



The Flow Boiling and Condensation Experiment (FBCE) Flight Testing and Capabilities

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TFAWS

GSFC • 2023

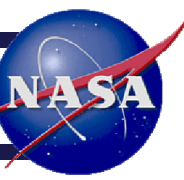
Thermal & Fluids Analysis Workshop

TFAWS 2023

August 21-25, 2023

NASA Goddard Space Flight Center

Greenbelt, MD



Outline

- Flow Boiling and Condensation Experiment (FBCE) Overview
- Capabilities
- Completed Testing
 - Flow Boiling Test Module
- Future Testing
 - Condensation Test Module
 - Transfer Line Test Module
- Timeline of Testing

What is the FBCE?

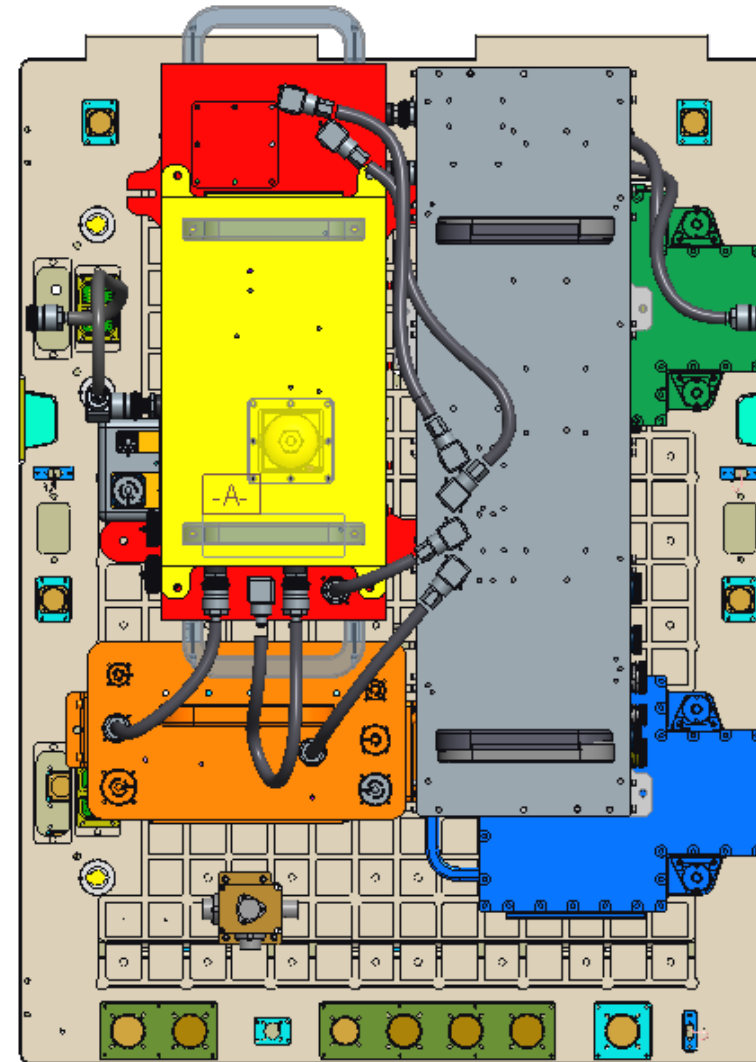
- The Flow Boiling and Condensation Experiment (FBCE) is an integrated two-phase flow facility operating in the Fluids Integrated Rack (FIR) aboard ISS.
- The FBCE serves as a primary platform for obtaining flow boiling and condensation heat transfer data in microgravity.



