National Aeronautics and Space Administration

Food in microgravity and beyond: How NASA scientists deliver ‘the right stuff’

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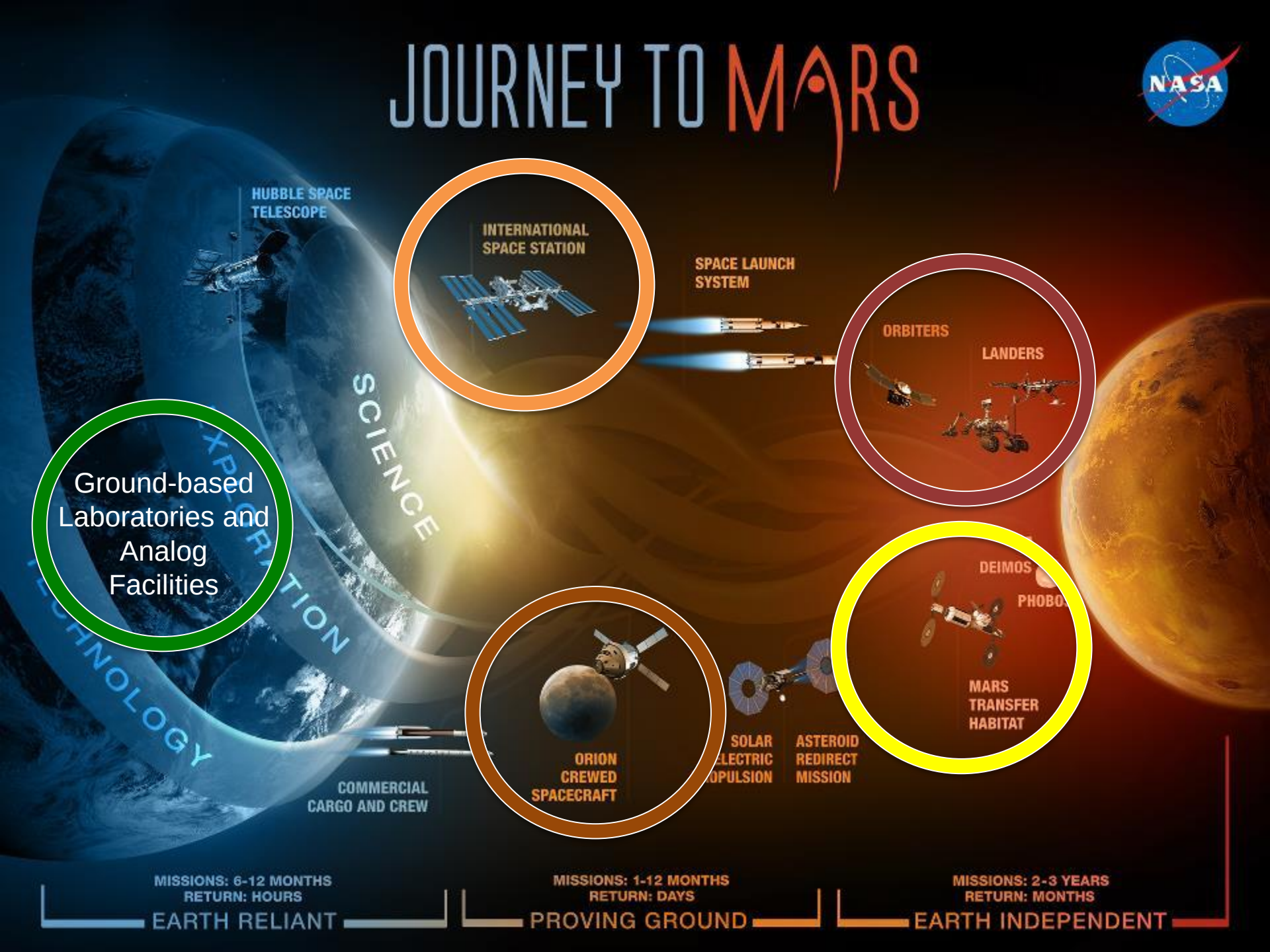
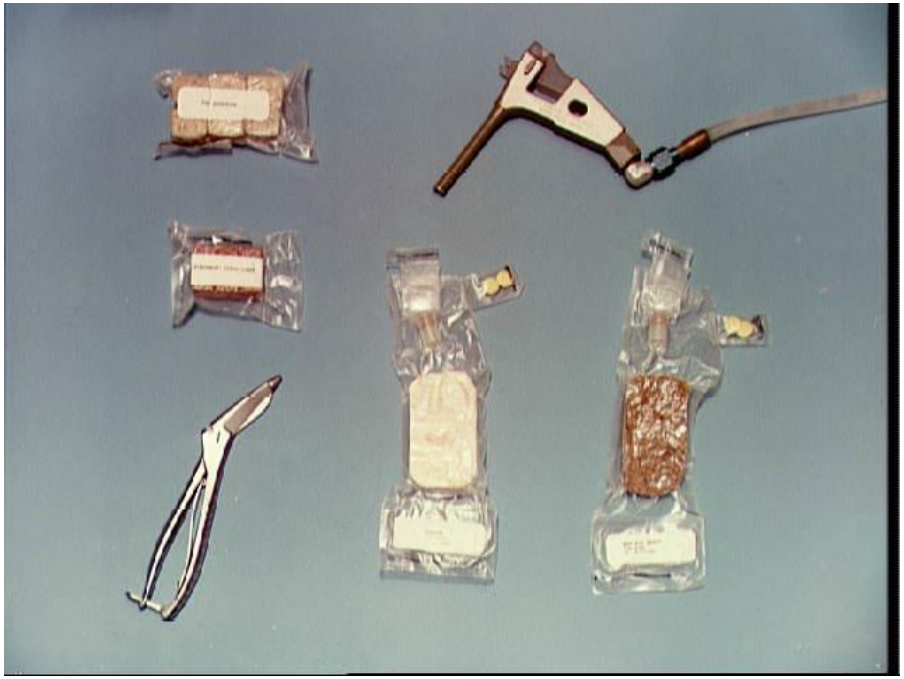

