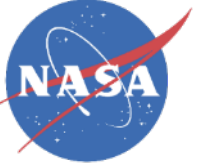


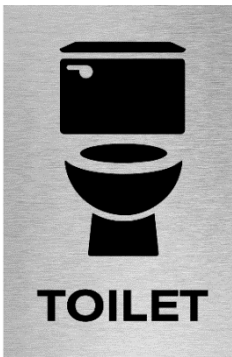
Developing Exploration Technologies on the ISS: Exploration Toilet Challenges October 17, 2019

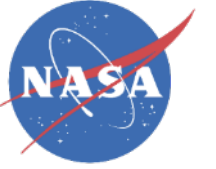
James Broyan | AES Logistics Reduction Project Manager | Crew and Thermal Systems Division | JSC



Introduction

- The Waste Collector System (WCS) is unglamorous but essential
 - WCS defined as collection of urine, menstrual, and fecal waste
- Unsuccessful WCS operation impacts crew performance
 - Crew cabin surfaces, clothing, crew and air become fouled resulting in unhygienic and noxious conditions
- Ineffective processing/storage of waste impacts the vehicle
 - Precipitates/growth can foul urine vents or processing equipment
 - Fecal/urine gas generation (e.g. ammonia) can impact CO₂ removal and trace contaminant control systems





Why WCS Hardware is Difficult?

- Human to hardware interface is critical
 - Variability in crew body contours and crew positioning during use
 - Difficult to separate waste from body
 - Surface tension dominates
 - Water unavailable for waste transport from use area once separated
- WCS development relative to vehicle development
 - Generally given inadequate consideration early in vehicle design
 - Vehicle mass and volume constraints compromise WCS functionality
- Difficult to verify and validate hardware performance
 - Lack of adequate urine and fecal simulates and delivery systems
 - Ground tests inadequate and parabolic aircraft flights too short
 - Require multiple space flights to discover and resolve performance



Space Toilet Historical Experience



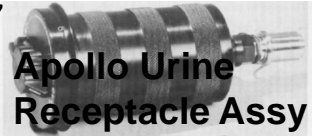
- 6 US and 3 Russian toilets have flow but inclusive hygienic collection is still elusive (2007-01-3227)
- Have worked well for some but not for all crew
 - Challenges for dual urination and defecation – more compatible for males
 - Escapes of urine and feces
 - Odor control of stored waste
 - Frequent component changeout

Vehicle	General System		Urine Collection	Fecal Collection
	Air Capture	Female Crew	Crew Feedback	Crew Feedback
US				
Mercury	n/a	n/a	neutral	n/a
Gemini	n/a	n/a	leaked	very negative
Apollo	n/a	n/a	adequate	very negative
Skylab	Yes	possible	positive	neutral
Shuttle	Yes	Yes	positive	neutral
US ISS WCS	Yes	Yes	positive	positive
Russian				
Soyuz	Yes	Yes	positive	negative
MIR	Yes	Yes	unknown	unknown
Service Module	Yes	Yes	positive	positive



Space Toilets have continued to evolve

Apollo 10 Lunar Lander transcript pilot Cernan: "Here's another goddam turd. What's the matter with you guys? Here, give me a —"



