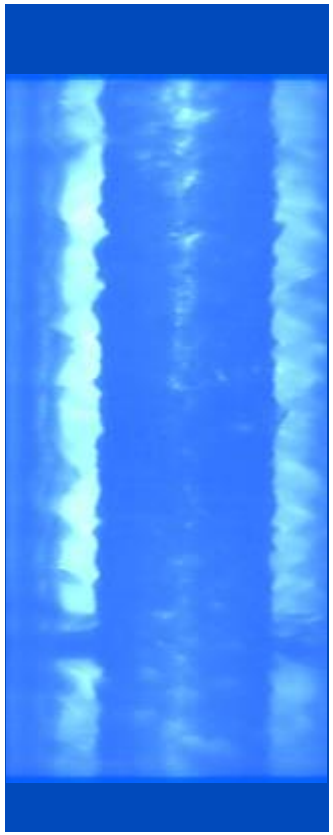
Flow Boiling and Condensation Experiment

Payload Design Overview

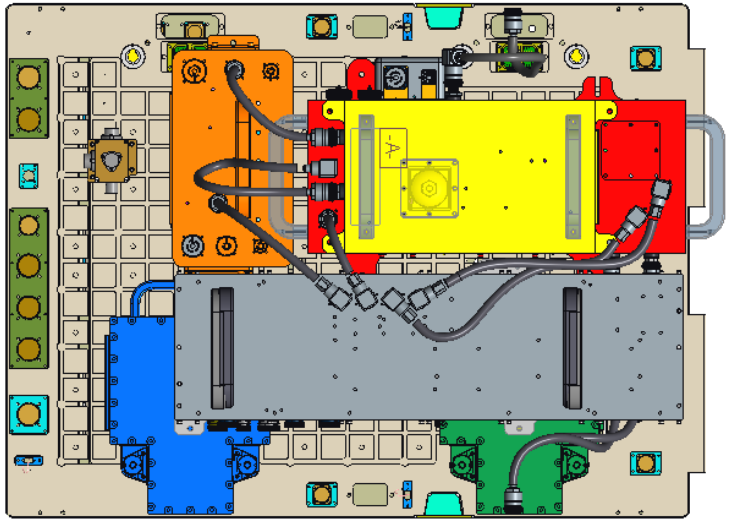
NASA SLPSRA Fluid Physics Workshop
NASA Glenn Research Center
Cleveland, Ohio

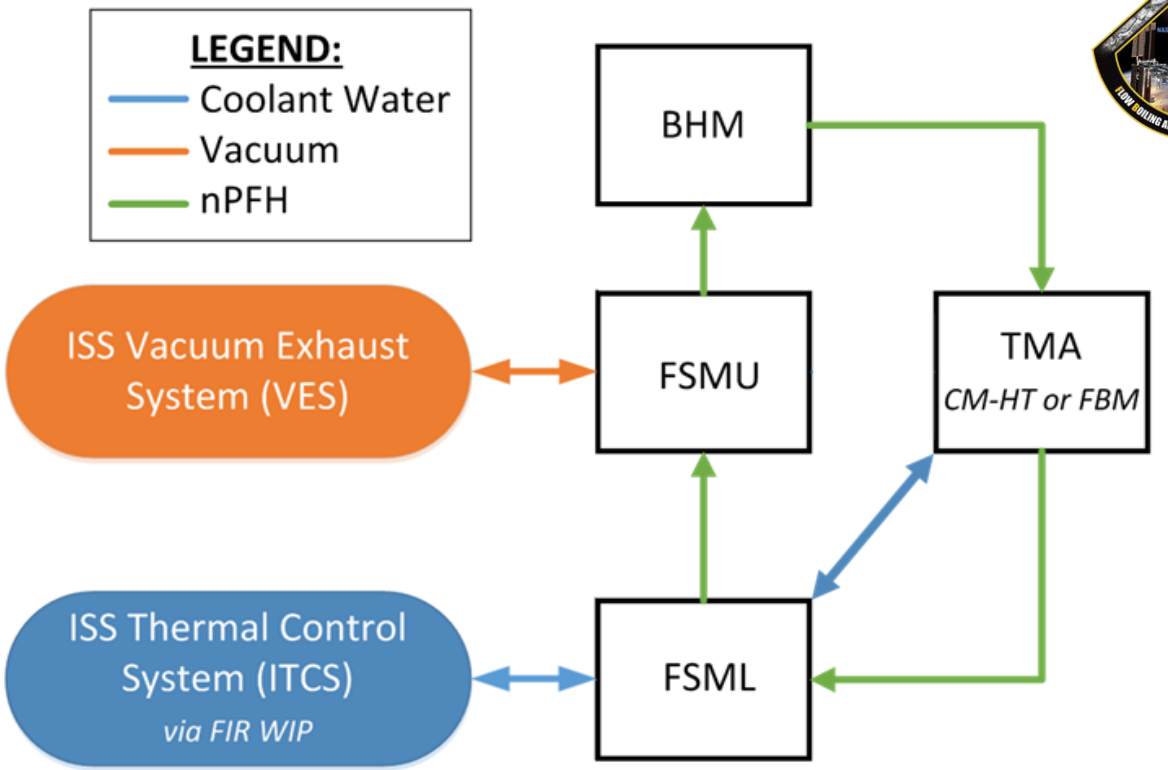
October 16-17, 2019

Monica C. Guzik, FBCE Payload Lead



FBCE System Overview





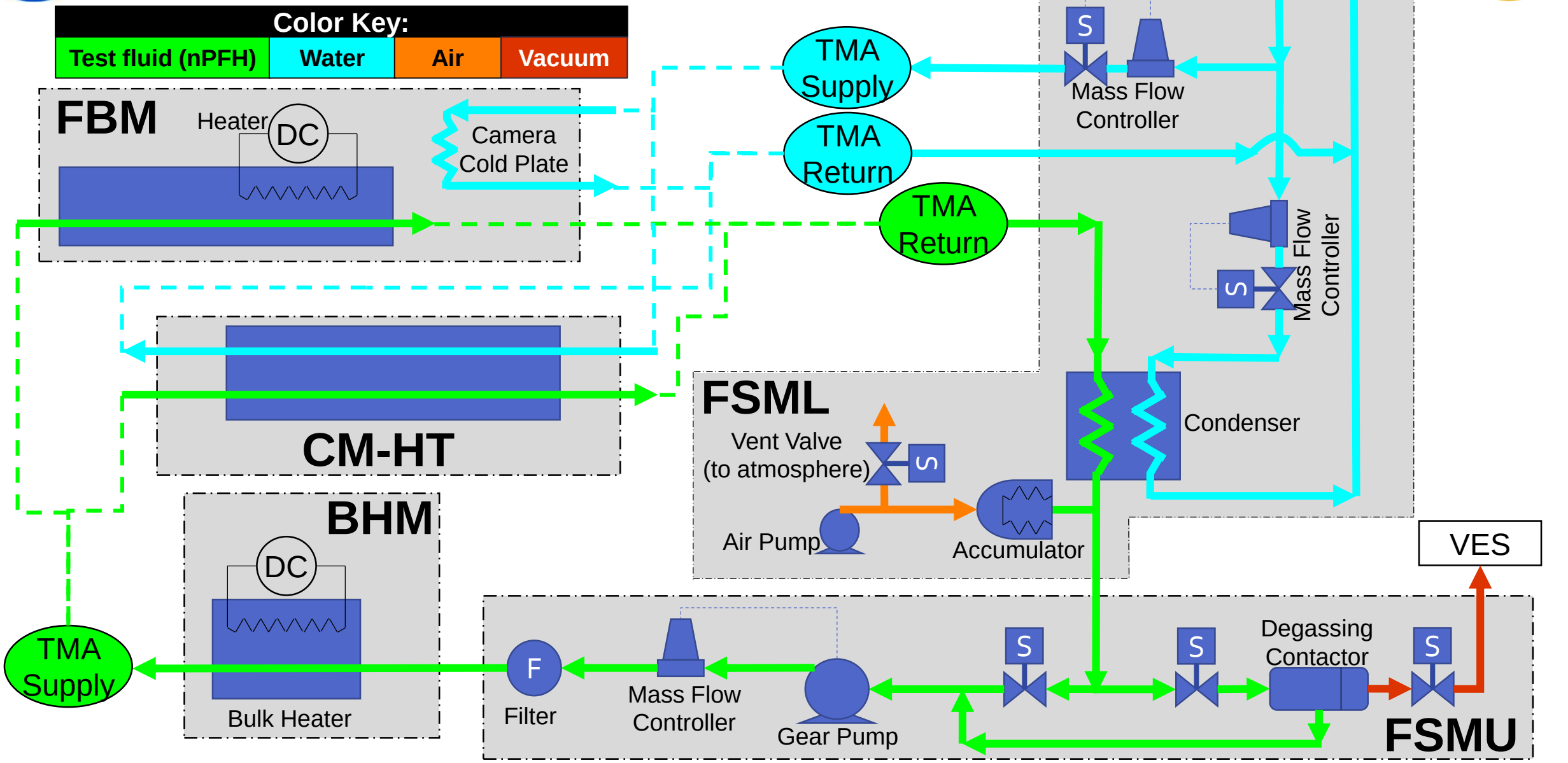
FBCE Modules:

- **BHM** – Bulk Heater Module
- **FSMU** – Fluids System Module - Upper
- **FSML** – Fluids System Module - Lower
- **RDAQM 1** – Remote Data Acquisition Module 1
- **RDAQM 2** – Remote Data Acquisition Module 2
- **TMA** – Test Module Assembly (1 of 2 installed):
  - **FBM** – Flow Boiling Module
  - **CM-HT** – Condensation Module - Heat Transfer

