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ISS ECLS System Overview of Events 2024

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Portable Breathing Apparatuses (PBA) implementation for fire response

- Per crew vehicle safe-haven operations, the ISS program repurposed part of its fleet of O₂-N₂ Recharge tank assemblies (RTAs) into an air variant tank named Crew Emergency Breathing Air Assembly (CEBAA).
 - Concerns arose about their fit into the visiting vehicle mounts.
 - In order to address these concerns until the tanks could be fit check in Dragon/CST vehicles, the ISS program repurposed part of their O₂-filled portable emergency bottles (O₂ PBAs) into the currently existing air variant)
- On-orbit operations on station matured and the fit checking of the CEBAA tanks into the respective visiting vehicles was successfully completed
 - However, this now left these units with no designated purposed.
- In 2024, the program reassessed allocation of these assets, allocated them for use in cabin fire situations
 - This was with the caveat that for users with a high flow demand and metabolic rate, there are phases in the breathing cycle where the inner volume of the mask can reach negatives pressure potentially have crew inhale a portion of their surrounding atmosphere.
- The fleet of Air PBAs is still active and designated primary hardware for on-orbit fire response as long as a sufficient quantity remain viable
 - Air PBAs will be eventually be replaced by Emergency Respirators (ERs).





Pre-breathe Hose Assembly (PHA) Blowout Investigation and Path Forward

- In January 2025, during preparations for an extravehicular activity (EVA), one of the pre-breath masks' harnesses used for inhaling pure O₂ experienced a rupture failure.
 - Failure mode previously documented in 2020 where the inflatable harness ruptured in a similar fashion during EVA Pre-breath operations.
- The 2020 unit was examined at Kennedy Space Center (KSC) laboratories
 - Signs of stiction were found, and a "sweating" residue indicative of polymer degradation and embrittlement was observed
- Common Failure mechanism appears to be material degradation due to aging: Both units manufactured in the same batch in 2011.
- Replacement ORUs have been launched
 - On-orbit Inflation tests were performed on the emergency variants of these masks.
 - These emergency response quick don masks are a suitable and pressure graded replacement for the pre-breath masks.





Vent and Relief Isolation Valve (VRIV) Cover Design and Delivery to ISS

- The Vent and Relief Isolation Valve (VRIV) is part of the Vent Relief Valve (VRV) system that provides overpressure relief and atmosphere venting.
 - In 2004 crew reported damage to the airlock VRIV J1 power connector
 - Joint between valve box and power connector damaged, leaving the cable loose
- Although the hardware remains functional, complete failure of the power connector could lead to VRV being unable to perform visiting vehicle operations through the Node 1 Vacuum Access Port
 - Future exploration extravehicular mobility unit (xEMU) CO₂ venting could also be affected
- The program requested development of a cover capable of holding the connector in place.
 - In the meantime, a protective barrier was installed behind the Airlock 1D0 closeout panel to protect the VRIV unit from any external loads.
 - Following the completion of the cover design in 2023 and a ground fit check in 2024 at Kennedy Space Center, the final clamshell, two-part cover with lateral foam-lined walls was validated for use.
- Installation of the VRIV cover remains on hold until VRV access is required for xEMU Mod Kit installation or other Airlock VRIV operations.





