



The International Space Station (ISS) Port 1 (P1) External Active Thermal Control System (EATCS) Ammonia Leak

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Purpose/Agenda



- **Purpose:** Discuss the ISS P1 EATCS ammonia leak investigation and current findings
- **Agenda:**
 - EATCS 101
 - Houston, We Have A Leak!
 - Locating the Leak
 - Root Cause Investigation
 - Discussion
 - Conclusion
 - Summary

*“3 potential failures that keep
my fellow astronauts and I
up at night onboard the ISS*

- 1. Fire*
- 2. Cabin depress*
- 3. Ammonia leak”*

- Daniel Burbank
Former NASA Astronaut

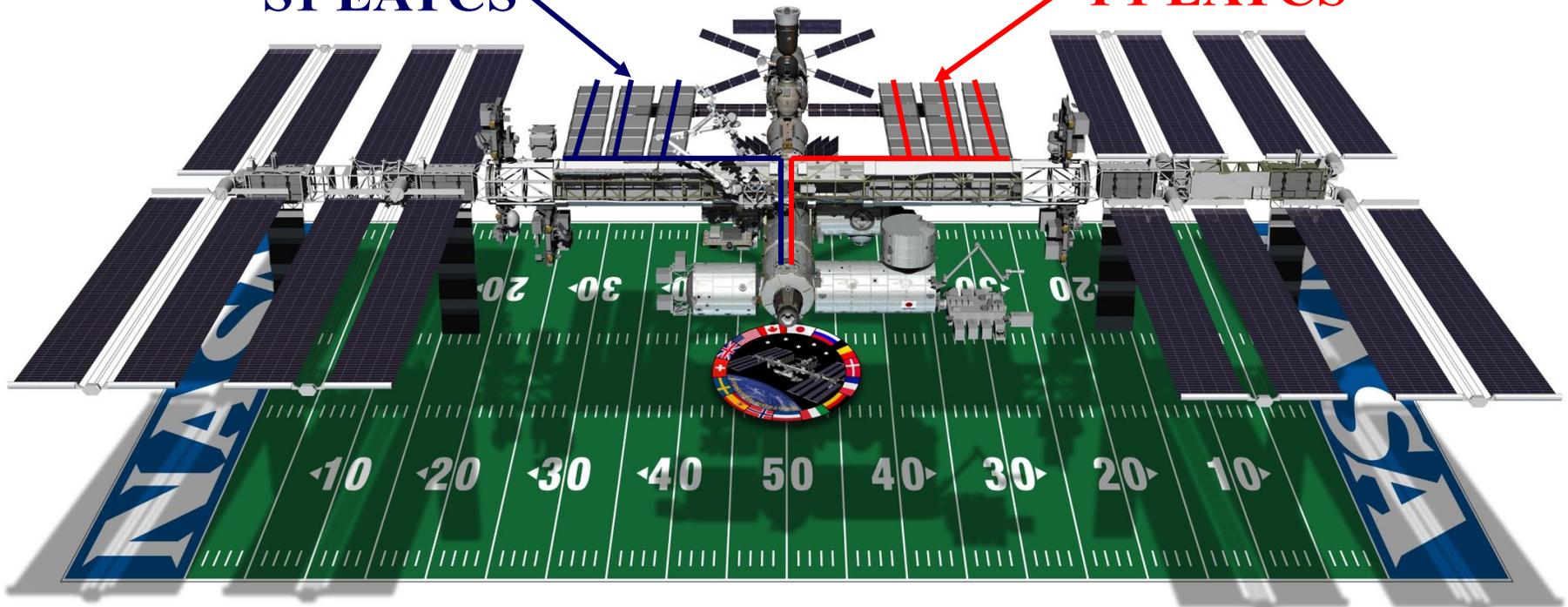


EATCS
Radiator

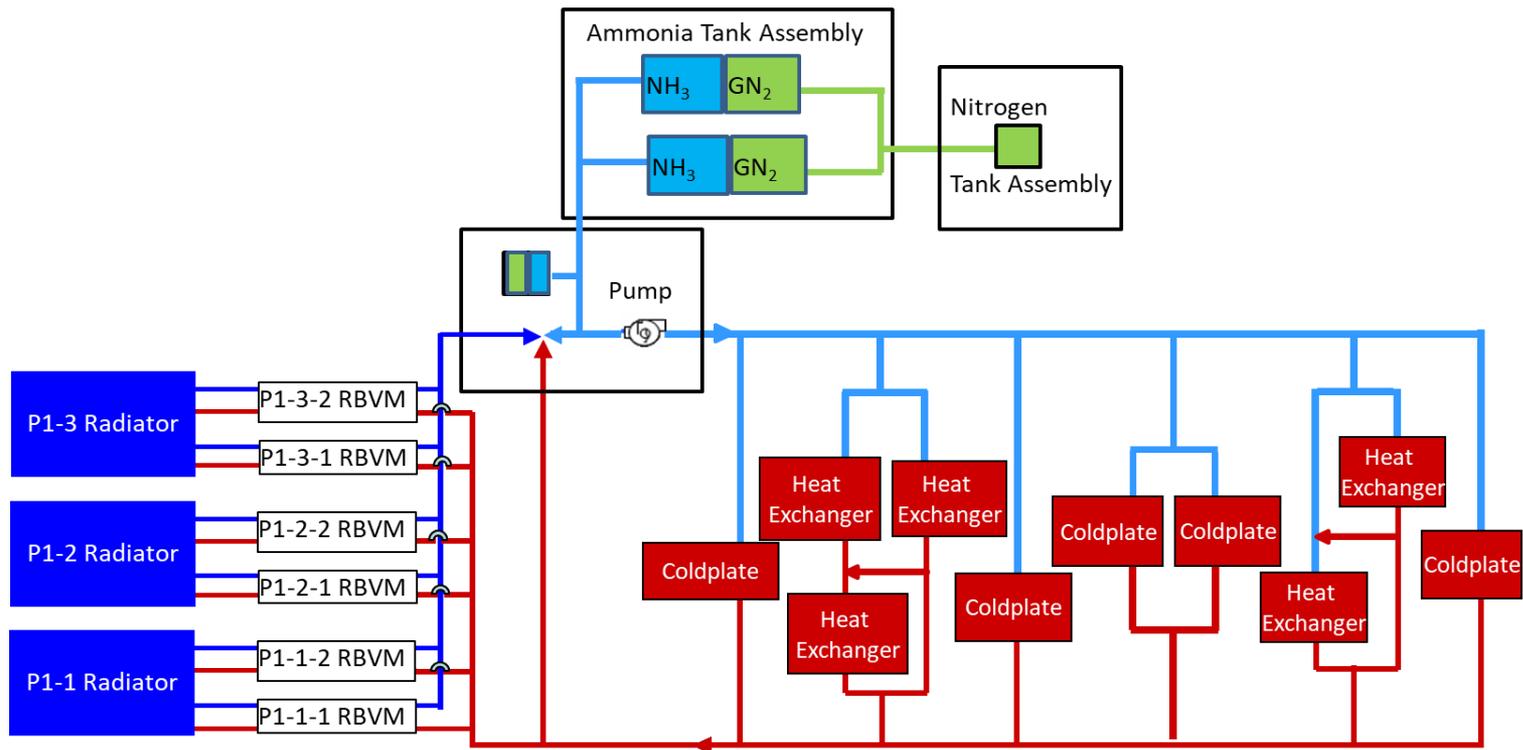


S1 EATCS

P1 EATCS



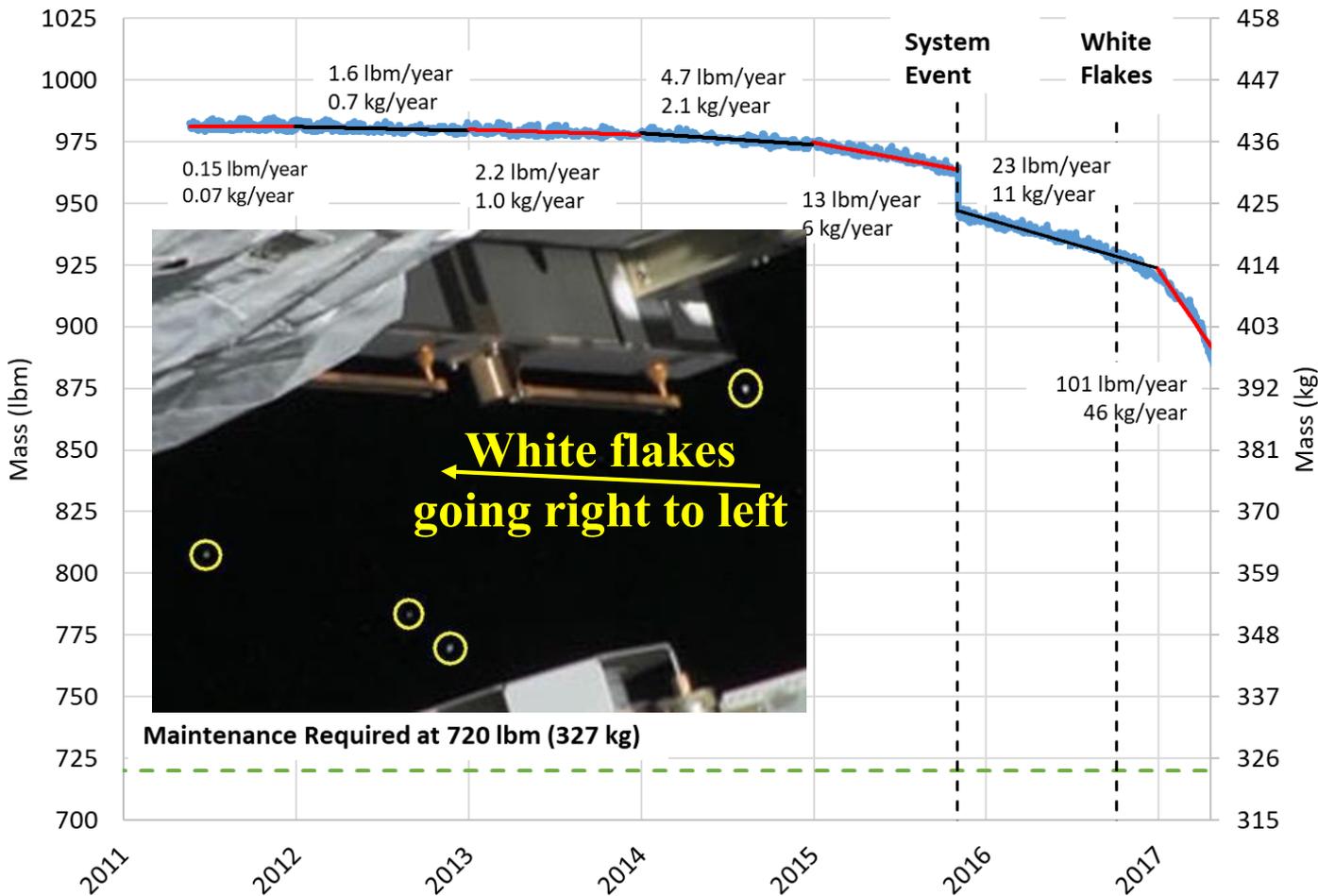
- EATCS - closed loop, single phase, mechanically pumped fluid system (two redundant loops)
- Heat Rejection Capability – up to 35 kW ($1.2E^5$ BTU/hr) per EATCS
- Starboard (S1) and Port (P1) EATCS were launched in 2002, filled with ammonia and activated in 2006



