Life Support Systems Project

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

ABSTRACT

The AES Life Support Systems (LSS) project is maturing Atmosphere Revitalization (AR), Water Recovery (WR) and Environmental Monitoring (EM) systems that will reduce risk, lower lifecycle cost, and validate operational process design and system architectural concepts for future human exploration missions. The project is maturing these technologies using the International Space Station (ISS) state-of-the-art hardware as a point of departure.

The current life support systems on the ISS are a baseline from which to measure capability advancements for Environmental Control and Life Support System (ECLSS). By addressing technology gaps, LSS will be able to improve reliability of ECLS systems and advance them toward integrated testing here on Earth and on the ISS before the first human missions in the proving ground of cis-lunar space.

By focusing on a common core architecture with modular components, the LSS project promotes safe, affordable, and sustainable systems development.

(This Project is a merger, beginning in FY15, of the AES Atmosphere Resource Recovery & Environmental Monitoring for Long Duration Exploration Project (ARREM) Project and AES Water Recovery Project)

ANTICIPATED BENEFITS

To NASA funded missions:

The project is advancing the technical maturity of candidate technologies for a flexible Atmosphere Revitalization (AR), Water Recovery (WR) and Environmental Monitoring (EM) system architectures spanning the range of exploration mission objectives and vehicle concepts, thus providing risk reduction and developmental economy to flight project development programs.

Life Support Systems Project

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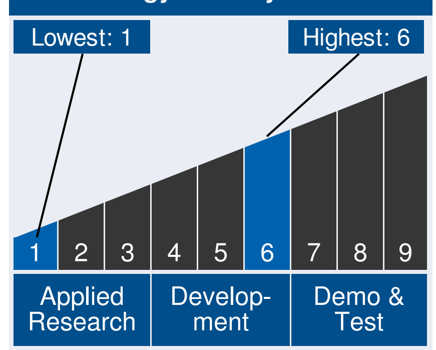
Technology Maturity



Anticipated benefits include:

- Technologies could be used to help reduce CO_2 levels in the environment
- Monitoring of harmful chemical contamination in air and water
- Improved air purification systems in closed environments
- Increased water loop closure
- Reduced water pre-treatment toxicity
- More reliable ECLSS systems

To NASA unfunded & planned missions:

The project is developing a set of resource recovery capabilities and monitors that can be added in modular “plug-n-play” fashion to a common set of core, modular Atmosphere Revitalization Systems (ARS) equipment. This will enable mission planners to extend crewed mission durations without compromising core equipment functionality.

The project is also developing technologies that can lead to a regenerable, reliable, closed-loop life support system that enables long-term human exploration beyond low Earth orbit.

To other government agencies:

The maturation of life support technologies can also potentially benefit Navy submarines and homeland security technology needs.

To the commercial space industry:

The project advances technologies and knowledge that may be provided on a commercial basis.

To the nation:

The project supports the development of sustainable human long-term human space exploration. The project advances technologies and knowledge that may be provided on a commercial basis. The maturation of life support technologies can also potentially benefit Navy submarines and homeland security technology needs.

Realized Benefits

2 Publications

Management Team

Program Director:

- Jason Crusan

Program Executive:

- Barry Epstein

Project Managers:

- Walter Schneider
- Sarah Shull

Technology Areas

- Human Health, Life Support, and Habitation Systems (TA 6)
- Environmental Control and Life Support Systems and Habitation Systems (TA 6.1)
- Autonomous Checkout (TA 6.2.3.4)
- Environmental Monitoring, Safety, and Emergency Response (TA 6.4)

DETAILED DESCRIPTION

The Life Support Systems (LSS) project develops life support systems for humans that will one day live and work in deep space. Current, a robust supply chain provides for astronauts on the International Space Station (ISS) with oxygen, water, and food. LSS is advancing technologies that will enable crews to travel further from Earth with reduced reliance on resupply missions from home. The further we go from Earth, the greater our need is to fully recycle oxygen and water through “closed loop” recycling and recovery systems.

Atmosphere Revitalization (AR): The project focuses on key physico-chemical process technologies for Atmosphere Revitalization Systems (ARS) that increase reliability, capability, and consumable mass recovery as well as reduce requirements for power, volume, heat rejection, and crew involvement. The project is demonstrating the evolution of the ISS state-of-the-art (SOA) Atmosphere Revitalization Systems (ARS) baseline via targeted advancements that benefit ISS operations in low Earth orbit (LEO) and exploration missions beyond Earth orbit. Benefits include improved operational margins and reliability, reduced technical risk, and lower lifecycle cost.

