NASA Exploration Hardware Status and Crew Feedback from Artemis-2 Demonstration

ICES-2024-071

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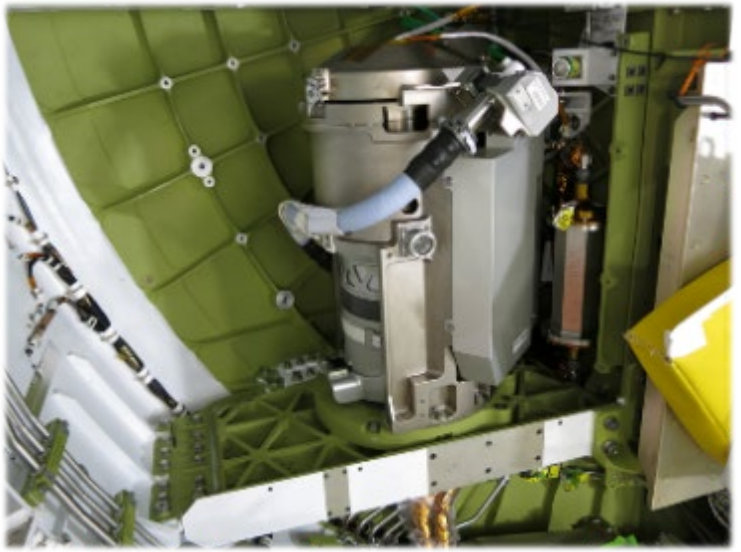
Universal Waste Management System (UWMS)

- Universal Waste Management System
  - ISS Unit – Toilet
  - Orion Unit – Waste Management System(WMS)
- Toilet for exploration missions
- Reduction in mass and volume
  - Toilet is 65% smaller and 40% lighter than current ISS toilet (WHC)
  - WMS is 61% smaller than Shuttle Toilet
- ISS Toilet
  - Delivered June 2020
  - Installed and checkout complete November 2021
  - Operational status: in work
- Orion WMS
  - Delivered December 2019
  - Installed Artemis-2 March 2021

ISS UWMS installed in Node 3, ISS

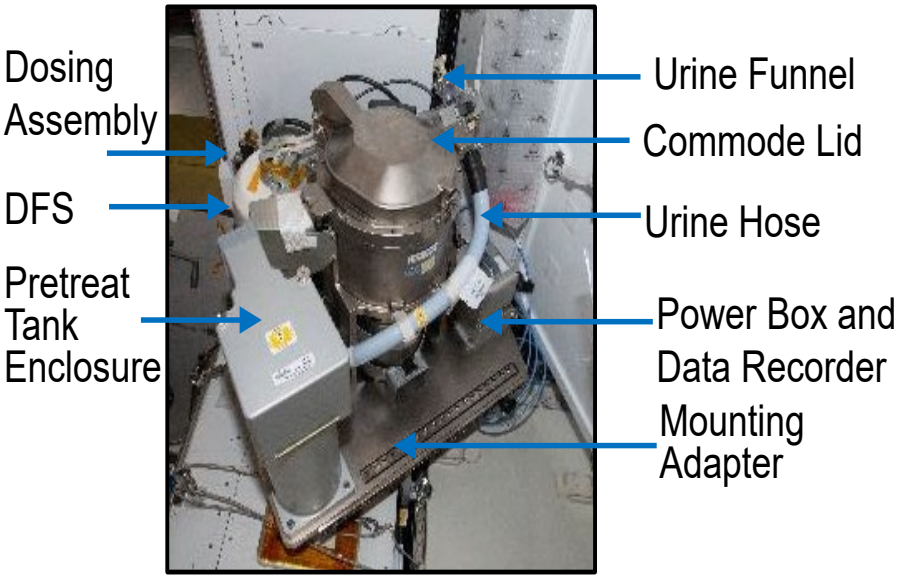


Orion UWMS installed in Artemis-2

UWMS and Toilet Integration Hardware on ISS

Key Elements

- Designed for Orion launch/landing loads and electrical interface and adapted for ISS
- Dual Fan Separator (DFS)
  - Unit uses air to aid in capture of urine and deposits of fecal material
  - Single motor drives two fans and rotary urine separator
  - Fiberglass acoustic enclosure (internal to UWMS)
- Simple operations with no control panel
- Urine Collection
  - Pretreat solution dose pump and conductivity sensor
  - Uses Russian pretreat concentrate tank
- Fecal Containment
  - Individual fecal collection bags
  - Canister holds ~13 deposits
  - Canister cap provides odor control
  - Lifting mechanism ensures tight seal to prevent odor release
- Simultaneous Urination and Defecation
  - Redesigned urine funnels, and notched housing to improve the ability of female crewmembers to perform simultaneous urination and defecation