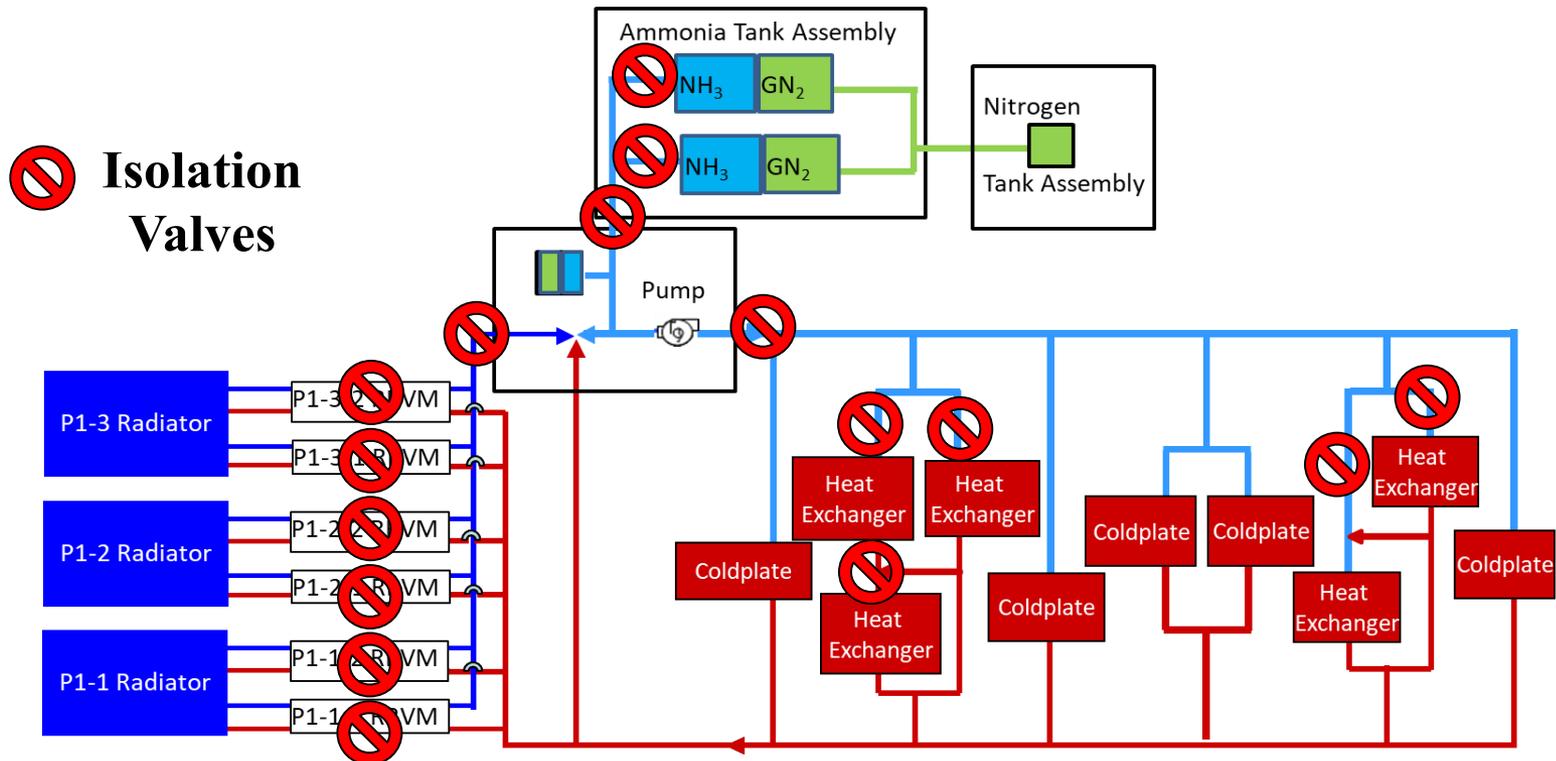
Houston, We Have A Leak!

- The Problem: Detected a coolant inventory decay in the P1 EATCS ~2012, and the leak began to continuously accelerate
- Cause/Location: Unknown at the time

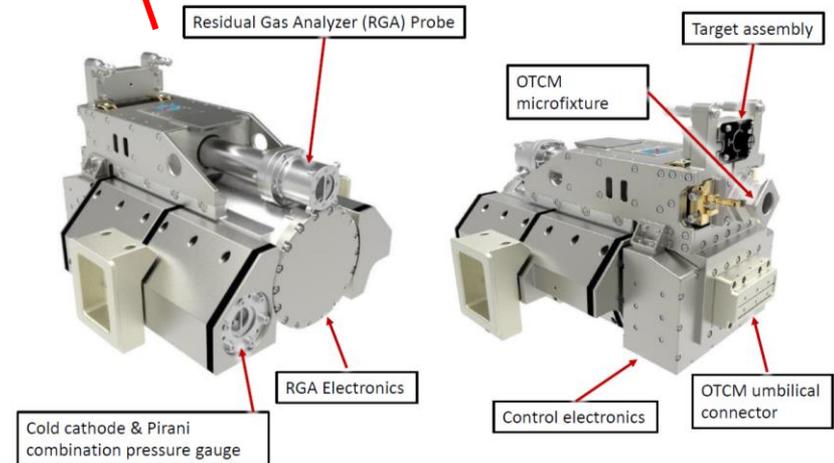
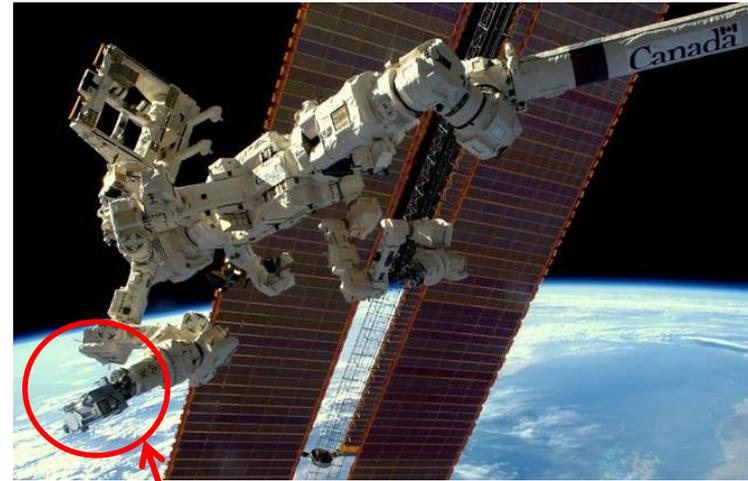
- Began observing mysterious “white flakes” on the P1 external high definition cameras
- Coincidence?
- Lack of depth perception made it difficult to estimate possible originating locations



- Existing techniques to locate a leak was to isolate a system into segments and monitor inventory decay
- Cons
 - Shutting down system, time, resources, low chance for success



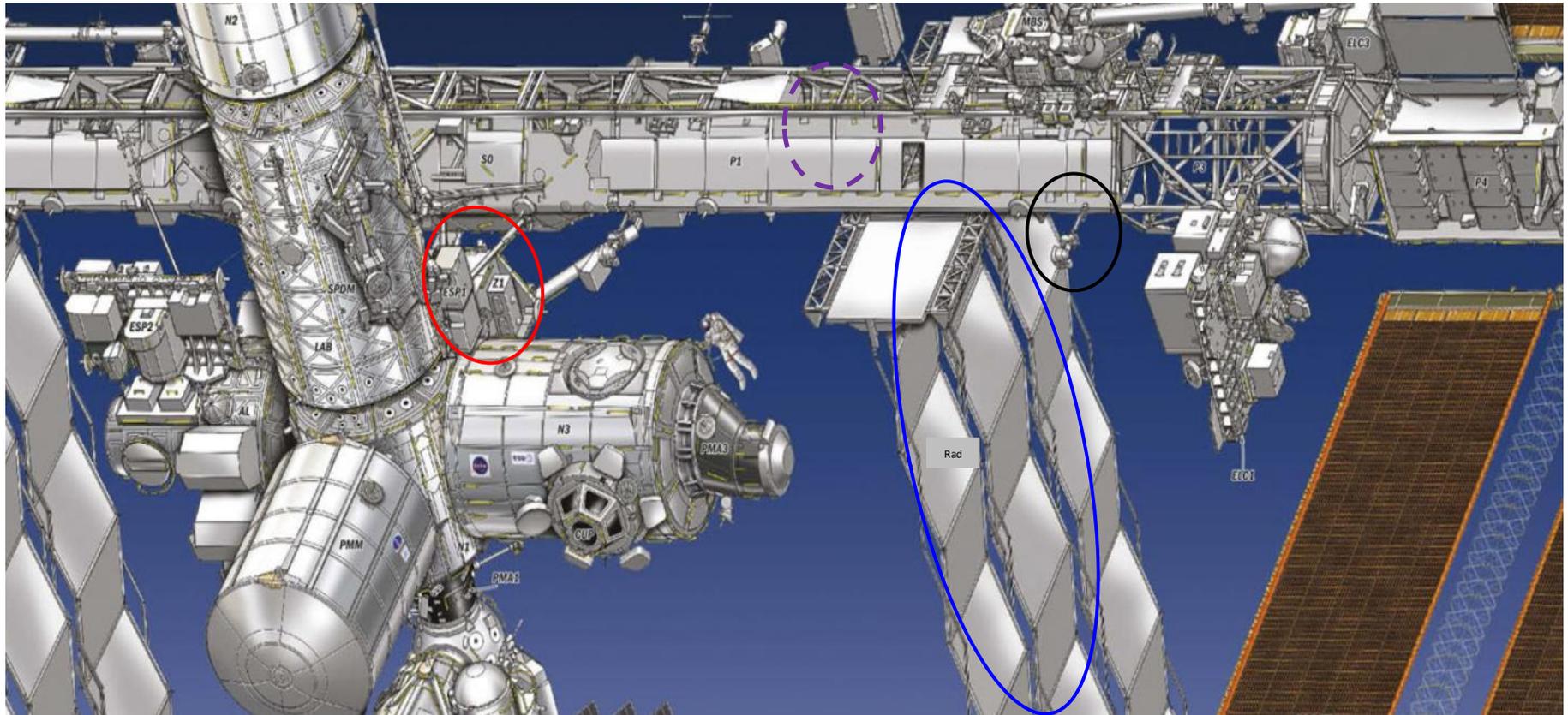
- The Robotic External Leak Locator (RELL)!
- New tool built to work with ISS Robotic Arm
- Remotely detect and ID various gases, and measure their pressures in a vacuum
 - Detect molecules up to 100 amu
 - Cold Cathode Ion Gauge measures total pressure
 - Residual Gas Analyzer (mass spec) measures partial pressure
 - Pressure measurements are directional in space environment
- Launched in 2015
- Coincidentally, in time to help locate P1 EATCS leak