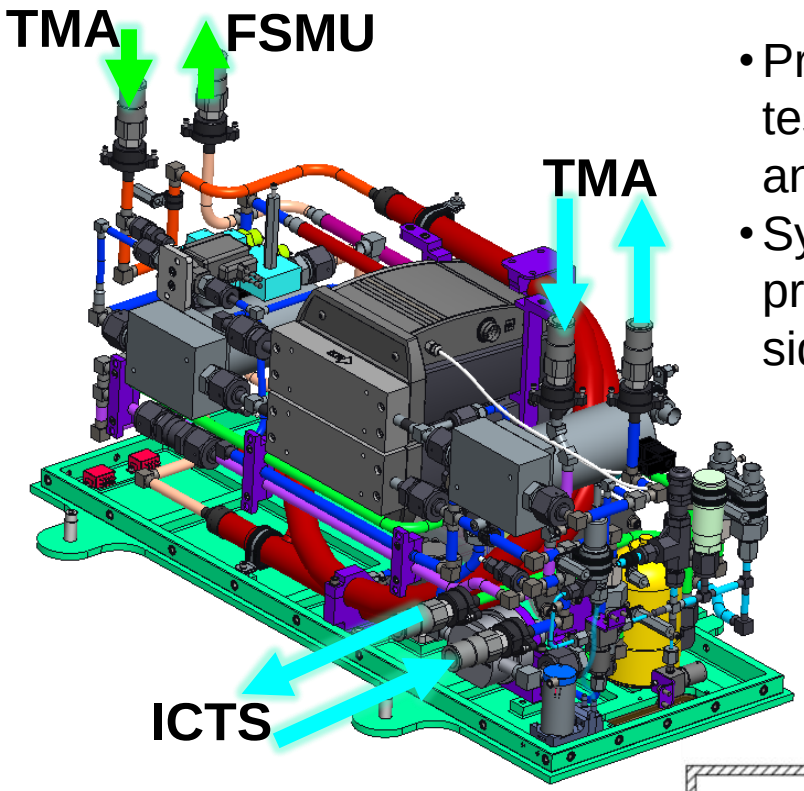
FIR Provided Hardware:

- SAMS – Space Acceleration Measurement System
- CCU – Confocal Control Unit (on back of rack)
- IPSU-CL – Imaging Processing Storage Unit – Camera Link (on back of rack)

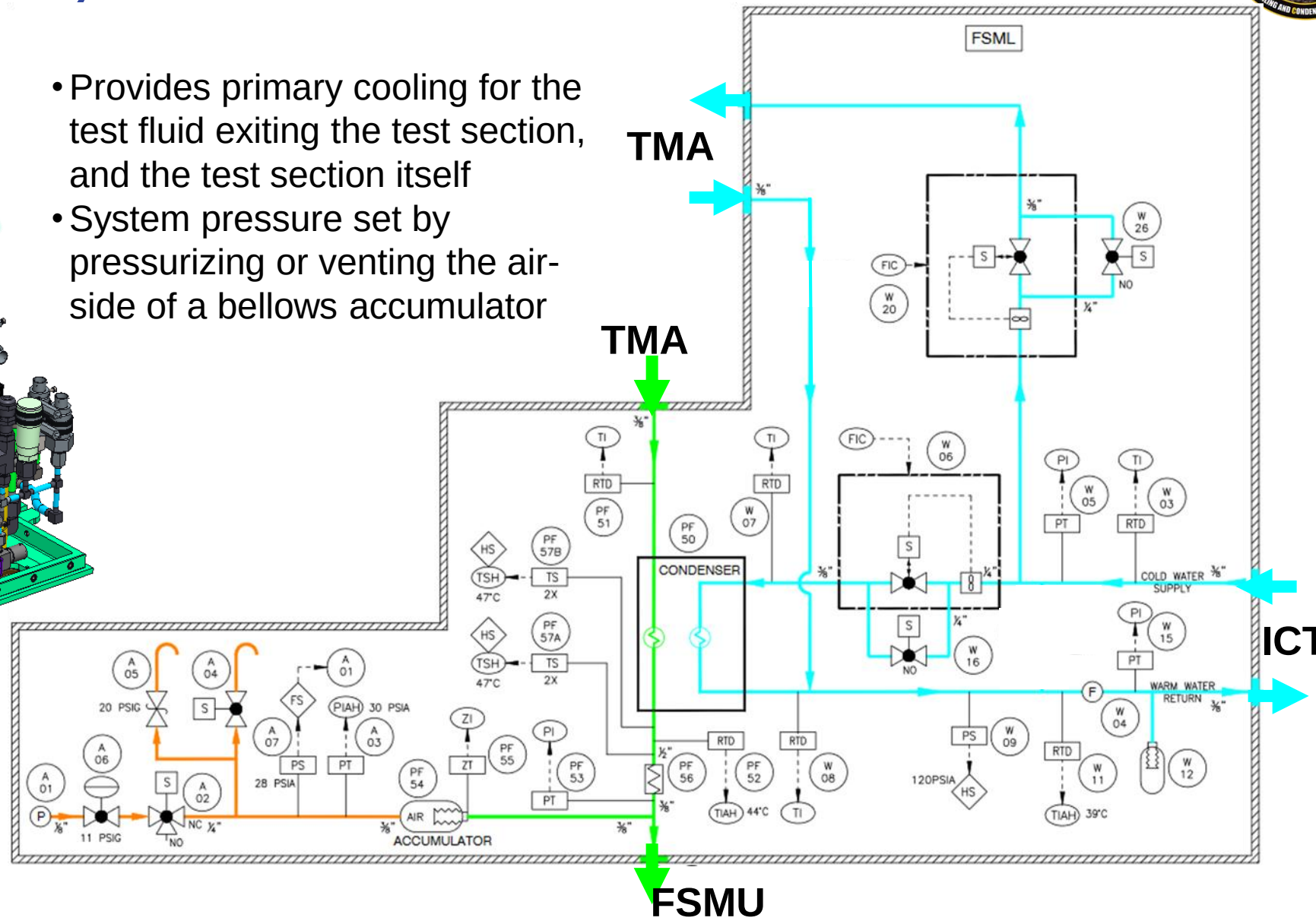
FBCE Fluid System Overview



FBCE Fluid System Module - Lower

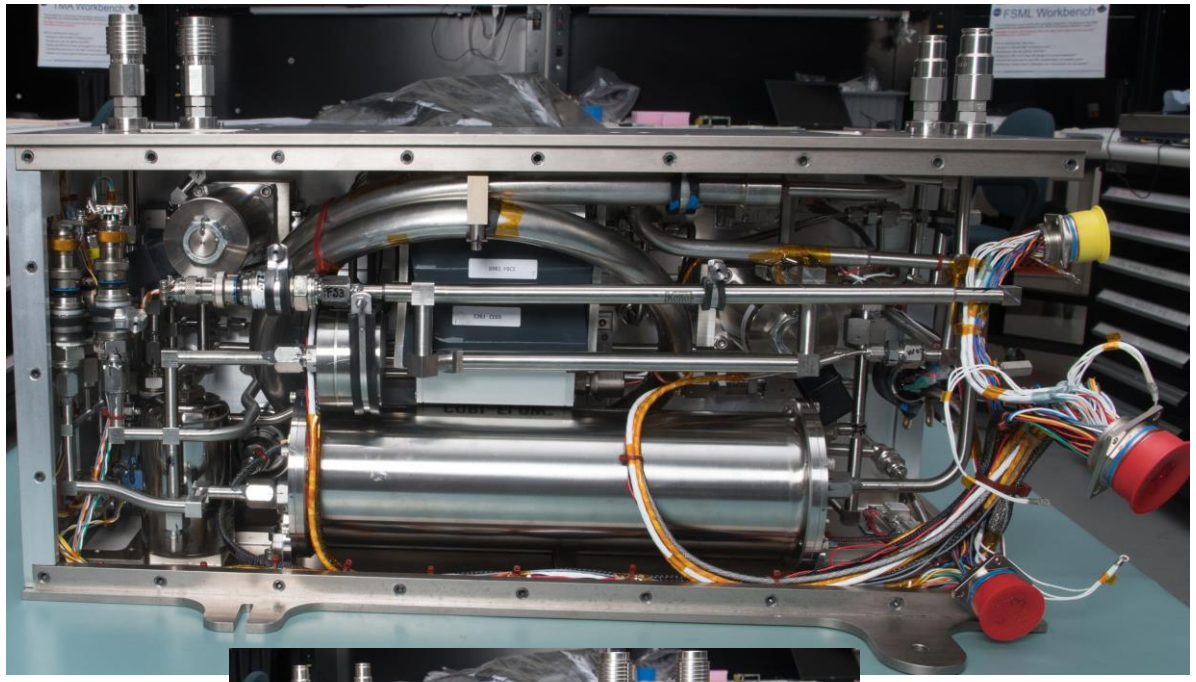


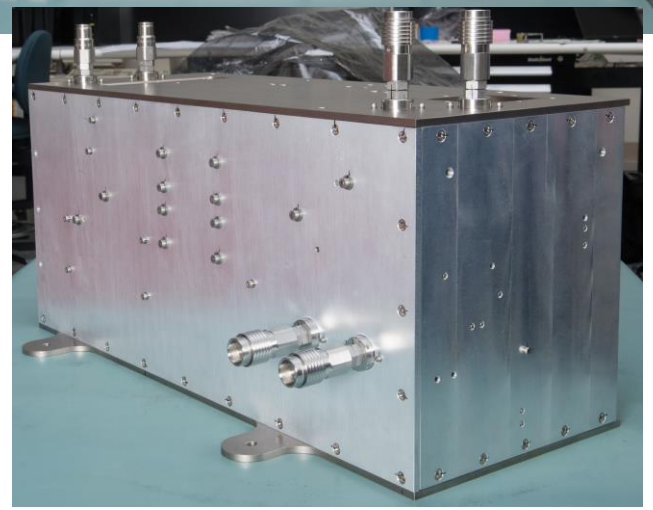
- Provides primary cooling for the test fluid exiting the test section, and the test section itself
- System pressure set by pressurizing or venting the air-side of a bellows accumulator