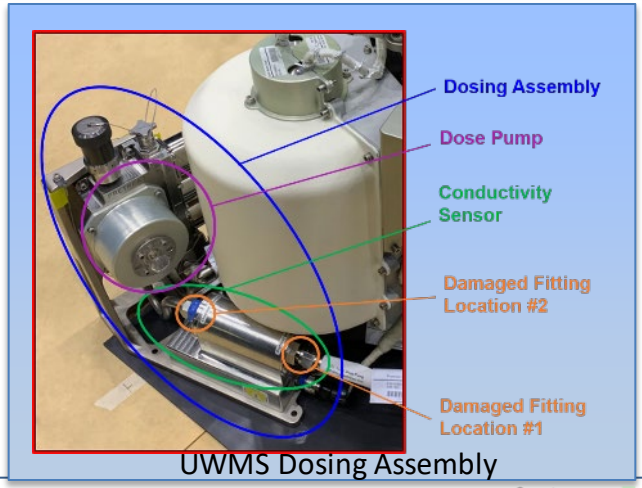
ISS UWMS installed in Node 3, ISS

Toilet Integration Hardware Stall installed in Node 3, ISS

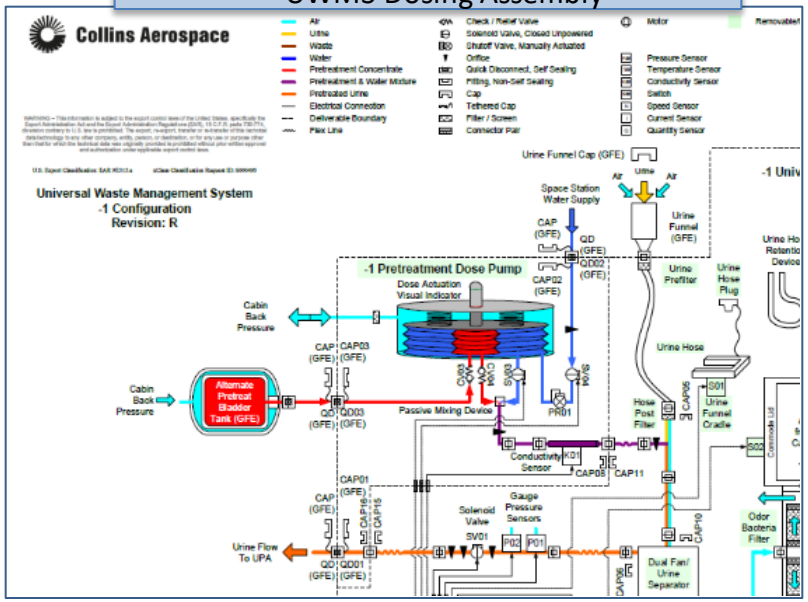
UWMS Urine Pretreatment on ISS

Urine Treated with Phospho Chromic Acid

- Urine collected with UWMS is planned for recycling after checkout
- Pretreat Concentrate/Water added to urine stream
- Pretreatment stabilizes urine and prevents fungal and microbial growth in system
- Pretreat Hose connects Tank and Dose Pump
- Dispensed with nested bellows Dose Pump
- Quality evaluated by Conductivity Sensor downstream of pump

