Trash Management during Human Space Exploration missions using Compaction in Combination with Heating to Remove Water and make the Trash Microbiologically Safe while producing a Low Volume Mechanically Stable Trash Tile

The launch mass of Life Support Hardware is one of the main drivers in the system's design

The NASA Space Launch System (SLS) that is proposed for future missions has an upper limit to its lifting capability

All spacecraft life support systems (and any other systems) must be designed to minimize **size**, **mass**, and **power** in order not exceed the SLS launch mass capability

The aspects of a life support system that affect launch mass are its volume, mass, power, and cooling.

Heating times are driven by time to remove water from the waste, melting plastic in the case of the heated compactor, and providing a sustained high temperature over a period long enough to kill or render microbes inert.

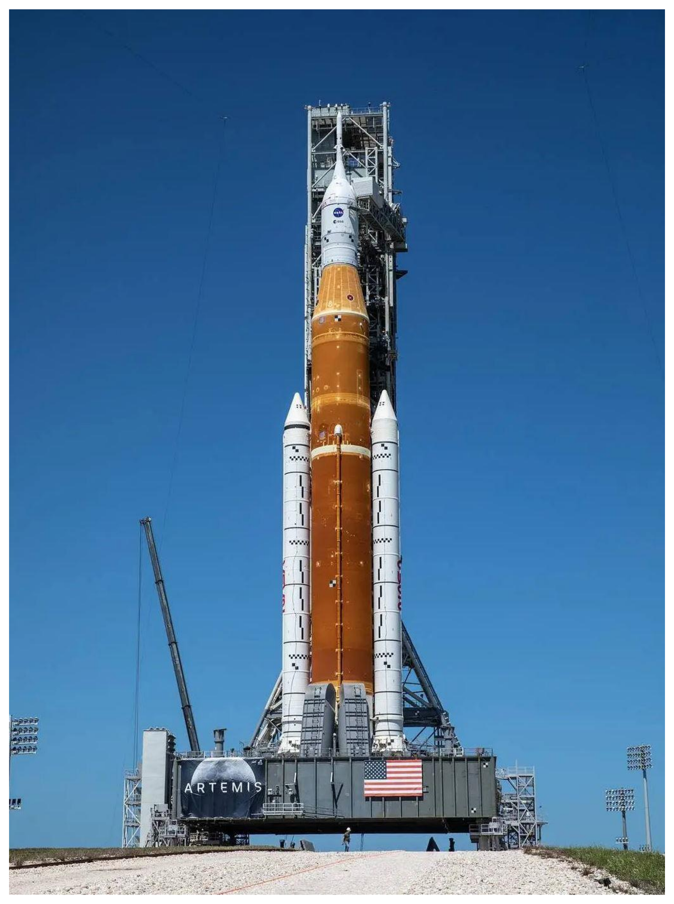


Figure 1. NASA Space Launch System

Trash accumulation on the International Space Station (ISS)

Trash accumulation on ISS is considered an issue but it has the luxury of being able to place its trash in the logistics re-supply vehicles which have a large volume *(see image below)* which is then discarded and burnt up in earths atmosphere.


Figure 2. Trash on-board the International Space Station

On future long-duration space exploration missions such as one to Mars, the astronauts will not have large a disposable volume such as a re-supply vehicle in which they can simply discard their trash.

Current State of the Art Trash Processing Technology

Trash is currently managed on ISS by putting it into a plastic bag and the compacting it by squeezing or by other methods as shown below then sealed with duct tape.

The processed product are called "trash footballs".


Figure 3. Astronaut Compaction System


Figure 4. Trash Footballs

Typical trash that occurs during human space flight

The trash typically contains used food and drink pouches that contain wet residues, sanitary wipes, toothpaste, chewing gum, used t-shirts, underwear, and towels, exercise clothes, tape, printer paper, discarded underarm deodorants, etc.

This trash becomes rancid and odorous relatively quick. It has been shown the harmful microbes can become more virulent in the increased radiation environment in space. The smaller volume of future spacecraft will greatly increase the chances of contact with potentially harmful microbes.


Figure 5. Typical ISS Trash


Figure 6. Dirty trash football


Figure 7. Food Residue

The Trash Compaction Processing System

A system called the Trash Compaction Processing System has been under development at NASA that uses compaction and heat to:

- Reduce trash volume through a combination of pressure, heat induced yielding of materials, and melting of the plastic which acts as bonding agent when the trash cools and the plastic solidifies.
- To produce a structurally stable square waste "tile" that minimizes void or wasted volume space when in storage


Figure 8. Trash tiles produced in the Gen 2 TCPS

- Remove water from the trash to:
  - To reclaim the water from the trash that can be reused and reduce the amount of water that needs to be launched
  - Reduce the water activity level in the trash to less than 0.6 to prevent microbial growth
- The processed tiles are also being considered for use as additional radiation shielding because they have a high hydrogen content.

