

A composite image of space featuring the Earth's horizon on the left, the Moon in the upper right, and a bright sun with lens flare in the lower left.

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

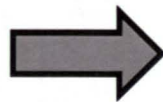
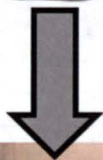
Paul E. Hintze

Chemistry Branch, NASA, Kennedy Space Center

AIAA Space 2013 Conference and Exposition



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

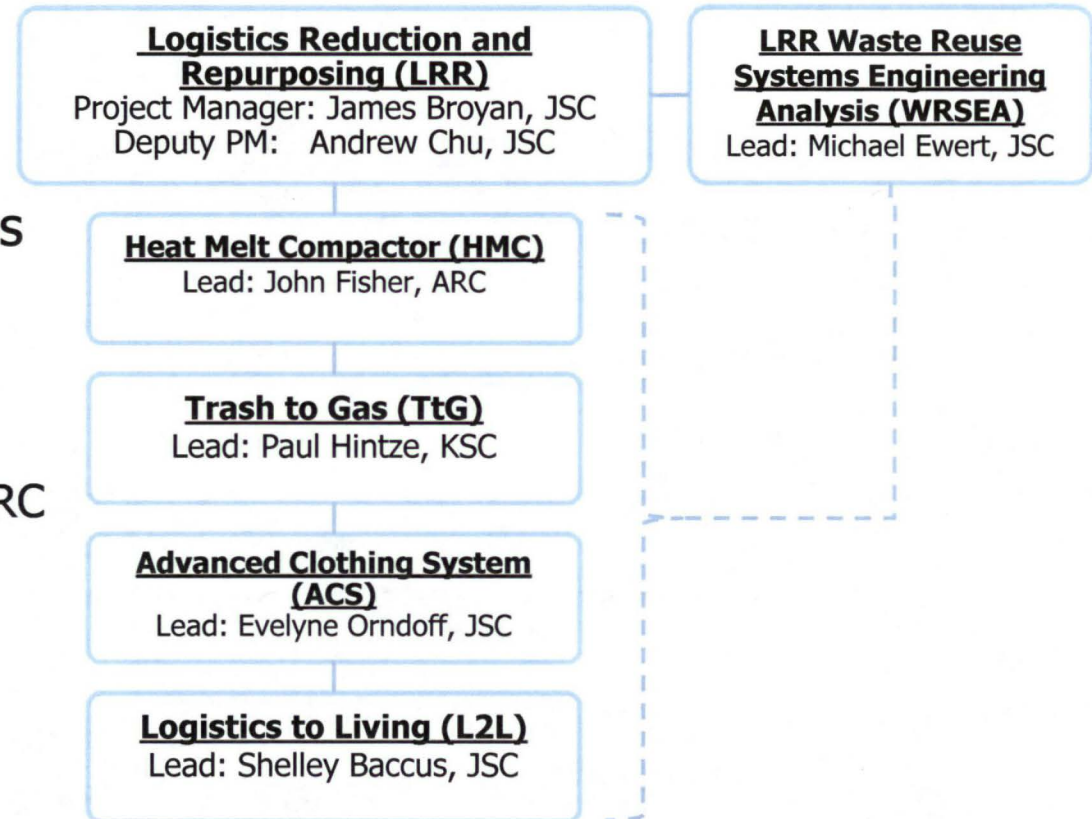




LRR Overview



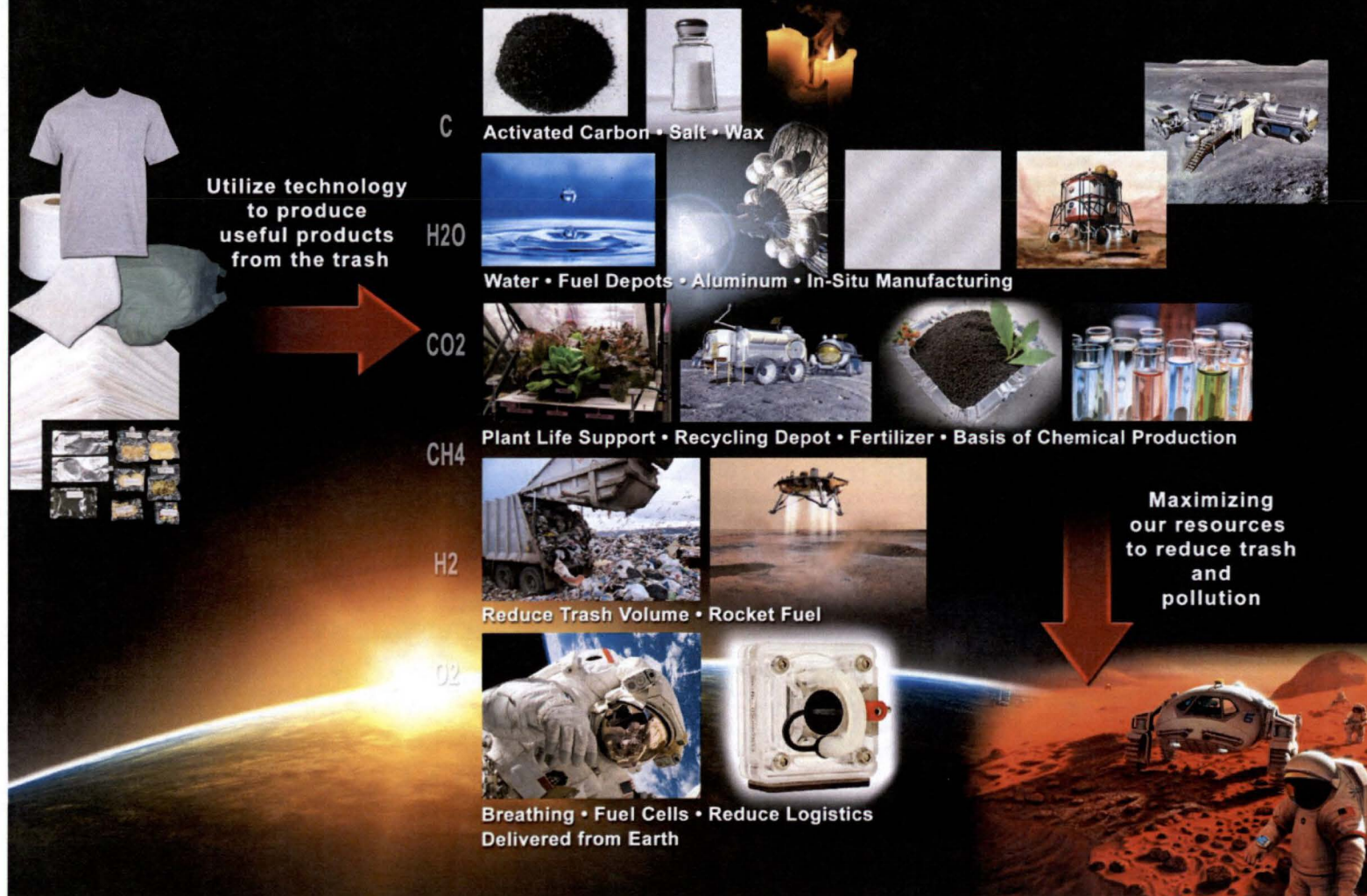
- LRR has four hardware oriented tasks and a systems engineering task
- Six NASA centers are participating
 - HMC: ARC/JSC/MSFC/KSC/GRC
 - TtG: KSC/GRC/ARC/JSC
 - ACS: JSC/WSTF
 - LTL: JSC/JPL/ARC



Human Spaceflight Produces Trash!



Utilizing Spaceflight Trash!