RELL Unit

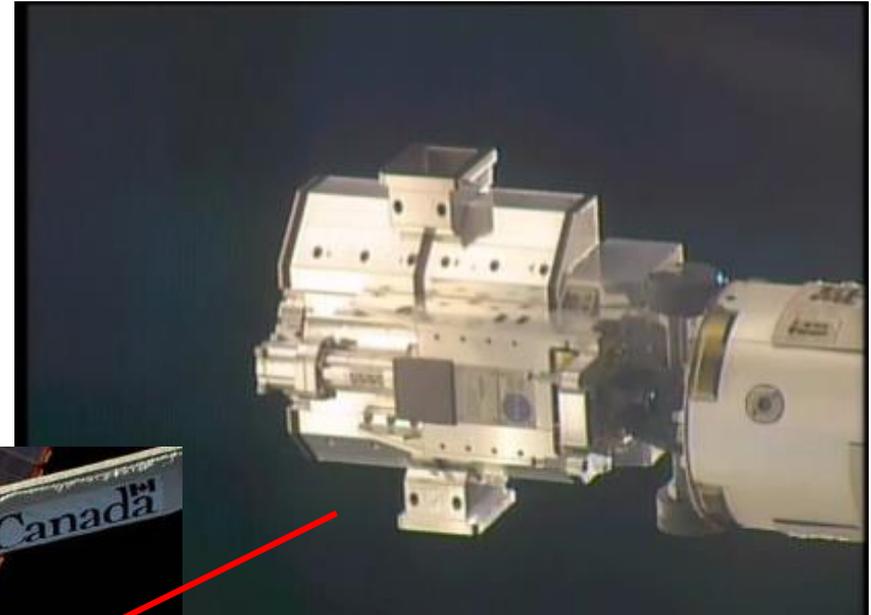
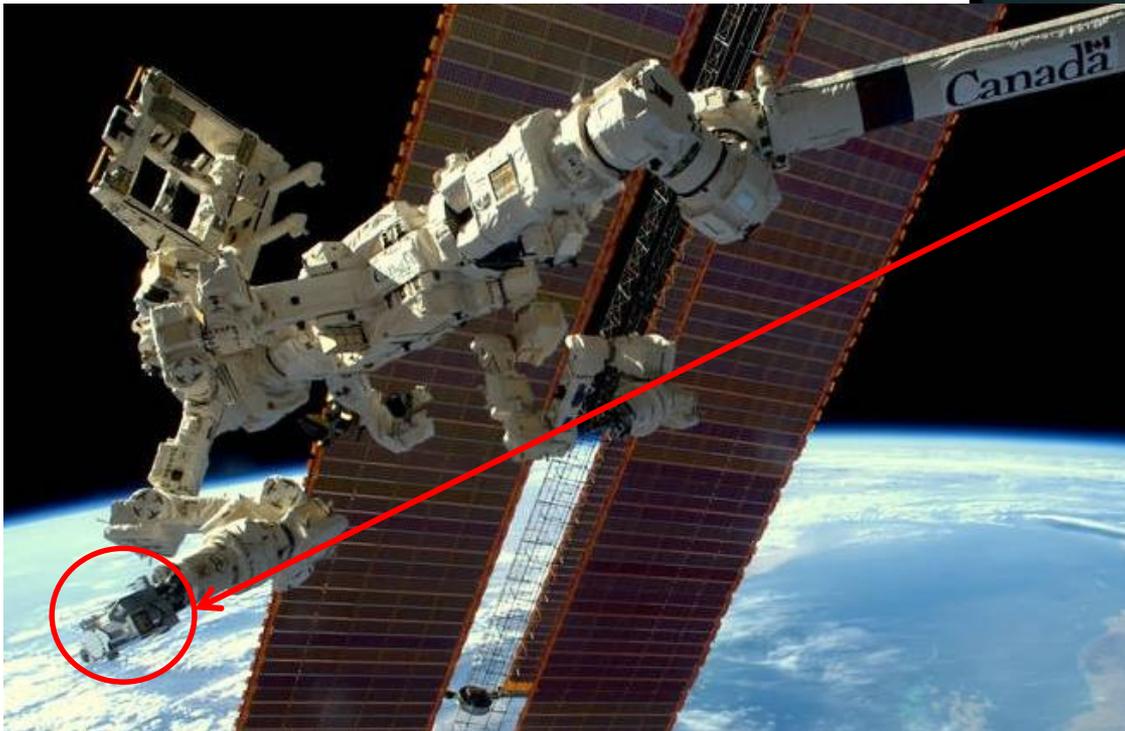
Possible White Flakes Sources Locations

- Unknown if the P1 EATCS ammonia leak and the white flakes were related



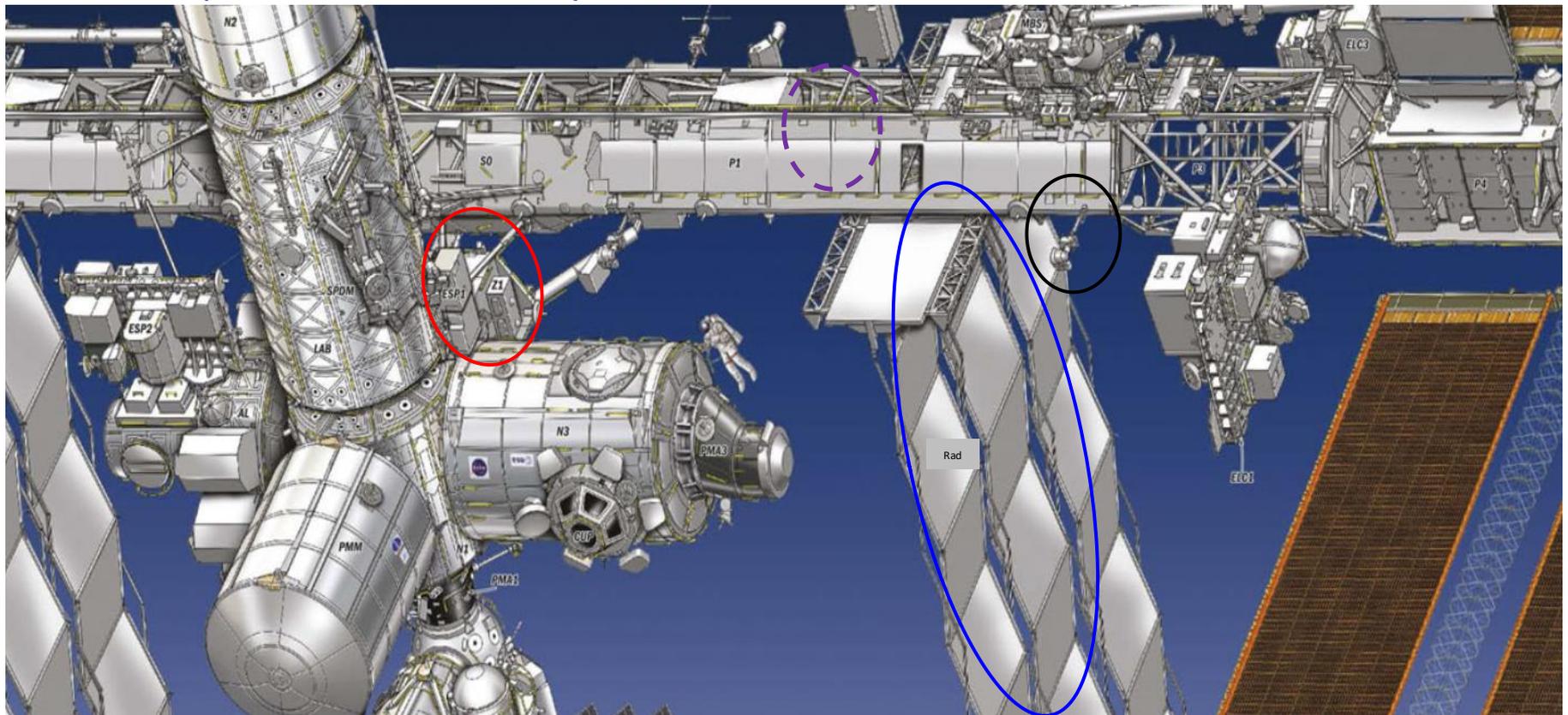
- P1 EATCS Radiators circled in blue, Z1 (decommissioned) and a spare Pump Flow Control Subassembly (PFCS) circled in red, P1 EHDC circled in black, ATA behind structure (dotted purple)⁹

- ISS background (natural atmosphere, ISS vents and outgassing)

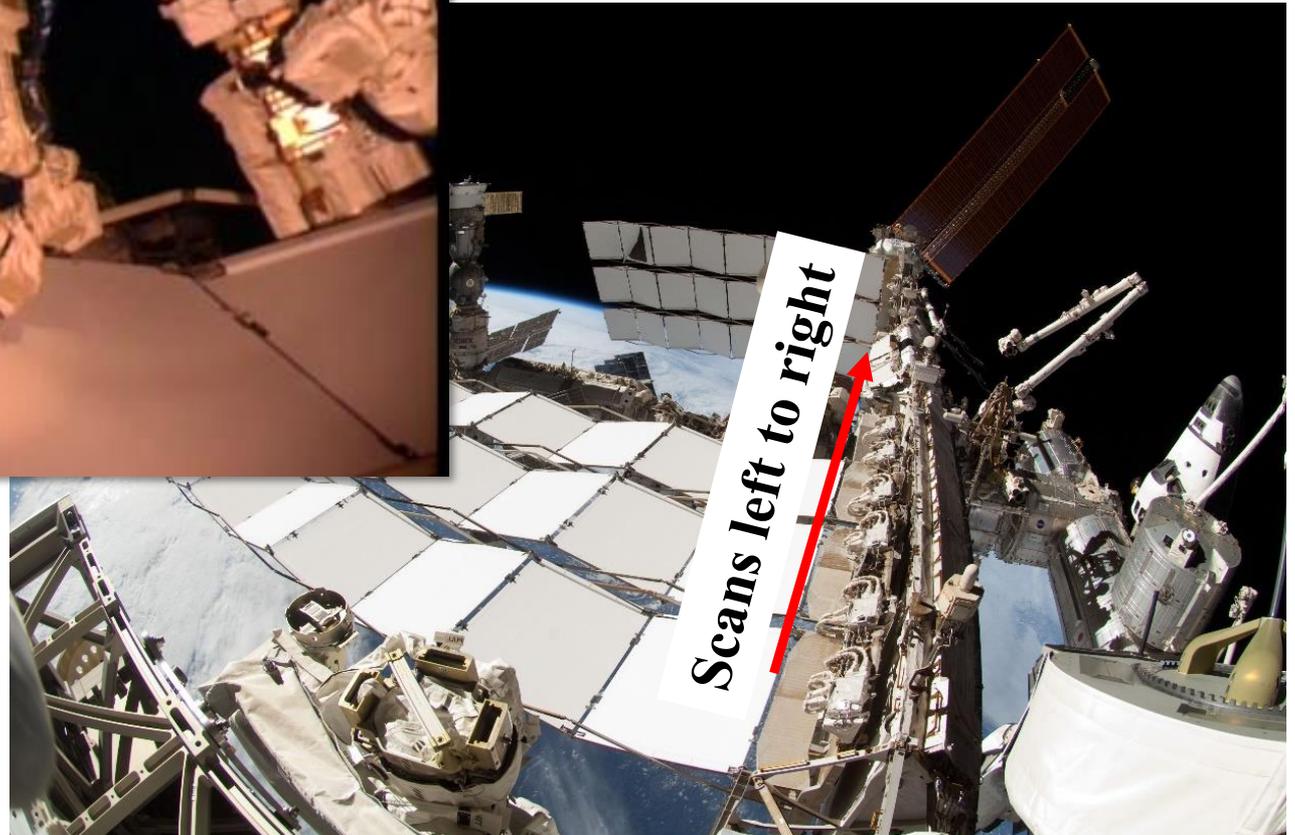


- Results
 - Mostly atomic oxygen (AMU 16)
 - Pressures measured $\sim E^{-12}$ to E^{-8} torr

- Z1, PFCS, ATA
 - No significant ammonia signature present ($\sim E^{-8}$ to E^{-7} torr)
- P1 EATCS Radiator Beam Valve Modules (RBVM)
 - Significant ammonia signature pressure

