The Challenges of Developing a Food System for a Mars Mission

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NASA Human Research Program

Layers at the Base of Mount Sharp (taken by Curiosity)
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.
## HRP Integrated Path to Risk Reduction

### Planetary DRM (Mars)

<table>
<thead>
<tr>
<th>Risks</th>
<th>FY14</th>
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<tbody>
<tr>
<td>Space Radiation Exposure (Radiation)</td>
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<td>Cognitive or Behavioral Conditions (BMed)</td>
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<td>Medications Long Term Storages (Stability)</td>
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<td>Vision Impairment/Intracranial Pressure (VIP)</td>
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<tr>
<td>Inadequate Food and Nutrition (Food)</td>
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### Team Performance Decrements (Team)

| Inflight Medical Conditions (Medical)      | 3x4  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Human-System Interaction Design (HSID)     | 3x4  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Bone Fracture (Fracture)                   | 3x4  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Renal Stone Formation (Renal)              | 3x4  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Sensorimotor Alterations (SM)              | 3x3  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Injury from Dynamic Loads (OP)             | 3x3  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Altered Immune Response (Immune)           | 3x3  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Host-Microorganism Interactions (Microhost)| 3x3  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Injury Due to EVA Operations (EVA)         | 3x3  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Hypobaric Hypoxia (ExAtm)                  | 3x3  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Sleep Loss (Sleep)                         | 3x3  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Reduced Muscle Mass, Strength (Muscle)     | 3x3  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Reduced Aerobic Capacity (Aerobic)         | 3x3  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Celestial Dust Exposure (Dust)             | TBD  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Decompression Sickness (DCS)               | 3x3  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Orthostatic Intolerance (OI)               | 3x2  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Cardiac Rhythm Problems (Arrhythmia)       | 3x4  |      |      |      |      |      |      |      |      |      |      |      |      |      |      |

### Milestones

- **ISS Required**
- **ISS Not Required**
- **Ground-based Milestones**
- **Mission Milestone**
- **Anticipated Milestone Shift**
- **End ISS**

### Legend

- **Hi LxC**
- **Mid LxC**
- **Low LxC**
- **Optimized**
- **Insufficient Data**
Ultimate goal is to provide a food system that supports all aspects of a Mars mission

- Develop a food system that is **Safe, Nutritious, Acceptable and**
- Efficiently balances appropriate vehicle resources such as: volume, mass, waste, water, power, cooling, air, crew time

**Example:** To maintain an adequate food system may require more packaging mass which conflicts with minimization of mass.
<table>
<thead>
<tr>
<th>Program</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>Mercury</strong></td>
<td>Highly engineered foods (Meal in a Pill concept) – cubes, tubes</td>
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<tr>
<td><strong>Gemini</strong></td>
<td>Highly engineered food with new introductions (Pudding, Chicken and Vegetables)</td>
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<tr>
<td><strong>Apollo</strong></td>
<td>Thermostabilized food, spoon bowl, natural form foods</td>
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## 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.
Current Space Food System – 130 options

- Natural Form Foods
- Rehydratable Foods
- Intermediate Moisture Foods
- Irradiated & Thermo-stabilized Foods
- Beverages

Not pictured: Extended shelf-life breads and fresh food (limited basis)
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 to eleven day standard menu cycle augmented by crew preference foods

Mars Expedition Scenario:
- 32 month mission; microgravity and reduced gravity
- Possibility of refrigerators or freezers for food storage
- No resupply; food may be prepositioned to accommodate high mass and volume
- Radiation impact is unknown
- Current food system is mass constraining and will not maintain nutrition/acceptability
**Prepackaged Food – 5 Year Challenge**

Focus on nutritional stability, acceptability, health promotion, and mass reduction

<table>
<thead>
<tr>
<th>Human Research Program</th>
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<tr>
<td><strong>Formulation</strong></td>
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<td><strong>Processing</strong></td>
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<td><strong>Packaging</strong></td>
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<td><strong>Environment</strong></td>
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<td><strong>Closed System</strong></td>
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</table>