The project is advancing the technical maturity of candidate technologies for flexible Atmosphere Revitalization Systems (ARS) architectures spanning the range of exploration mission objectives and vehicle concepts, thus providing risk reduction and developmental economy to flight project development programs. The technology advancement is needed for the ISS to reduce the resupply of spare parts from Earth and relieve maintenance burdens on the crew so they have more time available to conduct science experiments. For long-duration exploration mission beyond low Earth orbit, the LSS project is vital to assure systems can integrate into future crew habitats and operate reliably when distances from Earth prevent quick return or intervention from the ground. Such missions will require critical life support systems to recover more resources from metabolic byproducts and maintain reliable operation when the option for mission abort and timely return to Earth is not possible.

Specific AR technologies include: the Plasma Pyrolysis Assembly (PPA), which can be integrated into existing state-of-the-art systems to improve the percentage of oxygen recovered from carbon dioxide from 43% to over 75%; advanced carbon dioxide removal sorbents that improve reliability by minimizing dust generation; Oxygen Generation Systems with fewer components, to decrease mass and complexity; improved air-born Trace Contaminant Control systems that reduce ancillary components and protects water condensate from undue chemical contamination; and a suite of miniaturized environmental monitoring sensors that considerably improve the capability to monitor both air and water quality to assure crew are exposed to only clean air and water conditions. These technologies are the basis for requirements to meet the next generation exploration missions and enable humans to explore new destinations beyond the reach of Earth’s influence.

For the Environmental Monitoring (EM) systems effort, the project is developing and demonstrating onboard analysis capabilities which will replace the need to return air and water samples to Earth for ground analysis. This effort is addressing these challenges by adopting a new architecture that is based on the modular integration of multiple sensing modalities, employing a hybrid combination of simple, rugged technologies and, where needed, highly capable complex approaches, to completely address monitoring needs of the future. It incorporates Microelectromechanical Systems (MEMS) technologies to enable significant miniaturization over current systems, and selects elements offering both low resources and high reliability operation for affordability. The project is developing, demonstrating, and/or testing leading process technology candidates and system architectures that will meet or exceed current requirements and fill capability gaps or significantly improve the efficiency, safety, and reliability over the state-of-the-art (SOA). The project's main goal is to demonstrate test articles (at various technology readiness levels) in a ground test facility under relevant flight conditions.

For the Water Recovery System (WRS): Recycling of life support consumables is necessary to reduce resupply mass and provide for vehicle autonomy. Although an integrated life support system is made up of a variety of systems to sustain functions such as atmospheric revitalization, thermal control, and waste management, a major driver in the sizing of a life support system is the Water Recovery System (WRS). As mission durations increase, recycling of water becomes critical. Stored water is inadequate, and wastewater sources must be recycled into potable water. The SOA WRS used on board the ISS relies on a high rate of consumable use and has experienced issues with precipitation and biofouling that have required operational and design changes. Due to these issues, the recovery rate of wastewater on ISS (Condensate and Urine) is currently limited to approximately 74%.

The LSS project is developing advanced water recovery systems in order to enable NASA human exploration missions beyond LEO. A primary objective of the project is to develop water recovery technologies critical to near term missions beyond LEO. A secondary objective is to continue to advance mid-readiness level technologies to support future NASA missions. They also lead to further closure of the WRS, approaching the goal of 98% closure established by the Human Health, Life Support, and Habitation Systems road map (OCT TA06).

The testing and maturation of technologies by the project will provide an assessment of the operation of advanced technology as part of a regenerable, reliable, closed-loop life support system. In addition, the work demonstrates integrated operation of technologies essential to enable long-duration space flight. Combined, these features reduce the risk for other long-duration life support missions.

