National Aeronautics and Space Administration

The Challenges of Developing a Food System for Space Exploration

Michele Perchonok, Ph.D.
Manager, Program Science Management Office
NASA Human Research Program

Layers at the Base of Mount Sharp (taken by Curiosity)

Evolution of the Space Food System

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

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

Apollo
- Thermostabilized food, spoon bowl, natural form foods

Evolution of the Space Food System

Skylab

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

Shuttle / MIR

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

International Space Station

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

Evolution of the 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)

Human Research Program Goal

The goal of HRP is to provide human health and performance

countermeasures,

knowledge,

technologies, and

tools

to enable safe, reliable, and productive human space exploration.

Food System Considerations

International Space Station:

- 6 month microgravity missions
- No refrigerators or freezers for food storage, all food processed and prepackaged
- Regularly scheduled resupply
- Eight day standard menu cycle augmented by crew preference foods

Mars Expedition Scenario:

- 2.5 year mission; microgravity and reduced gravity
- No refrigerators or freezers for food storage
- No resupply; food may be prepositioned to accommodate high mass and volume
- Current food system is mass constraining and will not maintain nutrition/acceptability

Advanced Food Technology

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

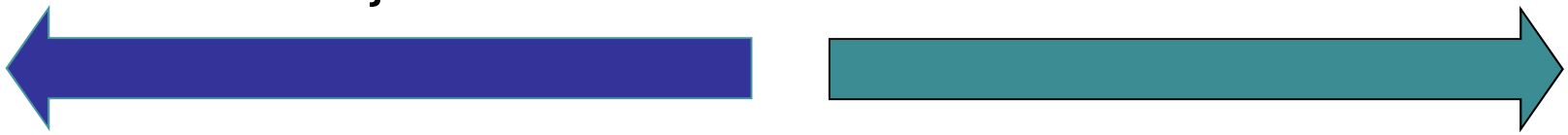
and

- 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.



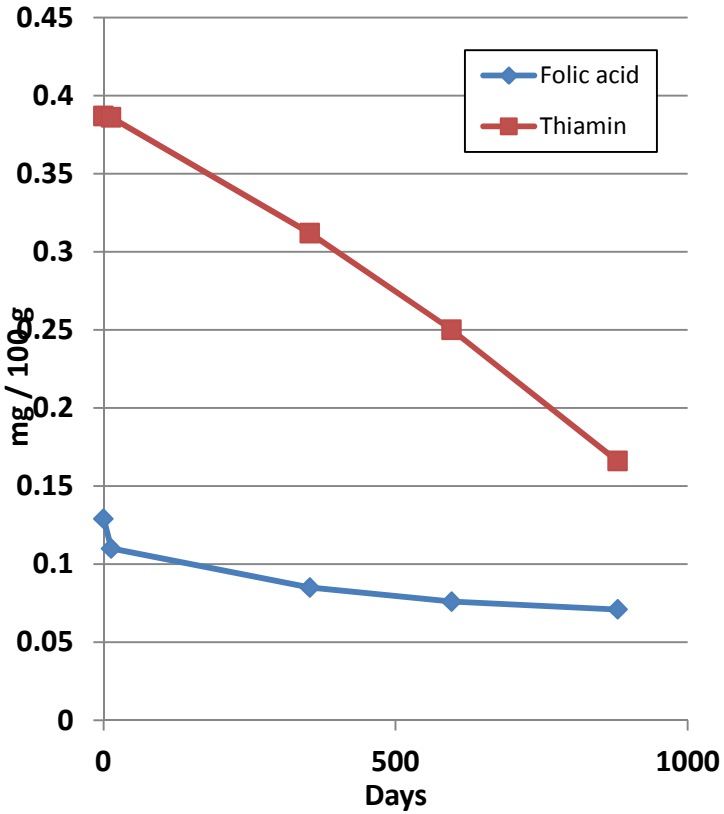
Safe, Nutritious, Acceptable Minimize Resources

<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.