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)

- Similar processes on Earth



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NASA's Version of Mr. Fusion

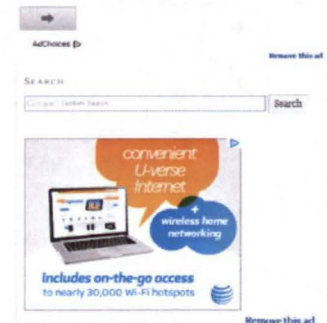
by NANCY ATKINSON on DECEMBER 13, 2012



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

- Waste produced in spaceflight
 - Crew of 4 for 360 days produces about 2500 kg of waste processed by TtG
 - Waste types: Human Waste, Packaging,, Uneaten Food, MAGS, Gray Tape, Paper, Clothing, Towels, Clothing
- 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)



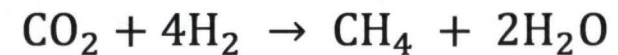
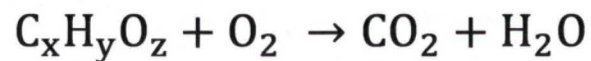
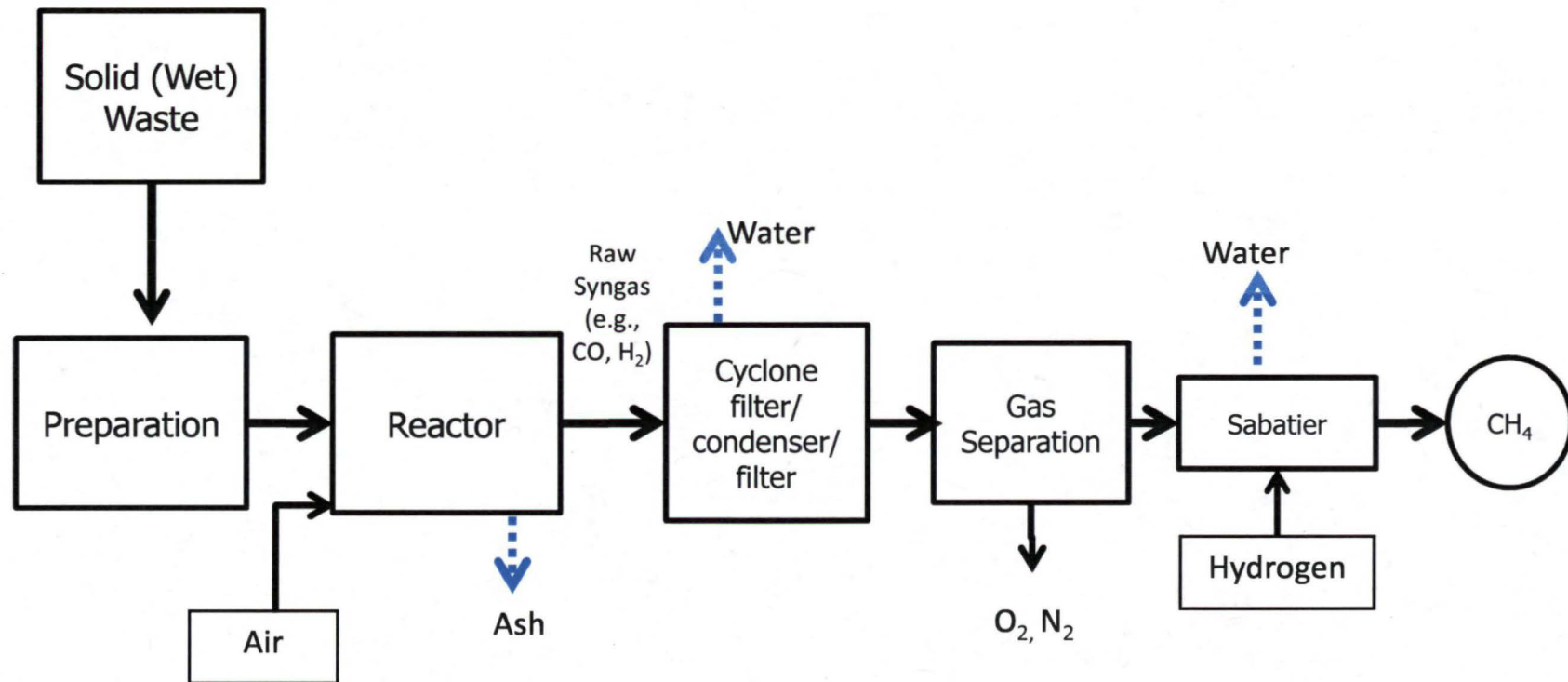
Shuttle mission waste



