NASA-STD-3001 Technical Brief

Food and Nutrition

OCHMO-TB-013
Rev D

Executive Summary

Nutrition has been critical in every phase of exploration on Earth, from the time when scurvy plagued seafarers to the last century when polar explorers died from malnutrition or, in some cases, nutrient toxicities.

The space food system must provide food that is safe, nutritious, and acceptable to the crew to maintain crew health and performance during space flight. Nutritional standards in NASA-STD-3001 are based on [National Institutes of Health (NIH) standards] dietary recommended intake (DRI). Achieving and maintaining food system acceptability, nutrition, and safety for space flight is complex and influenced by factors such as availability of mass, volume, power, crew time, food preparation capability, preference foods, resupply, variety, mission duration, and required shelf life.

NASA astronaut Kjell Lindgren (left) and Japan Aerospace Exploration Agency (JAXA) astronaut Kimiya Yui, participate in a food tasting session.

Relevant Technical Requirements

NASA-STD-3001 Volume 1, Rev C

[V1 3002] Pre-Mission Preventive Health Care
[V1 3003] In-Mission Preventive Health Care
[V1 3004] In-Mission Medical Care
[V1 3016] Post-Mission Health Care
[V1 3018] Post-Mission Long-Term Monitoring
[V1 4019] Pre-Mission Nutritional Status
[V1 4020] In-Mission Nutrient Intake
[V1 4022] Post-Mission Nutritional Assessment and Treatment

NASA-STD-3001 Volume 2, Rev D

[V2 3006] Human-Centered Task Analysis[1]
[V2 6026] Water Quality
[V2 6039] Water Dispensing Rate
[V2 6040] Water Dispensing Increments
[V2 6109] Water Quantity
[V2 6110] Water Temperature
[V2 7001] Food Quality
[V2 7002] Food Acceptability
[V2 7003] Food Caloric Content
[V2 7004] EVA Food Caloric Content
[V2 7007] Food Microorganism Levels
[V2 7008] Food Preparation
[V2 7009] Food Preparation and Cleanup
[V2 7010] Food Contamination Control

(continued on next page)

1. [OCHMO-TB-018 Human-in-the-Loop (HITL) Technical Brief]

Executive Summary (continued)

Regulatory Guidance and Requirements

- FDA Food Code – retail best practices for safe food handling
- FoodSafety.gov – news, alerts, and tips on safely handling and storing food to prevent food poisoning
- Food Safety Modernization Act (FSMA) – U.S. Congressional act that requires the prevention of foodborne illness
- Current Good Manufacturing Practice (CGMP), Hazard Analysis, and Risk-Based Preventive Controls for Human Food (Title 21 CFR Part 117) – required throughout the food preparation and transport process
- Control of Communicable Diseases (Title 21 CFR Part 1240) – requirements on food illness prevention and food handling for interstate shipments
- Interstate Conveyance Sanitation (Title 21 CFR Part 1250) – vessel requirements on food and drink preparation, storage, handling, and service
- Hazard Analysis Critical Control Point (HACCP) – a systematic approach to the identification, evaluation, and control of food safety hazards
- US Dept of Agriculture (USDA) – alerts on recalls, statistics, response, tips on food handling and preparation
  - Food Safety and Inspection Service (FSIS) – ensuring food safety through inspection of meat, poultry and egg products
- National Institutes of Health (NIH) standards – dietary recommended intake (DRIs) for micro- and macronutrients

Risks of Inadequate Food & Nutrition for Long Duration Space Missions – Why is the food so important?

- Adequate food and nutrition prevents:
  - Performance decrements[1]
  - Negative health effects[2]
- Drug/nutrient interactions must be understood to prevent unexpected deficiencies[3]

Relevant Technical Requirements

NASA-STD-3001 Volume 2, Rev D
[V2 7011] Food and Beverage Heating
[V2 7012] Dining Accommodations
[V2 7014] Food Spill Control
[V2 7015] Food System Cleaning and Sanitizing
[V2 7100] Food Nutrient Composition
[V2 7110] Food and Impacts to Environmental Systems
[V2 7111] Food Safety
[V2 7112] Food Production Facility
[V2 7052] Stowage Location
[V2 8001] Volume Allocation
[V2 11025] Suited Nutrition
[V2 11029] LEA Suited Hydration
[V2 11030] EVA Suited Hydration

Houston, We Have a Podcast: Interview with Dr. Scott Smith.
https://www.nasa.gov/johnson/HWHAP/diet-like-an-astronaut

1. *OCHMO-TB-016 Behavioral Health and Performance Technical Brief*
2. *OCHMO-TB-030 Bone Loss and Prevention Technical Brief*
3. *OCHMO-TB-006 Pharmaceutical and Medications Technical Brief*

Background

Throughout history, one of the performance-affecting factors for explorers on Earth was the availability of an adequate food supply. Even with tremendous gains in scientific knowledge, the need for adequate and acceptable food is underestimated. In space, inadequate food and nutrition provisions and intake has led to weight loss, bone and muscle loss, cardiovascular deconditioning, and impaired immune function, among other health and performance decrements.

