Propylene Loop Heat Pipe Design and Thermal Performance

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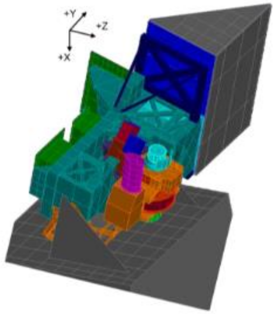
NASA Plankton, Aerosol, Cloud, ocean Ecosystem (PACE)

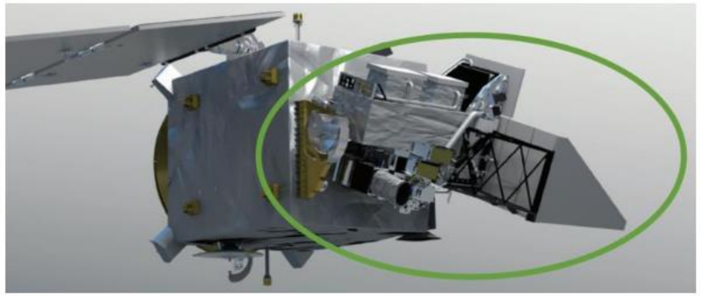
- Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) is a NASA Earth-observing satellite mission that will continue and advance observations of global ocean color, biogeochemistry, and ecology, as well as the carbon cycle, aerosols and clouds.
- PACE has two fundamental science goals:
  1. To extend key systematic ocean color, aerosol, and cloud data records for Earth system and
  2. climate studies, and to address new and emerging science questions using its advanced instruments, surpassing the capabilities of previous and current missions.
- The ocean and atmosphere are directly connected, moving and transferring energy, water, nutrients, gases, aerosols, and pollutants. Aerosols, clouds, and phytoplankton can also affect one another.
- Anticipated launch 2023.

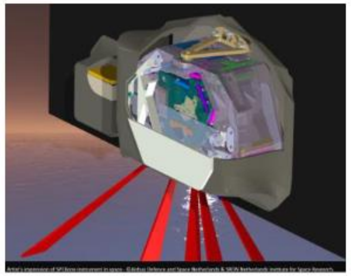
PACE Instruments

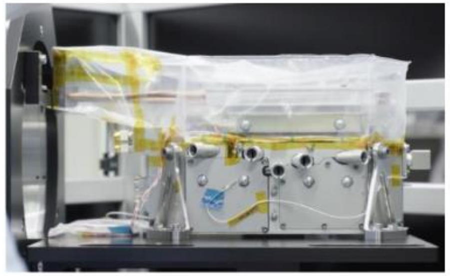
- **Ocean Color Instrument (OCI)**, primary sensor, is a highly advanced optical spectrometer that will be used to measure properties of light over portions of the electromagnetic spectrum. It will enable continuous measurement of light at finer wavelength resolution than previous NASA satellite sensors, extending key system ocean color data records for climate studies. It is capable of measuring the color of the ocean from ultraviolet to shortwave infrared.
- **Spectro-Polarimeter for Planetary Exploration (SPEXone)** is a multi-angle polarimeter that provides continuous wavelengths coverage in the range 385-770 nm. It measures the intensity, Degree of Linear Polarization (DoLP) and Angle of Linear Polarization (AoLP) of sunlight reflected back from Earth's atmosphere, land surface, and ocean.
- **Hyper-Angular Rainbow Polarimeter #2 (HARP2)** is a wide angle imaging polarimeter designed to measure aerosol particles and clouds, as well as properties of land and water surfaces.

	OCI	SPEXone	HARP2
Spectral range *[bandwith]*	342.5 - 887.5 @ 5 nm steps *[5 nm]*	385 - 770 nm @ 2-4 nm steps	440, 550, 670 *[10 nm]* & 870 nm *[40 nm]*
Shortwave infrared (OCI) / Polarized bands (SPEXone, HARP2)	Seven bands centered on 940, 1038, 1250, 1378, 1615, 2130 & 2260 nm	Same range in 15 to 45 nm steps	All
Number of viewing angles *[degrees]*	Fore-aft tilt +/- 20° to avoid sun glint	Five [-57°, -20°, 0°, 20°, 57°]	10 for 440, 550, 870 nm & 60 for 670 nm *[spaced over 114°]*
Coverage *[swath width]*	+/- 56.5° *[2663 km at 20° tilt]*	+/- 4° *[100 km]*	+/- 47° *[1556 km at nadir]*
Days for global coverage	1-2	About 30	2
Ground sample distance	1 km at nadir	2.5 km	3 km
Institution(s)	Goddard Space Flight Center	SRON Netherlands Institute for Space Research, Airbus Defence and Space Netherlands, TNO	University of Maryland – Earth and Space Institute

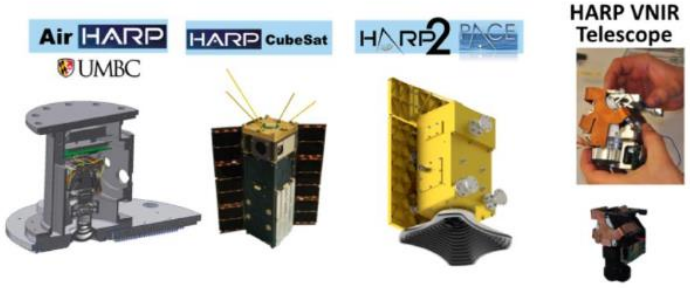








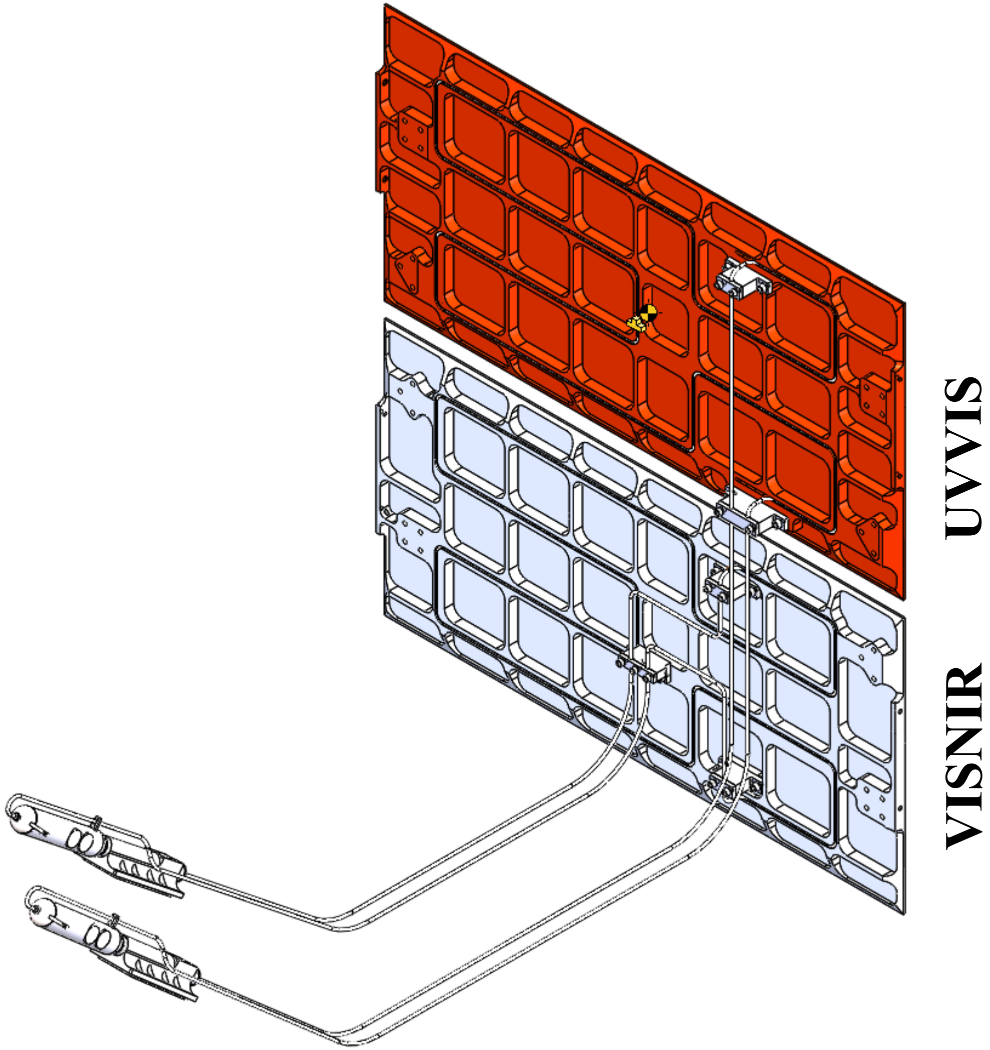
Artist's rendition of the HARP2 payload in orbit.