**Fortification**
- Food Matrix
- Functional Foods
- Meal Replacement
- Variety

**Processing**
- Pressure Assisted Thermal Sterilization (PATS)
- Lyophilization Improvement
- Microwave Sterilization
- 3D Printing (SBIR)

**Packaging**
- Improve barrier
- Mass reduction
- In Suit Delivery System

**Environment**
- Atmosphere
- Temperature
- Radiation
- Microgravity
- Partial Gravity

**Closed System**
- Variety
- Limitations
- Psychosocial support
- Physiological impacts

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**Improved barrier**
- Mass reduction
- In Suit Delivery System

**Closed System**
- Variety
- Limitations
- Psychosocial support
- Physiological impacts

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**NASA**

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Psychology of Food

There are **psychological benefits** of the food system

- Socialization during mealtimes.
- **Food quality, variety and acceptability** are important. Highly acceptable food is a familiar element in an unfamiliar and hostile environment.
Taste Changes in Microgravity

There are anecdotal reports that food does not taste the same in space:

- 85 – 90% of what you taste is what you smell
- Hot air (volatiles) does not rise in microgravity
- Food is not heated to very hot temperatures
- Food is eaten out of packages with small openings
- Fluid shifts in the body result in a feeling of congestion in the nasal passages
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)
Mass Reduction Opportunities

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.

Orion has challenged the food system to a 25% mass reduction

- Four **Meal Replacement Bars** enabling 10% reduction in mass developed through Natick (NSRDEC); acceptability testing underway in four 2016 HERA missions; stability testing through 2018

- In the event of cabin depressurization, crewmembers may be required to don pressurized suits and will require nutrition during contingency operations
  - Guidelines were determined for contingency beverages that meet macro-nutritional requirements, a minimum one-year shelf life, and compatibility with the delivery hardware. These beverages could reduce mass for nominal operations
Integrate Bioregenerative Foods

International Space Station
Supplement prepackaged with “Pick and Eat” beginning with Veggie chamber

Mars Scenario
Optimize mission specific phased implementation and balance with prepackaged foods – based on nutrition, acceptability, resources

Research gaps
Infrastructure, resource use, radiation effects, safe handling/micro procedures, system integration, crew time usage
Potential Exploration Food Systems

**Prepackaged**
- Less Infrastructure
- Reduced Micro Risk
- Less Crew Time
- No Risk of Food Scarcity
- Nutrient Degradation
- Quality Loss
- High Mass and Volume
- No customization

**Bioregenerative**
- Lower Food Stowage Mass
- Agri-Therapy
- Higher Nutrient Density
- Fresher Food
- Variety / Customization
- High Crew Time
- Microbiological Risk
- Infrastructure
- Risk of Food Scarcity
### Possible Bioregenerative Food System

#### Greenhouse Crops

<table>
<thead>
<tr>
<th>Greenhouse Crops</th>
<th>Lettuce</th>
<th>Tomato</th>
<th>Peas</th>
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<tbody>
<tr>
<td>Spinach</td>
<td>Strawberry</td>
<td>Snap Beans</td>
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<tr>
<td>Celery</td>
<td>Radish</td>
<td>Sweet Potato</td>
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<tr>
<td>Green Onion</td>
<td>Bell Pepper</td>
<td>White Potato</td>
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<tr>
<td>Carrot</td>
<td>Mushrooms</td>
<td>Dwarf Plum</td>
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#### Bulk Ingredients

<table>
<thead>
<tr>
<th>Bulk Ingredients</th>
<th>Rice</th>
<th>Peanuts / Peanut Oil</th>
<th>Soybeans</th>
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<tbody>
<tr>
<td>Dry Beans</td>
<td>Wheat Berries / Wheat Flour</td>
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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
Thanks to current and former HRP Advanced Food Technology Team Members!
Questions?

Mars Explorers Wanted Poster