JOURNEY TO MARS
NASA
HUBBLE SPACE TELESCOPE
INTERNATIONAL SPACE STATION
SPACE LAUNCH SYSTEM
ORBITERS
LANDERS
SCIENCE
EXPLORATION
TECHNOLOGY
Ground-based Laboratories and Analog Facilities
DEIMOS
PHOBOS
MARS TRANSFER HABITAT
ORION CREWED SPACECRAFT
SOLAR ELECTRIC PROPULSION
ASTEROID REDIRECT MISSION
COMMERCIAL CARGO AND CREW
MISSIONS: 6-12 MONTHS
RETURN: HOURS
EARTH RELIANT
MISSIONS: 1-12 MONTHS
RETURN: DAYS
PROVING GROUND
MISSIONS: 2-3 YEARS
RETURN: MONTHS
EARTH INDEPENDENT

Space Food System Challenges

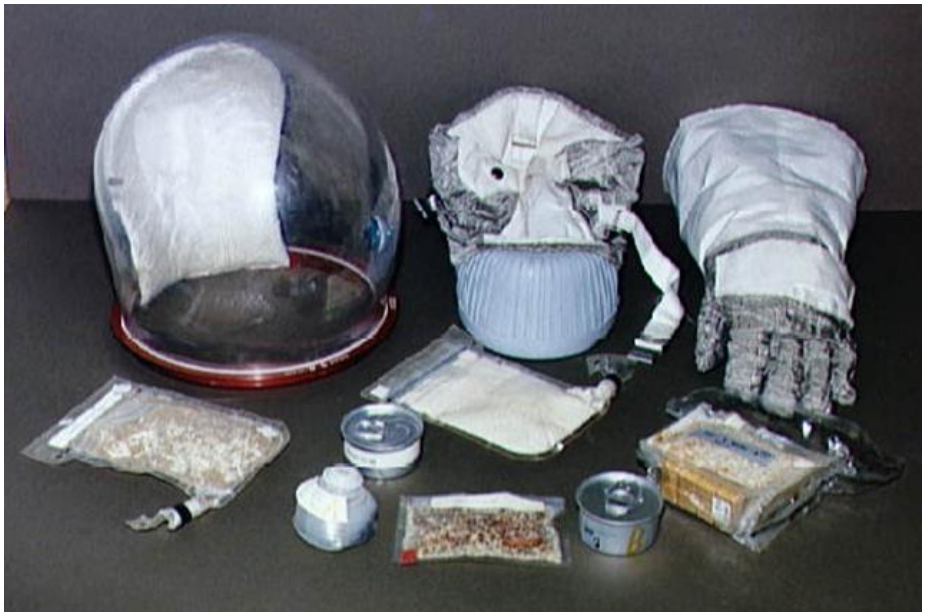
Mercury and Gemini 1961-1966

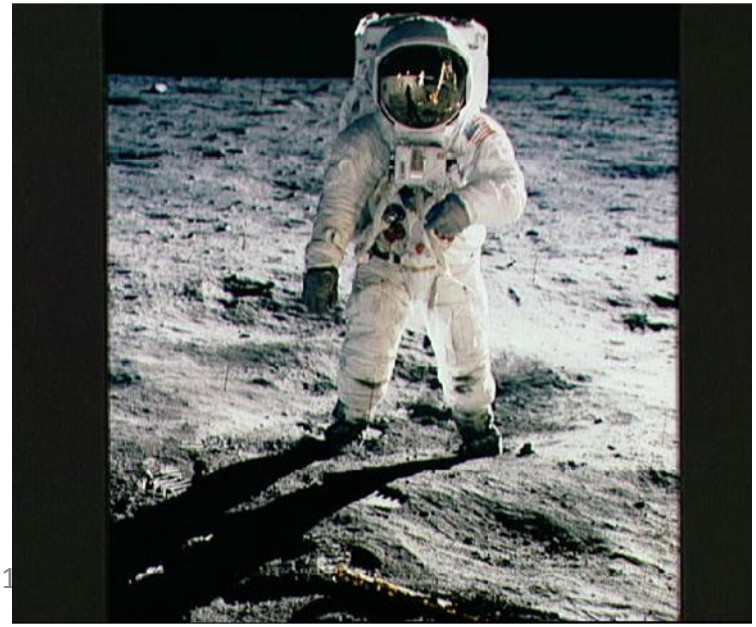
- Highly engineered
  - Cubes and Tubes
  - Freeze-dried



