



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

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Purpose/Agenda

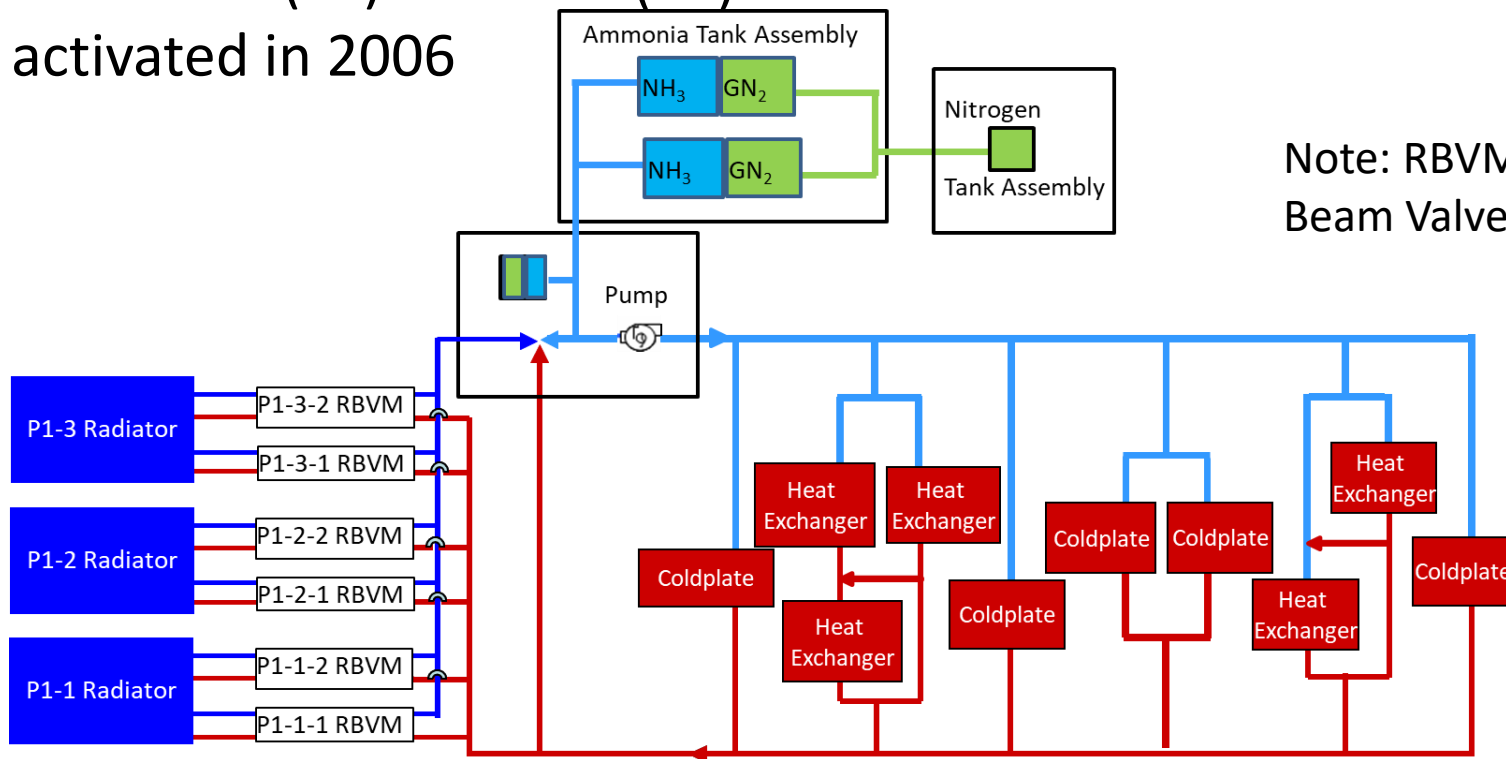
- **Purpose:** Discuss the ISS P1 EATCS ammonia leak investigation and current findings
- **Agenda:**
 - EATCS 101
 - Houston, We Have A Leak!
 - White Flakes
 - Locating Leaks
 - Root Cause Investigation and TT&E
 - Discussion
 - Conclusion
 - Summary





EATCS 101

- EATCS - closed loop single phase system (two redundant loops)
- Mechanically pumps liquid ammonia to cool avionics, payloads and electronic equipment onboard the ISS
- Starboard (S1) and Port (P1) EATCS were launched in 2002, and activated in 2006

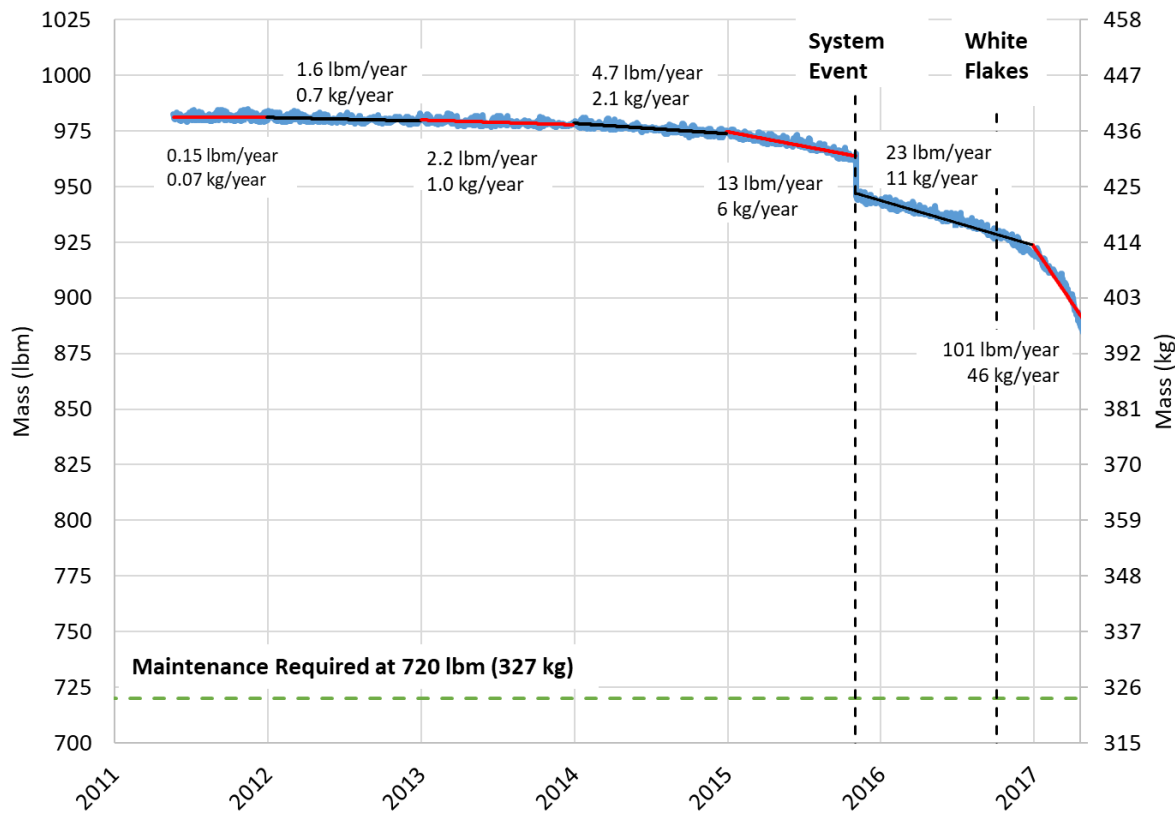


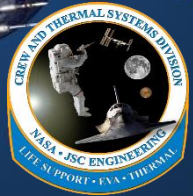
Note: RBVM= Radiator Beam Valve Module



Houston, We Have A Leak!

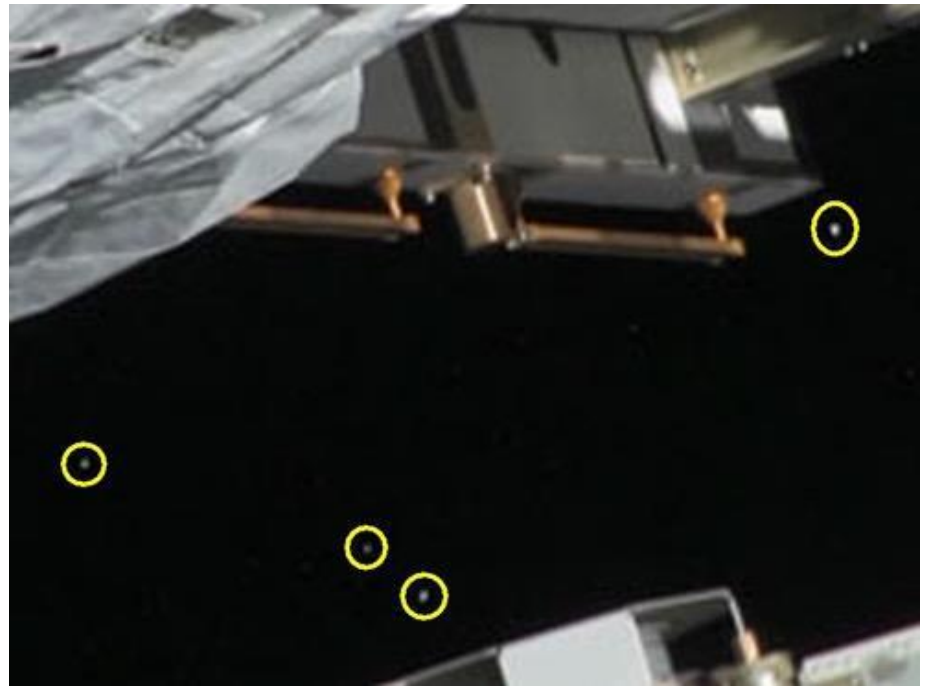
- The Problem: P1 EATCS -detected a coolant inventory decay in 2012,leak began to accelerate
- Cause/Location: Unknown at the time