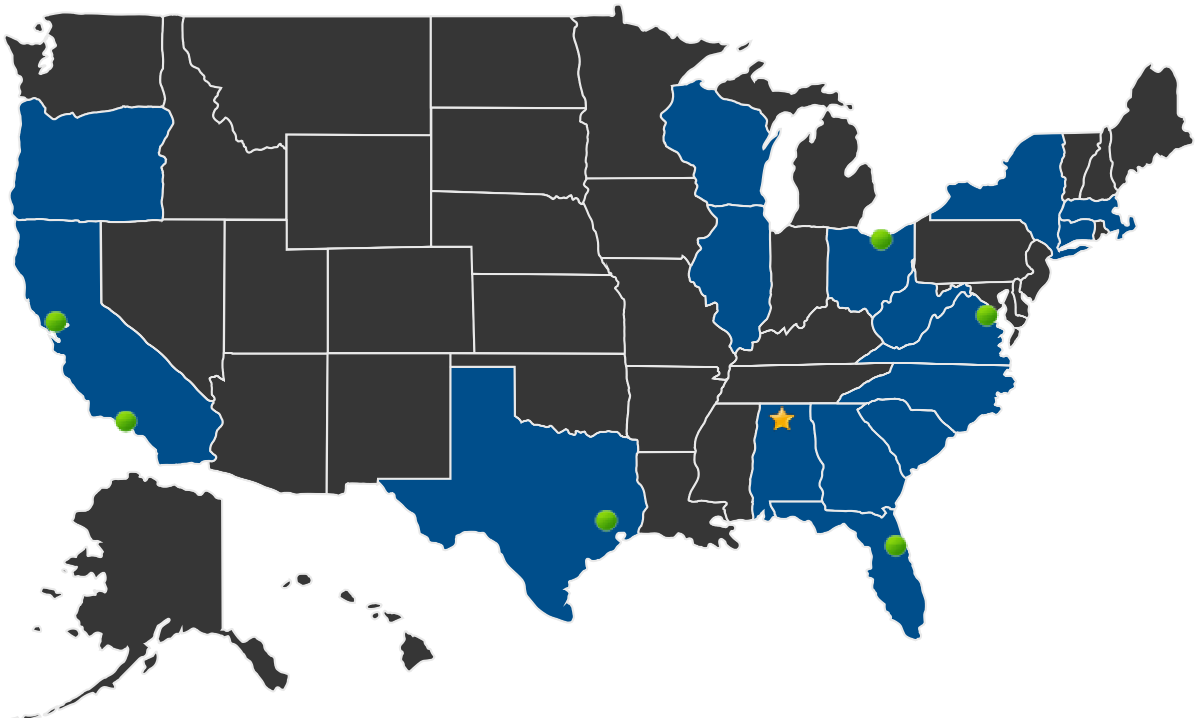
The key WRS technologies selected for maturation and testing as part of the LSS project are the

Cascade Distillation System (CDS), advancements in water chemistry, and brine treatment technologies. Cascade distillation represents a rotary distillation system design to process wastewater with a potential for greater reliability and lower energy costs than existing distillation systems. Advancements in water chemistry includes evaluating safe (e.g., less toxic) and effective means for stabilizing and storing wastewater (showers, urination, etc.) for long periods before treatment. More effective means of maintaining potable water quality will be evaluated. In addition, brine dewatering treatment technologies will be evaluated with the objective of achieving 98% water recovery.

For FY15-17, the LSS project is focused on six areas:

- Systems Engineering, ECLSS Architecture, Modeling and Simulation
- Carbon Dioxide Removal
- Environmental Monitoring
- Oxygen Generation and Recovery
- Trace Contaminant and Particulate Control
- Wastewater Processing and Water Management

U.S. WORK LOCATIONS AND KEY PARTNERS



U.S. States With Work

Lead Center:
Marshall Space Flight Center

Supporting Centers:

- Ames Research Center
- Glenn Research Center
- Jet Propulsion Laboratory
- Johnson Space Center
- Kennedy Space Center
- NASA Headquarters

Other Organizations Performing Work:

- Al Razaq Computing Services
- Dynamac Corp.
- ECLS Technologies
- Georgia Tech
- Giner, Inc. (Newton, MA)
- Honeywell, Inc.
- Jacobs Engineering Group
- Jacobs ESSA (Engineering Center Support Contract)
- JSC Engineering, Technical, and Science (JETS)
- Millennium Engineering and Integration
- MTS MIPSS (Engineering Center Support Contract)
- NanoMaterials Company (Malvern, PA)
- Orbital Technologies Corporation (Madison, WI)
- Paragon Space Development Corporation (Tucson, AZ)
- Port City Instruments, LLC
- Portland State University
- Precision Combustion, Inc. (North Haven, CT)
- QinetiQ North America/ESC
- Reactive Innovations, LLC (Westford, MA)
- Teledyne Brown Engineering
- Thorleaf Research, Inc. (Santa Barbara, CA)
- Tietronix
- UMPQUA Research Company (Myrtle Creek, OR)
- University of California, Berkeley
- University of California, San Diego (La Jolla, CA)
- University of Puerto Rico
- University of Southern California
- Wyle Laboratories