- Loop Heat Pipe Specification
  - FPA Heat Load 5W – 20W
  - Cold Start Transient 90W
  - Operating Temperature -40C to -20C at the evaporator
  - Sink Temperature Range -159C to -123C
  - Temperature Control ±0.5C over a 90 minute period
    - Film heater on reservoir
  - Storage Temperature Range -55C to 45C

Propylene Loop Heat Pipe Design and Thermal Performance

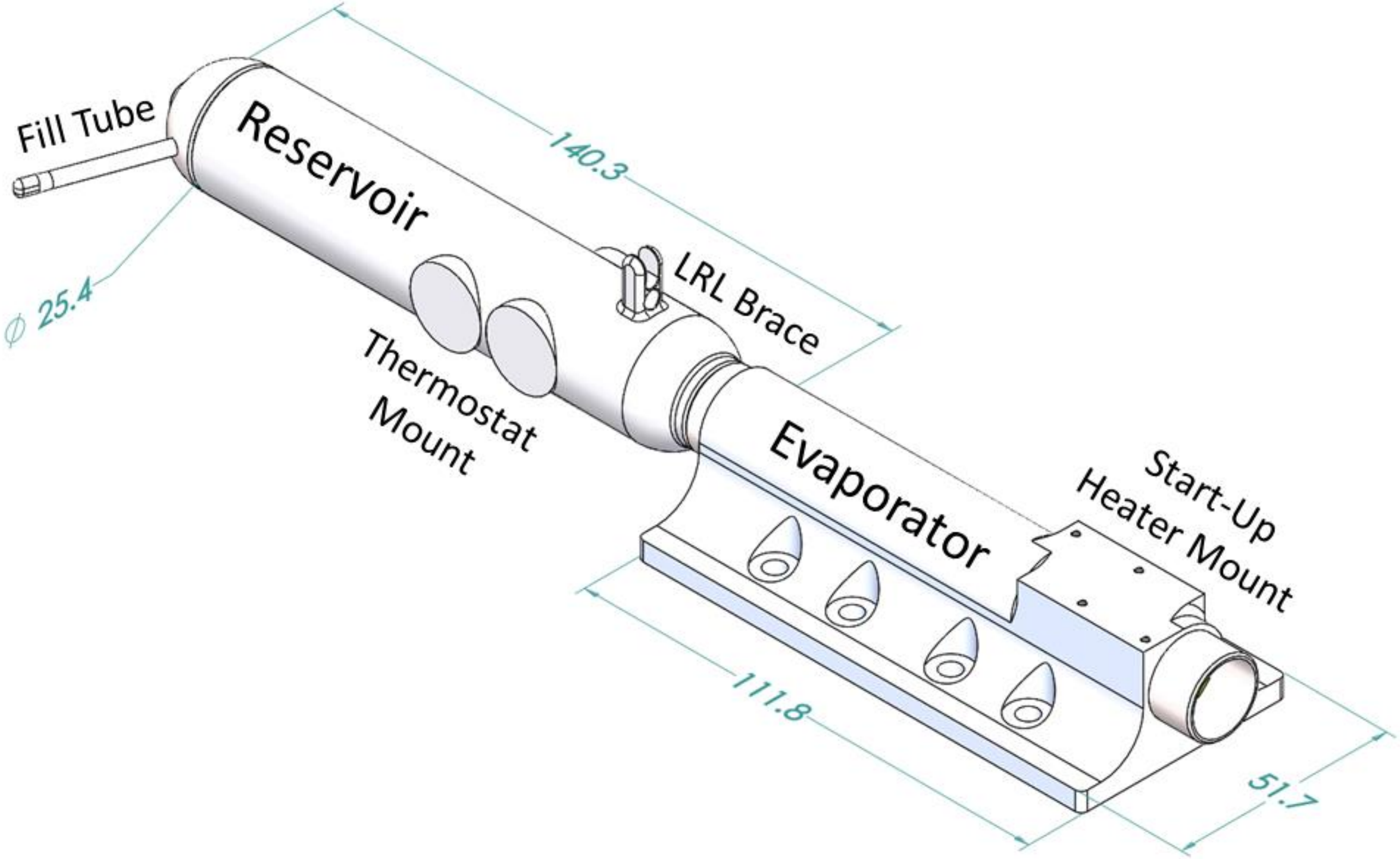
- Loop Heat Pipe Construction
  - Propylene working fluid
  - All wetted components stainless steel
  - Evaporator saddle Al 6063
  - Radiator plate Al 6061
- 2 LHP Design Variants
  - UVVIS Spectrometer
  - VISNIR Spectrometer
  - Shared evaporator design
  - Similar radiator design
  - Different transport line lengths



Propylene Loop Heat Pipe Design and Thermal Performance

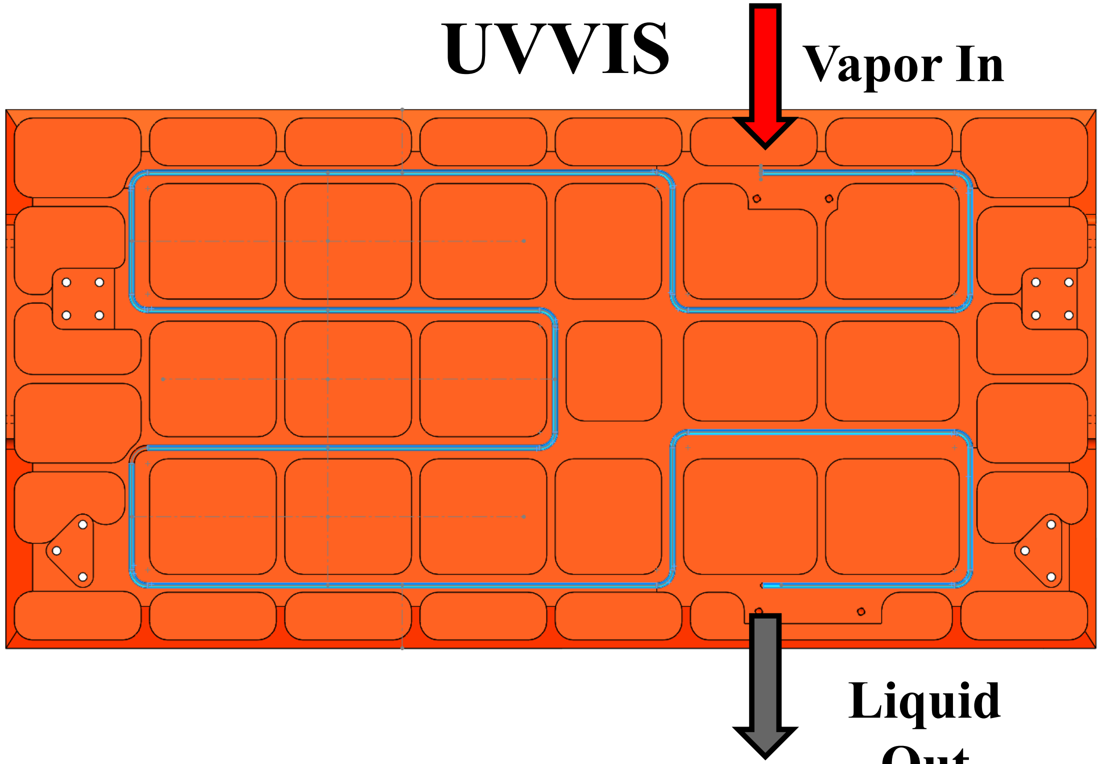
- Evaporator Details
  - Wick ~3 micron sintered stainless steel powder
    - Wick hot inserted into a stainless steel sleeve
    - Sleeve hot inserted into the aluminum saddle
- Reservoir coaxial
  - Knife edge seal pressed into wick
  - Secondary wick stainless steel mesh construction