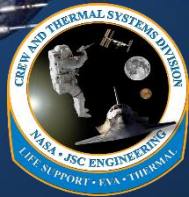




White Flakes

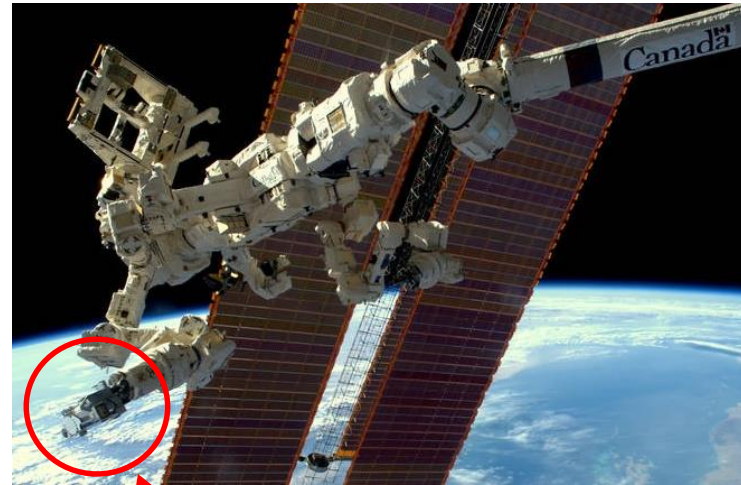
- In early 2016, began observing mysterious “white flakes”, on the P1 external high definition cameras as the leak rate approached 30 lbm/year (13.6 kg/year)
- Uncertain if related to ammonia leak, what else could they be?
- Leaks that produce visible particles or flakes typically thought to be > 50 lbm/day
- Flakes were sporadically seen moving across camera field of view seeming to come from a common location
- Lack of depth perception made it difficult to estimate possible originating locations



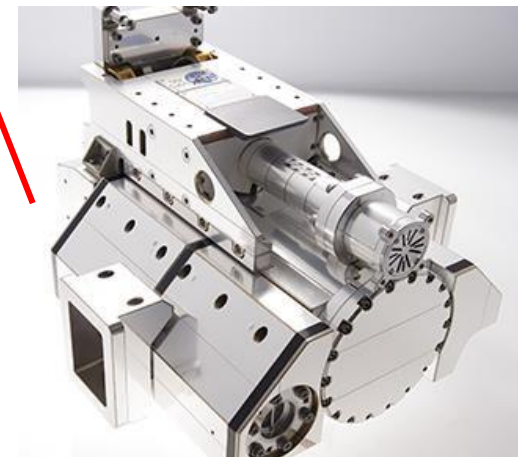


Locating leaks

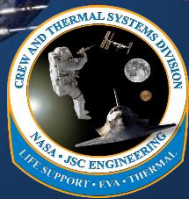
- Existing techniques to locate a leak was to isolate system into segments and monitor inventory decay
- Cons
 - Shutting down system, time, resources, low chance for success
- Remedy.....the Robotic External Leak Locator (RELL)
- New tool built to work with ISS Robotic Arm
- Remotely detect and ID various gases, and measure their pressures in a vacuum
- Launched in 2015
- Coincidentally, in time to help locate P1 EATCS leak



RELL Attached to the ISS Robotic Arm

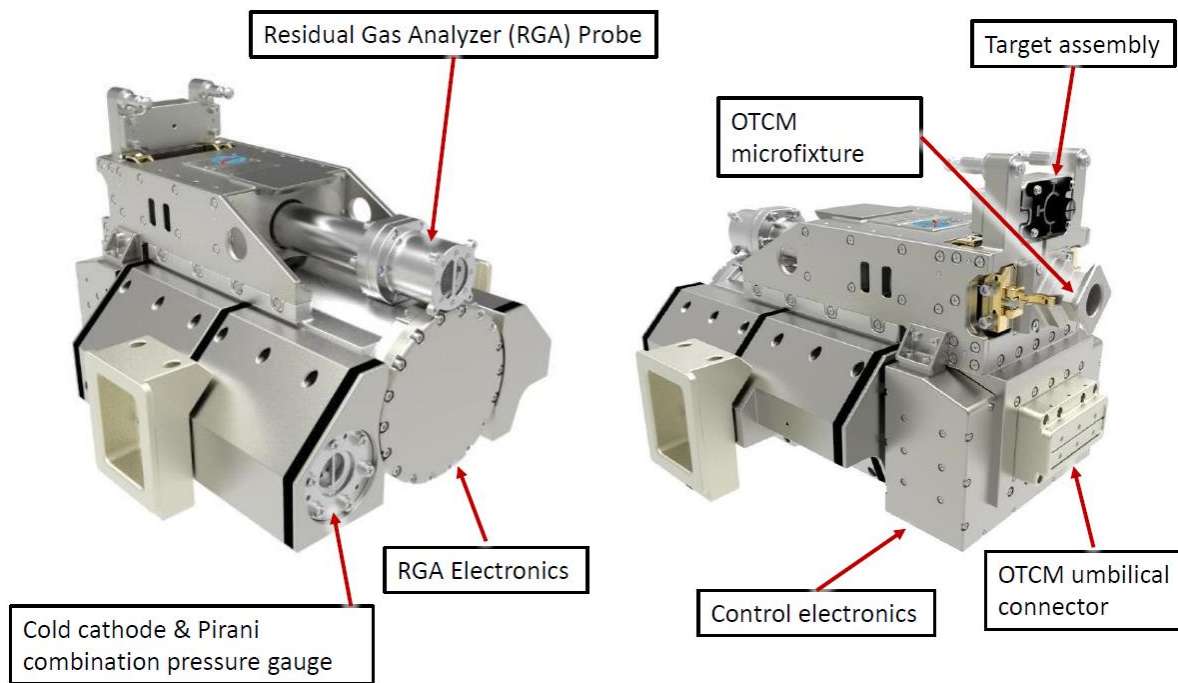


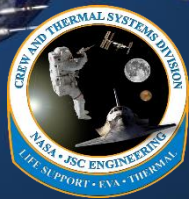
RELL Unit



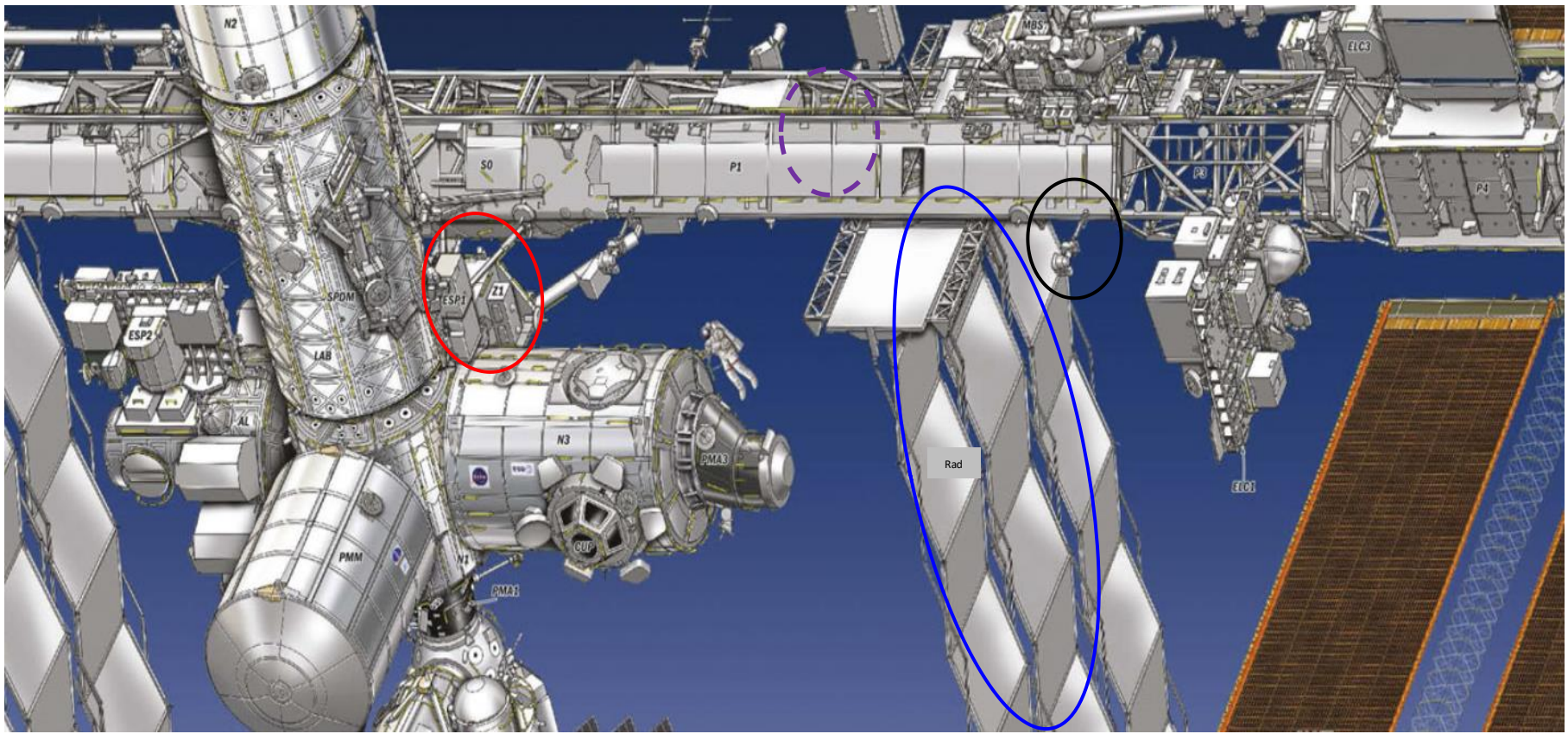
RELL Capabilities

- Detect molecules up to 100 atomic mass units (amu)
- Measure pressures from standard atmosphere to $\sim E^{-12}$ torr
- Cold Cathode Ion Gauge measures total pressure
- Residual Gas Analyzer (mass spec) measures partial pressure of range of amu
- Pressure measurements are directional in space environment