Historical Events

1897-1899 Belgica Expedition (Cook)

Beri beri (thiamine deficiency) that led to death, shortness of breath, irregular heart rate and edema

1910-1913 Terra Nova Expedition (Scott)

Weight loss due to inadequate caloric intake that was 1500-3000 kcal less than expended

Inadequate wound healing due to Vitamin C deficiency that led to skin rotting, loss of nails and a hand wound that began to suppurate

Gemini, Apollo, Skylab, ASTP, and ISS flights

Weight loss occurred even during the short durations due in part to food acceptability

Biosphere 2

Weight loss of 14-21% due to inadequate food availability

Mars 500

Food likely became the greatest problem in isolation (Šolcová et al., 2016)

Houston, We Have A Podcast: Interview with Dr. Grace Douglas https://www.nasa.gov/johnson/HWHAP/eat-like-a-martian

"An army marches on its stomach." – *Napoleon Bonaparte*

Food System Evolution

Mercury – Semi-solid, sterile, tubed foods, fruits, and meat combinations packaged in collapsible aluminum tubes. Supplementing the semi-solid foods were special dry bite-size foods.

Gemini – More complex, all dehydrated food system with more meals per person per day. Some of the bite-size foods had to be altered to control crumb problems.

Apollo – Greater attention was focused on astronaut preferences which resulted in greater menu variation of both bite-sized and rehydratable foods. Hot water was available for food rehydration and "wet packs" were introduced.

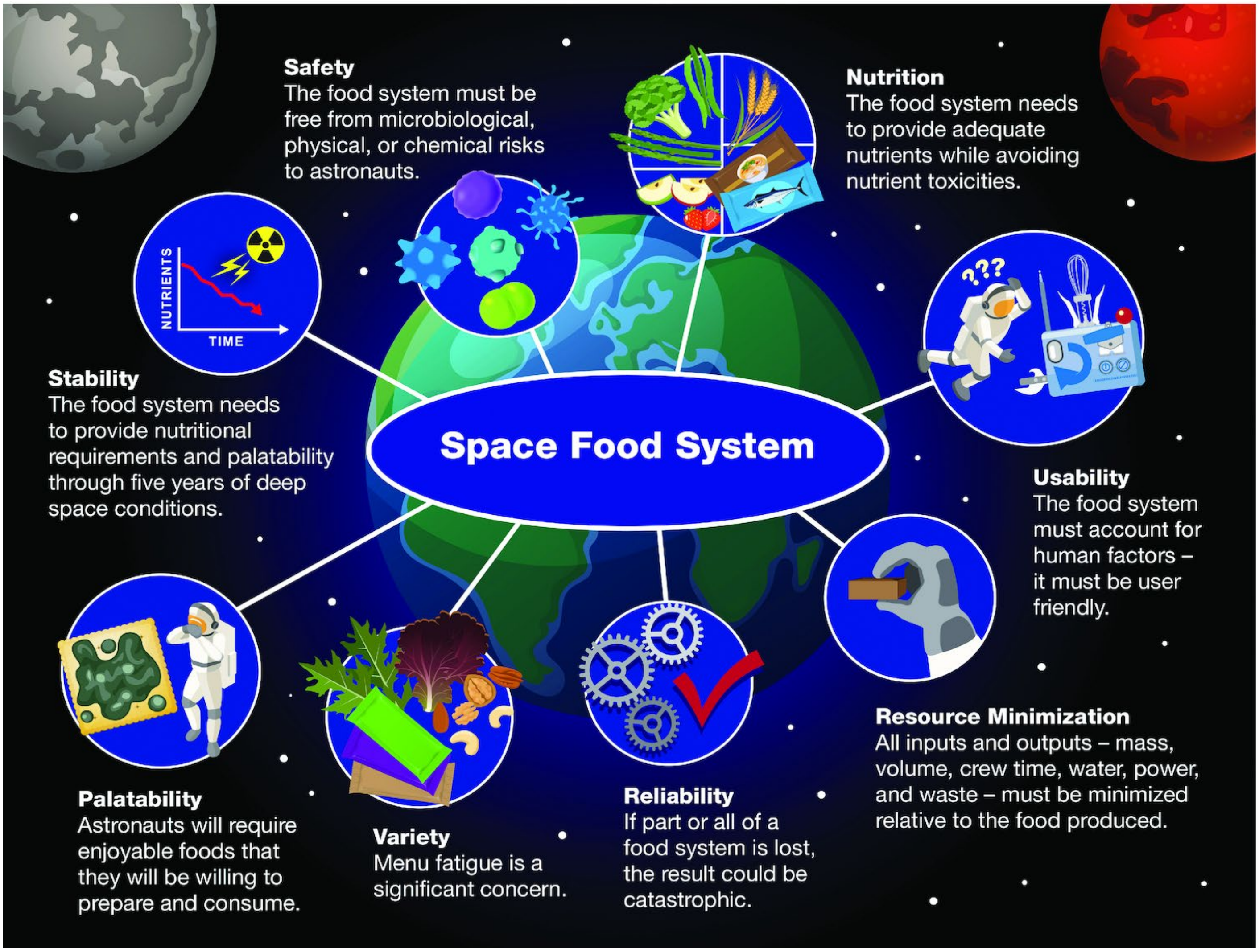
Skylab – Efforts were focused on making food a positive morale factor by including variety and acceptance. Menus were on a 6-day cycle with more consistent nutrient content. A food warmer for canned and freezer foods were provided.