Apollo 1968-1972

- Addition of
  - Thermostabilized cans and pouches
  - Spoon bowls
  - Natural form foods



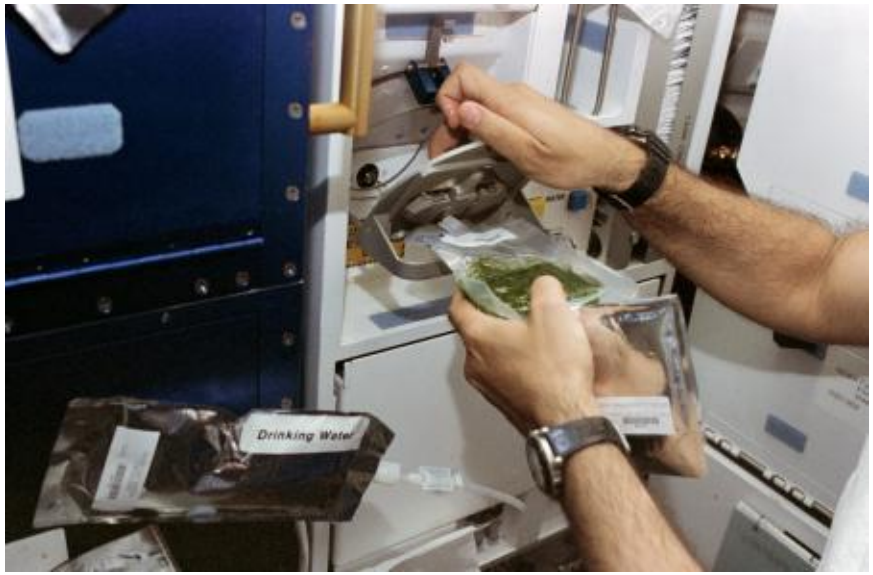


Skylab 1973-1979

- Continued to include freeze-dried and thermostabilized foods
- Only space missions to include frozen foods

Shuttle 1981-2011

- Higher quality food
- Lighter weight/flexible packaging
- Food trays
- Galley to heat/rehydrate food



International Space Station 1998-present

Space Food Evolution

Mercury and Gemini

Tubes and cubes, some rehydratables

Apollo

Hot water, utensils and canned foods

Limited, consistent body mass loss

Shuttle

Approximately 120 menu items

Crew preference menus

Consistent body mass loss

ISS Food System: E1-16

- Food packed to crew preference menus, 120 menu items available
- Resupply delays = menus did not coincide with correct crew
- Average BODY MASS LOSS ~5%. Results in significant bone and muscle loss, cardio deconditioning

ISS Food System: E16-current

8 Standard Menu Categories packed in BOBs

Breakfast

Vegetables and Soups

Rehydratable Meats

Beverages

Fruit and Nuts

Meat and Fish

Side Dishes

Desserts and Snacks

Limited crew specific food, fresh food, condiments available

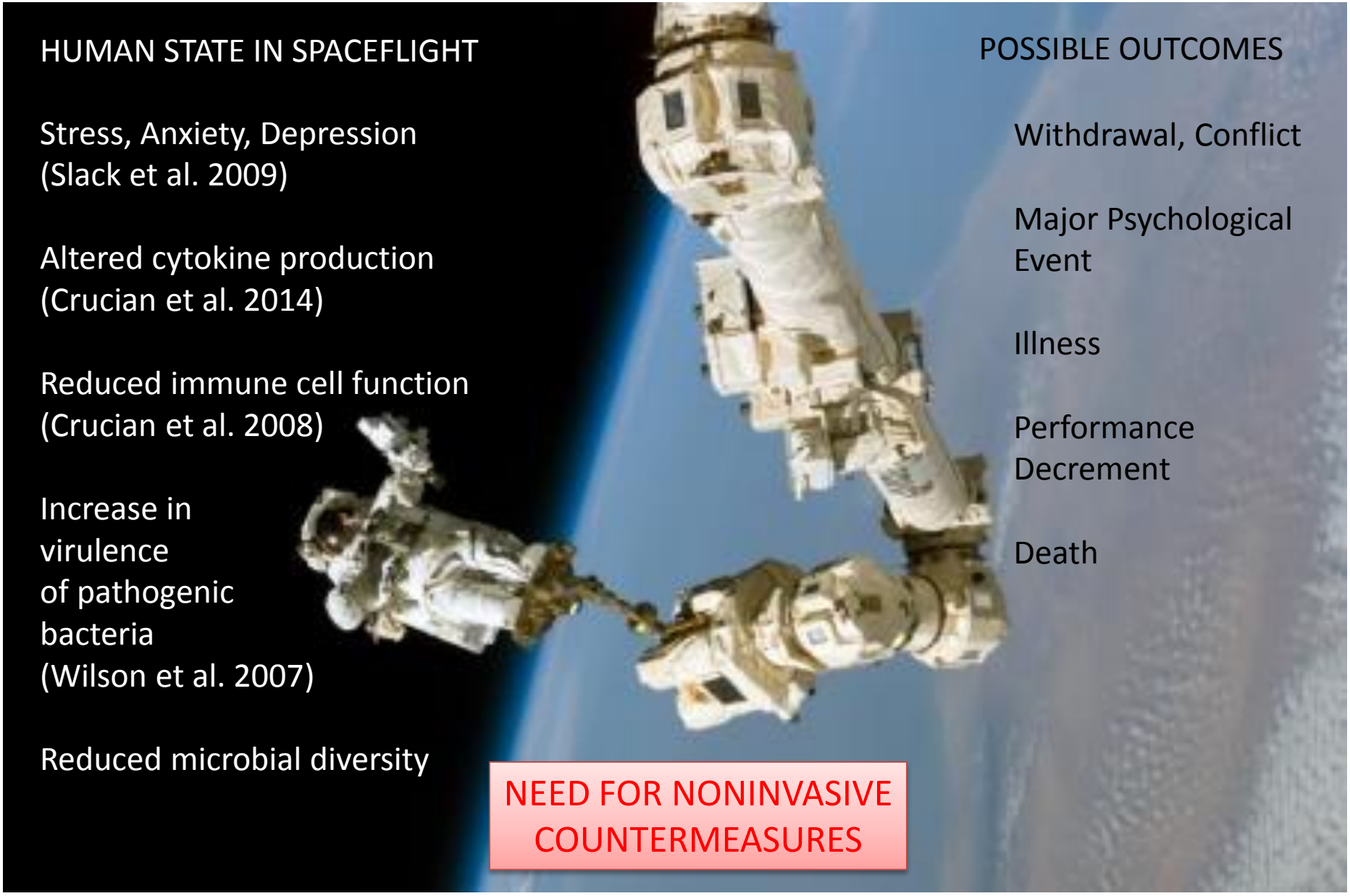
Bulk Overwrap Bag (BOB)