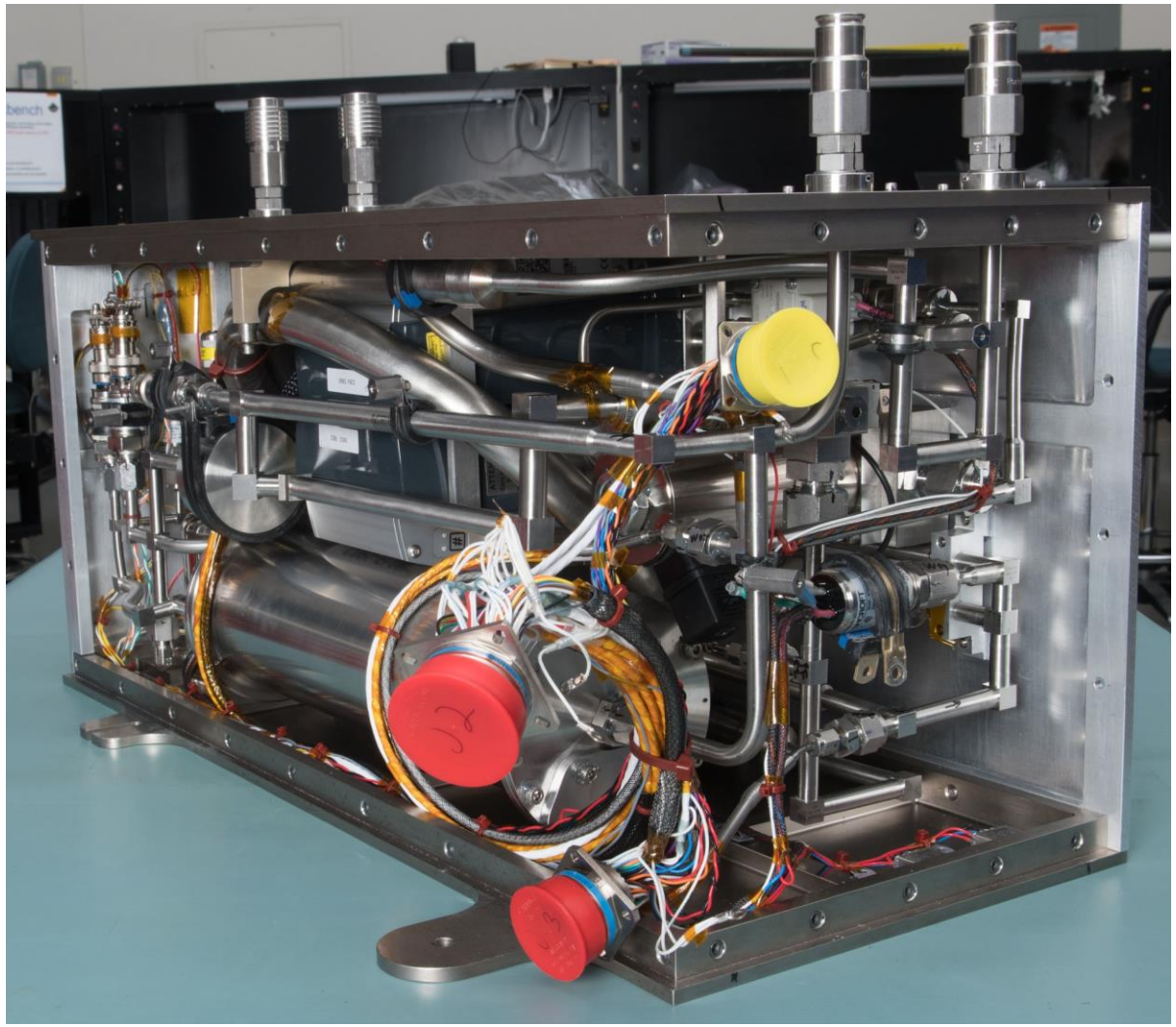


Color Key:		
Test fluid (nPFH)	Water	Air

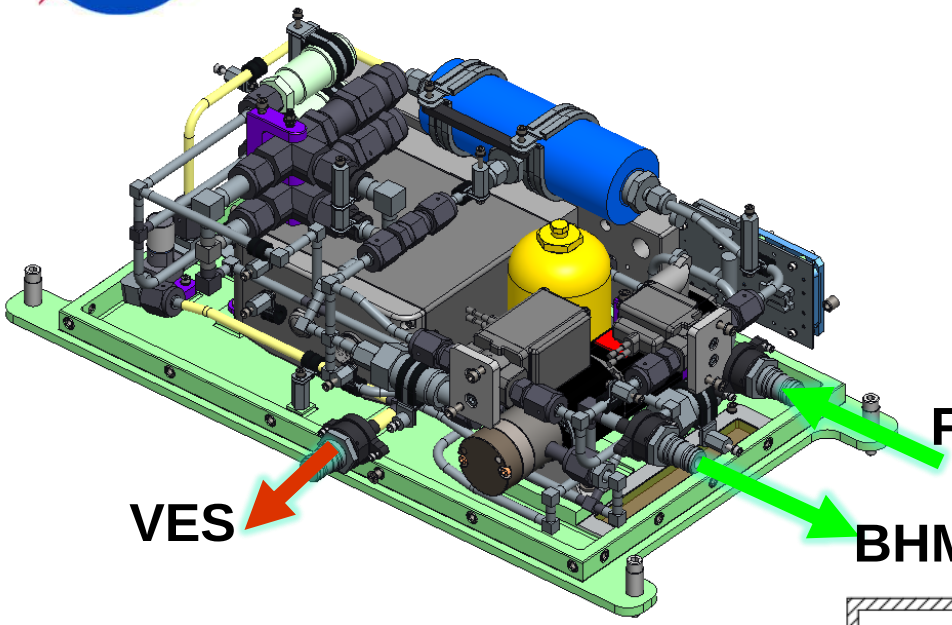
FBCE Fluid System Module - Lower



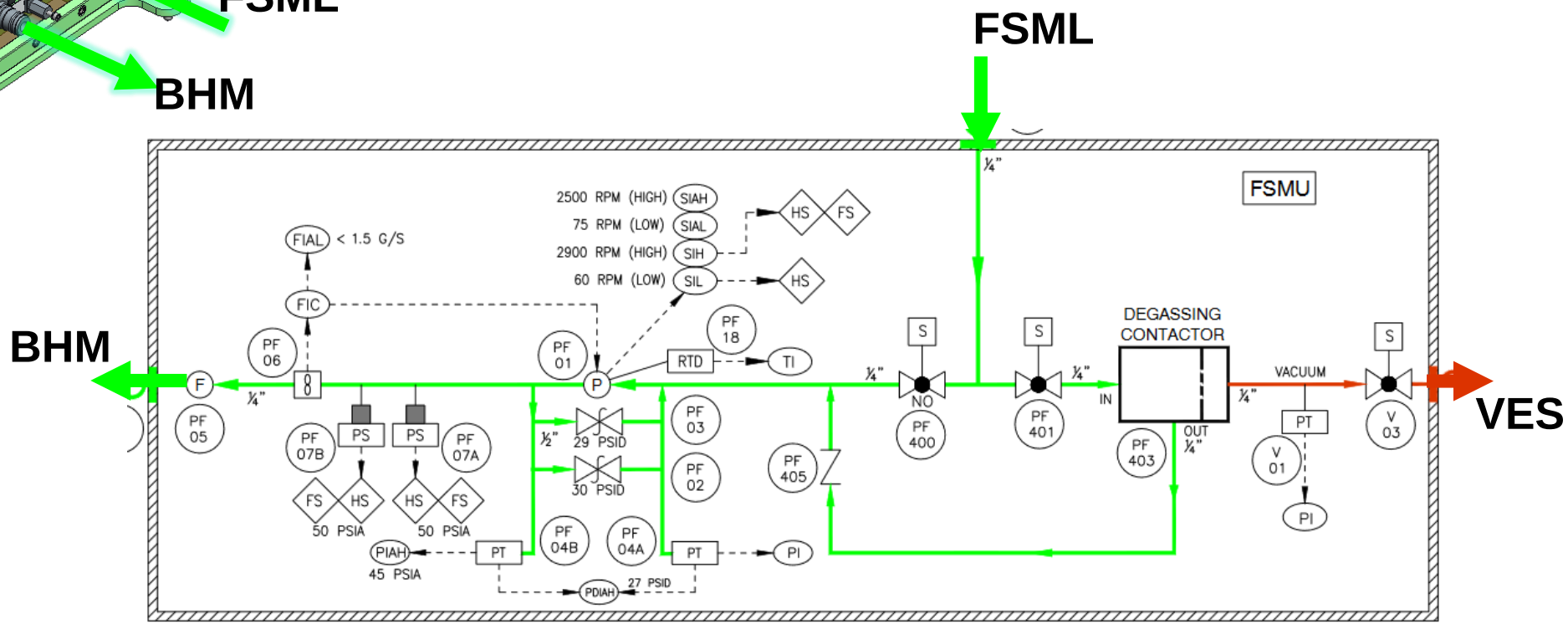




Fluid System Module - Upper

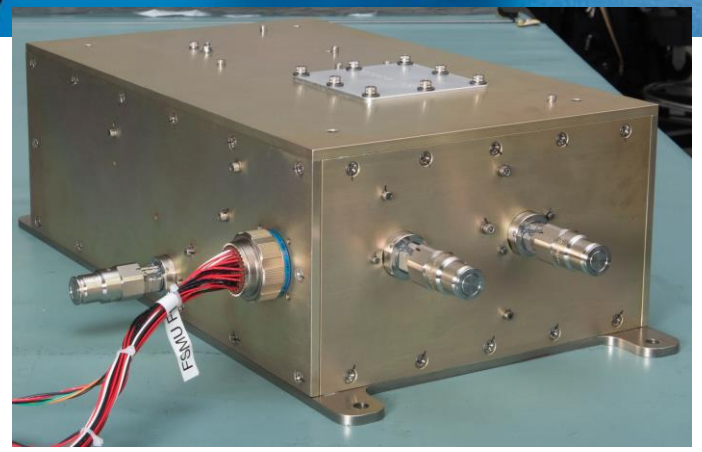


