Human Factor Investigation of Waste Processing System During the HI-SEAS 4 Month Mars Analog Mission in Support of NASA's Logistic Reduction and Repurposing Project: Trash to Gas

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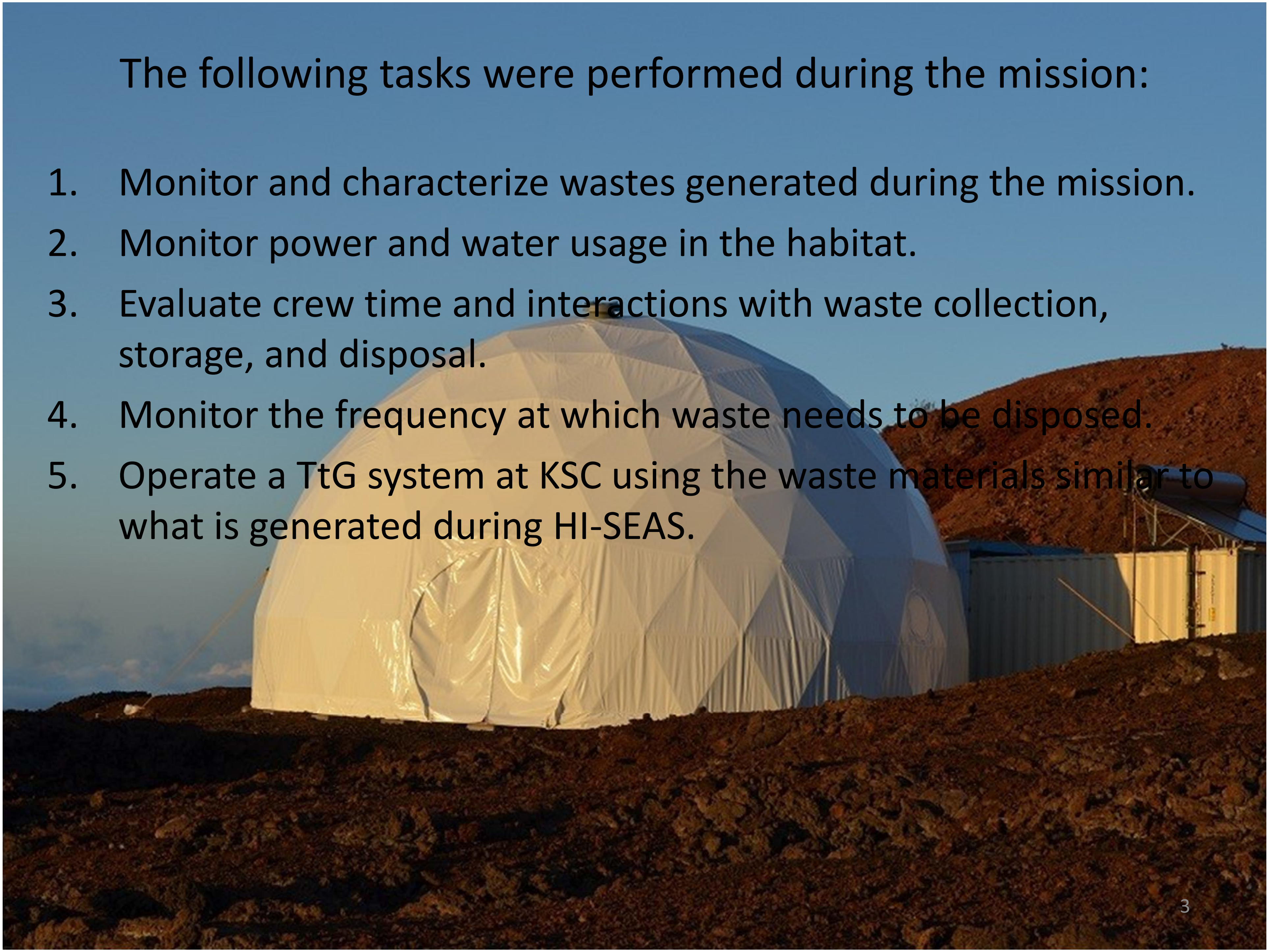
Motivation

- Long duration deep space missions will require many closed loop, self-sufficient and highly sustainable technologies.
- Conditions will create a seemingly independent operation from support personnel located back on Earth, especially during day-to-day mission operations.
- Closed-loop life-support-systems with minimal or no re-supply from Earth have the greatest technical challenges to development.
- The Trash to Gas (TtG) is part of the Logistics Reduction and Repurposing (LRR) project. TTG technology has proven successful in laboratory studies, a number of assumptions were made to facilitate testing, leading to questions pertaining to the design of a flight unit.
- Analog tests, where the conditions of long duration, deep space missions are simulated, can be used to evaluate new technologies.
- TtG : Develop space technology alternatives for converting space waste into a gas that may be converted into high-value products or a gas that can be easily vented as a 'jettison function'.

The following tasks were performed during the mission:

1. Monitor and characterize wastes generated during the mission.
2. Monitor power and water usage in the habitat.
3. Evaluate crew time and interactions with waste collection, storage, and disposal.
4. Monitor the frequency at which waste needs to be disposed.
5. Operate a TtG system at KSC using the waste materials similar to what is generated during HI-SEAS.




ILA / HI-SEAS Systems Monitor
(Aloha....)
View: [dashboard] [sensors] [cam]
2014-04-26 @ 12:00:51
POWER
Battery A: 99 %
Battery B: 99 %
H2 FC A: 50.00 psi
H2 FC B: Offline
generating
3.09 kW
consuming
3.44 kW
WATER
0.000
gallons
-15.0 %
full
WEATHER
05:57
RISE
18:46
SET
1014.10
SOLAR
55.2°F
TEMP
0.00 in.
RAIN
30.89
BAR
84
HUMID
50.7
DEW
NEbE
0.00
WIND
62.0°F
185.0°F
71.0°F
68.1°F
61.5°F
CO
Mars Habitat / Mauna Loa