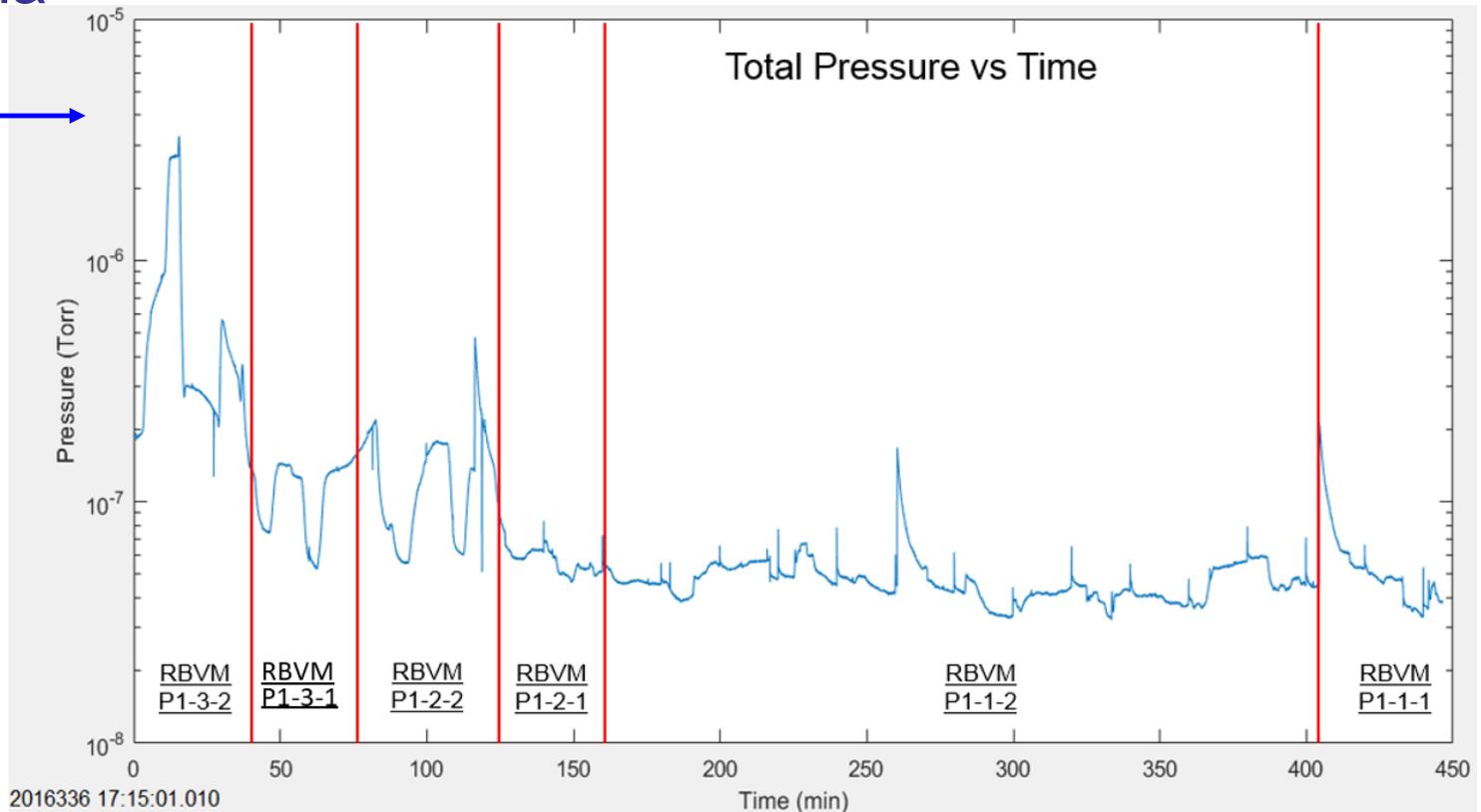


- P1 ISS EATCS Radiator Beam Valve Modules (RBVM)

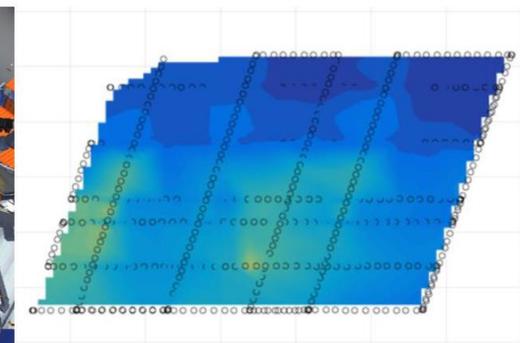
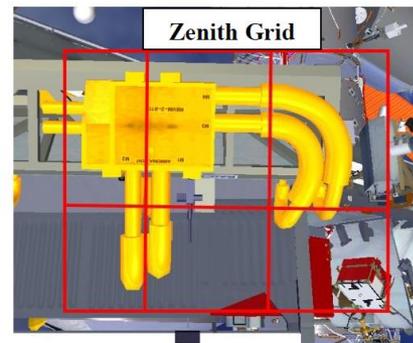
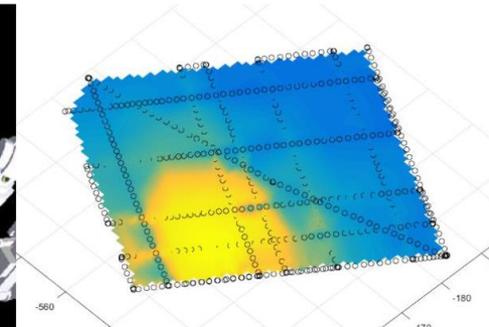
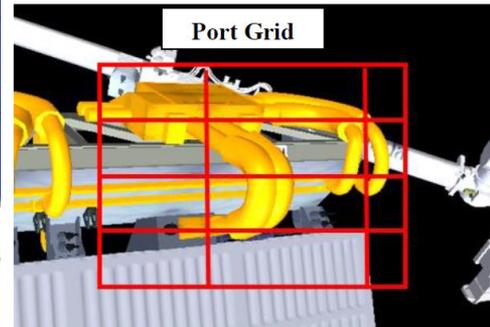
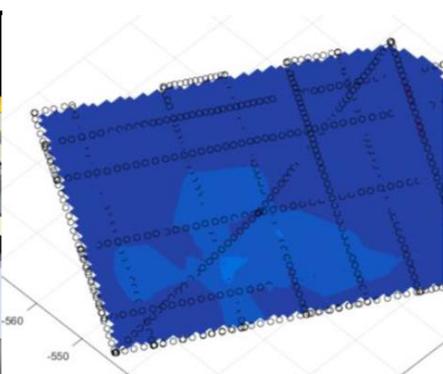
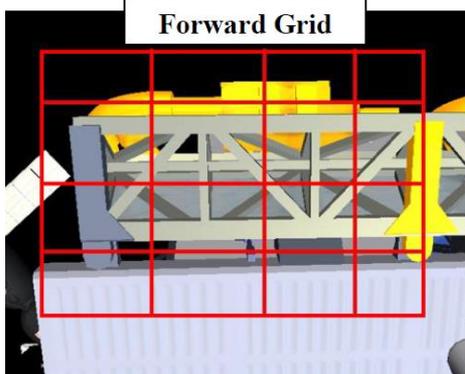
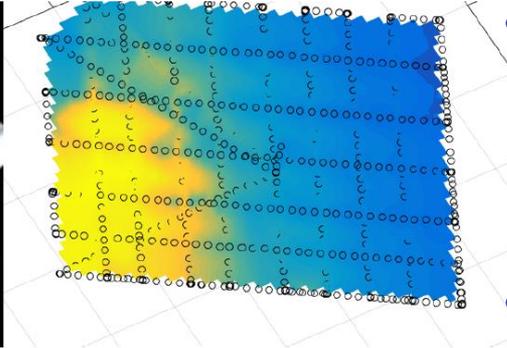
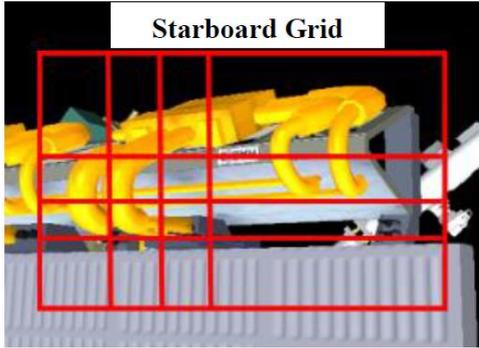


- Noticed total pressure spike at P1-3-2 RBVM on order of $\sim 5E^{-5}$ torr from the Cold Cathode Ion Gauge
- Low levels of ammonia around other RBVM $\sim 5E^{-7}$ torr
- Partial pressure from Residual Gas Analyzer correlated with ammonia

