RRM3

Progress on the RRM3 Cryogen Demonstration System

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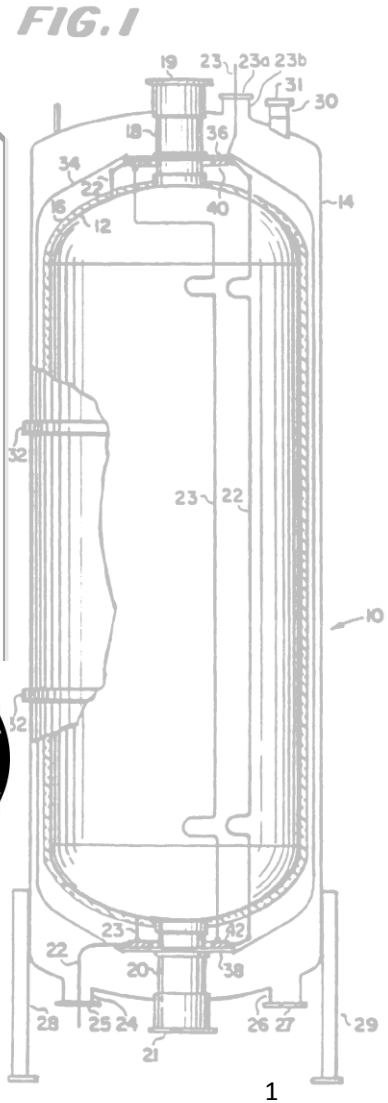
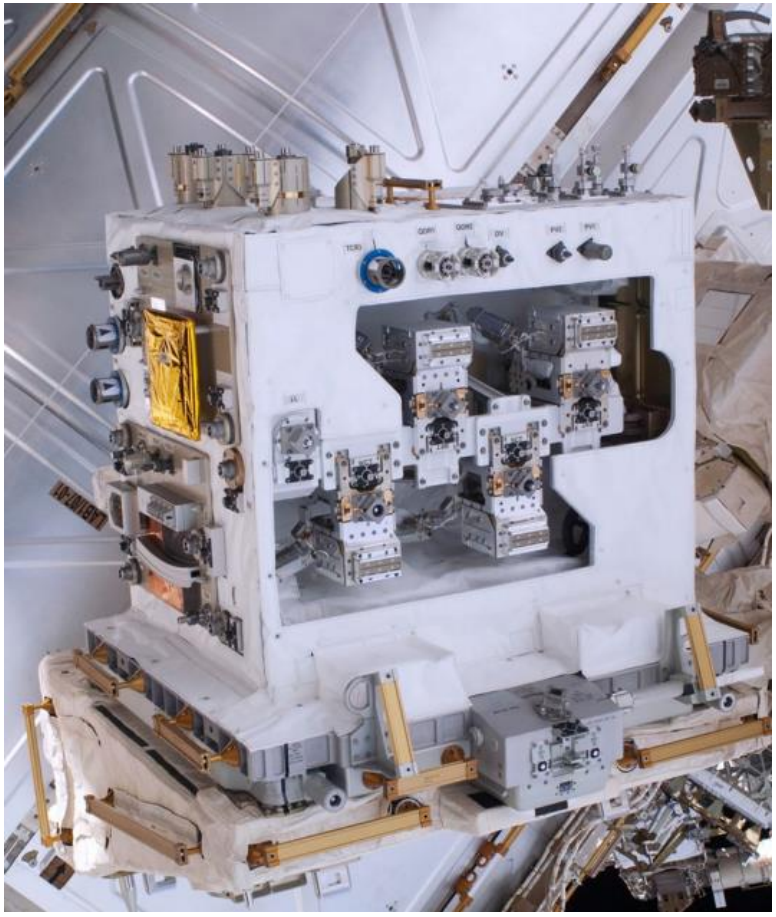
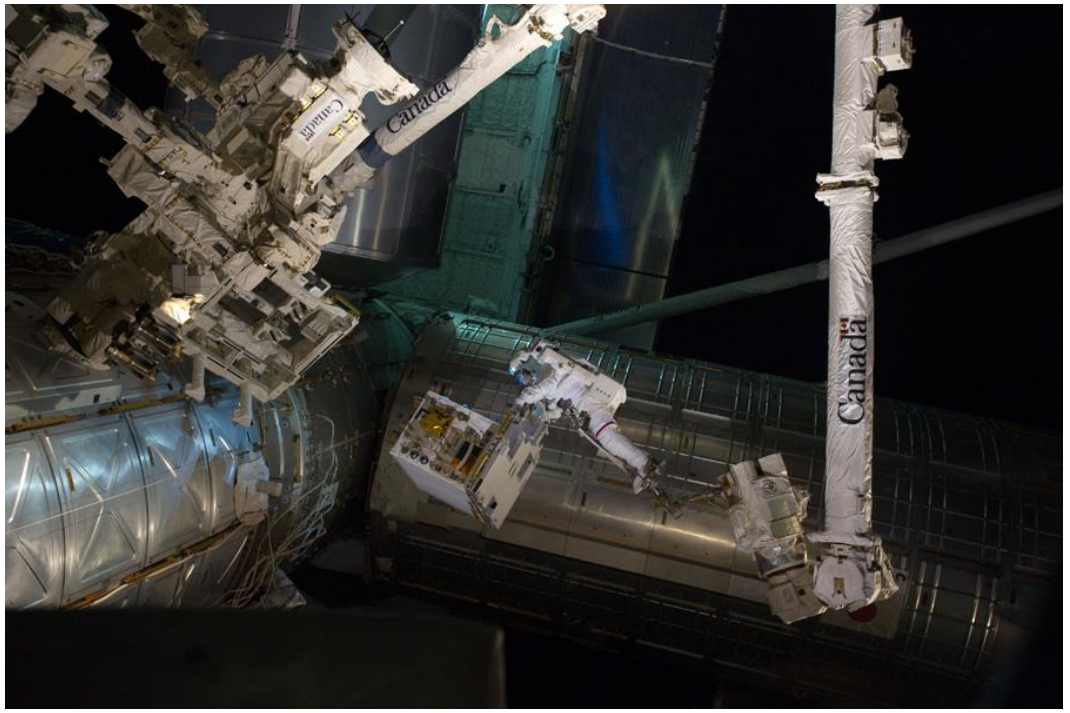


