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

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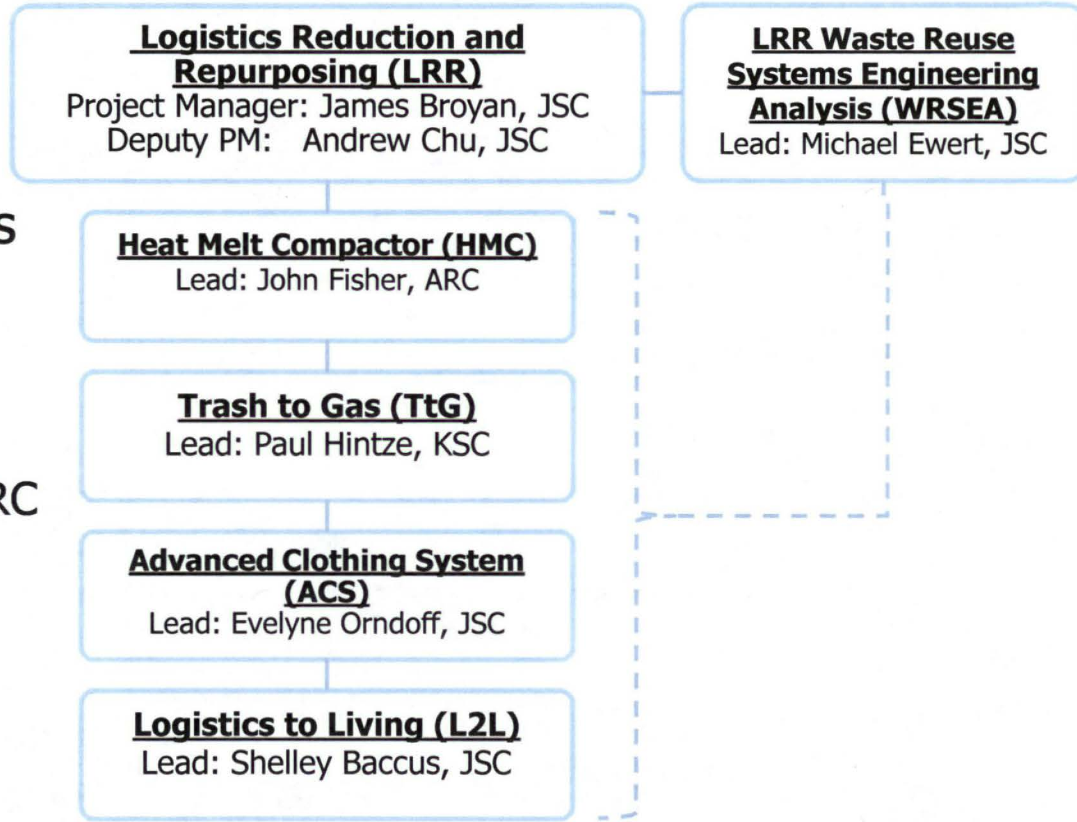
Agenda