Pressure Management Device (PMD) Anomalies and Troubleshooting



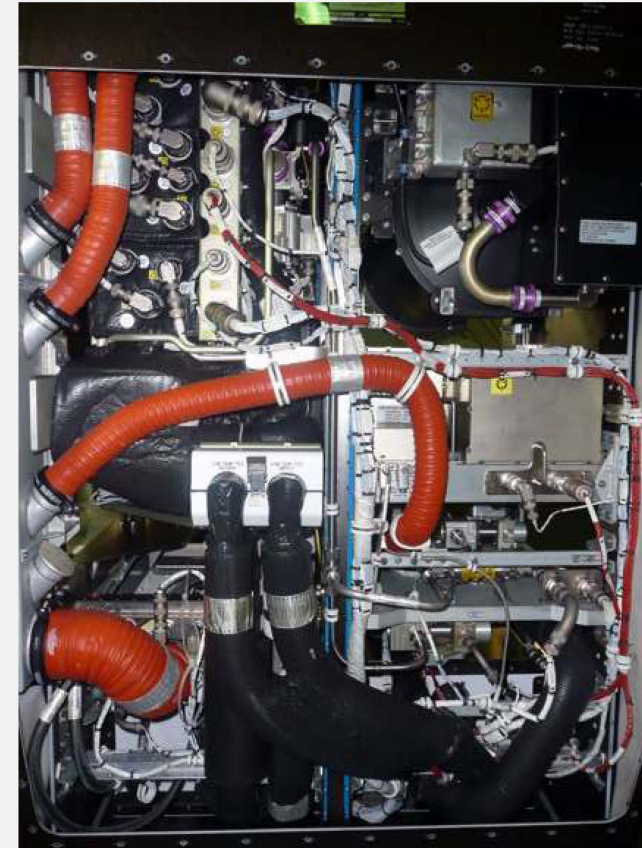
- PMD is a large pumping and venting unit developed and maintained by KBR-Wyle Laboratories
 - Used for pumping air out of small volumes (i.e. NanoRacks Airlock) to minimize loss of air when venting those volumes to space
- PMD S/N 1002 flown in September 2025 to replace failed S/N 1001
- Issue with high current draw arose immediately upon checkout in Node 3
 - Scroll pumps draw about 4 amps nominally
 - Currents observed were over 6 amps, causing the PMD to enter a safe state
- Troubleshooting in Node 1 could not reproduce the anomaly despite over 50 activation-deactivation cycles on the pump in multiple valve configurations
- High-rate current monitoring employed in next Node 3 activity to characterize the anomaly, but results were inconclusive
 - The anomaly could be external to the PMD, as the high current draw does not always occur
 - Changing the DC-to-AC inverter that conditions power to the PMD temporarily stopped the anomalous current draw, but it returned shortly thereafter
- Additional troubleshooting is expected this year; testing on a ground unit is ongoing





Air Revitalization

- Carbon Dioxide Removal Assembly (CDRA)
 - CDRA has only been used in spot-duty, as needed to supplement use of NASA Technical Demonstrations CO2 scrubbers
 - In 2024, the adsorbent beds in both the Lab and Node 3 CDRA's were cleaned on orbit. The beds were removed and replaced (R&R) with the on orbit spares. Then the removed beds were cleaned on a later date to be reused at a future time if needed
 - The Node 3 CDRA has showed some slow valve transitions indicating a potential need for a valve replacement at some point in the future
- Major Constituent Analyzer (MCA)
 - Only operates to support EVAs
 - There was a suspected partial blockage in the Sample Distribution Assembly (ORU 06) so ORU 06 was R&R'ed. However, this did not fix the problem; the voltage is still at the lower limit of 15V.
 - Before the R&R, N3 MCA could not sample from the forward modules. The problem appears to be getting worse, as the Lab also cannot be sampled
 - There was an RPCM failure that affected two of the MCA SDS valves. The positions of the SDS valves are stuck and prevents both MCAs from sampling any modules forward of Lab and as well as the Lab MCA cannot sample from the Lab module.
- Trace Contaminant Control System (TCCS)
 - Node 3 TCCS failed to start up following the Node 3 CDRA bed cleaning activities at the end of 2024 due to a severed power cable.
 - This most likely occurred when the TCCS was slid back into the Node 3 AR Rack
 - The power cable was repaired and Node 3 TCCS functionality was restored
 - The Node 3 TCCS Sorbent Bed Assembly (SBA) reached the end of its 6.3 year operational life and was replaced at the end of 2025





Vacuum System

- The Vacuum Exhaust System (VES) was originally designed to vent one payload at a time, but it has been approved to vent payloads simultaneously.
- This is due to the VES becoming the primary vent for CO₂ Scrubber Technical Demonstrations:
 - Four Bed CO₂ (FBCO₂) and
 - Thermal Ammine Scrubber (TAS)
- FBCO₂ became the primary CO₂ scrubber so it vents on the VES all the time.