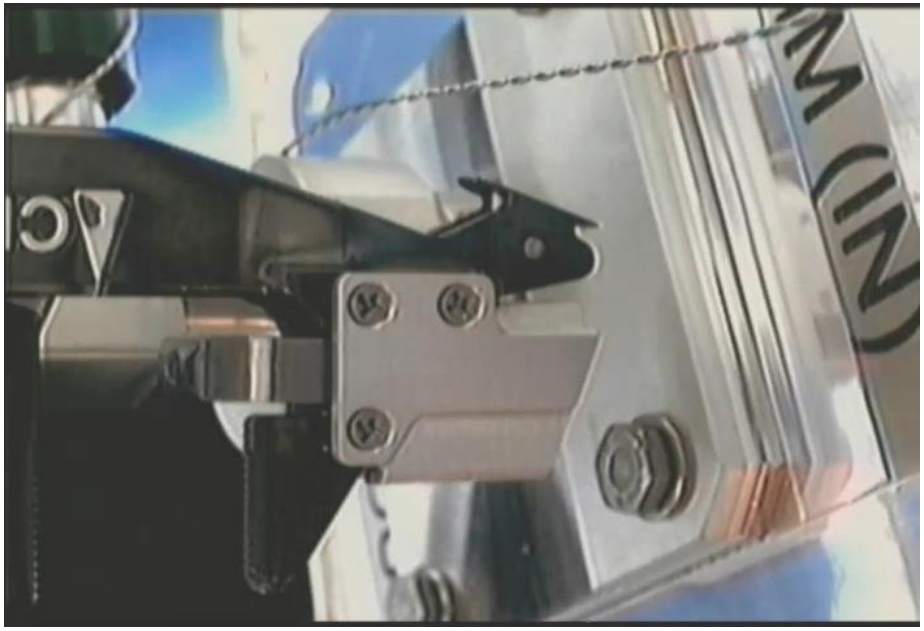
History of RRM

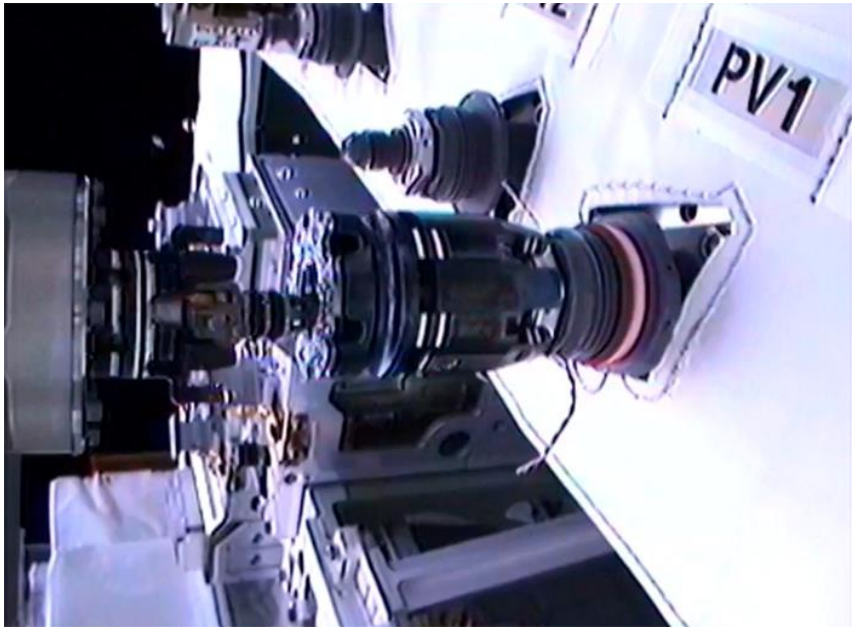




RRM was launched on STS-135 and installed on ISS/ELC4 in 2011. It is an experiment designed to utilize the on-orbit SPDM ('Dextre') to develop technologies and perform demonstrations of satellite servicing tools, technologies and techniques that could be used to service legacy spacecraft.

