THE CHALLENGES OF DEVELOPING A FOOD SYSTEM FOR A MARS MISSIONS

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Overview

- Evolution of the Space Food System
- Introduce Advanced Food Technology Project
- Mars Mission
- Research Gaps
- Current Mars Mission Research

Evolution of the Space Food System

Changes to the space food system design are driven by:

- Knowledge of physiological processes in microgravity
  - *Swallowing and digestion in space* (1960s)
  - *Impact of salt on bone resorption* (2000s)
- Available food processing technology
- Available mission resources
  - *Food stowage volume, food mass*
  - *Power requirements*
  - *Trash volume, trash mass*
  - *Crew time*
- Mission duration
- Crew satisfaction

Evolution of the Space Food System

Mercury
1961-1963

- Highly engineered foods (Meal in a Pill concept) – cubes, tubes

Gemini
1965-1966

- Highly engineered food with new introductions
  (Pudding, Chicken and Vegetables)

Apollo
1968-1972

- Thermostabilized food, spoon bowl, natural form foods

Evolution of the Space Food System

Skylab
1973-1974

- Freeze-dried, thermostabilized, natural form and frozen foods
- No resupply – all food stored at the time of launch

Shuttle
1981-2011

- Higher quality food in lighter packaging
- Assignment of 9-month shelf life on food

International Space Station
2000-present

- Irradiated items (meats) through special FDA allowance.
- Aluminum film overwraps allow 12-18 month shelf life for most food.

General Food Requirements

- No refrigerators or freezers on board for food preservation although a small chiller was recently added on the International Space Station for chilling beverages
  - All food must be stable at room temperature for the required shelf life
- All food items are packaged in individual serving sizes
- Minimize crumbs
- Food needs to be wet enough so that surface tension allows for food to “stick” to package and utensils
- Utensils available – fork, 2 spoons, knife, and scissors
- Once food package has been opened or food has been hydrated, there is a potential for harmful bacteria to grow.
  - The food must be consumed within four hours. Otherwise, there is a chance of foodborne illness (nausea, vomiting, diarrhea)
- **18 month shelf life on International Space Station**

The Current Space Food System

Natural Form Foods

Rehydratable Foods

Intermediate Moisture Foods

Beverages

Irradiated & Thermo-stabilized Foods

Not pictured: Extended shelf-life breads and fresh food (limited basis)

Advanced Food Technology

- Develop a food system that is **Safe, Nutritious, Acceptable**

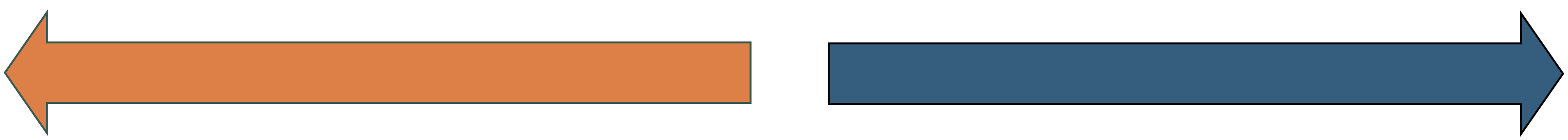
and

- Efficiently balances appropriate vehicle resources:

volume, **mass**, **waste**, **water**, **power**, **cooling**, **air**, **crew time**

However,

At times the objectives of AFT are at odds with one another.



Safe, Nutritious, Acceptable   Minimize Resources

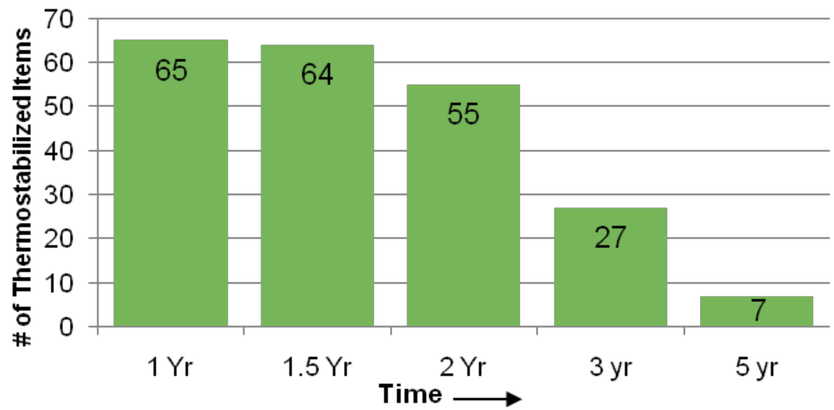
<u>Example</u>: To maintain an adequate food system may require more packaging mass which conflicts with minimization of mass.