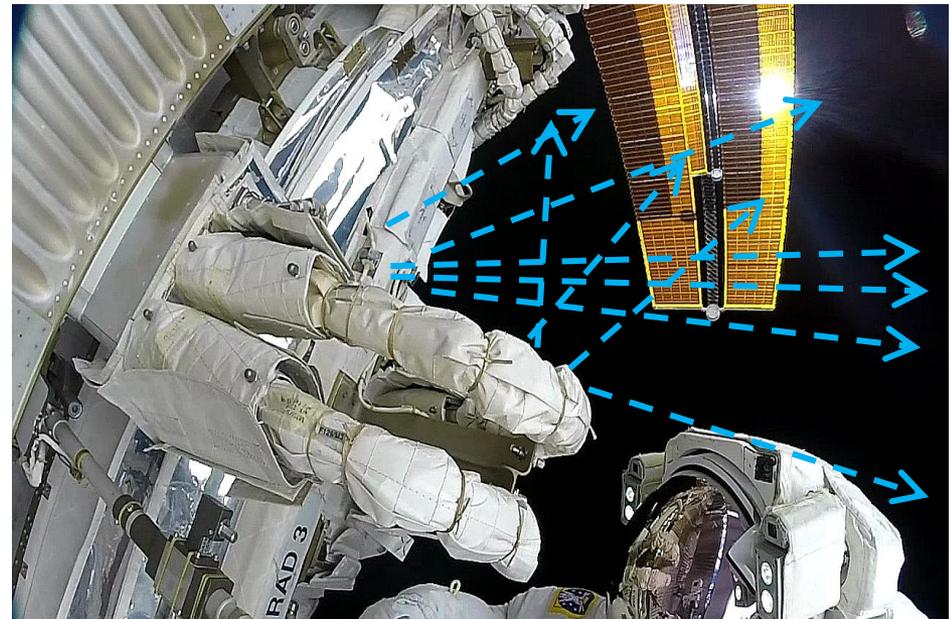
**Scan
Direction** →

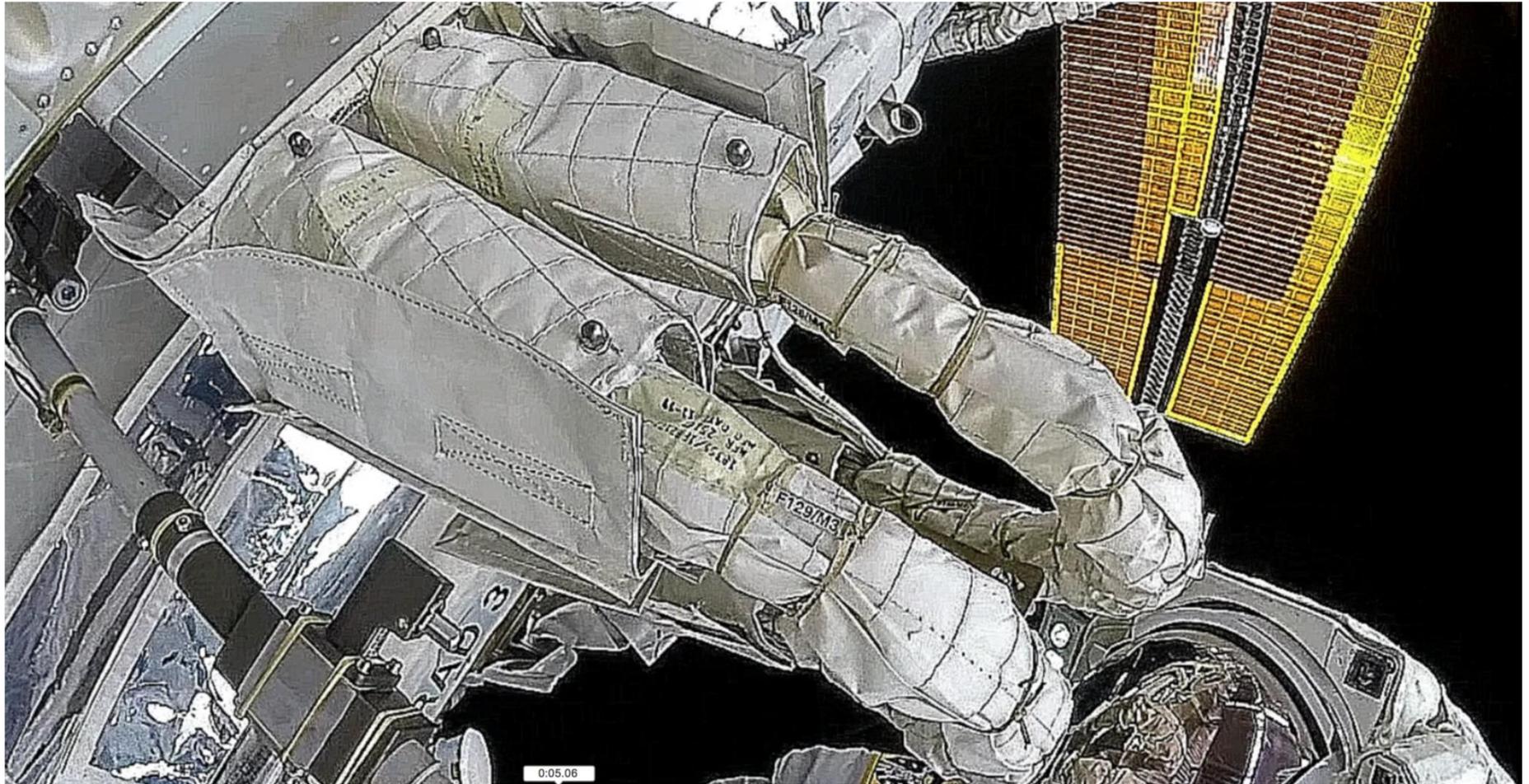


- Highest Pressures @ P1-3-2 RBVM to the radiator jumper hoses, and the hard lines underneath them
- Pressures E^{-5} torr \sim 50 lbm/year (22.6 kg/year)

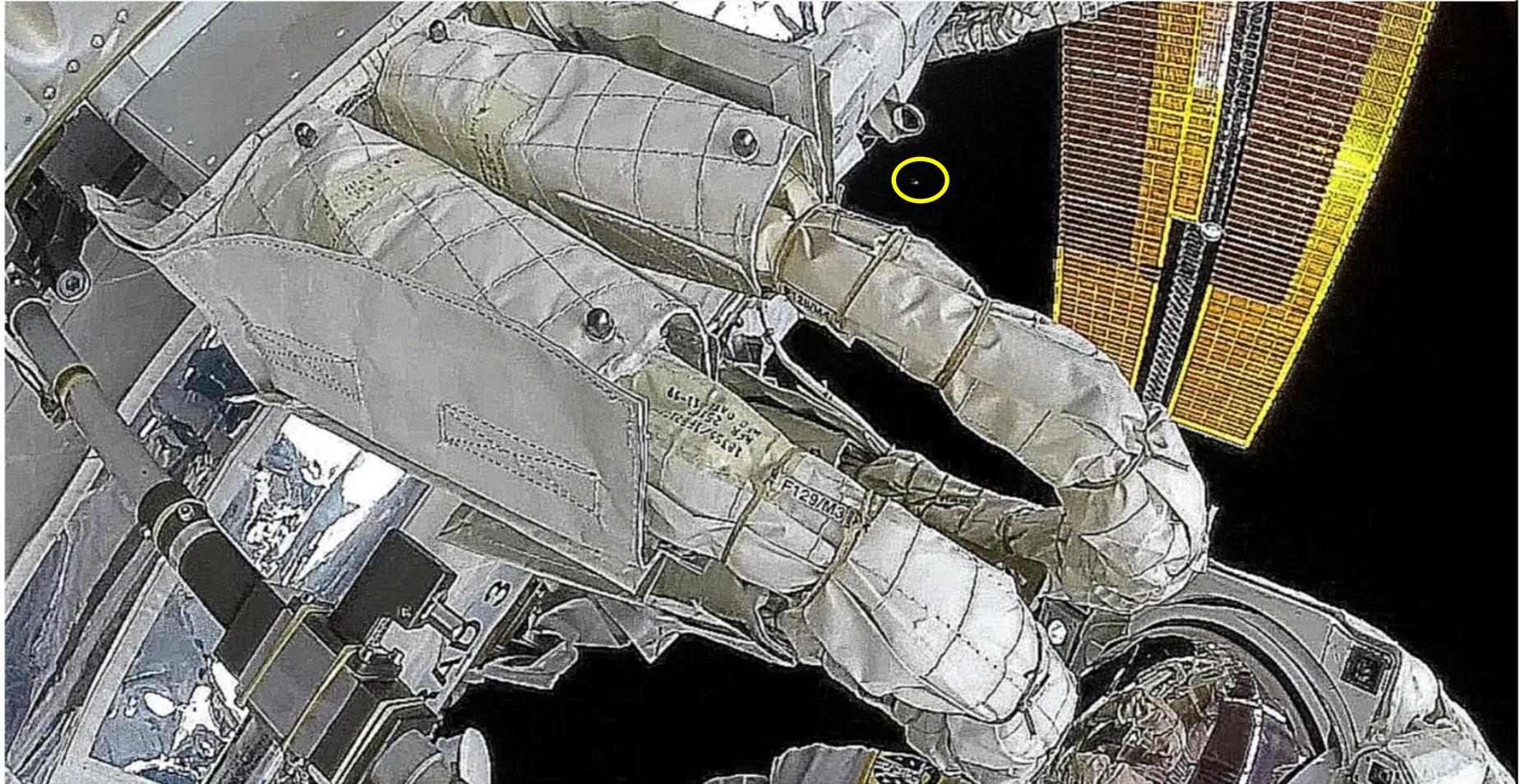


- Inspections of the RBVM jumpers hoses and system lines performed during an EVA in March 2017
- Nothing noteworthy observed from the crew
- Post EVA review, multiple white flakes seen from EVA GoPro video

