

The Challenges of Developing a Food System for a Mars Mission

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

JOURNEY TO MARS



HUBBLE SPACE
TELESCOPE

INTERNATIONAL
SPACE STATION

SPACE LAUNCH
SYSTEM

ORBITERS

LANDERS

TECHNOLOGY
EXPLORATION
SCIENCE

DEIMOS
PHOBOS

MARS
TRANSFER
HABITAT

COMMERCIAL
CARGO AND CREW

ORION
CREWED
SPACECRAFT

SOLAR
ELECTRIC
PROPULSION

ASTEROID
REDIRECT
MISSION

MISSIONS: 6-12 MONTHS
RETURN: HOURS

EARTH RELIANT

MISSIONS: 1-12 MONTHS
RETURN: DAYS

PROVING GROUND

MISSIONS: 2-3 YEARS
RETURN: MONTHS

EARTH INDEPENDENT



Human Research Program

Human Research Program

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)		FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28
Risks	LxC	ISS 1YM	Asteroid Phase A	CCP				EM-2	AARM	EM-3	EM-4	EM-5	ISS End	EM-6 (ARCM)		Mars Phase A
Space Radiation Exposure (Radiation)	3x4	Acute CNS Risk Characterized → NASA Cancer Risk Model v2020 → Late CNS Risk Characterized → Acute CNS Stds Updated → NASA Cancer Risk Model 2025														
Cognitive or Behavioral Conditions (BMed)	3x4	Risk Factors Understood → Monitoring Tools Developed → CMs & Treatment Developed														
Medications Long Term Storage (Stability)	3x4	Most Common Usage Determined → Ground Stability Testing Complete → Stability Testing → TRG Validated Stability Device → Med Usage Understood														
Vision Impairment/Intracranial Pressure (MIP)	3x4	Potential CNS Damage → CMs Optimized														
Inadequate Food and Nutrition (Food)	3x4	Updated Nutritional Requirements to AFT → CM Validated → FOOD-02 Risk Understood → FOOD-01 Risk Understood → Mqts & Tools Validated → Nutrition Optimized														
Team Performance Decrements (Team)	3x4	Standards Dev & Val → Standards Validated														
Inflight Medical Conditions (Medical)	3x4	Initial Concept of Operations → Integrated Medical System → ConOps for all DRMs → Pharmacy Recommendation → Select Technologies → Optimized Medical Syst														
Human-System Interaction Design (HSID)	3x4	HARI Risk Understood → TRAIN Risk Understood → NHV Validate → TASK CM Validated → HCI CM Validated → TRAIN CM Validated → HARI CM Validated														
Bone Fracture (Fracture)	2x4	Update Bone Std → Fracture Risk Characterized → Osteo Risk Understood → Risk Quantification Updated → In-flight CM Validated														
Renal Stone Formation (Renal)	3x4	CMs Validated → Treatment Validated → Treatment Validated														
Sensorimotor Alterations (SM)	3x3	Standard Update → Risk Understood → CMs Developed Standard Validated → Inflight CMs Validated														
Injury from Dynamic Loads (OP)	3x3	Standards Update → Validated Analytical Tool → Risk Characterized, Standard Updated														
Altered Immune Response (Immune)	3x3	Determine clinical significance of altered imm response → Analog Identified → Risk Characterized/Identify CM → Inflight CM Validated														
Host-Microorganism Interactions (Microhost)	3x3	MICRO-02 Inform Risk → Inform Risk MICRO-04 & 05 → MICRO-03 Inform Risk → Develop Virulence Countermeasures														
Injury Due to EVA Operations (EVA)	3x3	Suit Injury Data Identified → Update Suit Requirements → Updated Requirements for Suit, Crew, and Ops														
Hypobaric Hypoxia (ExAtm)	3x3	Short Duration Interim Review → Short term Chamber Eval Down-select → Risk Characterized														
Sleep Loss (Sleep)	3x3	Key Monitoring Tools Developed & Validated → Risk Understood → Key CMs Individualized & Validated → Integrated Monitoring Tools/CMs Validated														
Reduced Muscle Mass, Strength (Muscle)	3x3	Standard Update → Standard Validated → Inflight CM Validated Current Hardware → Inflight CM Validated Exploration Hardware														
Reduced Aerobic Capacity (Aerobic)	3x3	Standard Update → Standard Validated → Inflight CM Validated Current Hardware → Inflight CM Validated Exploration Hardware														
Celestial Dust Exposure (Dust)	TBD	Initial Risk Characterization Mars Dust														
Decompression Sickness (DCS)	3x3	Standard Update → Risk Understood → Risk Model Defined														
Orthostatic Intolerance (OI)	3x2	In-/Post-flight CM Validated														
Cardiac Rhythm Problems (Arrhythmia)	3x4	Risk Understood														
Concern of Intervertebral Disc Damage (IVD)	TBD	Inflight Monitoring Method Validated → Risk Understood, CM Identified														
Concern of Effects of Medication (PK/PD)	TBD	Most Common Usage Determined → PK/PD Risk Characterization														

ISS Required
 ▲ Milestones Requires ISS
 ▼ ISS Mission Milestone
 Anticipated Milestone Shift
 End ISS
ISS Not Required
▲ Ground-based Milestones
▼ Mission Milestone
 Hi LxC
 Mid LxC
 Low LxC
 Optimized
 Insufficient Data

Accepted Risks

Concerns



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

Human Research Program

- 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.



