SBIR/STTR
Small Business Innovation Research / Small Business Technology Transfer

NASA SBIR 2019 Phase I Solicitation

H3.02 Spacecraft Solid Waste Management

Lead Center: JSC

Participating Center(s): ARC, KSC, MSFC

Technology Area: TA15 Aeronautics

This subtopic has two areas of scope. The primary area of emphasis is water recovery and stabilization of human metabolic waste (feces). The secondary scope seeks robust flow meters for effluent gas measurement from waste processors.

Water Recovery and Stabilization of Human Metabolic Waste (Feces)

Human solid waste (feces) contains ~75% water by mass that is currently not recovered on ISS. Feces are collected and stored in relatively impermeable containers for short term storage (1-3 months) and disposed of in departing logistics vehicles. Quantified, this represents approximately 170 g per crew member per day of recoverable water, which translates to 0.68 kg per day for a crew of 4 and can total as much as 680 kg for a 1,000-day long duration human exploration mission. In addition to water recovery, stabilization of feces is a critical gap for long duration human planetary exploration missions to Moon and Mars. Water removal is a first step in stabilization and has the potential to decrease odor control technology mass. Technologies are requested to recover water and stabilize feces for use on long duration human exploration missions to Moon and Mars.

Simplified, low temperature, and robust methods for recovery of water from human solid metabolic waste are sought. Low temperature (<110 C) is desired to reduce the release of volatile organic compounds, avoid organic compound oxidation to CO and CO_2 and their subsequent treatment prior to return to the cabin air. The range of technologies can include air drying, vacuum drying, freeze drying and alternative low energy methods. The cost for recovering fecal water, in terms of mass, power, volume and crew time equivalents must not outweigh mass savings obtained by its recovery. Drying and stabilization of feces can reduce odor generation and prevent microbial proliferation if the water activity level is less than 0.6. Technologies must be able to recover >80% of the water content. Captured water should have minimal free gas and be suitable for eventual delivery to a waste water tank. Purification of the water is not requested because it will be processed by downstream treatment systems. However, the chemical constituents of the recovered water must be characterized. Technologies must be able to accommodate a wide range of condensable and non-condensable mass flow rates as the feces are processed and dried. Water recovery should be accommodated directly or with an assumed regenerative heat exchanger to recover energy prior to phase separation (as necessary). Systems must be capable of microgravity and/or planetary surface operation (moon or Mars) for 1 to 18 months at a time, with 11 to 18-month periods of dormancy, and with minimal crew maintenance. Compatibility with existing waste collection hardware is of interest. Planned fecal waste collection (Universal Waste Management System - UWMS) consists of individual defecations and hygiene wipes collected in gas permeable bags. 15-25 individual bags are contained in rigid containers that are changed out every 2-3 days.

It is highly desirable that on-demand manufacturing (i.e., additive manufacturing and post finishing) be considered for consumable or maintenance items. Technologies must consider accumulation of organics and microbial proliferation between normal waste processing cycles and extended dormancy and any change in performance should be characterized. Evolved gases during processing may require treatment and could consider absorbers and or materials (membranes) that prevent the transmission of volatile organic carbon. Thermal and power efficiency must be addressed. It is desirable that rigid UWMS canisters be reusable to reduce logistical resupply mass. Alternatives to the rigid UWMS canister are acceptable if it does not require significant changes of UWMS operations. It is desirable that the processed fecal material and associated wipes and bags occupy less volume than the preprocessed state. Information on UWMS can be found at: Logistics Reduction: Universal Waste Management System (LR-UWMS): https://techport.nasa.gov/view/93128.

