Active Project (2014)

Logistics Reduction Project

Advanced Exploration Systems Program | Human Exploration And Operations Mission Directorate (HEOMD)

ABSTRACT

All human space missions, regardless of destination, require significant logistical mass and volume directly proportional to mission duration. As our exploration missions increase in distance and duration, reduction of these logistics requirements becomes even more important. Anything that can be done to reduce initial mass and volume of supplies or reuse items that need to be launched will be very valuable. Logistics are a subset of the habitation domain and has many interfaces with habitat life support and crew health systems. This project targets the best opportunities to demonstrate logistics reduction and repurposing. These technologies and innovations will make future exploration missions much more affordable. System engineering analysis using equivalent system mass (ESM) techniques are used in comparing the potential technologies for different exploration missions.

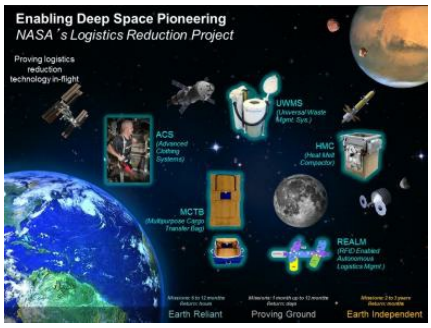
ANTICIPATED BENEFITS

To NASA funded missions:

All human space missions, regardless of destination, require significant logistical mass and volume that is strongly proportional to mission duration. As exploration missions lengthen in distance and duration, reduction of these logistics requirements becomes even more important. This project works to reduce initial mass and volume of supplies or reuse items that have been launched. Logistics/trash volume reductions increase the habitable volume and can improve the habitat's usability and crew hygiene.

To NASA unfunded & planned missions:

All human space missions, regardless of destination, require significant logistical mass and volume that is strongly proportional to mission duration. As exploration missions lengthen in distance and duration, reduction of these logistics requirements becomes even more important.This project works to reduce initial mass and volume of supplies or reuse items that



Proving logistics reduction technology in flight

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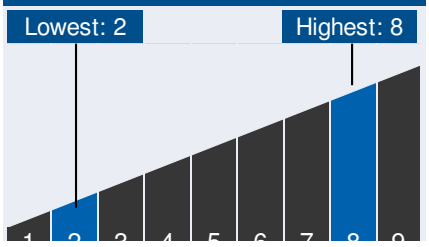
Technology Maturity



have been launched.

To other government agencies:

Technologies developed under this project could also be utilized by other government agencies whose personnel live and work in extreme remote environments, such as the military, the National Science Foundation research stations, etc.

To the commercial space industry:

These technologies may have broad use for potential commercial providers of future space systems, providing benefits for reduction of logistics requirements and improved habitability.

To the nation:

The project can enable sustainable human long-term space exploration and support personnel living and working in extreme remote environments. Terrestrial technology spin-offs may also include new environmentally friendly technologies in areas such as clothing systems, reuse of items and waste-to-energy.

DETAILED DESCRIPTION

The Advanced Exploration Systems (AES) Logistics Reduction (LR) project will enable a mission-independent cradle-to-grave-to-cradle approach to minimize logistics contributions to total mission architecture mass and improve space habitability. The goals of LR are to systematically engineer common crew consumables, container configurations, and waste management. There are five fundamental approaches to reduce logistical mass:

Management Team

Program Director:
- Jason Crusan

Program Executive:
- Barry Epstein

Project Manager:
- James Broyan

Logistics Reduction Project

1. Direct reduction of logistical mass.
2. Improved automated tracking of logistical items in packaging containers and cabin environments to allow denser logistical packaging at launch and to save on-orbit crew time.
3. Direct reuse and repurposing of logistical items to avoid flying separate items to meet both functions.
4. Reprocessing of logistical items to provide a secondary function, increase habitable volume, improve habitability,and enhance life support closure.

The goals of the Logistics project will be accomplished through five hardware tasks plus a strong systems engineering analysis and integration function. These logistics/habitation technologies were selected from a wider range of technology needs due to their overall mission benefit and ability to be infused into near term exploration missions. The five hardware oriented tasks are:

Technology Areas

- Human Health, Life Support, and Habitation Systems (TA 6)
- Environmental Control and Life Support Systems and Habitation Systems (TA 6.1)
- Particulate and Microbial Control (TA 6.1.1.4)
- Waste Management (TA 6.1.3)
- Metabolic Waste Management (TA 6.1.3.1)
- Trash Management System (TA 6.1.3.3)
- Habitation (TA 6.1.4)
- Multi-Purpose Cargo Transfer Bag (MCTB) (TA 6.1.4.2)
- Long-Wear Clothing (Advanced Clothing) (TA 6.1.4.5)
- Laundry Freshening System (Simple Laundry) (TA 6.1.4.6)
- Lightweight Crew Quarters (TA 6.1.4.7)
- Radiofrequency Identification (RFID)-Based Medical Inventory Tracking Hardware and Software (TA 6.3.1.6)
- Contingency Air Scrubber (TA 6.4.4.1)
- Post-Fire Air Scrubber (TA 6.4.4.3)
- In-Situ Passive Shielding from and in the Spacecraft (TA 6.5.3.2)