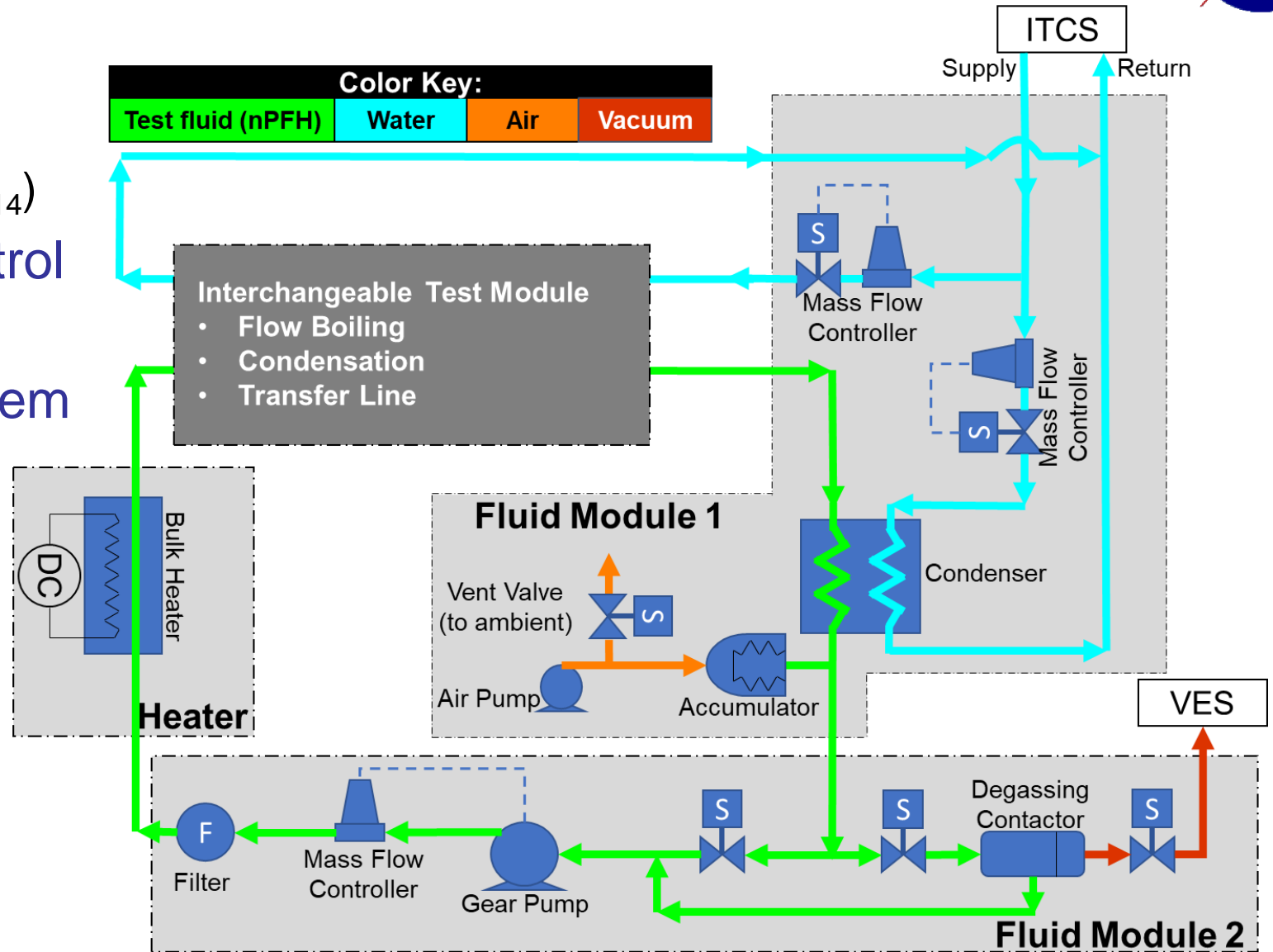
FBCE in the FIR Ground Integration Unit (GIU) at GRC

FBCE Modules:

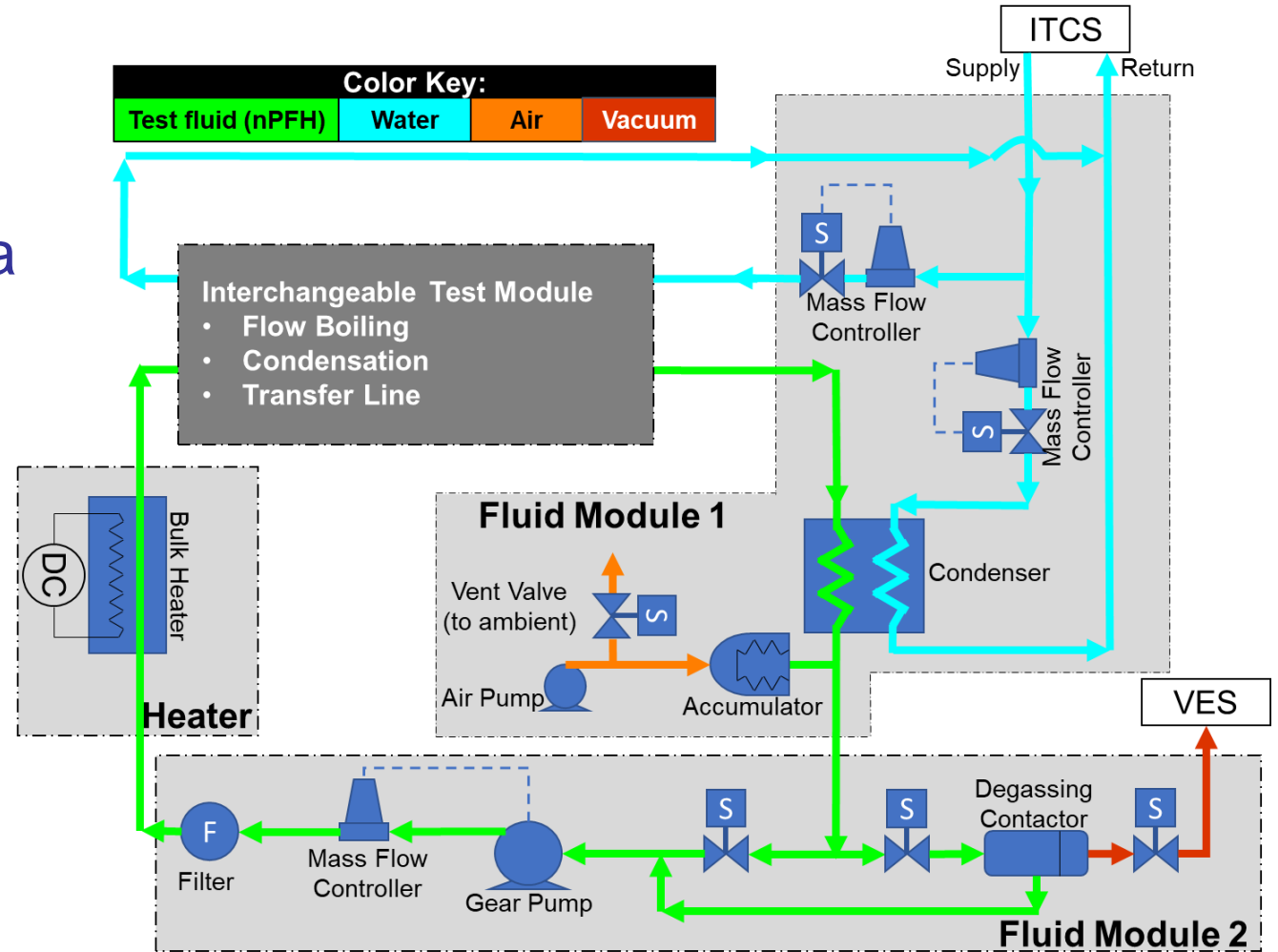
- **Heater Module**
- **Fluid Module 1**
- **Fluid Module 2**
- **Avionics 1**
- **Avionics 2**
- **Test Module** (1 of 3 installed):
 - Flow Boiling Test Module
 - Condensation Test Module
 - Transfer Line Module (under development)
- **Power Filter Module - Not Shown**