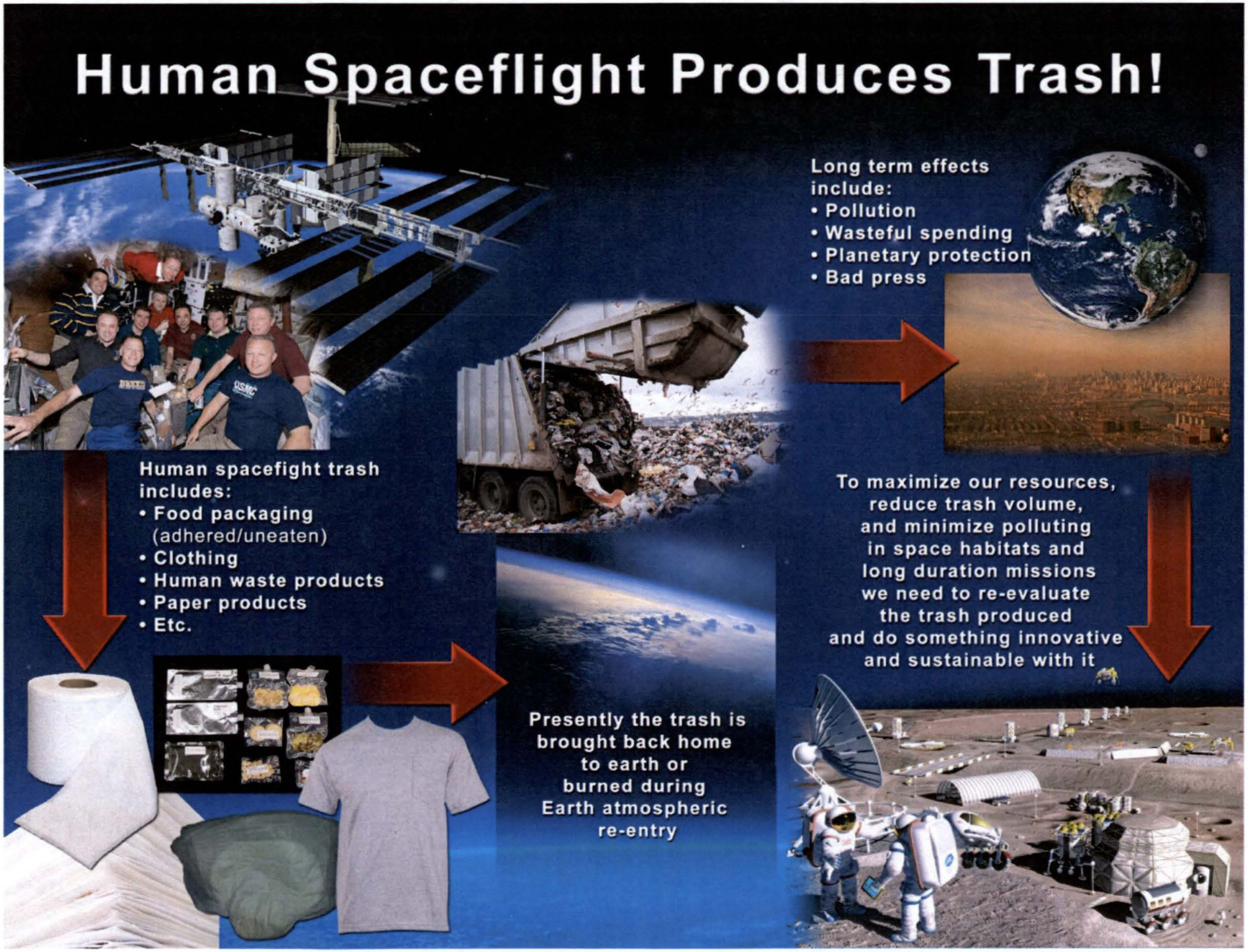
- Logistics, Reduction and Repurposing (LRR) Project Overview
- TtG overview
- TtG Incineration System