History of RRM





On-Orbit Demonstrations Included:

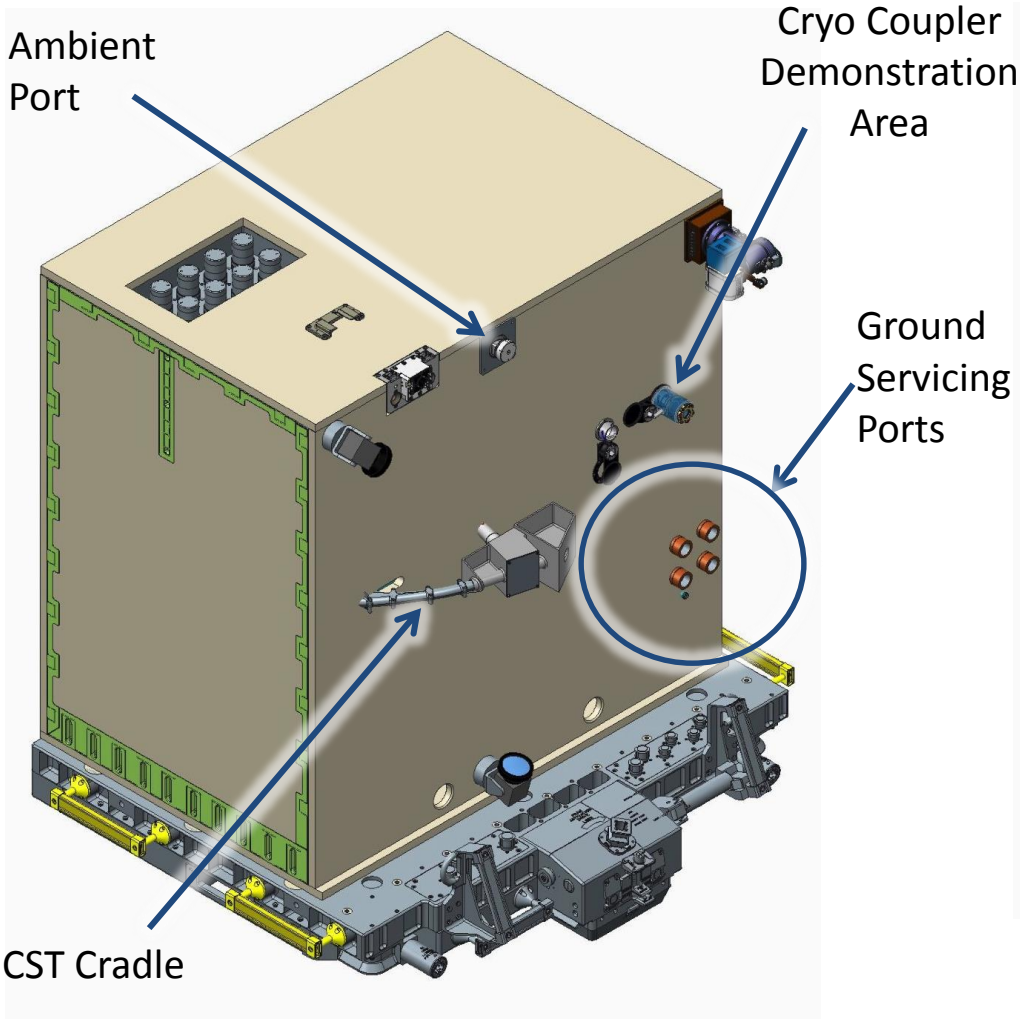
- Valve lockwire cutting
- Removal and capture of various satellite valve caps and SMA electrical caps
- Fluid transfer through an on-orbit mated valve connection
- Tape cutting and MLI manipulation
- #10 Torque Set manipulation