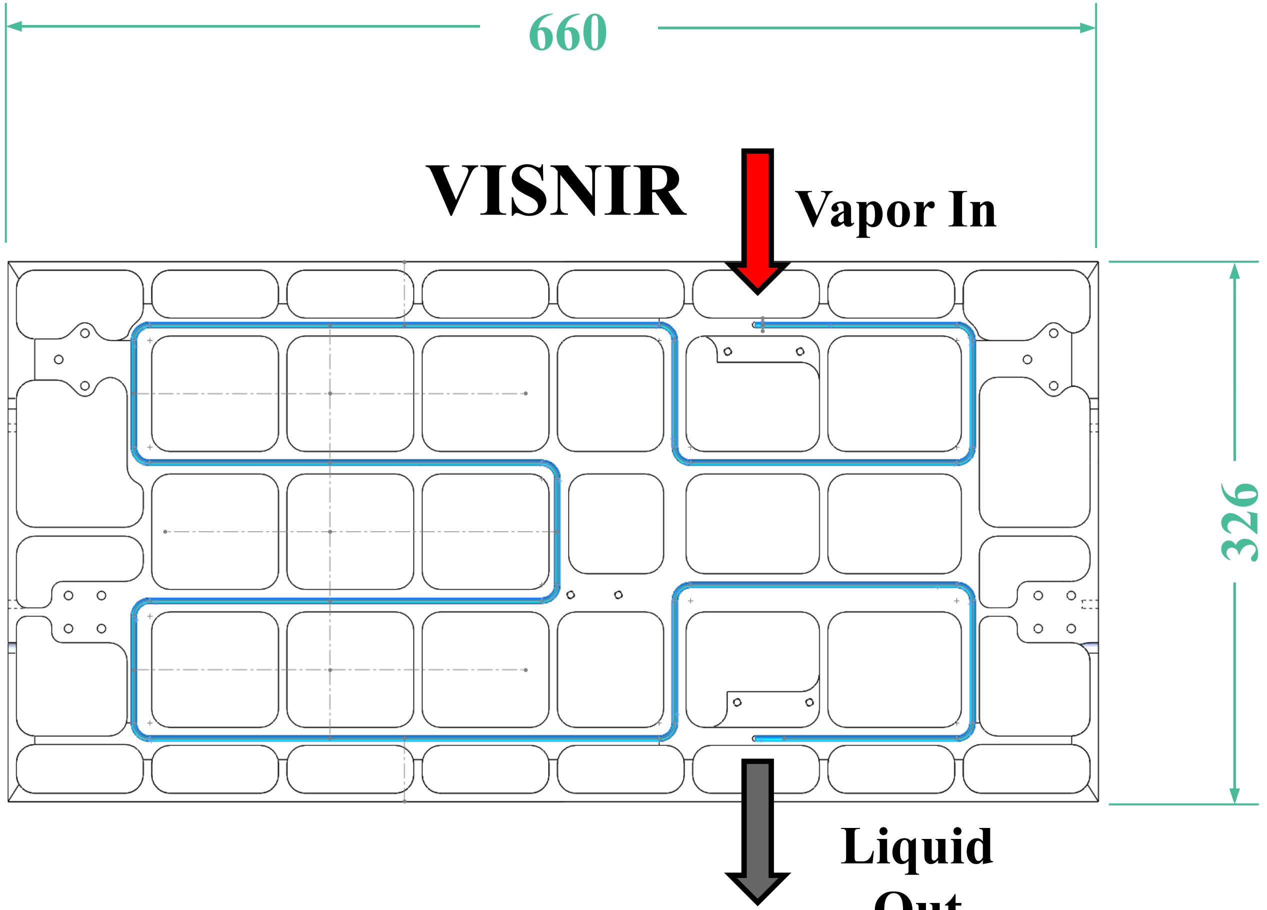
- Evaporator Details



- Radiator Details
  - Aluminum plate, machined “egg crate”
    - 0.040” thick plate, 0.5” bosses
    - Nickel plated
  - Condenser tube pressed & soldered into groove
    - SnPb solder
  - Slight variance in the serpentine tube path

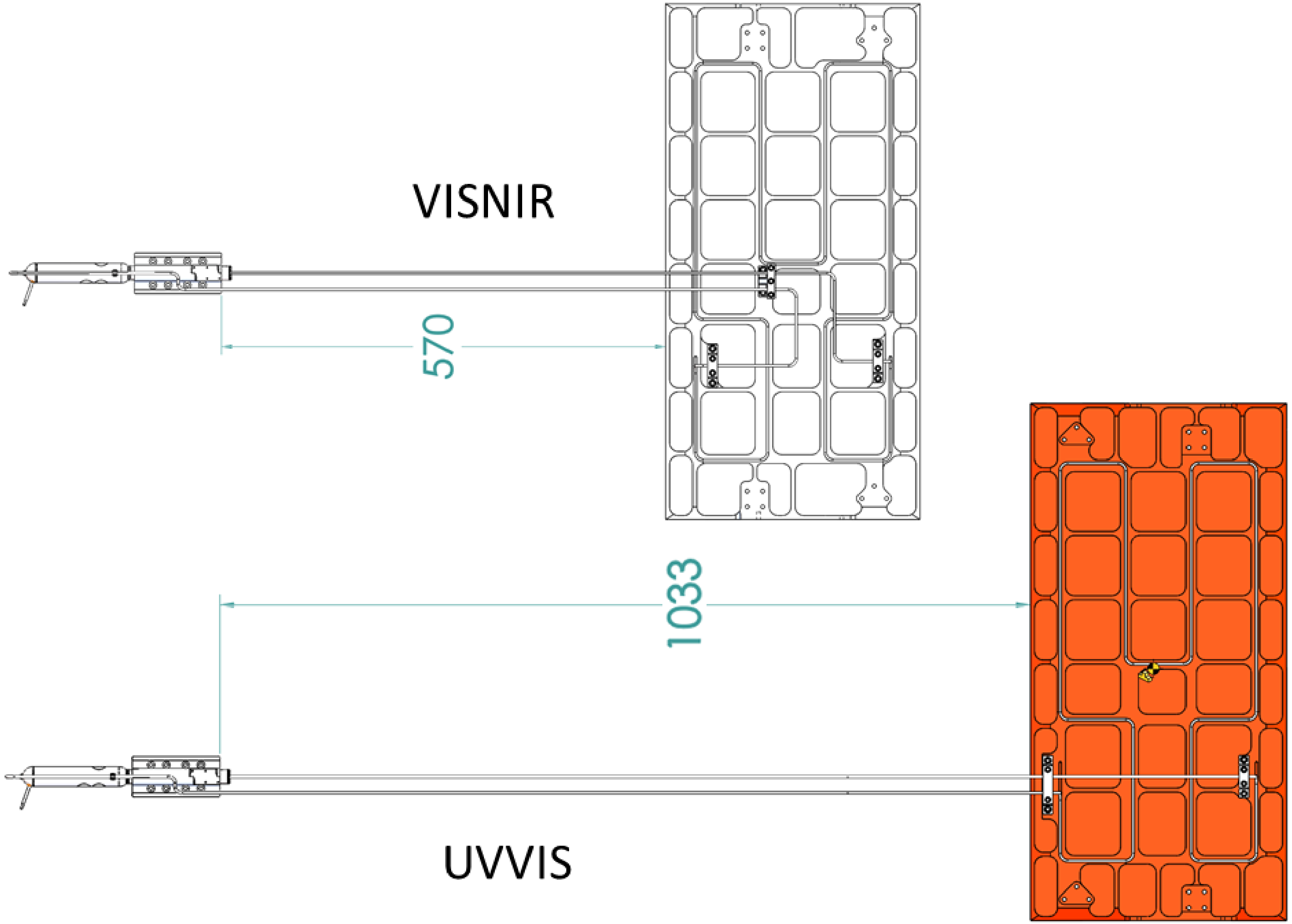
- Radiator Details
  - Condenser line path