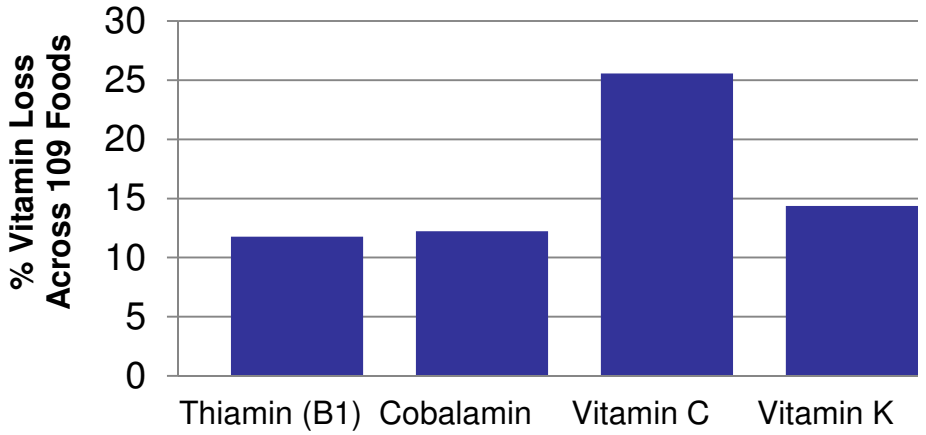
Effect of Storage Time on Nutrition

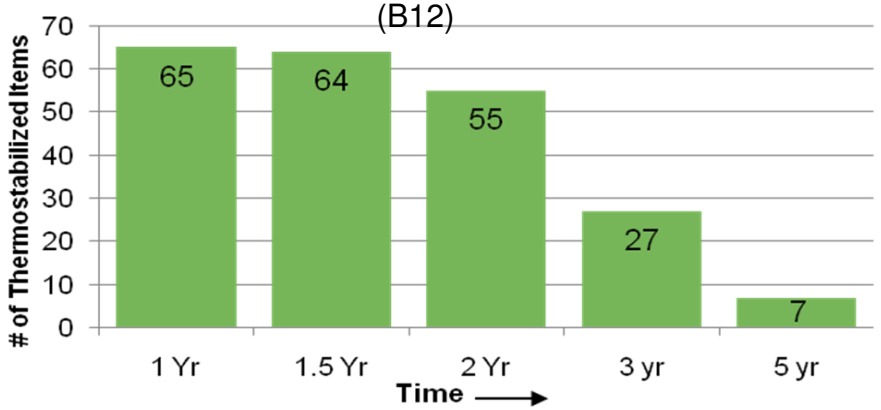
- Folic acid and thiamin degradation in tortillas over time (Zwart et al, 2009)



Nutrition and Acceptability Impacts of Room Temperature Storage

- Critical micronutrients show concerning degradation in space food system after 1 year of storage.
- Only 7 out of 65 thermostabilized foods are expected to be palatable after 5 years of storage. (Catauro. JFS. 2011)
- Current mass requirement for 3000 kcal per crewmember per day is 1.83 kg. Total mass for a Mars scenario (6 crewmembers, 1095 days) is 12,023 kg.





Prepackaged Food – 5 Year Shelf Life Challenge

Processing

Pressure Assisted Thermal Sterilization (PATS)

Lyophilization Improvement

Microwave Sterilization

3D Printing Technology (SBIR)

Packaging

Improve clarity

Improve barrier

Mass reduction

Formulation

Fortification

Food Matrix

Functional Foods

Meal Replacement

Environment

Atmosphere

Temperature

Radiation

Recently Completed AFT Projects

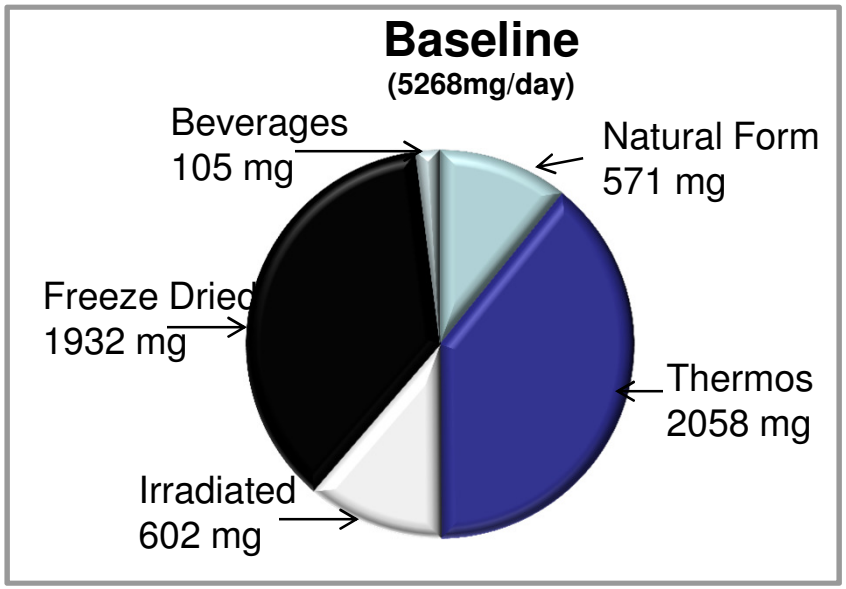
- <u>Food Processing vs. Packaged Food Study</u>
  Analyzed mass and crew time trades for bioregenerative food system compared to prepackaged; developed 90 formulations from 15 crops and 11 ingredients

