ICESat-2/ATLAS

ATLAS LTCS Vertically Challenged System Lessons Learned

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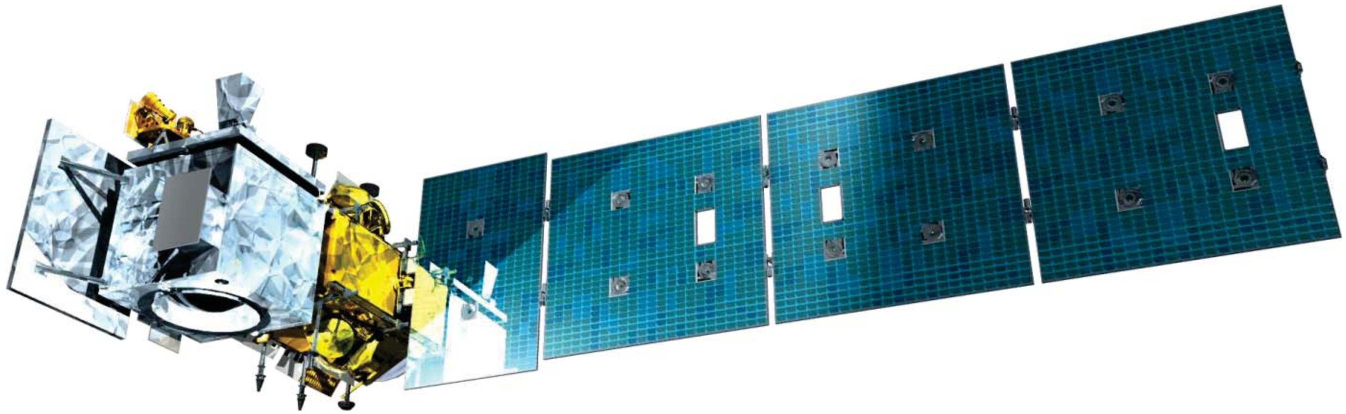
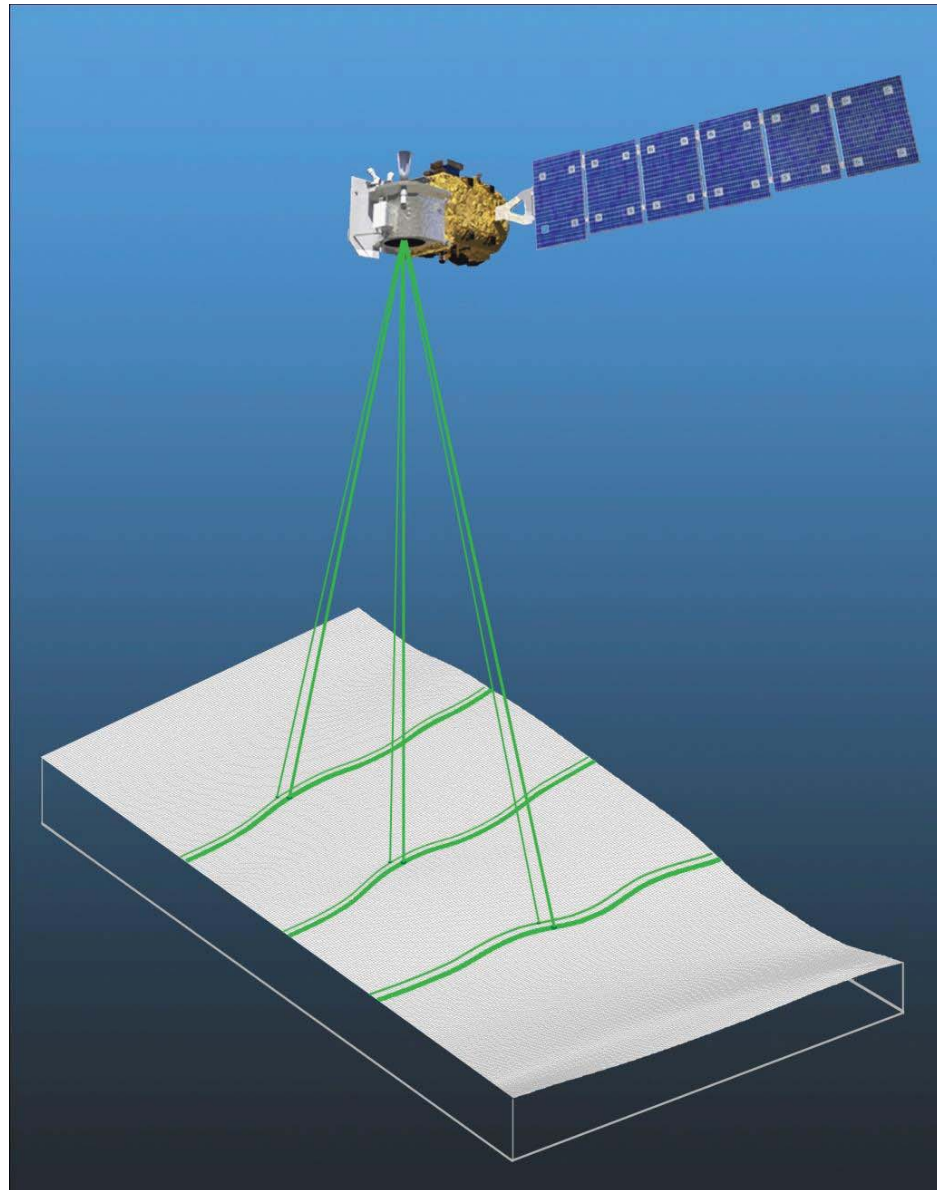
Outline