Apollo Urine Receptacle Assy



Apollo Urine Transfer System



Apollo/Gemini Fecal Bag



Skylab Waste Mng Compartment



Soyuz ACY



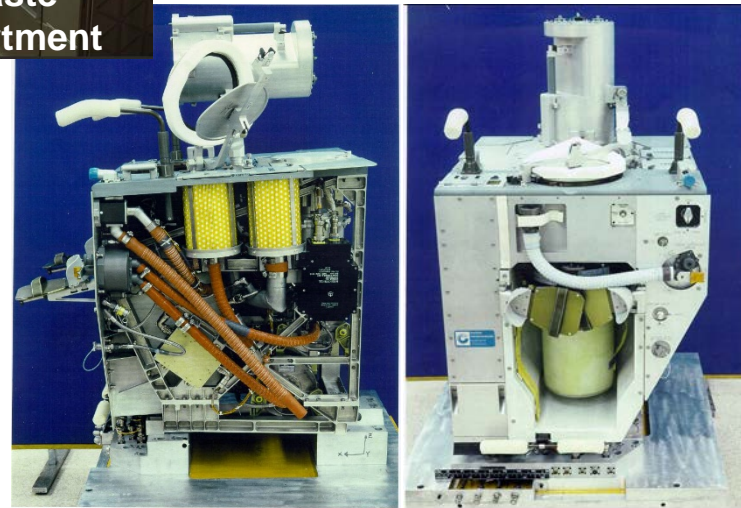
Shuttle Waste Collection System



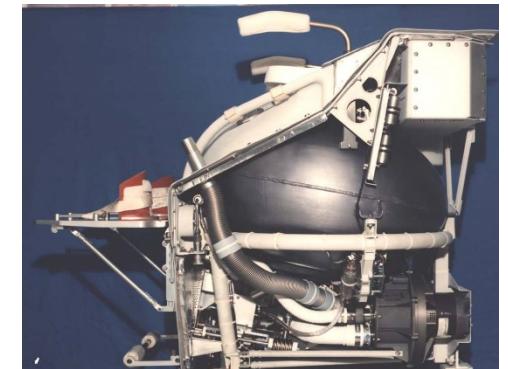
ISS N3 WHC



ISS SM ACY



Shuttle/ISS Risk Reduction WCS



Popular crew photo ops and YouTube



Popular topic in books, movies, TV, web

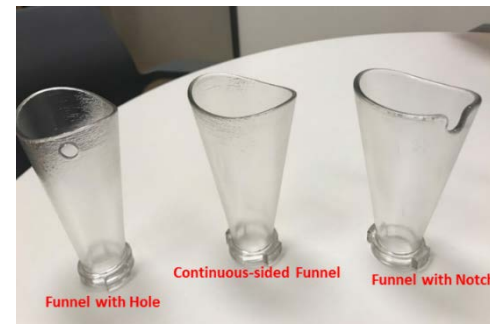


- *The Big Bang Theory* TV sit-com
 - Wolowitz Zero-gravity waste disposal system
- *The Star Trek Enterprise* TV sit-com
 - Trip explains how a toilet works
- *The Apollo 13* movie
 - Various waste components in use, floating by, and urine venting
- *The Martian* movie
 - Uses waste to grow potatoes
- The book '*Packing for Mars*'
 - Has an entire chapter on space toilets, '*Separation Anxiety*'

Detailed internal technical discussion – less so



- Crew debrief capture crew experience of an individual
 - Originally difficult to both male and female to attend and ask technical questions
- Toilet usage is very personal but technical dialog and data required to improve functionality
- Goal is to develop toilet with functionality and user interfaces that supports a wide range of techniques and body shapes
- Initiated frequent in-house NASA crew-engineering discussions
 - 3 design thinking secessions focused on specific toilet features 11 crew (6 female)
 - 2 seat evaluations 34 crew (15 female)
 - 4 funnel evaluations 51 crew (25 female)
 - Multiple overall toilet evaluations +25 crew

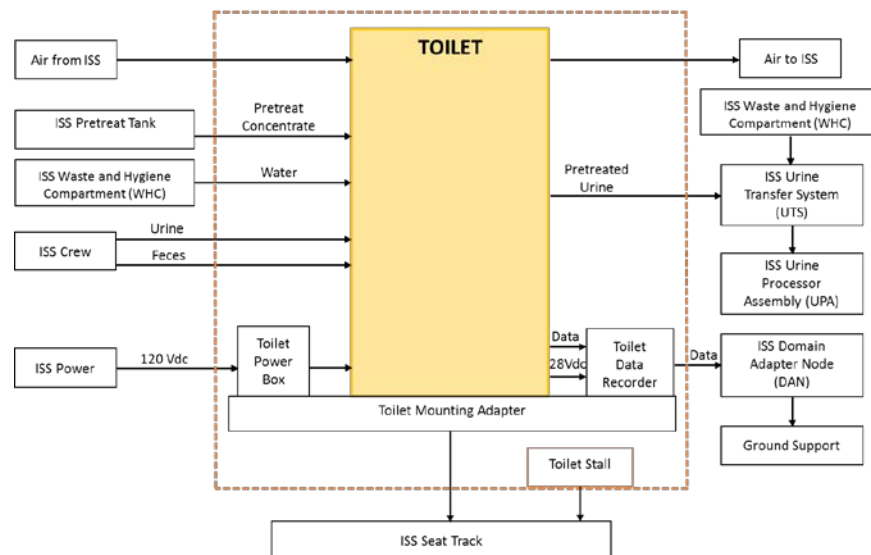
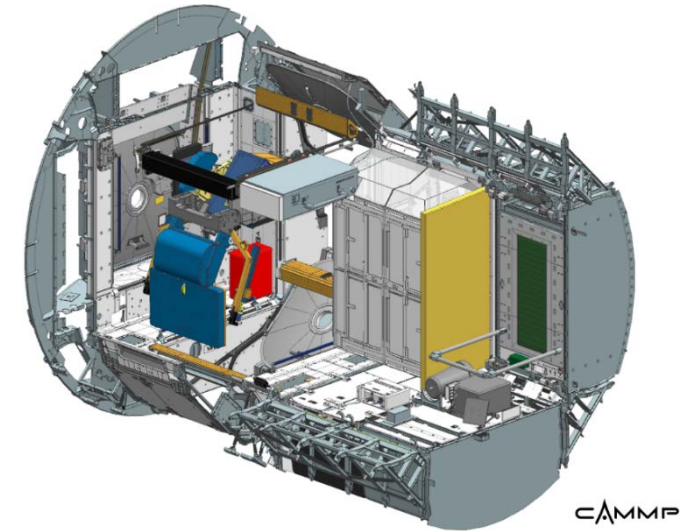