Ultimate goal is to provide a food system that supports all aspects of a Mars mission.

Overview of Hypothetical Mars Expedition

- Approximately 2.5 year mission
  - Earth-to-Mars transit: ~6 months
  - Mars surface stay: ~18 months
  - Mars-to-Earth transit: ~6 months
- A 5-yr shelf life requirement is expected
  - Food prepositioning may be required to accommodate high mass and volume of food
  - Production and stowage will take time due to volume
- The current food system would become unacceptable before the mission ended
  - No refrigerators or freezers available for food preservation

Research Gap - Packaged Food Shelf Life of 5 Years



2010

2035

Formulation

Packaging

Processing

Nutritious

Safe

Acceptable with Adequate Variety

Minimize Resources

Research Gap - Optimized Food Packaging for NASA

Current Packaging

	Oxygen Permeability @ 73.4 °F,100% RH (cc/100in^2/day)	Water Vapor Permeability @ 100 °F,100% RH (g/100in^2/day)
Overwrap	0.0065	< 0.0003
Thermostabilized & Irradiated Pouch	< 0.0003	0.0004
Rehydratable Lid & Natural Form Pouch	5.405	0.352
Rehydratable Bottom (heat formed)	0.053	0.1784

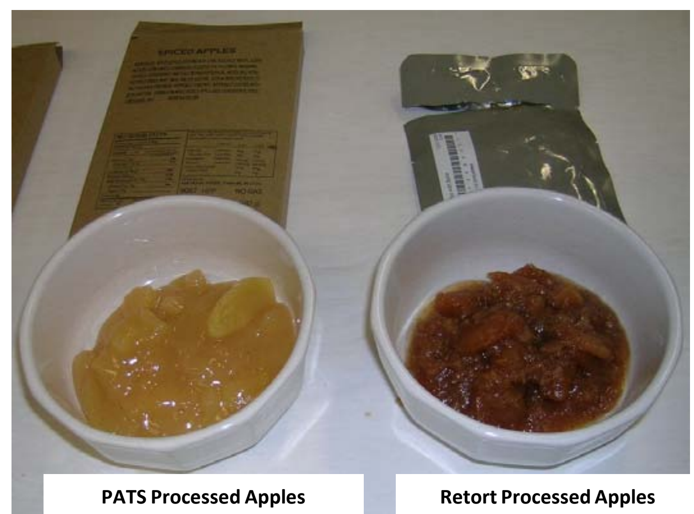
New Packaging

- Same barrier properties as the thermostabilized pouch
- No foil to accommodate microwave sterilization and pressure assisted thermal sterilization
- Flexible to accommodate vacuum packaging
- Transparent to view broken pieces

Research Gaps – Vitamin Delivery

- NASA food items – preliminary results
  - Retort process induces loss of vitamins A and C, thiamin, and folic acid
  - 1 year results
    - Vitamin A, folic acid, and thiamin continues to degrade over time
    - Vitamin C content is zero after one year of ambient storage
- Emerging technology such as PATS starts at a higher level of quality and over time may maintain vitamin content

