
EXPLORE MOON to MARS
MOON LIGHTS THE WAY

Logistics Reduction Advancements and Future Plans for NASA's Exploration Missions

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Top row: REALM demo in mockup at JSC, DMS tags, Installation of REALM-3 on ISS by Jessica Watkins,
Second row: AFC with HFC, TCPS containing trash in Sea to Summit bag
Third row: Tide Infinity in CHAPEA Habitat, UWMS on ISS, ISM HYDRA Smart Stow antenna
Bottom row: Tide Pen on ISS, Subscale HPG, OSCAR TtG unit in use at KSC, Washer Dryer SBIR

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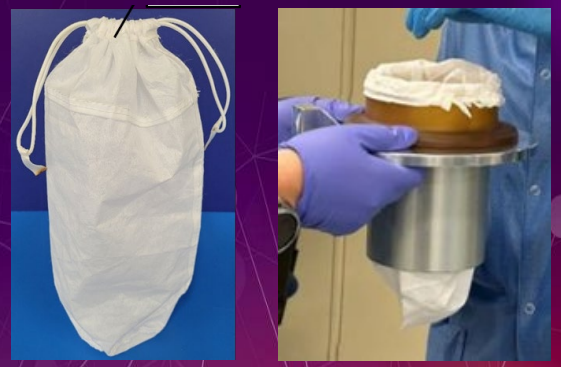
Introduction

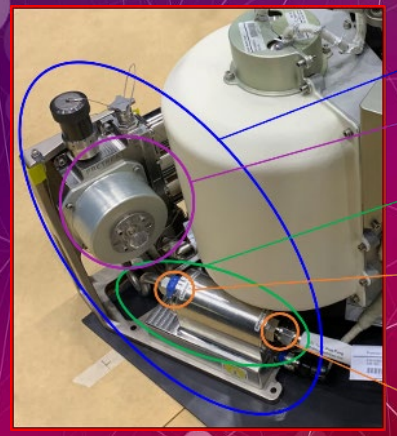
- **Logistics Reduction is about….**
  - **TECHNOLOGIES for reducing crew consumable mass, reducing crew time for logistics management, and managing trash**
  - **…Reducing mass, volume, and crew time**
  - **and addressing exploration technology gaps using a range of government and industry collaborations to enable the space economy.**
- **This means…**
  - **Compact toilets, optimization of fecal canisters mass and volume, trash management strategies, autonomous tracking of cargo, autonomous manipulation of cargo using robotics, and longer wear crew clothing**

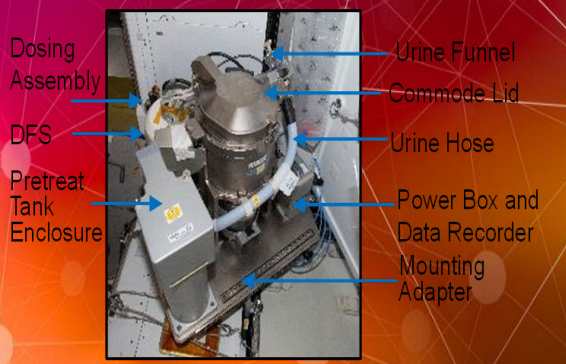
- **WHY?**
  - **Less mass and volume directly assist in spacecraft design**
  - **Reductions in logistics-related crew time frees up time for science, vehicle critical activities and ….**

Metabolic Waste UWMS (Toilet)



Updated Fecal Bag and Seat for evaluation in UWMS





ISS UWMS installed in Node 3, ISS

Orion UWMS installed in Artemis-II

- Universal Waste Management System
  - ISS Unit – Toilet
  - Orion Unit – Waste Management System (WMS)
- ISS Toilet
  - 2/23 Artemis-2 Demonstration – 4 crew/12 days of use
    - Logged 3 crew days of use of UWMS
    - Aborted due to Dose Pump failure to dispense urine pretreat solution
    - After Dose Pump returned to ground, failure investigation showed catastrophic failure of check valve internal component (PEEK) that was traced to incompatibility with the strong acid pretreat solution
- Orion WMS
  - Crew feedback led to updated fecal collection bag and commode seat for Artemis-2
  - Updated seat and fecal bag components planned for evaluation on ISS in 2024.

Other Metabolic Waste Advancements

- Pursuing SBIR contracts for fecal processing for water recovery and stabilization of waste
  - Advanced Fuel Research – Torrefaction of feces at temperatures up to 250°C
  - Ultrasonic Technology Solutions – Using piezoelectric transducers to mechanically shake water out of feces with ultrasonic waves
    - Completed a ground prototype and zero-g testing.

