Exploration Toilet Integration Challenges on the International Space Station
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Development of New Exploration Toilet

- The new Exploration Toilet currently in development is based on the Shuttle Extended Duration Orbiter (EDO) Waste Collection System
  - More compact design to accommodate smaller exploration vehicle volumes
  - Urine is collected via a funnel/hose arrangement with airflow to aid in controlling urine flow
  - Feces is collected in a bag and stored in a replaceable fecal canister
- Two units are currently in development
  - The first unit will be integrated into the Orion vehicle for the first crewed mission
  - The second unit will be flown to ISS for a 3-year technology demonstration
Toilet System Overview

• **Toilet System** consists of Toilet Hardware + Toilet System Integration Hardware
  - The official ISS operations nomenclature for the new exploration Toilet is “Toilet”
• NASA(JSC) is the Principal Investigator for the *Toilet System Technology Demonstration on ISS*
• NASA(JSC) is also the hardware developer for the *Toilet System Integration Hardware*:
  – Toilet Stall
  – Toilet Mounting Adapter
  – Toilet Pretreat Tank Enclosure
  – Fluid Hoses
  – Urine Funnels
  – Toilet Power Box
  – Toilet Data Recorder
• Collins Aerospace is the developer for the *Toilet Hardware*
Top View of the Toilet Stall with Toilet and Integration Hardware Installed
ISS Technology Demonstration

- On ISS, the Toilet System will undergo two technology demonstration periods
- The first period will demonstrate the following:
  - Two 30-calendar day testing periods with a minimum 90-day quiescent period
  - Daily use by at least 3 crew - combination of male and female crew (if possible)
  - Continuous fan operation for one period of a minimum of 60 min
  - Evaluate at least 2 different seats
  - Periodic photo documentation of crew interfaces
  - Acoustic survey at the user’s head position
  - Return of minimum of three full fecal canisters to assess compaction efficiency
- The second period will demonstrate the following:
  - Operation for a minimum of 3 years
  - Characterize system reliability, including validation of spares and consumables usage rates
  - Characterize long-term operation of the Toilet System integrated with the vehicle ECLS system (i.e. UPA)
  - Daily use by at least 3 crew - combination of male and female crew (if possible)
Toilet Interfaces on ISS

- Air from ISS
- ISS Pretreat Tank
- ISS Waste and Hygiene Compartment (WHC)
- ISS Crew
- ISS Power
  120 Vdc
- Toilet Power Box
- Pretreat Concentrate
- Water
- Urine
- Feces
- Toilet Mounting Adapter
- Toilet Stall
- ISS Seat Track
- ISS to ISS
- ISS Waste and Hygiene Compartment (WHC)
- ISS Urine Transfer System (UTS)
- ISS Urine Processor Assembly (UPA)
- ISS Domain Adapter Node (DAN)
- Ground Support
Toilet Stall

- Stall provides two separate volumes for the Toilet System and the Waste and Hygiene Compartment (WHC)
  - Replaces the current WHC Kabin
- Includes 6 panel assemblies which attach to ISS seat track
- Stall is ~1.7 m high and is located 20 cm above the Node 3 Deck
- Each Stall compartment includes:
  - Bi-fold door that opens inward
  - Mesh frame for containing free fluids/particles
  - External/Internal seat track for attaching crew translation aids
  - Internal attachment points for crew items

Toilet Stall will be installed in Node 3 in front of the WHC and forward midbay.
Toilet Mounting Adapter

• Mounting Adapter provides the mechanical interface between the Toilet System and ISS
  • Includes a baseplate for hardware attachment, an adjustable strut and bracket to attach to ISS seat track on the WRS2 rack and Midbay Deck
  • Adjustable strut accounts for installation tolerances and keeps the baseplate level with the Node 3 Deck
• Pretreat Tank Enclosure protects the Russian Pretreat Tank from kick loads
  • Mounted on the Mounting Adapter
  • Lid opens via captive fasteners to access tank for replacement
Toilet Power and Data

- Toilet Power Box will connect the Toilet to ISS Power
  - Removes power from the Toilet if the power draw is too high
  - Include an on/off switch with indicator light to remove power from Toilet for maintenance activities
  - Mounted on top of Toilet Data Recorder
- Toilet Data Recorder captures Toilet operational data
  - Data is sent to the ground real-time
  - Operational data such as pressure, temperature and motor speed are captured
  - Powered by the Toilet (28Vdc interface)
  - Mounted on the Mounting Adapter (mounting interface for the Power Box)
Toilet Fluid Transfer (1/2)