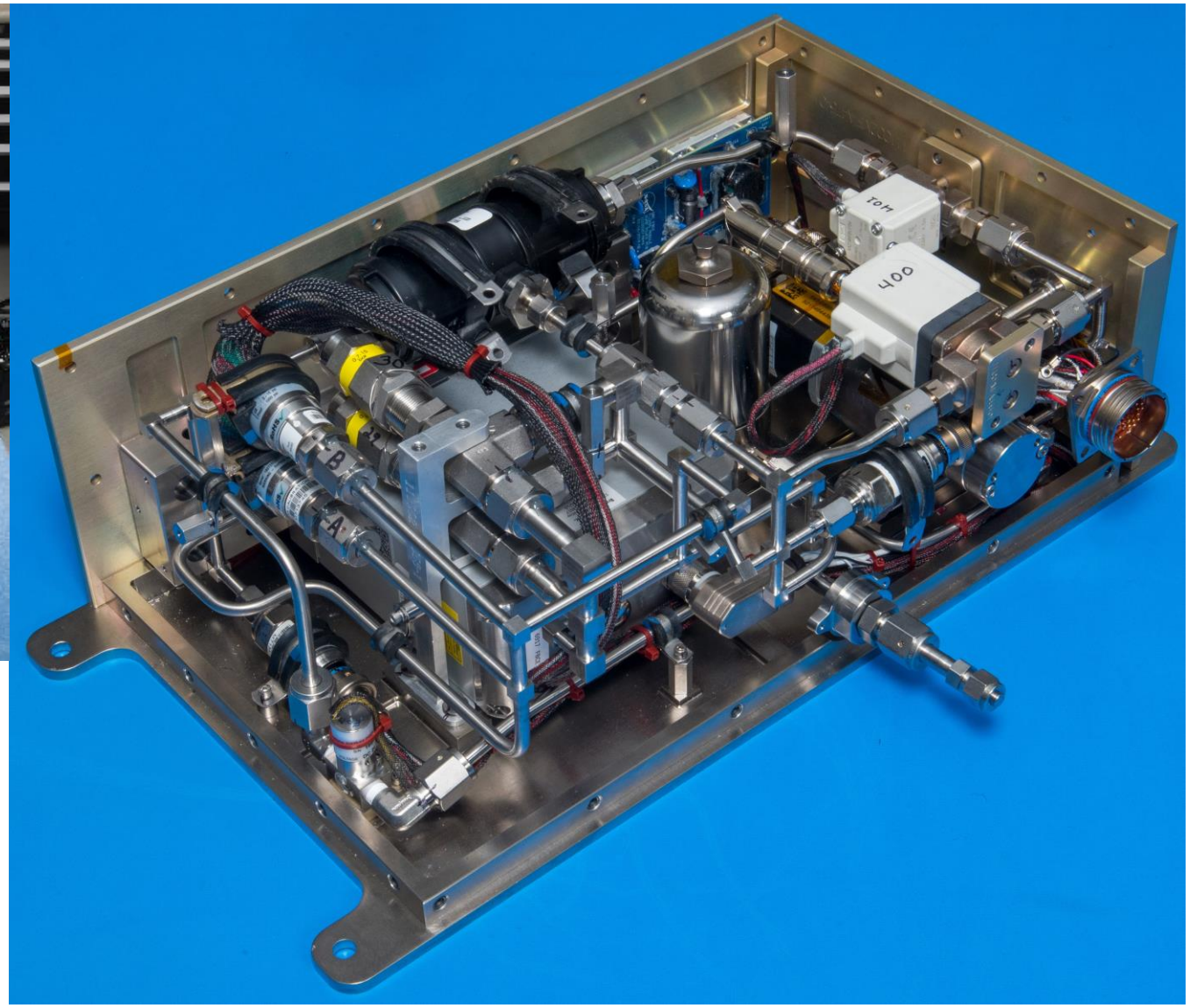
- Mass flow controller drives a gear pump to provide flow throughout the closed loop system
- Multiple controls in place to prevent over-pressurization
- Degassing contactor removes dissolved gases from test fluid when membrane exposed to vacuum



