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### Logistics Reduction Technologies for Exploration Missions

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Human exploration missions under study are very limited by the launch mass capacity of existing and planned vehicles. The logistical mass of crew items is typically considered separate from the vehicle structure, habitat outfitting, and life support systems. Consequently, crew item logistical mass is typically competing with vehicle systems for mass allocation. NASA's Advanced Exploration Systems (AES) Logistics Reduction and Repurposing (LRR) Project is developing five logistics technologies guided by a systems engineering cradle-to-grave approach to enable used crew items to augment vehicle systems. Specifically, AES LRR is investigating the direct reduction of clothing mass, the repurposing of logistical packaging, the use of autonomous logistics management technologies, the processing of spent crew items to benefit radiation shielding and water recovery, and the conversion of trash to propulsion gases. The systematic implementation of these types of technologies will increase launch mass efficiency by enabling items to be used for secondary purposes and improve the habitability of the vehicle as the mission duration increases.

This paper provides a description and the challenges of the five technologies under development and the estimated overall mission benefits of each technology.

- The Advanced Clothing System's ground testing of antimicrobially treated, commercial state of the art, exercise clothing and planned ISS technology demonstration experiment will be described. The benefits of moving from cotton based to polymer based clothes will be identified with respect to the issues of lint production, disposal options and potential increase in flammability. The benefits of a water-based laundry system and simpler clothing freshening systems or techniques will also be discussed in relation to the proposed lighter weight clothing system.
- The Logistics to Living (L2L) concept looks to repurpose items originally used for interior cargo packaging into useful crew outfitting hardware. Cargo items include cargo transfer bags, foam packaging, and stowage racks. This paper will expand on previous work to describe outfitting concepts for crew quarters and solar storm shelters. The L2L technology is actively working with the AES Radiation project to deploy HMC tiles in a cargo transfer bag derived storm shelter concept.
- Autonomous Logistics Management (ALM) is a broad area, but LRR will focus on radio frequency identification (RFID) technologies, 3D localization strategies, and complex event processing to enable automatic inventory tracking as resources move around a vehicle. LRR will investigate combinations of both open area, or "sparse zone", and shielded area, or "dense zone", RFID

readers. ALM will reduce crew time in locating stored items and enable more accurate inventories.

- The Heat Melt Compactor (HMC) processing of plastic-containing trash to produce a stable, sterilized, compact tile will be described. The HMC will provide a 10:1 reduction in trash volume which has the capability to increase habitable volume over the course of a mission. Additional benefits of the HMC tile are that it is relatively high in hydrocarbons and useful for solar event radiation shielding. The complexity of the trash stream results in complex water and gas constituents that need to be addressed by life support processing equipment. The HMC can reduce the dedicated radiation shielding and water resupply masses for exploration.
- The Trash to Gas (TtG) section will summarize early feasibility testing of the process to convert the hydrocarbons in trash into methane for propulsion, into a gas mixture for venting, or resistojet propulsion station keeping. The TtG approach would result in large volume reduction of trash and potentially be suitable for planetary missions where planetary protection is important. TtG has significant technical challenges to achieve robust hardware and significant testing with waste stimulants is underway to identify potential complexities.
- Overall the AES Logistics system analysis has generated an updated Exploration waste model based on current ISS manifest data with accommodations for likely logistics improvements. The major elemental consistency of this trash allows predictions of mission benefits for each of the technologies. System analysis will provide options for logistics and waste management to exploration programs to enable reduced launch mass of dedicated radiation protection material, water, and habitat outfitting.