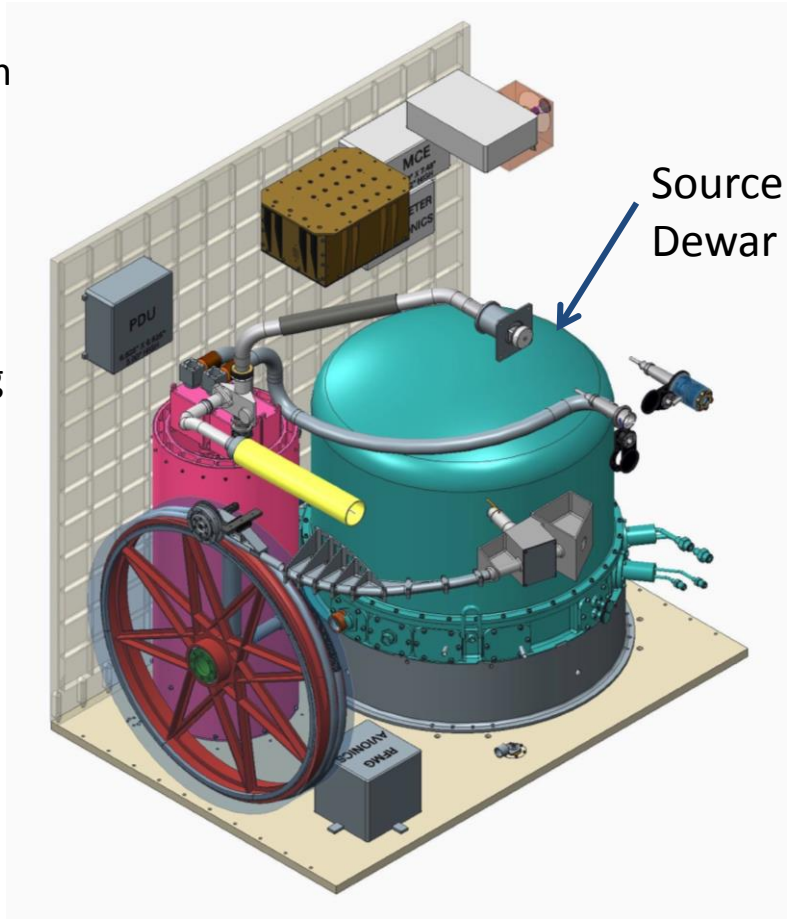
RRM Phase 3

- Goal:
  - RRM 3 will demonstrate the ability to transfer and freeze a cryogenic fluid in zero-g
  - RRM 3 will demonstrate the ability to transfer Xenon gas in zero-g

- Concept:
  - RRM 3 will be a new ISS payload with two tanks between which a liquid methane will be transferred and robotic tools will demonstrate ability to make the connections for transfer. In addition, a system for mating two gas tanks and transferring Xenon gas will be included.
  - Hardware readiness date is targeted for April 2017