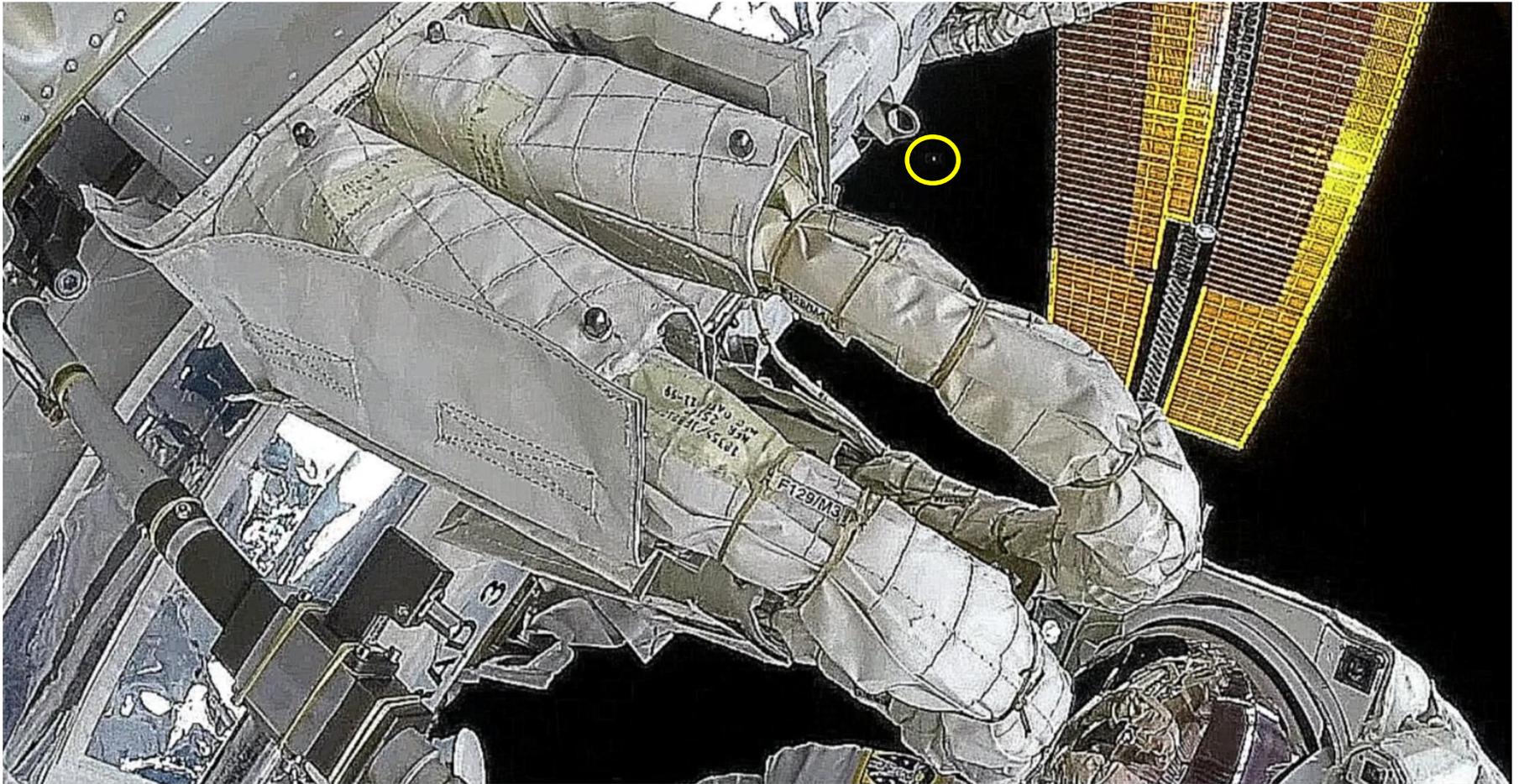




- White flakes appearing to originate from the P1-3-2 RBMV to radiator hoses

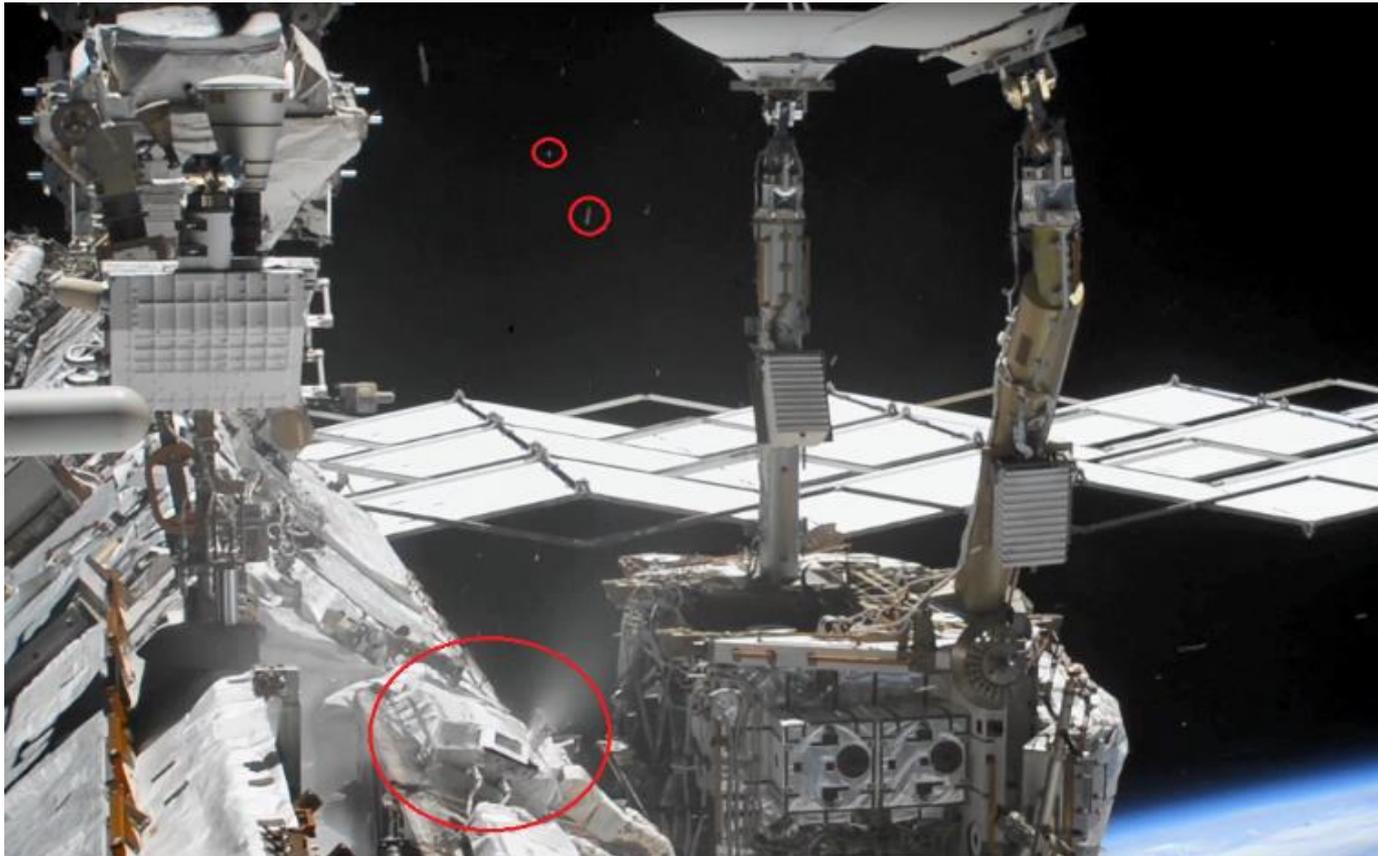


- More confidence that the leak source was the P1-3-2 RBVM to the radiator hoses as we saw white flakes appearing to originate from them



P1-3 Radiator Ammonia Vent

- Following the EVA in May 2017, ground teams remotely closed the P1-3-2 RBVM; isolating that radiator flow path
- Ammonia was then vented to space

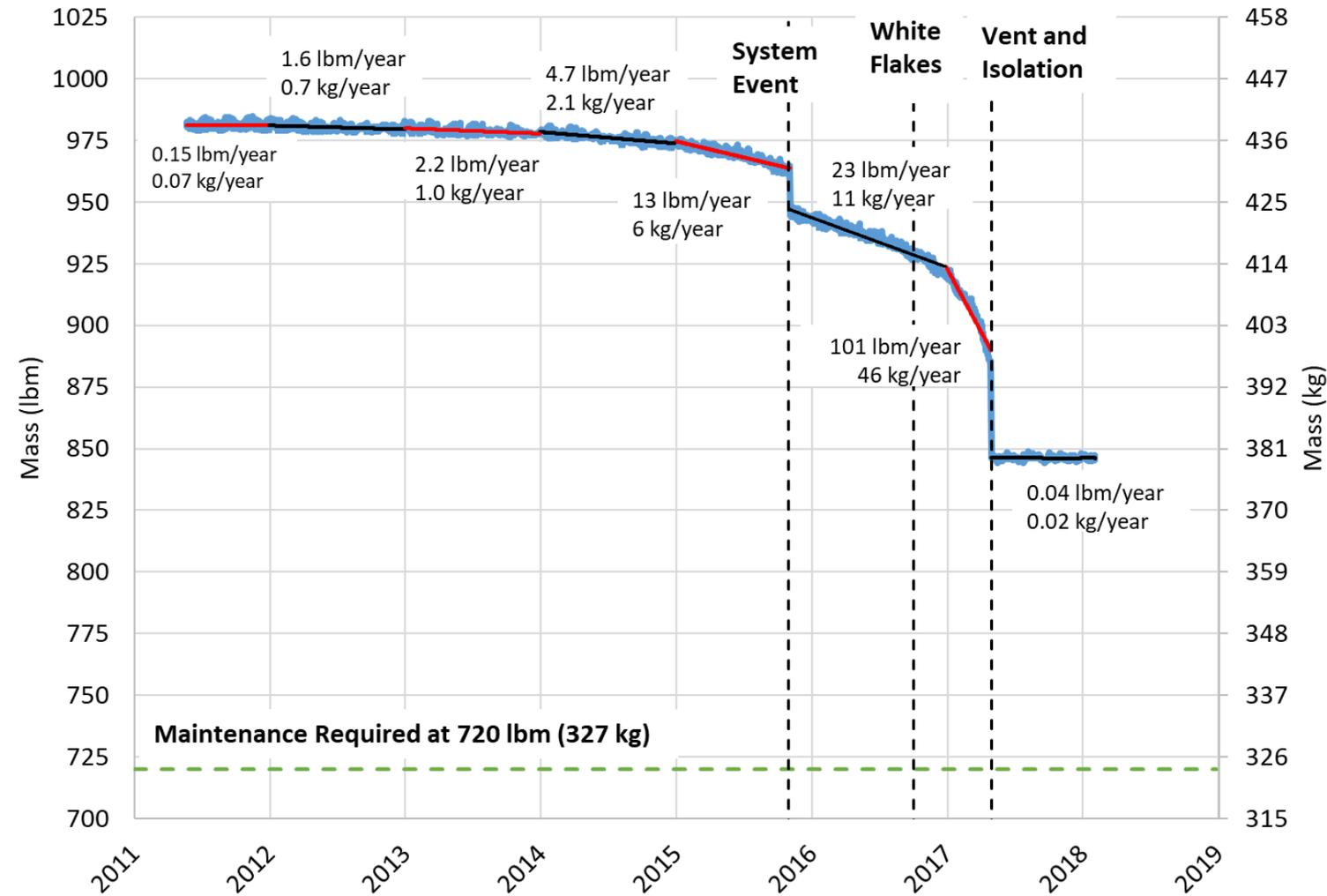


Link to the ammonia vent video

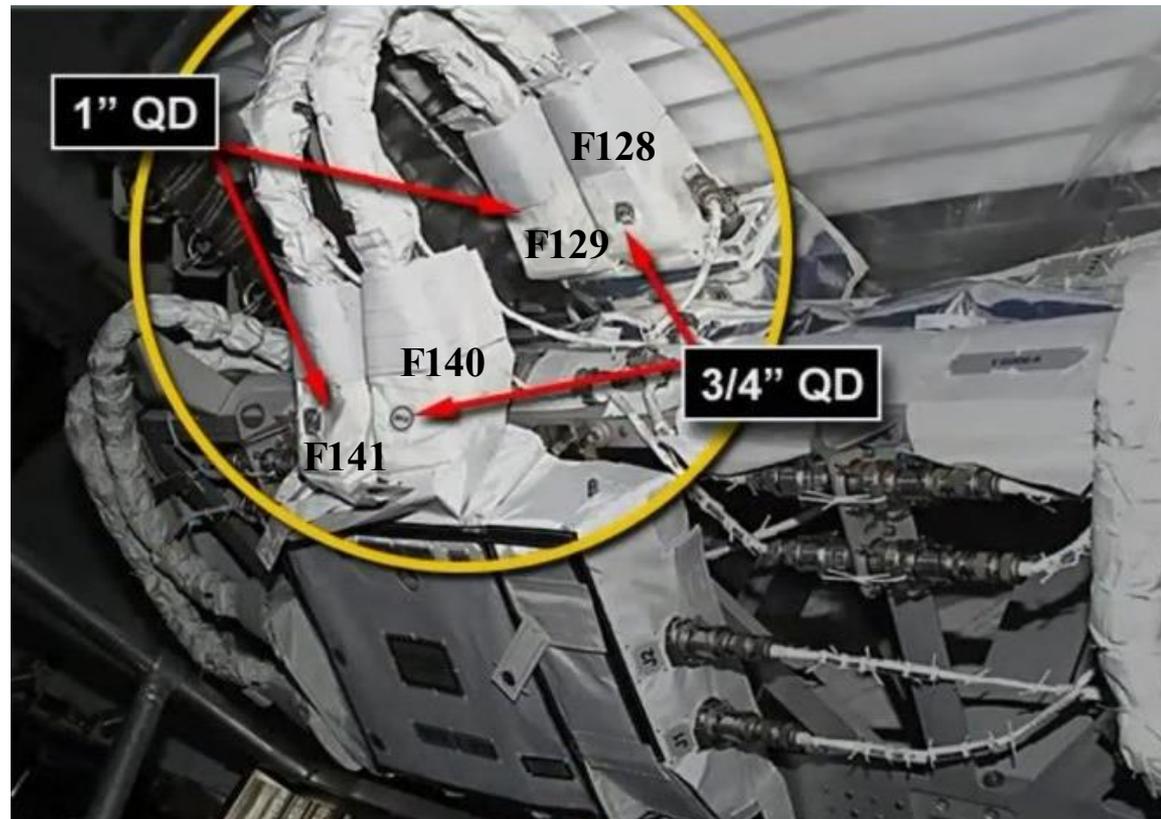
- https://youtu.be/PJzjs4EI22k?list=PL4Bmr2TXQTcQnxXpZ7BkGk_t0lhTByrDy

- Determined that the P1 EATCS ammonia leak had stopped after several months of data trending

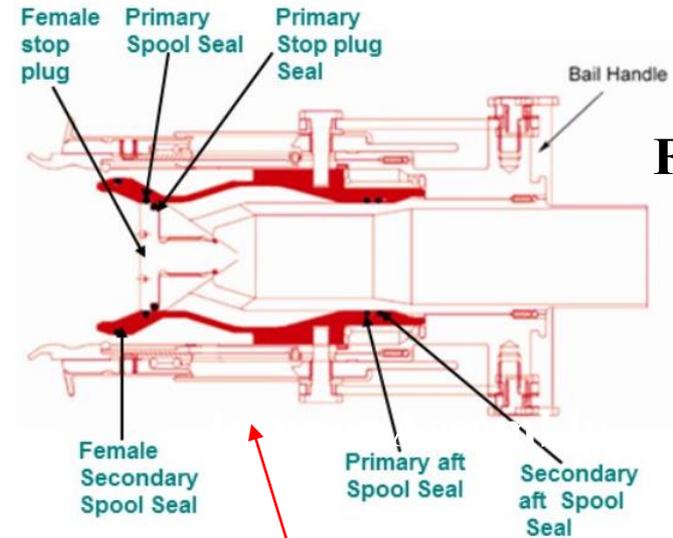
- White flakes have not been observed since



- The ISS Program agreed to remove the P1-3-2 RBVM hoses and returned them to the ground for investigation
- The purpose of the investigation is to determine if leaky hoses are unique or common
- Each radiator has 4 hoses
- Hoses were removed during an EVA in March 2018, and return to the ground in May 2018