- Introduction
- Test Setup
- Test Results
- Test Investigation
- Lessons Learned

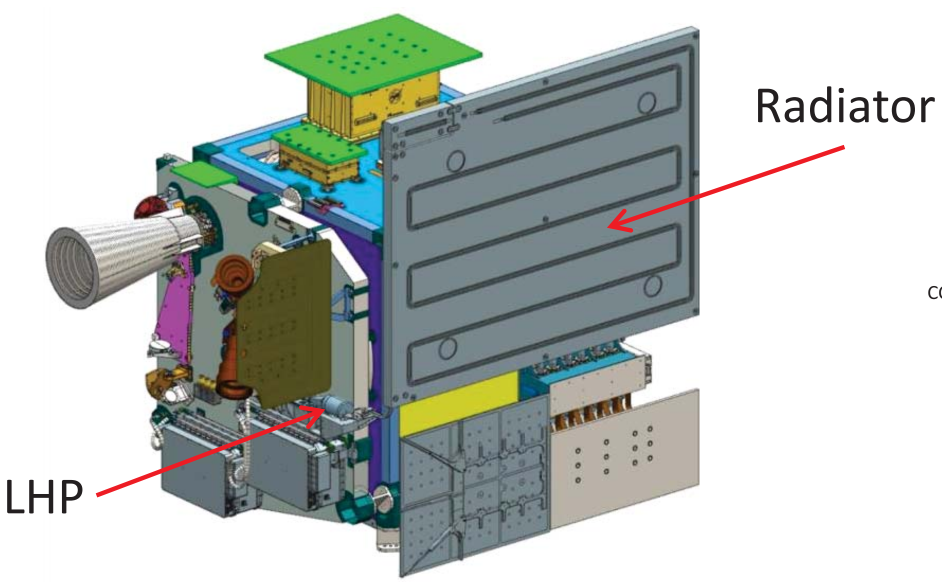
Introduction

- The objective of ICESat-2 is to collect altimetric measurements of Earth's surface, optimized to measure heights and freeboard of polar ice.
- ATLAS (Advanced Topographic Laser Altimeter System) instrument, sole for the mission, carries two lasers onboard. Only one laser is operational at any given time. The test that this presentation will cover is of the LTCS (Laser Thermal Control System) that was designed to maintain temperature of the operational laser.