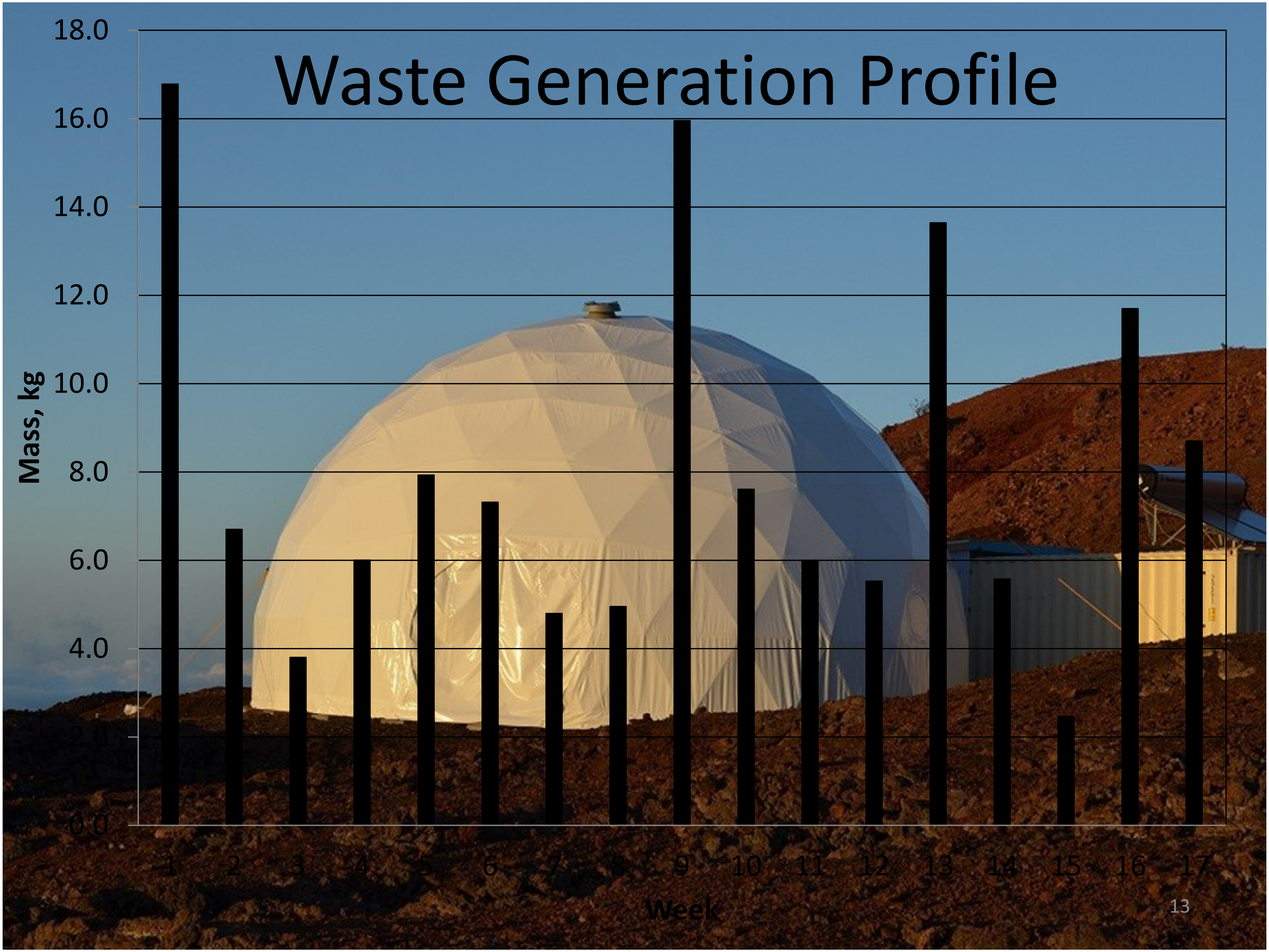
HI-SEAS Waste Storage


Crew A
EGGS

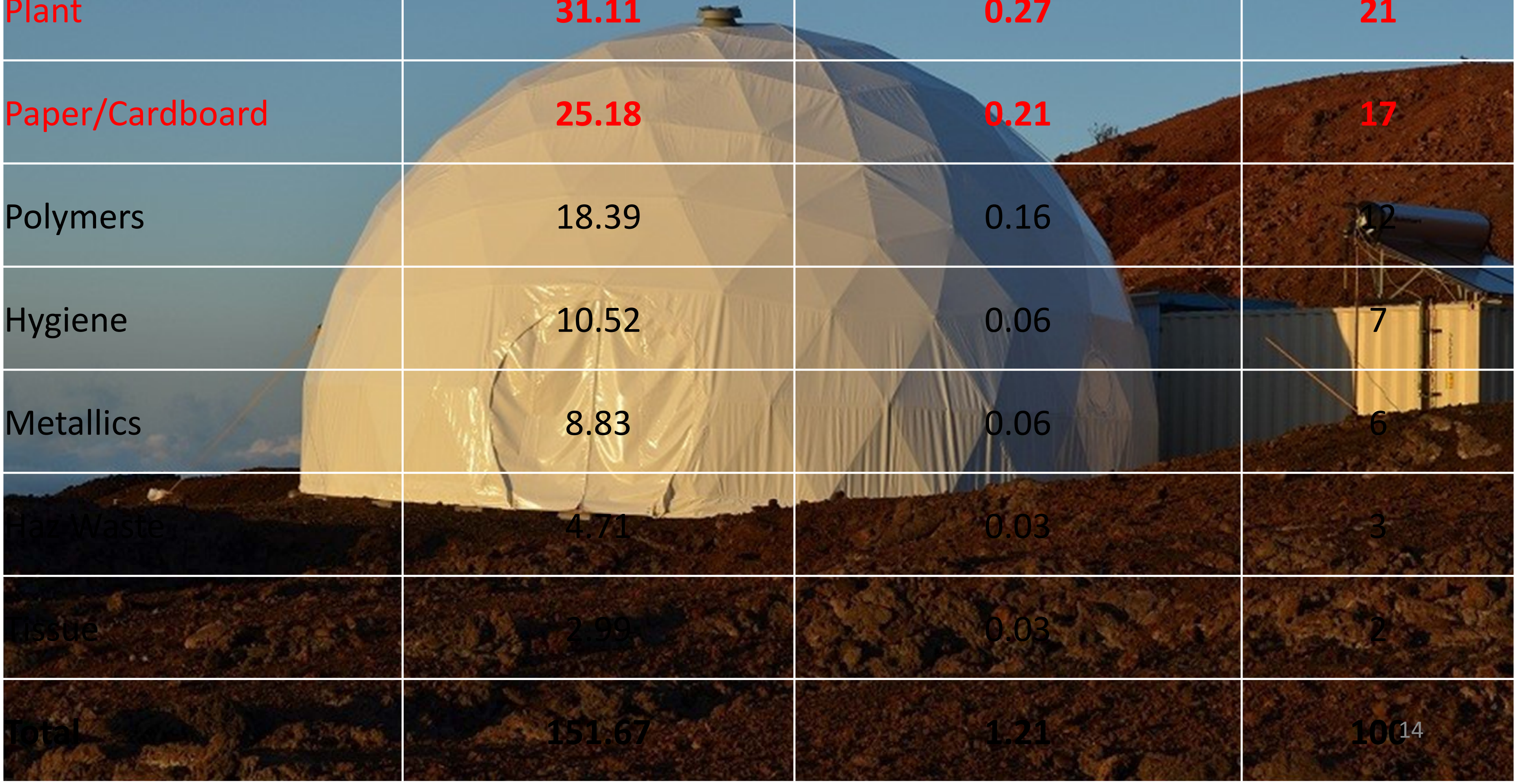

FOOD ONLY!
Cardboard/Paper/Tissue waste
CARDBOARD
Metal/Aluminum waste
METAL Waste
Plastics Waste
PLASTIC WASTE
Metals
Hygiene
Food
HEINZ
ALL NATURAL
DISTILLED WHITE VINEGAR
Emergency Essentials
BePrepared.com
1-800-999-1863
48 MORE LOADS!


Do Not Bump!

Waste Generation Results



Waste Generation Profile
Mass, kg
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Week