ISS Inventory and Stowage and REALM Experiments

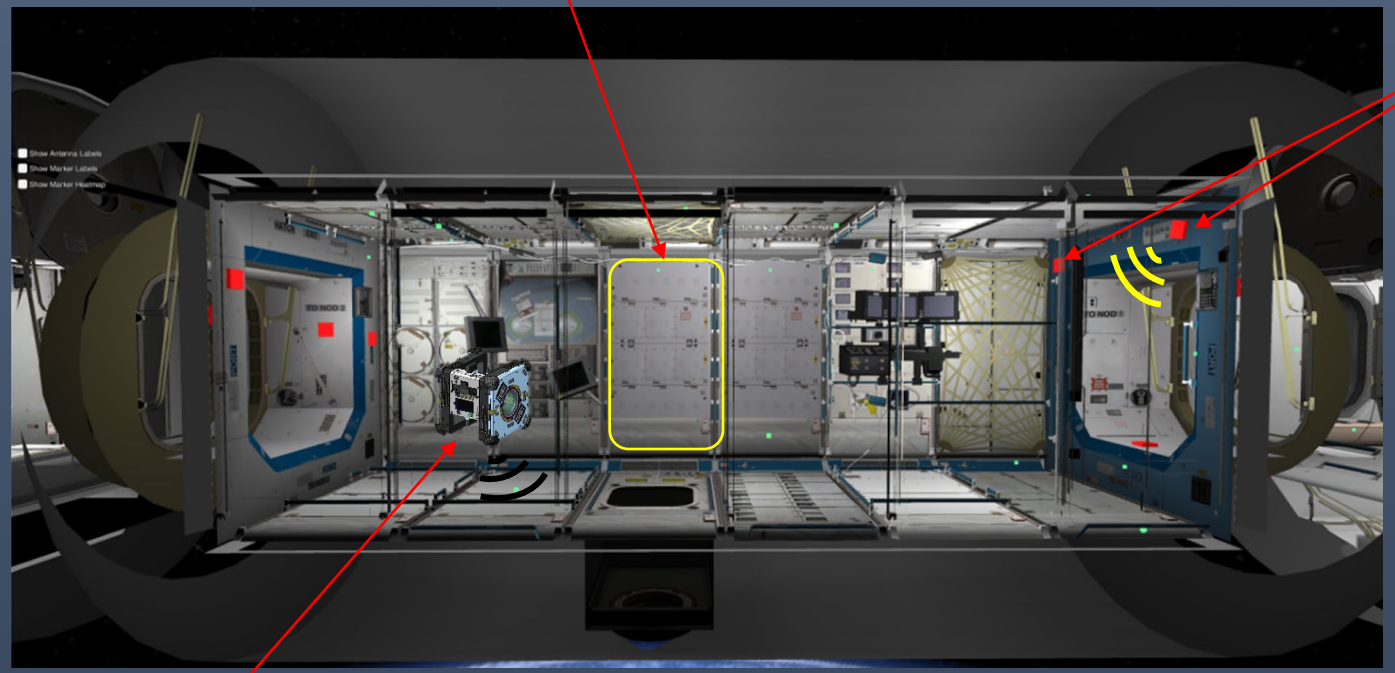
- ISS has approx. 118 cu m (2250 CTBe) of usable stowage space
  - CTBe: Cargo Transfer Bag equivalent
- On board stowage is tracked and utilized via the Inventory Management System (IMS)
  - Tracks over 130,000 items (2019)
    - 64,000 items are active
    - ~3,000 items are considered lost
- RFID-Enabled Autonomous Logistics Management (REALM) experiments are jointly funded by NASA's Advanced Exploration Systems (AES) and ISS Programs
- Why: Autonomous Logistics Management (ALM) was identified in 2015 as a high priority technology need for long duration Human Exploration missions
  - Identify location of all items
  - Allows for more efficient packing
- Objectives:
  - Use ISS to learn how to implement Autonomous Logistics Management
  - Determine combinations of RFID strategies and how they might vary according to mission needs
  - Apply knowledge to define a REALM system for Artemis and other remote exploration missions

REALM RFID Technology Building Blocks

REALM-3

- Smart stowage system (reader integrated into drawers/racks)