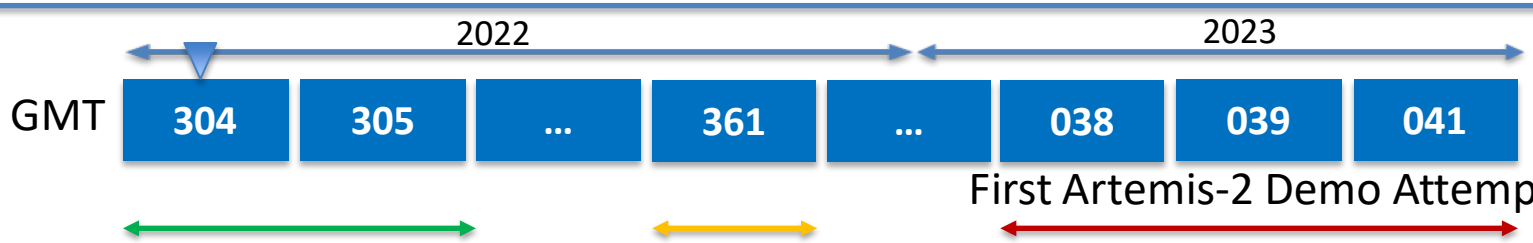


UWMS Dosing Assembly



UWMS schematic

ISS UWMS Timeline of Events 2021-2023

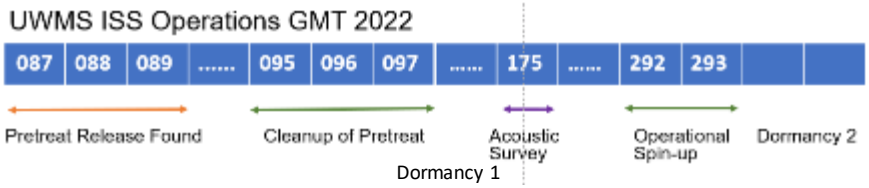


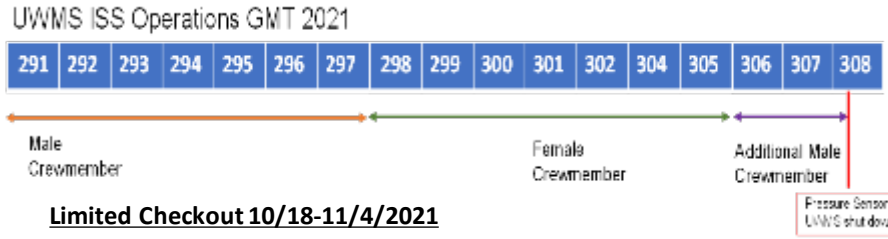
- COTS Conductivity Sensor (CCM) installed
- Good Pretreat Quality Indications from Pressure Readings
- CCM readings off-nominal

- Inconclusive Pretreat Quality Indications from Pressure Readings
- CCM readings off-nominal

- Bad Pretreat Quality Indications from Pressure Readings
- CCM readings off-nominal

ISS UWMS





Data Gathering, Discovery of Pretreat Release

- Operations started to replace OBF and Pretreat tank
- Halted when ***pretreat residue*** and corrosion discovered on exterior of UWMS; successful spin test, air filter inspection
- Cleanup of Pretreat residue
  - April 5-6, 2022
- Operational spin up; no liquid found; Dormancy
  - September 8, 2022

CCU Demo with UWMS Non-operational for contingency case on Orion

- Male and Female Crewmember used Collapsible Contingency Urinal (CCU)
  - 3/6/2022

Limited Checkout 10/18-11/4/2021

- 3 crewmembers
- 17 days
- ~80 uses

- Toilet was successfully used by the ISS crew for 17 days
- Pressure sensor hard fault at day 17
- UWMS Pretreat Quality Indication Sensor inoperable