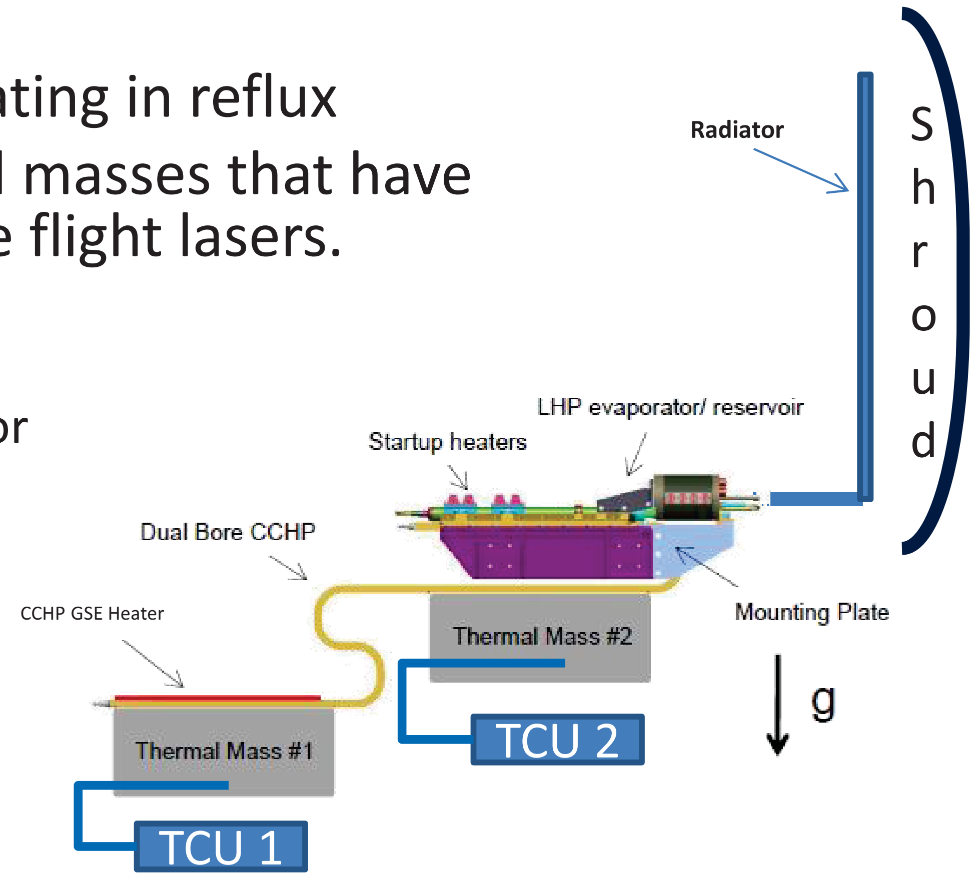


Test Setup

- Flight laser thermal control system, including loop heat pipe, constant-conductance heat pipe, and radiator
  - Heat pipe and LHP both operating in reflux
  - The test comprises of thermal masses that have similar capacitance that of the flight lasers.