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



TtG Overview



TtG Overview

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

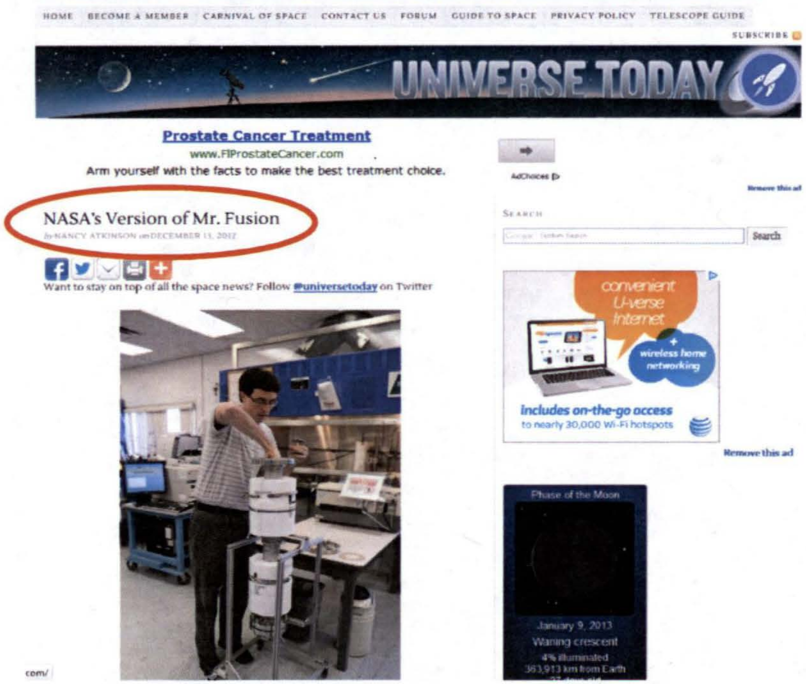
KSC-01PP-0726: Workers in the Space Station Processing Facility are removing contents from the Multi-Purpose Logistics Module (MPLM) Leonardo to begin removing the contents after STS-102. The MPLM brought back nearly a ton of trash and excess equipment from the Space Station.