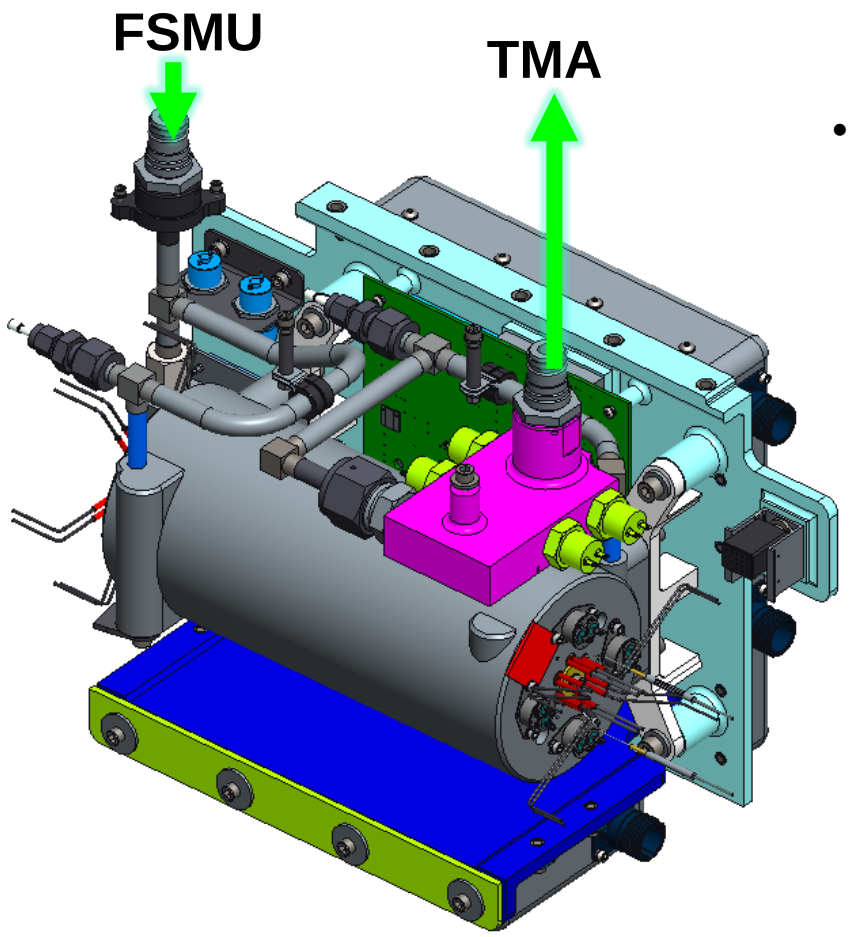
Color Key:	
Test fluid (nPFH)	Vacuum

FBCE Fluid System Module - Upper





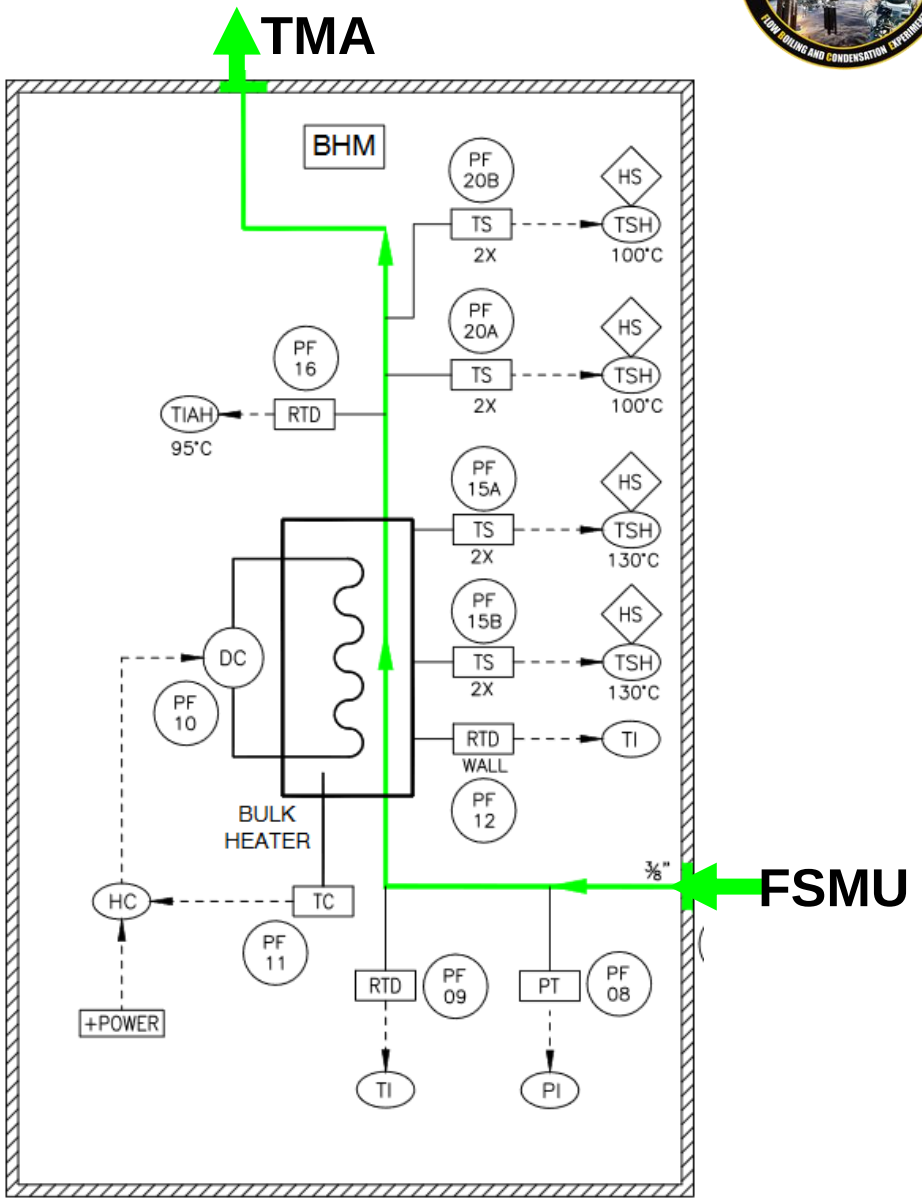
Bulk Heater Module



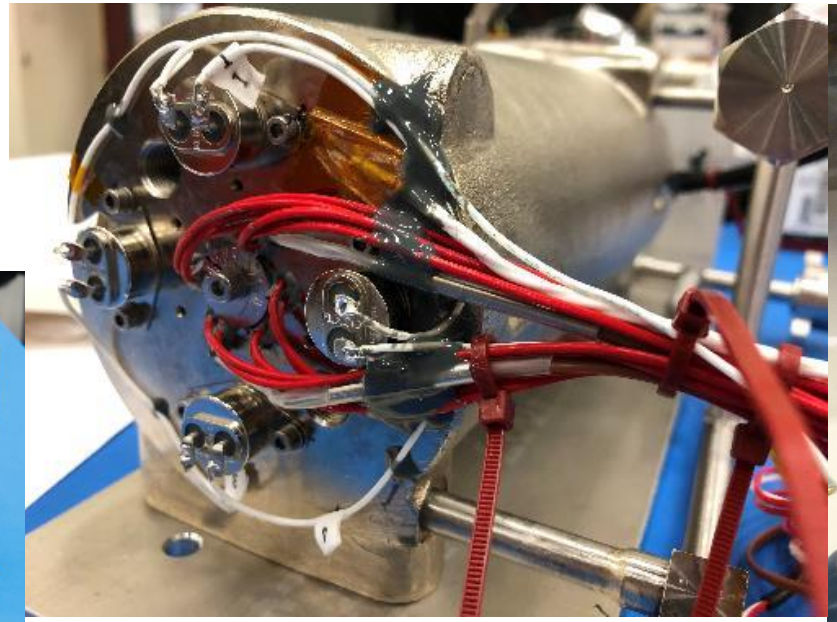
- Primary source of heating to condition test fluid to required test section inlet conditions
- Three 120V primary heaters and three 28V backup heaters can be operated at any time, with backup heaters available
  - Multiple safety devices in place to prevent overheating of the test fluid

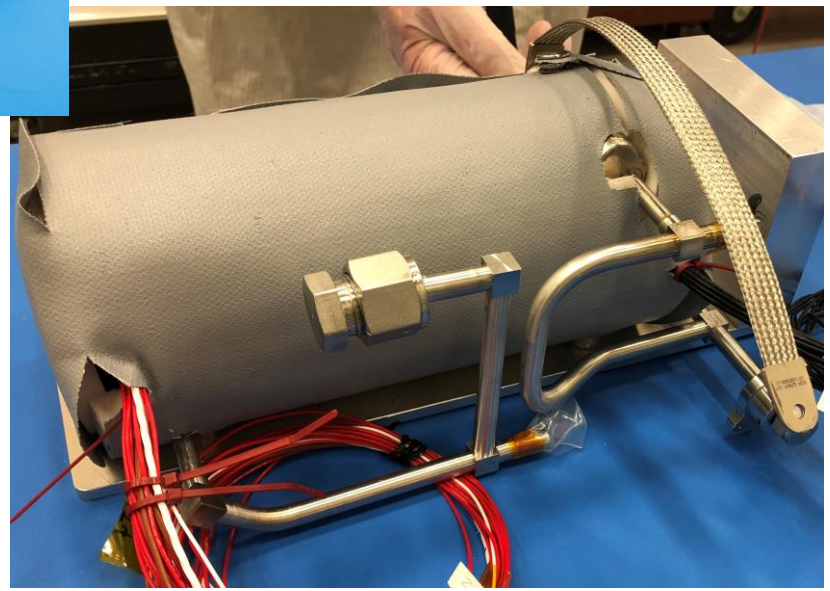
Color Key:

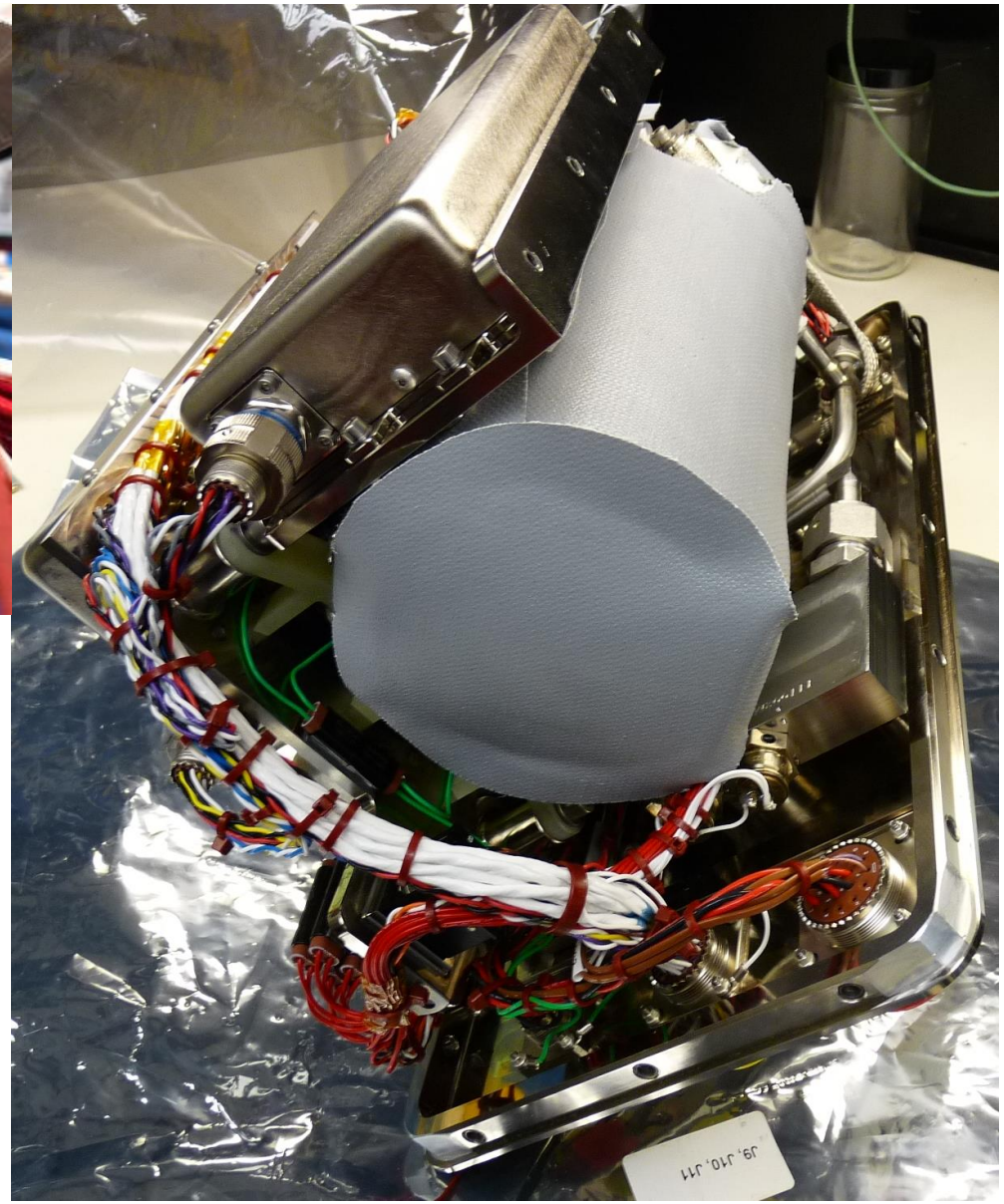
Test fluid (nPFH)