LTCS Assembled with ATLAS



LTCS Test Setup

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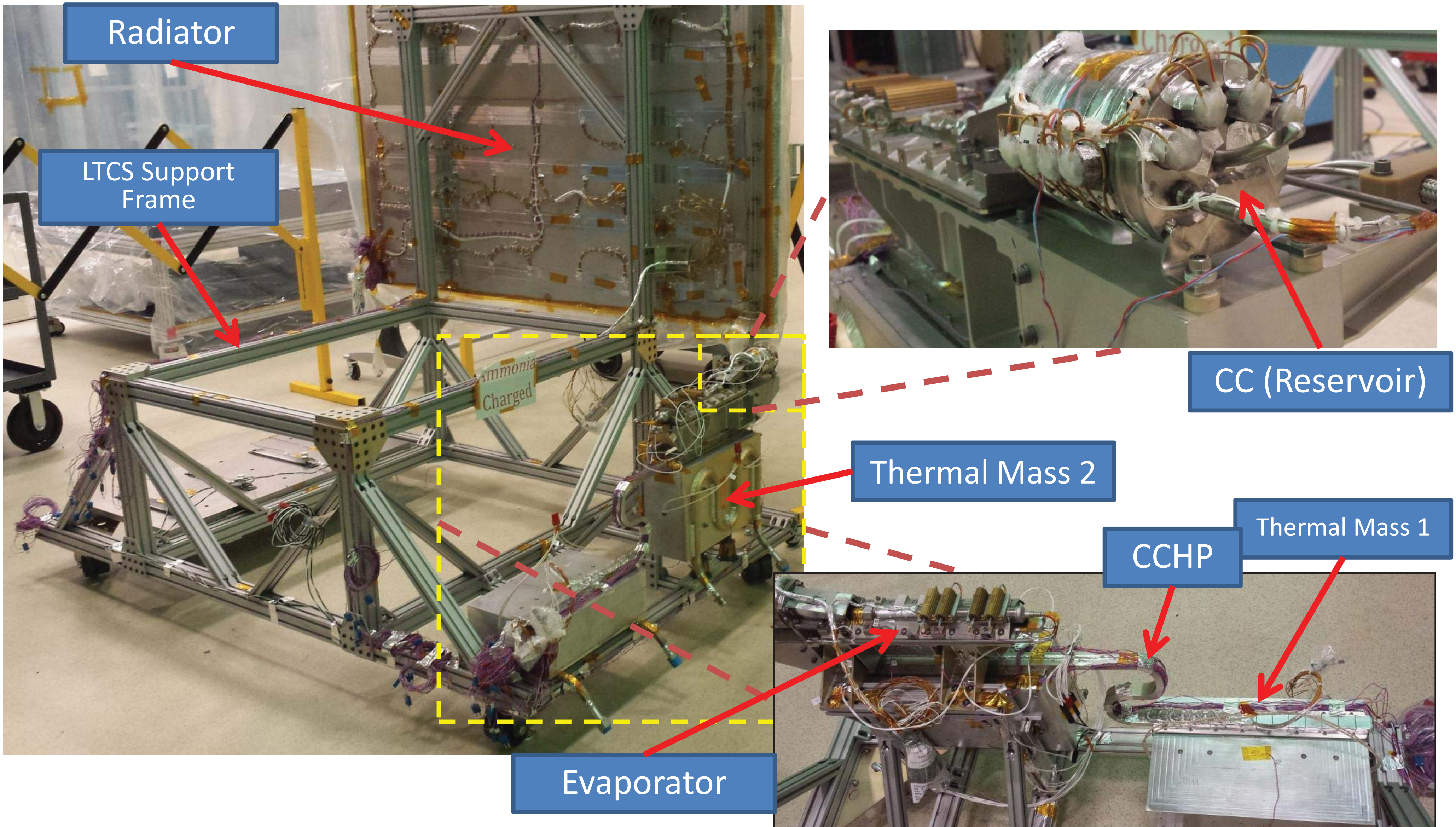
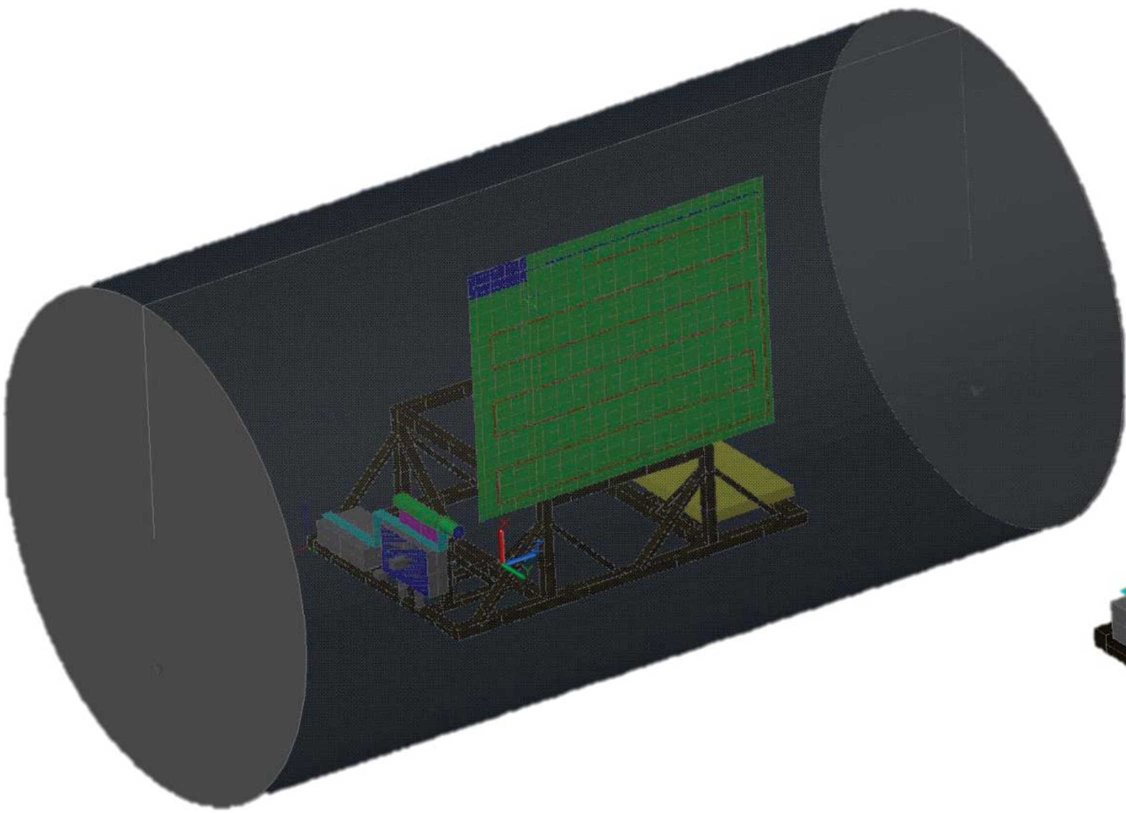
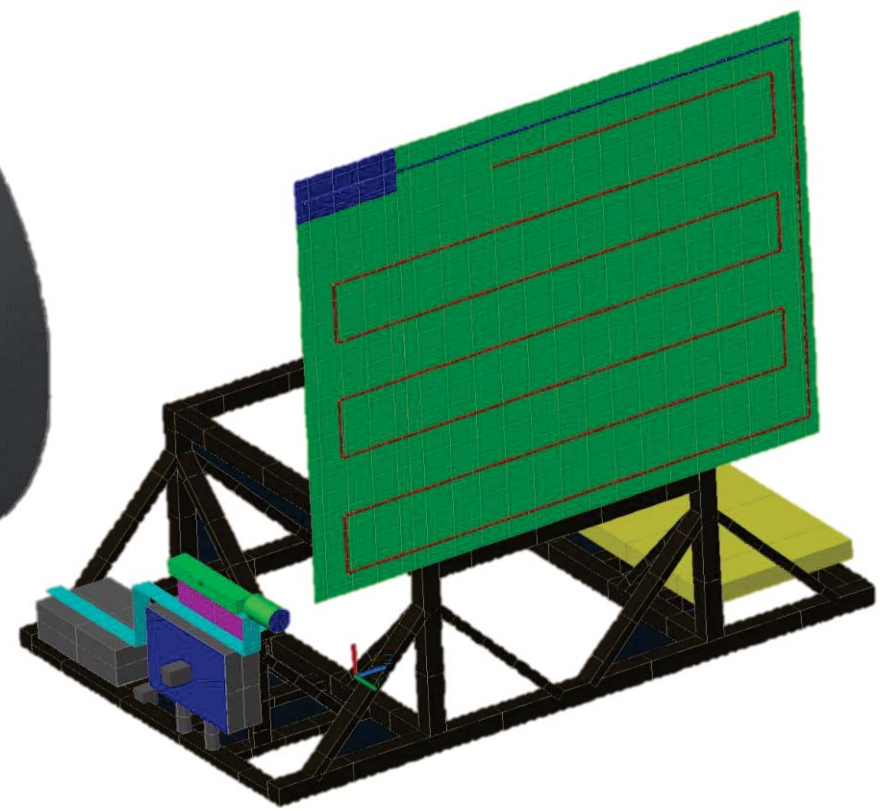
Test Setup