Artemis-2 Demo on ISS, First Attempt

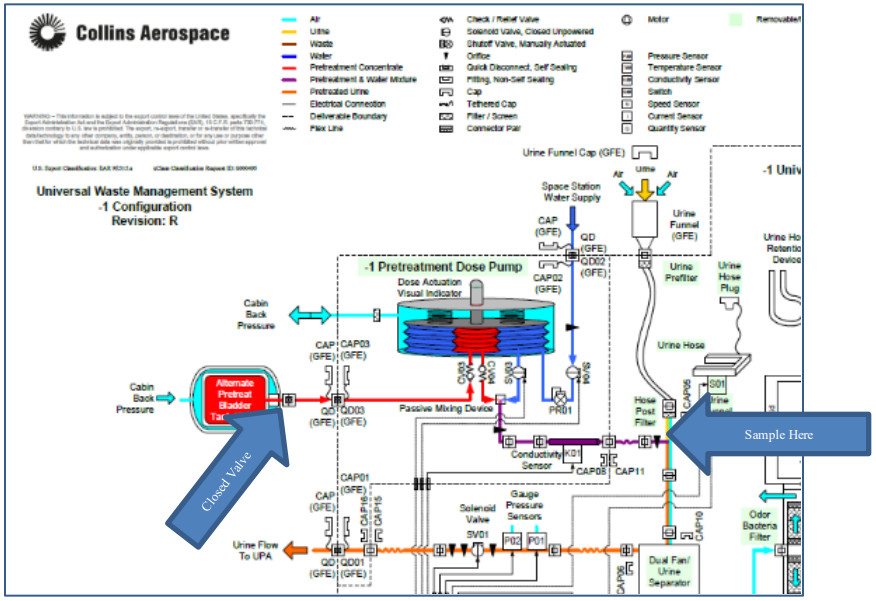
- Demonstration to validate operations for Orion's Artemis-2 Mission
  - Planned for 4 Crewmembers using UWMS for 12 days
  - Data on consumables such as wipes, gloves, fecal canisters needed to finalize Artemis-2 Demonstration
  - Run time with crew use resulting in operational stress of urination over mission period
- Data from previous COTS Conductivity Monitor (CCM) installation (12/2022) showed good conductivity readings using pressure sensor data
  - CCM did not function to validate data during this time
- Started 2/7/2023 with planned checkout
  - Single Female Crewmember use for one day followed by single male crewmember use for one day
  - Data analysis during checkout showed no urine pretreat dispensing
  - Demonstration halted on 2/9/23

Check #	# Viable Doses	Pre-Dose (psig)	Post-Dose (psig)	Delta-P (psig)	Notes
1	8	13.04	14.1	1.05	Bad Dose - seems like water only
2	8	13.26	14.14	0.19	Bad Dose - seems like water only
3	3	13.56	14.4	0.85	Bad Dose - seems like water only
4	7	13.56	14.32	0.75	Bad Dose - seems like water only indication or partial bellows stroke

Summary of data from Artemis-2 Demonstration Crew Operations

On-Orbit Troubleshooting >> No Pretreat Present

- Troubleshooting was performed on-orbit to validate the pressure data and determine if pretreat was not actually dispensing.
  - Sample drawn from the base of the urine hose for a color check and Crew reported very obviously a clear liquid.
  - Color of the urine and fluid collected in an external tank was evaluated as well.
  - Pretreat tank valve closed and dose pump cycled
    - Confirmed one of the dose pump check valves was not operational