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1. Use of an Advanced Clothing System (ACS) to directly reduce the mass and volume of clothing needed to be flown. Antimicrobial treatments are applied to current and lighter weight commercial off-the-shelf (COTS) exercise clothing to investigate if they could be used for longer periods of time. Longer wear clothing will change the break-even point for laundering (vs. clothing disposal) sufficiently to delay development until Mars surface missions are planned.
2. Use of radio frequency identification (RFID) Enabled Autonomous Logistics Management (REALM) methods and 3D localization and complex event processing to enable automatic inventory tracking as resources move around a vehicle. REALM will reduce crew time in locating stored items in densely packed areas and enable the location of lost items.
3. Repurposing of multipurpose cargo transfer bags (MCTBs) for on-orbit outfitting. MCTBs can be used for constructing crew quarters, privacy or acoustic sound-adsorbing partitions, contingency water storage or waste water processing units, and dense-area RFID enclosures for REALM. Reuse of the MCTB logistics carriers prevents the need to fly separate items.
4. Conversion of waste and used logistical items to useable products with a heat melt compactor (HMC). Waste items are heated and mechanically compacted into stable tiles that can be used for radiation shielding. Additionally, water is recovered for life support processing. For a one-year mission, it is estimated that HMC could recover ~8 cubic meters of habitable volume, produce over 900 kg of radiation shielding tiles, and recover 230-720 kg of water.
5. Use of a Universal Waste Management System (UWMS) to reduce mass and volume from the current state-of-the-art waste management systems (toilet) and promote consumables and hardware sharing between vehicles, reducing overall integrated mission logistics.

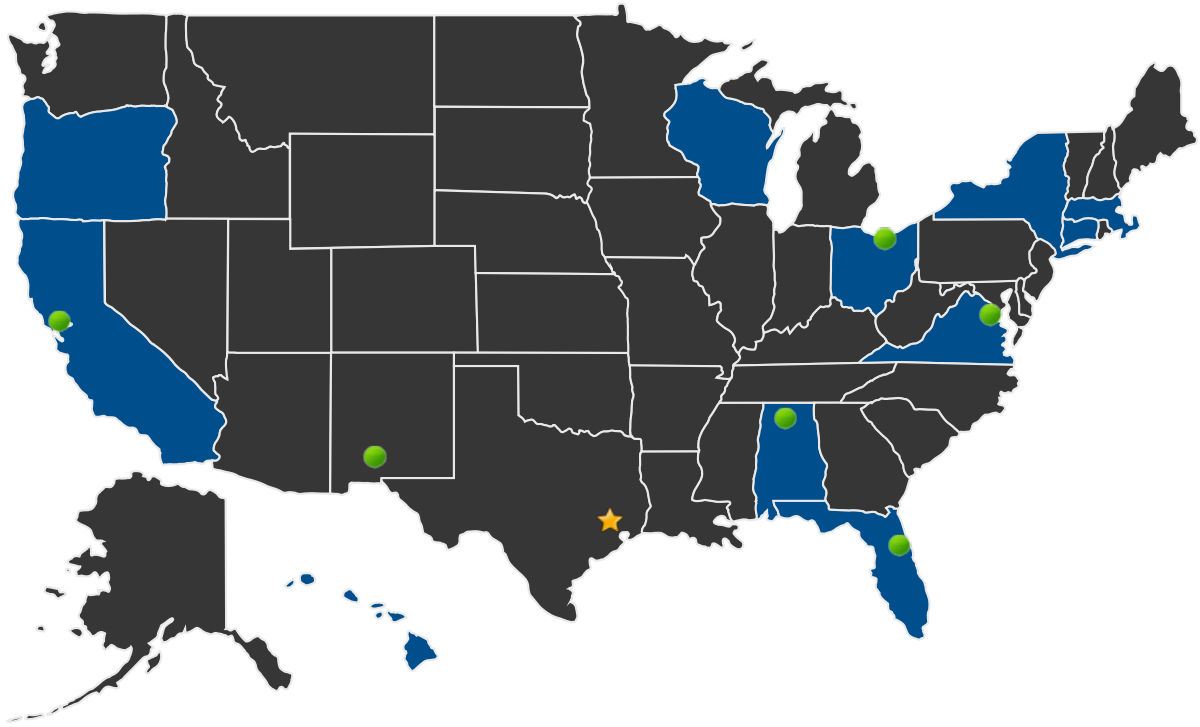
In addition to the five hardware-oriented technology