Test Setup

- Radiator views shroud surface and all other components are blanketed with SLI (Single Layer Insulation). The SLI is a VDA (Vapor Deposited Aluminum) on both sides with e of 0.05





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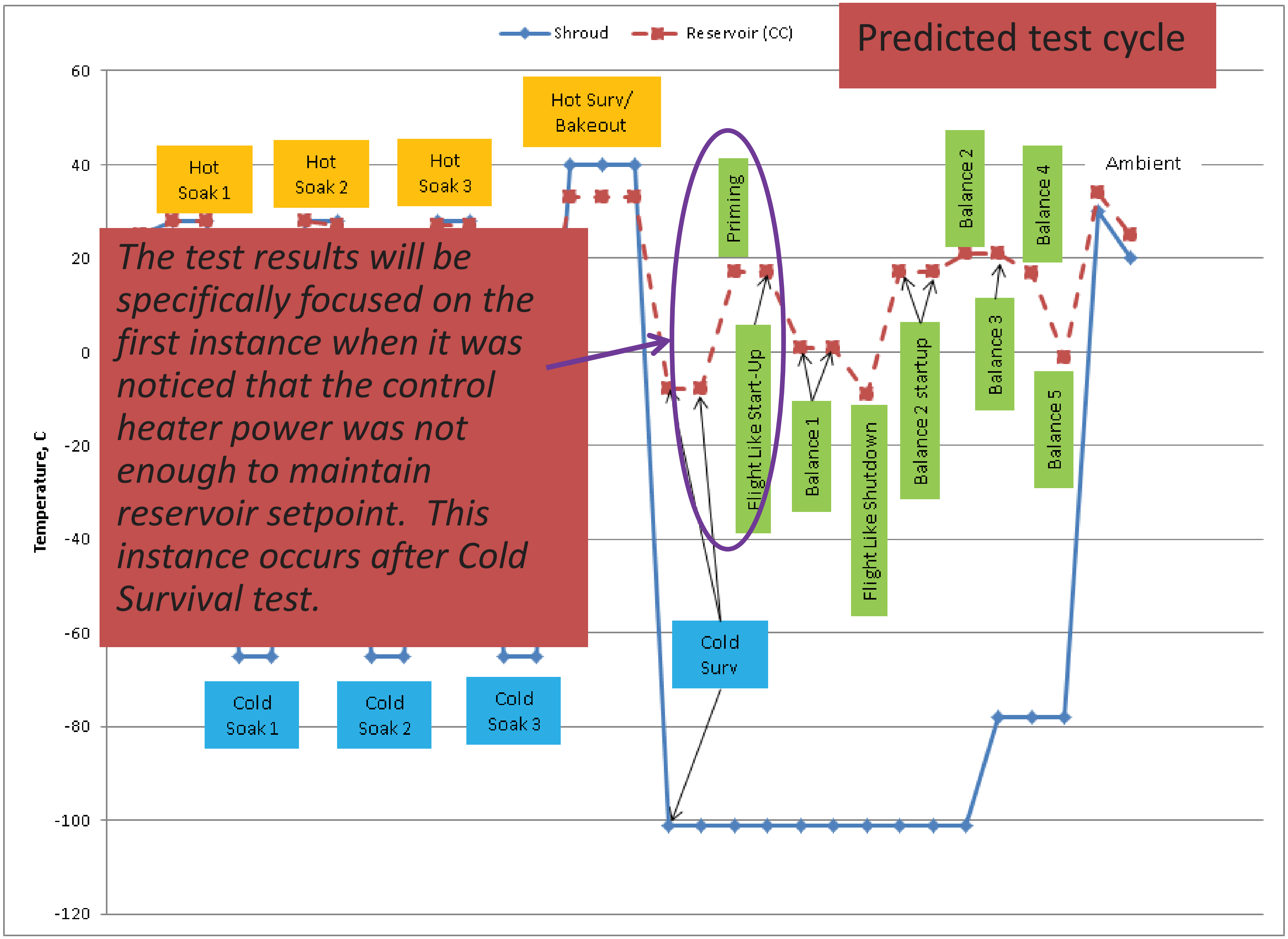
Test Results



The test results will be specifically focused on the first instance when it was noticed that the control heater power was not enough to maintain reservoir setpoint. This instance occurs after Cold Survival test.