- Toilet Pretreated Urine (PTU) Hose delivers pretreated urine from the Toilet to ISS for processing (Urine Processor Assembly)
  - Includes a 100-micron filter to reduce the number of particles introduced into the UPA
  - Length of 4.6 meters and diameter of 1.3 cm
- Toilet Pretreat Hose delivers pretreat concentrate from the Pretreat Tank to the Toilet
  - Length of 96.5 cm and diameter of 1.3 cm
- Toilet Water Hose delivers water from the WHC Flush Water Interface to the Toilet
  - Flush Water interface located on the WHC front panel
  - Length of 3 m and diameter of 0.95 cm
Toilet Fluid Transfer (2/2)

- The Toilet EDV Adapter is used nominally with the Urine Transfer System to deliver pretreated urine to a backup tank
  - If UPA and UTS are unavailable, the EDV Adapter can interface to the PTU hose to deliver pretreated urine to a backup tank
  - Length of 20 cm
- Urine Funnels collect urine from the crewmember via the Toilet Urine Hose
  - Designs based on previous Shuttle funnels and current Russian funnels
    - New designs are intended to aid female during simultaneous urination and defecation (improved alignment with seat and body)
    - Three designs launched on NG-10 for crew evaluations with WHC
    - Comments included decreasing funnel length to improve cleaning, materials selection and improving cap closure mechanism

Funnels evaluated on ISS

3-D printed Funnel prototypes
Integration Challenges on ISS (1/3)

- Mounting Adapter
  - The biggest integration challenge for the Mounting Adapter was hardware placement in a limited volume
    - All Toilet hardware will reside inside the Stall volume and be installed on the Mounting Adapter baseplate
    - Mounting adapter baseplate is approximately 76.2cm x 88.9cm (30”x35”)
  - Required several design iterations to optimize hardware location
    - Maximize the volume around each piece of hardware to aid in installation
    - Provide adequate habitable volume for the crew to perform waste collection activities
    - Provide adequate space for air inlets and outlets, fluid hose bend radius and cable bend radius
    - Provide enough access to HEPA filters on Deck Midbay for weekly cleaning
Integration Challenges on ISS (2/3)

• For the Toilet Stall, integration challenges included:
  • Identifying a permanent location for the 3-year tech demo
    • Node 3 not scarred for an additional Toilet
  • Advanced Resistive Exercise Device (ARED) dynamic envelope interferences
    • Stall attachment hardware protrudes into the dynamic envelope
    • Design changes to the Stall hardware would only reduce the protrusion
      • Decision was made to train crew on these additional protrusions when using ARED
  • Crew translation aids (handrails) installed on the Stall panels also protrude into the envelope
  • An operational constraint limits locations on the Stall where handrails can be installed

Toilet Stall installed in Node 3 (in front of WHC and Midbay)
Integration Challenges on ISS (3/3)

• Accommodate new hardware
  • Brine Processor Assembly (BPA) will be installed in Midbay Overhead
  • Stall mesh frame was modified to allow access to BPA for regular maintenance

• Node 3 Seat Track Variability
  • Midbay seat track is installed at a 45 degrees angle from rack seat track
  • It is also offset approximately 1 cm (0.35”) in the vertical direction from the seat track on the WHC rack
  • Introduced uncertainty in the mounting locations for Stall
    • Photogrammetry was used to analyze photos taken on ISS to quantify the dimensions needed to design the Stall mounting interfaces
      • Dimensions were obtained that were within 0.25 cm (1/10 inch) accuracy
      • Data provide confidence that hardware would install as designed
    • In addition, adjustable struts were added to allow adjustments to be made in the wall angles/location (as needed) during installation
      • Insured proper interface between the 3 Stall walls
      • Added rigidity to reduce audible rattle

• Mesh Frame
  • Complex geometry to accommodate BPA and provide additional head room during Toilet use
ISS Hardware Status

• In February 2019, the Toilet Stall hardware was deployed on ISS
  • Crew will use the Starboard side for WHC activities
  • Crew was given the option to perform other hygiene activities on the Port side until the remaining Toilet hardware arrives
• The remaining integration hardware and the Toilet will be launched and deployed at a later time

Toilet Stall deployed on ISS Node 3
Concluding Remarks

• Integrating any new piece of hardware on ISS can introduce challenges
• Overcoming challenges requires:
  • A flexible design
  • Extensive coordination with hardware stakeholders and vehicle integration teams
• Crew Evaluations/Inputs are beneficial
  • Toilet is a crew-centric piece of hardware (it needs to be usable by the crew)
  • Crew evaluations provide crew perspective on how hardware will be used
    • Valuable inputs on hardware location, crew interfaces and volume that will ease use
  • Important to involve crew early in the design cycle to minimize potential changes during manufacturing phase
Questions?