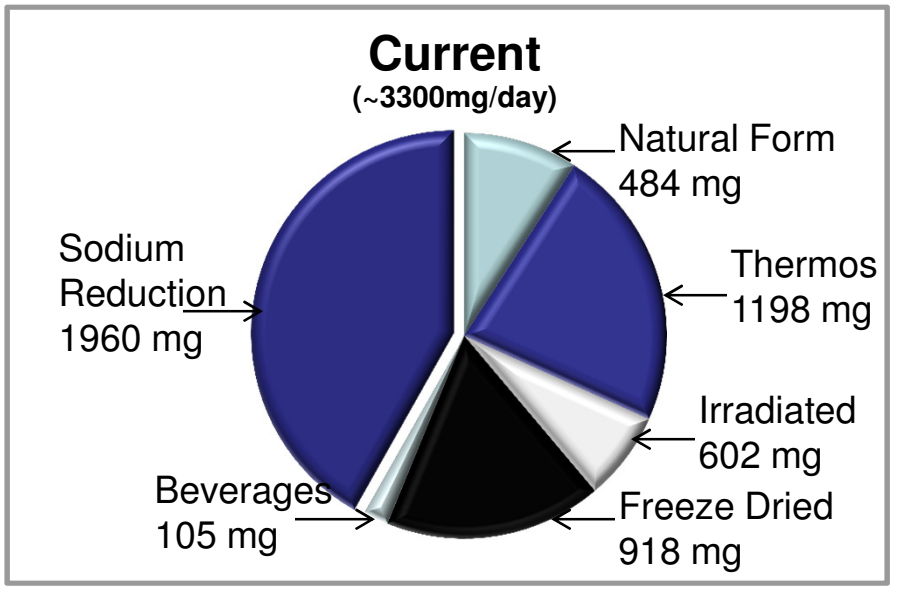
- <u>Mass Reduction Technology Development</u>
  Developed meal replacement bar and beverage prototypes with significant mass reduction capability

- <u>Suited Contingency Ops Food - 2</u>
  Developed delivery system prototype, both package and beverage requirements

Space Food System
Sodium Reduction Challenge

- Sodium exacerbates bone loss, possible factor in intracranial induced vision changes
- Reformulated 90 foods and reduced sodium content to ~3300 mg/d
- Maintained sensory acceptability similar to or better than original formulations (score of 6.0 or greater on a 9.0 point hedonic scale.