Technology Areas *(cont.)*

- Human Exploration Destination Systems (TA 7)
- In-Situ Resource Utilization (TA 7.1)
- Sustainability and Supportability (TA 7.2)
- Autonomous Logistics Management (TA 7.2.1)
- Power Scavenged Wireless Sensor Tag Systems (TA 7.2.1.3)
- Dense Zone Technology (Radio Frequency Identification Enclosure) (TA 7.2.1.4)
- Sparse Zone Technology (TA 7.2.1.5)
- Logistics Complex Event Processing (TA 7.2.1.6)
- Six Degree of Freedom Logistics Tag System (TA 7.2.1.7)
- Multipurpose Cargo Transfer Bag (TA 7.2.1.9)

development tasks described above, a sixth critical LR task is to ensure proper integration and architectural decisions among the various logistics reduction and repurposing technologies and interactions with habitat, crew health, and life support systems. Under AES LR, a waste and logistics model considers all consumable items launched, using the ISS as a baseline and real world data sources. This data is compared against reference missions to determine the best waste processing methods for material reuse for ISS and future exploration missions. Mass, power, volume, thermal control, and crew time trade studies are conducted to allow sound programmatic decisions. An equivalent system mass (ESM) technique is used to include all these factors. In addition to general logistics/trash modeling, this sixth LR task also supports detailed LR technology trade studies.

U.S. WORK LOCATIONS AND KEY PARTNERS



U.S. States With Work

Lead Center:
Johnson Space Center

Supporting Centers:

- Ames Research Center
- Glenn Research Center
- Kennedy Space Center
- Marshall Space Flight Center
- NASA Headquarters
- White Sands Test Facility

Other Organizations Performing Work:

- The University of Massachusetts, Amherst (Amherst, MA)

Contributing Partners:

- Advanced Fuel Research, Inc.
- Advanced Systems & Technologies, Inc.
- Cornell University
- Materials Modification, Inc.
- Orbital Technologies Corporation (ORBITEC)
- UMPQUA Research Company
- University of Hawaii
- Roscosmos

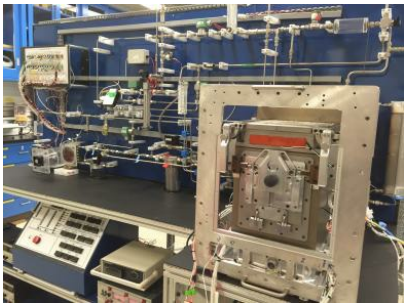
PROJECT LIBRARY

Publications

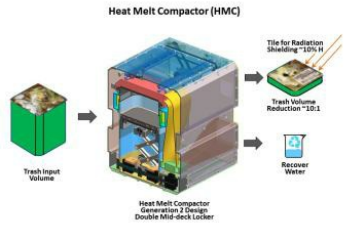
- Success Story: Advanced Clothing System Results Informing Future Space Crew Clothing
  - (http://techport.nasa.gov:80/file/26156)
- Success Story: Bag Turned Acoustic Blanket Reduces Sound Level for Crew Exercise
  - (http://techport.nasa.gov:80/file/26172)

IMAGE GALLERY

Acoustic T-60 Reverberation Test performed on the Acoustic Multipurpose Cargo Transfer Bags (AMCTBs) June 22-23, 2015



The Gen 2 HMC (right) with the Water Recovery System (WRS) in the background.



An overview of the HMC functions

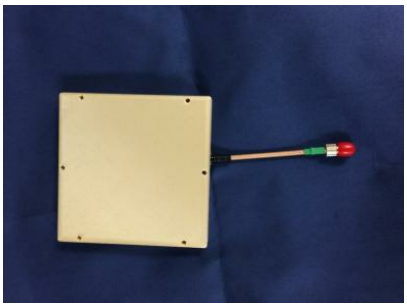
Increment 40 crew members in their IVA Clothing Study exercise clothing

Astronaut Steve Swanson exercising in IVA Clothing Study shirt and shorts

Exploration: Trash = Opportunity

Fit check of the AMCTB prototype as an 'acoustic blanket' in the JSC Space Vehicle Mockup Facility (building 9) ISS Node 3 mockup

REALM-1 reader unit with fan assembly in flight-like housing



REALM-1 flight antenna that was developed in-house. ~80% smaller than COTS antenna and maintains similar performance.

DETAILS FOR TECHNOLOGY 1

Technology Title

Advanced Clothing System (ACS)

Technology Description

This technology is categorized as a material for wearable applications

The goal of the ACS is to use advanced commercial off-the-shelf fibers and antimicrobial treatments to directly reduce the mass and volume of clothing. The textile industry has made significant progress with new fiber blends and garment finishing. The ACS team is leveraging existing state-of-the-art technology from the private industry to make advancements in the crew wardrobe.

The current clothing state-of-the-art on the International Space Station (ISS) is disposable, mostly cotton-based, clothing with no laundry provisions. Each clothing article has varying use periods and will become trash. The goal is to increase the length of wear of the clothing to reduce the logistical mass and volume.