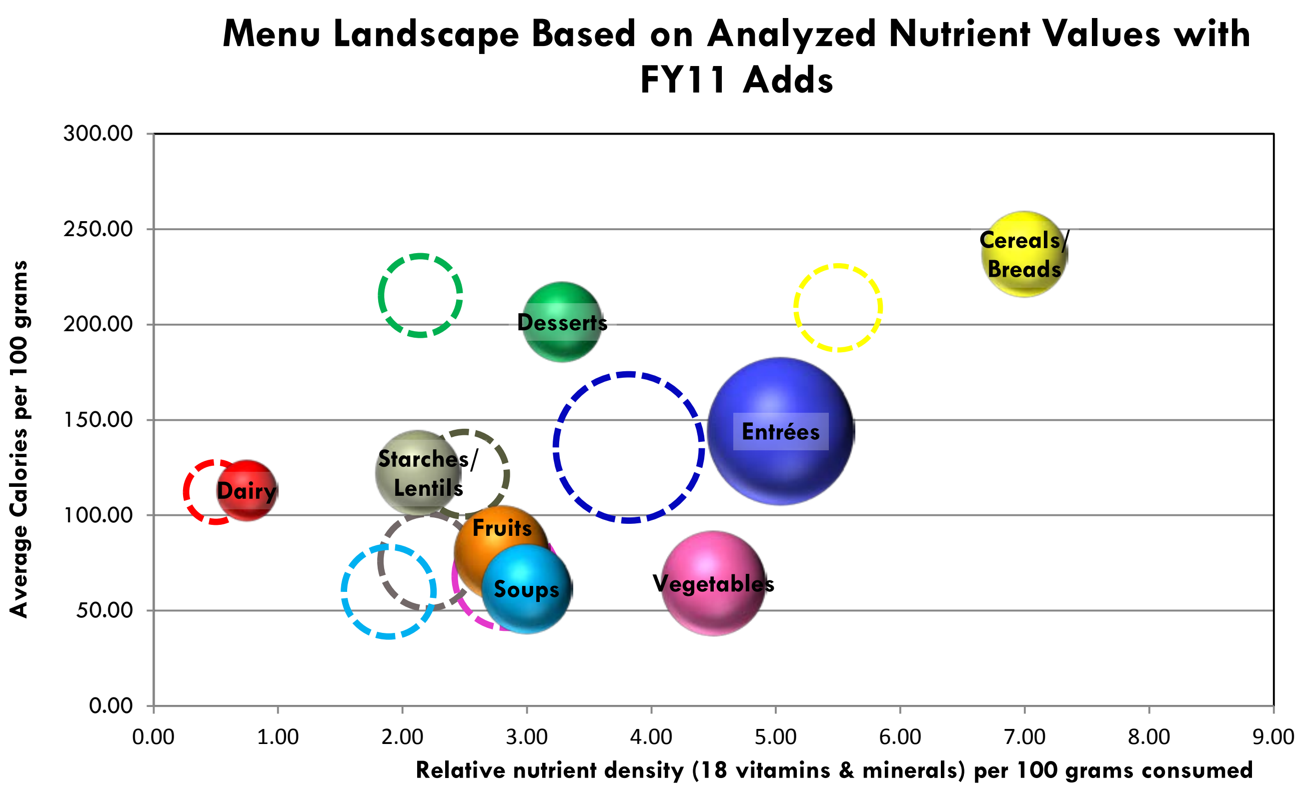
PATS Processed Pears | Retort Processed Pears



PATS Processed Apples | Retort Processed Apples

Effect of Processing and Storage on Nutrition

- <u>Objective</u>: Determine the impact of stabilization processing and the subsequent ambient storage on the nutrient profile of the current space foods.



Research Gaps – Nutrient Dense Foods

- Mass of transit food system for a Mars Mission has been estimated to be **9660kg**. Packaging waste is **1440kg** of this mass. (Assumes 100% stored food for 1000 days for a crew of 6)
  - 1.83 kg/person-per day

- Reduce the mass of the food by developing nutrient dense foods
  - Reduce water content
  - Increase fat content

  → mass decreased by 321 g per day, or 22%

  - Add meal replacement bars or nutrient rich beverages → mass decreased by 240 g per day, or 17%

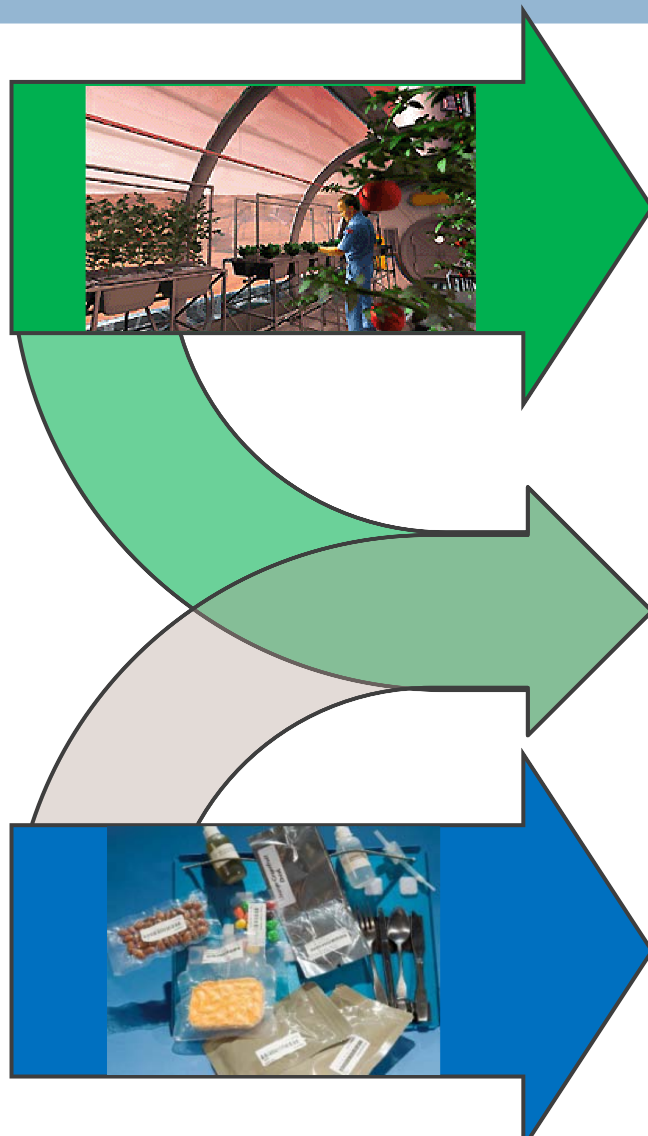
Combining both approaches , food system mass can be reduced by as much as 529 g, or 36%