Waste Type	Mass Waste Total (kg)	Average Mass per Day (kg)	Mass Percent (%)
Food	**49.94**	**0.38**	**33**
Plant	**31.11**	**0.27**	**21**
Paper/Cardboard	**25.18**	**0.21**	**17**
Polymers	18.39	0.16	12
Hygiene	10.52	0.06	7
Metallics	8.83	0.06	6
Haz Waste	4.71	0.03	3
Tissue	2.99	0.03	2
Total	**151.67**	**1.21**	**100**

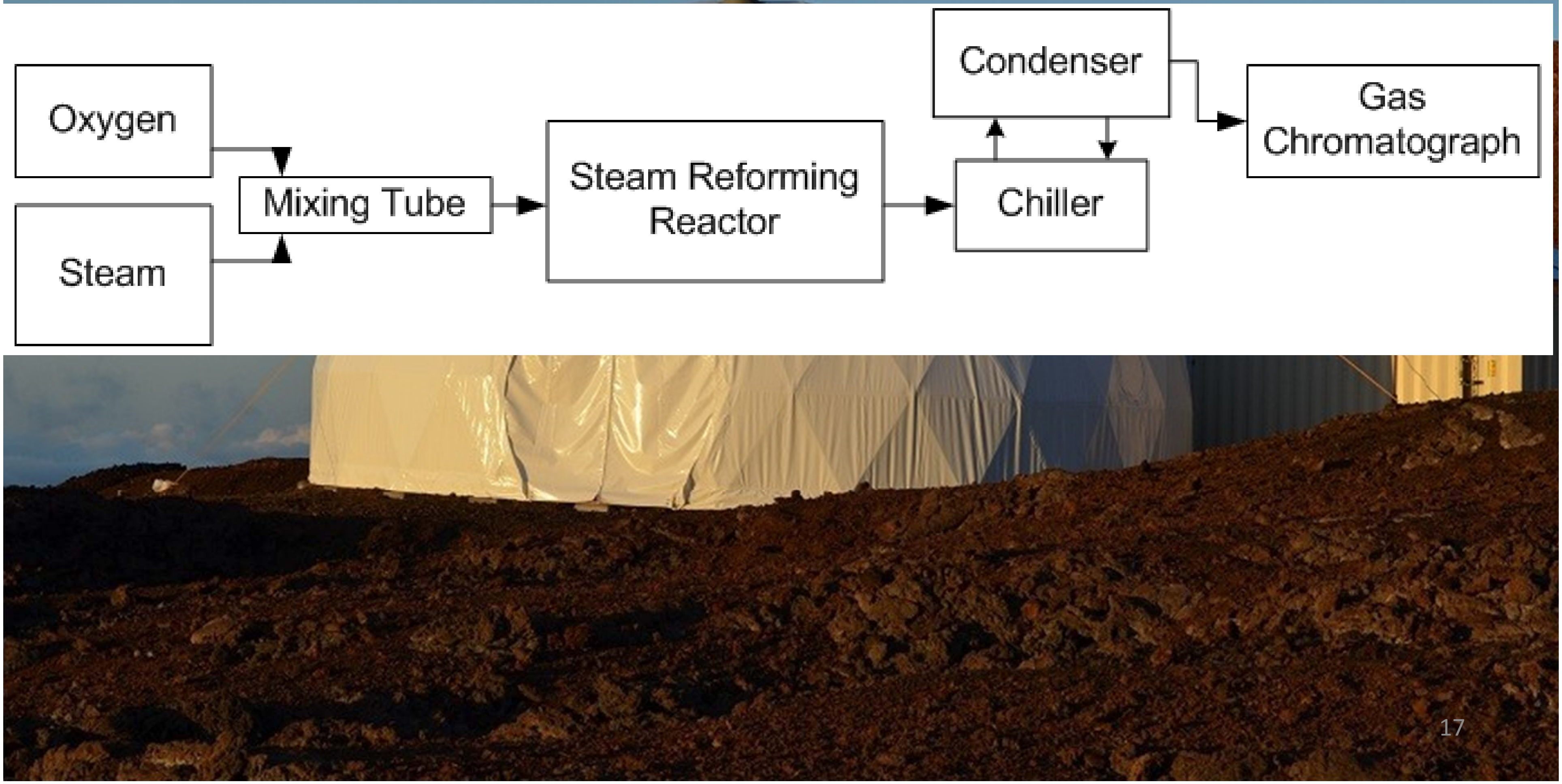
Volume Reduction via Footballs

- **154 TOTAL FOOTBALLS**
  - (not everything could be made into a football)
- Uncompressed Volume: 2.65m^3
- Compressed Volume: 1.51m^3 (43% reduction!)