Test Results

- The goal was to warm the CC warmer than the thermal mass, and simultaneously warm the thermal mass up to 10C.
- CC temperatures were warming up to their goal ahead of thermal mass.
- Current test conditions:
  - Sink @ -101C
  - CC @ 15C
  - Thermal mass @ 10C
  - Radiator (average) @ -55C
- Once the thermal mass reached 10C, the starter heater was applied

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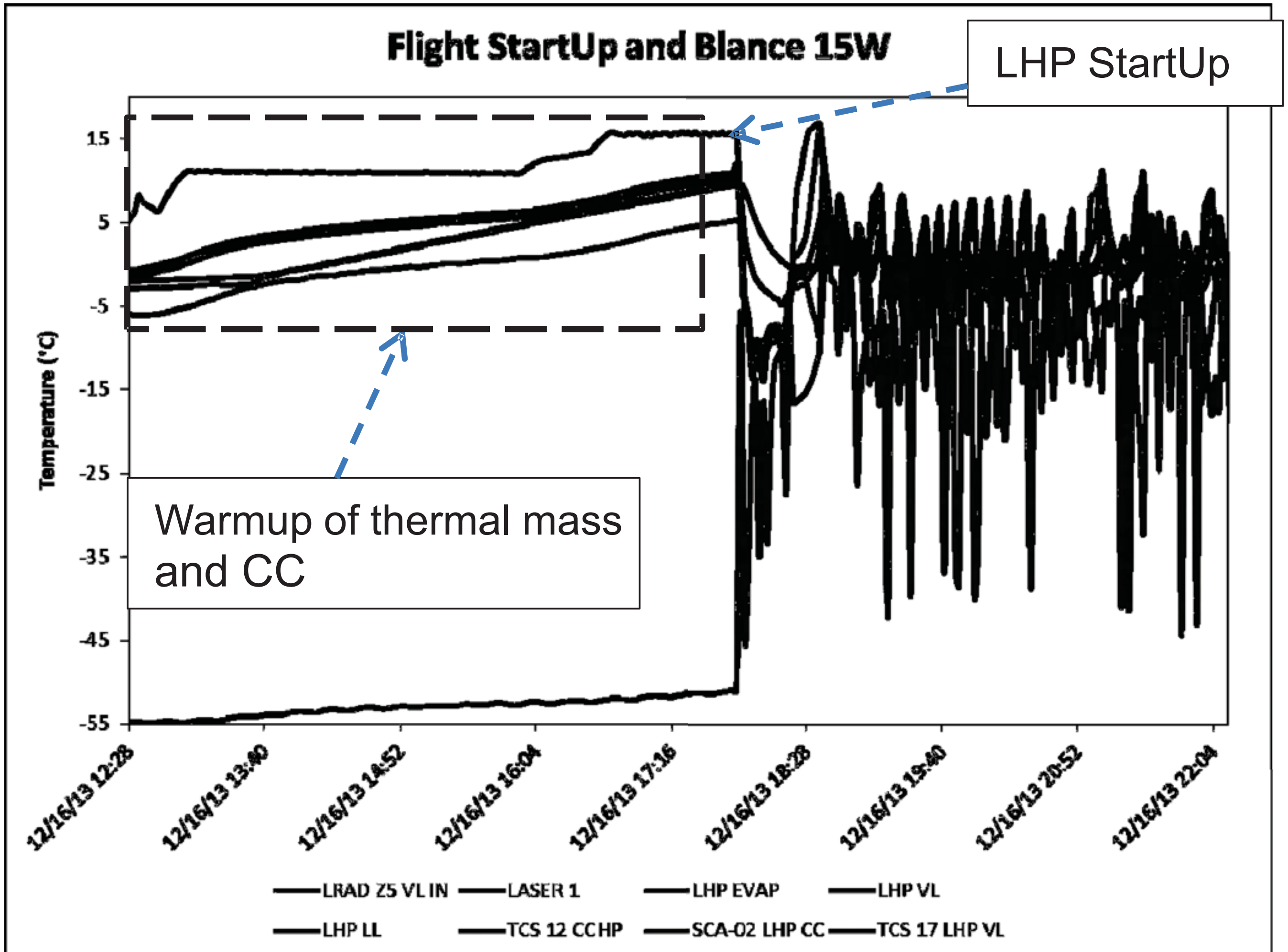
Test Results

- As the starter heater was applied, the behavior was noticed as shown in following figure:



NOTE: This presentation is not covering the reason for the oscillations or a detail on the loop pressure analysis. This information will be covered in Dr. Ku's presentation.