Future Food System Paths

Bioregenerative & Bulk Ingredients Only

Bioregenerative & Packaged Combo

Packaged Foods Only

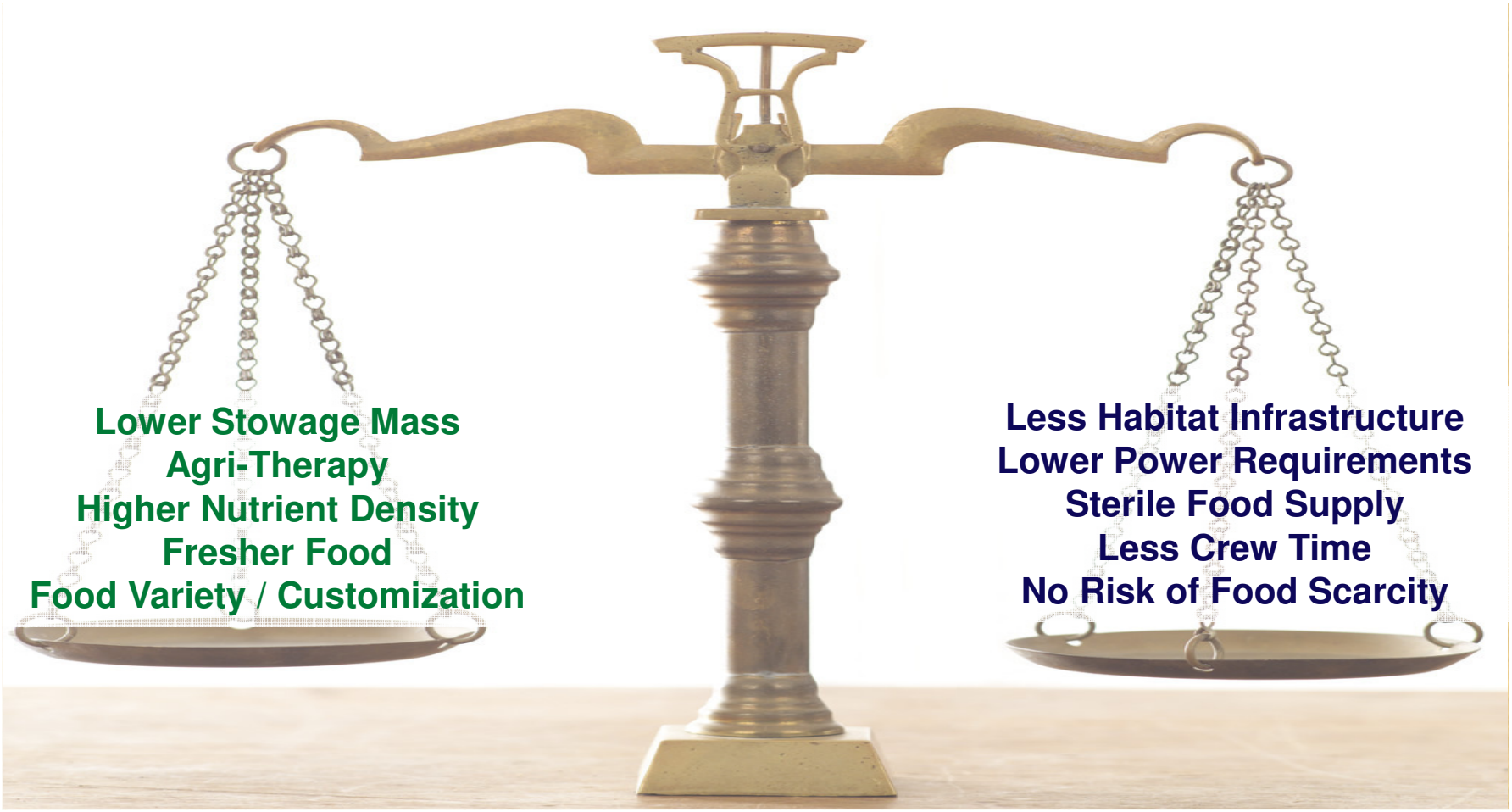
Key Assumptions

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

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

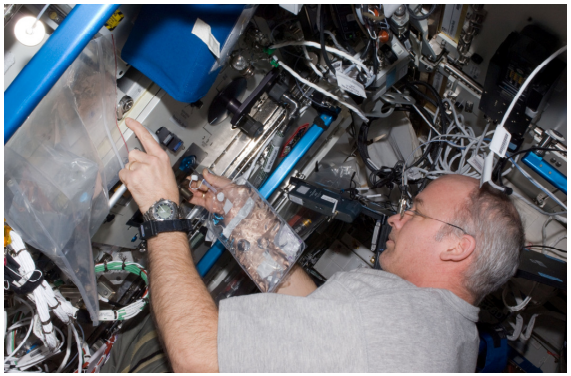
Frozen and refrigerated storage are presumed to deliver feasible food shelf life.

Food Processing vs. Prepackaged Food



Food Preparation Current to Future

Food Warmer



Potable Water Dispenser

From top left: A) Pressure cooker, (B) Juicer, (C) Soymilk Maker, (D) Dehydrator, (E) Stand Mixer, (F) Pasta press, (G) Immersion blender, (H) Tofu mold, (I) Grain mill, (J) Induction burner