Possible White Flakes Sources Locations

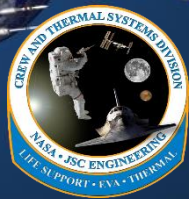


- P1 EATCS Radiators circled in blue, Z1 (decommissioned) and a spare Pump Flow Control Subassembly (PFCS) circled in red, P1 EHDC circled in black, ATA behind structure (dotted purple)



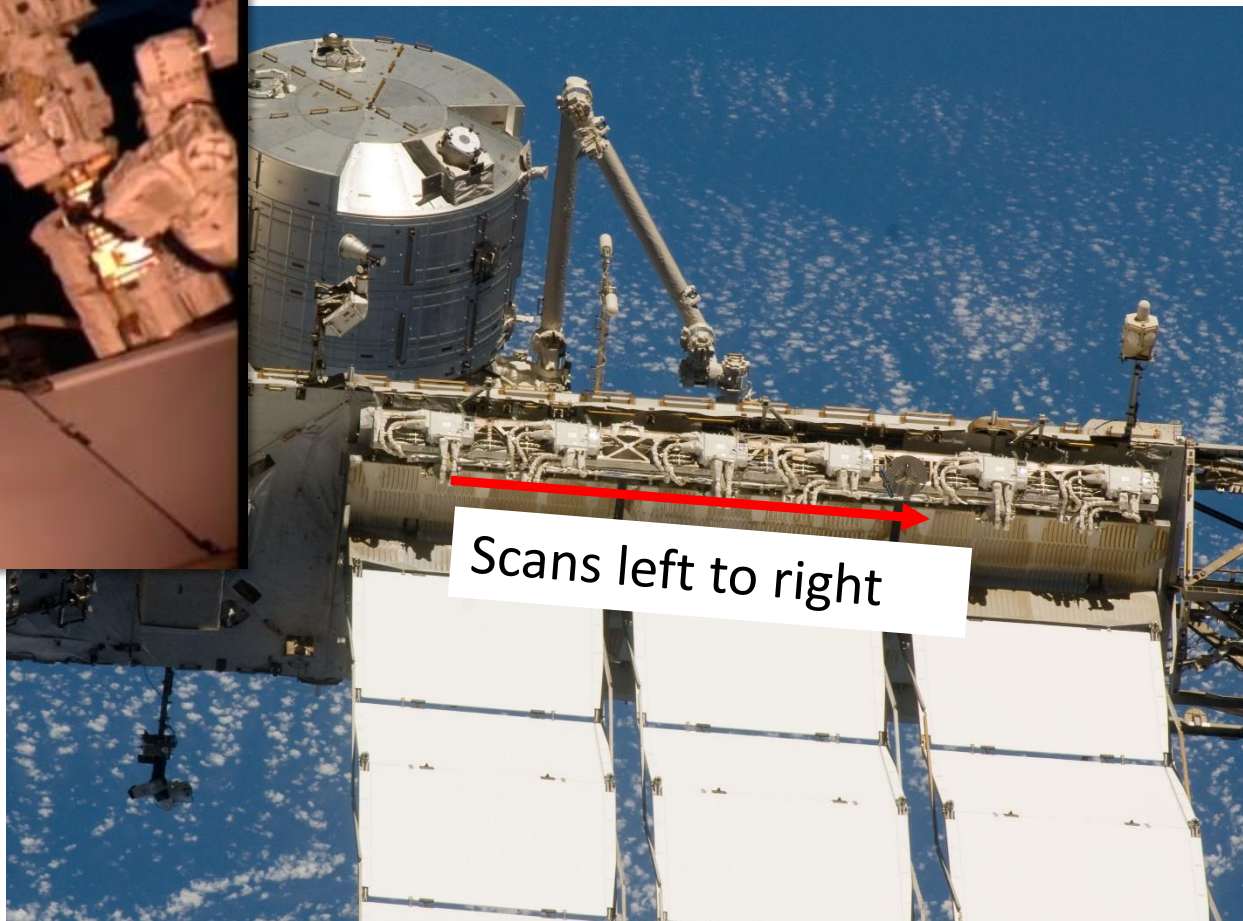
2016 RELL Scans

- Demonstration Scans
 - ISS background (natural atmosphere, ISS vents and outgassing)
 - Pressures measured $\sim E^{-12}$ to E^{-8} torr
- P1 EATCS leak and white flake scans
 - 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**



RELL Scan Locations

- P1 ISS EATCS Radiator Beam Valve Modules

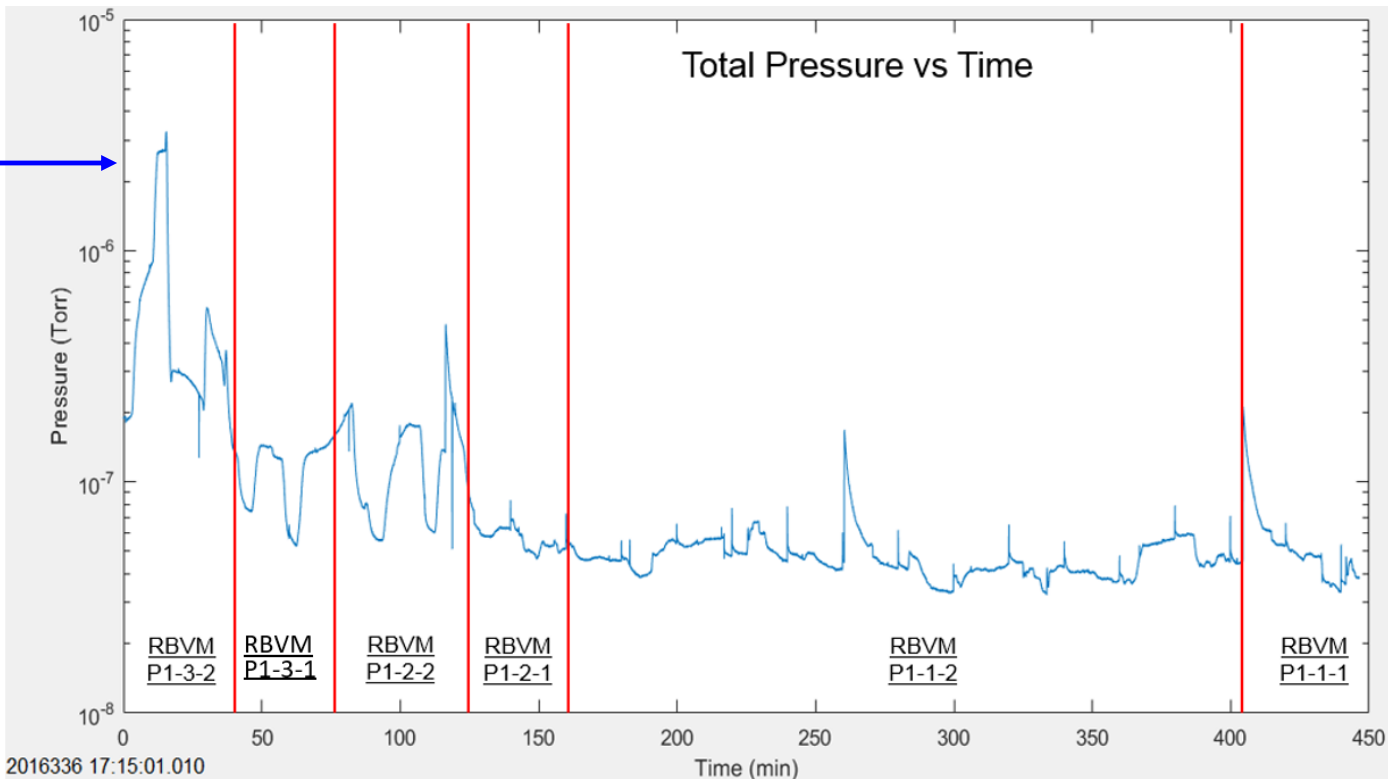


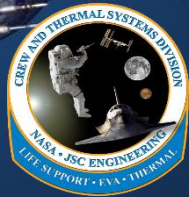


RELL Scans - RBVM

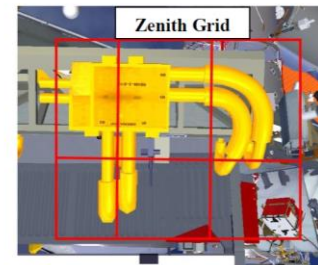
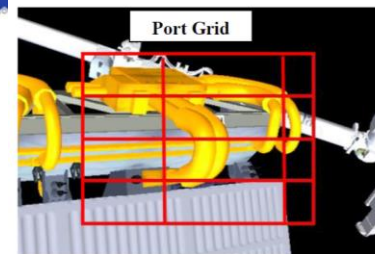
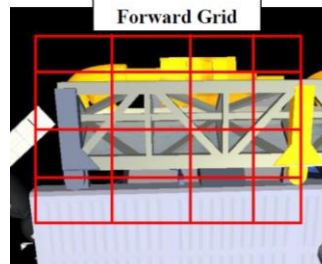
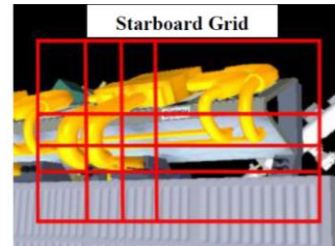
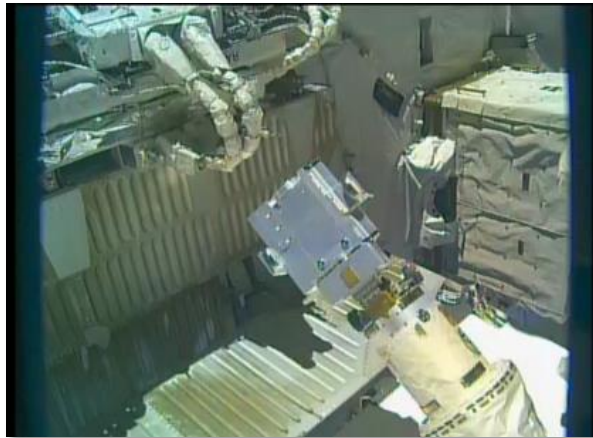
- Noticed total pressure spike at P1-3-2 RBVM on order of $\sim 5E^{-5}$ torr
- Low levels of ammonia around other RBVM $\sim 5E^{-7}$ torr
- Partial pressure from RGA correlated with ammonia