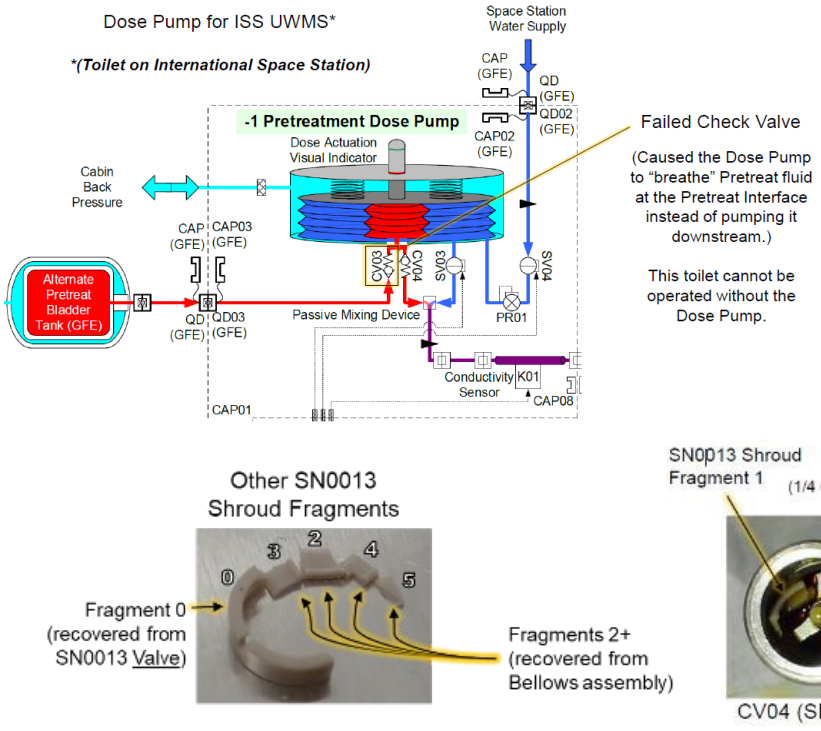


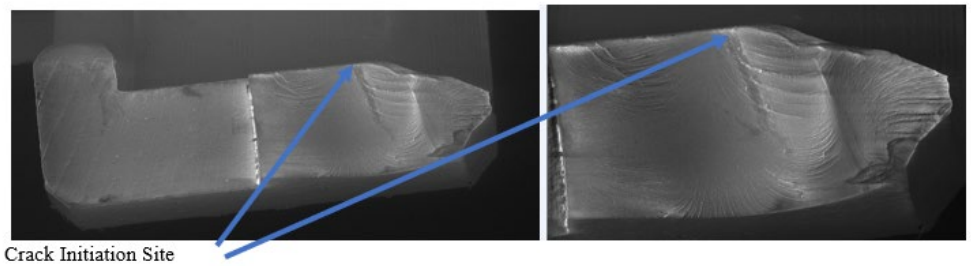
Location of sample and valve closed for troubleshooting

Comparison of UWMS-filled EDV (Russian tank) on left that shows no pretreat and tank previously filled from WHC on right with expected color with pretreated urine.

Ground Troubleshooting >> Inlet Check Valve Failed

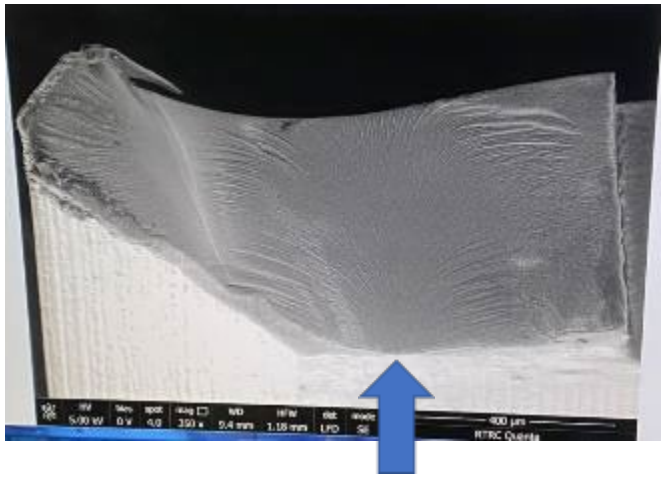
- Fault Tree showed likely cause to be Dose Pump Check Valves
- Inspection showed PEEK shroud in inlet check valve failed catastrophically and broke apart
  - Shroud pieces from CV03 found downstream in CV04 and in Bellows
- Scans showed failure initiation not at stress concentration at installation notch as expected



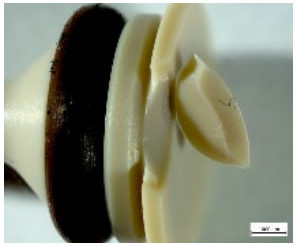


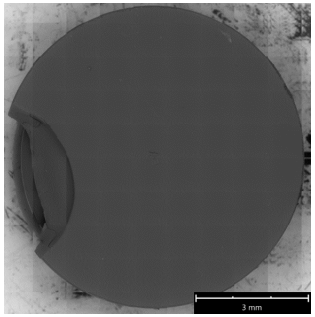
Ground Troubleshooting >> RTRC Testing and Results

- Confirmed shroud crack initiation and showed evidence of embrittlement along the fractured edge.
- Poppet broke during handling and showed evidence of brittleness in the failure similar to shroud failure
- Photos of poppet installed in check valve show line of fracture before removal