Key attribute: RF penetration into dense collections



REALM-1

- Fixed reader/antenna System

Key attribute: pervasive, 24/7 coverage

REALM-2

- Robotic free-flyer equipped with RFID reader

Key attribute: mobile, coverage extension, homing

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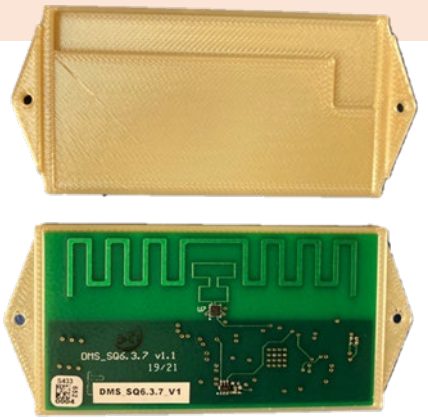
Autonomous Logistics / REALM – Drawer Monitor System (DMS)

Six (of 12) DMS tags on NO1S4 ZSR doors on ISS



DMS RFID Motion Sensor Tag (~2.75” x 1.75” x 0.3”)

What is it….

- DMS is an RFID Sensor system that incorporates an accelerometer-based motion sensor for logistics.

What does it do….

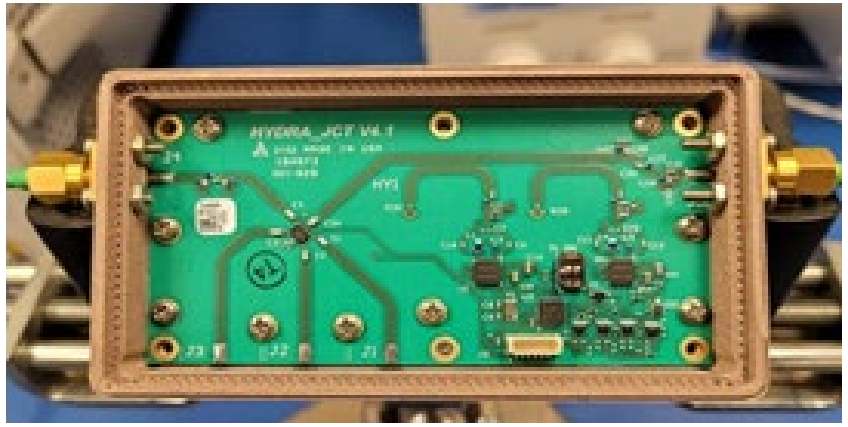
- By adding DMS motion sensing tags to stowage doors, open/close events can be time stamped and utilized by machine learning to improve inferences on item location.
- REALM-1 antennas provide indication of the vicinity of a tagged item, event data gives context for finer location resolution

Status….

- January 2023 Commissioned and evaluated on ISS
- Only a few of 16 tags responded because batteries were depleted
- Firmware bug on tags prevented deep, ultra-low current sleep
- Limited evaluation performed and provided positive results
- Bug corrected and ground testing confirmed low-power sleep mode
- March 2024, 18 updated tags launched on SpX-30

InSpace Manufacturing (ISM)

- Synergy with manufacturing of REALM antennas and housing
- The REALM-2 flight housing is additive manufactured
- Titanium RFID antenna bases
  - Replace bulky polymer/metal composite bases used in the past.
  - Much lighter and stiffer as antenna bases
  - Significant weight reductions
  - Potential expansion of the REALM system with additional antennas for performance enhancement

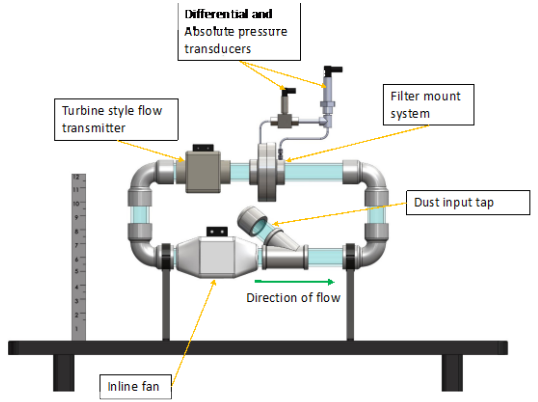


HYDRA PCB in ISM 3D-printed housing. Weight: 56% of Aluminum housing, RF loss: 2.25 dB, 1.8 dB for AL

Trash Management – Trash Compaction and Processing System (TCPS)