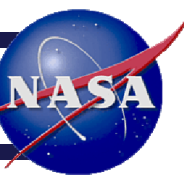


- Test Fluid: nPFH
 - normal-Perfluorohexane (C_6F_{14})
- ITCS: Internal Thermal Control System
- VES: Vacuum Exhaust System



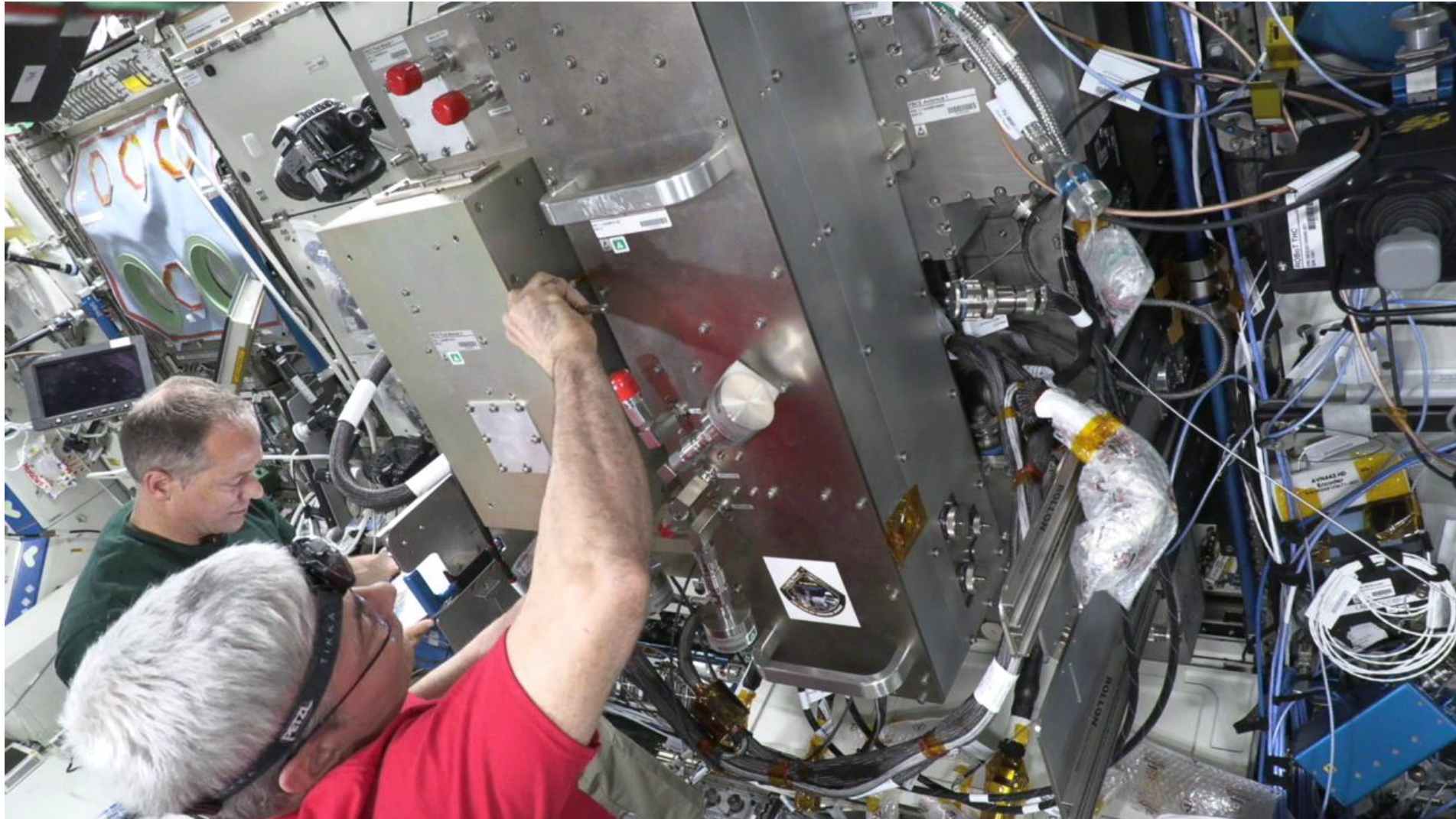
- Test Fluid Flow: 2.5-40 g/s
- Heater Power: 0-1500 W
- Test Fluid Pressure: ~12.5-21 psia
 - Measured at accumulator outlet
 - Test module inlet pressure is dependent on flow rate and accumulator set pressure
- ITCS Water Flow: 0 – 40 g/s
 - Combined between both loops