- Average football mass: 904g (range:60-1200g)
- Average football volume: 0.006m^3

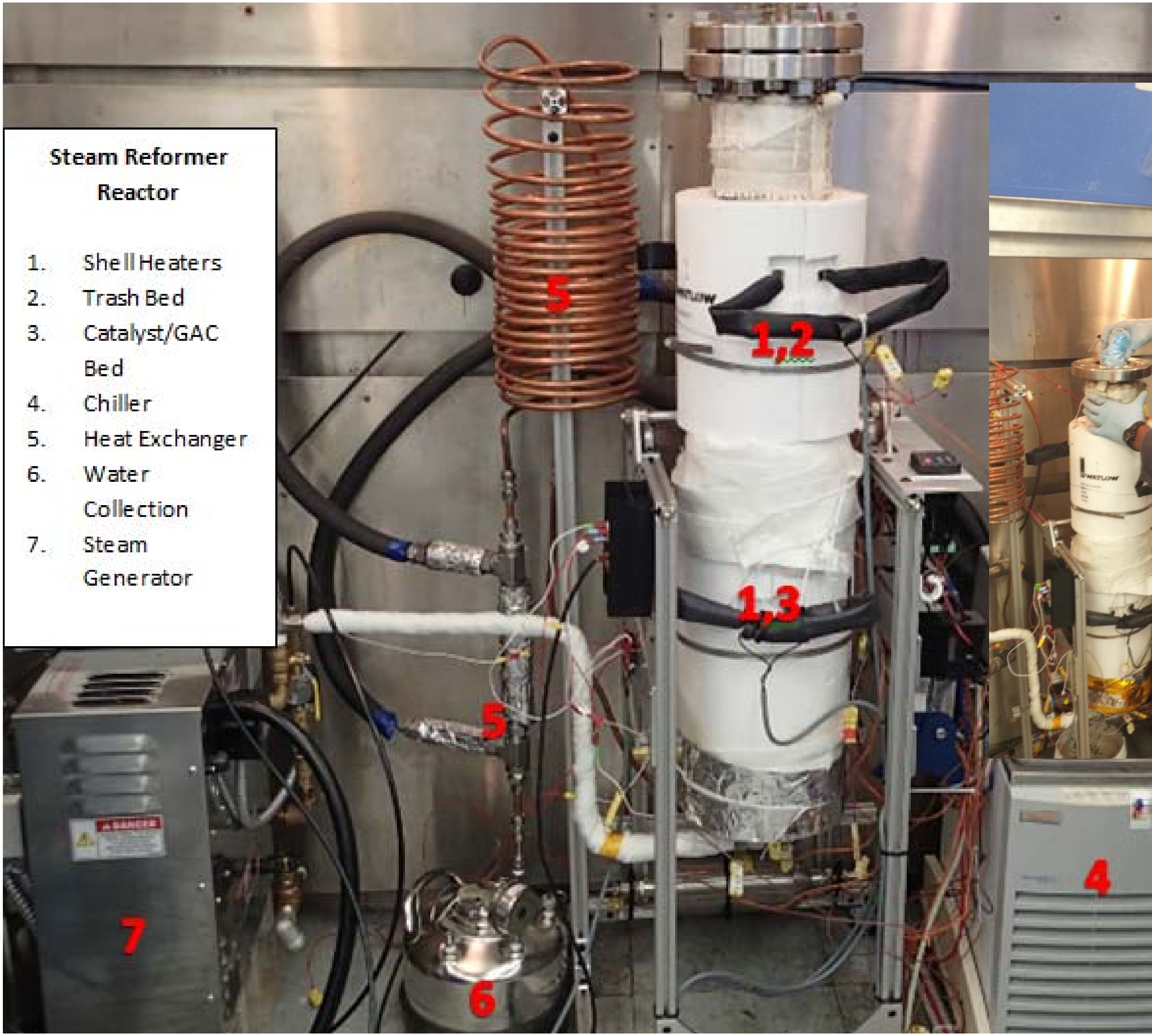
KSC Trash to Gas Technology

Reactor System Flow Diagram



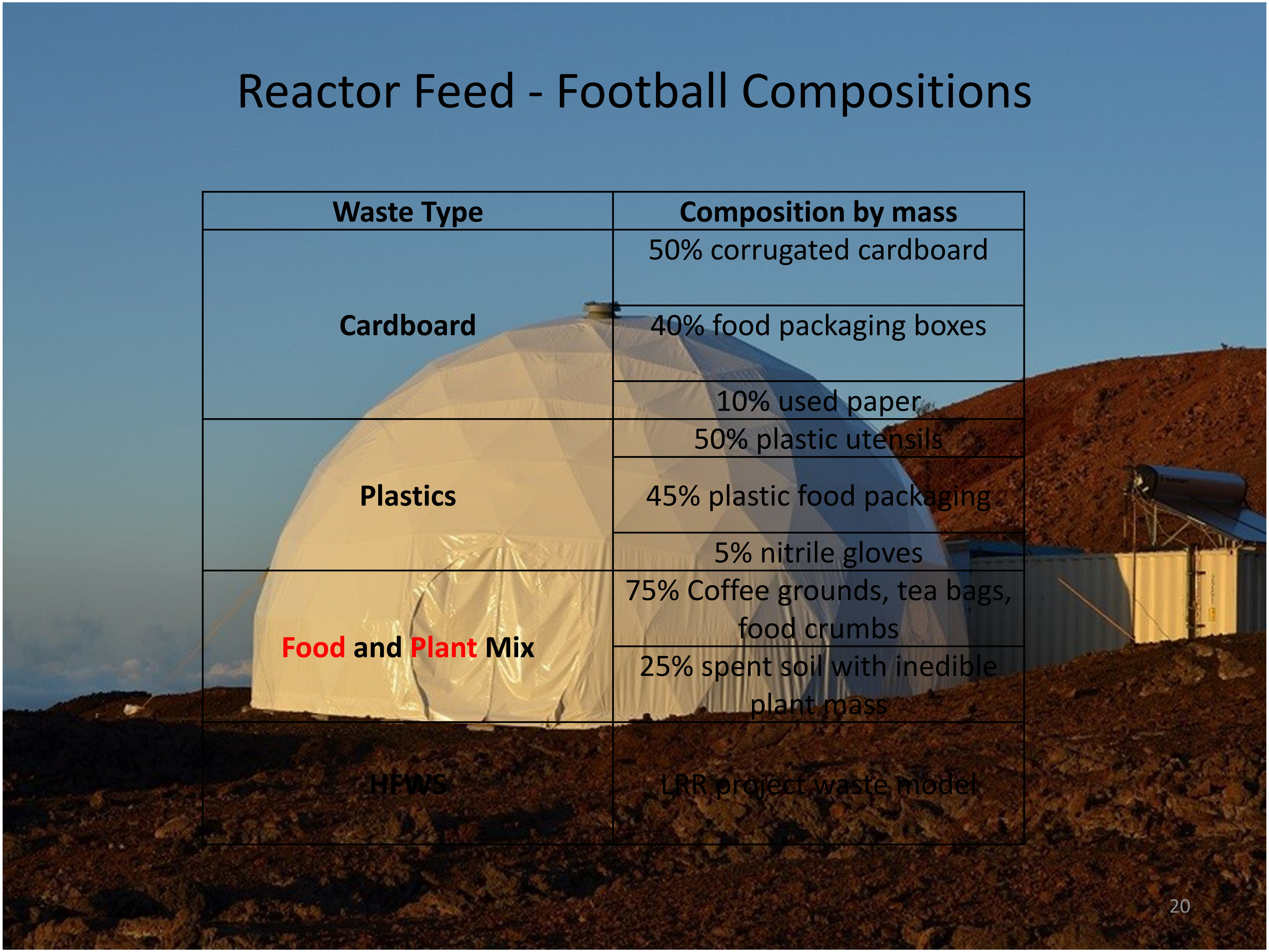
Steam Reformer Reactor

1. Shell Heaters
2. Trash Bed
3. Catalyst/GAC Bed
4. Chiller
5. Heat Exchanger
6. Water Collection
7. Steam Generator



KSC Trash to Gas Steam Reforming Reactor Results

Reactor Feed - Football Compositions



Waste Type	Composition by mass
Cardboard	50% corrugated cardboard
	40% food packaging boxes
	10% used paper
Plastics	50% plastic utensils
	45% plastic food packaging
	5% nitrile gloves
Food and Plant Mix	75% Coffee grounds, tea bags, food crumbs
	25% spent soil with inedible plant mass
HFWS	LRR project waste model

Reactor Projections for Methane Production/Power

Waste Type	CH_4 (kg)	kWh	Processing time (hr)
Cardboard	22	307	98
Plastics	12	168	69
Food and Plant Mix	11	162	162
Total	45	637	329

Summary

- 115 days of mission waste collected
- 151.7 kg of wet and dry waste was accounted for (not including human, waste water or brine).
  - **1 Year, 4 person crew:**
    - **HI-SEAS**: 385kg
    - **LRR Full Waste Model**: 2,559kg (with feces, brine, clothing, etc.)
    - **LRR**: 735kg (hygiene, food, food packaging,and food storage)
      - 52% difference

CONCLUSION

- The amount of waste produced during the HI-SEAS was measured and is less than would be expected from long duration space missions.
- The waste collection data showed that large amounts of waste were generated during certain times, such as when the monthly food supplies were unpacked.
- This indicates that the TtG process must be able to handle a waste stream that will vary in composition, and that it is possible for a crew of five to segregate wastes over a mission.
- The amount of time required to process all the waste during this mission was 12% of the mission time, based on the reaction rates using the existing reactor at KSC.
- A more automated system, would likely require less crew time. (Currently 10%).
- The KSC TtG process successfully processed the three waste types, and could produce 9% of the power needed during the mission.

ACKNOWLEDGEMENTS

- NASA's Advanced Exploration Systems Program Office
- Logistics Reduction and Repurposing Team, esp. KSC/JSC
- HI-SEAS Mission 2 Crew Members: Lucie Poulet, Tiffany Swarmer, Ross Lockwood, Casey Stedman
- HI-SEAS P.I. Dr. Kim Binsted and Dr. Jean Hunter.
- Gasmet Technologies Inc.

Questions?