200 Menu items available

- New bags are opened every 7 to 9 days based on a crew's calculated caloric needs.

With this food system and resistive exercise, many crew maintained body mass and bone density

Humans in Space



HUMAN STATE IN SPACEFLIGHT

Stress, Anxiety, Depression
(Slack et al. 2009)

Altered cytokine production
(Crucian et al. 2014)

Reduced immune cell function
(Crucian et al. 2008)

Increase in
virulence
of pathogenic
bacteria
(Wilson et al. 2007)

Reduced microbial diversity

POSSIBLE OUTCOMES

Withdrawal, Conflict

Major Psychological Event

Illness

Performance Decrement

Death

NEED FOR NONINVASIVE COUNTERMEASURES

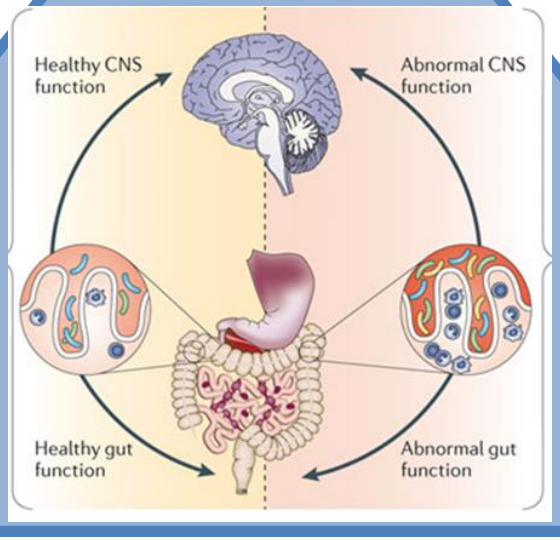
Environmental Influences:

Microgravity
Sleep shift
Temperature
Air Quality
Light
Noise
Exercise
Antibiotics/Meds
Pathogens

FOOD

HUMAN GENETICS AND EPIGENETICS

HUMAN STATE



MICROBIOME
90% of cells in the human are microbe, impacted by external factors

Dinan and Cryan 2012
Nature Reviews
Neuroscience

FOOD SYSTEM

Daily environmental influence that is
Greatly Modifiable
and
Has Potential To Promote Health

Food, Physiological, and Psychosocial Health

How do we design a food system that promotes crew health and performance on a mission to Mars?