Toilet Integration – Its more complicated than you think

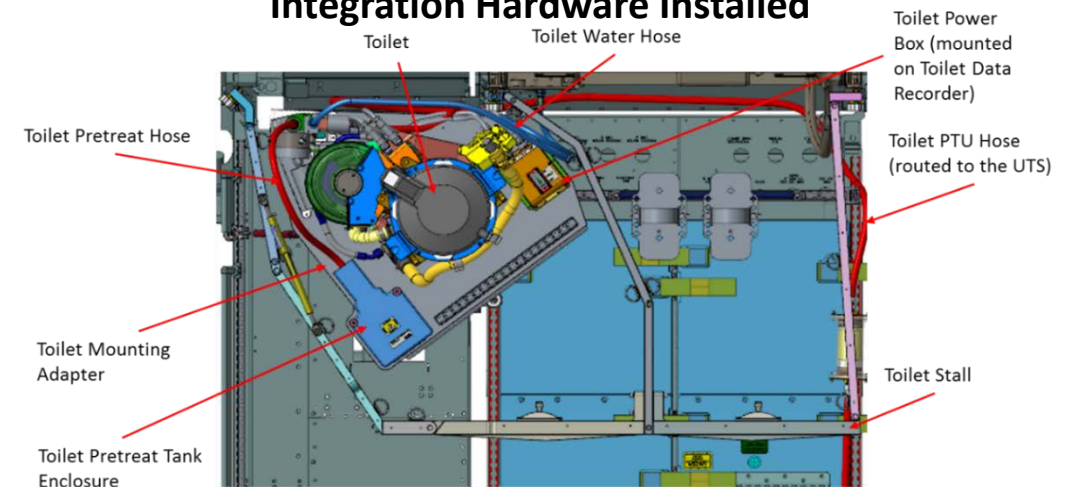


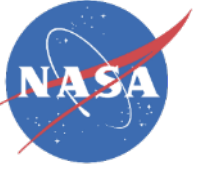
- Small vehicle volumes
- Too much or too little airflow
- Wide range of crew alignments
- Odor control during use
- Preventing vents or processing equipment failures

Toilet Stall installed in Node 3
(in front of WHC and Midbay)



