

Project Description

The Advanced Exploration Systems, Logistics Reduction project called the Trash Compaction and Processing System (TCPS) is a waste management technology. Currently, there are no trash 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 objective of the TCPS task is to develop a reliable trash processing system to support long endurance human space missions (target TRL 8/9). The TCPS itself is a project that plans an International Space Station (ISS) technology demonstration.

The TCPS objectives are to: *reduce volume of trash*, *safely* processed trash to reduce risk of biological activity, *stabilize* processed trash for efficient storage and disposal, and to *recover water and manage gaseous effluents*. Processed TCPS trash appear as tiles and can be used for radiation shielding augmentation. For a one-year, four-person crew mission, it is estimated that TCPS could recover ~8 cubic meters of habitable volume, produce over 900 kg of radiation shielding tiles, and recover 230kg of water from ~1,300 kg of trash. Additionally, the tiles could be jettisoned during a transit mission to reduce propellant needs.

FY2012-FY2018

This period saw the development of the Heat Melt Compactor (HMC). The HMC is a full-scale TCPS precursor that was developed to refine previous versions' trash processing capabilities, finalize operational parameters, and identify hardware issues. During the period between FY2012 and FY2016 various trash compactor prototypes were developed. This included an SBIR Phase 2 Plastic Melt Compactor System developed by Orbital Sciences Corporation (aka Sierra Nevada Corp), and the Generation 1 HMC developed at Ames. In FY2016, a Generation 2 (Gen2) HMC with an ISS "flight-like" design was designed and built at Ames. Limited Gen2 HMC ground testing began in 2017 but was not completed due to inability to reach desired compaction pressure and vacuum. In FY2018, the hardware was repaired to partially restore its desired capability. Several SBIR awards related to the HMC have occurred in the following areas: microgravity-compatible condensing heat exchanger designs, trash bag liners to allow hygienic tiles after HMC processing, and general HMC system design.

FY2019 – FY2021

In FY2019, two contractors were selected for Phase A contracts under the NASA Next Space Technologies for Exploration Partnerships (NextSTEP) Appendix F: Logistics Reduction in Space by Trash Compaction and Processing System (TCPS), Broad Agency Announcement (BAA). The two contractors were the Sierra Nevada Corporation (SNC) and UTC Aerospace Systems (UTAS), also known as Collins Aerospace. The BAA is given here: <https://www.nasa.gov/feature/nasa-selects-two-companies-to-help-take-out-the-deep-space-trash/>

Phase A was implemented in FY19-20 and completed in FY20. Phase A developed and validated TCPS flight concepts to inform SNC and Collins in flight hardware development. Risk reduction activities at NASA's Ames Research Center (ARC) HMC facility in support of the Phase A contractors' work included: gas and water effluent analysis, system operations, product quality, and design analysis including 15 trash processing runs of various trash models. Collins completed their compactor development work in June 2020 and SNC completed their work of a compactor, water recovery, and effluent gas management in October 2020.

In FY2020 and FY2021, the ARC team continued risk reduction activities that included tests of the HMC Gen2 under different operational scenarios. The information gained was used to inform Phase A TCPS contractors as they developed their PDR-lite designs and prototypes. A HMC/TCPS Generation 3 (Gen3) by SNC was delivered to NASA ARC as part of a SBIR Phase II by Materials Modification Incorporated (MMI). MMI developed high-temperature, low outgassing, and semi-permeable bags for use with the TCPS.

Phase A work was completed in FY2021, but the contract was extended into FY2022.
FY2022

The HMC/TCPS Gen3 that was delivered to ARC in FY21 was used to supply test gases for the Source Contaminant Control System (SCCS). Testing consisted of identifying species in TCPS outlet gases using a GasMet FTIR analyzer before and after the SCCS. The TCPS ran using unbagged trash. A particulate matter measurement system determined particulates given off during use of the TCPS system. Finally, TCPS processing ran at lower temperatures to determine how well a tailored Trash-to-Gas feedstock could be created.

The SCCS is designed to remove toxic gases such as CO, CH₄, and volatile organic compounds. This system consists of an activated charcoal adsorbent bed and a catalytic oxidizer. Precision Combustion Inc. (SBIR Phase II) sized the SCCS catalytic oxidizer for use with the HMC/TCPS.

The ARC team worked with Glenn Research Center's aerosol team to design a particulate matter system to measure and monitor particulates released during TCPS operations: trash loading, tile removal, and handling of the product tiles. The particulate matter system consisted of a SBIR Phase II analyzer which is similar to current ISS flight hardware. Additionally, semi-permeable trash containment bags from MMI and ISS-approved wet trash bags were tested for their ability to prevent the release of particulates during tile TCPS operations while reducing gas and water contaminants and still allowing water recovery.

FY2023

On Aug. 26, 2022 the NextSTEP Broad Agency Agreement (BAA) Phase B contract modification was awarded to Sierra Nevada Corporation (now Sierra Space) of Madison, Wisconsin. The period of performance is from Sept. 1, 2022, through Aug. 31, 2027, and includes four option periods, ending in an ISS flight demonstration with the possibility for continued use to support ISS operations. Currently, the team is working towards a Critical Design Review in late 2023.

Current risk-reduction test activities include characterizing SCCS efficiency for toxin removal from TCPS outlet gases using bagged trash in the compactor. Testing using ordinary nylon bags is complete. Testing with vapor-permeable bags to see if a greater liquid amount will be given off from the trash will be completed in 2023. The trash models are characterized as nominal, high-liquid, high-cloth, and benign. The benign model is thought to be safe for TCPS outlet gases to vent directly to the ISS cabin without need of SCCS gas processing. Upcoming testing includes testing non-standard trash items like inkjet cartridges that astronauts would likely put into common trash. Batteries, sharps, hazardous materials, and metabolic waste will not be included in these tests. An astronaut will typically generate up to 1.1 kg of waste per day.

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Anticipated Benefits

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

The TCPS technology would benefit any long-duration operation with limited habitable volume. The goal is to reduce trash volume and microbiologically inactivate it. This will provide less odor generation and improve habitat hygiene. As an alternative to radiation shielding, increased habitable volume, and recovered water, TCPS processed trash 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.