Developing Exploration Technologies on the ISS:
Exploration Toilet Challenges
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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

<table>
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<tr>
<th>Vehicle</th>
<th>General System</th>
<th>Urine Collection</th>
<th>Fecal Collection</th>
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<td>Female Crew</td>
<td>Crew Feedback</td>
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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 —”
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 – It’s 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
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
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

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References