Top View of the Toilet Stall with Toilet and Integration Hardware Installed





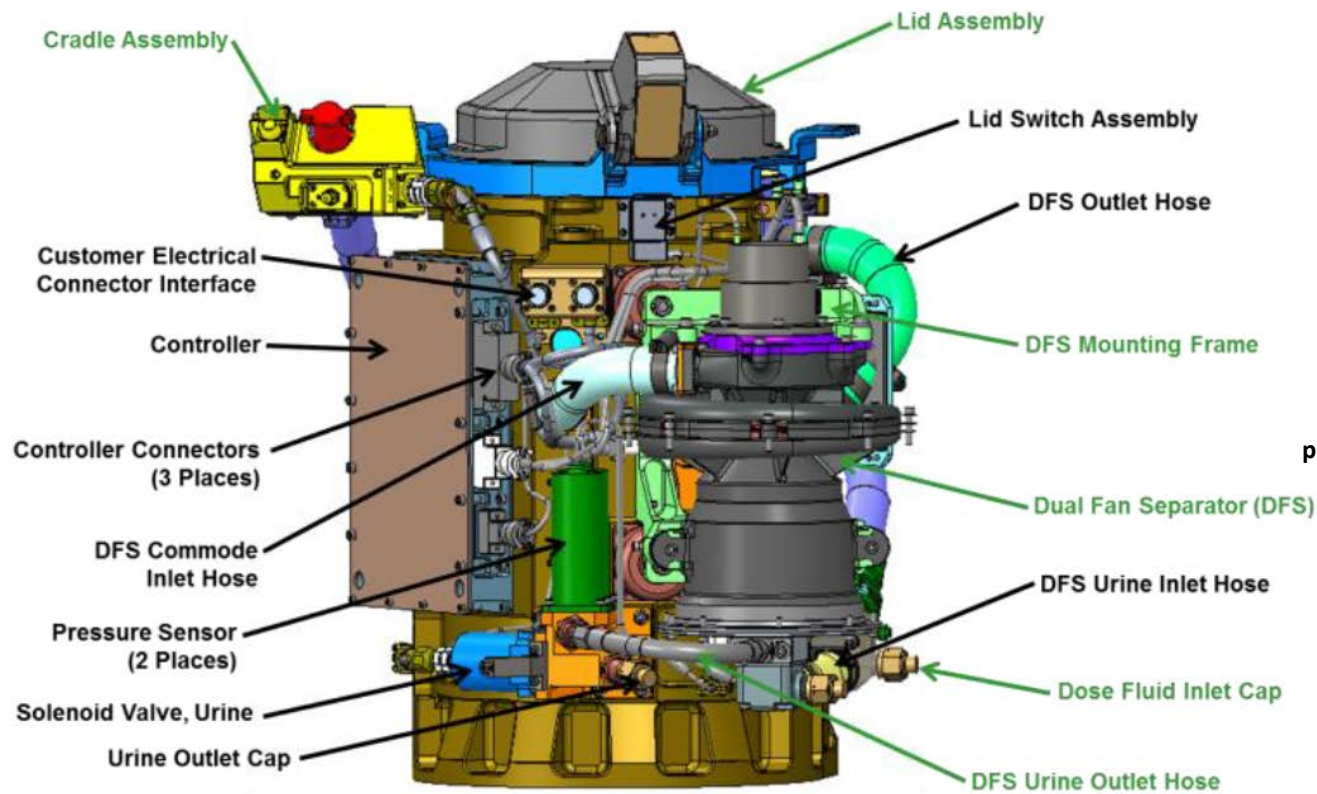
Development of New Exploration Toilet

- The new Exploration Toilet currently in development is based on the Shuttle Extended Duration Orbiter (EDO) Waste Collection System
 - Compact design to accommodate smaller exploration vehicle volumes
 - Urine is collected with improved funnel/hose for more efficient capture
 - Feces is collected in individual bags stored in replaceable canisters with odor control
- Two units are currently in development
 - The first unit is for the first crewed Orion
 - The second unit will fly to ISS, NG-TBD
 - ISS Dual privacy stall flew to ISS on NG-xx
 - Early funnels delivered for early evolution on NG-10