Scan
Direction →

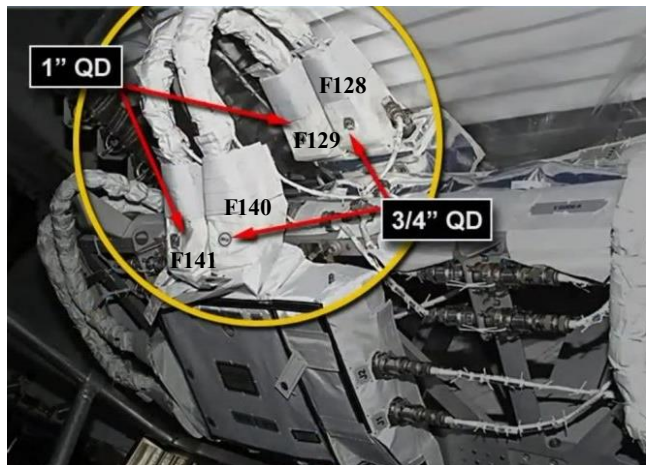




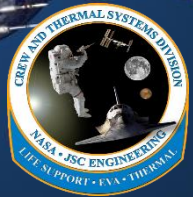
Focused RELL Scans – P1-3-2 RBVM



Highest Pressures @ P1-3-2 RBVM to the radiator jumper hoses, and the hard lines underneath them

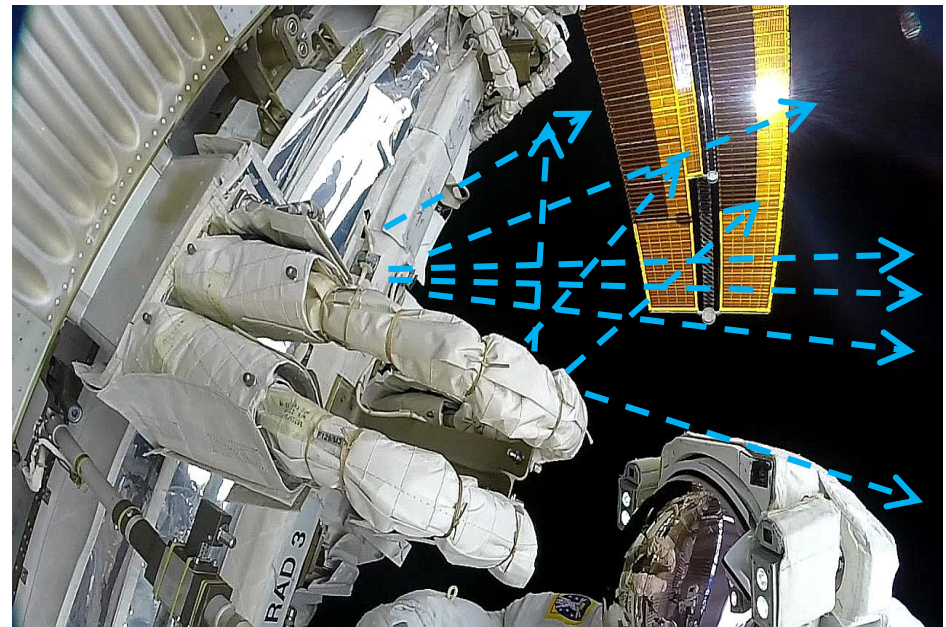
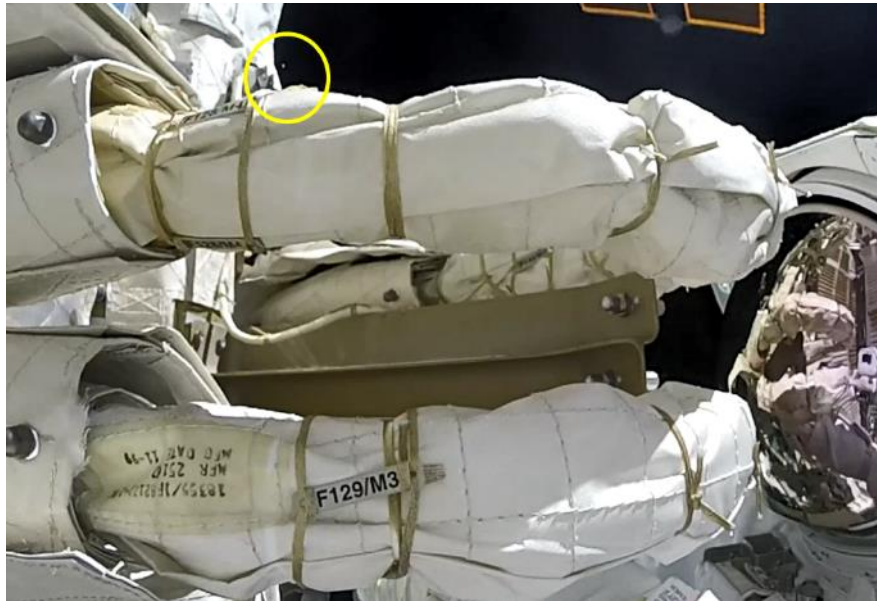


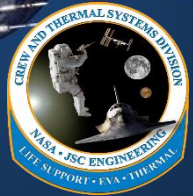
Pressures E^{-5} torr \sim 50 lbm/year (22.6 kg/year)



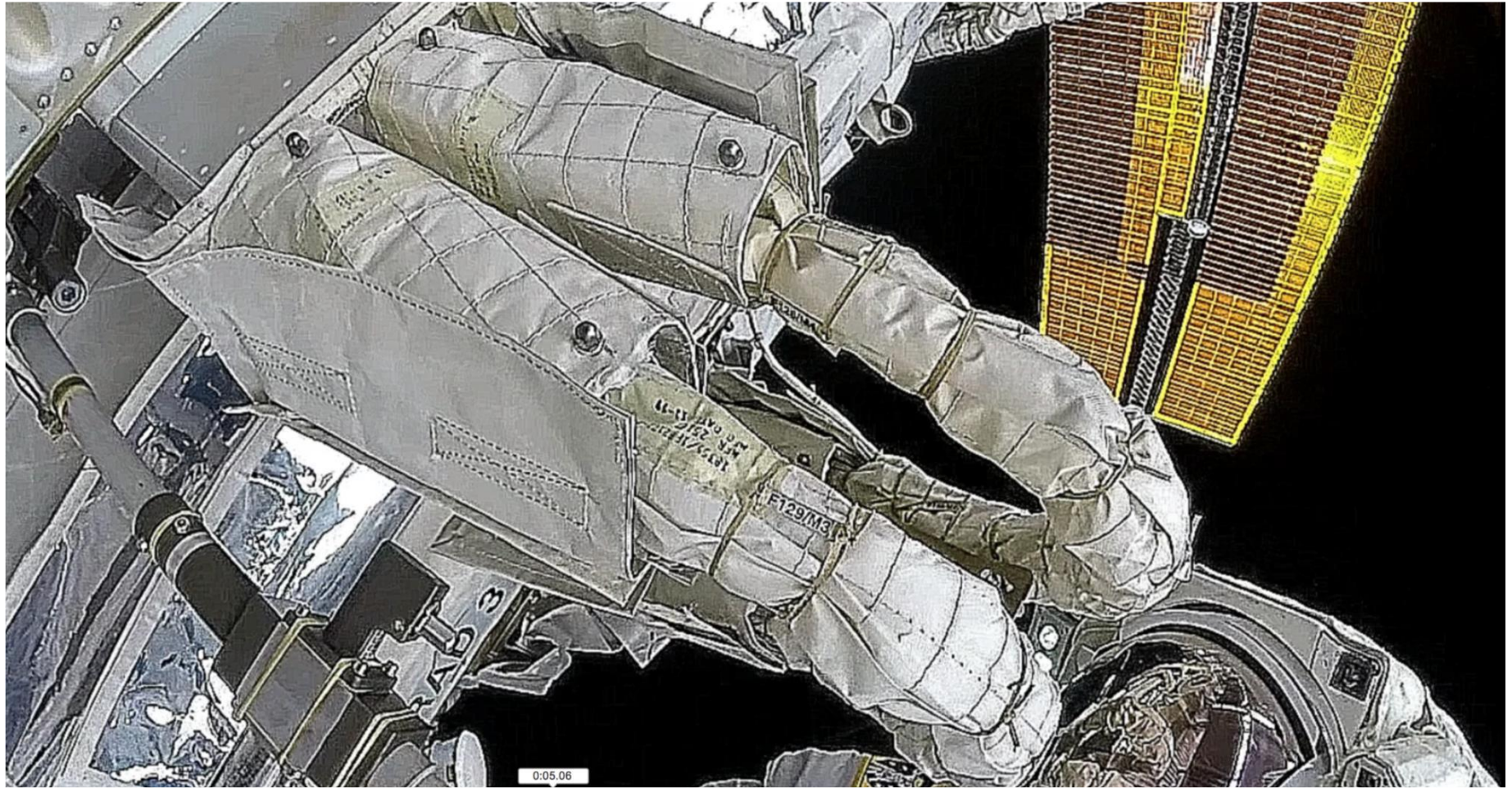
Extravehicular Activity (EVA) Jumper Inspection