PROJECT LIBRARY

Publications

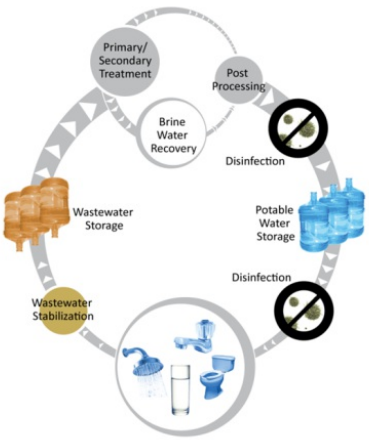
- Success Story: Micro-machined Gas Chromatograph
    - (http://techport.nasa.gov:80/file/26162)

Continued on following page.

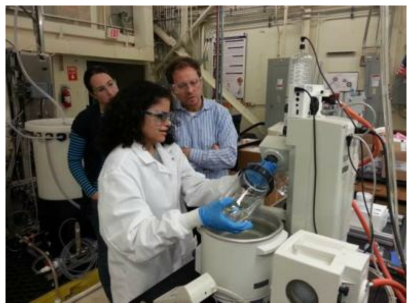
Publications *(cont.)*

- Success Story: Sampling Airborne Particles on the International Space Station (ISS)
    - (http://techport.nasa.gov:80/file/26163)

IMAGE GALLERY

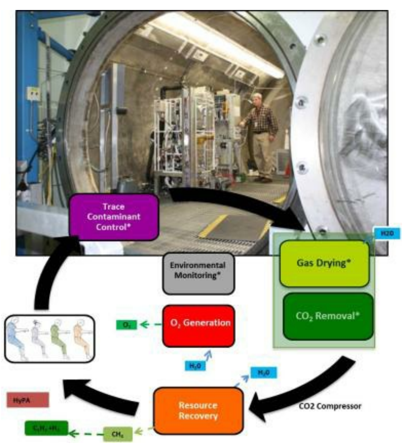


1. Water Recovery



2. Team working on GreenTreat in the JSC Water Lab.

3. Team running Cascade Distillation System test.



4. Air Cycle

DETAILS FOR TECHNOLOGY 1

Technology Title

Carbon Dioxide Removal

Technology Description

This technology is categorized as a hardware system for manned spaceflight

The CO_2 Removal and associated air drying development efforts are focused on improving the current state-of-the-art system on the International Space Station (ISS) utilizing fixed beds of sorbent pellets by seeking more robust pelletized sorbents, evaluating structured sorbents, and examining alternate bed configurations to improve system efficiency and reliability. CO_2 conditioning efforts seek to increase the dependability and decrease the resource consumption of the state-of-the-art mechanical compressor in use on the International Space Station.

Capabilities Provided

For FY15-17 the Carbon Dioxide Removal task is focused on the following:

- Investigating Operational Changes to Increase CO_2 Removal Performance
- Performing Test Scenarios on Desiccant Bed to Optimize Performance
- Screening Alternative Sorbents to Determine the Best Candidate for Exploration CO_2 Removal System
- Testing Structured Sorbents as a Replacement for state-of-the-art Pellet Sorbents
- Ground Testing of a Carbon Dioxide Removal and Compression System as an Alternative to state-of-the-art CO_2 Removal

Potential Applications

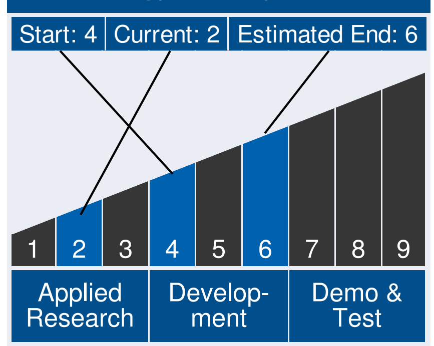
ISS and future human missions beyond LEO