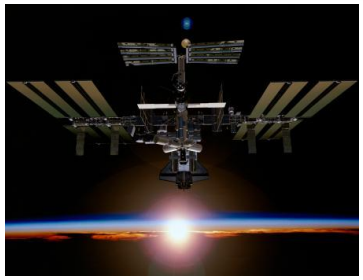
Safe

Nutritionally Stable

Sensory acceptability and variety

Balance with resource constraints

Food System Constraints



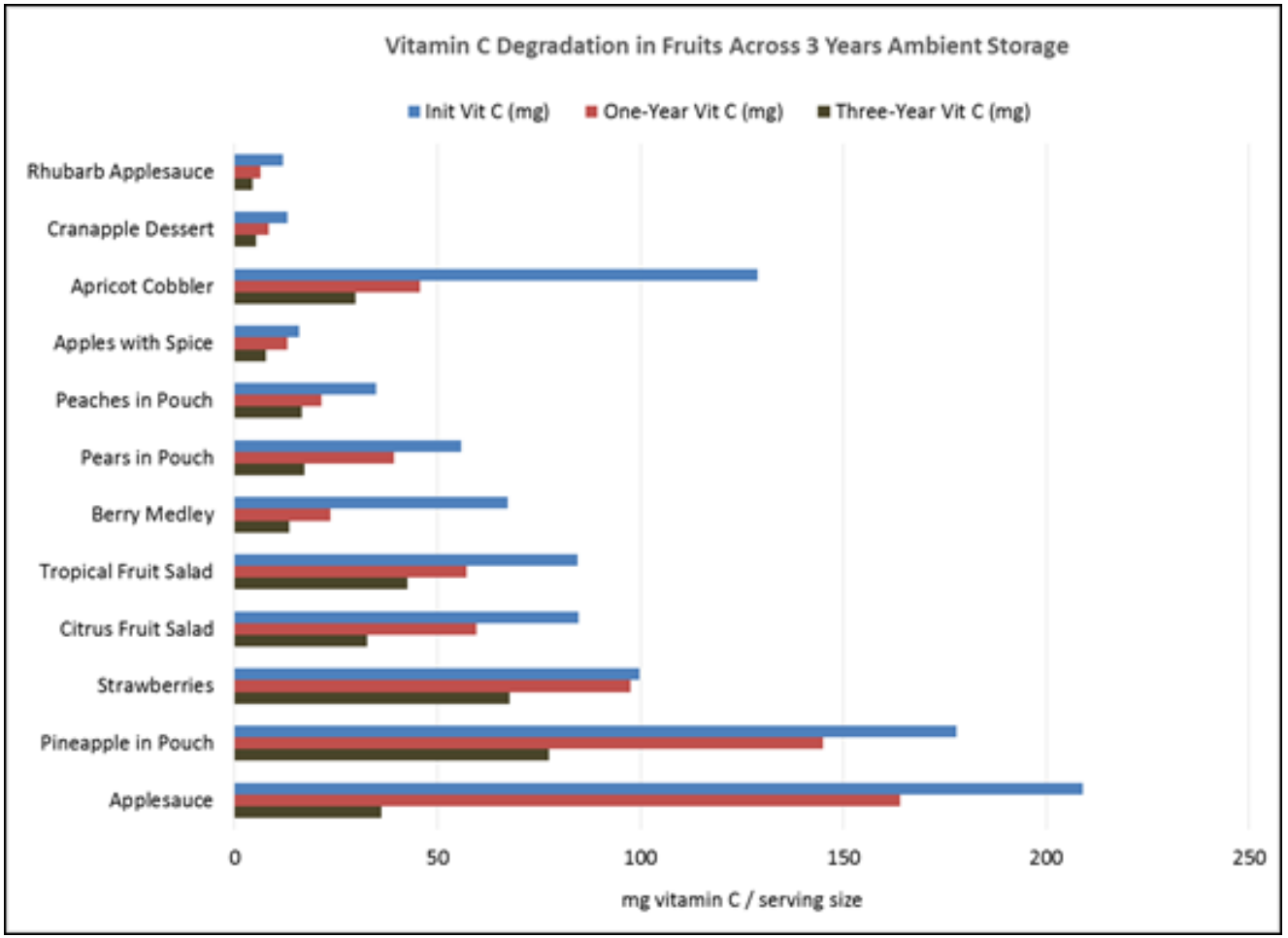
International Space Station:

- 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:

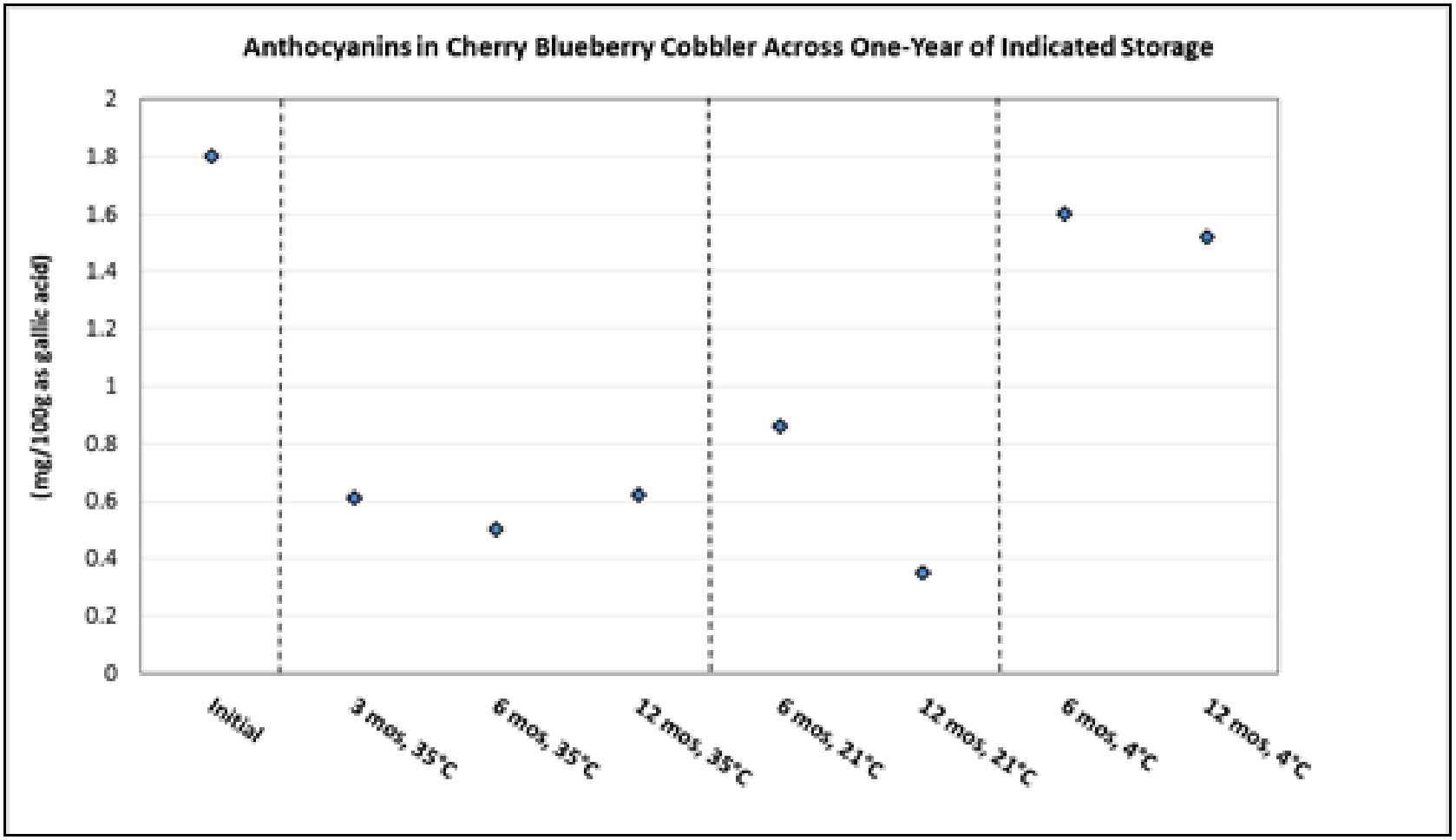
- 2.5 year mission; microgravity and reduced gravity
- Possibility of refrigerators or freezers for food storage
- No resupply; food may be prepositioned to accommodate high mass and volume
- Radiation impact is unknown
- Current food system is mass constraining and will not maintain nutrition/acceptability