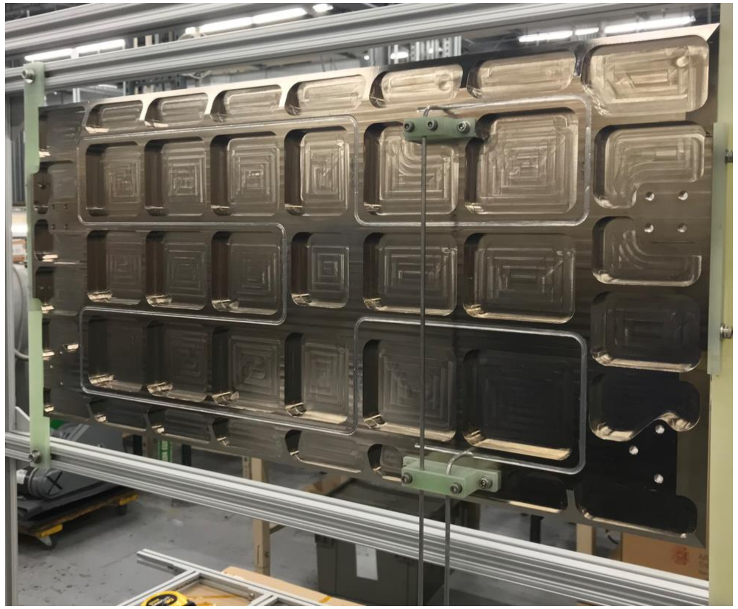


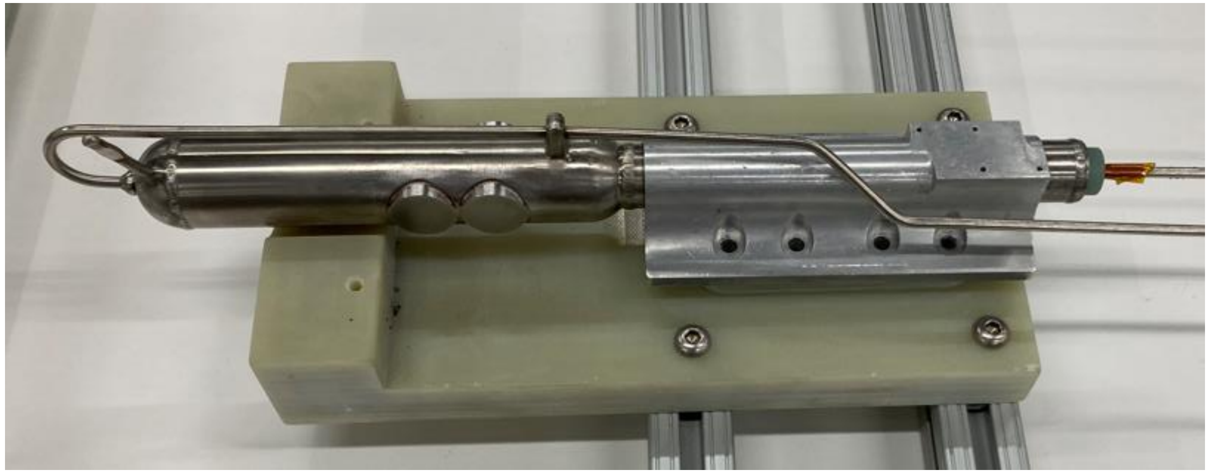
- Transport Lines
  - SS 316L
  - 0.125" OD
  - 0.016" wall thickness
  - Orbital weld joints
- LHP's were processed, tested & delivered straight
- NASA did TVac testing simulating "0g"
- The transport lines were then bent while at GSFC
- NASA did more TVac in the final configuration

- Transport Lines



- Hardware Photos





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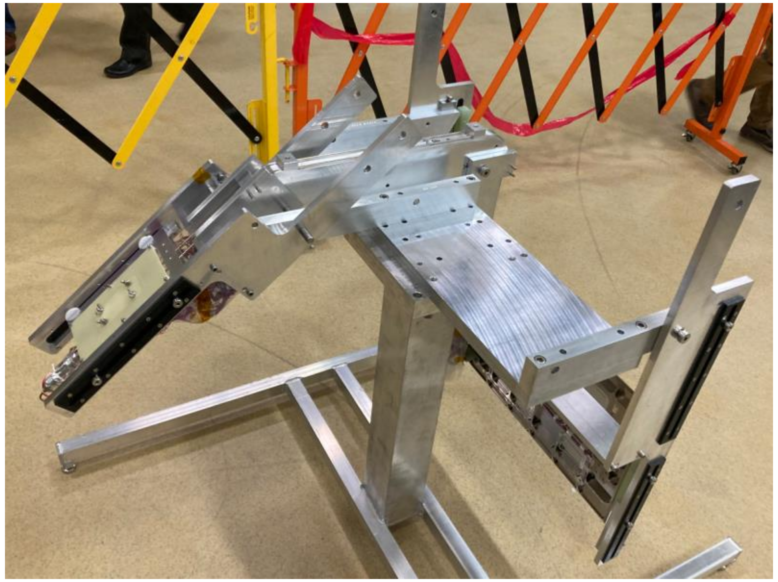