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

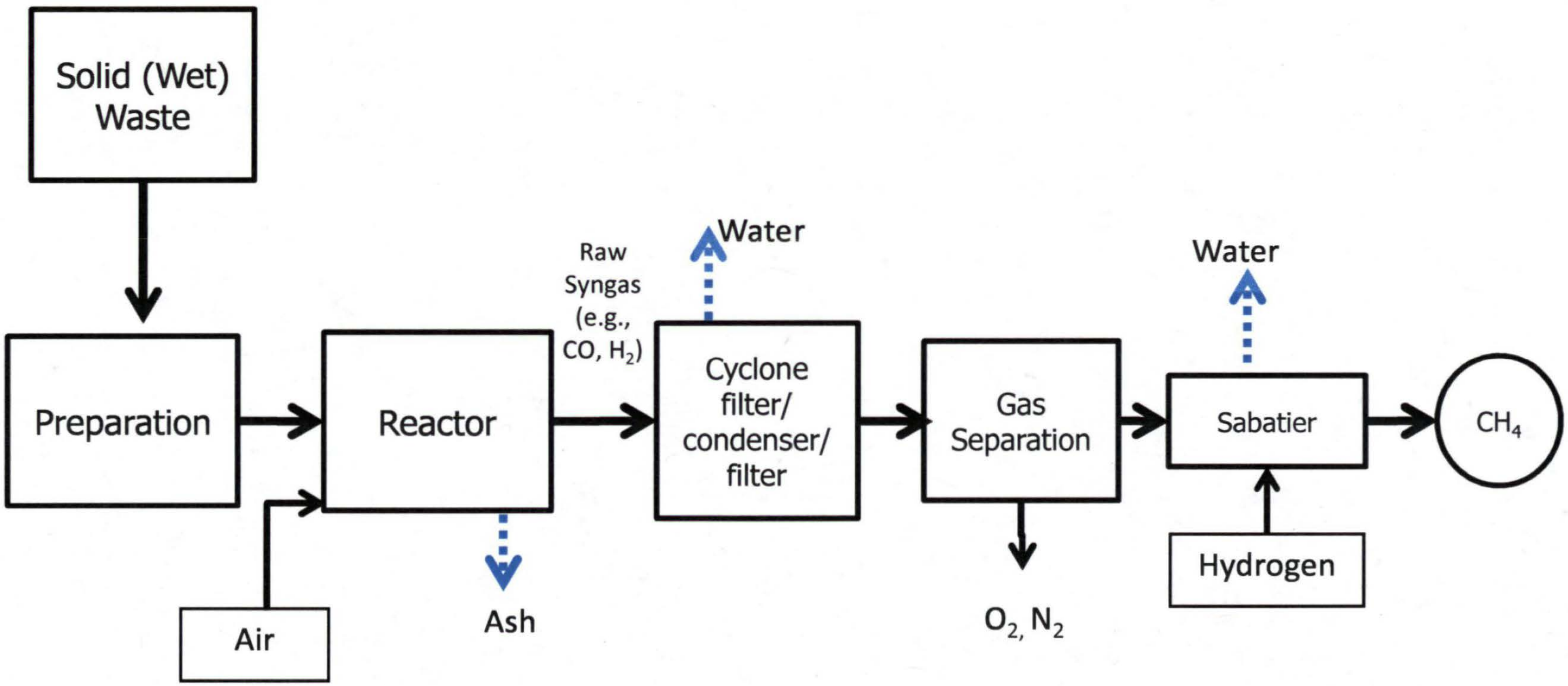
TtG Overview

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



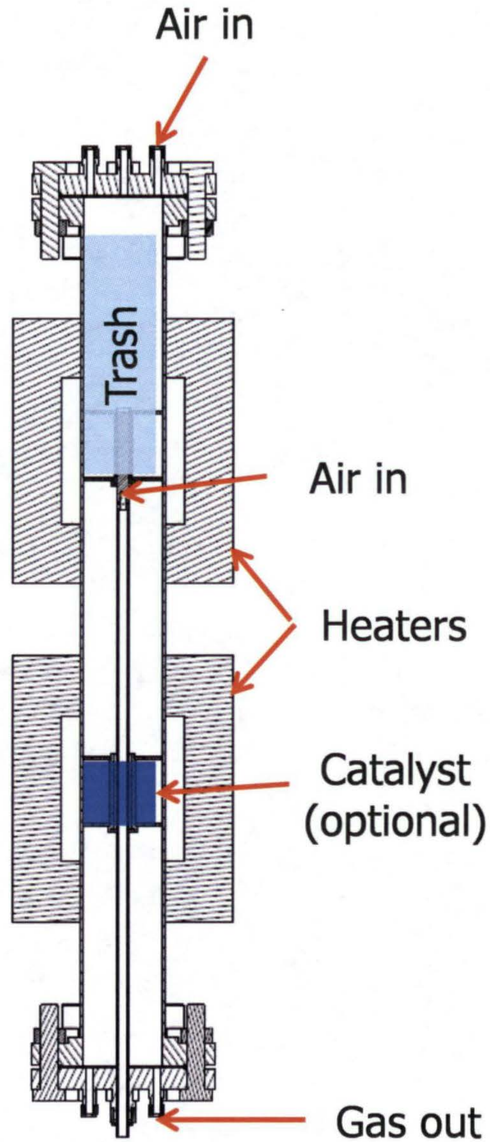
$$C_xH_yO_z + O_2 \rightarrow CO_2 + H_2O$$

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$$

TtG Incineration System

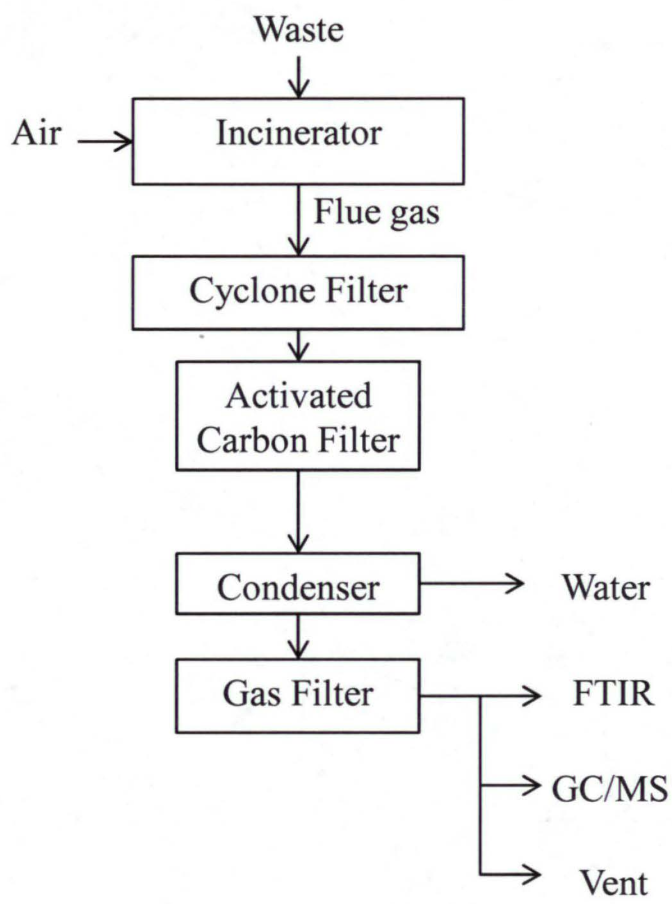
- Two air inlets
  1. Top of the reactor
  2. Just below the trash
- Two heaters
  - Enables dual temperature zones
- Catalyst bed
  - Current results do not incorporate the catalyst