- 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



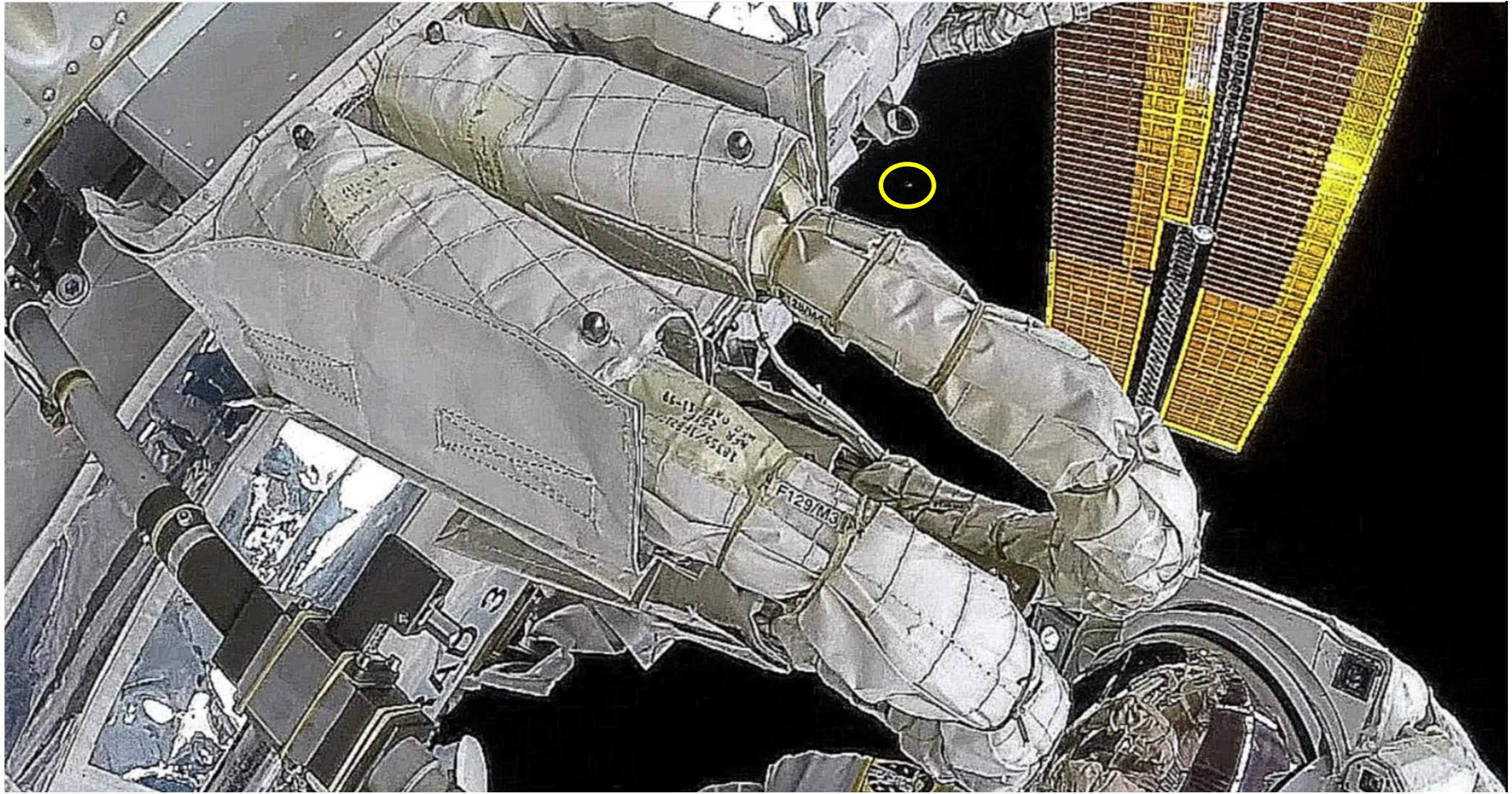


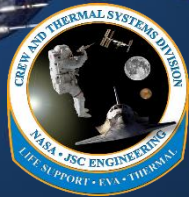
EVA Go Pro Video – Still Image



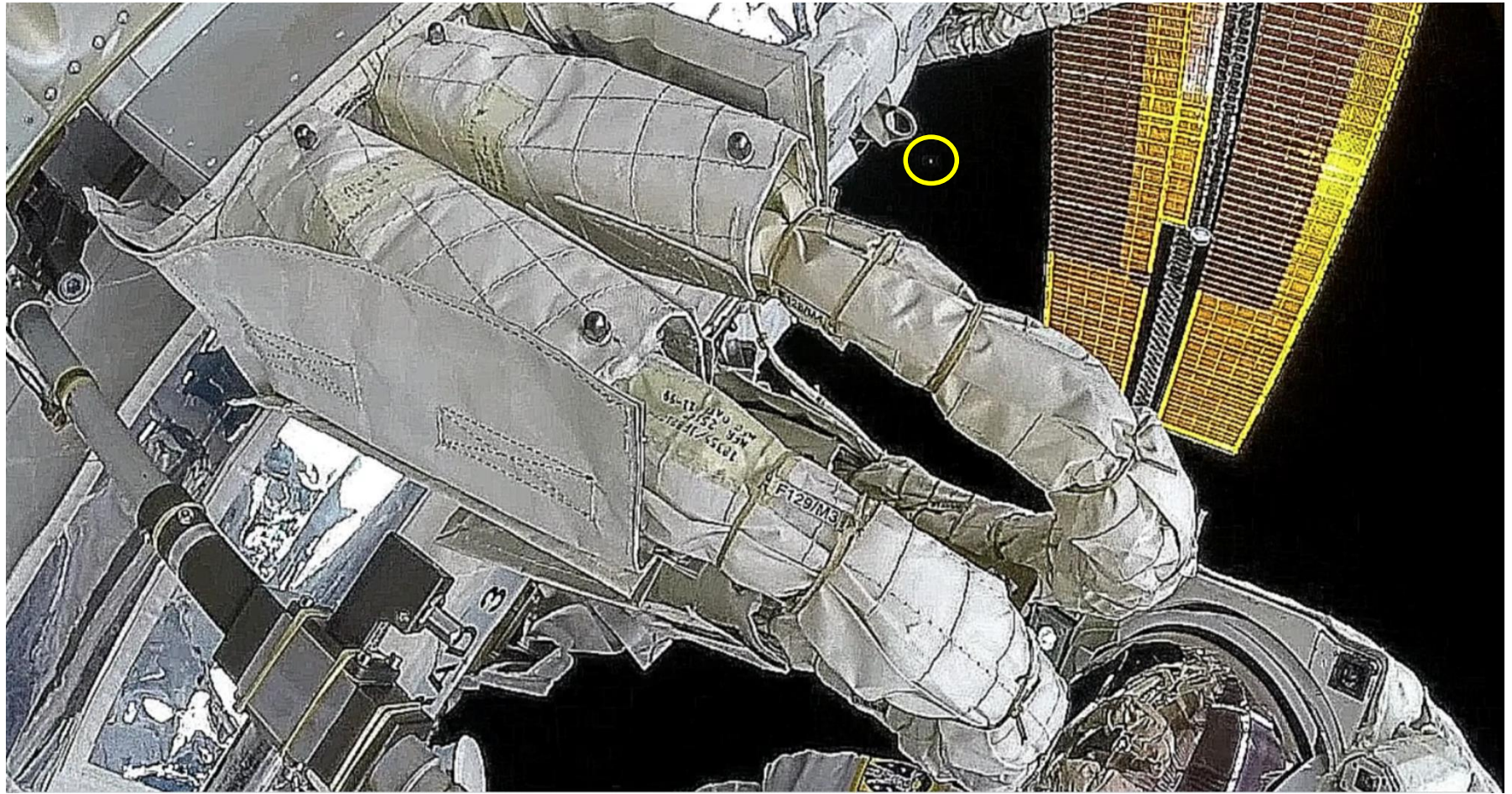


EVA Go Pro Video – Still Image





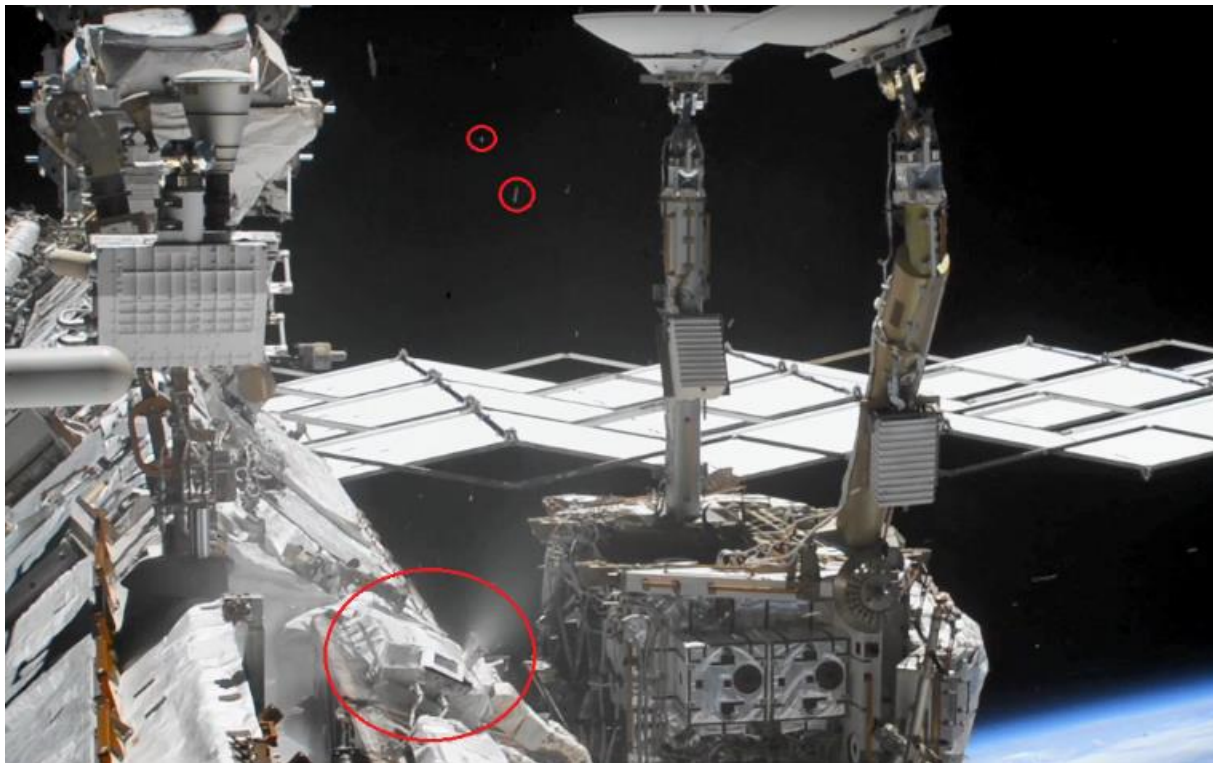
EVA Go Pro Video – Still Image





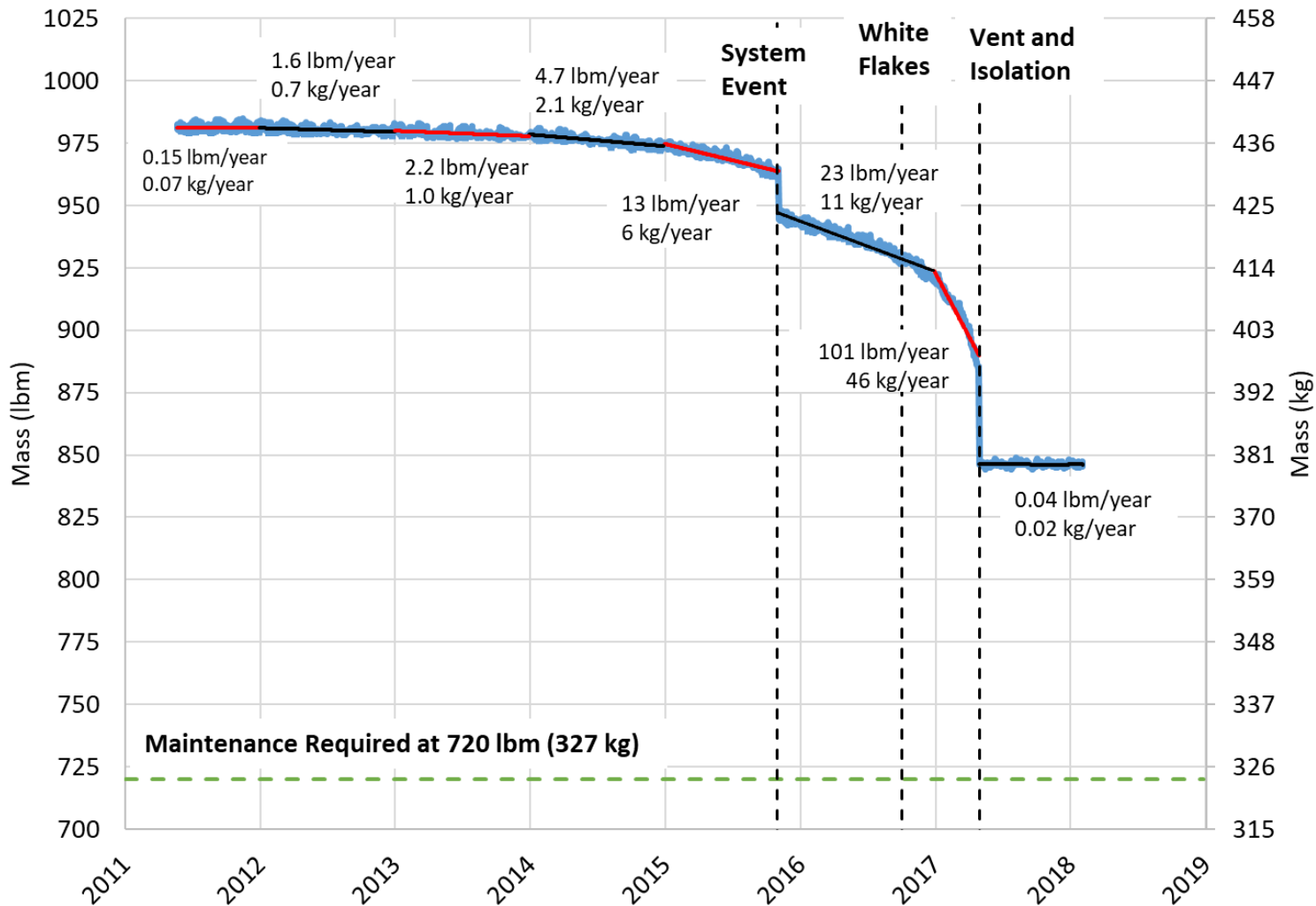
Leak Stopped by [unclear]

- Following the EVA in May 2017, ground command remotely closed the RBVM to the P1-3 radiator; isolating that flow path