Test Results

- Midnight of 12/16/2013
  - Temperatures of the thermal mass and reservoir were drifting colder.
  - The control heater was fully powered and yet CC was showing no sign of positive temperature transition.
  - A LHP expert on duty mentioned that the loop is not going to be able to maintain thermal mass temperatures, given the current state of the hardware.
  - Before performing any other checks, it was postulated that gravity might brining the subcooled liquid at much faster rate than the CC has the ability to warm up.

Test Investigation

- A panel of LHP experts reviewed the test data and suggested a group of diagnostic tests to conclude a possible cause for the behavior of the loop.
  - Control heaters not receiving power
  - Control heaters not receiving enough power
  - Heat Leak through components
  - Issues with heater racks
  - Under-utilization of the radiator
  - Gravity-induced effects

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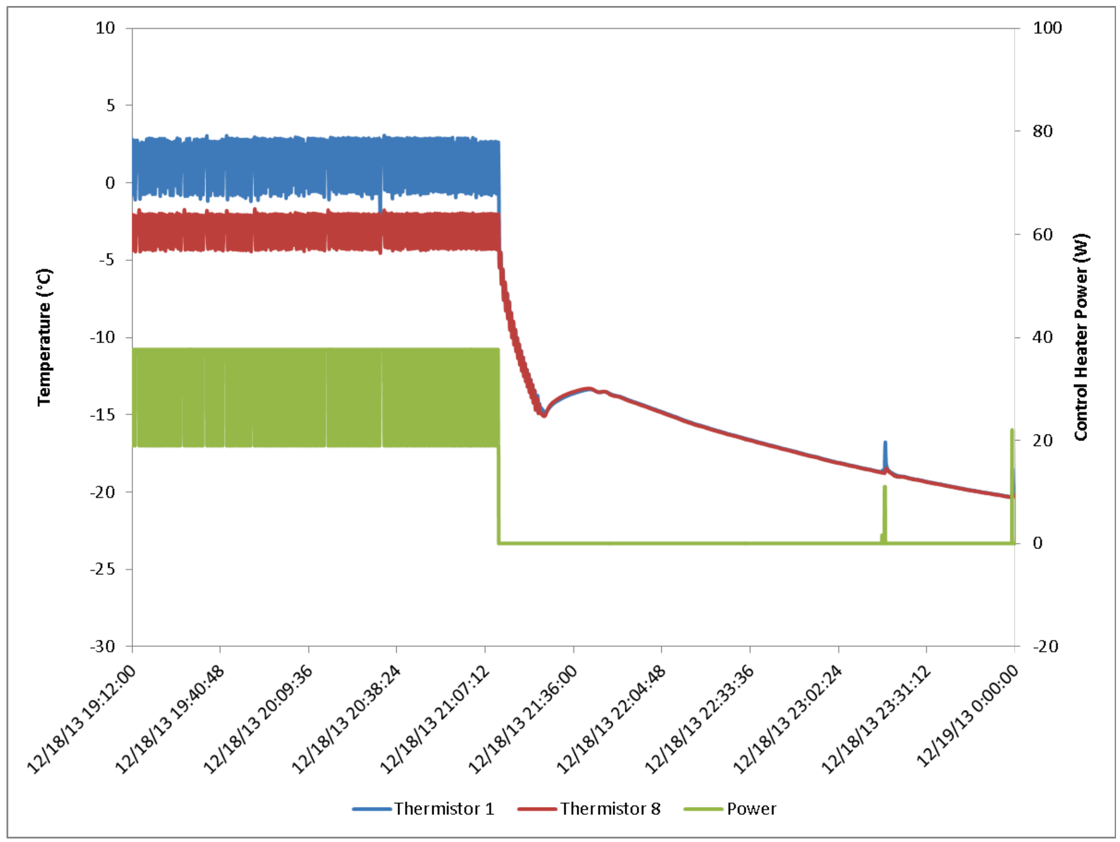
Test Investigation

Control heaters not receiving power, or enough power

- The control heaters were disabled to verify whether the control heater was receiving power or not
  - CC temperatures dropped from -3C to -15C in about 10mins indicating that the reservoir is receiving control heater power
- The control heaters were not receiving all the power.
  - The resistance through the heater harnesses was checked and was measured out to the design value.