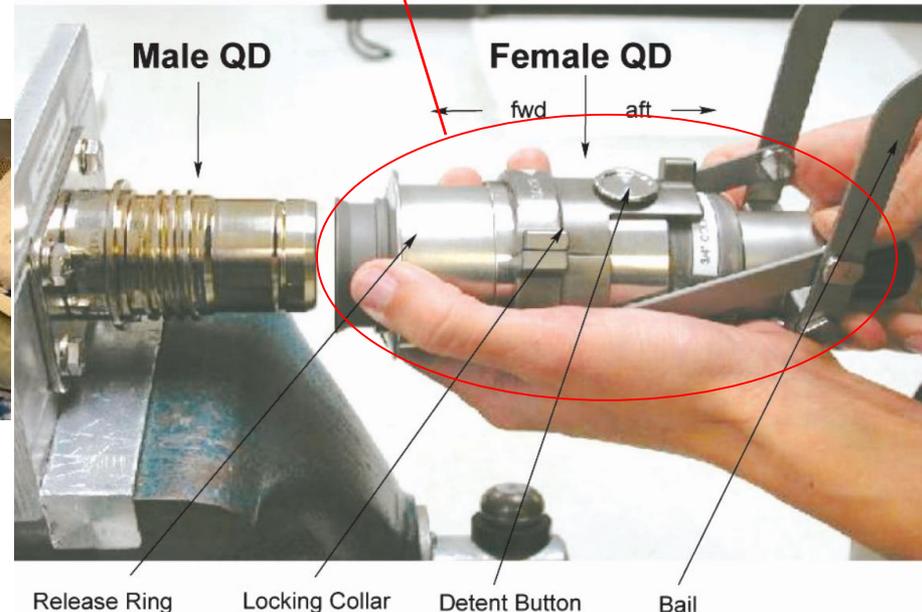
- Each RBVM has a 1" supply and 3/4" return hose connecting to a radiator
- Each hose contains two female Quick Disconnects (QD)
- Each QD contains multiple seals
- Some seals are not visible without significant QD disassembly



Female QD

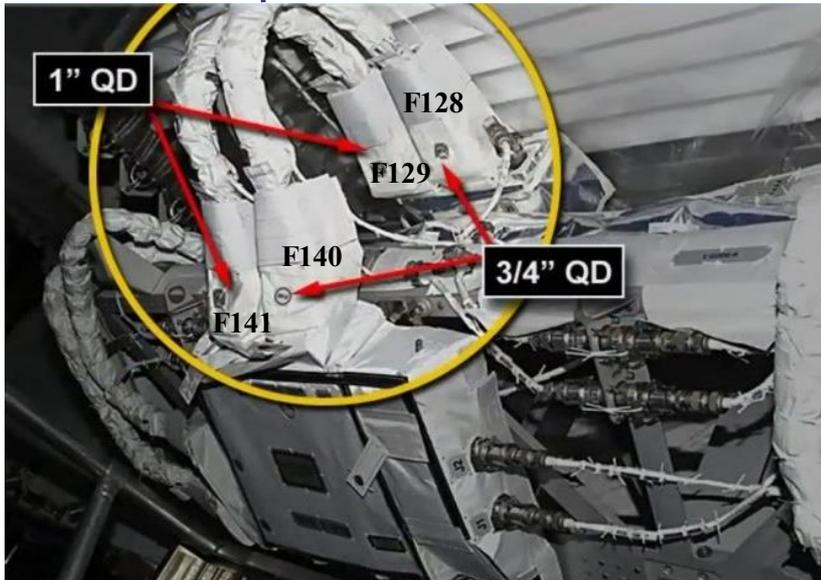


Jumper Hose

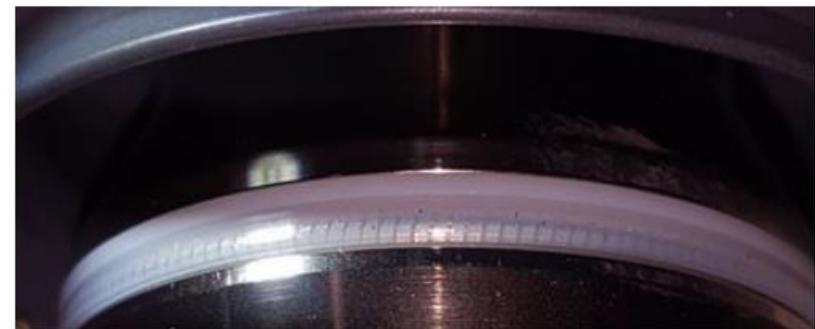


1" Supply Hose

- Visually the 1" supply hose looked good
- Barely failed the leakage requirement of 1 E^{-4} sccs of Helium at 500 psia (3447 kPa)
- Considered acceptable to be reused "as is", and returned to the ISS in April 2019



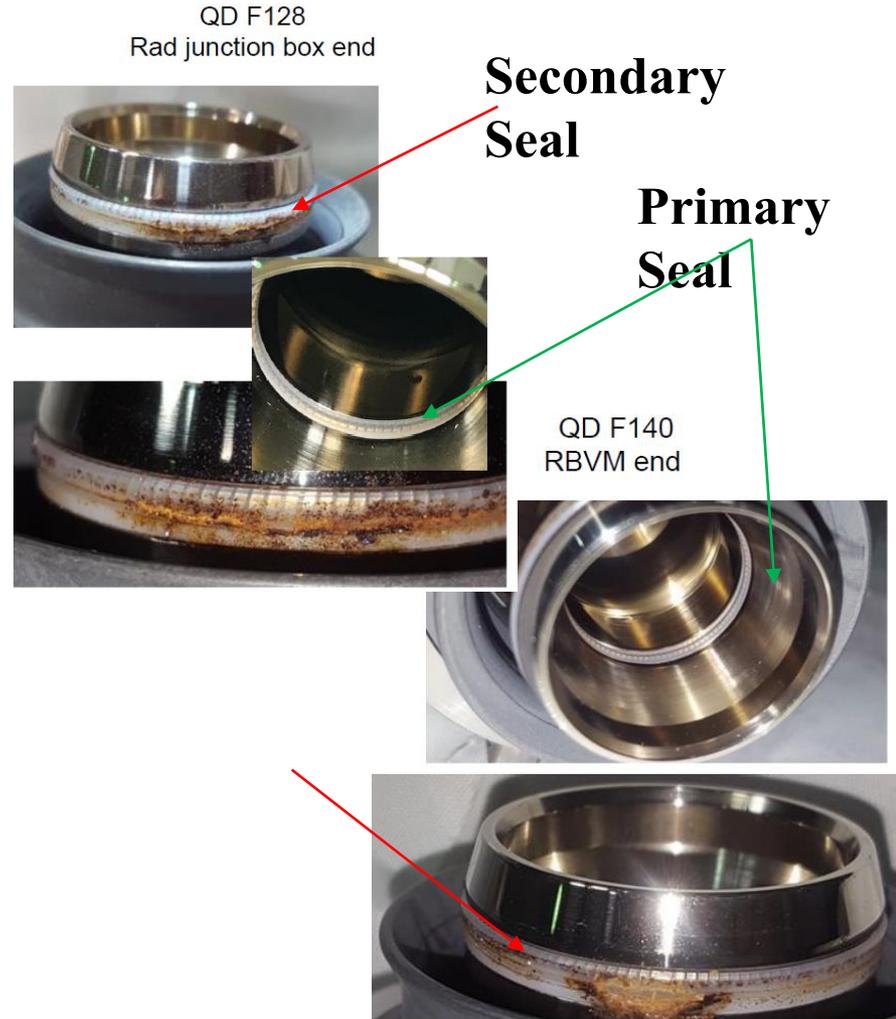
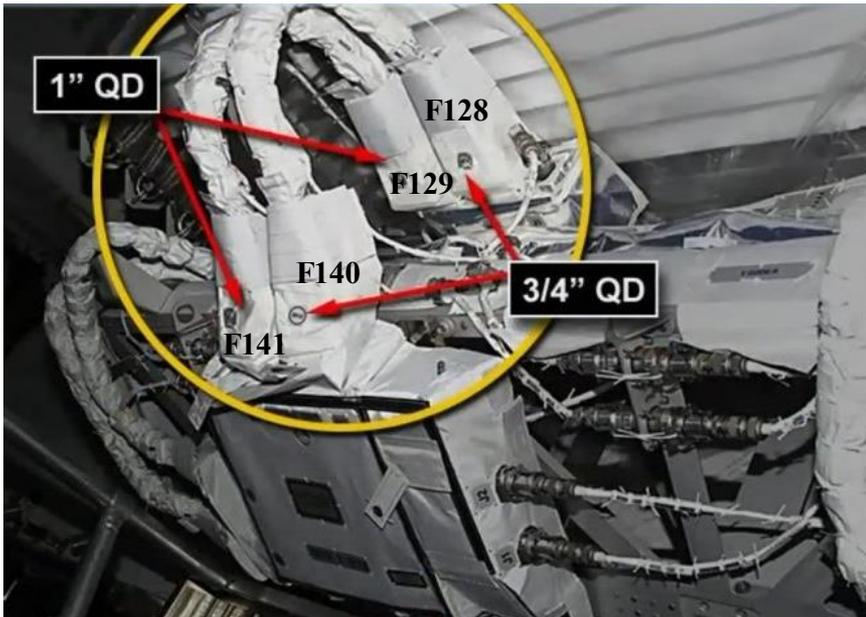
F141 QD secondary seal



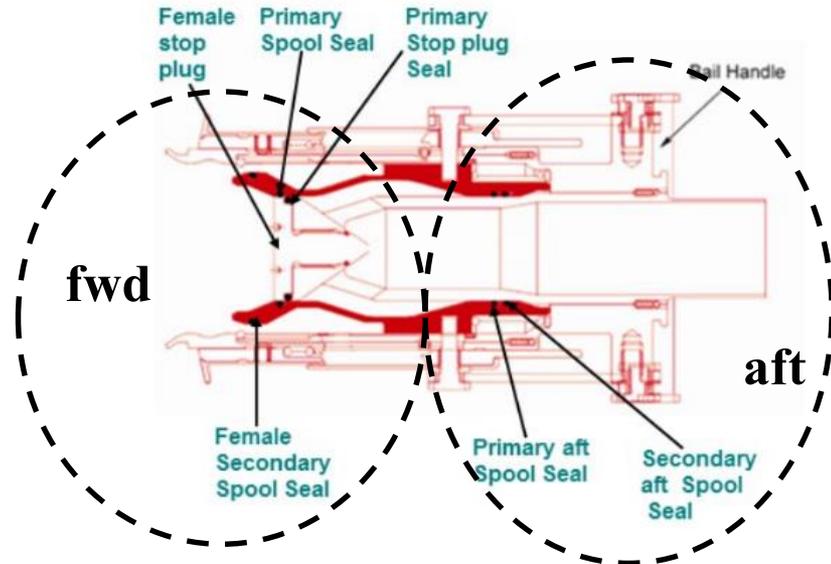
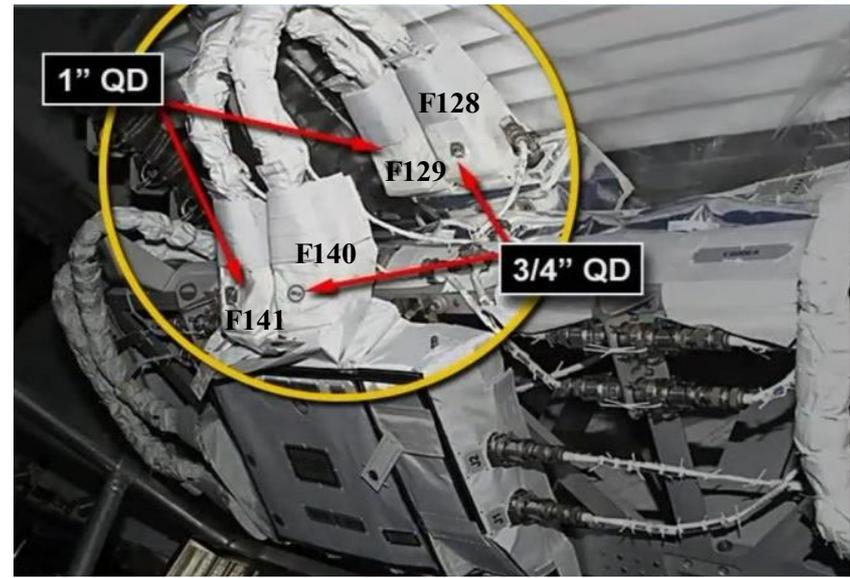
F129 QD secondary seal