- Ammonia was vented to space, stopping the leak
- White flakes have not been observed since and subsequent mass plots show the leak stopped





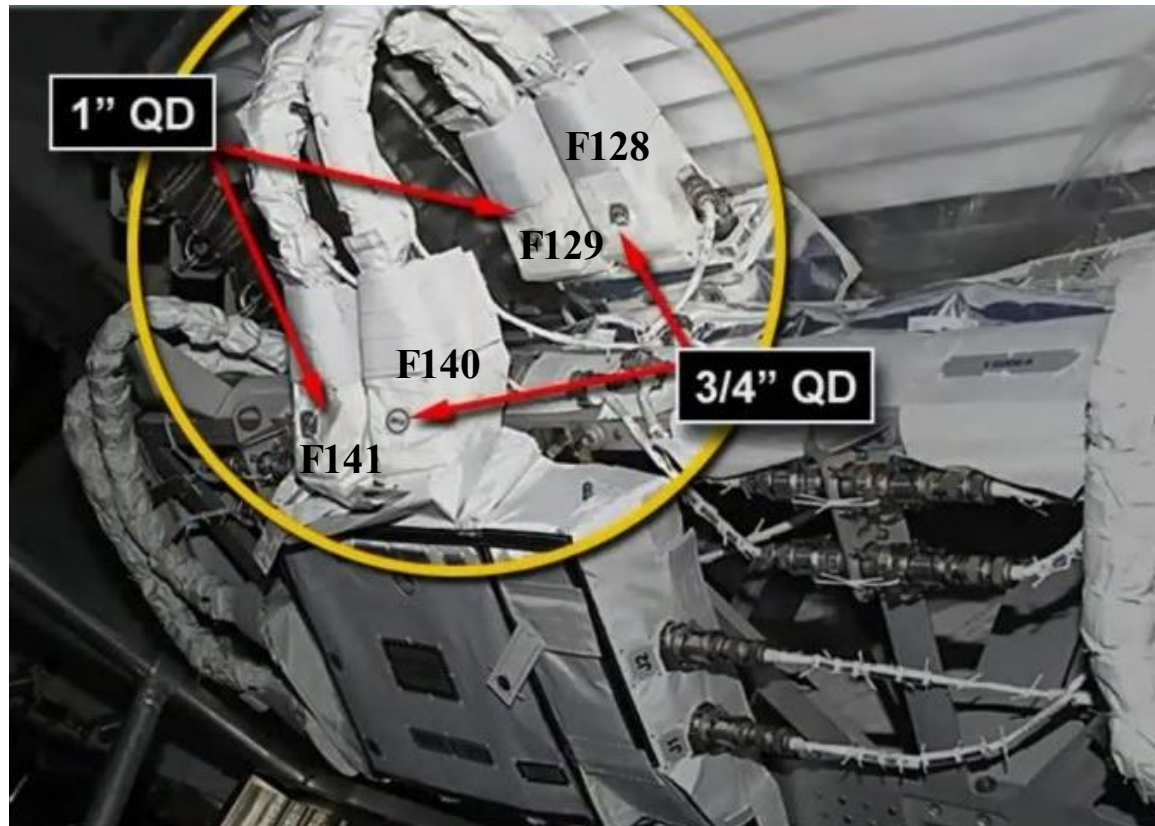
Leak Stopped

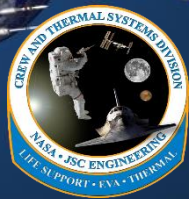




Root Cause investigation

- Most likely leak source - RBVM jumper hoses rather than the hard lines underneath them
- ISS Program agreed to remove the RBVM hoses and returned them to the ground for investigation
- Hoses removed during an EVA in March 2018, and return to the ground in May 2018