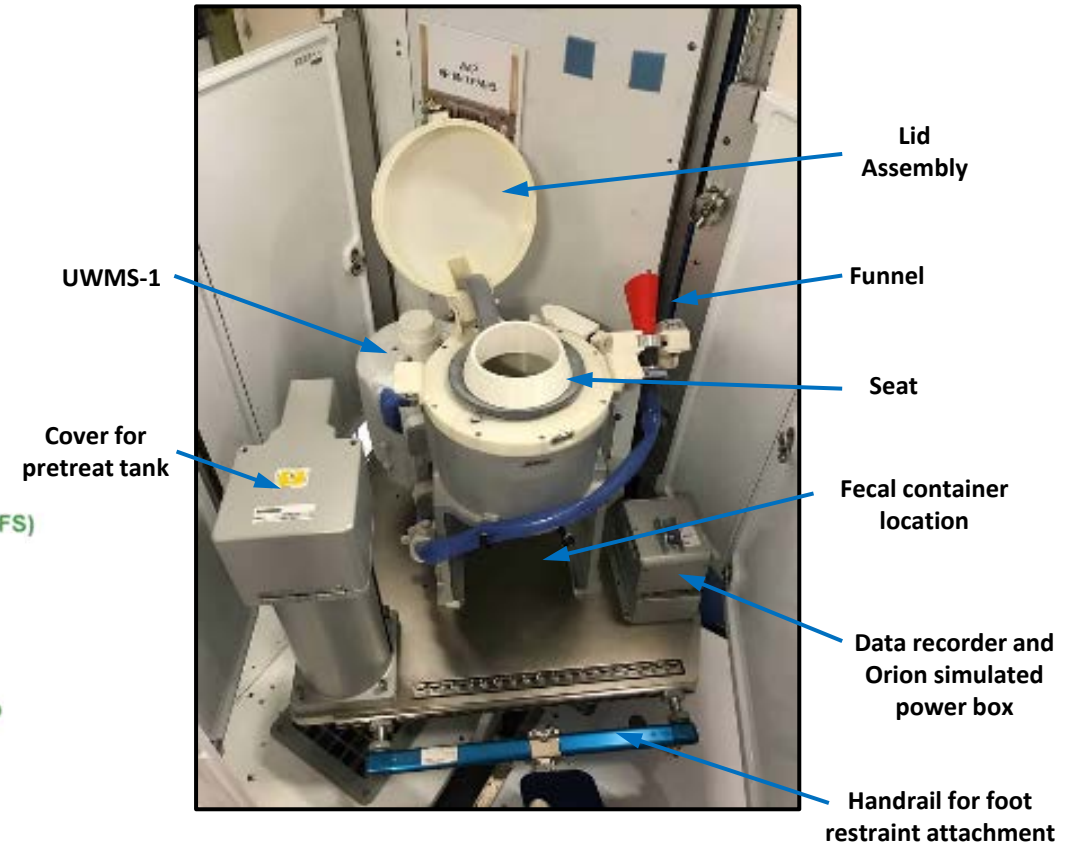


Toilet Stall deployed on ISS Node 3 – modular panels allow partial removal for maintenance in adjacent racks

Development of New Exploration Toilet



Efficient central structural core allows access to all components

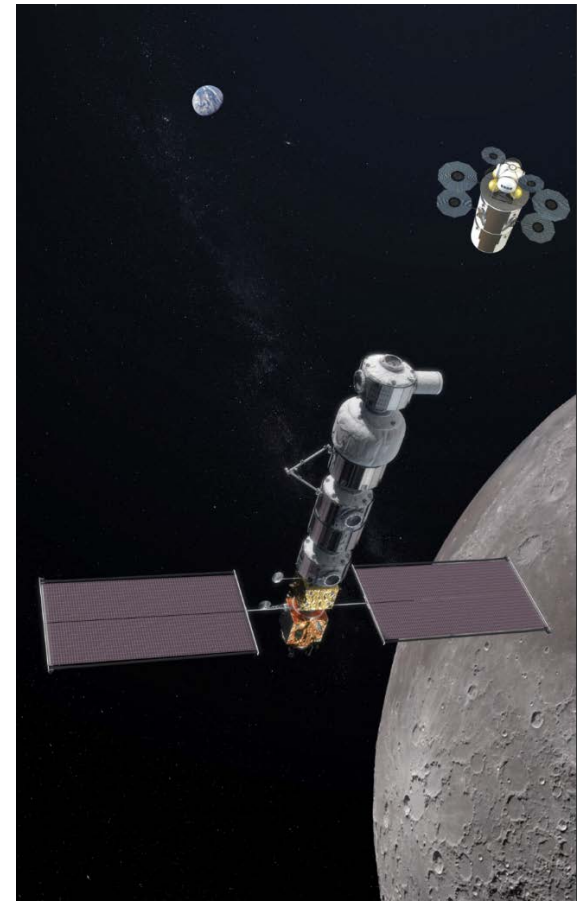


ISS Toilet System Trainer Hardware in Privacy Stall



Future Exploration Toilet Development

- ISS Technology demonstration will validate in inform design modifications
 - Minimum of 100 calendar daily use - combination of male and female crew
 - Evaluate at least 2 different seats
 - Evaluate 5 different funnels (3 already evaluated early)
 - Periodic photo documentation of crew interfaces
 - Acoustic survey at the user's head position
 - Continuous fan operation for one period of a minimum of 60 min
 - Return of three full fecal canisters to assess compaction efficiency
- Extended ISS operations for a minimum of 3 years
 - Characterize system reliability, spares, and consumables usage rates
- Reduce mass and volume of toilet consumables



Backup Slides

Acknowledgements & References



Acknowledgements

The exploration toilet has been jointly funded by the Advanced Exploration Systems Logistics Reduction Project, the ISS Program, and the Orion Program. Substantial technical, operational, and integrations support has been provided by many NASA engineers, operations, crew members, and Collins Aerospace engineers.

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