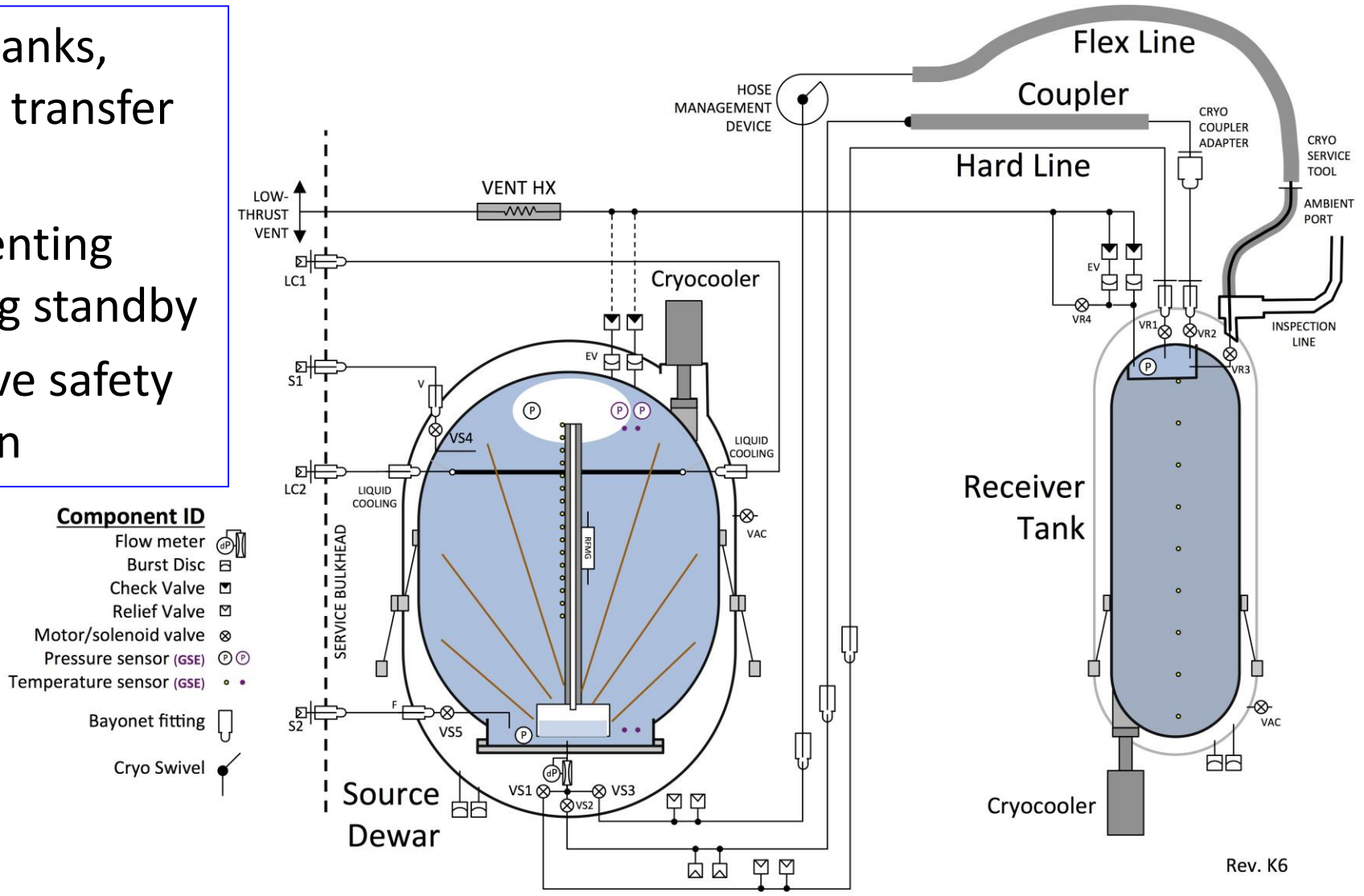
Fluid Xfer Module Concept for RRM3





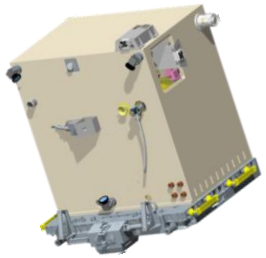
CDS Schematic

- Two tanks, three transfer lines
- No venting during standby
- Passive safety design

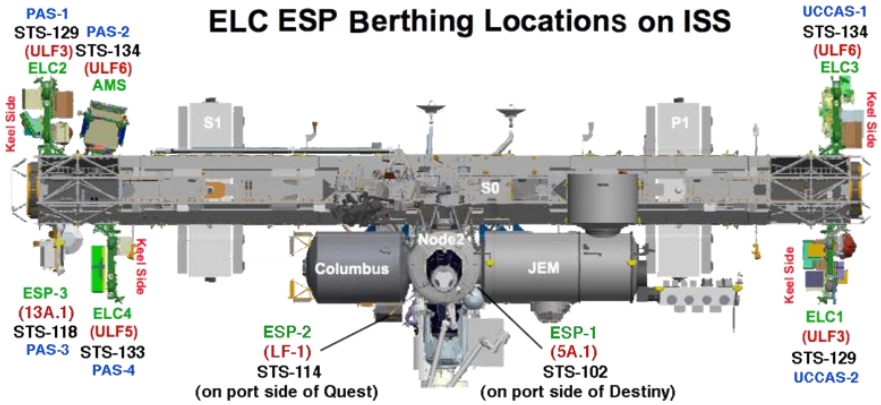


Concept of Operations

- Conduct I&T at Goddard with liquid argon
- Ship dry to KSC
- Fill at KSC with 19 kg methane, maintain with cryocooler



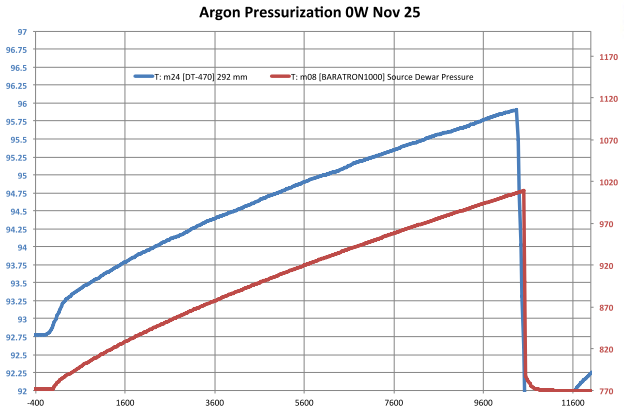
- Integrate with COTS flight, launch to ISS
- Transfer to ELC
- Perform hard line transfer at earliest opportunity
- Perform flex line transfer subject to robotics schedule