Future Food System Paths

Key Assumptions

Bioregenerative & Bulk Ingredients Only

15 different crops (including soybeans and tomatoes) and 11 bulk ingredients plus minors are used in menu development and analysis.



Bioregenerative & Packaged Combo

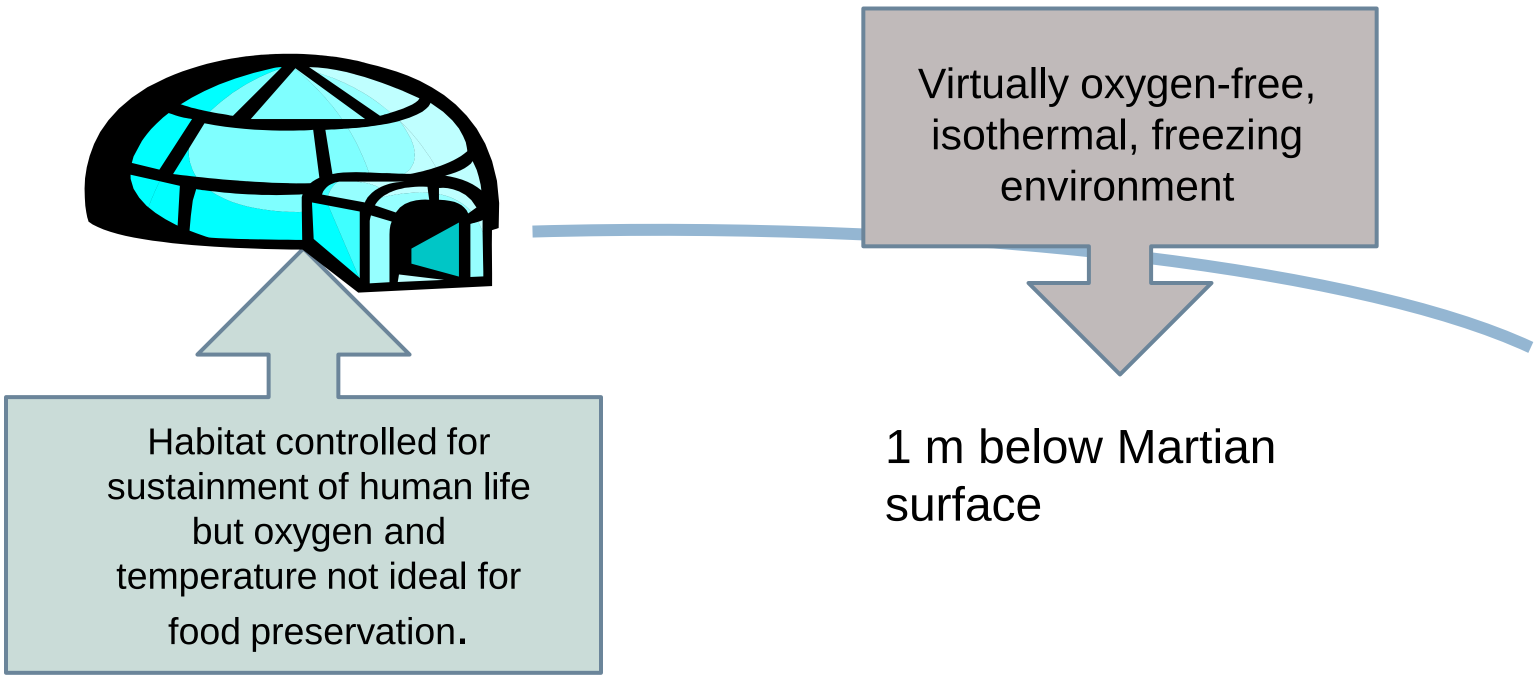
Only existing products with a shelf life > 3 years are used to supplement the above bioregenerative menu.