Reducing Launch Mass Through Thermal Efficiency

Figures 9 and 10 below show the second Generation TCPS developed at NASA with a flight like compaction unit and laboratory breadboard ancillary systems such as the water processing and contaminant control system

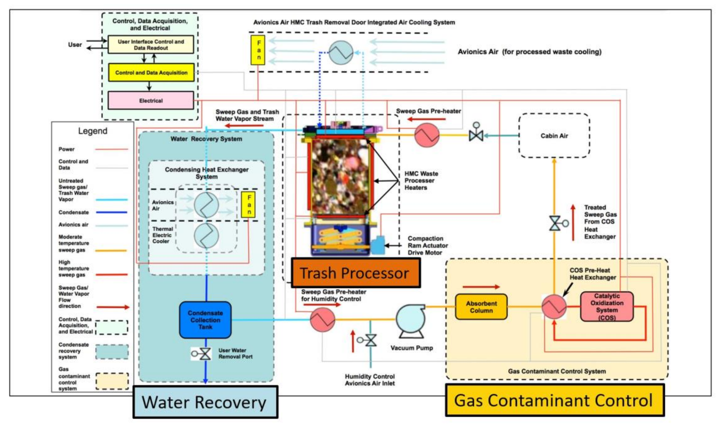


Figure 9. TCPS Hardware and Process Flow Diagram


Figure 10. Trash being placed in the Gen 2 system

One area of focus has been to reduce the spacecraft mass increase associated with additional power and cooling system needs.

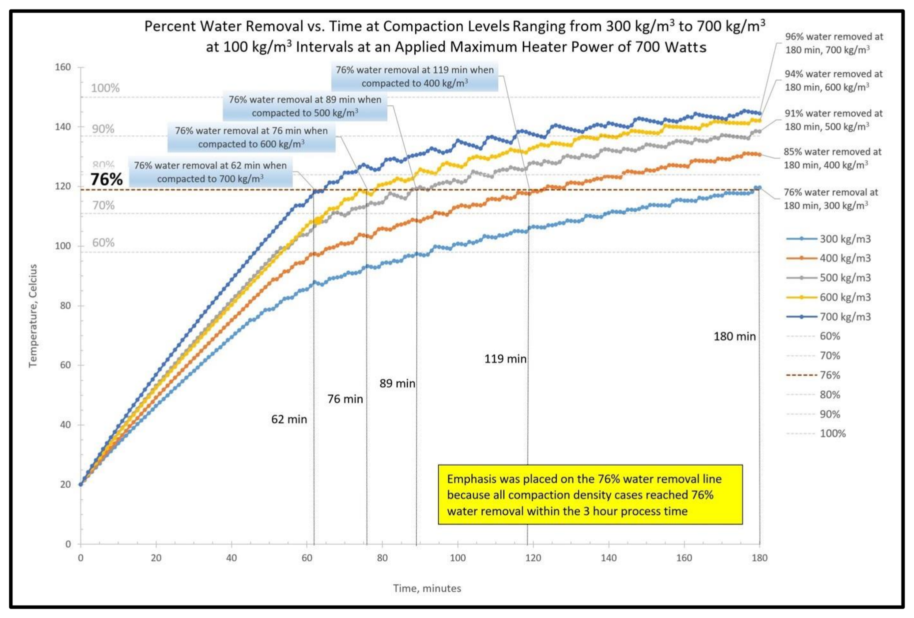


Figure 11. Reduced process times as a function of density increase

Increasing the density of the trash during thermal processing provides a two-fold benefit:

- Compressing the trash minimizes the amount of volume filled with highly insulating air or water vapor. **This significantly increases the Thermal Conductivity of the trash!!!**
- Compressing the trash reduces the distance the heat must propagate through the trash **which significantly reduces heat transfer time!!!**

There are additional power and energy related benefits to providing greater compaction of the trash during thermal processing:

Figure 11 compares the reduction in heating time due to increased compaction at a heater power of 700 Watts while **Figure 12** compares the effect of the combination of increased compaction while halving the heater power.

Note in **Figure 11** that the 600 kg/m³ tile being heated at 350 Watts reached 87% water removal at 180 minutes compared to the 300 kg/m³ being heated at 700 Watts which only reached 76% water removal at 180 minutes.

The ability to operate at lower peak power will allow other systems to run simultaneously and allow greater flexibility for access to spacecraft power resources for other hardware systems!!!