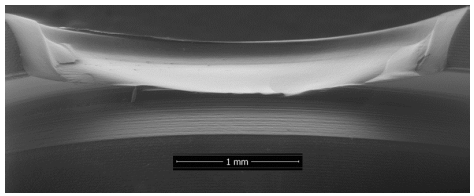


Scans from RTRC of failed shroud with initiation site marked





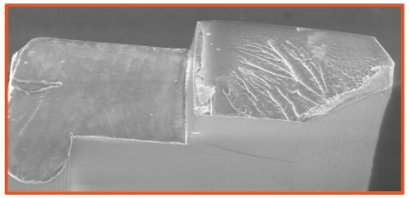
Poppet failure



SN0013 Check Valve

Outlet side of valve viewed immediately after Dose Pump teardown (still wet with Pretreat)

Poppet fractured during nominal handling after removal from SN0013 Valve

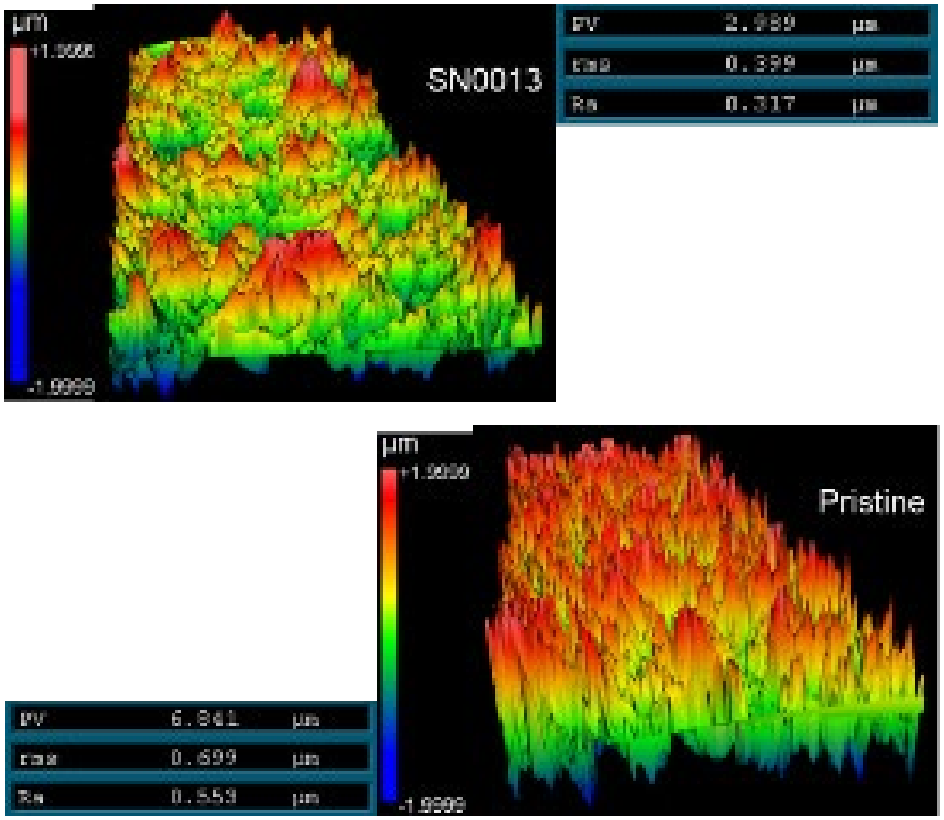


SN0013 Shroud Fragment 0 Fracture Face 0A

(Fragment 0 = Half-Shroud piece)
(Fracture face with short area (in castellation) remaining)

RTRC Further Findings

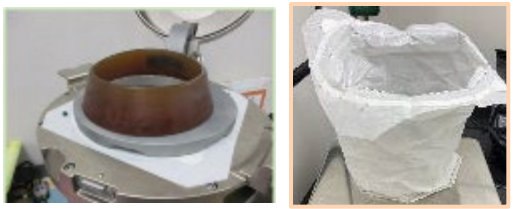
- Failed PEEK part's surface appears etched in comparison to pristine PEEK part (no exposure to pretreat concentrate).
- Embrittlement caused by exposure to Pretreat concentrate was suspected.
- Some parts showed ductility.
- Exposure to pretreat concentrate may cause embrittlement that can be reversed if removed and dried.
- Undetermined swelling of PEEK due to pretreat exposure and tight shroud-poppet clearances may result in persistent tensile stresses in shroud
- **Conclusion:** Exposure to pretreat concentrate caused embrittlement, swelling and combined with tight clearances as in the check valve configuration caused the parts to break apart.