Flow Boiling Test Module

- The Flow Boiling Test Module is the first module to be integrated with the FBCE facility hardware
- It is intended to gather flow boiling data in microgravity
- Areas of Impact: Correlations made with this data will help to enable design of Rankine cycle power systems, and two-phase thermal control systems for spaceflight applications

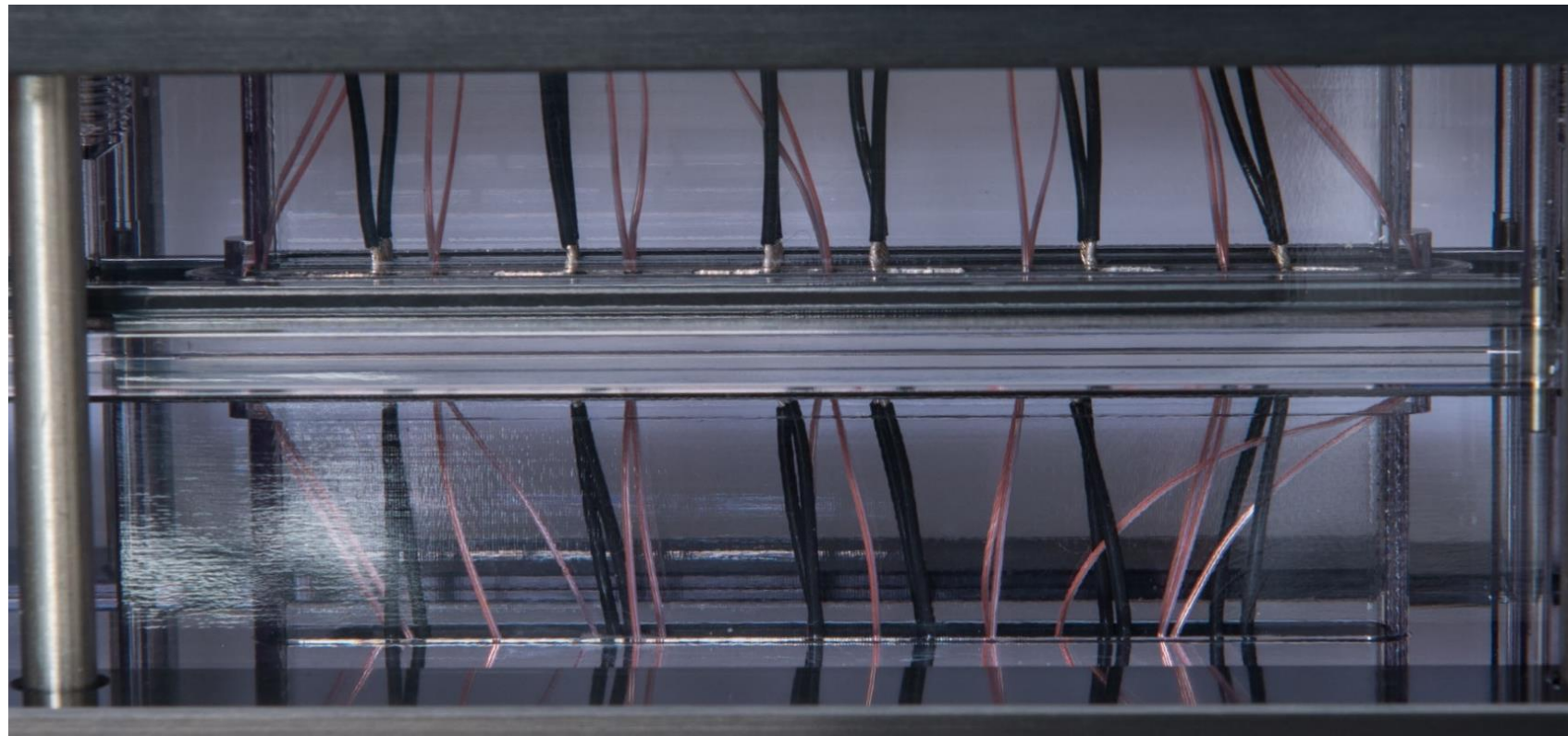


Mark Vande Hei installing the FBCE into FIR aboard ISS

Mock-up of the Flow Boiling Test Module copper strip heaters



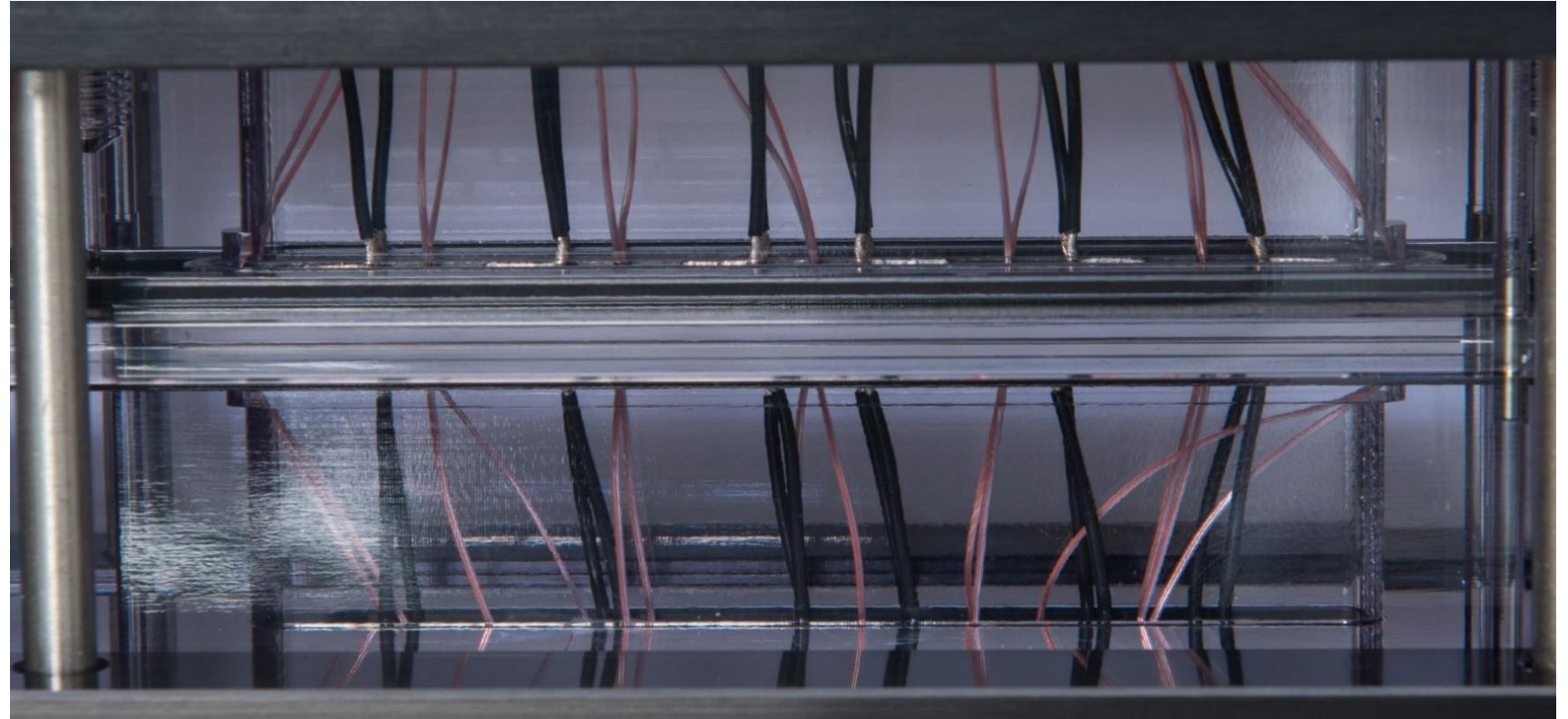
Flow Boiling Test Module Test Section



Mock up of the Flow Boiling Test Module copper strip heaters