Long Life Robust Flow Meters for Effluent Gases from Waste Processors

Currently human space exploration life support waste management systems have need for a robust mass flow measurement method in mixed water vapor and hydrocarbon gas flows that are produced from processing trash and waste streams. Thermal processing of trash and waste will evolve a ‘dirty’ gas flow comprised of large number of complex organic and non-organic gaseous mixtures with a high water vapor content. Mass flow measurement can be used for process control of the heating of the waste or as a non-condensable gas flow control device for a vehicle vacuum system. Current gas flow measurement systems do not operate well in a dirty gaseous stream for the operating conditions required on long duration missions such as to Mars. Gaseous compounds deposit on downstream process tubing and sensors with surface temperature and pressure conditions that are favorable to condensation. Over time, deposits can render sensors inaccurate or inoperative. Such effluents will include but are not limited to time-variant mixture of air, water vapor, gaseous organic and inorganic components, entrained liquids and sticky compounds that appear as precipitates. Information on trash processing and effluent characteristics are provided in the following reference: NextSTEP F: Logistics Reduction in Space by Trash Compaction and Processing System (TCPS): https://www.nasa.gov/nextstep/trash.

The proposed flow sensor technologies will operate in a range of conditions depending on the trash processing application. Sensors should be capable of operation over the range of 6-55 kPa, temperature ranges of 15-180 C, and 0.001-2.0 g/min. The sensor will be exposed to high relative humidity and saturated water vapor conditions, and to volatile organic gases. The sensor will be monitoring flow in fluid passages from 3-20 mm. It is desired that proposed technologies have low pressure drop, contaminant tolerant surfaces, and long-term operation between calibrations. The accuracy of the proposed technology across the range of operation conditions should be defined in the proposal.

For both areas of scope, hardware attributes should include robust design, low volume and compact size, low mass, reduced or zero requirements for crew time, and minimized consumable mass. Phase I Deliverables - Reports demonstrating proof of concept, test data from proof of concept studies, concepts and designs for Phase II. Phase I tasks should answer critical questions focused on reducing development risk prior to entering Phase II. Phase II Deliverables - Delivery of technologically mature components/subsystems that demonstrate performance over the range of expected spacecraft conditions. Prototypes must be full scale unless physical verification in 1-g is not possible. Robustness must be demonstrated with long term operation and with periods of intermittent dormancy. System should incorporate safety margins and design features to provide safe operation upon delivery to a NASA facility.

The expected TRL for these scopes is 2 to 4.

References:

- National Aeronautics and Space Administration, NASA Technology Roadmaps, TA 6: Human Health, Life Support, and Habitation Systems (National Aeronautics and Space Administration, Draft, May 2015, www.nasa.gov/sites/default/files/atoms/files/2015_nasa_technology_roadmaps_ta_6_human_health_life_support_habitation.pdf).
- Miriam Sargusingh, Molly Anderson, Jay Perry, Robyn Gatens, James Broyan, Ariel Macatangay, Walter Schneider and Nikzad Toomarian "Development and Maturation for Exploration: 2017 to 2018 Overview", 48th International Conference on Environmental Systems, Paper ICES-2018-182 https://ttu-ir.tdl.org/ttu-ir/bitstream/handle/2346/74153/ICES_2018_182.pdf
- Logistics Reduction: Universal Waste Management System (LR-UWMS): https://techport.nasa.gov/view/93128

- Advanced Exploration Systems Program, Life Support Systems Project: https://www.nasa.gov/content/life-support-systems
- NextSTEP F: Logistics Reduction in Space by Trash Compaction and Processing System (TCPS): https://www.nasa.gov/nextstep/trash
- Fisher, John W. and Lee, Jeffrey M. "Space Mission Utility and Requirements for a Heat Melt Compactor", 46th International Conference on Environmental Systems, Paper ICES-2016-377 https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20160008947.pdf
- Lee, Jeffrey M., Fisher, John W. and Pace, Gregory "Heat Melt Compactor Development Progress", 47th International Conference on Environmental Systems, Paper ICES-2017-267 https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170011317.pdf
- John P. Wetzel, Robert J. Surdyk, Joe Klopotic and Krishnaswamy K. Rangan "Heat Melt Compactor Test Unit", 48th International Conference on Environmental Systems, Paper ICES-2017-267 https://ttu-ir.tdl.org/ttu-ir/bitstream/handle/2346/74255/ICES_2018_318.pdf