Micronutrients in a Processed Food System

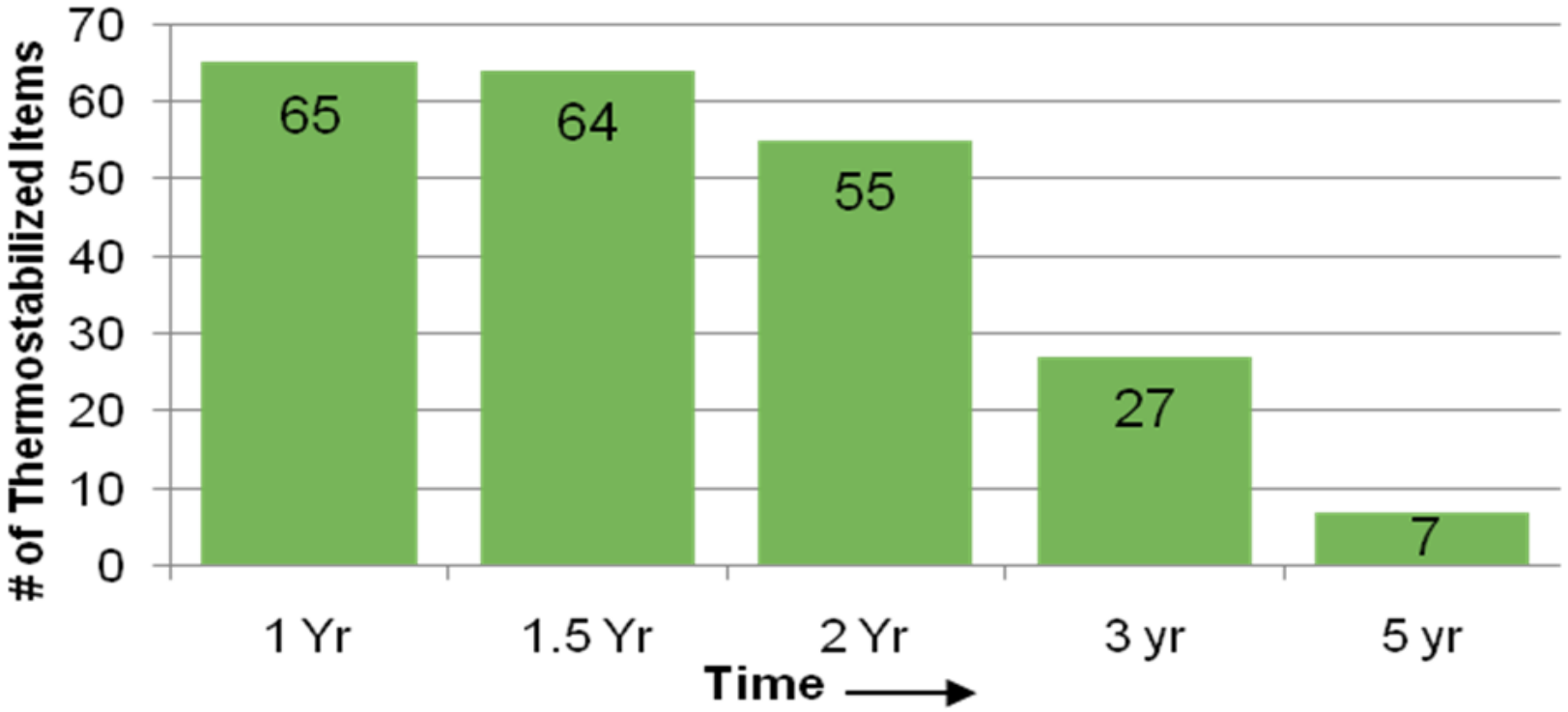


WHY NOT USE A VITAMIN SUPPLEMENT?