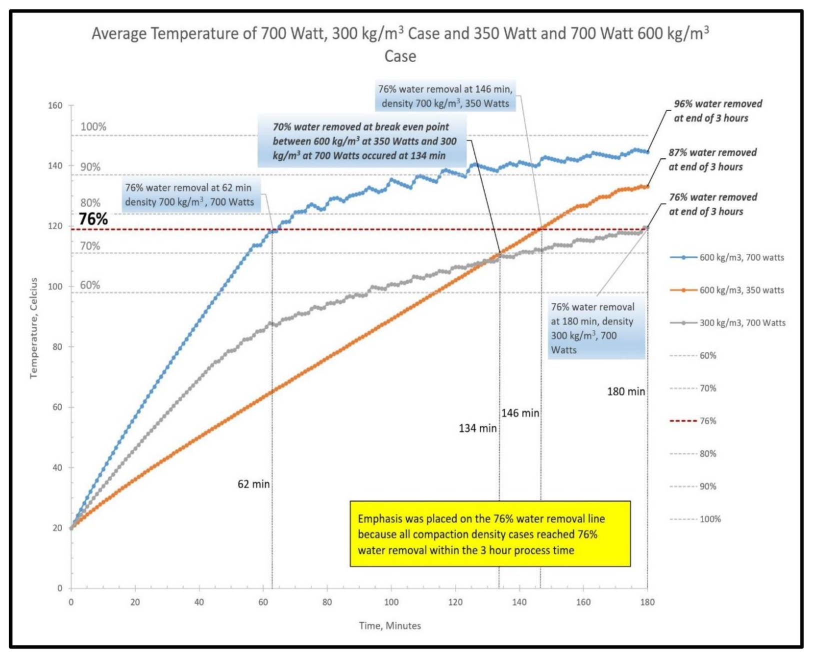


Figure 12. Reducing instantaneous Power

TCPS Developments to reduce Equivalent System Mass (ESM)

NASA uses a method called Equivalent System Mass (ESM) to evaluate and compare the overall launch mass of different hardware systems. The purpose of ESM is to aid in the selection of the best technology to pursue.

ESM converts volume, power, cooling, and even crew-time to a mass equivalent. Any increase in spacecraft volume requires additional structure that adds mass to the spacecraft. The same is true for both power and cooling systems.

The mass conversion factors look at mass per volume, mass per kW for power, mass per kW for cooling, and mass per crew-time.

Table 1. Equivalent System Mass for a Transit to Mars

Mass Factor (kg/kg)	Volume Factor (kg/m³)	Power Factor (kg/kW)	Cooling Factor (kg/kW)	Crew-time Factor (kg/(cm-hr))
1	79	162	180	0.802