Flow Boiling Test Module Test Section



Flow Boiling captured with the Flow Boiling Test Module high speed camera



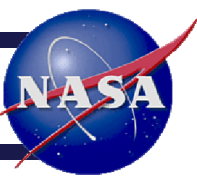
Flow Boiling Module Testing



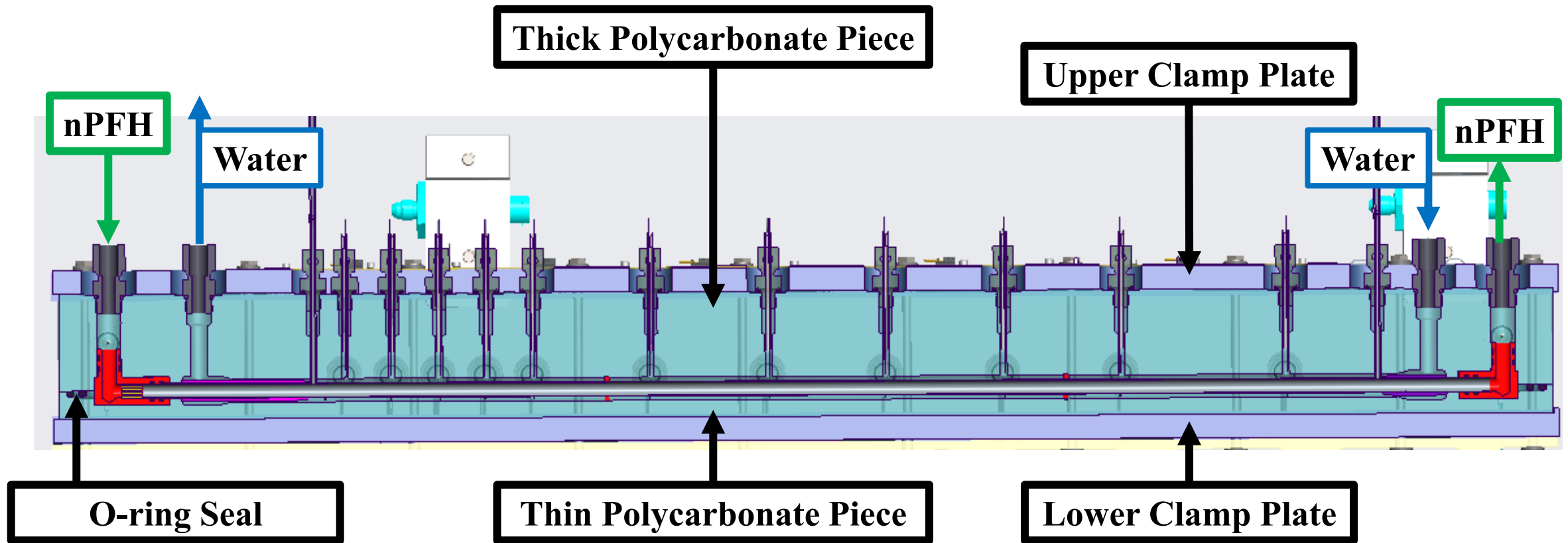
- 3 Teams of Principal Investigators
 - Purdue
 - University of South Carolina (USC)
 - Rensselaer Polytechnic Institute (RPI)/New Jersey Institute of Technology (NJIT)
- Science: Feb,2022-Jul,2023
 - Was originally intended for 3 months of science operations
- Issues
 - Test Fluid Leak: Need for refill stopped operations for ~ 2 months from Mid September to Mid November 2022
 - Backlight LED Issues
- Scheduled for return on SpaceX 29 (~Jan 2024)