Food waste 'football'



TtG Incineration System



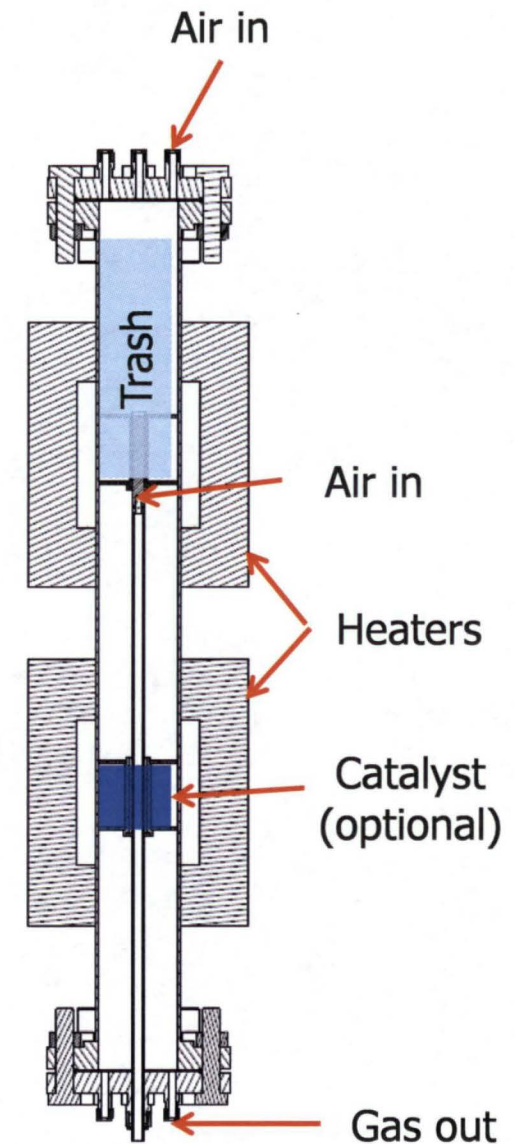


TtG Incineration System



- 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

Condition	Top Inlet Flow (SLM)	Bottom Inlet Flow (SLM)	Temperature (°C)
A	1 → 4	4 → 1	500
B	1 → 4	4	500
C	5	5	500
D	1 → 4	4 → 1	600
E	5	5	600