Technology Areas

Primary Technology Area:
Human Health, Life Support, and Habitation Systems (TA 6)
- Extravehicular Activity Systems (TA 6.2)
  - Power, Avionics, and Software (TA 6.2.3)
    - Autonomous Checkout (TA 6.2.3.4)
    - Autonomous Checkout (TA 6.2.3.4)

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

Technology Maturity



DETAILS FOR TECHNOLOGY 2

Technology Title

Environmental Monitoring

Technology Description

This technology is categorized as a hardware system for manned spaceflight

The Environmental Monitoring (EM) systems task objectives are to develop and demonstrate onboard monitoring, detection, and analysis capabilities that will replace the SOA need to frequently return air, water and microbial samples to Earth for ground-based laboratory analysis. This effort will address these challenges by adopting new analytical technologies and techniques that will allow for a modular EM system architecture that integrates multiple sensing modalities to address the monitoring needs of future deep-space exploration missions. The EM system architecture will incorporate microelectromechanical systems (MEMS) technologies to enable significant miniaturization over current systems, and select monitoring techniques that offer both low (and potentially no) resource consumption and highly reliable operation for life cycle affordability. The EM systems architecture will leverage previous NASA developmental results in the field and emerging commercial and academic accomplishments to achieve these goals.

Capabilities Provided

For FY15-17 the Environmental Monitoring task is focused on:

- Developing an Atmosphere Monitor (Spacecraft Micro Total Atmosphere Monitor (SAM)) to Monitor the Spacecraft Atmosphere and Alert the Crew when Limits are Exceeded

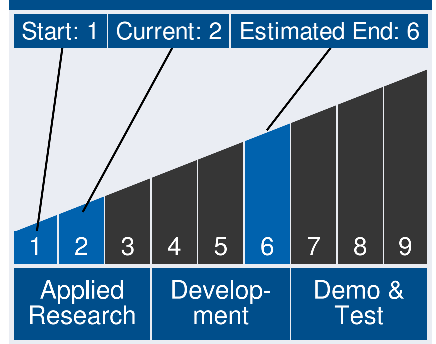
Continued on following page.

Technology Areas

Primary Technology Area:
Human Health, Life Support, and Habitation Systems (TA 6)
└─ Environmental Monitoring, Safety, and Emergency Response (TA 6.4)

Secondary Technology Area:
Human Health, Life Support, and Habitation Systems (TA 6)

Technology Maturity



- Developing Tunable Laser Spectroscopy Used to Provide Customized Environment Monitoring (e.g. Combustion Products Monitoring for Fire Detection, Ammonia Hydrazine Detection)
- Developing Real Time Water Monitoring Technologies

Potential Applications

ISS and human missions beyond LEO

DETAILS FOR TECHNOLOGY 3

Technology Title

Oxygen Generation and Recovery

Technology Description

This technology is categorized as a hardware system for manned spaceflight

The Oxygen Recovery technology development area encompasses several sub-tasks in an effort to supply O_2 to the crew at the required conditions, to recover O_2 from metabolic CO_2, and to recycle recovered O_2 back to the cabin environment. Oxygen supply technologies requiring water as a feedstock for electrolysis assume a clean water supply for this purpose. Oxygen supply technologies requiring ambient air as a feedstock assume a cabin environment with a nominal O_2 concentration. Technologies designed to recover O_2 from metabolic CO_2 assume a readily available compressed CO_2 supply and an as-available H_2 supply

Capabilities Provided

For FY15-17 the Oxygen Generation and Recovery task is focued on:

- High Pressure/High Purity O_2 Technology Development for Exploration Vehicles

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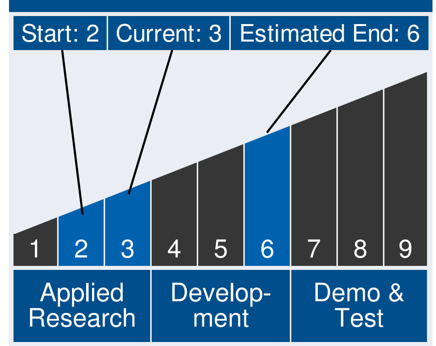
Technology Areas

Primary Technology Area:
Human Health, Life Support, and Habitation Systems (TA 6)
└─ Environmental Control and Life Support Systems and Habitation Systems (TA 6.1)