Packaged Foods Only

Frozen and refrigerated storage are presumed to deliver feasible food shelf life.

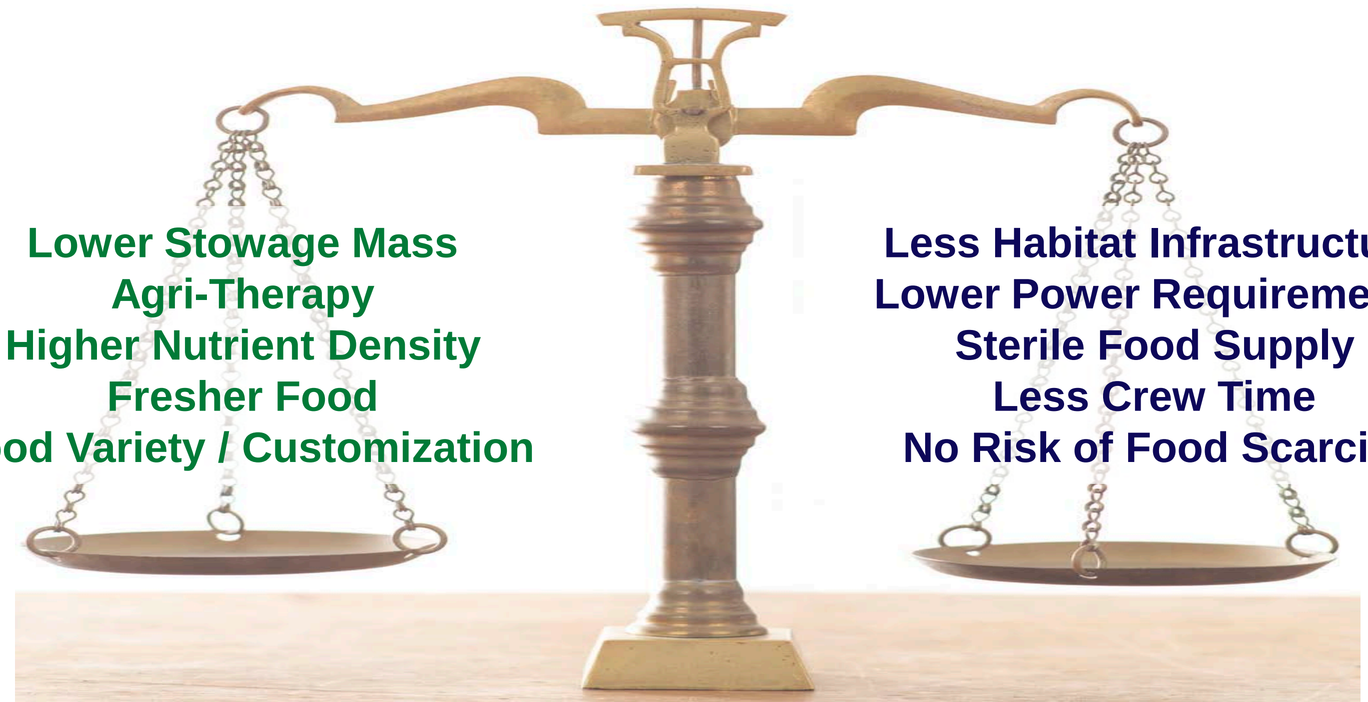
Integration of Product, Process, Package, and Environment

- <u>Objective</u>: Re-evaluate the main determinants of shelf life for current space food (product, process, package, and environment) such that the feasibility of attaining a 5-year shelf life for the packaged food system is determined.



Food Processing vs. Prepackaged Food Trade Study

- Objective: Compare the efficiencies and adequacies of growing produce and processing baseline crops into edible ingredients as compared to the efficiencies and adequacies of utilizing the existing prepackaged food system



Thanks to the AFT Team!

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Questions??