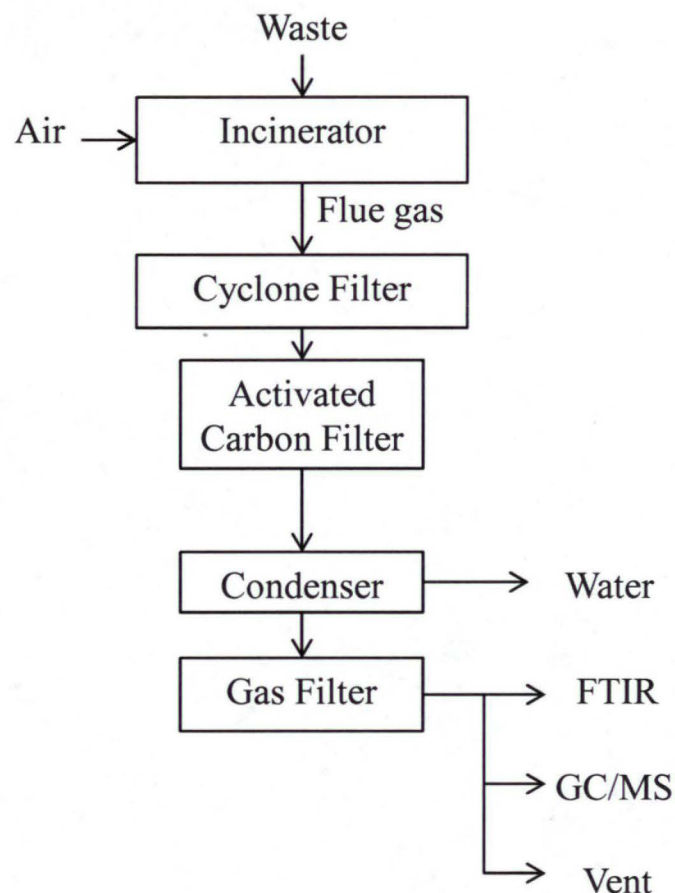




TtG Incineration System



- 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

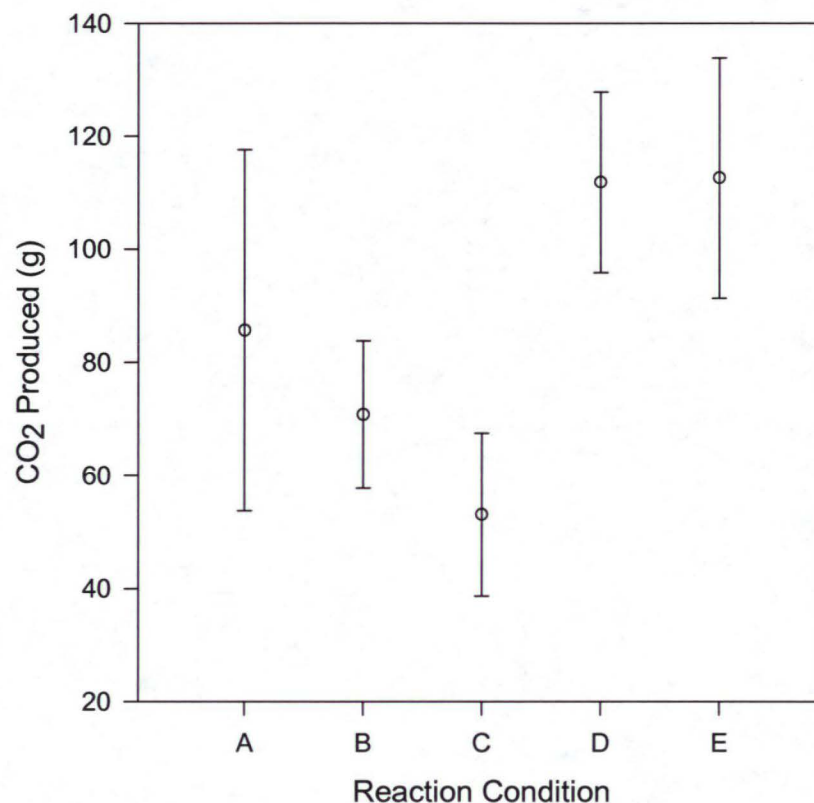




TtG Incineration System



- 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



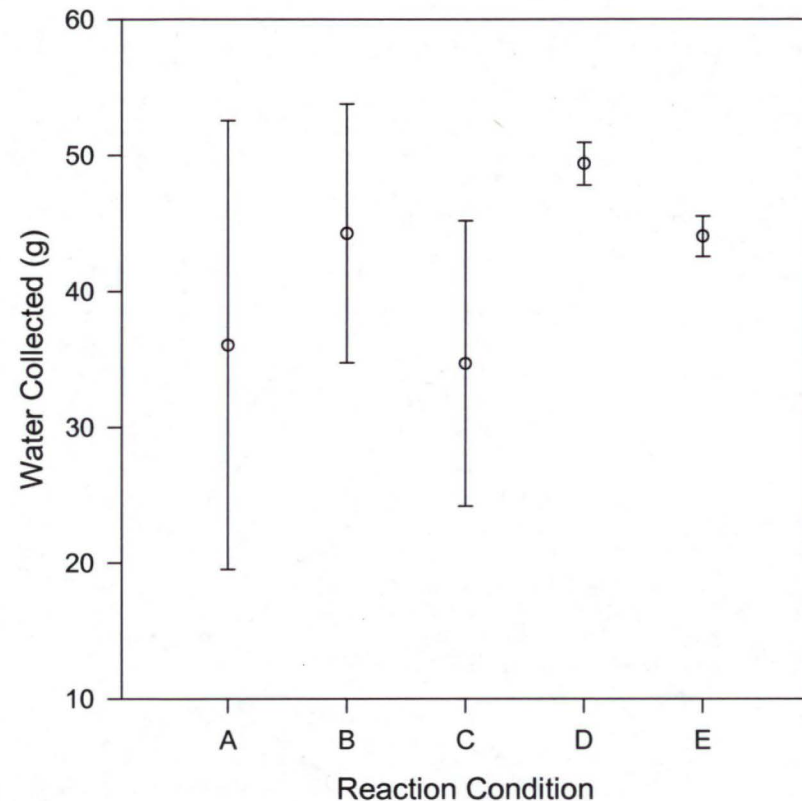
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TtG Incineration System



- 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