Secondary Technology Area:
Human Health, Life Support, and Habitation Systems (TA 6)

Technology Maturity



- Advancing state-of-the-art oxygen delivery and supply system
- Developing Technologies to Recover Oxygen to Increase Oxygen Recovery from the state-of-the-art to Meet Exploration Requirements

Potential Applications

ISS and human missions beyond LEO

DETAILS FOR TECHNOLOGY 4

Technology Title

Trace Contaminant and Particulate Control

Technology Description

This technology is categorized as a hardware system for manned spaceflight

Work in the area of trace contamination and particulate control is focused on characterizing COTS adsorbent media for trace contaminant control applications, evaluating carbon monoxide catalyst performance, developing and characterizing selective catalytic ammonia reduction catalysts, and evaluating technical maturity of photo-catalytic oxidation (PCO) processes for trace contaminant control.

Capabilities Provided

For FY15-17 the Trace Contaminant and Particulate Control task is focused on:

- Developing New Technologies to Control Trace Contamination
- Testing Technologies to Monitor Aerosols in Spacecraft
- Developing Filtration Technologies for Particulate Control to meet Exploration Requirements and Reduce Crew Maintenance Requirements

Potential Applications

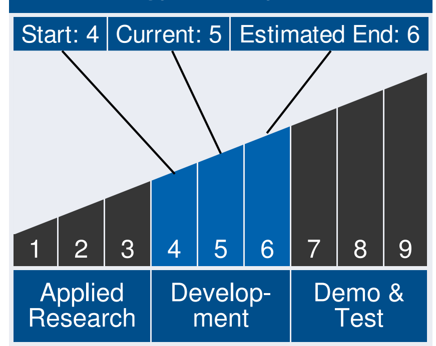
ISS and human missions beyond LEO

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)

Secondary Technology Area:
Human Health, Life Support, and Habitation Systems (TA 6)
└─ Environmental Monitoring, Safety, and Emergency Response (TA 6.4)

Technology Maturity



DETAILS FOR TECHNOLOGY 5

Technology Title

Wastewater Processing and Water Management

Technology Description

This technology is categorized as a hardware system for manned spaceflight

Within an integrated life support system, water recovery systems provide water for use by various environmental control and life support functions on board the spacecraft.These functions may include drinking water, food re-hydration, water for crew hygiene, flush water for the spacecraft urinal, source water for oxygen generation, and, depending on the complexity of the life support system, water for crew shower and laundry.The wastewater streams that returned from these uses and require treatment to be returned back to a potable state can include stabilized urine and flush water, humidity condensate, shower and laundry grey water, and water from carbon dioxide and wet-trash processing systems. The purpose of the water recovery system is to close the water loop by removing the contaminants associated with the various wastewater streams and then returning the balance of clean water back to the potable water bus in a stabilized form suitable for storage and reuse.

Capabilities Provided

For FY15-17 the Wastewater Processing and Water Management task is focused on the following:

- Developing Cascade Distillation System as a Potential Alternative to the ISS state-of-the-art Urine Processor
- Testing Membrane Technology to Replace the Multi-Filtration Beds Used on the ISS Water Processor Assembly

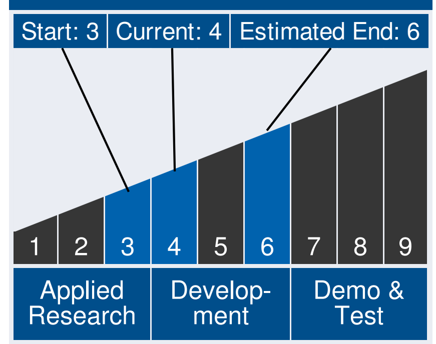
Continued on following page.

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)

Secondary Technology Area:
Human Health, Life Support, and Habitation Systems (TA 6)

Technology Maturity



- Testing Low Toxicity Urine Stabilization Formulas for Possible Replacement of Sulfuric Acid Urine Pre-Treat Used on ISS
- Developing Brine Processing Technologies to Increase Water Recovery to Meet Exploration Requirements
- Investigating Biological Water Processing as an Alternative to ISS state of-the-art Water Treatment
- Testing Silver Biocide as an Alternate to Iodine Used on ISS to Control Microbial Growth in the Water

Potential Applications

ISS and human missions beyond low Earth orbit.