The ACS task will focus on the subtasks of alternative laundry and clothing sanitation technologies in FY16. The subtasks of clothing sanitation and alternative laundry are starting at TRL

Technology Areas

Primary Technology Area:
Human Health, Life Support, and Habitation Systems (TA 6)
- Environmental Control and Life Support Systems and Habitation Systems (TA 6.1)
  - Habitation (TA 6.1.4)
    - Multi-Purpose Cargo Transfer Bag (MCTB) (TA 6.1.4.2)
    - Long-Wear Clothing (Advanced Clothing) (TA 6.1.4.5)
    - Long-Wear Clothing (Advanced Clothing) (TA 6.1.4.5)

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Capabilities Provided

The ACS technology is a continuation from the Logistics Reduction and Repurposing project. The initial focus was exercise clothing and routine wear tops since the use period is shorter. A ground-based experiment was conducted to evaluate current and lighter weight commercial off-the-shelf (COTS) exercise clothing and antimicrobial treatments to investigate if they could be used for longer periods of time. The best performers were selected for an experiment on the International Space Station (ISS) - Intravehicular Activity (IVA) Clothing Study. The experiment was conducted during ISS increments 39 through 41 with six crew members. A laundry trade-off study was conducted to quantify how longer-wear clothing changes the break-even point for laundering vs. clothing disposal. The analysis indicates that use of ACS selected garments (e.g. wool, modacrylic, polyester) can increase the breakeven point for laundry to about 300 days. ACS studies also investigated lint reduction and microbial behavior on textiles.

Potential Applications

Advanced Clothing Systems would benefit any long-duration operation with limited logistics transportation or stowage capacity. This is accomplished by extending the use of clothing before it has to be laundered or replaced.

Performance Metrics

Metric	Unit	Quantity
Clothing resupply mass	0.2	kg/crew-day

Technology Areas *(cont.)*

Secondary Technology Area:
Human Health, Life Support, and Habitation Systems (TA 6)
- Environmental Control and Life Support Systems and Habitation Systems (TA 6.1)
  - Habitation (TA 6.1.4)
  - Habitation (TA 6.1.4)

Continued on following page.

Logistics Reduction Project

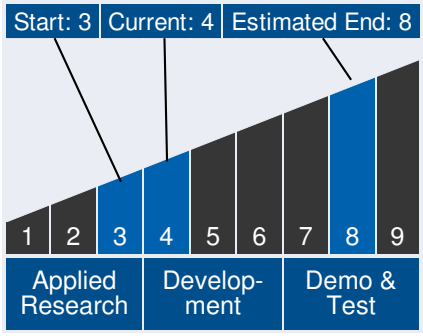
Advanced Exploration Systems Program | Human Exploration And Operations Mission Directorate (HEOMD)

Technology Areas *(cont.)*

Additional Technology Areas:

Human Health, Life Support, and Habitation Systems (TA 6)
- Environmental Control and Life Support Systems and Habitation Systems (TA 6.1)
  - Air Revitalization (TA 6.1.1)
    - Particulate and Microbial Control (TA 6.1.1.4)
    - Particulate and Microbial Control (TA 6.1.1.4)
  - Habitation (TA 6.1.4)
    - Laundry Freshening System (Simple Laundry) (TA 6.1.4.6)
    - Laundry Freshening System (Simple Laundry) (TA 6.1.4.6)
- Environmental Monitoring, Safety, and Emergency Response (TA 6.4)
  - Remediation (TA 6.4.4)
    - Contingency Air Scrubber (TA 6.4.4.1)
    - Post-Fire Air Scrubber (TA 6.4.4.3)
- Radiation (TA 6.5)
  - Protection Systems (TA 6.5.3)
    - In-Situ Passive Shielding from and in the Spacecraft (TA 6.5.3.2)

Technology Maturity



DETAILS FOR TECHNOLOGY 2

Technology Title

Heat Melt Compactor (HMC)

Technology Description

This technology is categorized as a hardware subsystem for manned spaceflight

The HMC technology is a waste management technology that is a continuation from the previous Logistics Reduction and Repurposing and Exploration Life Support projects. Currently, there are no waste management practices that are being implemented in the space environment other than manual compaction of waste into a plastic bag. The current practice does not recover critical resources such as water, does not prevent the growth of potentially harmful microbiological pathogens, and provides only limited volume reduction.

The primary purpose of the HMC is to reduce the volume and microbially stabilize the waste. The HMC is a device that compacts and heats the trash. The trash is heated to the point where some of the plastic softens and fills the interstitial voids between non-melted trash. The compacted trash is then cooled, resulting in a dry, relatively solid tile that does not exhibit the spring back of traditional compactors. The shape of the tile is predictable and maximizes the efficiency of storage volume.

Technology Areas

Primary Technology Area:
Human Health, Life Support, and Habitation Systems (TA 6)
- Environmental Control and Life Support Systems and Habitation Systems (TA 6.1)
  - Waste Management (TA 6.1.3)
    - Trash Management System (TA 6.1.3.3)
    - Trash Management System (TA 6.1.3.3)

Continued on following page.