FBCE Bulk Heater Module

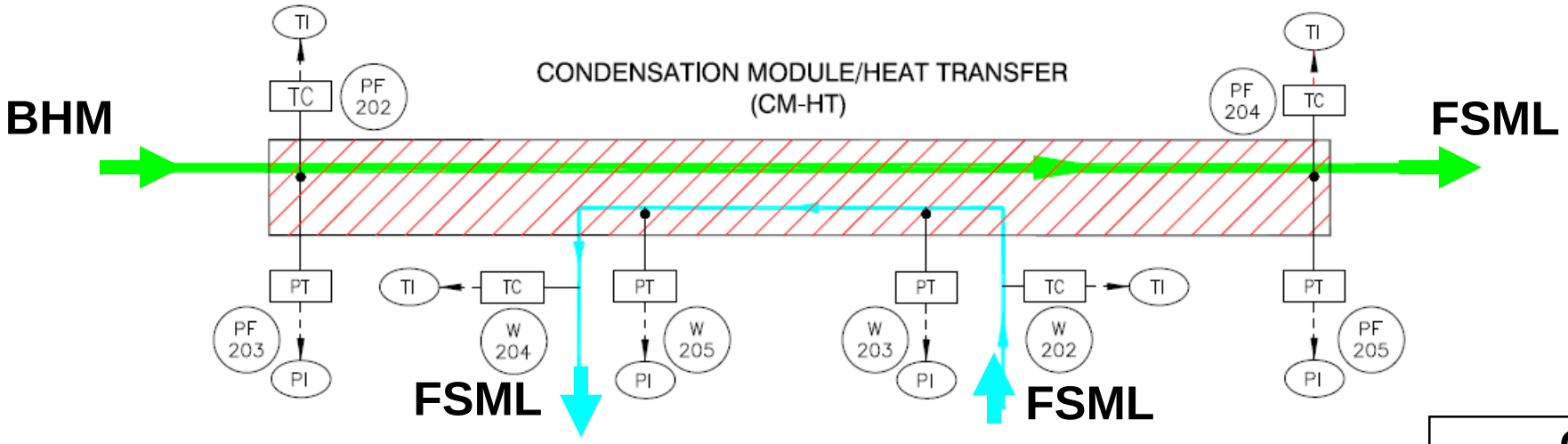




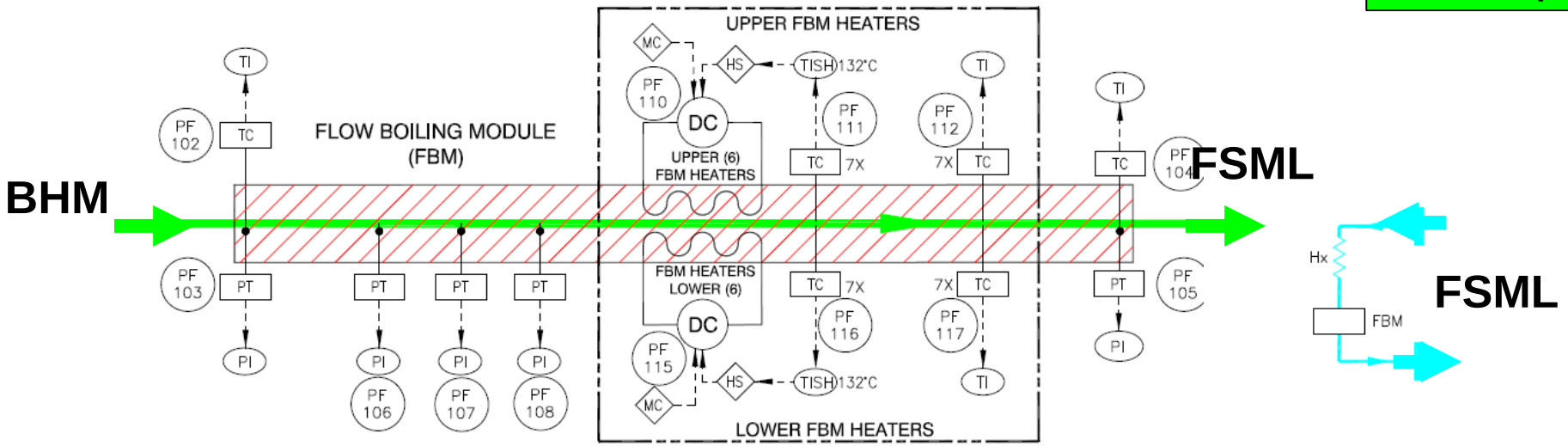


Test Module Assemblies

Condensation Module - Heat Transfer (CM-HT)

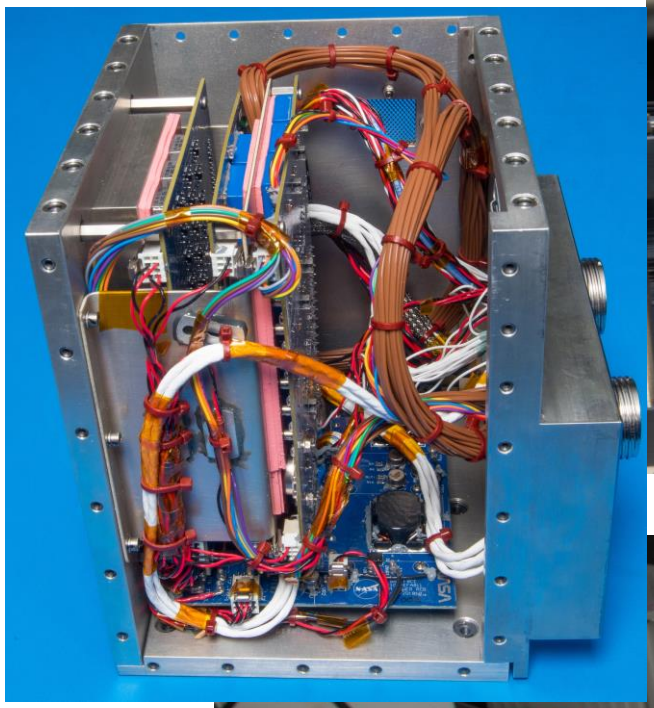


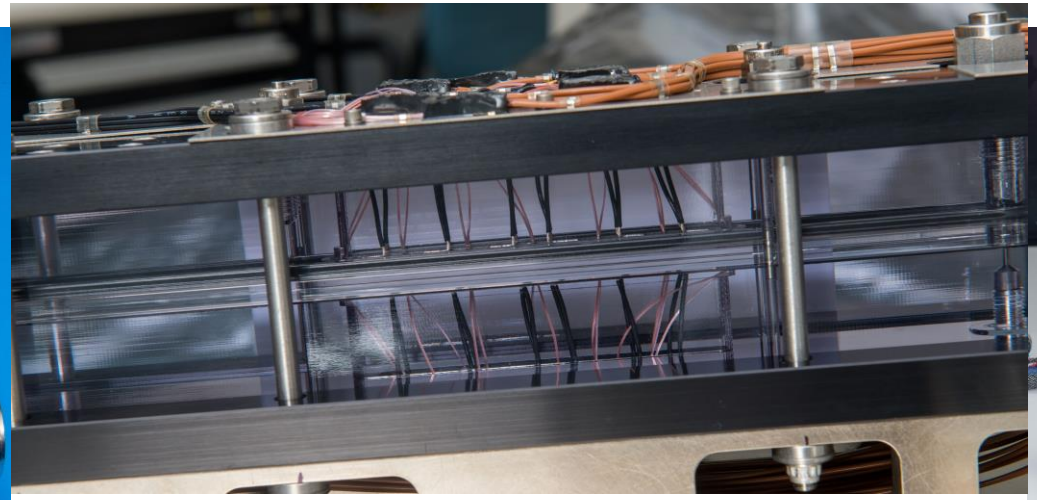
Flow Boiling Module (FBM)