THC: IMV Fan – End of Life Issues

- 2022 - Lab Forward Port Fan making a high pitch noise – R&R performed
- 2024 -Node 3 Port Forward IMV Fan which failed when the Remote Power Controller (RPC) associated with the fan tripped open
 - Several attempts were made to reclose the RPC, but, not successful. R&R performed
 - Sparing concerns would later lead the ground team to request a test at the Node 1 Starboard Aft location, installing the previously removed Node 3 Port Forward IMV Fan into this Node 1 location
 - This was done to prove that the RPC trips were not fan-related, but due to an RPC issue instead
 - The IMV Fan was exonerated as the cause of the RPC trips, and the removed fan was retained as a functional spare
- The Lab Aft Port Fan began making a loud noise and was R&R'd
- The next IMV Fan to encounter issues was the Lab Forward Port IMV fan that was previously R&R'd in 2022. Crew commented about noise in the area of the fan and acoustics data confirmed that this IMV Fan was the source of the noise
 - With only one available spare on-orbit at this time, IMV Fan swap was performed instead of consuming the only available spare
 - Lab Forward Port IMV Fan was swapped with the Lab Forward Starboard IMV Fan, as it is nominally 'off'
 - Having the noisy fan installed in this location was deemed acceptable due to its use only for short duration to provide occasionally supplementary flow
- Issues have led to evaluation of ground fleet – three fans with their motors removed
 - The motors had been undergoing hand spins to keep the grease and oil mixed in the bearings
 - Motors put into Test, Teardown and Evaluation (TT&E) to determine which of the IMV Fans could be rebuilt without bearing replacement
 - One motor was acceptable, while the others were marginal and unacceptable. Marginal and acceptable units were rebuilt



THC: Charcoal High Efficiency Particulate Air (HEPA) Integrated Particle Scrubber (CHIPS)

- CHIPS filters were launched and installed across the USOS in 2019
 - Filters are comprised of a two-inch-thick HEPA Filter and a two-inch-thick Charcoal Filter, layered with the Charcoal Filter upstream from the HEPA Filter
 - Each part can be replaced independently
 - Charcoal scrubbing was added to the filters to scrub the air of organosilicons (trimethylsilanol (TMS), dimethylsilanediol (DMSD), siloxanes), which degrade the Common Cabin Air Assembly (CCAA) Heat Exchanger (HX) coating and contribute to Total Organic Carbon (TOC) levels in the WPA, as well as create issues for other hardware downstream of the CCAA HX.
- Initial HEPA installed life left unchanged from previous HEPA-only filters (2.0 to 5.0 years, depending on the module)
 - The previous filters were cleaned weekly via vacuum, which left the filters vulnerable to physical damage
 - With the HEPA portion of the CHIPS Filters downstream of the Charcoal portion, it less vulnerable, and cleaned only as needed
 - Several inspections performed since initial installation, and other than a light dusting of FOD, the filters look virtually new
- Initially, the Charcoal Filter installed life was set to six years
 - This was based on early ground assessments
 - However, in early 2023, data showed an increase of TMS, DMSD, and TOC in the WPA and Potable Water Dispenser (PWD) systems, which led to full R&R the installed Charcoal Filters in mid-2023



THC: Charcoal High Efficiency Particulate Air (HEPA) Integrated Particle Scrubber (CHIPS)

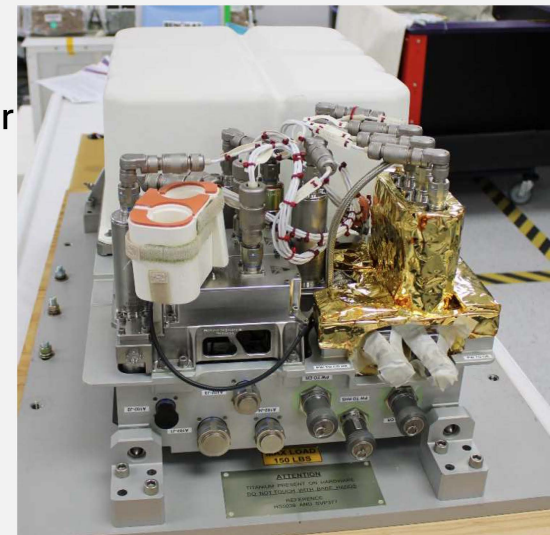
- Filters returned to ground for evaluation following 2023 R&R
 - HEPA - 1 filter returned from Node 3 (Tested at Glenn Research Center (GRC):
 - Increase in dP of 0.04 in. H₂O compared to pre-flight testing
 - efficiency measured at 99.98%, which exceeding requirements
 - Installed life modified to 'Run to failure', given the 'like-new' condition after ~4.25 years of use
 - CHIPS - (1 filter from Node 1, Node 2, Lab and Airlock, 2 filters from Node 3)
 - One filter was tested at GRC and five filters were tested at Boeing Central Labs in Huntsville, AL
 - Testing showed that, after the filters were installed for ~4.25 years in Node 3, they had reached their maximum loading capacity
 - The Node 2 and Lab filters showed similar loading
 - The filters also showed that the majority of the FOD that was collected by CHIPS was in the Charcoal Filter, despite not being HEPA rated
- On-orbit air data indicated that TMS levels began to rise in the air ~1.5 years after install, and returned to the higher pre-installation levels approximately three years after installation
 - Installed life of the CHIPS Charcoal reduced from six years to three years.