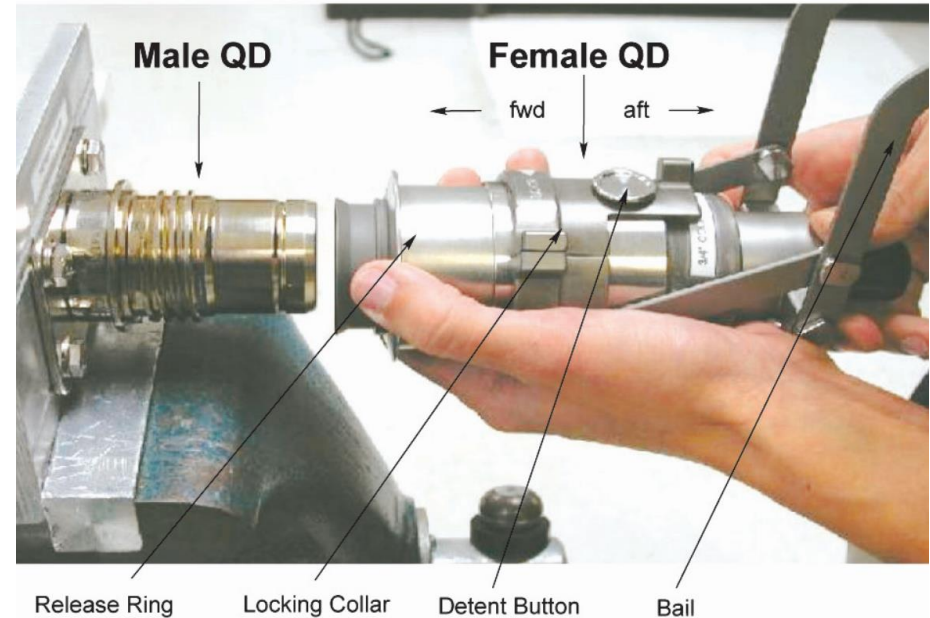
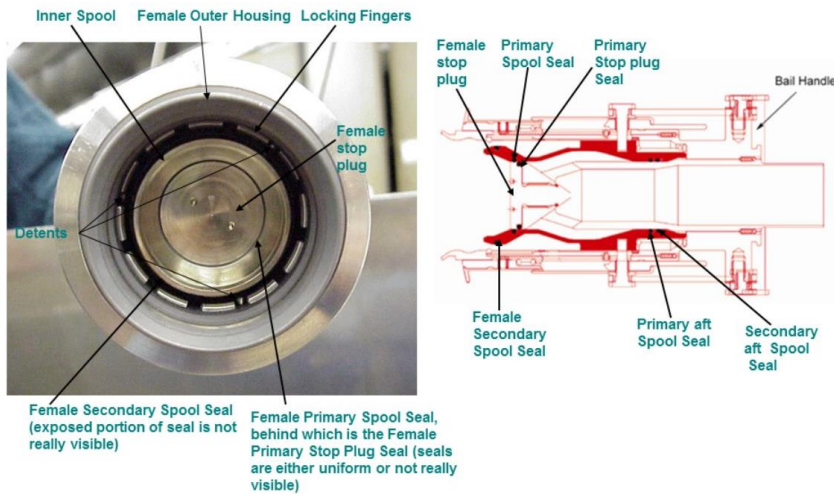
TT&E-Jumper Hose Assembly Overview

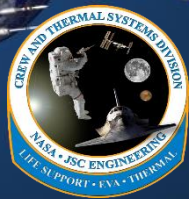
- 1" supply and 3/4th return hose
- Each hose contains two female Quick Disconnects (QD)
- Each QD contains multiple seals
- Some seals are not visible without significant QD disassembly



Jumper Assembly

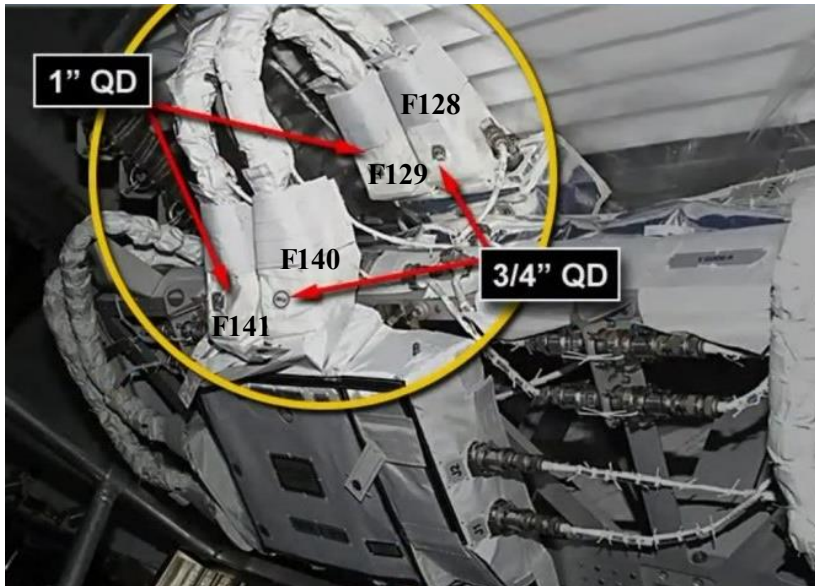
Female QD



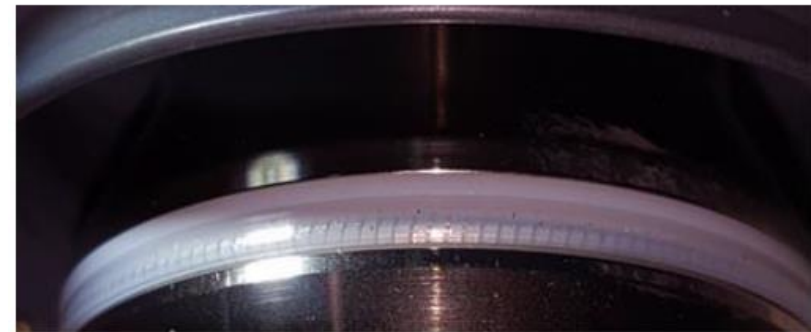


TT&E - 1" Supply Hose

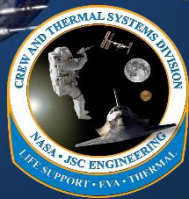
- Inspection shows the 1" supply hose looked good
- Barely failed Leakage requirement of 1 E^{-4} sccs of Helium at 500 psia (3447 kPa)
- Considered acceptable to be reused "as is", and returned to the ISS in April 2019



F141 QD secondary seal

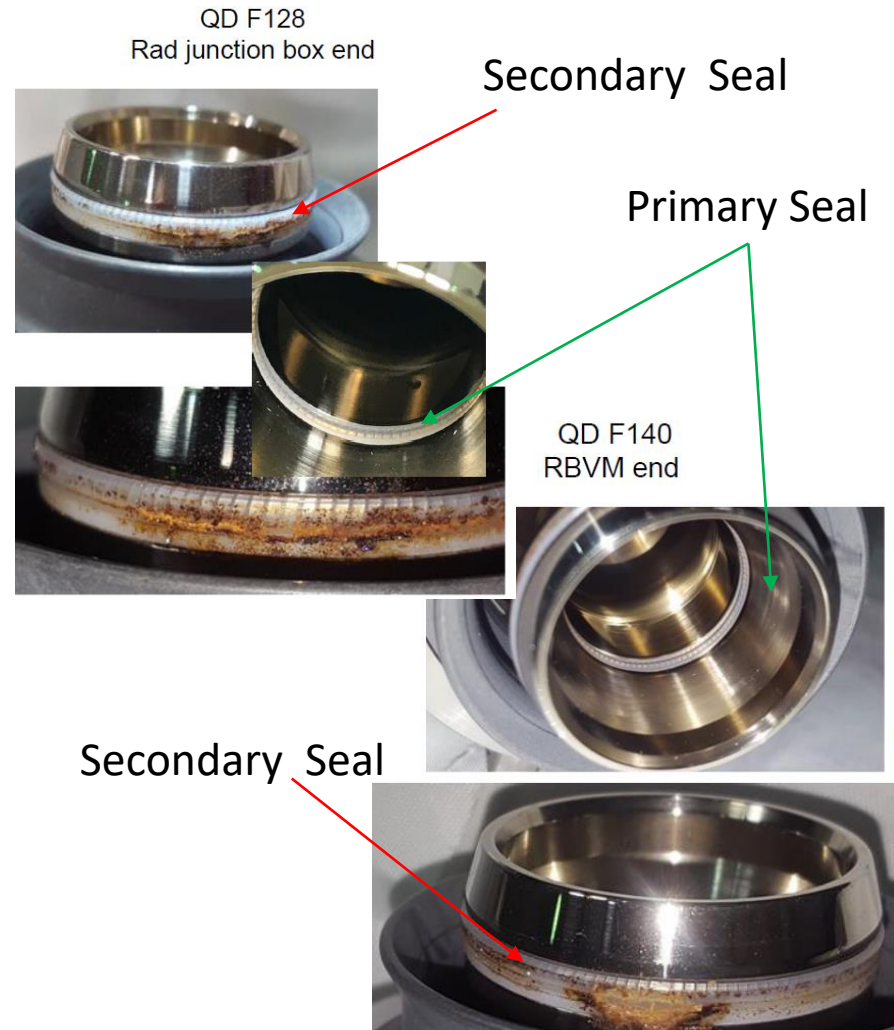
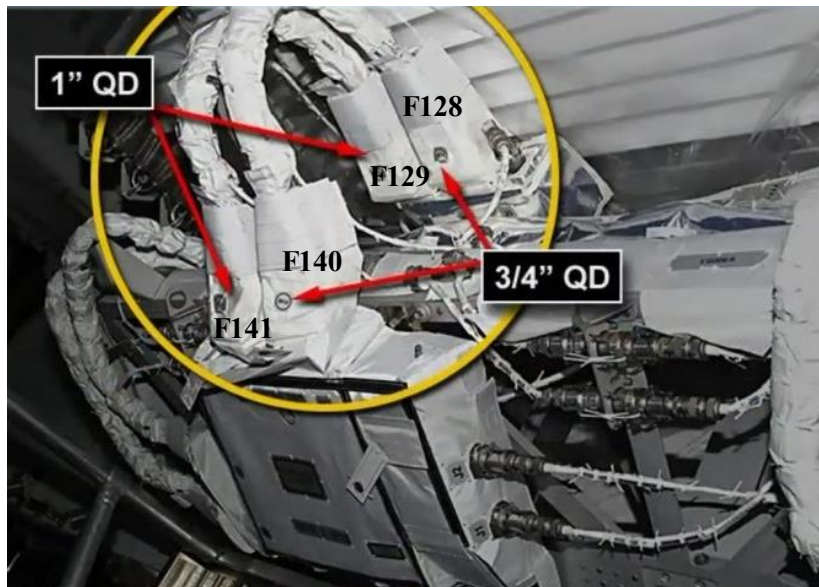