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



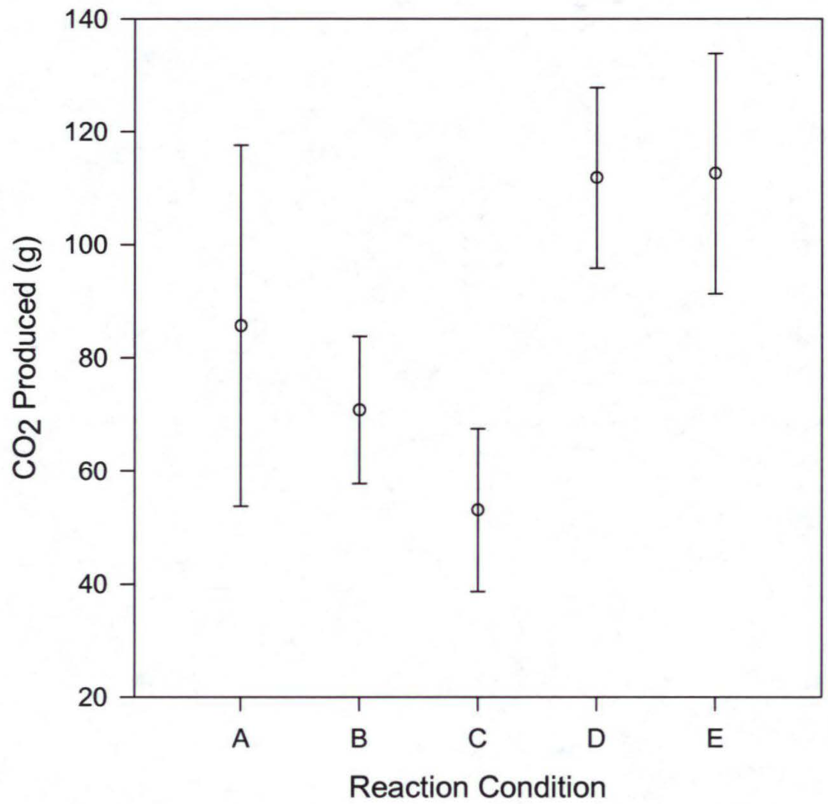
TtG Incineration System

- 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

- CO_2 production was maximized at 600 ºC
- CO_2 production did not depend on flow rate
- CO production was about 1/10th the amount of CO_2 under all conditions
- 100% conversion of carbon in waste to CO_2 and CO at 600 ºC