Evolution of the Space Food System

Human Research Program

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

Human Research Program

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

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Natural
Form
Foods

Beverages

Rehydratable
Foods

Intermediate
Moisture
Foods

Irradiated &
Thermo-
stabilized
Foods



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



Food System Considerations

Human Research Program



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

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Formulation



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



21°C

-80°C

Atmosphere

Temperature

Radiation

Microgravity

Partial Gravity

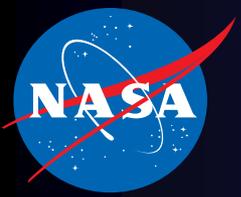
Closed System



Variety Limitations

Psychosocial support

Physiological impacts



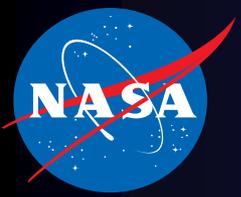
Psychology of Food

Human Research Program

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

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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

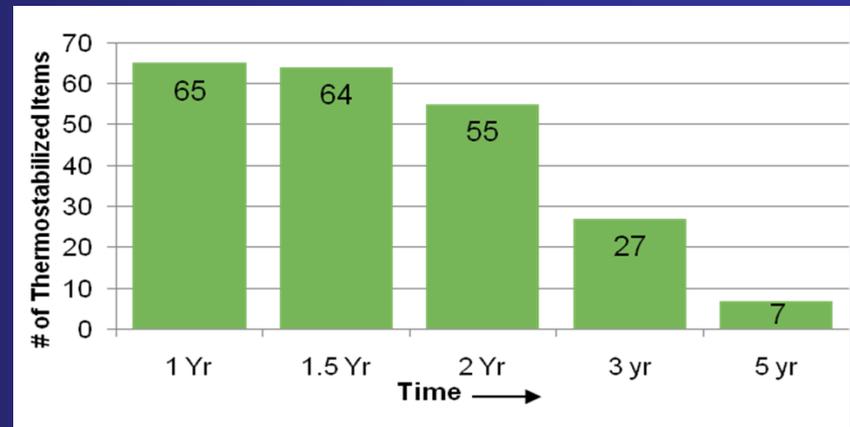
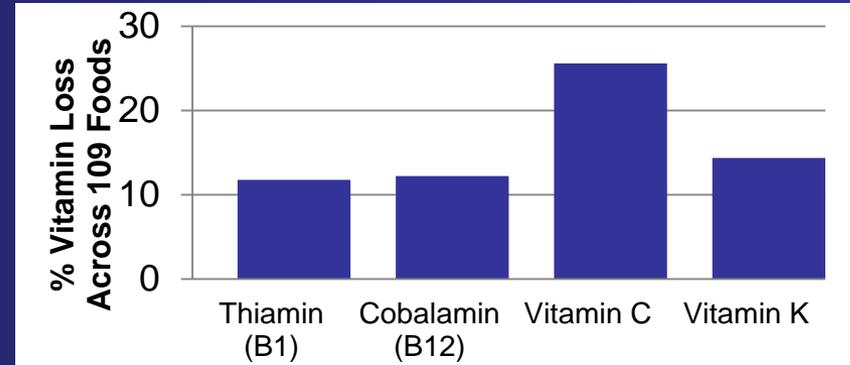




Nutrition and Acceptability Impacts of Room Temperature Storage

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- 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

Human Research Program

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

Human Research Program

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

Human Research Program

Prepackaged

Less Infrastructure
Reduced Micro Risk
Less Crew Time
No Risk of Food Scarcity

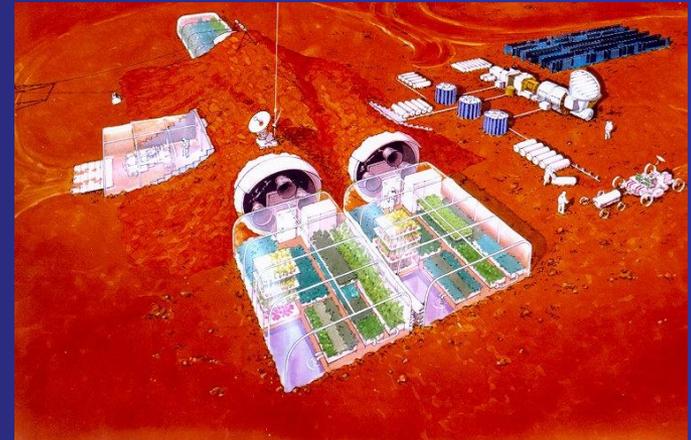
Nutrient Degradation
Quality Loss
High Mass and Volume
No customization



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

Human Research Program

Greenhouse Crops

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

Bulk Ingredients

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



Food Preparation Current to Future

Human Research Program

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!**





FARMERS WANTED

Questions?

Mars Explorers Wanted Poster

<http://mars.nasa.gov/multimedia/resources/mars-posters-explorers-wanted/>