WRM: Water Processor Assembly (WPA) Catalytic Reactor Swap Out

- March 2024 - Catalytic Reactor S/N 07 showed signs of leakage due to increasing frequency of faults in the system
 - Consistent with previous Catalytic Reactors which leaked through elastomeric seals
 - The “upgraded” Demonstration Test Objective (DTO) Catalytic Reactor was to be installed next
 - Upgrades included metal seals and new catalyst with improved performance
 - Catalytic Reactor S/N 06 was unfortunately installed instead of the DTO Catalytic Reactor
 - Due to Urgency of validating the upgraded DTO Catalytic Reactor, Catalytic Reactor SN 06 was swapped out
 - Catalytic Reactor SN 06 was exposed to non-sterile wastewater and additional steps were required to mitigate microbial concerns once removed from the WRS-1 Rack
 - DTO Catalytic Reactor approximately lasted thirteen days before the unit saw significant water leakage signatures, similar to end-of-life signatures of Legacy Catalytic Reactors.
- Catalytic Reactor S/N 06 was reinstalled in March 2024 and continued to operate until July 2025 where it was replaced with Catalytic Reactor S/N 01





WRM: WPA Catalytic Reactor S/N 01 Valve Anomaly



- September 2025, the R&R for the Separator Filter ORU was planned
 - Ground teams commanded WPA to a maintenance state
 - The inlet solenoid valve (SV 1126_1) failed to close causing the system to fault.
 - Fault indicated both undercurrent fault and overcurrent fault
 - The valve was unable to close
- SV 1126_1 not required for nominal WPA operations
 - WPA was able to return to nominal operation without further faults
 - WPA lost its ability to transition to maintenance state with current Catalytic Reactor



OGS: Oxygen Generator Assembly (OGA) Statistics and Status

- As of May 31, 2026, OGA accumulated 15.2 years of run time with an average O₂ production rate of ~6.1 lbm /day and has produced 33,894 lbm of O₂ and 4,270 lbm of H₂
- H₂ ORU SN 4 installed in 2021 and R&R'd on Sep 16, 2024, due to degrading cell 1 voltage – same failure as ORU SN 2 and SN 3.
 - Cell 1 started to show sign of degradation in March 2024 - slower to charge up and faster to discharge
 - Cell 1 Standby voltage trend downward toward 1.4V before R&R. SN 4 ORU has 2.9 yrs of total cumulative life compared to SN 2, and 3 with ~5 yrs of runtime. The main reason for difference in ORU life for SN 4 was higher average production rate which accelerate membrane thinning and cell degradation .
 - The H₂ Dome Back Pressure Regulator (BPR) was unstable from 10/ 2021 – 09/2024, resulting in low and erratic recirculation loop pressure.
 - Multiple RSA High fault trip during reactivation from 2021 to 2024 cause by additional RSA fill during the Active Built In Test (ABIT) 2 before cell stack powered. To prevent the nuisance fault, RSA fault limit was increased from 10 in³ to 15 in³ and the pump extended shutdown run time increase to 5 mins to reduce the amount of gas in the recirc loop.
- Oct 2024, activated Carbon/Ion Exchange (ACTEX) life was reduced from 675 days to 527 days. 675 days assumed 10% remaining capacity and 527 days assumed 30% remaining capacity. Chemical analysis on three returned ACTEXs shows fluoride near breakthrough. ORU life was reduced to minimize the risk of breakthrough and protect the cell stack.



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OGS: Advanced Oxygen Generator Assembly (AOGA) Status

- AOGA follows the existing OGA architecture with key upgrades:
 - Redesigned cell stack
 - Implement industry best practices
 - Better mechanical support
 - Replace obsolete membrane with chemically stabilized nafion
 - Two independent domes (replacing single dome)
 - Reduces logistics/resupply requirements
 - Improves fault tolerance and maintainability
 - New hydrogen sensors (COTS H2 sensors under H2ST)
 - New, more reliable sensors to reduce crew maintenance and eliminate special purge tools
 - Lower crew intervention and improved reliability
 - Redesigned ACTEX (ARMADILLO)
 - Increase installed life, reduce delta pressure



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Questions?

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