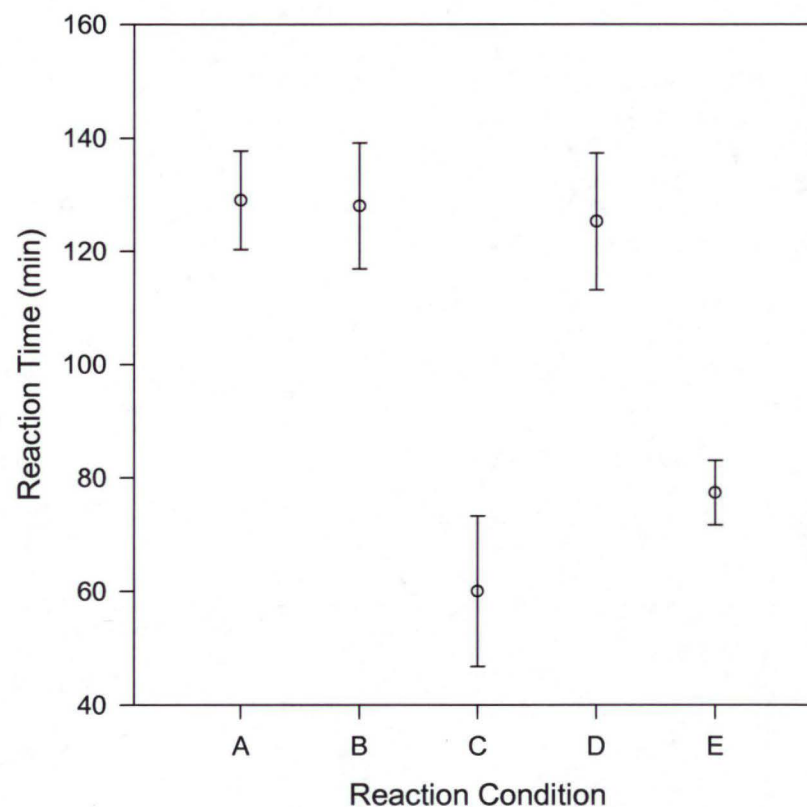
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TtG Incineration System



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



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A	1 → 4	4 → 1	500
B	1 → 4	4	500
C	5	5	500
D	1 → 4	4 → 1	600
E	5	5	600



Acknowledgements



- NASA Advanced Exploration Systems (AES) Program
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