3/4" Return Hose

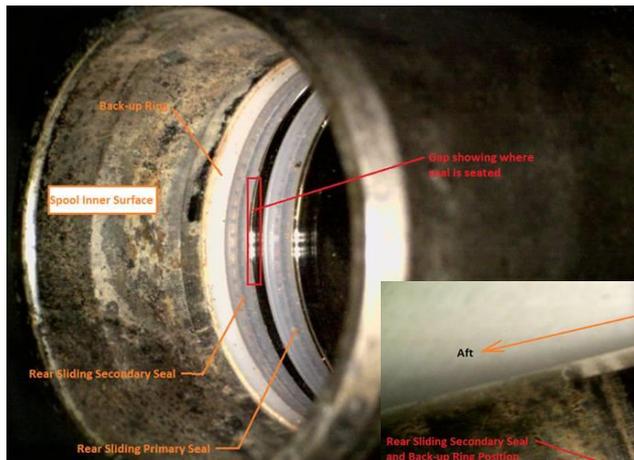
- There were noticeable brown residue on the forward seals of the 3/4" return hose
 - Samples were taken to Materials and Process laboratory
 - Consisted on non-volatile residue (NVR), and the amount was consistent with what was allowed
- QD F140 failed the leakage requirement at $2.8E^{-3}$ sccs of Helium at 500psia (3447 kPa)
- QD F128 failed the leakage requirement at 1.91 sccs of Helium at 500 psia (3447 kPa)



- Forward half failed the leakage requirement at $2.2E^{-1}$ sccs of Helium at 500 psia (3447 kPa)
- Aft half failed at 0.5 sccs of Helium @ 500 psia (3447 kPa)
- QD 128 and 140 were removed for additional TT&E
- New QDs were installed on the hose, and assembly launched to the ISS in April 2019

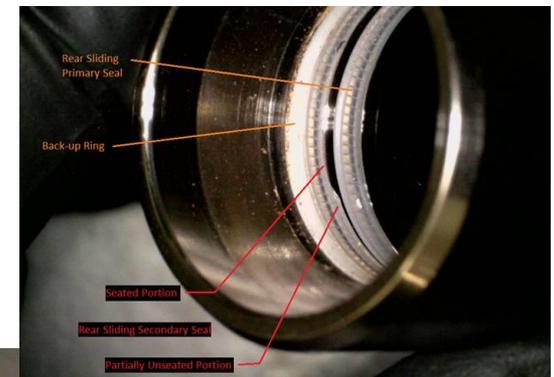


- QDs were sent to the vendor for disassembly to observe the aft seals
- No obvious signs of damage to either QDs
- Like the forward seals, significant amount of NVR was found on the aft seals of QD F128, which had the largest measurable leak rate
- Further analysis of the deposits and examination of surfaces is planned in the near future

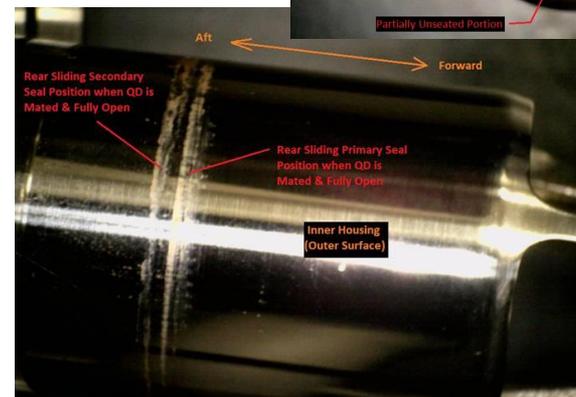
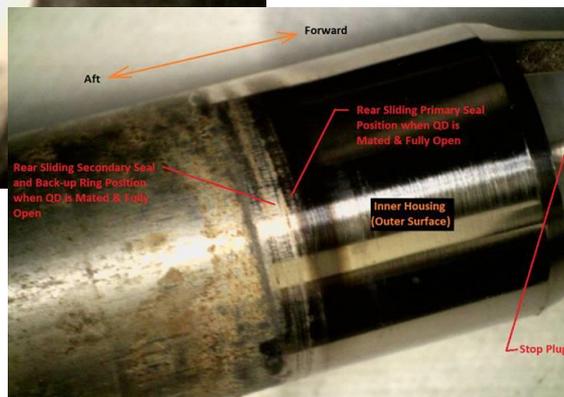


**QD F128
Spool**

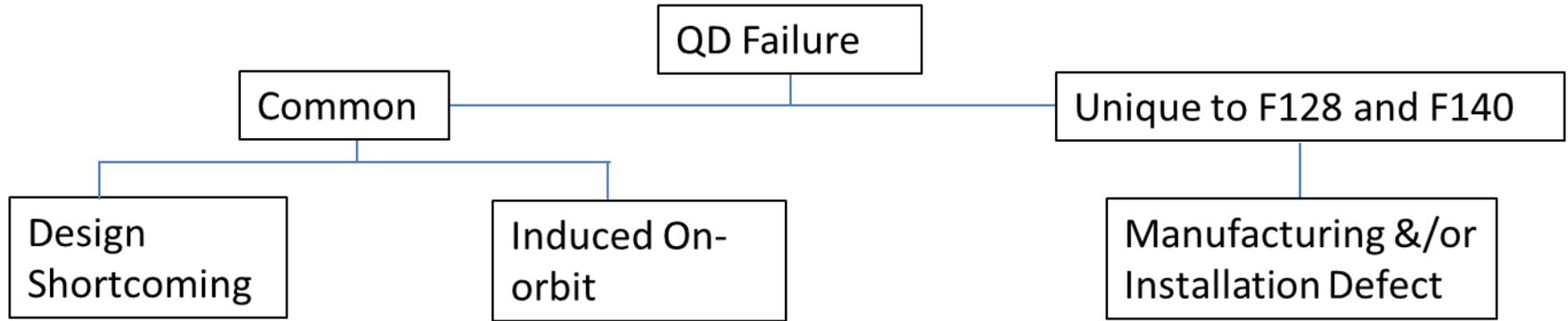
**QD F140
Spool**



**QD F128
Inner
Housing**

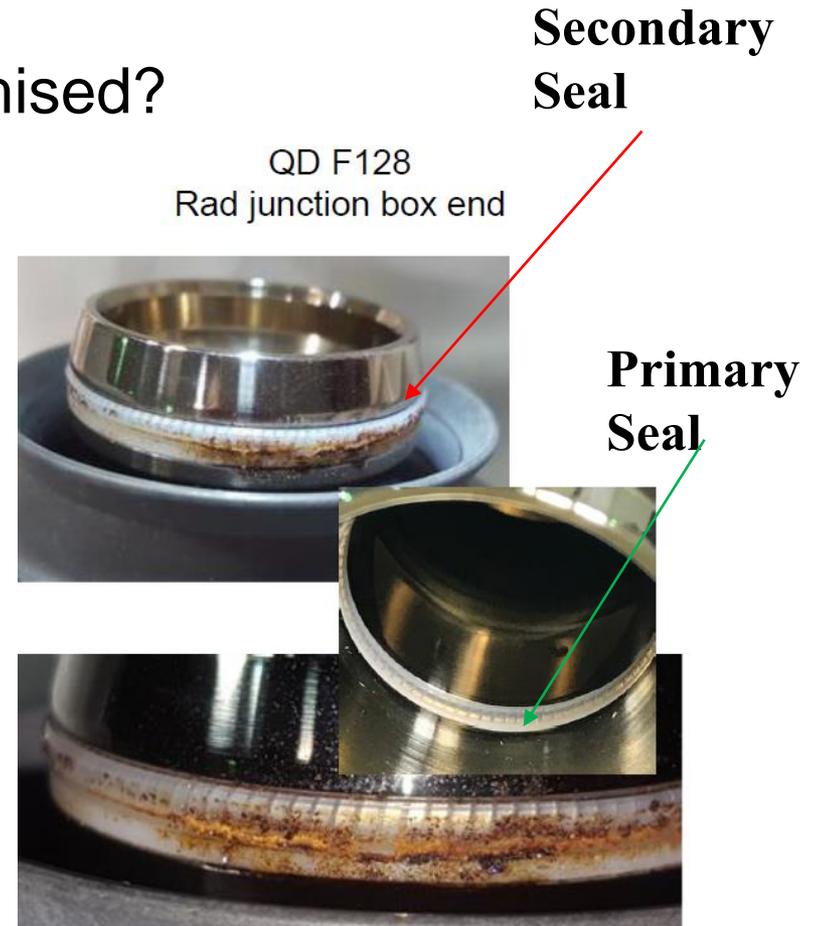
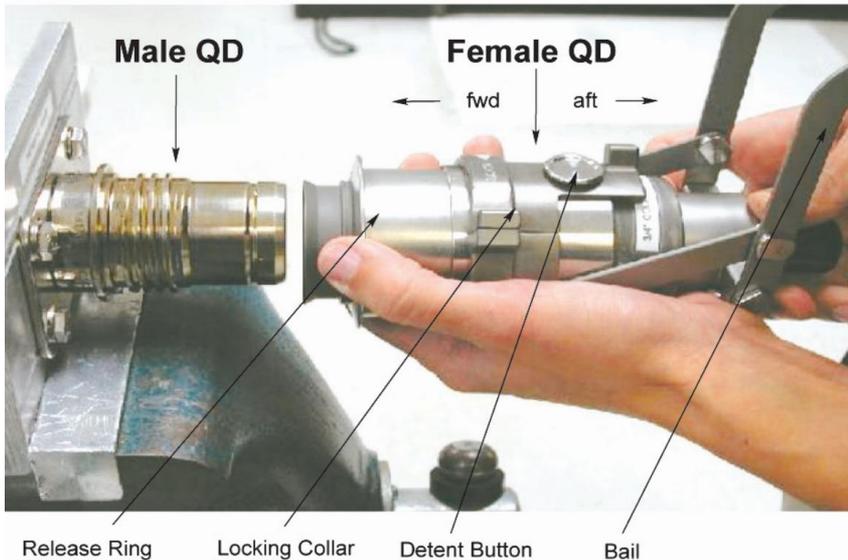


**QD F140
Inner
Housing**



- 200 QDs per EATCS, and 36 are the $\frac{3}{4}$ " RBVM return hose
- All RBVM to radiator hoses exposed to similar thermal environments
- No other significant leaks observed to date
- A GN2 filled radiator flow paths is slowly leaking ($\sim 5E^{-3}$ sccs He) overboard
- All QD seals are made of the same material
- Seals leak worse while exposed to cold temperatures based on qualification and verification testing
- QD F128, source of the P1 EATCS leak, failed the leak test on the ground before launch, but seals were replaced before launch
- EATCS were filled on-orbit, and the ammonia chemistry (in particular the NVR) could not be evaluated prior to launch

- The results of the QD F128 failure investigation should help address the following:
 - Unique or common failure
 - Male QD counterpart compromised?
 - Possible design changes
 - Sparing posture
 - On-orbit operation changes



Summary

- The ISS P1 EATCS had a slowly increasing ammonia leak, and white flakes were observed from the ISS HD video cameras
- The RELL narrowed down the source of the leak to the P1-3-2 RBVM supply and return jumper hoses
- Hoses and radiator flow paths were isolated, and vented of ammonia; stopping the leak
- White flakes have not been observed since
- Hoses returned to the ground, refurbished and relaunched to ISS
- Leak source determined to be the aft seals in QD F128 (radiator end) on the $\frac{3}{4}$ " RBVM return hose
- Further evaluation in work