Logistics Reduction Project

Advanced Exploration Systems Program | Human Exploration And Operations Mission Directorate (HEOMD)

When the trash is heated, it results in a microbiologically safe tile that can be safely handled by the crew. The HMC can process both wet and dry trash. The water that is driven off the waste is collected and returned to the Water Recovery System. The tiles have ~10% hydrogen from the plastics, wipes, and residual food and can be used to provide additional radiation shielding in the spacecraft.

A full-scale second-generation (Gen2) HMC has been developed and is being used to finalize operational parameters and identify hardware issues. Gen2 HMC tests will allow development of an eventual ISS flight unit. Two companies were awarded SBIRs are working on microgravity-compatible condensing heat exchanger designs that potentially could address HMC functional requirements.

Capabilities Provided

The HMC task will develop a highly reliable technology primarily for reducing trash volume. HMC will also recover water from waste materials and produce microbially stable, low volume tiles for radiation protection, storage or disposal. For a one-year mission of four crew, it is estimated that HMC could recover ~8 cubic meters of habitable volume, produce over 900 kg of radiation shielding tiles, and recover 230-720 kg of water.

Limited Gen2 HMC ground testing will begin in 2016, to be followed by development of the flight HMC unit for a launch to ISS in the early 2020s.

Potential Applications

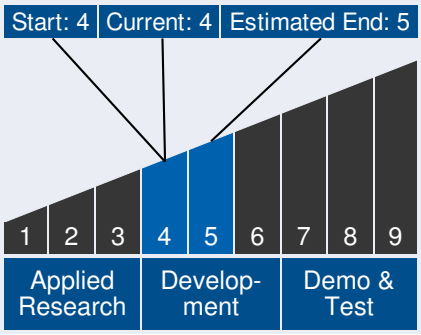
The HMC technology would benefit any long-duration operation with limited habitable volume. The goal is to reduce trash volume and microbially inactivate it. This will provide less odor generation and improve habitat hygiene. As an alternative to radiation shielding, increased habitable volume, and recovered water, HMC processed trashed could be processed further using trash-to-gas technology to produce methane, or the tiles could be a compact form for trash disposal/ejection from the vehicle.

Technology Areas *(cont.)*

Additional Technology Areas:

Human Health, Life Support, and Habitation Systems (TA 6)
- Environmental Control and Life Support Systems and Habitation Systems (TA 6.1)
  - Habitation (TA 6.1.4)
    - Lightweight Crew Quarters (TA 6.1.4.7)
    - Lightweight Crew Quarters (TA 6.1.4.7)
- Radiation (TA 6.5)
  - Protection Systems (TA 6.5.3)
    - In-Situ Passive Shielding from and in the Spacecraft (TA 6.5.3.2)
    - In-Situ Passive Shielding from and in the Spacecraft (TA 6.5.3.2)

Technology Maturity



Performance Metrics

Metric	Unit	Quantity
Compaction Ratio	>8:1	Inital volume:Final volume
Energy Consumption	<1.3	kW-hr/kg
Trash dryness (water activity level)	<0.6	unitless
Installed mass	82	kg

DETAILS FOR TECHNOLOGY 3

Technology Title

Multipurpose Crew Transfer Bag (MCTB)

Technology Description

This technology is categorized as a hardware assembly for manned spaceflight

The MCTB task focuses on repurposing cargo transfer bags for on-orbit outfitting. The MCTB task, which is derived from the previous LRR Logistics to Living (L2L) task, converts cargo transfer bags into useful crew items or life support augmentation on-orbit after they have provided their primary logistics function. Reuse of the MCTB logistics carriers prevents the need to fly additional items. By repurposing MCTBs, dedicated crew items do not have to be launched and the overall launch mass is decreased. For non-LEO missions, the vehicle interior habitat volume will be relatively fixed. MCTBs will enable this volume to be used more effectively through reuse and rearrangement of logistical components. MCTBs reduce habitation trash generation rates. This effort is in collaboration with the ISS program vehicle office

Capabilities Provided

MCTBs can be used for constructing crew quarters, privacy or sound-adsorbing partitions, contingency water storage, or waste water processing units.

Technology Areas

Primary Technology Area:
Human Health, Life Support, and Habitation Systems (TA 6)
- Environmental Control and Life Support Systems and Habitation Systems (TA 6.1)
  - Habitation (TA 6.1.4)
    - Multi-Purpose Cargo Transfer Bag (MCTB) (TA 6.1.4.2)
    - Multi-Purpose Cargo Transfer Bag (MCTB) (TA 6.1.4.2)

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The MCTB team has worked with the JSC Acoustics Office to determine the optimal material layup of an acoustic MCTB to absorb the sound of the ISS treadmill. Located in Node 3 on ISS, the treadmill reaches the noise hazard limit of 85 dBA when operated at high speeds. As such, the treadmill has been added to the Noise Hazard Inventory, and hearing protection has become mandatory when the treadmill is used above 10 mph per the Noise Constraint Flight Rule. An acoustic MCTB has been designed with a material layup specifically designed to absorb the sound generated by the treadmill. After serving their primary purpose of carrying logistics, the MCTBs will be reconfigured to flat panels and attached in a dual layer to two walls in proximity to the treadmill.