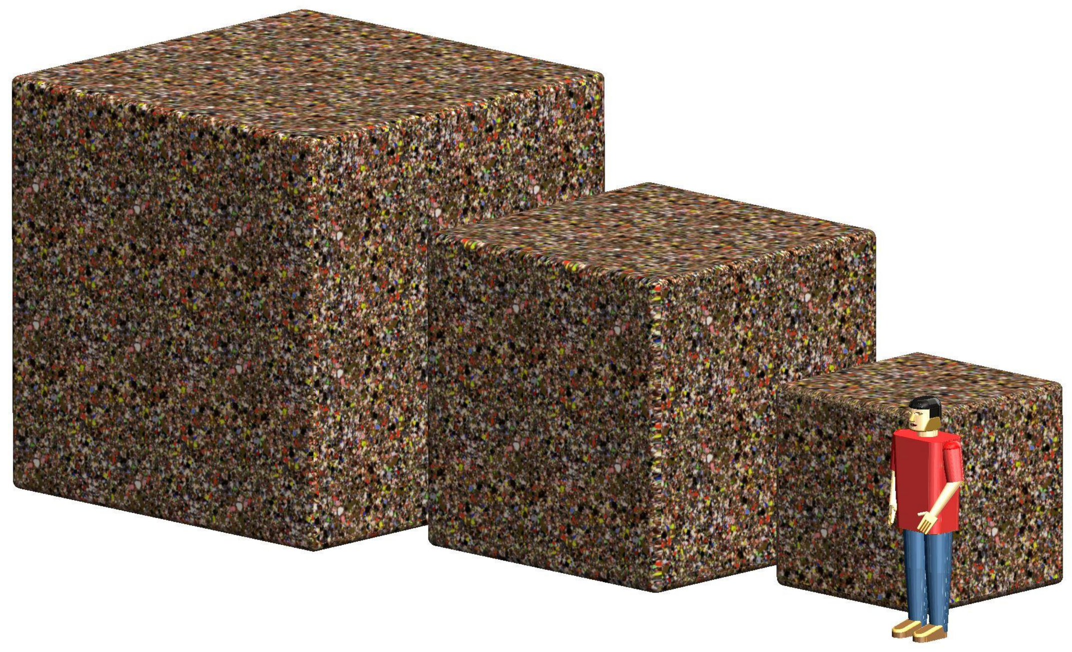


Figure 13. Visual comparison of volume reduction to different densities

Each cube in figure 12 represents the accumulation of 500 days (the outbound leg to Mars) of trash produced at a rate of 4.4 kg per day for a total of 2,200 kg of trash for a 4 person crew at selected densities. The cubes densities starting from the left are 70 kg/m³, 160 kg/m³, and 600 kg/m³.

The ESM savings due to volume are as listed below:

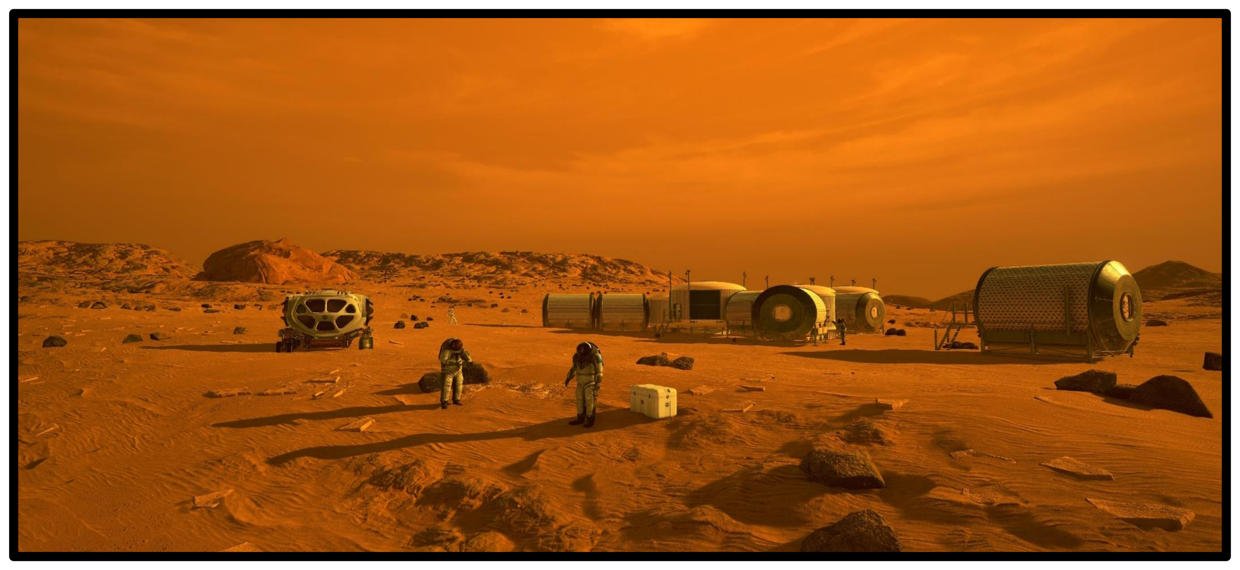
- Hand compaction vs. no compaction reduces Volume ESM from 2,484 kg to 1,086 kg for a reduction of launch mass of 1,398 kg.
- TCPS vs. no compaction reduces Volume ESM from 2,484 kg to 290 kg for a reduction of launch mass of 2,194 kg.
- TCPS vs. hand Compaction reduces Volume ESM from 1,086 kg to 290 kg for a reduction of launch mass of 796 kg.

The TCPS will play a major role in Planetary Protection on the surface of Mars

Volume Reduction of the trash can make possible the use of storage containers by reducing the volume requirement that might otherwise make them impractical to use.

The thermal process of the TCPS can render inert and kill microbes to reduce the chance of contamination and propagation across the Martian surface.

In Conclusion: Work will continue on TCPS and it will be tested on the International Space Station helping close the gap in the Advanced Life Support Technologies Suite and bring us one step closer to the dream of getting to Mars



Credit for work on the TCPS Project: The Waste Management Team at NASA Ames Research Center: Steve Sepka, NASA; Justine Richardson, NASA; Kevin Martin, NASA; Greg Pace, KBR; Janine Young, KBR; and Serena Trieu, Logyx; as well as many others from NASA Johnson Space Center, NASA Kennedy Space Flight Center, NASA Marshall Space Flight Center, and NASA Glenn Research Center