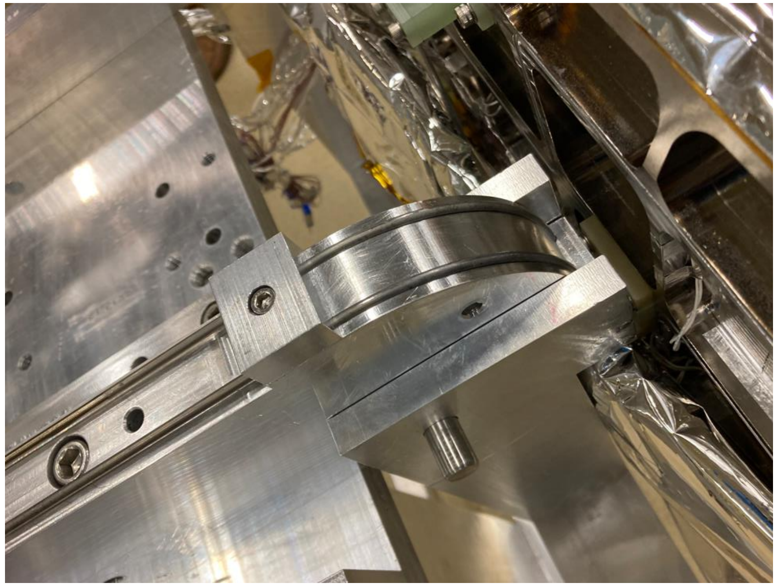

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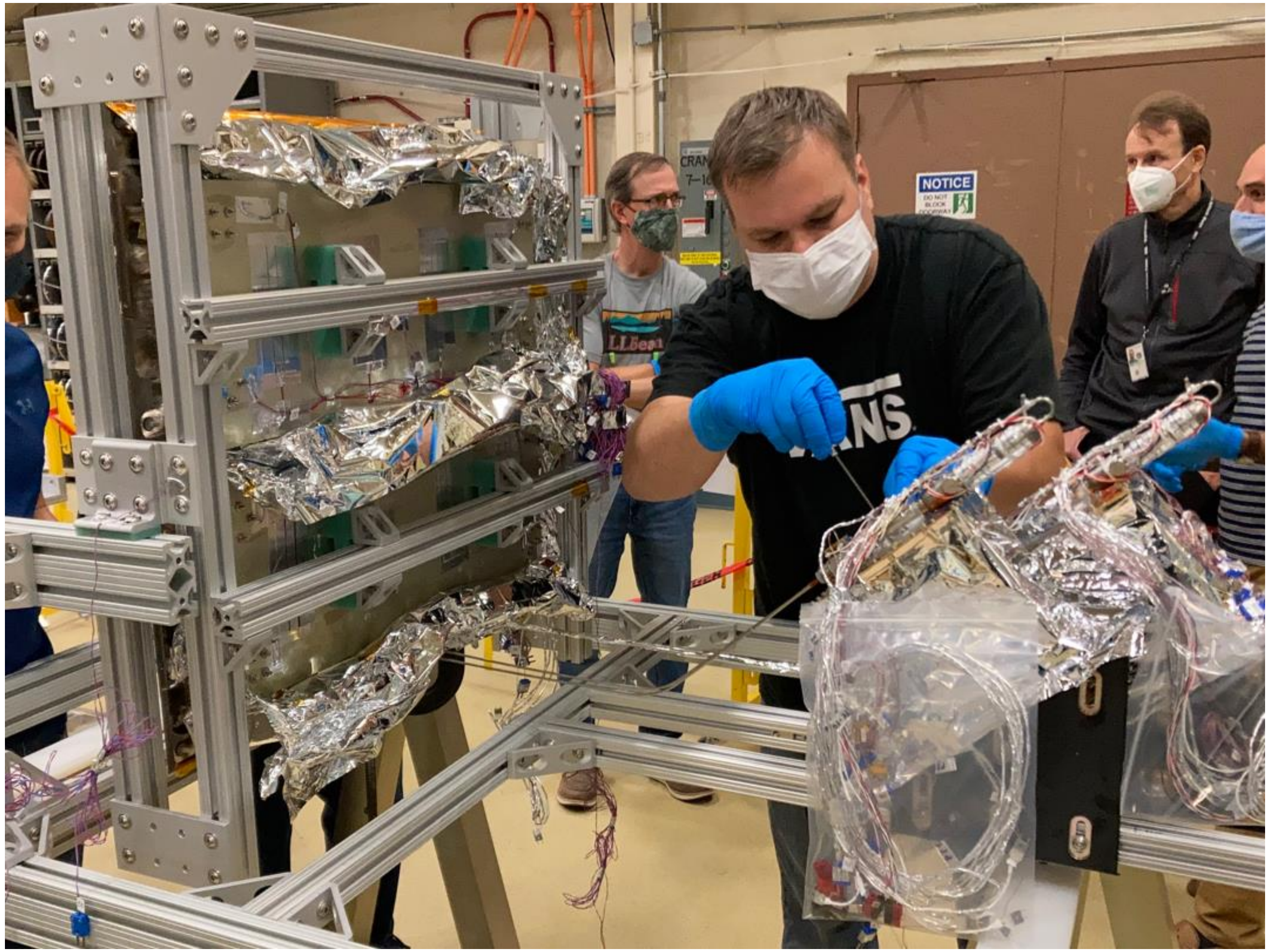


- Various Tests during Fabrication
  - Pore Radius Bubble Tests
  - Transport Line Flow Restriction.
  - Mass Spectrometer Helium Leak Checks to the various subassemblies
  - Vibration Tests
    - Evaporator/Reservoir Pump
    - Transport Line/Radiator
  - CT Scan of Knife Edge Seal and Wick, before and after vibration test
  - Weld X-Rays
  - X-Ray examination of Transport Line solder joint into the Radiator after vibration test
  - Proof Pressure and Thermal Proof Pressure
  - Pinch-off Leak Check via RGA
  - Secondary Wick Heat Transport Capability test.

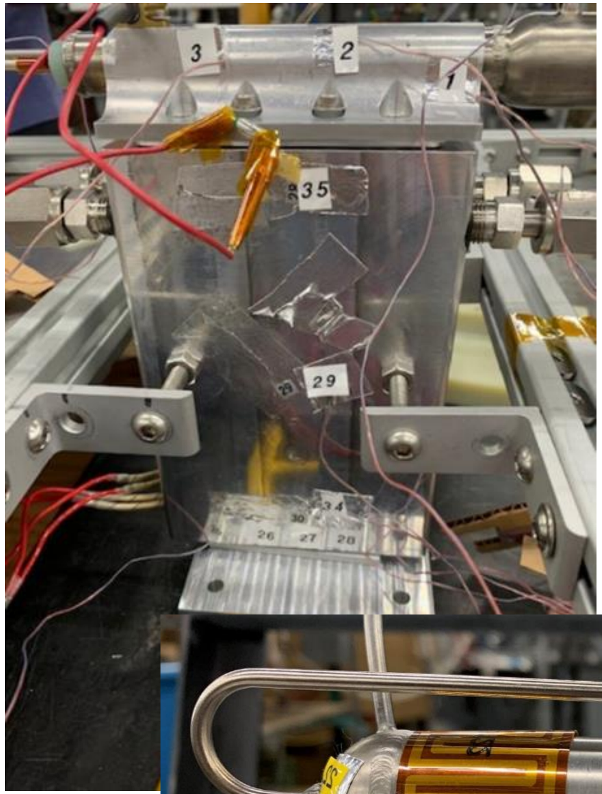
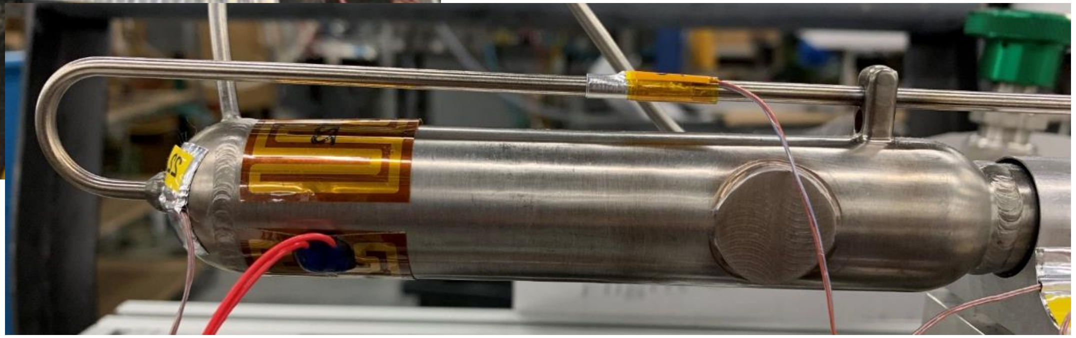
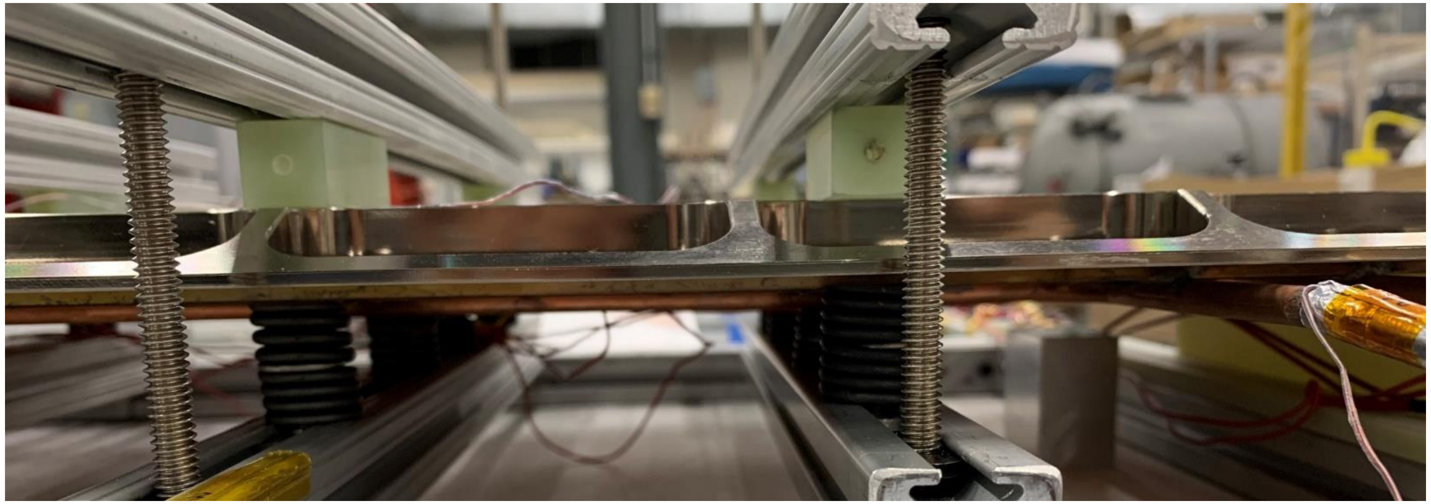
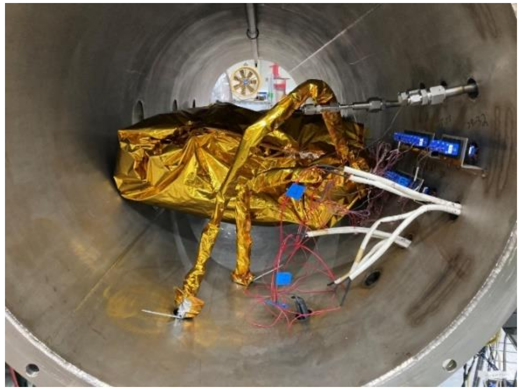
Propylene Loop Heat Pipe Design and Thermal Performance