Bioactive Compounds in a Processed Food System



Food Acceptability in a Processed Food System



(Catauro. JFS. 2011)

Food Mass for a Mission to Mars

- 3000 kcal a crewmember a day
- How much does this weigh?

Mars Scenario:

6 crewmembers

1095 days

12,023 kg

IF THEY EAT TO ZERO SCENARIO

Potential Long Duration 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

Prepackaged Food – 5 Year Shelf Life Challenge

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

Formulation

Fortification

Food Matrix

Functional Foods

Meal Replacement

Variety

Processing

Pressure Assisted Thermal Sterilization (PATS)

Lyophilization Improvement

Microwave Sterilization

3D Printing/bulk automated processing (SBIR)

Packaging

Improve clarity

Improve barrier

Mass reduction

In Suit Nutritional Delivery System

Environment

Atmosphere

Temperature

Radiation

Microgravity

Partial Gravity

Contingency In-Suit Nutritional Delivery

- Scenario: Vehicle depressurizes, 144 hour crew return in pressurized suit
  - Requirement: Nutrition delivery system to overcome 4 psi suit pressure

- Solutions:
  - Bag-in-Bag Pressure Equilibration
  - Low-residue complete nutrition

Testing performed with the Launch/Entry Suit & Crew Protection Systems Laboratory

Human Exploration Research Analog (HERA)

Environment that simulates exploration mission scenarios

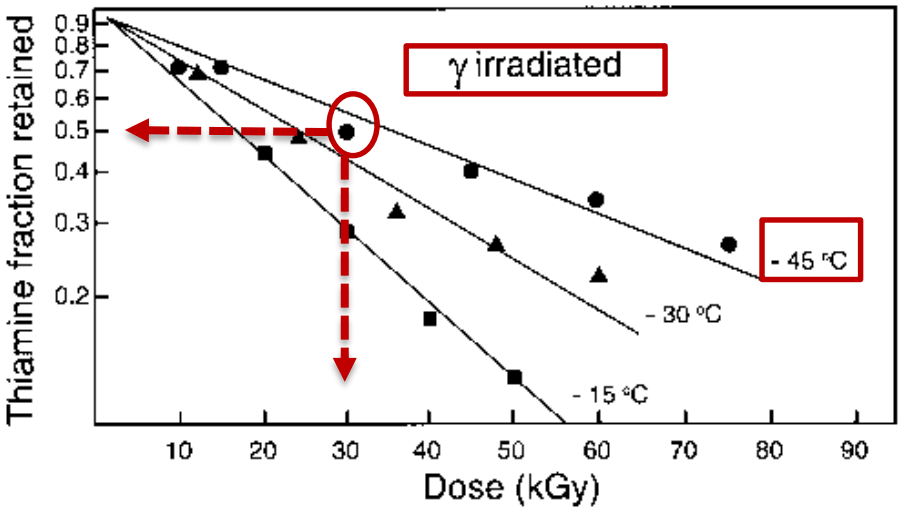
- Isolation / Confinement
- Environment
- Communication Delay

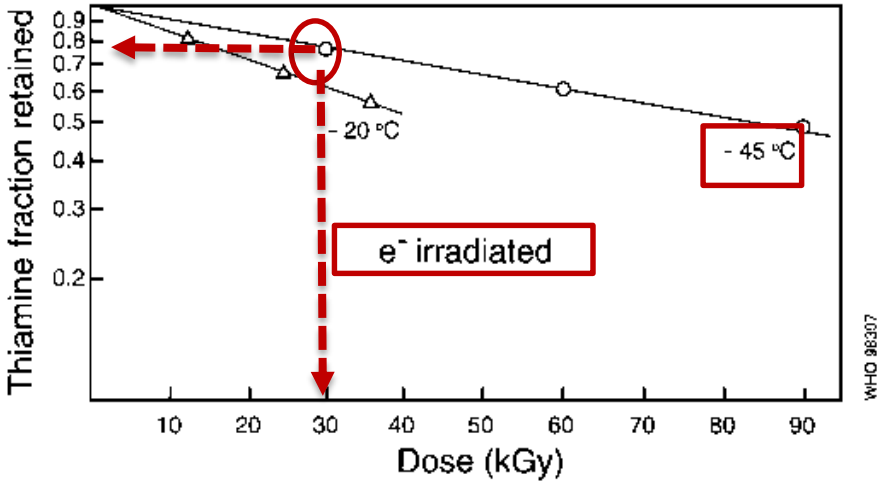
Evaluate food system scenarios

- Variety Limitations
- Controlled Menus
- Human Health and Performance Effects

Radiation

- Sources have drastically different effects on food.
- Food is frozen for treatment.
- The effect of deep space radiation on food is **unknown.**





WHO Tech Report, 1999

Integrate Bioregenerative Foods

International Space Station

Supplement prepackaged with “Pick and Eat,” beginning with Veggie chamber.