Crew Feedback from Artemis-2 Demo

- Crew feedback resulted in redesign of Seat and Fecal Bags
  - Crew preference for 4” seat
    - UWMS originally had 4” and 5” seats
      - Crew preferred 4” seat
    - HLS LOO design uses a 4.3” seat
    - WHC ACY has a 4” opening
    - Redesigned seat with 4” opening
  - Crew comments that Fecal Bags are too big and location not optimal for adherence of fecal deposits
    - Current UWMS Fecal Bags are smaller than used on Shuttle, larger than HLS LOO and WHC ACY design
    - Redesigned Fecal Bags incorporate drawstring closure and smaller size
    - Located over redesigned seat

WHC/KTO Bag and Point of Use



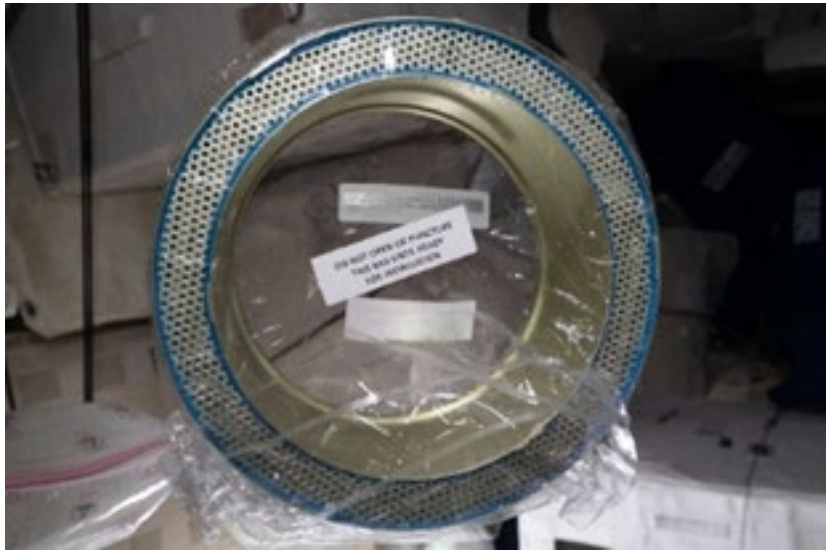
UWMS Seat and Bag

HLS LOO Seat and Bag

Updated UWMS Seat and Bag

Crew Feedback on Odor Toilet Air Filter

- Odor Bacteria Filter (Toilet Air Filter)
  - Used to control odors during Toilet use as well as when not in use
  - Activated carbon material is used to absorb odor constituents
- Updated Feedback: No odor present when UWMS was not in use or when in use
  - Previously during Limited Checkout, odor was detected in Node 3 and adjacent locations.
  - Odor Bacteria Filter sealing gasket was found to be folded over during installation



Toilet Air Filter in packaging on ISS (Odor Bacteria Filter (OBF))

Hardware Redesigns and Upgrades

- Each activation of Toilet on ISS provides lessons learned about the design, operational performance and the crew preferences for user interfaces
- Planned for resumption of Artemis-2 Demo on ISS in 2024
  - Updated CCM design with bubble diverter
  - Updated Fecal Bag and Seat for crew evaluation
    - Down select for Artemis-2
  - Evaluation of Dry Wipe options with WHC and UWMS
  - Reflight of original design of Dose Pump

Conclusion and Next Steps

- Completion of UWMS technology demonstration on ISS is paramount to informing exploration missions including Artemis-2 and beyond
  - Consumables use
  - Ability of the crew to perform simultaneous urination and defecation operations
  - Use of a compact toilet in micro-gravity
- Work is ongoing on resolving technical challenges, completing the tech demo, and making necessary upgrades and refinements for current and future toilets

Questions and Feedback?

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