- Acceptance Testing
  - Cold Start Test
  - Shutdown
  - Day-in-the-Life
    - 15W
    - 25W
  - Maximum Heat Transport Capability
  - Heat Load Step-Down (Secondary Wick Test)

- Test Setup
  - Heater on Evaporator
    - Large block, replicating the mass of the spectrometer
  - Control heater on the Reservoir
    - Film heater wrapped around far end of reservoir
    - PI Controller
  - Start-Up heater on the Evaporator
  - Chiller-cooled cold plate in contact with the Radiator
  - 40 Type-T TC’s
  - MLI
  - Vacuum Chamber
  - Datalogger
  - DC Power Supplies

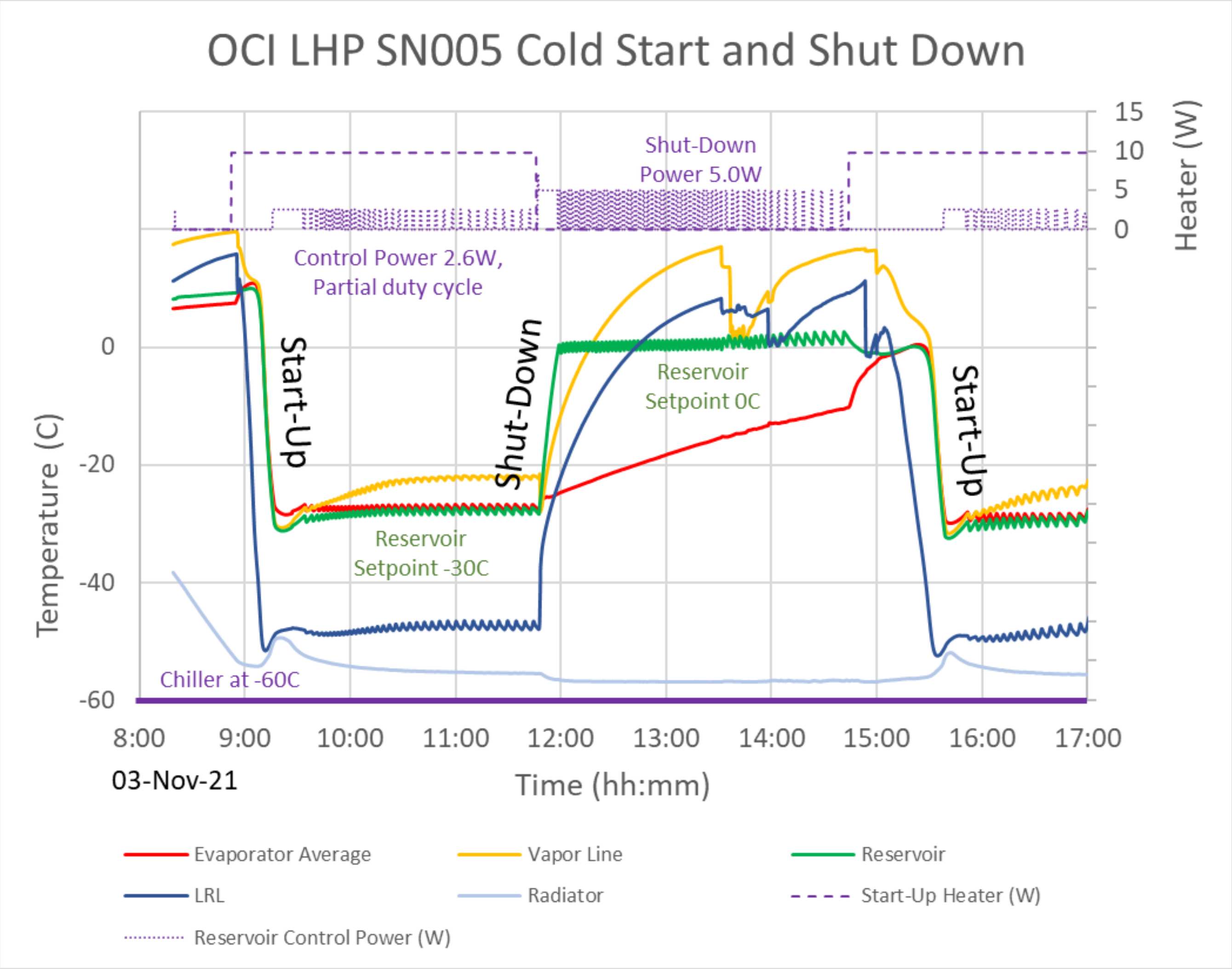
Propylene Loop Heat Pipe Design and Thermal Performance