Condensation Test Module

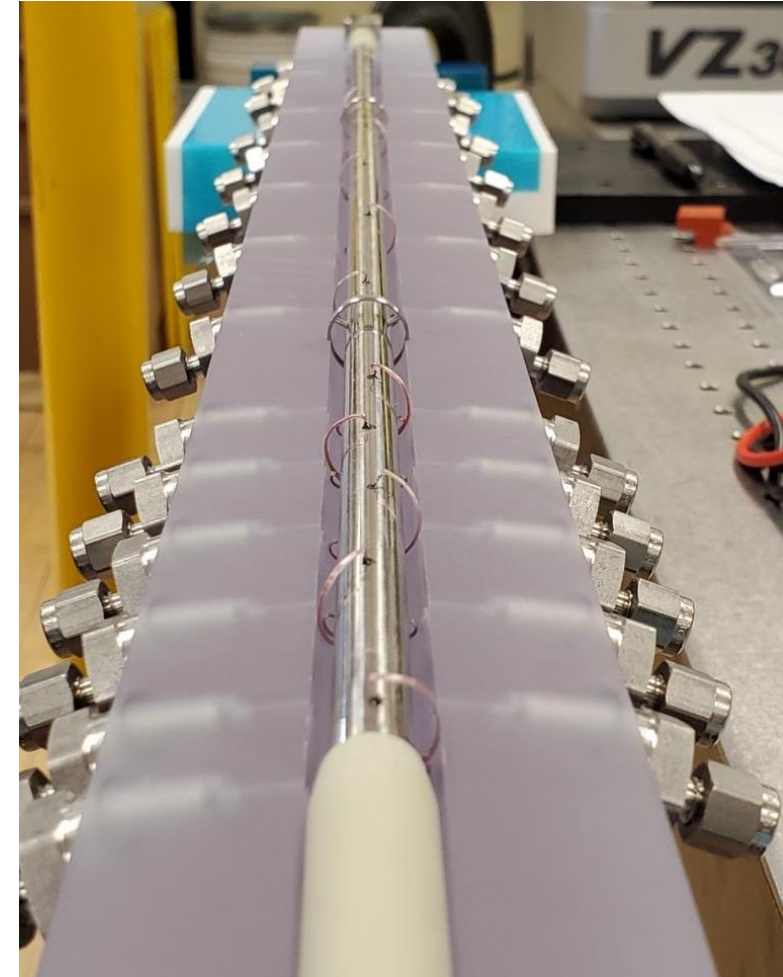


- The Condensation Test Module is the second module to be integrated with the FBCE facility hardware
- It is intended to gather flow condensation data in microgravity
- Areas of Impact: Correlations made with this data will help to enable design of Rankine cycle power systems, and two-phase thermal control systems for spaceflight applications





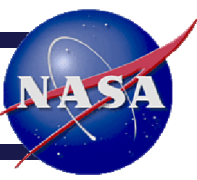
Condensation Test Module assembled polycarbonate Test Section