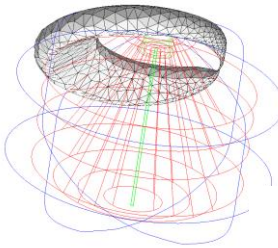


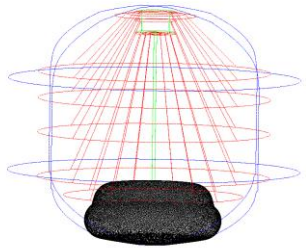
- Perform cryo coupler transfer subject to robotics schedule
- TBD additional transfer operations
  - Decision based on first three runs
- Dispose as necessary

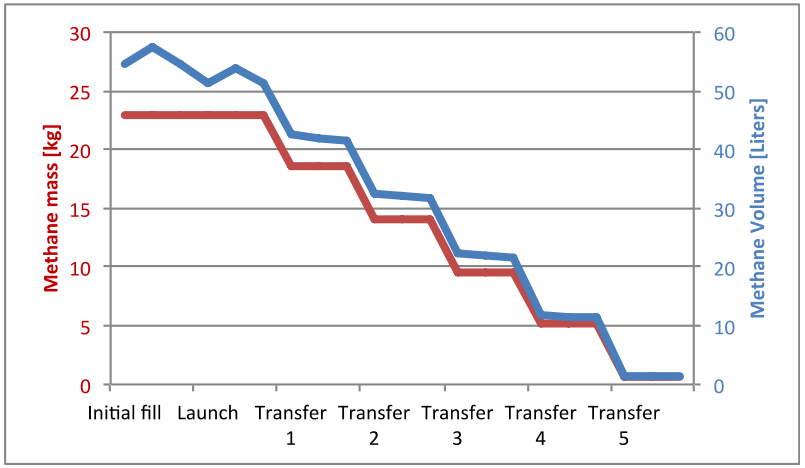
On Orbit Demonstrations

- Fluid management
  - CFD validation, vane dynamics
  - RFMG operation
- Pressure control
  - Cryocooler operation
  - Ullage temperature
- Pressurization
  - Wick performance
- Hard line transfer and Freeze
  - Sublimation through low-thrust vent
- Flex line transfer and Freeze
  - Sublimation through low-thrust vent
- Cryo coupler transfer and Freeze
  - Sublimation through low-thrust vent



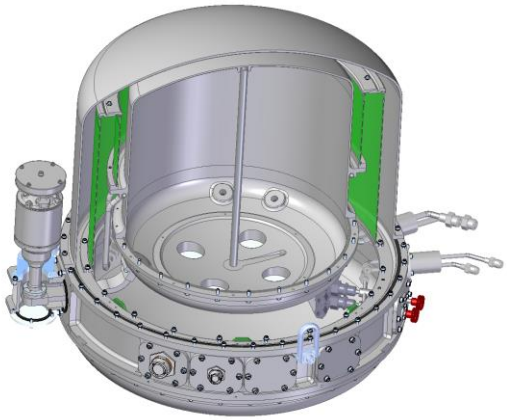




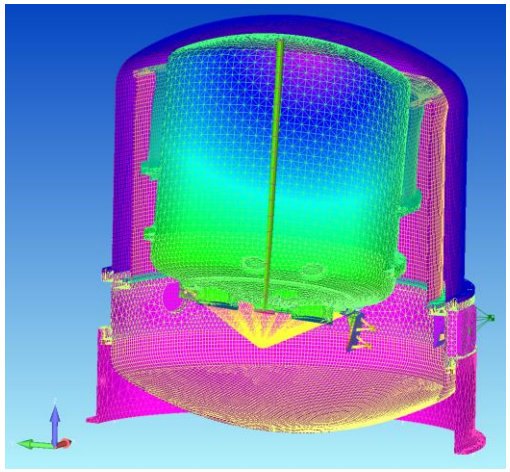


Source Dewar

- Fabrication contract w SDL
  - 50 liters, 50 kg dry mass
  - Delivery March 2016

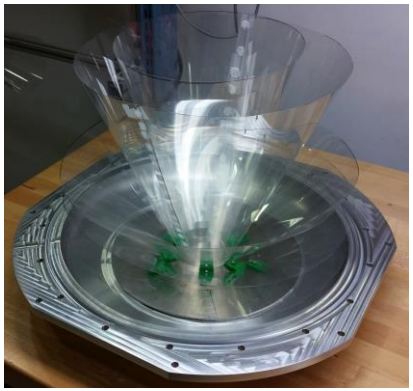


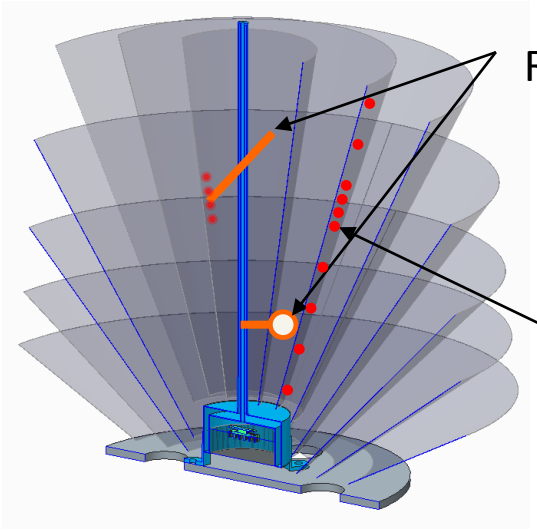
- Cryo valves
  - Upcoming procurement
  - Looking for latching solenoid valves