- Test Setup

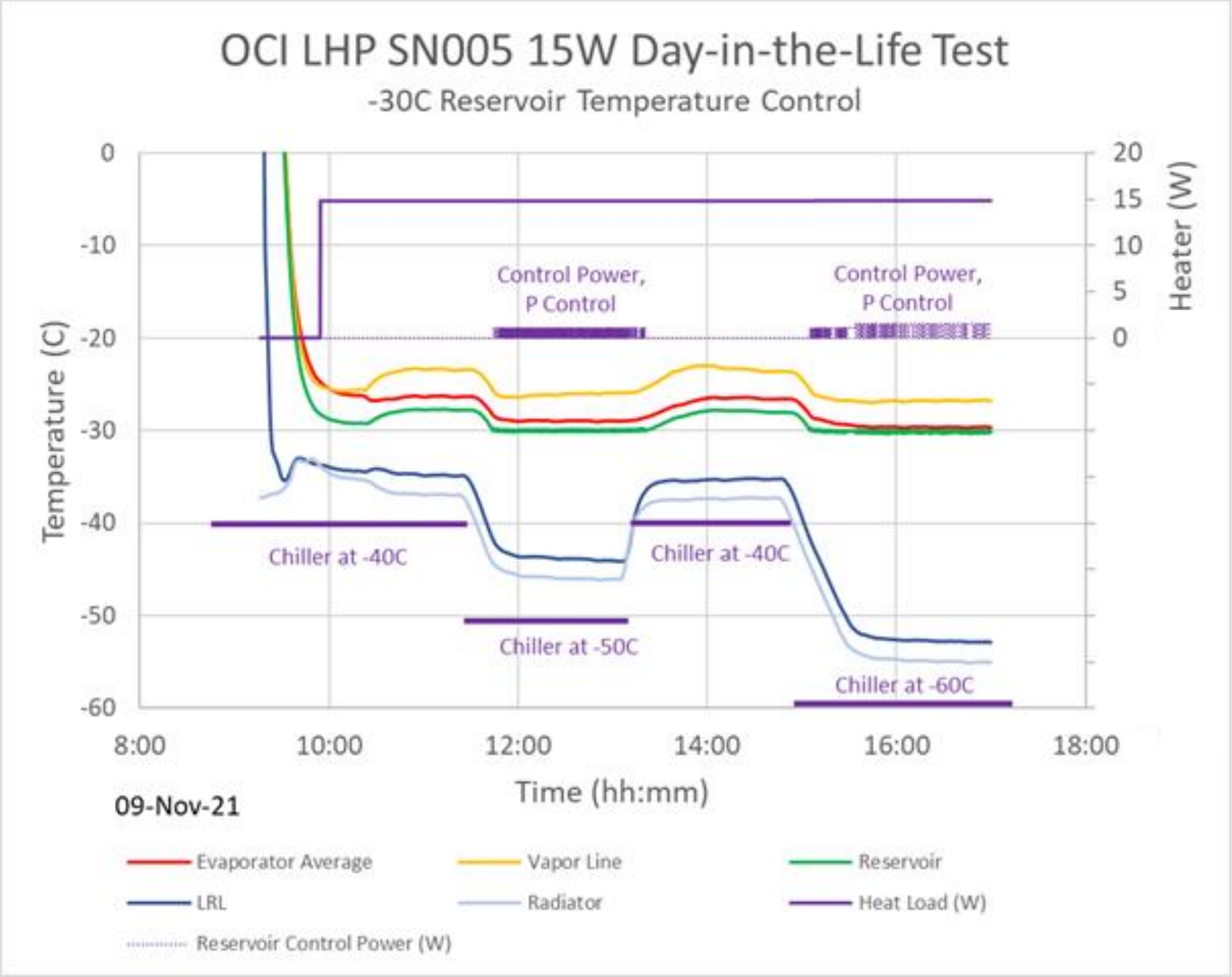

Propylene Loop Heat Pipe Design and Thermal Performance

- Cold Start
  - Chiller circulating at -60C
  - Reservoir setpoint to -30C
  - Apply 10W to Start-up heaters
- Shutdown Test
  - Remove heat from Start-up
  - Reservoir setpoint to 0C
    - Hotter than evaporator, 5W



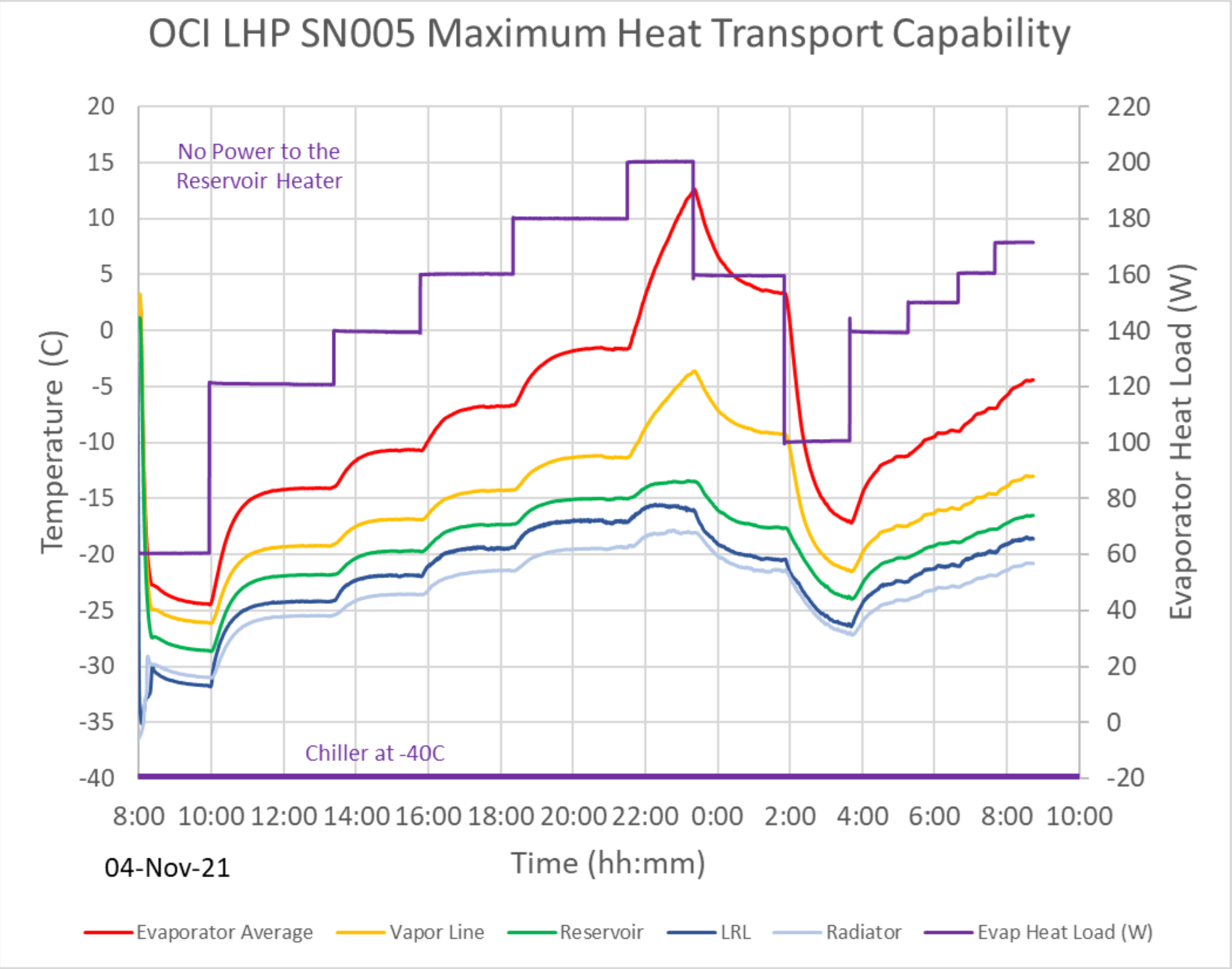
Propylene Loop Heat Pipe Design and Thermal Performance

- 15W Day-in-the-Life
  - Apply 15W to Evaporator
  - Set Reservoir to -30C
  - Set Radiator Chiller to -40C
  - Circulate to steady state
  - Set Radiator Chiller to -50C
  - Circulate to steady state
  - Set Radiator Chiller to -40C
  - Circulate to steady state
  - Set Radiator Chiller to -60C
  - Circulate to steady state

