Mars Habitat Resource Recycling & Manufacturing System

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Members:

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1 Problem Definition

1.1 Need Statement

During a three-year mission, an eight-person crew would accumulate over 12,000 kg of inorganic waste, or trash, which is a huge problem. If the issue is not addressed as soon as possible, we humans might cause some permanent damage to the environment on Mars.

1.2 Goal

Find an efficient and reliable way to recycle and reuse the waste on Mars.

1.3 Objectives

Objective	**Basis for Measurement**	**Units**
Must be reliable	The endurance of the solution (how many years it can last)	Years
Must not be too expensive	The cost to implement the solution	CAD
Must minimize the emission	The amount of chemical the solution might emit	–
Must be buildable by no more than eight people	Number of people required for the workload	People

Table 1: Objectives and Measurement Basis

1.4 Constraints

- Solutions must be completed within one week.
- Solutions must not burn anything without proper collection on Mars.
- Solutions must not cost too much money.
- Solutions must not be too complicated to implement.

2 Our Solution

Mars Habitat Recycling-to-Manufacturing System (MHRMS)

2.1 Purpose

This system is designed to convert waste materials from Mars habitat operations into usable 3D printing filament and manufacturing feedstock, with emphasis on CO2 extraction byproducts.

2.2 Design Philofophy

- Modular
- relocatable
- powered by habitat frid
- zero-waste discharge

2.3 Mars Environment Context

1. Mars has a thin atmosphere made up mostly of carbon dioxide, nitrogen, and argon gases, with temperatures ranging from 70°F (20°C) to -225°F (-153°C)
2. Mars' sparse atmosphere doesn't offer much protection from impacts by meteorites and the thin atmosphere causes heat from the Sun to easily escape
3. Dust storms can cover much of the planet, sometimes taking months for all dust to settle
4. Mars completes one rotation every 24.6 hours (a "sol"), with a year lasting 687 Earth days
5. These conditions directly impact recycling system design: thermal management is critical, dust mitigation essential

2.4 Design Considerations

Waste behavior in Mars Environment

1. Vacuum Exposure Challenges: Based on NASA Glenn Research Center analysis of waste behavior when exposed to vacuum

2. Water Sublimation: When waste is exposed to Mars' near-vacuum conditions (0.6% Earth pressure), approximately 20% of water content will sublimate before the waste completely freezes. This process takes:

   - Small items (3mm droplets): 7 seconds to freeze
   - Standard waste "football" (20cm compressed bundle): 3.4 hours to freeze

3. Implications for recycling system:

   (a) Pre-processing must handle both frozen and partially sublimated materials

   (b) Vapor capture systems required to prevent water loss during initial processing

   (c) Grinding chambers must be sealed to capture sublimating volatiles

   (d) Temperature control critical: waste arriving at facility may be frozen solid (-153°C from overnight exposure)

4. Thermal management on mars

   (a) Challenge: Mars temperature swings from 70°F (20°C) to -225°F (-153°C)

   (b) Solution:
      - Insulated processing chambers: Maintain optimal processing temperatures (150-1400°C depending on module)
      - Pre-heating systems: Thaw frozen waste before processing
      - Waste heat recovery: Capture heat from processing for habitat use
      - Phase-change thermal buffers: Smooth out temperature fluctuations

5. Mars sol adaptation

   (a) Mars day: 24.6 hours VS Earth's 24 hours

   (b) Operational impact:
      - Processing schedules calibrated to Mars sols
      - Automation advantage: rovers and processing continue during crew sleep cycles
      - Benefit: Extra 39 minutes per sol allows for extended processing cycles

Source: NASA Mars Facts.

3 Input Categories

1. Category A – Carbon Materials:
   - Surplus carbon from CO2 extraction (primary feedstock)
   - Activated carbon filters (spent)
   - Carbon-containing composites
2. Category B – Polymers/Plastics:
   - Nitrile gloves
   - Resealable bags (PE/PP)
   - EVA waste from spacesuits and cargo transfer bags (Nomex, nylon, polyester)
   - Packaging materials (air cushions, bubble wrap, anti-static bags)
   - Tape, labels, plastic clips
   - Foam packaging (Zotek F30, Plastazote foam)
3. Category C – Fabrics:
   - Clothing (cotton, polyester, nylon)
   - Washcloths and wipes (cellulose, cotton)
   - Disinfectant wipes
4. Category D – Food Packaging:
   - Overwrap materials
   - rehydratable pouches (polyester, polyethylene, aluminum, nylon)
   - Drink pouches
   - Thermal pouches
5. Category E – Metals:
   - Filter mesh (stainless steel, aluminum)
   - Broken tools and fasteners
   - Structural components from temporary structures
   - Electronics casings
   - Wire scraps
   - Aluminum structures
6. Category F – Composites:
   - Polymer matrix composites with carbon fiber
   - Multi-layer materials
   - Fabric-backed materials
   - Adhesive-bonded assemblies

4 Alternative Option

1. Option A – Direct Venting to Space (NOT RECOMMENDED)
   NASA Glenn Research Center evaluated simply disposing waste via airlock to space. Key findings: Technical Challenges:

   (a) Time-intensive: Using existing airlock technology (3-hour depressurization cycle), disposing of waste from a 180-day, 4-person mission would require 1,250-2,500 hours of crew time

   (b) Hazard: 20% of water content sublimates and can re-condense on spacecraft surfaces or contaminate equipment

   (c) Trajectory risk: Low-velocity disposal at L2 libration points risks waste re-impacting spacecraft

   Conclusion: Direct disposal to space is impractical and hazardous for Mars missions

2. Option B: Partial Processing to Mixed Gases

   (a) NASA's "Trash-to-Gas" (TtG) Approach: Process waste in primary reactor only, producing mixed gases:

      i. Benefits: Simpler system (fewer processing steps); can provide station-keeping propulsion; lower energy requirements

      ii. Limitations: Lower-quality propellant (vs. pure O_2/CH_4); still requires makeup water; limited manufacturing applications

Works Cited

- cite here