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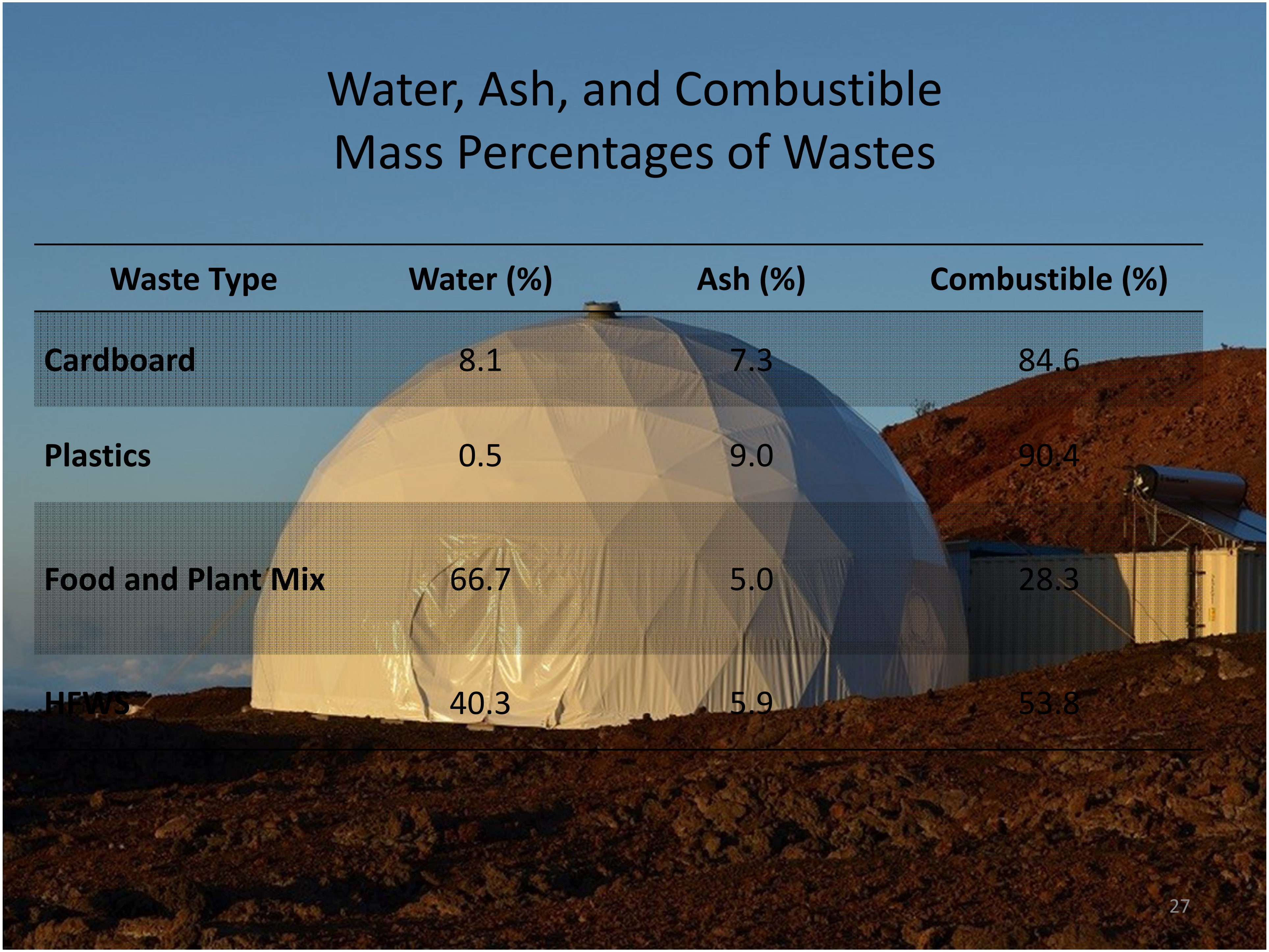
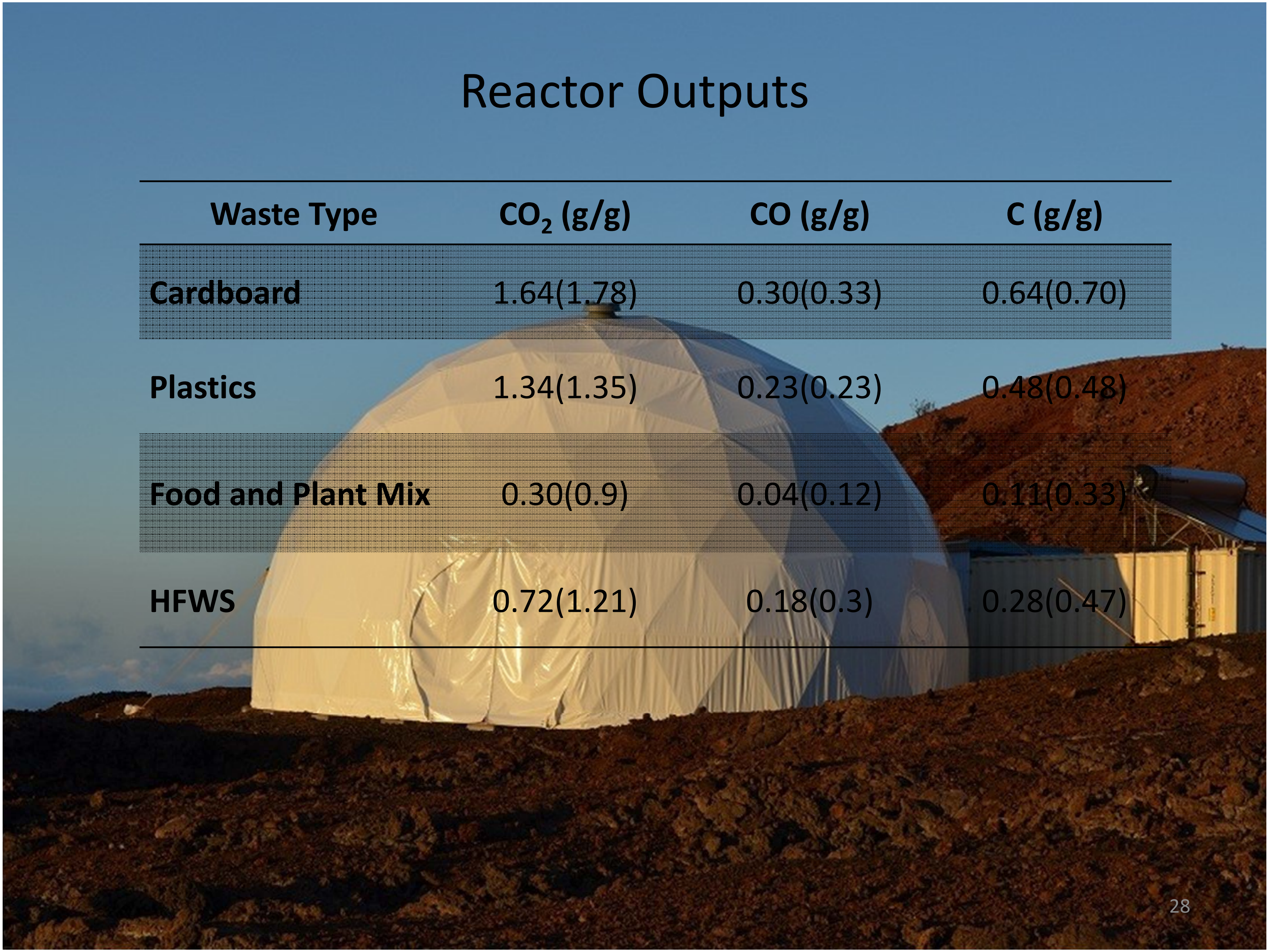
Backup Slides



Water, Ash, and Combustible Mass Percentages of Wastes

Waste Type	Water (%)	Ash (%)	Combustible (%)
Cardboard	8.1	7.3	84.6
Plastics	0.5	9.0	90.4
Food and Plant Mix	66.7	5.0	28.3
HFWS	40.3	5.9	53.8