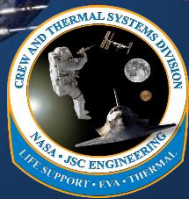
F129 QD secondary seal



TT&E - 3/4" Return Hose

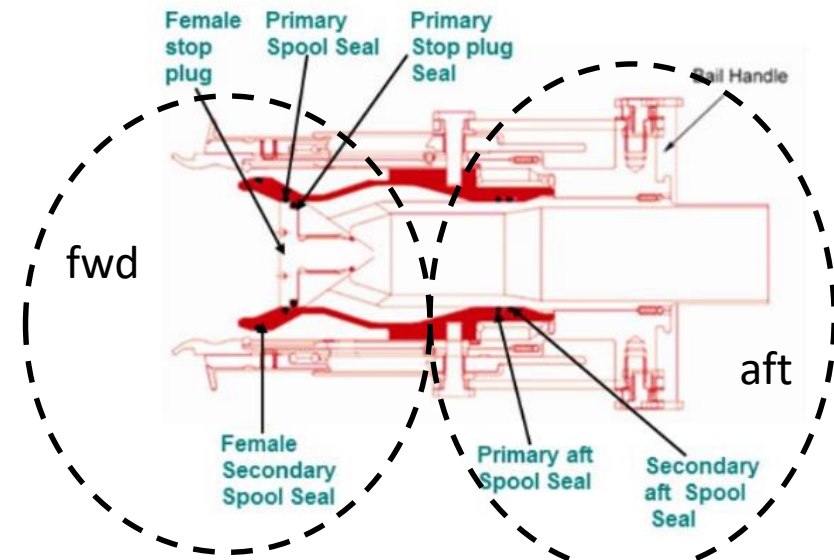
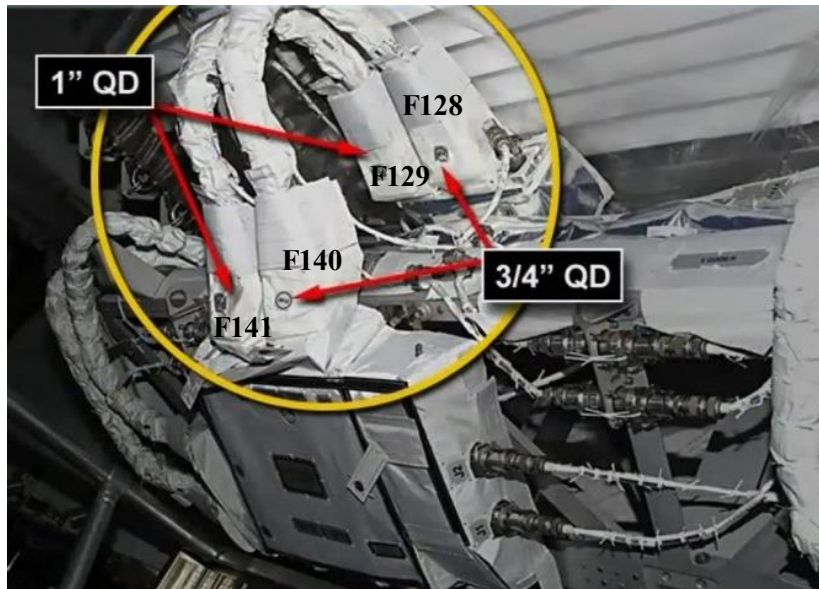
- The 3/4" return hose – not so good
- QD F140 failed the leakage requirement at $2.8E^{-3}$ sccs of Helium at 500psia (3447 kPa)
- QD F128 failed the leakage requirement at 1.91 sccs of Helium at 500 psia (3447 kPa)

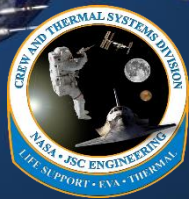




TT&E - 3/4" Supply Hose Additional Leak Test

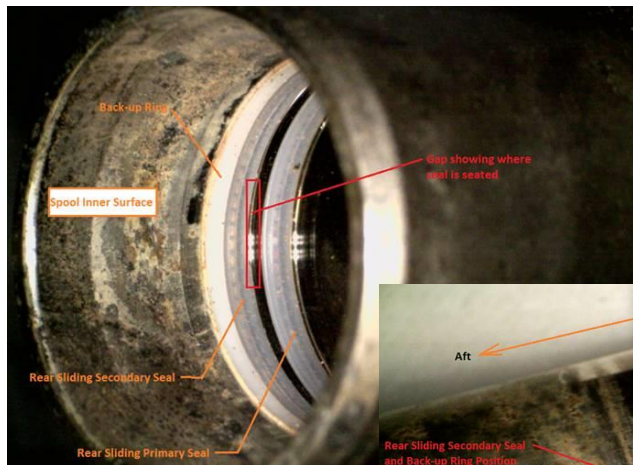
- Forward half QD F128 failed the leakage requirement at **2.2E-1 sccs** of Helium at 500 psia (3447 kPa)
- Aft half failed at **0.5 sccs** of Helium @ 500 psia (3447 kPa)
- QDs removed for additional TT&E
- New QDs installed, hose assembly launched to the ISS in April 2019



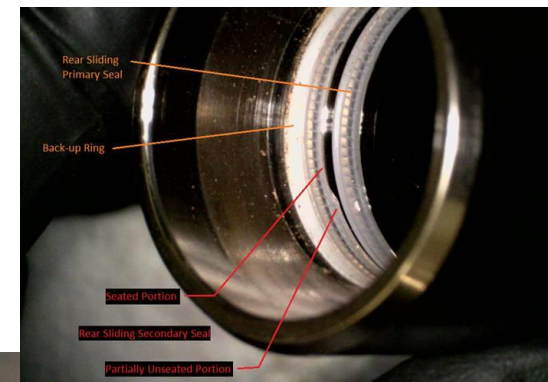


TT&E - QD F128 & F140 Disassembly

- Appears aft spool seals of QD F128 were responsible for the majority of the P1 EATCS leak
- Further analysis of the deposits and examination of surfaces is planned in the near future

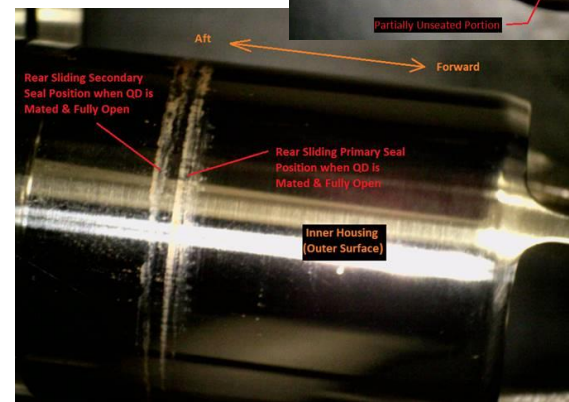
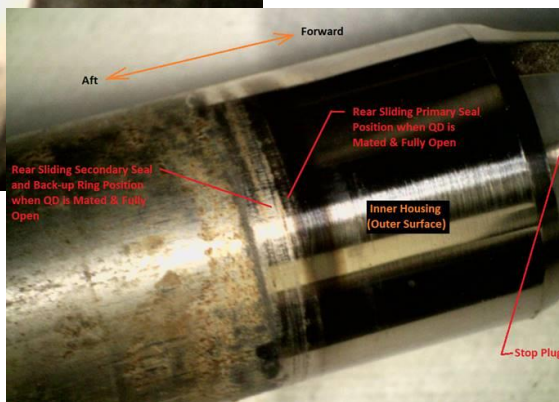


QD F128
Spool

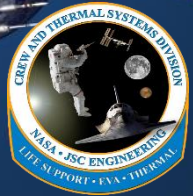


QD F140
Spool

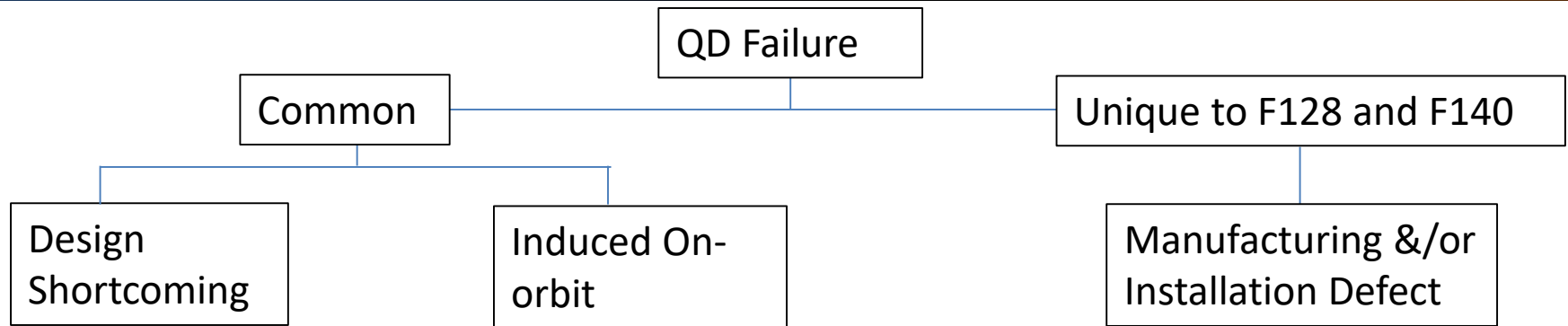
QD F128
Inner Housing



QD F140
Inner
Housing



Discussion

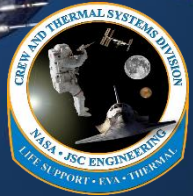


- 200 QDs per EATCS, and 36 are the $\frac{3}{4}$ " hose
- All RBVM-to-radiator hoses exposed to similar thermal environments
- No other significant leaks observed to date
- GN2 filled radiator flow paths is slowly leaking (5E-3 sccs He) overboard
- All QD seals are made of the same material
- Seals leak worse while exposed to cold temperatures
- F128 QD, leaky QD, failed the leak test on the ground before launch but seals were replaced
- No leaks were detected for 4 years after activation
- EATCS were filled on-orbit, and the ammonia chemistry could not be evaluated



Conclusion

- 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 video cameras
- 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 – aft seals in QD F128 (radiator end) on the ¾” return hose
- Further evaluation in work