The Acoustic MCTBs have been developed for a flight experiment that will occur in FY16. Test data with the flight Acoustic MCTBs indicates that this implementation will decrease the sound level by 2-3 dBA. Since dBA is measured on a logarithmic scale, a 3 dBA reduction is a halving of the sound energy.

Four Acoustic MCTBs were designed, fabricated, and delivered in the first half of 2015 and launched to ISS on Orbital's fourth cargo resupply mission (Orb-4) in December 2015. It will be deployed and tested on ISS in early 2016.

Potential Applications

For non-LEO missions, the vehicle interior volume will be relatively fixed. MCTBs will enable this volume to be used more effectively through reuse and rearrangement of logistical components. Reuse of cargo bags improves habitation functionality and reduces the packaging trash after the cargo bag contents are utilized.

Technology Areas *(cont.)*

Additional Technology Areas:

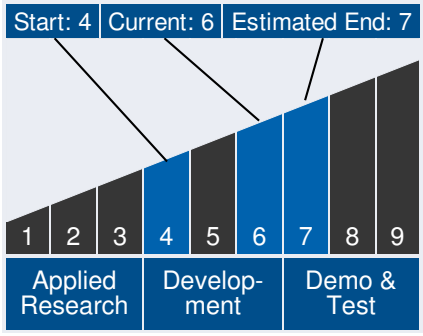
Human Health, Life Support, and Habitation Systems (TA 6)
- Environmental Control and Life Support Systems and Habitation Systems (TA 6.1)
  - Habitation (TA 6.1.4)
    - Lightweight Crew Quarters (TA 6.1.4.7)
    - Lightweight Crew Quarters (TA 6.1.4.7)
- Radiation (TA 6.5)
  - Protection Systems (TA 6.5.3)
    - In-Situ Passive Shielding from and in the Spacecraft (TA 6.5.3.2)
    - In-Situ Passive Shielding from and in the Spacecraft (TA 6.5.3.2)

Human Exploration Destination Systems (TA 7)
- Sustainability and Supportability (TA 7.2)
  - Autonomous Logistics Management (TA 7.2.1)
    - Multipurpose Cargo Transfer Bag (TA 7.2.1.9)
    - Multipurpose Cargo Transfer Bag (TA 7.2.1.9)

Performance Metrics

Metric	Unit	Quantity
Mass savings through MCTB reuse	40	kg/crew-year

Technology Maturity



DETAILS FOR TECHNOLOGY 4

Technology Title

RFID Enabled Autonomous Logistics Management (REALM)

Technology Description

This technology is categorized as a hardware system for manned spaceflight

The LR REALM task focuses on the subset of autonomous logistics management functions pertaining to automated localization and inventory of all physical assets pertaining to, or within, a vehicle utilizing RFID technologies. REALM technology can provide detailed data to enable autonomous operations such as automated crew procedure generation and robotic interaction with logistics and deep space habitats; this is especially of value where communication delays with Earth drive the need for self-reliance.

The problem of locating all mission items within and around a vehicle are complicated by many factors, including the desire to rely only on passive tags, restrictions on RF transmit power, layered storage of logistics, the challenging RF scattering environment of vehicles, and metallic storage enclosures. To address this complex problem, associated RFID technologies are partitioned into three classes:

Technology Areas

Primary Technology Area:
Human Exploration Destination Systems (TA 7)
- In-Situ Resource Utilization (TA 7.1)
- In-Situ Resource Utilization (TA 7.1)
- Sustainability and Supportability (TA 7.2)
  - Autonomous Logistics Management (TA 7.2.1)
    - Sparse Zone Technology (TA 7.2.1.5)
    - Sparse Zone Technology (TA 7.2.1.5)

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1. Dense Zone technologies
2. Sparse Zone technologies
3. Complex Event Processing

Dense Zone technologies pertain to enclosures with conductive, or shielded, boundaries and an integrated RFID reader to interrogate the items contained therein. Sparse zone technologies address all areas exclusive of the dense zones, including the open areas of a habitat module in addition to crevices, for example, behind a rack. These technologies include fixed zone readers, steered beam antenna readers, and mobile readers such as robotic elements, crew- held readers or crew-worn readers. With both dense and sparse zones, guaranteed real-time on-demand reads are not possible, so “smart” applications, e.g., Complex Event Processing (CEP), are required to infer item locations based on context from the sparse and dense zone technologies.