Reactor Outputs

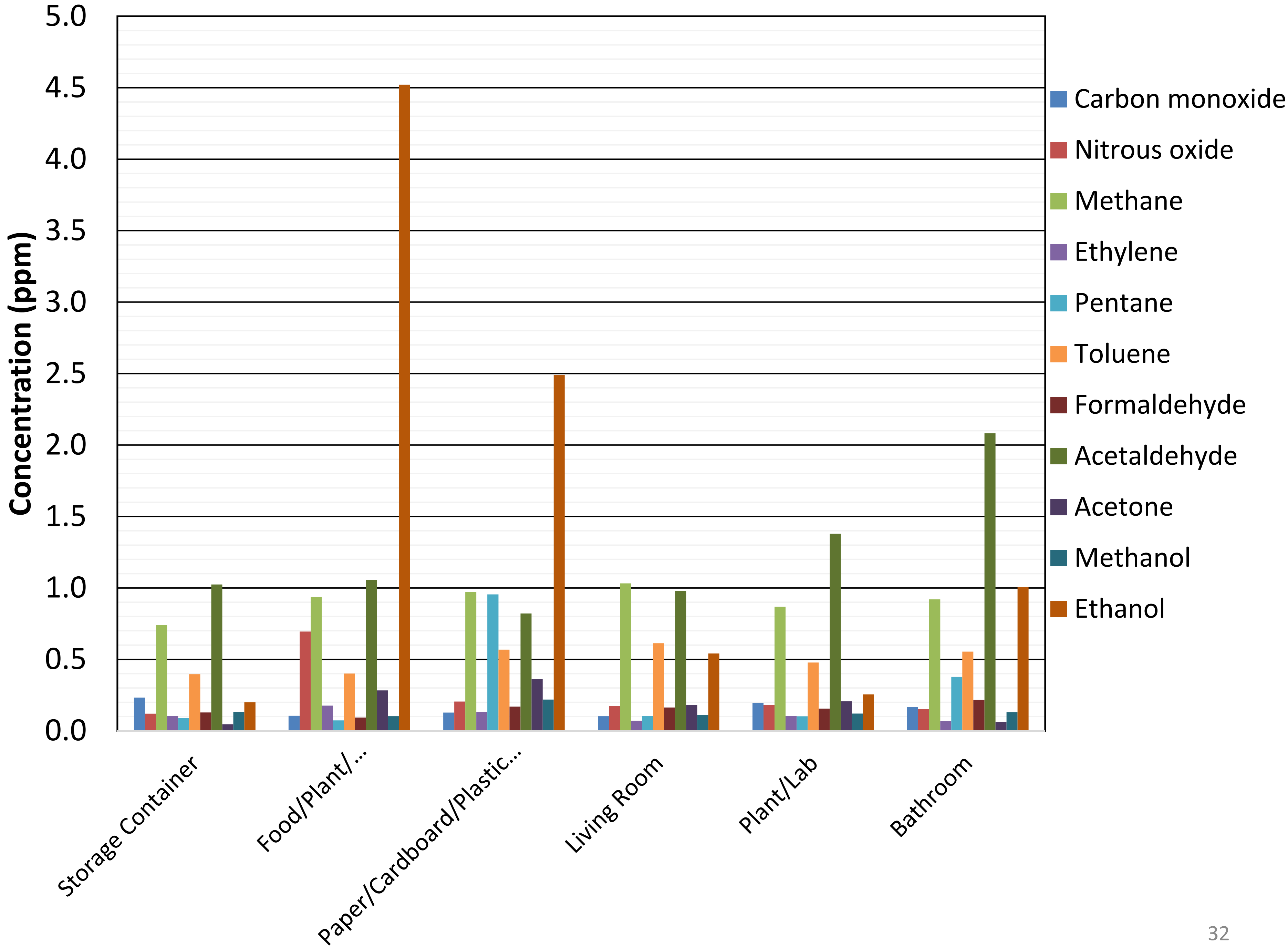


Waste Type	CO_2 (g/g)	CO (g/g)	C (g/g)
Cardboard	1.64(1.78)	0.30(0.33)	0.64(0.70)
Plastics	1.34(1.35)	0.23(0.23)	0.48(0.48)
Food and Plant Mix	0.30(0.9)	0.04(0.12)	0.11(0.33)
HFWS	0.72(1.21)	0.18(0.3)	0.28(0.47)

Fourier Transform Infrared Spectroscopy (FTIR)