Condensation Test Module SS tube assembled into the thick polycarbonate piece

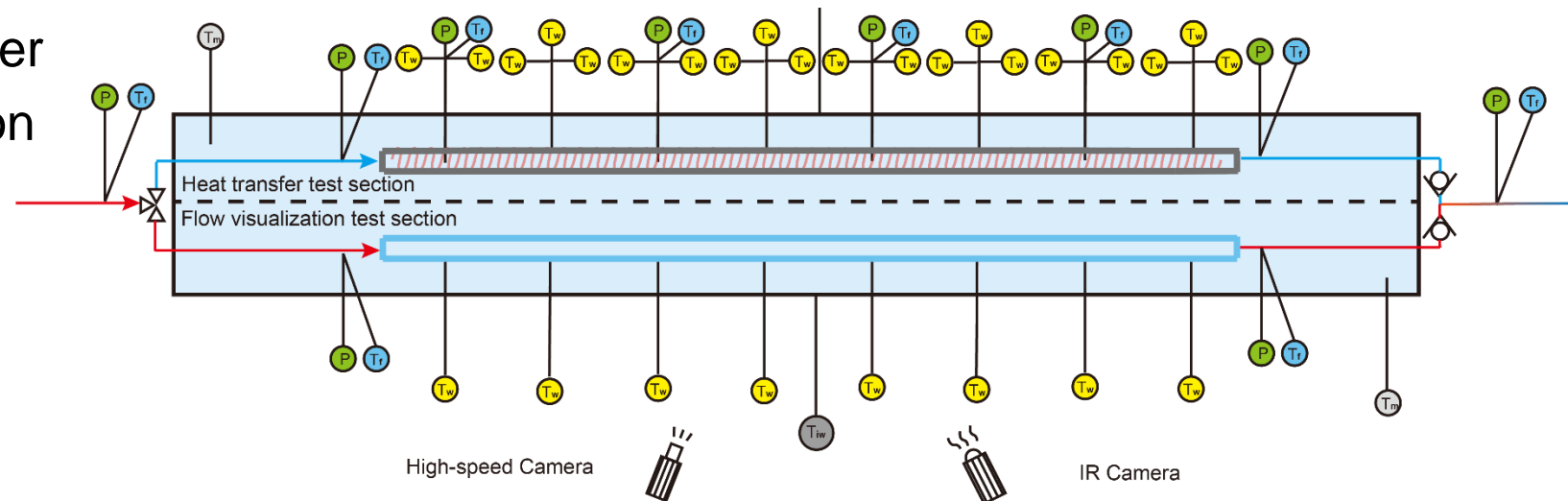


Condensation Test Module Testing

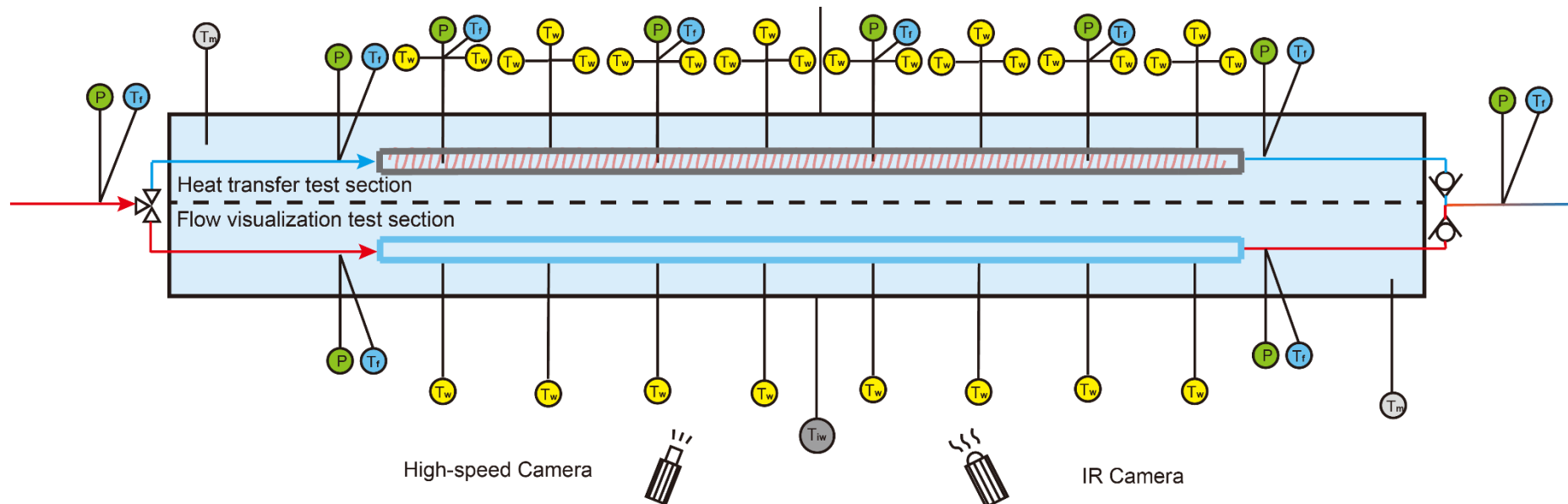


- 3 Teams of Principal Investigators
 - Purdue
 - University of South Carolina (USC)
 - Rensselaer Polytechnic Institute (RPI)/New Jersey Institute of Technology (NJIT)
- Current Schedule
 - Launch early-August aboard NG-19
 - Integration in late-August
 - Checkout testing late August through mid-September
 - Science beginning mid to late-September
- One year of science currently planned
 - Purdue (6 months)
 - USC (3 months)
 - RPI/NJIT (3 months)