Mission details might drive a different combination of these three technologies. Therefore, in addition to maturing these individual technology areas, the LR REALM team will learn which combinations of technologies are best suited for specific missions. For example, dense zone technologies can be made highly accurate but entail greater mass compared to sparse zone technologies. Sparse zone technologies typically cover greater volume per reader, but are more apt to miss tags because they cover a larger area. They still require readers, cables and antennas to accomplish their function. The operational intelligence provided by CEP can likely be traded for the size, weight, and power associated with dense and sparse zone technologies, but the extent, and specific implementation, remain as knowledge gaps to be addressed by this effort.

Capabilities Provided

The REALM task is divided into three sub-technology projects: REALM-1, 2, and 3.

REALM-1 (Logistics AWareness – LAW)

Technology Areas *(cont.)*

Human Health, Life Support, and Habitation Systems (TA 6)
- Human Health and Performance (TA 6.3)
  - Medical Diagnosis and Prognosis (TA 6.3.1)
    - Radiofrequency Identification (RFID)-Based Medical Inventory Tracking Hardware and Software (TA 6.3.1.6)
    - Radiofrequency Identification (RFID)-Based Medical Inventory Tracking Hardware and Software (TA 6.3.1.6)

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In a three-year period, REALM-1 infrastructure will be developed and evaluated on ISS, with RFID hatch readers and antennas deployed in ISS Node 1, U.S. Laboratory, and Node 2. A ground-based CEP center will receive data from the ISS hatch readers and will provide operational intelligence that infers item locations. This effort is in collaboration with the ISS program payloads office.

In FY15, manufacturing of the hatch readers, known as EMBER (EMBEdded RFID Reader), began, along with resident software development. In parallel, the CEP center was established, and the CEP team, including a university partner, began tailoring prior CEP work to NASA's REALM goals. The REALM Test Bed was utilized for testing CEP concepts of operation prior to the processing of ISS REALM-1 data in succeeding years.

In FY16, the hatch readers, antennas, and RF cables are under development. REALM-1 hardware is scheduled to be certified and delivered in mid-2016 for subsequent launch. Testing, evaluation, and advancement of the CEP will continue using the REALM Test Bed in advance of REALM-1 data downlinked from ISS.

FY17 will be devoted to the 12-month ISS technology demonstration of REALM-1. Multiple cycles of visiting vehicles, and the subsequent loading, off-loading, and translation of cargo through ISS will provide for thorough REALM-1 assessment. During this time, the CEP software will reside in a ground system and utilize the ISS REAM-1 data with crew activity data, inventory surveys, and imagery to improve the CEP location algorithms and evaluate the effectiveness of the hatch reader locations and ability to assess tagged item locations in non-REALM instrumented nodes.

REALM-2 (LOgistics REconnaissance - LORE)

REALM-2 is an AES LR RFID interrogator payload on the Space Technology Mission Directorate (STMD) Next Generation Free-Flyer (NGFF) that will take RFID "snapshots" during cargo

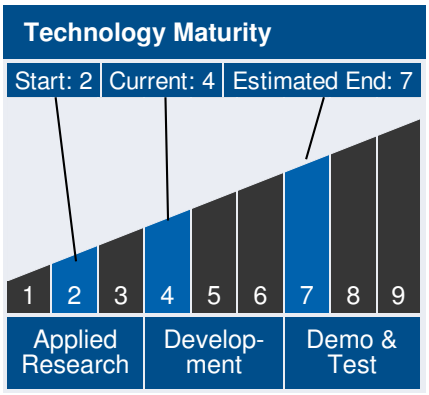
Technology Areas *(cont.)*

- Human Exploration Destination Systems (TA 7)
  - Sustainability and Supportability (TA 7.2)
    - Autonomous Logistics Management (TA 7.2.1)
      - Power Scavenged Wireless Sensor Tag Systems (TA 7.2.1.3)
      - Power Scavenged Wireless Sensor Tag Systems (TA 7.2.1.3)
      - Dense Zone Technology (Radio Frequency Identification Enclosure) (TA 7.2.1.4)
      - Dense Zone Technology (Radio Frequency Identification Enclosure) (TA 7.2.1.4)
      - Logistics Complex Event Processing (TA 7.2.1.6)
      - Logistics Complex Event Processing (TA 7.2.1.6)
      - Six Degree of Freedom Logistics Tag System (TA 7.2.1.7)
      - Six Degree of Freedom Logistics Tag System (TA 7.2.1.7)

movement and refine item localization. In FY15, REALM-2 and Astrobee initiated discussions and identified a preliminary payload architecture and preliminary interfaces.

In FY16, the REALM 2 activity will initiate formal interface development with the Astrobee project. REALM-2 will leverage RFID reader and soft antenna design features developed during the FY14 RFID MCTB feasibility tests. The REALM-2 task will also initiate development of flight software that will reside in the mobile reader. These two activities will allow a REALM-2 form and function prototype to be produced.

In FY17, REALM-2 will complete the flight hardware design and software development. The REALM-2 flight hardware will be fabricated, tested in an integrated Astrobee configuration, and certified for flight. It is anticipated that REALM-2 will be delivered in early FY18 to support Astrobee's FY18 ISS flight experiment window.