Variety of Crops, No Animal Protein

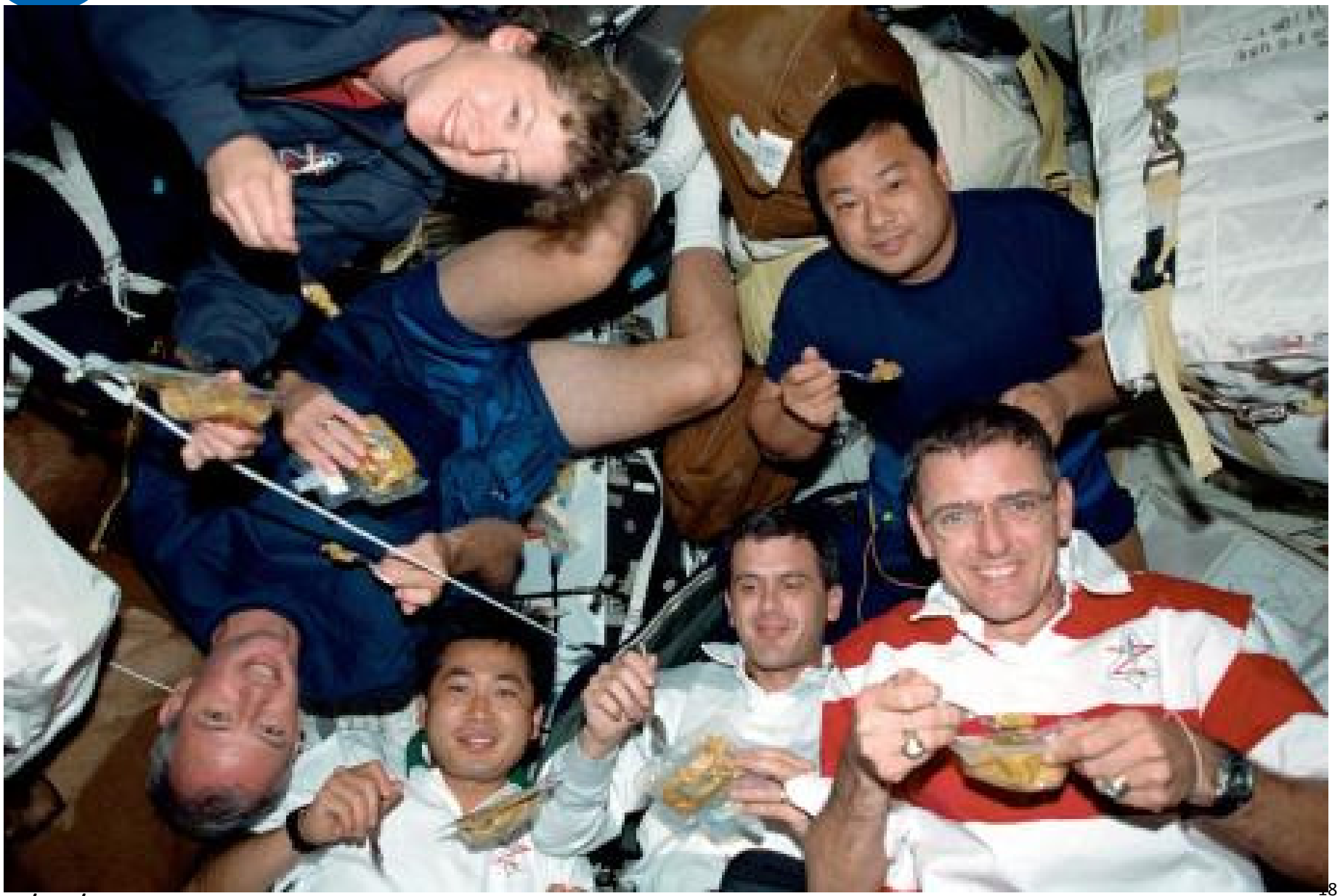
Lettuce	Tomato	Peas
Spinach	Strawberry	Snap Beans
Celery	Radish	Sweet Potato
Green Onion	Bell Pepper	White Potato
Carrot	Mushrooms	

Bulk Ingredients		
Rice	Peanuts / Peanut Oil	Soybeans
Dry Beans	Wheat Berries / Wheat Flour	

External Funded Research

- Department of Defense (DoD) Collaboration
  - Provides small amount of money to “get a seat at the table” with DoD consortiums/partnerships
- Small Business Innovative Research (SBIR)
  - Phase 1 (6 months) – Innovative concept feasibility
  - Phase 2 (2 years) – Deliverable “close” to commercialization
  - Topic descriptions can be changed annually
- NASA Research Announcement (basic research)
  - Cornell University
  - University of Minnesota
  - US Army Natick Soldier RD&E Center
- Innovation Opportunities
  - InnoCentive
  - Yet2.com
  - DeVenCI
  - NASA Human Health and Performance Center (NHHPC)

Questions



Thanks to current and former Advanced Food Technology Team Members!

Patricia Catauro
Maya Cooper
John Glass
Kimberly Glaus-Late
Vickie Kloeris
Monica Leong
Donna Nabors