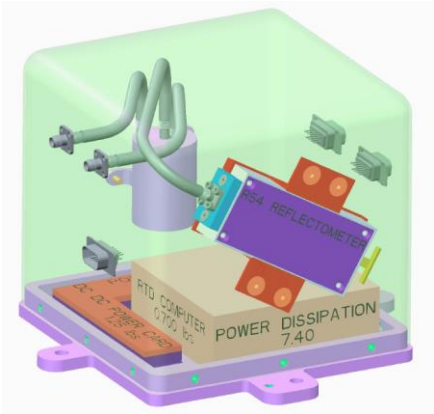
Source Dewar (cont'd)

- Fluid management
  - Vane system





- Radio Frequency Mass Gauge
  - NASA GRC contribution
  - Delivery June 2016



Source Dewar (cont'd)

- Cryocoolers
  - Sunpower Cryotel CT
  - 2 Procured by SDL
    - One installed on Source Dewar
    - One delivered for Receiver Tank

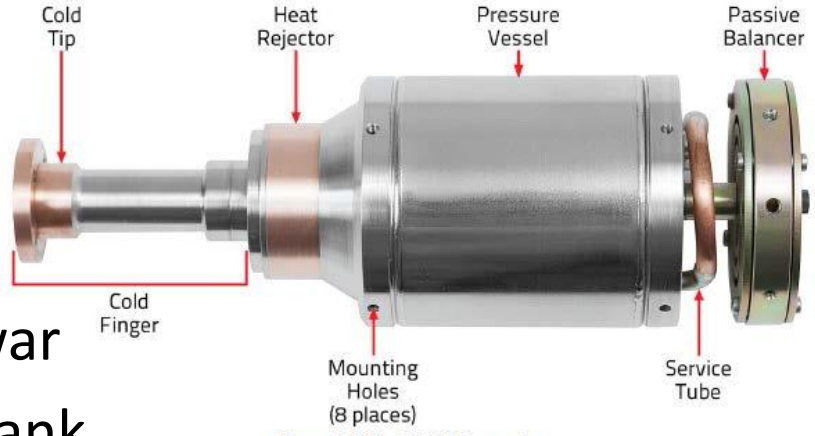
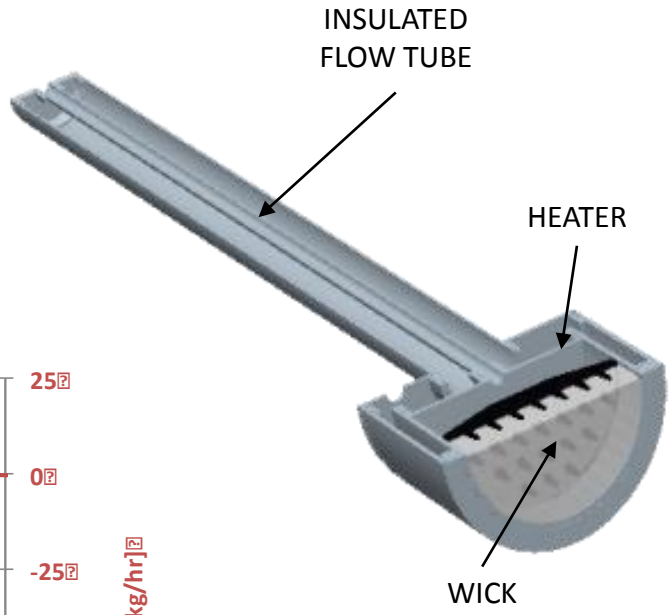