Processing of Bagged Trash in TCPS at Ames Research Center

- Waste management technology to reduce trash volume
  - Reduce risk of biological activity in trash
  - Stabilize trash for efficient storage
  - Water recovery and manage gaseous effluents
- TCPS Contract awarded to Sierra Nevada Corp (August 2022) to develop TCPS for an ISS flight demonstration
  - *Completed CDR January 2024*
  - *Engineering Development Unit in fabrication at Sierra Space*
- Other Trash Management Efforts
  - **NASA's risk reduction activities for TCPS**
    - Particulate measurement from handling processed tiles
    - Bagged vs Unbagged trash efficiency, impacts on water recovery, particulates, final trash density, gas effluent
    - Non-standard trash testing including epoxy putty, HEPA filters, pens markers, calculators, etc., for potential toxins
    - Off-gassing testing for management in the crew volume.
  - **Planetary Protection** → Planning testing on filters in a Mars environment
  - **Waste to Base** → Evaluating crowdsource concepts such as use of water-absorbent polymers as a packing foam replacement as well as biodegradable products
  - **Manual Trash Compactor** → Testing with refurbished manual compactor for final achievable volume, stability of processed trash, and particulate and gas effluent products as an alternative for specific applications



Pass-Through Test Rig Components

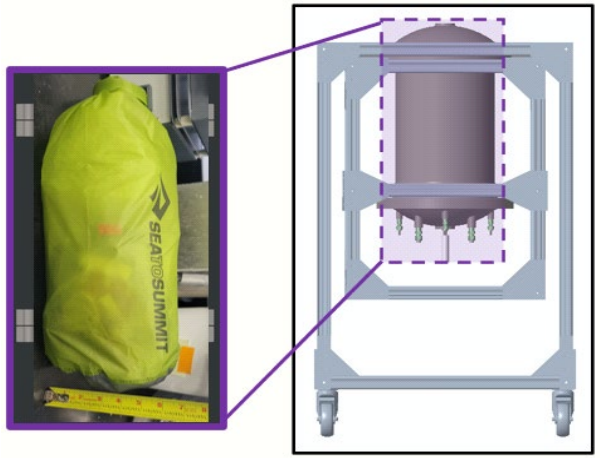
Proposed test apparatus to study the use of filters for long term waste storage on Mars

Lab Benchtop TCPS at ARC

Trash Management- Trash to Gas

- Trash to Gas: Solid trash deconstruction using thermal degradation
  - Mass and volume reduction
  - Potential to recover resources in the form of propellant or other ECLSS commodities.
    - Recovering water from the trash is highly desirable,
    - Residual dry trash has properties that can be utilized to
      - Convert to useful gases for fuel or commodity use,
      - Solids that will contain carbonaceous ash with crop nutrients and metals. The processed residual trash must be in a stable physical form and biologically inert for long-term storage.

Subscale Trash to Gas OSCAR reactor



TtG Reactor Conceptual Design

- Orbital Syngas/Commodity Augmentation Reactor (OSCAR)-Full Scale ground system is in design phase - 4-crew Trash to Gas/Trash Venting System for 6.7 kg/day trash processing. Larger throughput than OSCAR suborbital test unit.
  - Completed conceptual design and analysis of a high through-put reactor
  - Materials purchased for building the ground unit.
  - Funding currently unavailable for further progress in this area.
- SBIR Ignite Ph1 Kicked off 1/2023: “Point-of-Use Recycling for Optimized Space-Age Logistics.” Cecilia Energy: Catalytic Conversion of Waste Plastic to Hydrogen.
  - Completed Phase 1 successfully converting waste plastics into Hydrogen gas and carbon utilizing microwave-assisted thermocatalytic decomposition of crew waste. Phase II SBIR awarded.
- KSC/MSFC completed study for conversion of aluminum waste from crew food packaging to additive manufacturing feedstock
- Successful germination observed with solids remaining from commercial composting units with TtG processing. Elemental composition of remaining solids and water-soluble nutrients.

Tide Infinity in the CHAPEA habitat at JSC

ACS – Advanced Clothing Systems

- Clothing represents about 25% of an astronaut's crew provisions (excluding food) and there are no current washer/dryers certified for space
- Through a Space Act Agreement with Procter and Gamble (P&G), researchers developed Tide Infinity™ detergent to meet the constraints of being fully degradable and compatible with closed loop air and water systems
  - Evaluation of this detergent has continued over the past year in commercial washer/dryer combination machines in several NASA tests including a bioreactor water processor at Texas Tech University and the Crew Health And Performance Exploration Analog (CHAPEA) at JSC
- In-situ hydrogen peroxide generator being developed by the ACS team in collaboration with the NASA/JSC's Life Support project's air team and small business partner Faraday Technology
  - Ground testing and hardware lifetime improvements are underway at JSC
- Clothing for ISS is certified to meet flammability requirements up to 30% O_2 at 10.2psia, but capability up to 36% O_2 at 8.3 psia is desired for exploration missions
  - Phase 2 STTR awarded to Paragon/North Carolina State University to investigate novel fiber blends for high oxygen environments
  - 2 - Phase 2 SBIR's awarded
    - InnoSense, LLC for "Nanolayer-Coated Flame-Retardant Fabrics for Space Crew Clothing"
    - Materials Modification, Inc for "Flame Retardant Polyamide Fibers for Space Crew Clothing."
- Ultrasonic washer and dryer work on the Phase 2 SBIR with UTS continues