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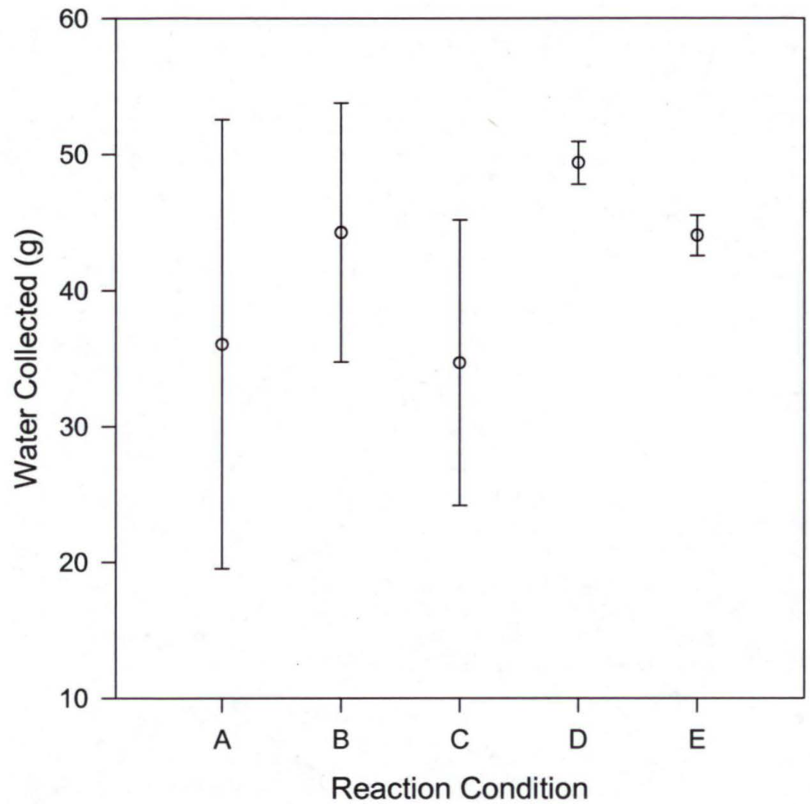
TtG Incineration System

- 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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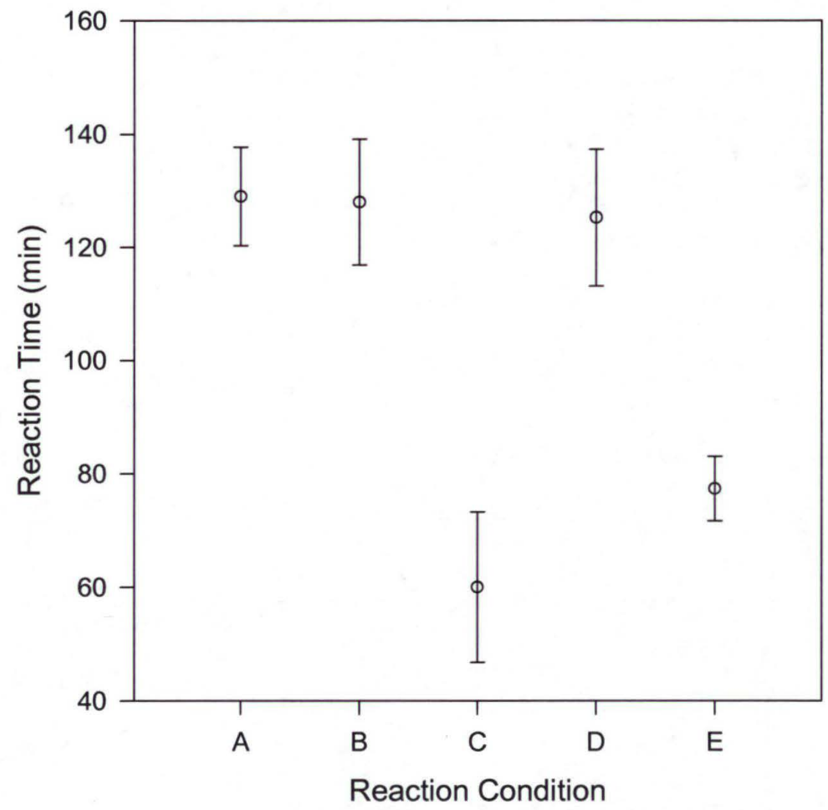
TtG Incineration System

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



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