Test Investigation

Heat-Leak through components / Issue with heater racks / Under-Utilization of the Radiator

- Heat leak through thermal masses, LHP components, or CCHP to the supporting frame or shroud radiation.
  - Radiation heat leak was minimum to none due to the blanketing of all components.
  - Conductive heat leaks were calculated and estimated to be around 2W (compared to 196W of thermal mass power).
    - These conductive leaks were not enough to cause an issue with the LHP
- Sensor issue with data reading system
  - Compared the two data systems
    - Both systems had a sensors reading temperature of the CC
  - No significant temperature difference was noticed.
- The radiator was designed for a power rejection capability of 250W.
  - During testing, the max power applied was 196W
  - Due to a non steady-state condition throughout all the attempted balances, no subcooled liquid temperatures could've been used to verify if there was more subcooling then predicted.

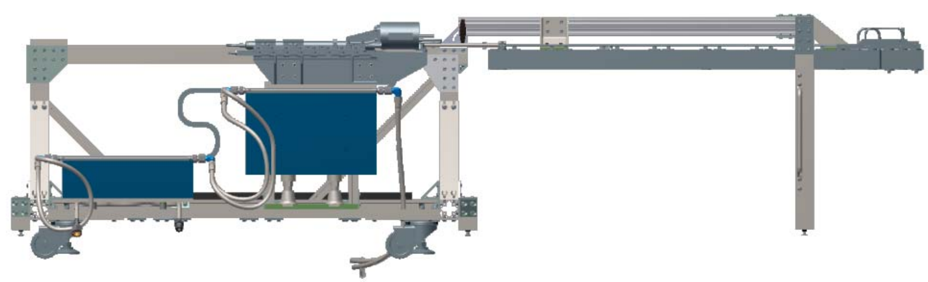
Test Investigation

Gravity-Induced effects

- The vertical distance between the exit of liquid line, from the condenser, to the entrance of the reservoir was around 1m.
  - This additional height increased the axial pressure of the liquid line, above the predicted value.
  - This effect was draining all the power from the control heater and causing the reservoir to cool down even after applying more than predicted control power.
  - During ATK's testing of the LTCS, it was noticed that the control heater power had increased 3X for the vertical orientation versus horizontal of the radiator.

Vertical Radiator Orientation

Horizontal Radiator Orientation

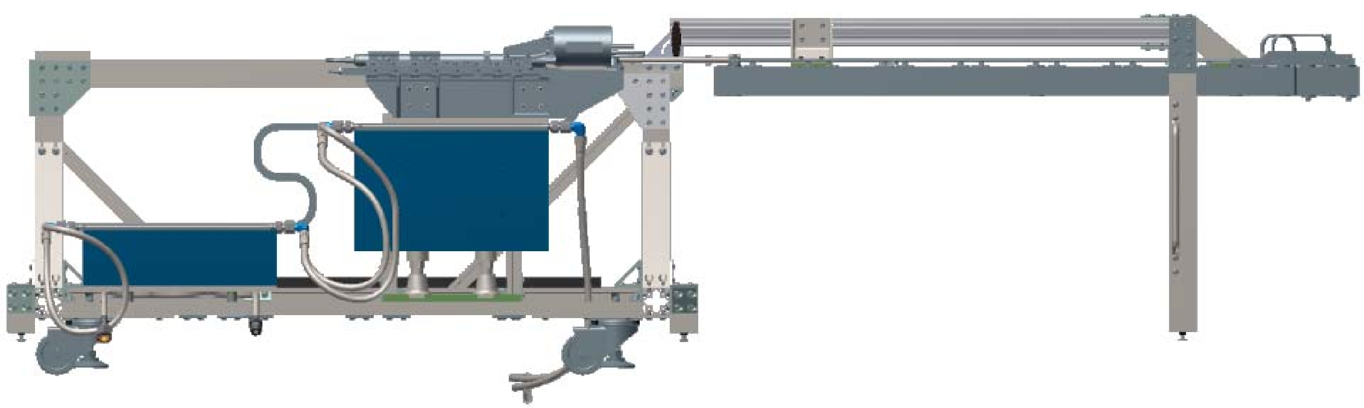


Lessons Learned

- Although modeling a loop heat pipe is very difficult, its best practice to perform pressure calculations of the system in the configuration it will be tested in.
- Consider all the external forces being applied on the system when performing test predictions.
- Perform checks and balances on all other areas such as heat leaks, equipment being used and calculation of test predictions to rule out the minor possibilities and confidently present major test failure factor.

Mitigation Test

- In order to overcome the extra subcooling return from the liquid line into the reservoir, a heater will be implemented onto the liquid line along the length of the radiator.
- A Horizontal test to remove the gravity effect, will be performed
  - Horizontal Configuration



Mitigation Test

- Vertical Configuration
  - This is the configuration the system will be functional during Instrument and Observatory testing of ATLAS
  - This will also verify whether the liquid line heater works as predicted.

Thank You for your attention

Any Questions?