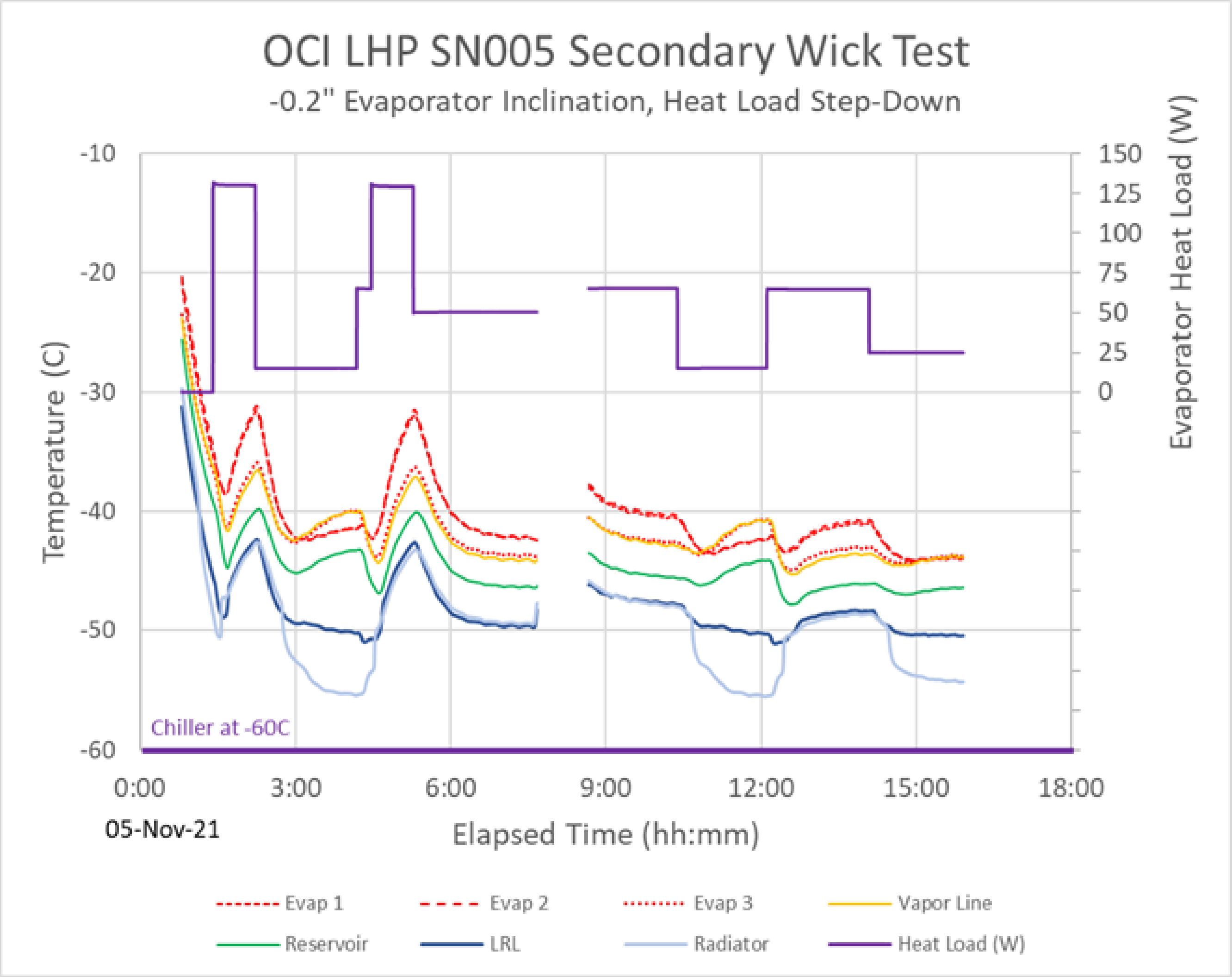


Propylene Loop Heat Pipe Design and Thermal Performance

- Maximum Heat Transport Capability
  - Set chiller at -40C
  - Gradually step up heat load until Evaporator temperature diverges
  - SN001 200W
  - SN002 180W
  - SN003 180W
  - SN004 160W
  - SN005 180W
  - SN006 155W

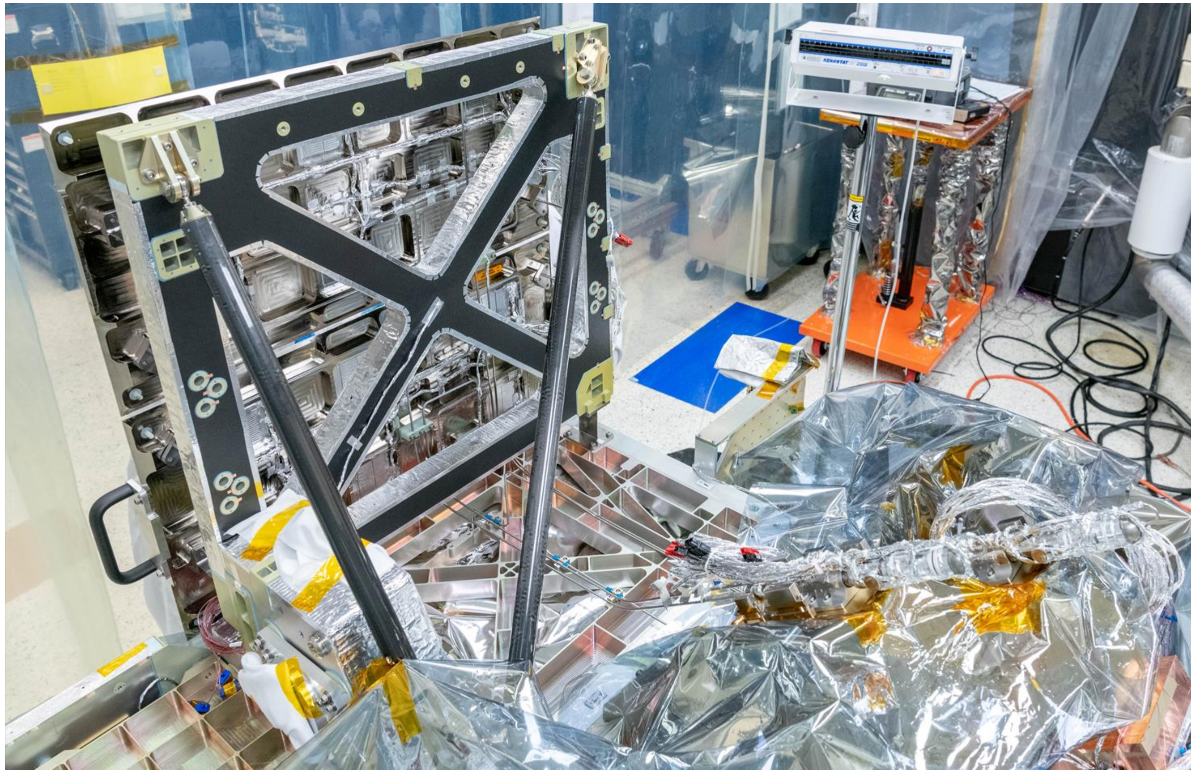


- Heat Load Step-Down (Secondary Wick Test)
  - Set chiller at -60C
  - Go through these Heat Load Steps:
    - 130W to 15W
    - 130W to 50W
    - 65W to 15W
    - 65W to 25W
  - Confirm that the Evaporator does not dryout



Propylene Loop Heat Pipe Design and Thermal Performance

- 6 loop heat pipes were delivered
  - 3 UVVIS
  - 3 VISNIR
- 1 pair has been installed on the OCI
- Satellite level Integration and Test activities completed
- Launch is planned for Jan 2024



PACE OCI Thermal Control System

- The OCI thermal control system employs two propylene Loop Heat Pipes (LHP). These LHPs transfer heat from the Focal Plane Array (FPA) sensors and electronic boxes of the OCI instrument to the radiator panels. The radiators reject heat into space.
- The TVAC testing of the flight and spare LHPs completed at GSFC.