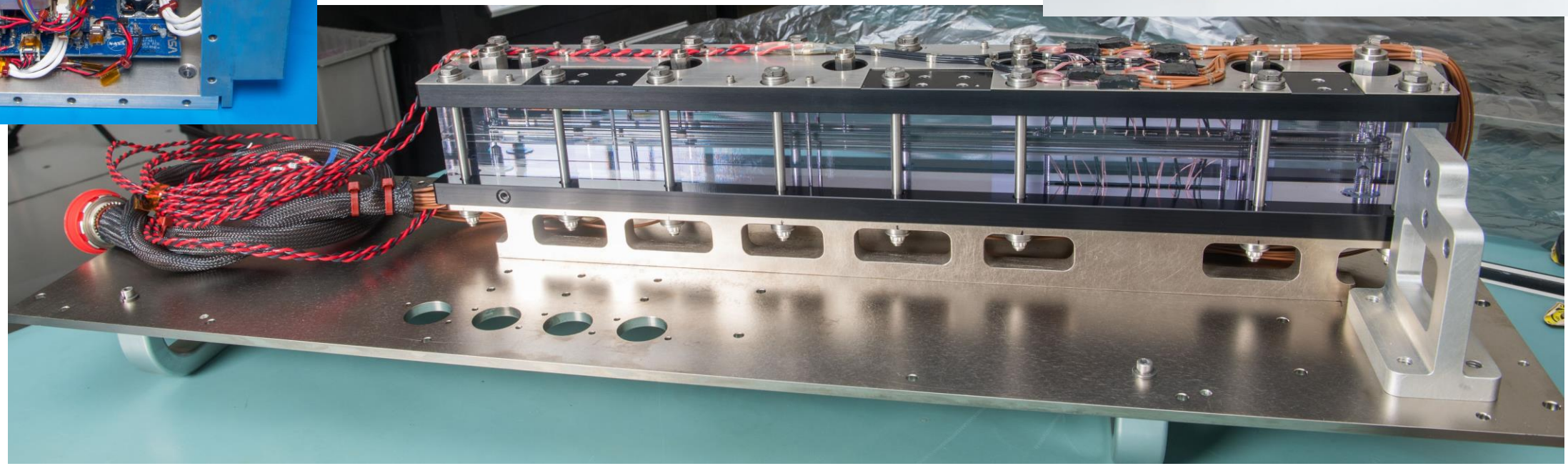


Color Key:	
Test fluid (nPFH)	Water

FBCE Flow Boiling Module

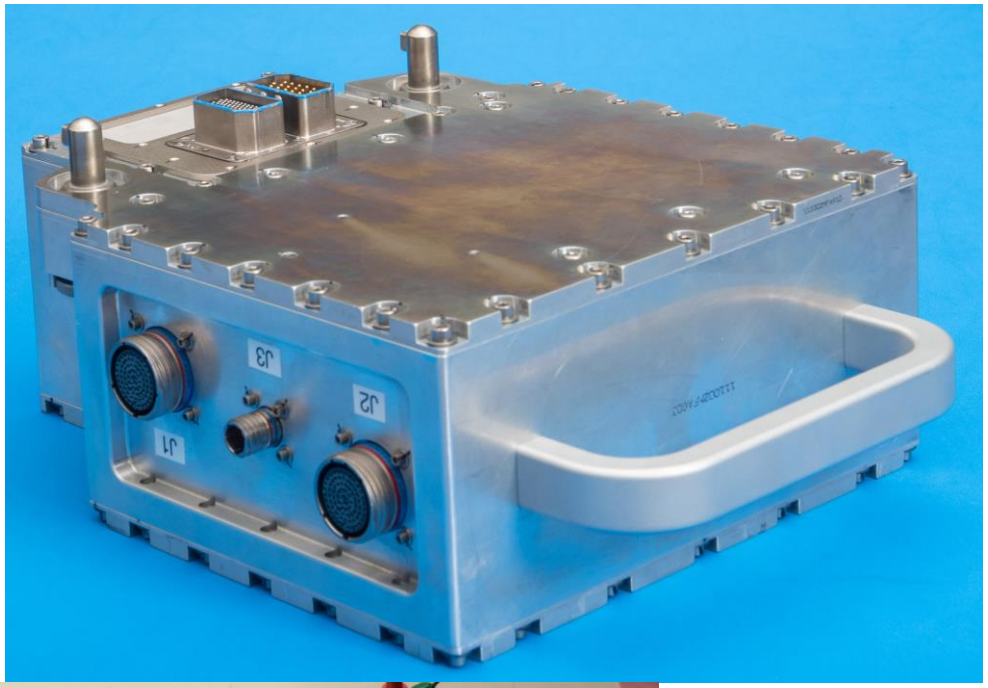


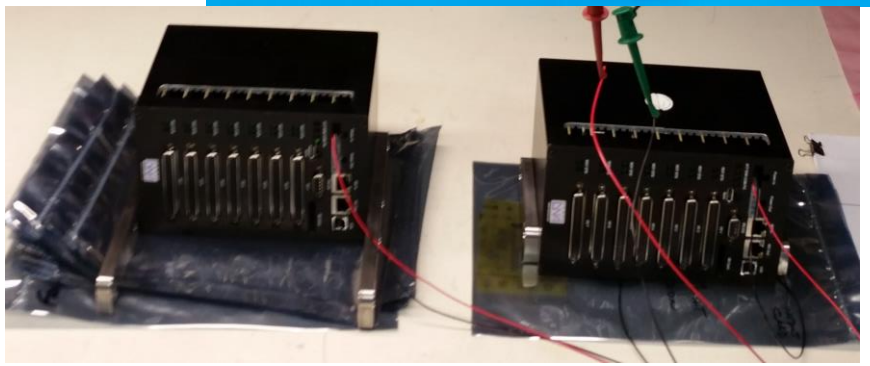




Remote Data Acquisition Modules

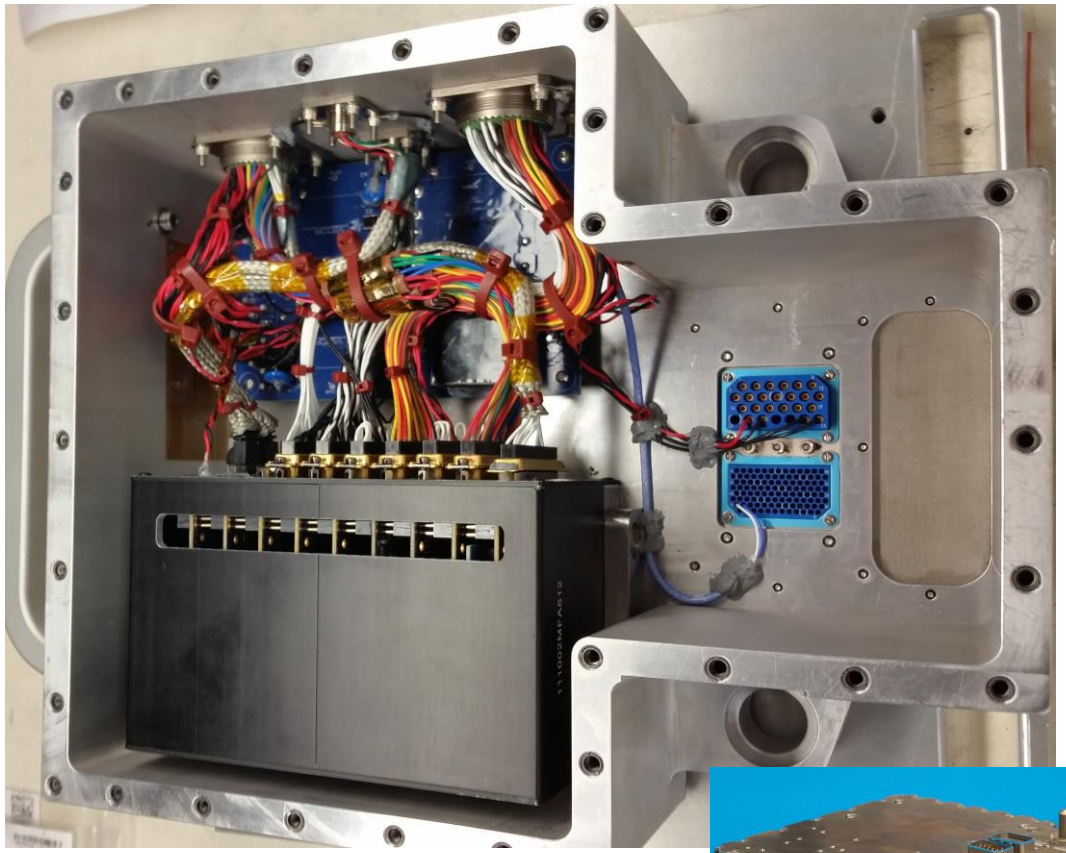
Remote Data Acquisition Module 1 (RDAQM1)





UEI Data Cubes [Thermocouple Signal Conditioning]

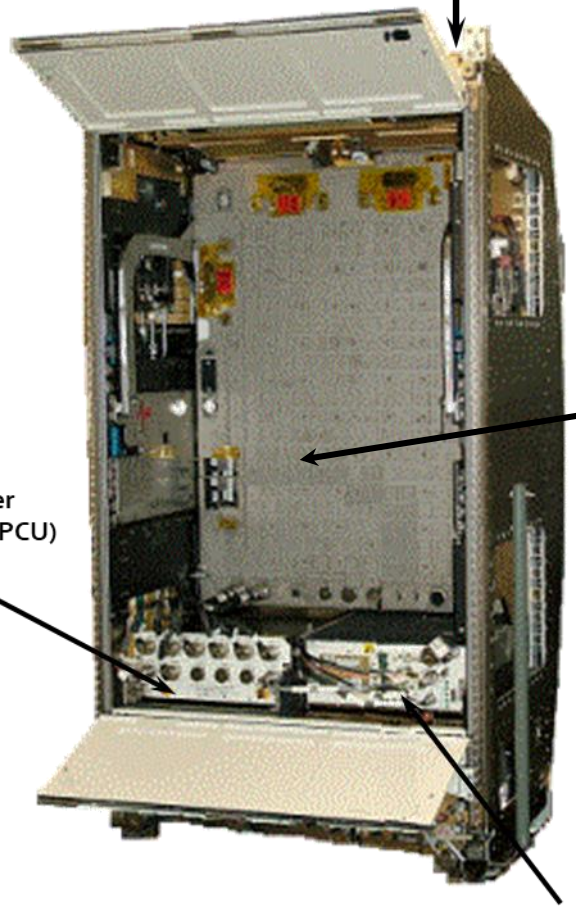
Remote Data Acquisition Module 2 (RDAQM2)



UEI Data Cube and Custom Sensor Supply Printed Circuit Board [Signal Conditioning and Power Distribution]

Fluid Integration Rack

Environmental Control (ECS)
- Air Thermal Control
- Fire Detection & Suppression
- Water Thermal Control
- Gas Interfaces (GN_2, VES, VRS)



Electrical Power Control Unit (EPCU)

Optics Bench

(2.94 ft x 4.01 ft)

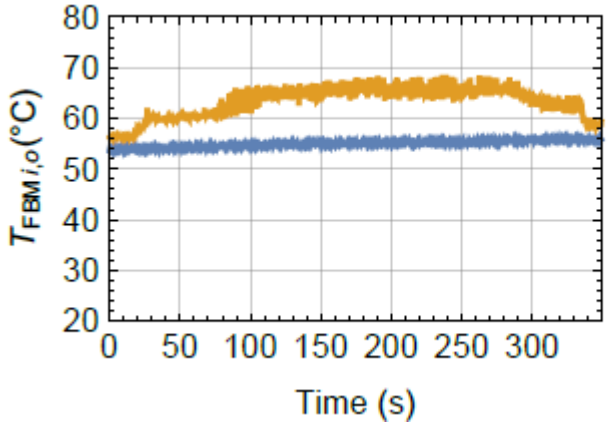
PI-specific hardware and FIR diagnostics