Food Safety

Cold Plasma

ProSan Wipes

Research gaps

Infrastructure, resource use, radiation effects, safe handling/micro procedures, system integration, crew time usage

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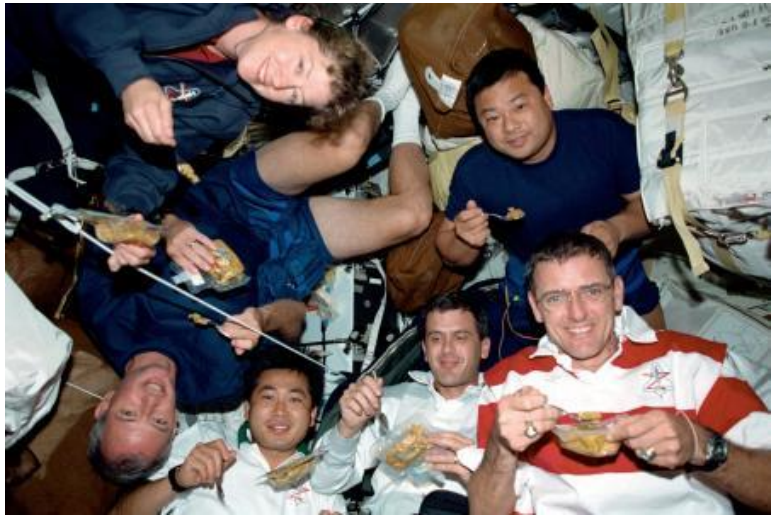

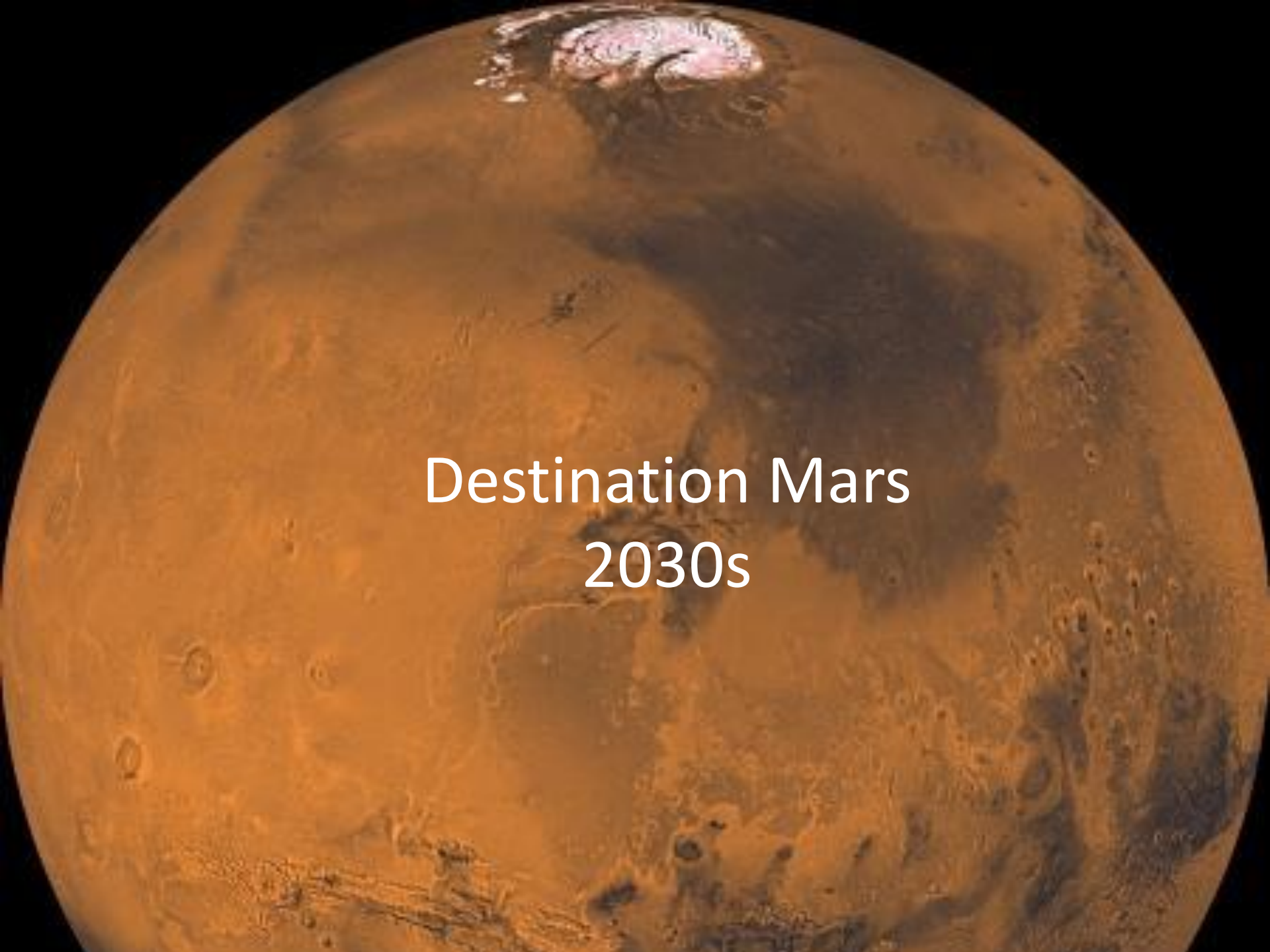
Destination Mars
2030s