REALM-3 (DEnse Logistics VErification – DELVE)

REALM-3 will provide a smart cargo transfer bag or rack drawer that can provide immediate feedback to the crew regarding items required for work or experiments. In FY15, REALM-3 was a small task and used the FY14 RFID MCTB prototypes to test various configurations. These tests supported REALM-1/CEP development and supported inquiries from potential future collaborators. For example, REALM-3 established a Memorandum of Agreement (MOA) with the U.S. Marine Corp to loan the RFID MCTB to them for evaluation in exchange for their test data and possible joint design improvements.

In FY16, REALM-3 is also limited in scope. The REALM team will determine concepts of operation and optimize benefits of the RFID-enabled CTB in coordination with stakeholders.

In FY17, REALM-3 will recommend an ISS flight demonstration based on the FY16 activity. The project will seek cost sharing from ISS for the ISS flight demonstration.

Potential Applications

The REALM technology has the potential to dramatically reduce crew time expended on general inventory management and searching for lost items. Moreover, assured localization of assets can enable heterogeneous packing to optimize volume efficiency rather than crew-time efficiency.

Currently, foam is used to package items less densely in order to facilitate crew access to items. REALM can allow rapid location of items in densely packed Cargo Transfer Bags (CTBs) that could reduce foam usage in logistics packaging by up to 50%. The reduction in foam volume will provide increased habitation volume in logistics vehicles and deep space habitats. For robotic precursor missions, REALM technology can enable machine interaction with logistics, including packing and assembly functions in advance of crew arrival.

Performance Metrics

Metric	Unit	Quantity
Sparse zone reader effectivness	>80	Percent readaccuracy
Dense zone reader effectivness	>95	Percent accuracy for <150 item
CEP integrated item missing rate	@-out-of 20,000	Number items lost out of total

DETAILS FOR TECHNOLOGY 5

Technology Title

Universal Waste Management System

Technology Description

This technology is categorized as a hardware subsystem for manned spaceflight

The objective of the UWMS task is to develop a compact commode and urine pretreatment dose pump/pretreatment quality indication device to enable water recovery.

The UWMS effort will result in a commode with reduced mass and volume that provides increased crew comfort and

performance. Procurement of the UWMS started late in 2015. UWMS Integration and ISS planning began in 2015 and will continue through 2017 in collaboration with the ISS Payloads Office and the Orion (Multi-Purpose Crew Vehicle) Program.

The UWMS will be flown on the ISS as a technology demonstration payload in FY19. The ISS UWMS demonstration will validate the hygienic collection of urine and feces. Effective collection is critical to maintain crew health and hygiene for long duration habitats. Additionally, the ISS technology demonstration will demonstrate the ability to pretreat urine and deliver it the ISS urine processor. The pretreat pump and pretreat quality sensor are important components of a future long-term space habitat water recovery system. A second UWMS unit will be developed to fly on the Multi-Purpose Crew Vehicle's (MPCV) EM-2 mission.

The waste management team will also evaluate a Phase 2 SBIR on torrefaction of feces to assess feasibility for space missions.

Capabilities Provided

Future exploration vehicles being developed by NASA have smaller habitable volumes, unlike the ISS and Space Shuttle. As habitable volumes decrease, so should commode hardware,so that crew comfort can be preserved. The UWMS would provide a significant volume reduction from the previous NASA commode. The UWMS consumables and replacement hardware could also be used by multiple vehicles, reducing overall integrated mission logistics complexity. The UWMS effort could eventually lead to development of low mass/volume fecal canisters, increasing packaging and stowage efficiency, which significantly reduces logistics for exploration metabolic waste collection. The fecal canisters could be designed to enable water recovery from feces, which further reduces logistical mass and volume.

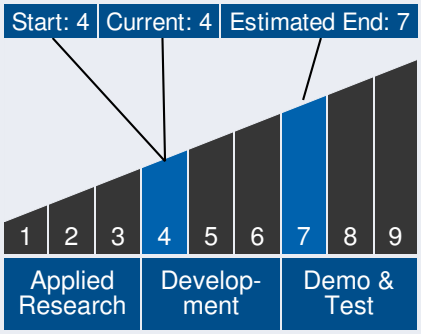
Potential Applications

The UWMS could be utilized on short- and long-duration NASA missions to provide a compact commode and urine pretreatment

Technology Areas

Primary Technology Area:
Human Health, Life Support, and Habitation Systems (TA 6)
- Environmental Control and Life Support Systems and Habitation Systems (TA 6.1)
  - Waste Management (TA 6.1.3)
    - Metabolic Waste Management (TA 6.1.3.1)
    - Metabolic Waste Management (TA 6.1.3.1)

Technology Maturity



dose pump/pretreatment quality indication device to enable water recovery.

Performance Metrics

Metric	Unit	Quantity
Installed system mass	<45	kg
Fecal collection consumable mass	0.22	kg/crew-day