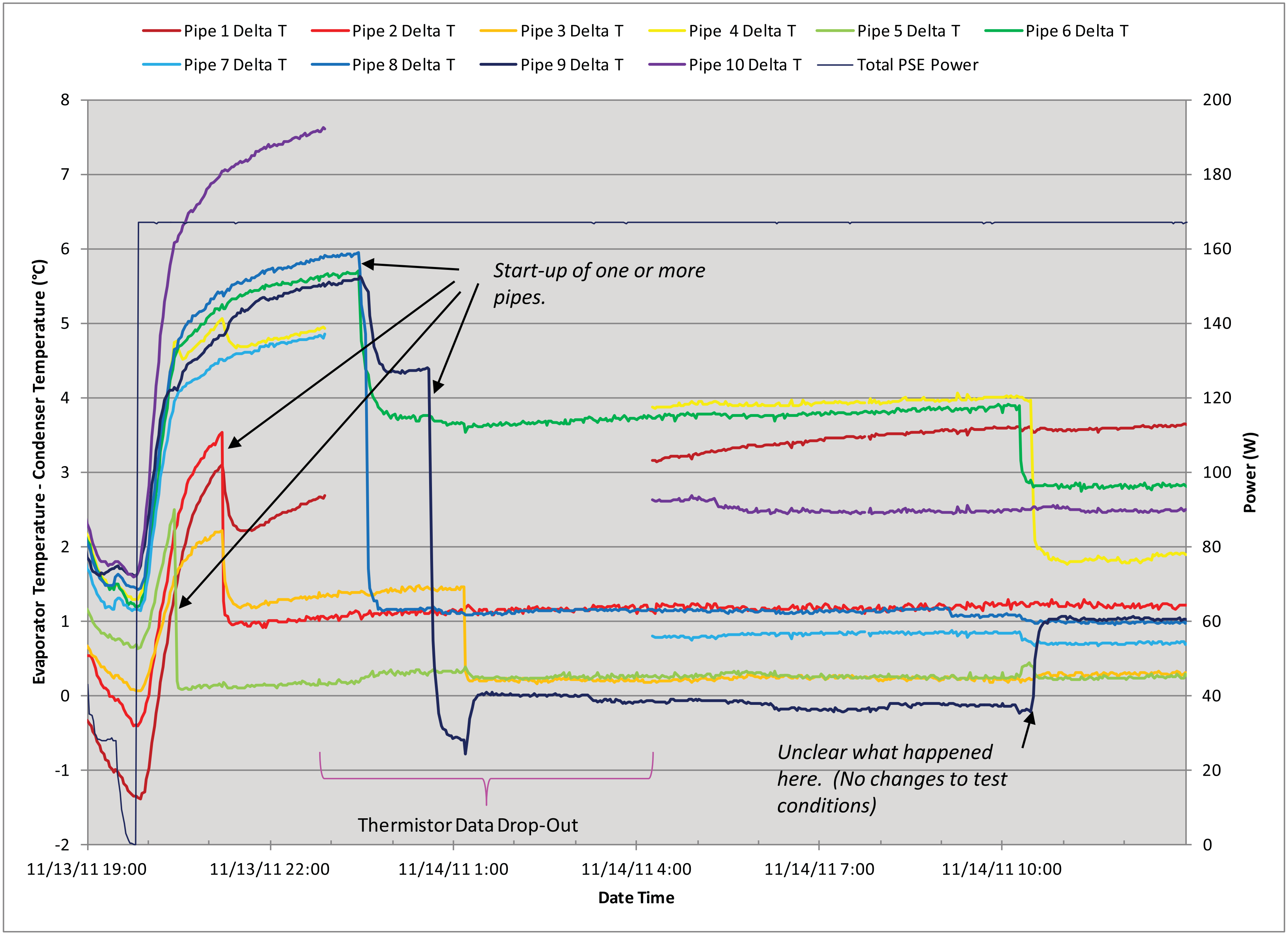
L-Shaped Spreader Pipes 1-5 Start-Up

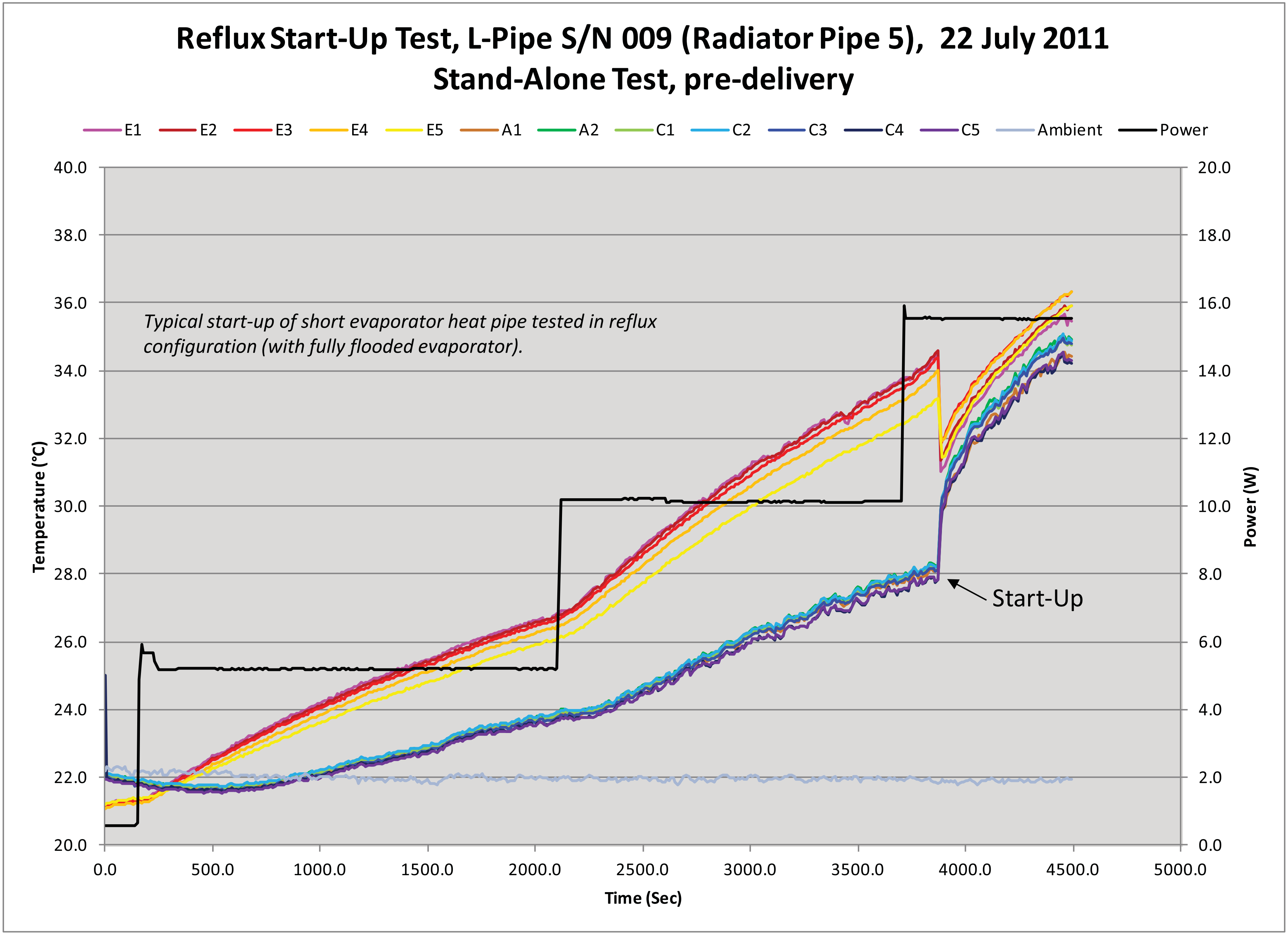


L-Shaped Spreader Pipes 6-10 Start-Up



L-Shaped Spreader Pipes Start-Up Delta Ts




Reflux Start-Up Test, L-Pipe S/N 009 (Radiator Pipe 5), 22 July 2011
Stand-Alone Test, pre-delivery
E1
E2
E3
E4
E5
A1
A2
C1
C2
C3
C4
C5
Ambient
Power
Typical start-up of short evaporator heat pipe tested in reflux configuration (with fully flooded evaporator).
Start-Up
Temperature (°C)
Power (W)
Time (Sec)
40.0
38.0
36.0
34.0
32.0
30.0
28.0
26.0
24.0
22.0
20.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0.0
500.0
1000.0
1500.0
2000.0
2500.0
3000.0
3500.0
4000.0
4500.0
5000.0

Conclusions

- Horizontal pipes (all transport pipes, straight spreaders in radiator) operated as expected
  - Started as soon as power was applied
  - Operated nearly isothermally throughout test
- Small heat pipes (operating in reflux mode) did not start immediately
  - This was consistent with previous testing of these pipes in this configuration and with testing of similar pipes on another program
  - Delayed start-up believed to be due to fully flooded evaporator and low power available to initiate nucleate boiling
- Simulator temperatures were well within temperature predictions and the system as a whole met all thermal requirements
- Inaccuracies in thermocouple measurements make comparisons between pipes and calculations of conductances difficult, if not impossible