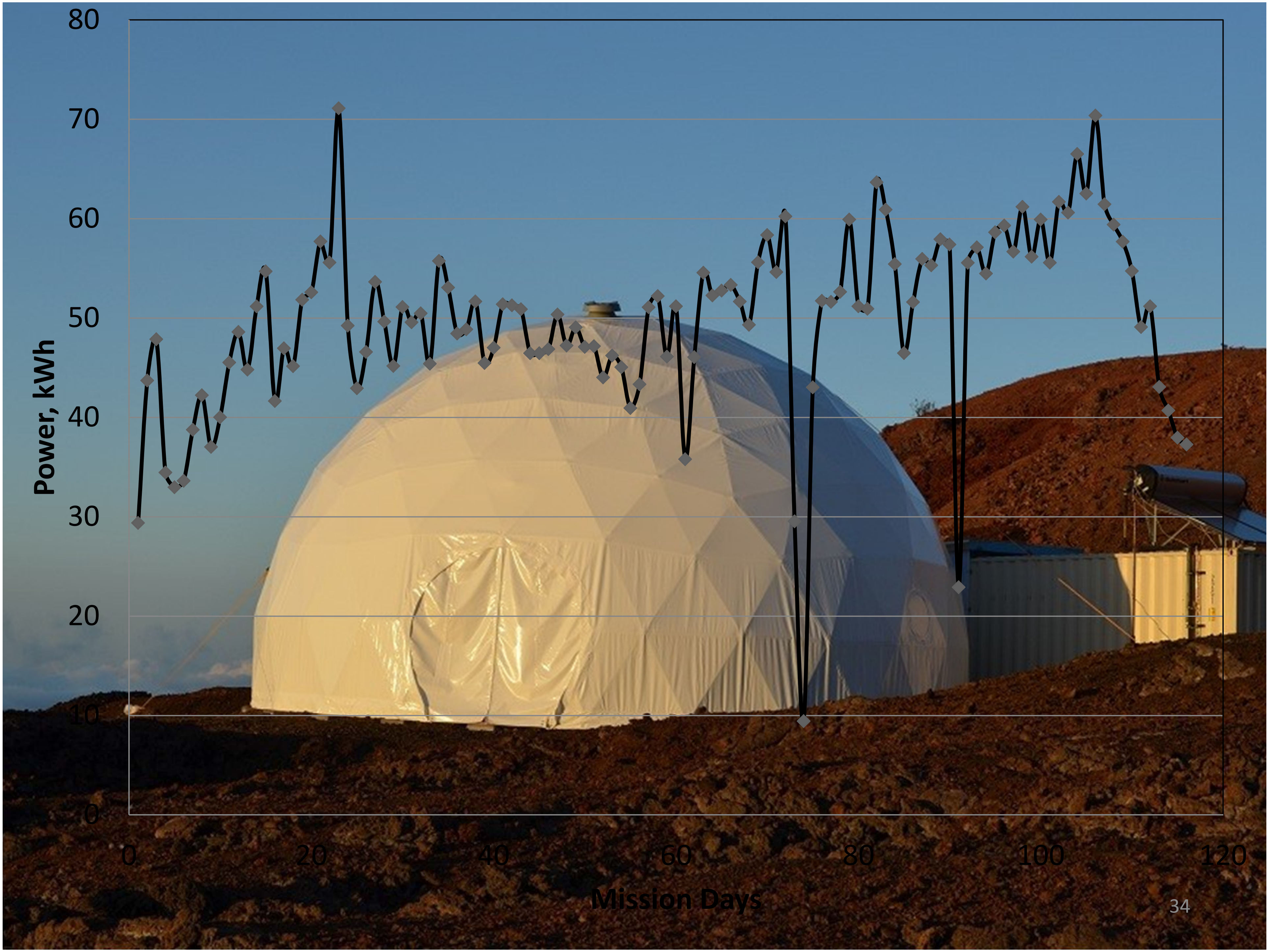

Annie Caraccio
TRASH TO GAS BIN
Do NOT MOVE!
Ziploc

FTIR RESULTS



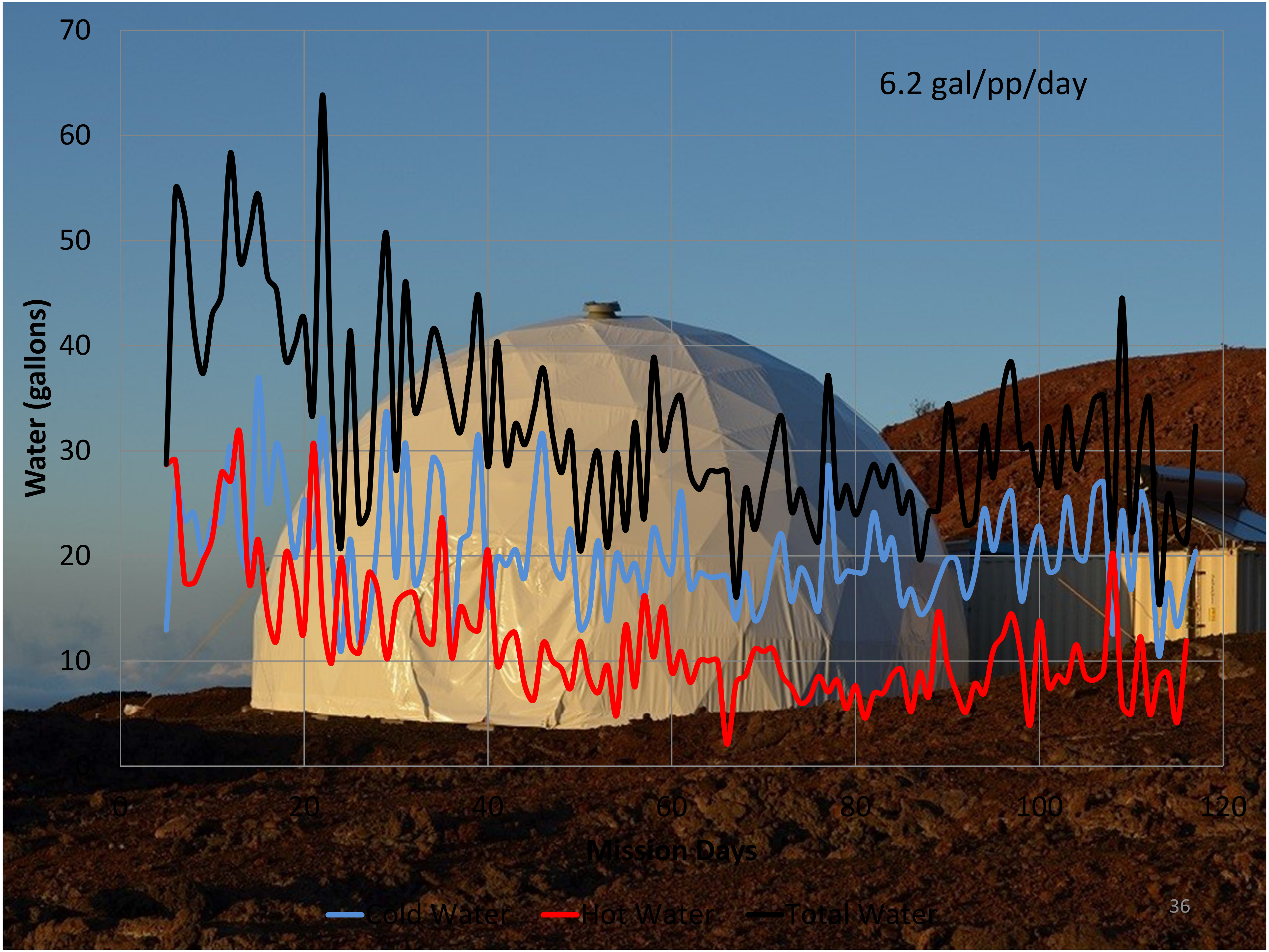
Concentration (ppm)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Storage Container
Food/Plant/...
Paper/Cardboard/Plastic...
Living Room
Plant/Lab
Bathroom
Carbon monoxide
Nitrous oxide
Methane
Ethylene
Pentane
Toluene
Formaldehyde
Acetaldehyde
Acetone
Methanol
Ethanol

Power Use



80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
Power, kWh
Mission Days

Water Consumption



6.2 gal/pp/day
Water (gallons)
Mission Days
0
10
20
30
40
50
60
70
0
20
40
60
80
100
120
Cold Water
Hot Water
Total Water