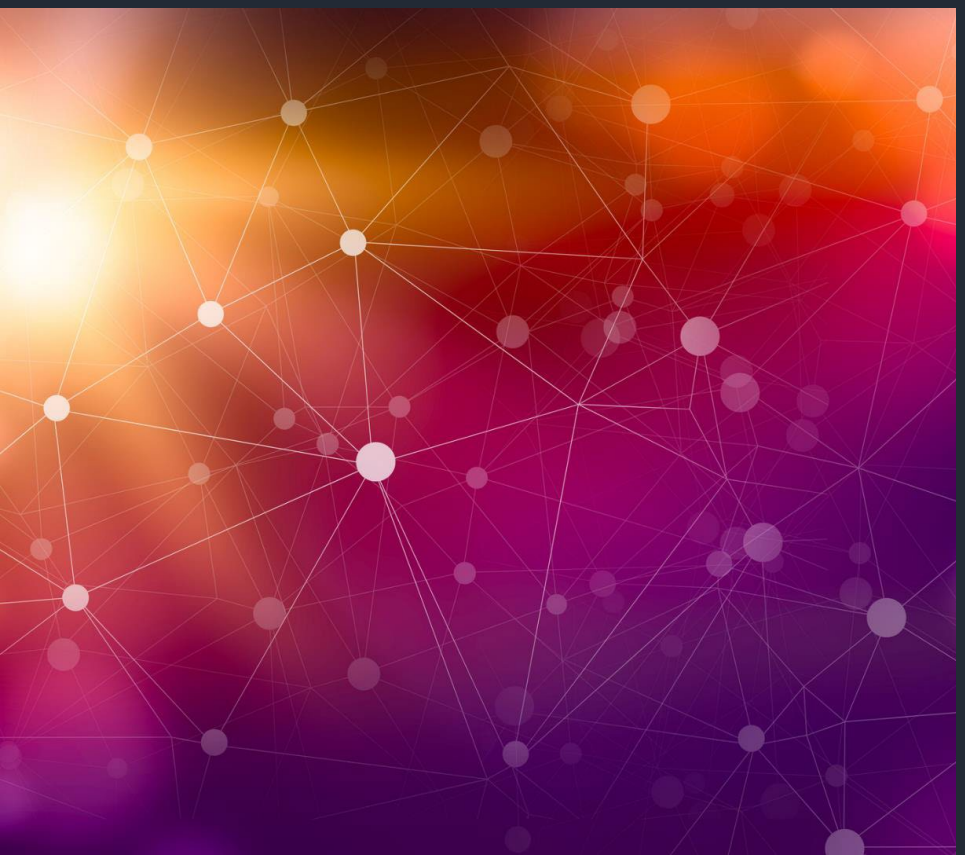
SE&I – Systems Engineering & Integration

- SE&I helps other LR elements optimize and fit into the big picture (e.g., roadmaps)
- Broad integrated waste study covering all Moon-to-Mars habitats
  - Waste management strategies linked to water closure, EVA frequency and mission requirements
  - Links to reuse for all waste
- Updated equivalent system mass (ESM) mission equivalencies
- BPA and TCPS water recovery impacts on ESM (table below)

Note that the BPA and TCSP savings can be additive since they work on different waste streams.

		ESM Equivalency Factors			Technology	
		Volume	Power	Cooling	ESM Savings with	
Mission	**# Days**	*(kg/m^3)*	*(kg/kW$_e$)*	*(kg/kW$_{th}$)*	**BPA**	**TCPS**
ISS	365	67	133	349	416	61
Mars Transit	850	18	69	88	1176	786
Lunar Hab	30	18	78	98	-60	-197

Conclusion



- *Logistics Reduction:*
  - **Helps improve current programs**
  - **Prepares for Moon and Mars Missions**
  - **Informs decisions on hardware and operational strategies**

Questions or Feedback?

- *Melissa K. McKinley*
  - ***Exploration Capabilities Logistics Reduction Project Manager***