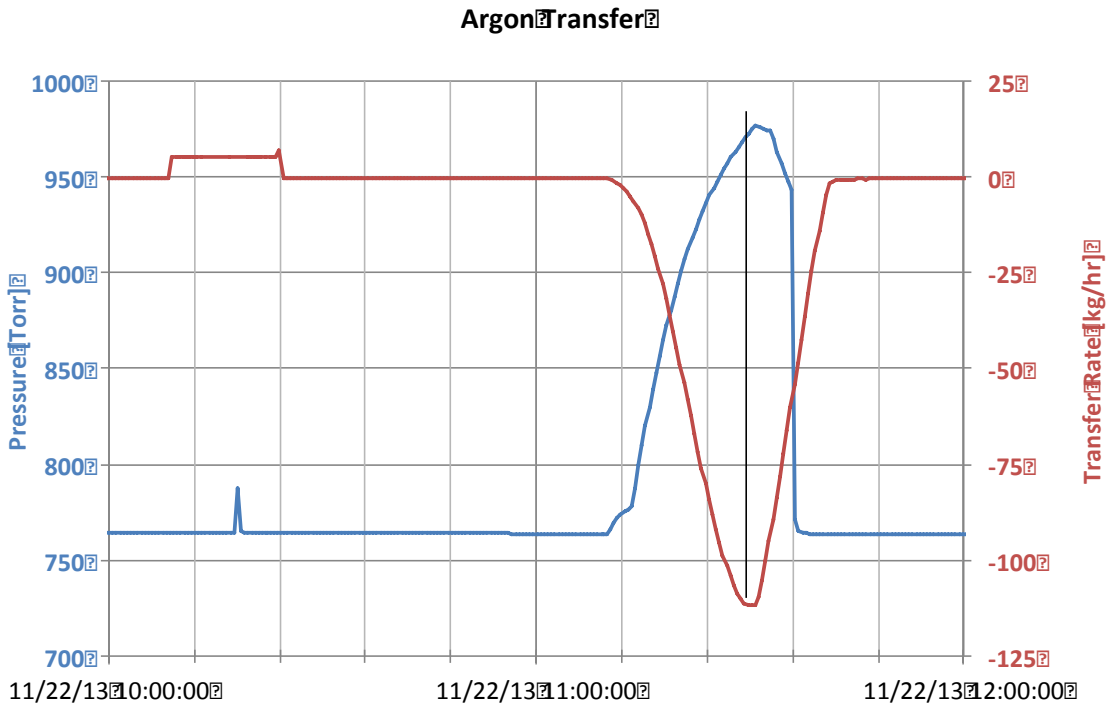
Figure 1-3. CryoTel CT Cryocooler

- Cryocooler electronics
  - In-house Joint Control Board
    - H bridge output, temp sensor input, FPGA

Source Dewar (cont'd)

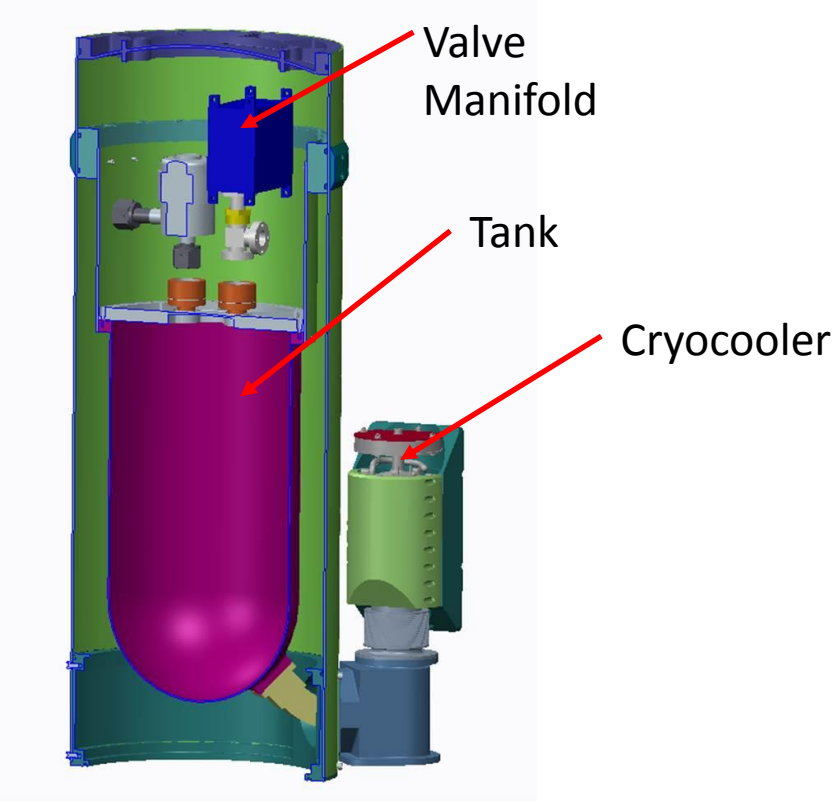
- Pressurization system
  - Autogenous system, wick with heater





Receiver Dewar

- In-house build
  - Soft vacuum jacket (fiberglass support cylinder) for ground test only
  - Cryotel CT for pressure and temperature control



Summary

- RRM3 experiment
  - Liquid methane storage and transfer
  - Scheduled for 2017 flight