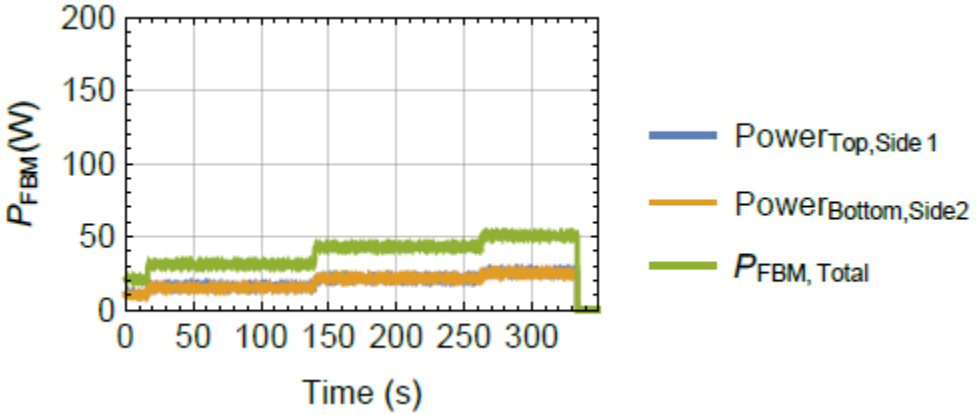
FBCE System Testing with FBM

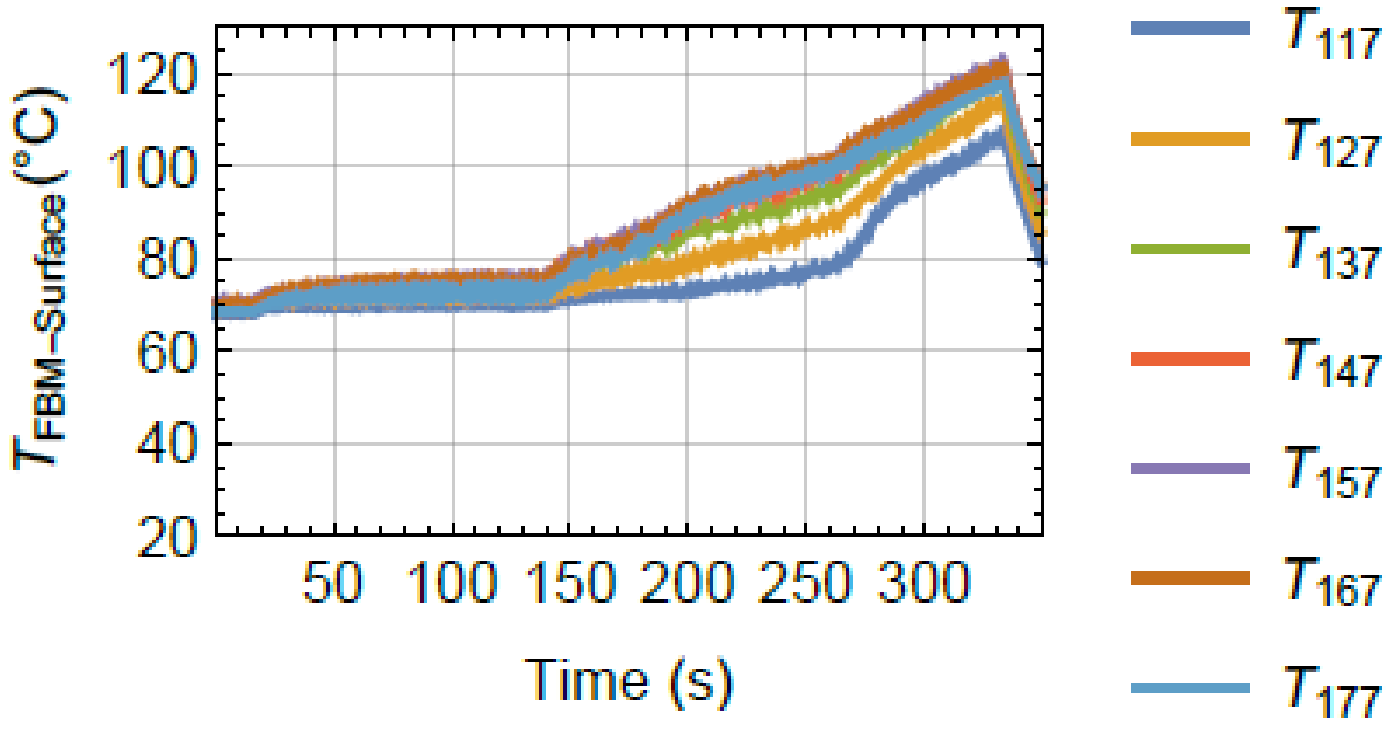
- Initial Checkout testing of the FBCE flight hardware for FBM operations was completed on August 14, 2019
  - All hardware and software systems performed as expected
  - Successfully ran four of the most aggressive test points in the FBM test matrix prior to relocating to the EMI test facility

Flight System Checkout Test Results [FBM]

nPFH Mass Flow Rate:	2.50302 g/s
Condenser Water Mass Flow Rate:	9.8679 g/s
BHM Average Power:	174.836 W
nPFH Inlet Pressure to Test Section:	21 psia
Critical Heat Flux:	**8.81864 W/cm²**







Future Work: Environmental Testing

Vibration
Module

Pressure Drop
Module

System Integration

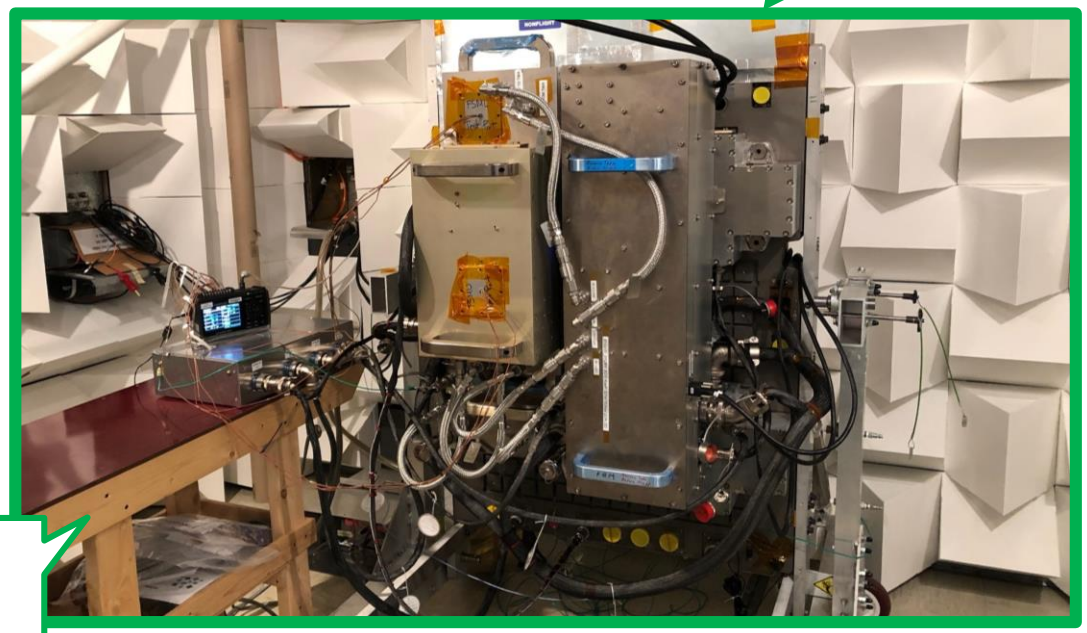
System C/O
System

Acoustic
System

EMI / EMC
Current
System

Thermal Cycle
System

FIR GIU System V&V and MST
System



FBCE in EMI Test Chamber

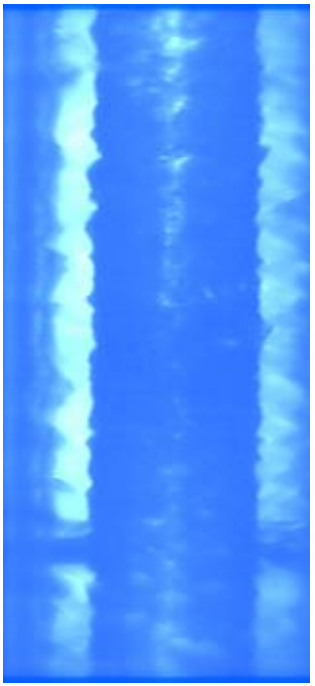
FBCE System Capabilities and Constraints*

- Capabilities:
  - Test Fluid: normal Perfluorohexane (nPFH)
  - Flow Rate to Test Section: 2 g/s – 40 g/s
    - 2 – 14 g/s for flow condensation experiments
    - 2 – 40 g/s for flow boiling experiments
  - Heat Delivery: up to 1540 W (BHM)
    - FBM additional heat delivery up to 340 W
  - Water Cooling to Test Section: up to 27 g/s
  - Water Return Temperature: 40 – 49°C
  - Test Fluid Degassing Capability
  - Test Fluid Delivery to Test Section: subcooled, saturated, or two-phase mixture
- Constraints:
  - Available power to test section
  - Water cooling to test section limited by system pressure drop and flow required through condenser
  - Volume constraint: 91.44x121.92x48.28 cm^3 (36x48x19 in^3)

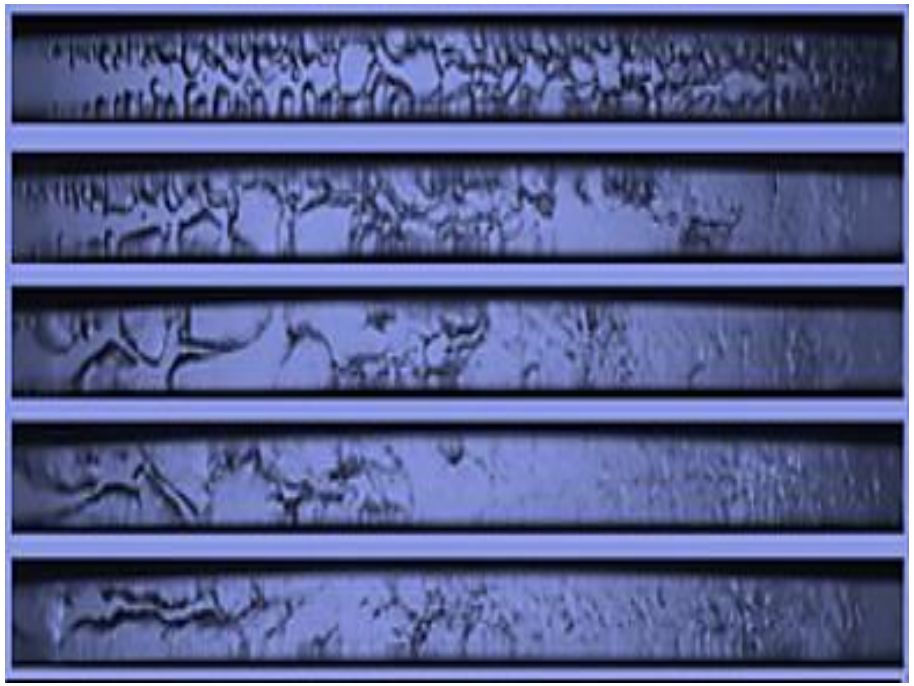
**NOTE: system capability numbers subject to change based on achieving finalized integrated system test results*

Acknowledgements

Andrew Suttles, Project Manager
Dr. Issam Mudawar, Principal Investigator
Dr. Mojib Hasan, Principal Investigator
Dr. Henry Nahra, Project Scientist
William Taylor, Chief Engineer
David Bittner, Chief Safety Officer
Timothy Schuler, Lead Systems Engineer
Mark Lefebvre, Assembly, Integration, and Test Lead
Mark Sorrells, Verification and Validation Lead
Jesse deFiebre, Fluids Discipline Lead
Dr. Jeffrey Mackey, Optics and TMA Lead
Rochelle May, Software Lead
Daniel Gedeon and Christopher Detardo, Mechanical Technicians
Robert Paulin, Gary Gorecki, Tiffany Vanderwyst, and Andrew Fausnaugh, Electrical Technicians
FBCE Engineering Team
FBCE Project Support Team



Back-up



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