Trash to Gas: Using Waste Products to Minimize Logistical Mass During Long Duration Space Missions

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Chemistry Branch, NASA, Kennedy Space Center
AIAA Space 2013 Conference and Exposition
Agenda

- Logistics, Reduction and Repurposing (LRR) Project Overview
- TtG overview
- TtG Incineration System
LRR Overview

- LRR has four hardware oriented tasks and a systems engineering task
- Six NASA centers are participating
  - HMC: ARC/JSC/MSFC/KSC/GRC
  - TtG: KSC/GRC/ARC/JSC
  - ACS: JSC/WSTF
  - LTL: JSC/JPL/ARC

Logistics Reduction and Repurposing (LRR)
- Project Manager: James Broyan, JSC
- Deputy PM: Andrew Chu, JSC

Heat Melt Compactor (HMC)
- Lead: John Fisher, ARC

Trash to Gas (TtG)
- Lead: Paul Hintze, KSC

Advanced Clothing System (ACS)
- Lead: Evelyne Orndoff, JSC

Logistics to Living (L2L)
- Lead: Shelley Baccus, JSC

LRR Waste Reuse Systems Engineering Analysis (WRSEA)
- Lead: Michael Ewert, JSC
TtG Overview

Human Spaceflight Produces Trash!

Long term effects include:
- Pollution
- Wasteful spending
- Planetary protection
- Bad press

To maximize our resources, reduce trash volume, and minimize polluting in space habitats and long duration missions we need to re-evaluate the trash produced and do something innovative and sustainable with it.

Presently the trash is brought back home to earth or burned during Earth atmospheric re-entry.

Human spaceflight trash includes:
- Food packaging (adhered/uneaten)
- Clothing
- Human waste products
- Paper products
- Etc.
Utilizing Spaceflight Trash!

Utilize technology to produce useful products from the trash.

- Water • Fuel Depots • Aluminum • In-Situ Manufacturing
- Plant Life Support • Recycling Depot • Fertilizer • Basis of Chemical Production
- Reduce Trash Volume • Rocket Fuel
- Breathing • Fuel Cells • Reduce Logistics Delivered from Earth

Maximizing our resources to reduce trash and pollution.
TtG Benefits

- Stabilizes all waste materials including human wastes
  - Reduces waste mass by 87% - Residual solids include metals and noncombustible materials
  - Produce 270 kg of water and 930 kg methane (hydrogen limiting case) or 1490 kg methane and 2300 kg of oxygen (carbon limiting case)
- Sufficient gasses produced for multiple mission options
  - Propulsion options in increasing Isp order: non-propulsive venting, cold gas, resistojet, methane
  - Provides yearly station keeping for L2-type mission
  - Refuel one lunar to L2 sample return lander with ~260kg payload
  - Mars mission mid-course corrections

KSC-01PP-0726: Workers in the Space Station Processing Facility are removing contents from the Multi-Purpose Logistics Module (MPLM) Leonardo to begin removing the contents after STS-102. The MPLM brought back nearly a ton of trash and excess equipment from the Space Station.
TtG Overview

- Evaluated multiple processes
  - Pyrolysis
    - Decomposition of waste materials with heat in the absence of oxygen
  - Gasification
    - Decomposition of waste materials with heat in the presence of oxygen and/or steam
  - Incineration
    - Decomposition of waste materials with combustion
  - Steam Reforming
    - Decomposition of waste materials with heat in the presence of steam
  - Catalytic Decomposition - Low Temperature Decomposition of waste materials in the presence of a catalyst
    - Wet air oxidation
    - Photocatalytic oxidation
  - Ozone Oxidation
    - Decomposition of waste materials with heat in the presence of ozone
- 2013 – Select one technology for further development
- 2014 – Design trash handling system and micro gravity compatible components
- 2015 and beyond – Spaceflight demo (looking for opportunities)
TtG Overview

- Similar processes on Earth

- Challenges
  - Miniaturization
  - Operation with minimal human interaction
  - Do not produce hazards/Gas cleaning and purification
  - Most existing processes use only one feedstock
TtG Overview

• Waste produced in spaceflight
  – Crew of 4 for 360 days produces about 2500 kg of waste processed by TtG

• Waste simulant used to standardize results with different technologies
  – 40.3% water content
  – 5.9% ash content
    • Ash consisted of aluminum and non-combustible materials
  – 33.8% carbon content (estimated)

Shuttle mission waste

Food waste 'football'
TtG Incineration System

\[
C_xH_yO_z + O_2 \rightarrow CO_2 + H_2O \quad \text{and} \quad CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O
\]
TtG Incineration System

- Two air inlets
  1. Top of the reactor
  2. Just below the trash
- Two heaters
  - Enables dual temperature zones
- Catalyst bed
  - Current results do not incorporate the catalyst

<table>
<thead>
<tr>
<th>Condition</th>
<th>Top Inlet Flow (SLM)</th>
<th>Bottom Inlet Flow (SLM)</th>
<th>Temperature (°C)</th>
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<tbody>
<tr>
<td>A</td>
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TtG Incineration System

- 100 g of waste simulant in each run
- Mass of water collected by condenser measured after each run
- Fourier Transform Infrared (FTIR) spectrometer used to quantify production of carbon dioxide, carbon monoxide and methane
- Gas Chromatography/Mass Spectrometry (GC/MS) for qualitative analysis of oxygen and other hydrocarbons
TtG Incineration System

- CO₂ production was maximized at 600 °C
- CO₂ production did not depend on flow rate
- CO production was about 1/10th the amount of CO₂ under all conditions
- 100% conversion of carbon in waste to CO₂ and CO at 600 °C

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<td>A</td>
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TtG Incineration System

- Water recovered did not differ statistically under different conditions
- 40 g of free water in simulant is recovered
- Water produced in combustion reaction is not fully recovered – need improved condenser

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TtG Incineration System

- Reaction time was reduced when using higher flow rates
- Temperature did not have an affect on reaction time

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Acknowledgements

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