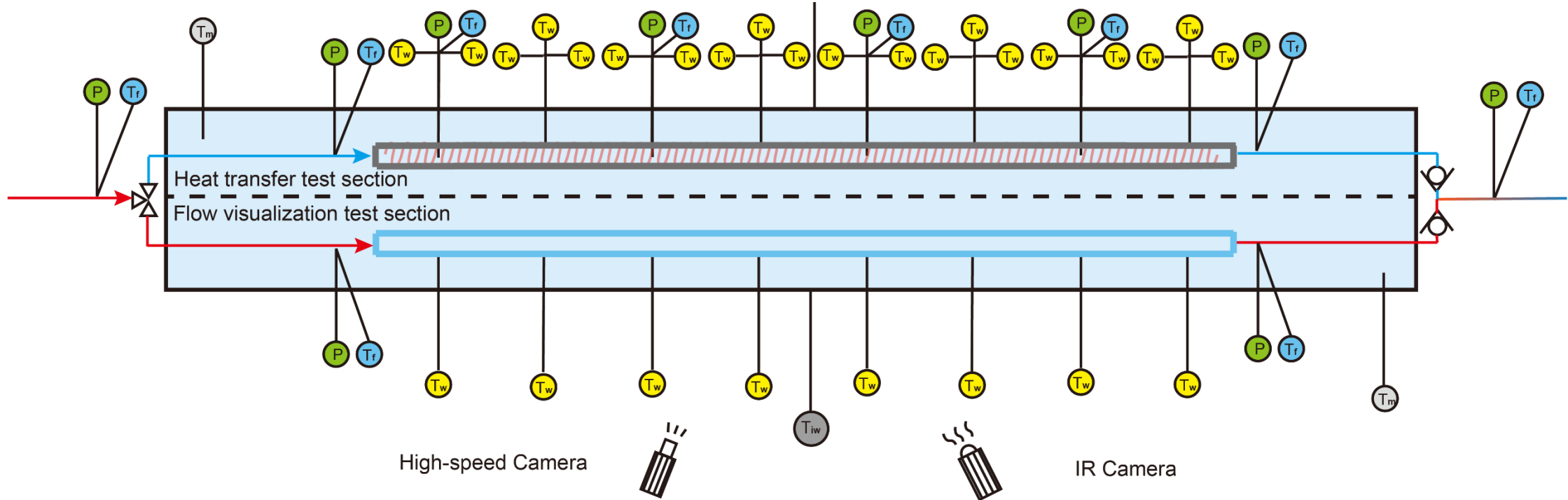
- Intended to investigate line chilldown in microgravity
 - Relevant to cryogenic in-space cryogenic tank-to-tank transfer
- Two teams of Researchers:
 - University of Illinois Urbana Champagne (UIUC)
 - Case Western Reserve University (CWRU)
- Requirements are currently being defined
- Two test sections:
 - Stainless Steel Heat Transfer
 - Sapphire (TBD) Visualization



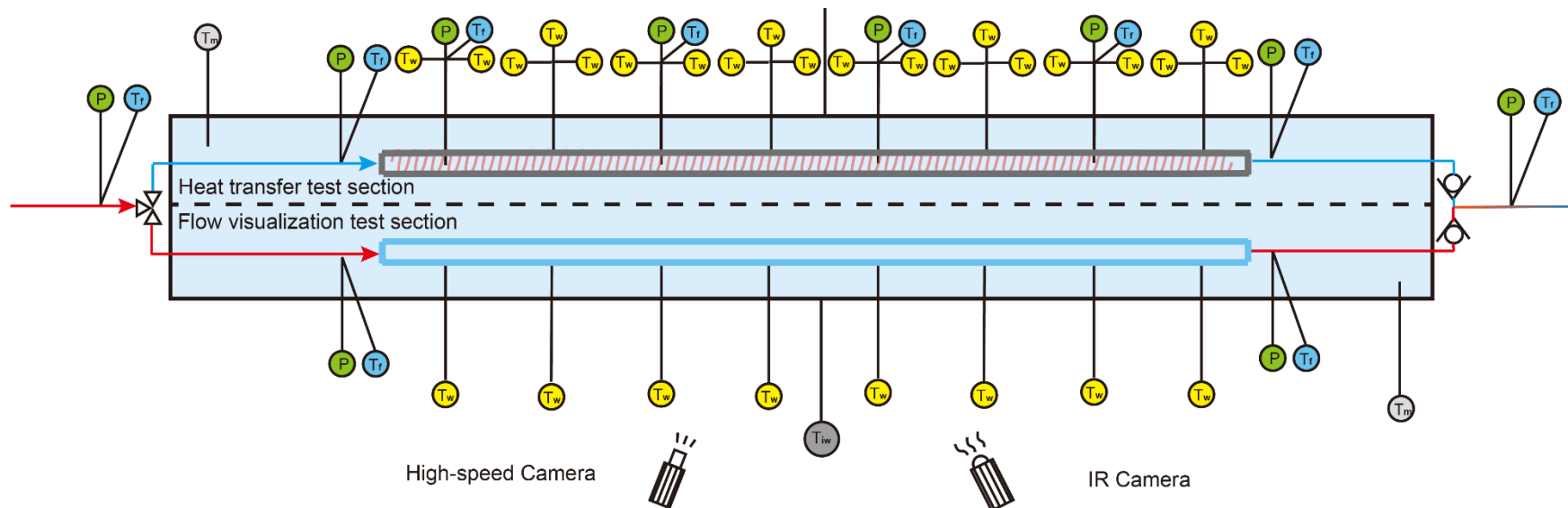
- Initial conditions:
 - Test section under test
 - Heated to desired temperature (entirely vapor)
 - Concurrently
 - Inlet conditions are achieved
 - Test section not under test acts as a bypass loop

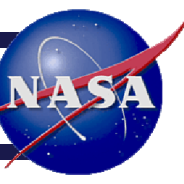


- Test:
 - Flow diverted from the bypass to the heated test section
 - Quenching occurs



- Completing requirements definition
- Investigating tube heating through direct electrification
 - Heat transfer test section: introducing electrical current directly to the SS tube
 - Visualization test section: introducing electrical current to a thin transparent, conductive coating on sapphire/quartz tubes
- Assembling a breadboard system





Timeline of Testing

- Flow Boiling Test Module testing completed 7/2023
- Condensation Test Module
 - Experiment operations scheduled 9/2023 through 9/2024
- Transfer Line Test Module
 - Experiment operations scheduled 1/2027 through 7/2027
- Options to close the gap in the schedule
 - Extend Condensation Test Module
 - Refurbish and re-fly the Flow Boiling Test Module
 - Accelerate Transfer Line Test Module Schedule