Apollo-Soyuz Test Project (ASTP) – Use of freeze-dried foods and irradiated meats. No freezer or food warmer available, along with limited water.

Shuttle – Redesigned packaging of rehydratables and improved galley that included convection oven and rehydration unit with hot and cold water.

ISS – Standard menu which provides eight Standard Categories that the crew can choose food from typically for a 7- to 9-day usage rate, but will be dependant on number of crew present. Crew Specific Containers are allotted to each crew member, typically one container per 20 days. Other supplemental containers include condiments, nutrition bars, and periodic fresh foods. ISS has hot metered water, ambient water, food warmers, and small chiller to aid in food preparation. However, there is currently no refrigeration for foods.

Reference Information



Requirements of space food systems. A depiction of the many facets of and requirements for space food systems. As described in the text, each element is critical for the ultimate success of a space mission, and failure of any aspect could endanger the mission and the crew. The moon and Mars are also depicted here, reflecting two likely destinations for future human space exploration.

Source: J Nutr, Volume 150, Issue 9, September 2020, Pages 2242–2244, https://doi.org/10.1093/jn/nxaa188

Houston, We Have A Podcast: Interview with Gioia Massa and Anna-Lisa Paul
https://www.nasa.gov/johnson/HWHAP/plants-in-space

Reference Information

> "The soldier who is well fed is not only in better bodily health and better able to resist disease, but he is more cheerful in difficulties and therefore more equal to any strain he may be called upon to endure." – *Surgeon-Lieutenant-Colonel GS Robinson*

Spaceflight Standards

NASA utilizes the appropriate age and gender matched macronutrient and micronutrient Dietary Reference Intakes (DRIs) as suggested by the National Institute of Health, except for Vitamin D, which is increased to counter the limited UV exposure from sunlight and protein intake. This can be modified based on individual crewmember needs identified pre-flight and in-flight.

Estimated Energy Requirement

NASA utilizes the terrestrial energy requirements and considers mission operations (such as EVAs) to determine additional caloric content.

Estimated Energy Intake

EER for men 19 years old and older

$EER\ (kcal/day) = 662 – 9.53 \times Age\ [y] + [activity\ factor] \times (15.9 \times Body\ Mass\ [kg] + 539.6 \times Height\ [m])$

EER for women 19 years old and older

$EER = 354 – 6.91 \times Age\ [y] + [activity\ factor] \times (9.36 \times Body\ Mass\ [kg] + 726 \times Height\ [m])$

Skylab Food System

Considerations for Off-Nominal Events

- Contingency food and water supplies will need to account for the needs of the crew in the event of a delayed or unplanned rescue
- For example, plans for a change in consumed calories, fats and carbs to conserve O_2 use and reduce CO_2 production during events where the ECLSS is strained

Technical Challenges

Use of alcohol on the ISS is prohibited due to impacts to the ISS ECLSS[1] and Body Waste Management Systems[2]. For future vehicles/habitats, use of any ingredients containing even minor levels of alcohol (methanol, ethanol, etc.), in the form of ethanol's such as extracts, vinaigrettes, or cooking wine, should be considered in the ECLSS and waste management system designs.

8 Standard Categories – feeds a crew of three for 7-9 days

1. Breakfast
2. Rehydratable Meats
3. Meat and Fish
4. Side Dishes
5. Vegetables and Soups
6. Fruits and Nuts
7. Desserts and Snacks
8. Beverages

Supplemental Categories

9. Condiments
10. Snack/nutrition bars
11. Personal Preference
12. Coffee/Tea Preference
13. Fresh foods (periodic)

Food Prep Equipment

Hot metered water
Ambient metered water
Food warmer
Small chiller

Ascent and descent

No rehydration or heating
Only water/ready to eat foods
Food mass limit

Current ISS Standard Food System

1. *OCHMO-TB-002 ECLSS Technical Brief*
2. *OCHMO-TB-042 Body Waste Management Technical Brief*

Application

[Hazard Analysis Critical Control Point (HACCP)](#) and [Current Good Manufacturing Practice (CGMP), Hazard Analysis, and Risk-Based Preventive Controls for Human Food (Title 21 CFR Part 117)](#) is required throughout the food preparation and transport process.

Space Food System Design – Pre-Mission Utilizing Regulatory Practices and Requirements

Considerations for Food Development:

Duration of Mission[1]

- Following dietary recommended intake (DRIs) and addition of VitD
- Low sodium vs preservatives
- Shelf life
- Resupply

Packaging

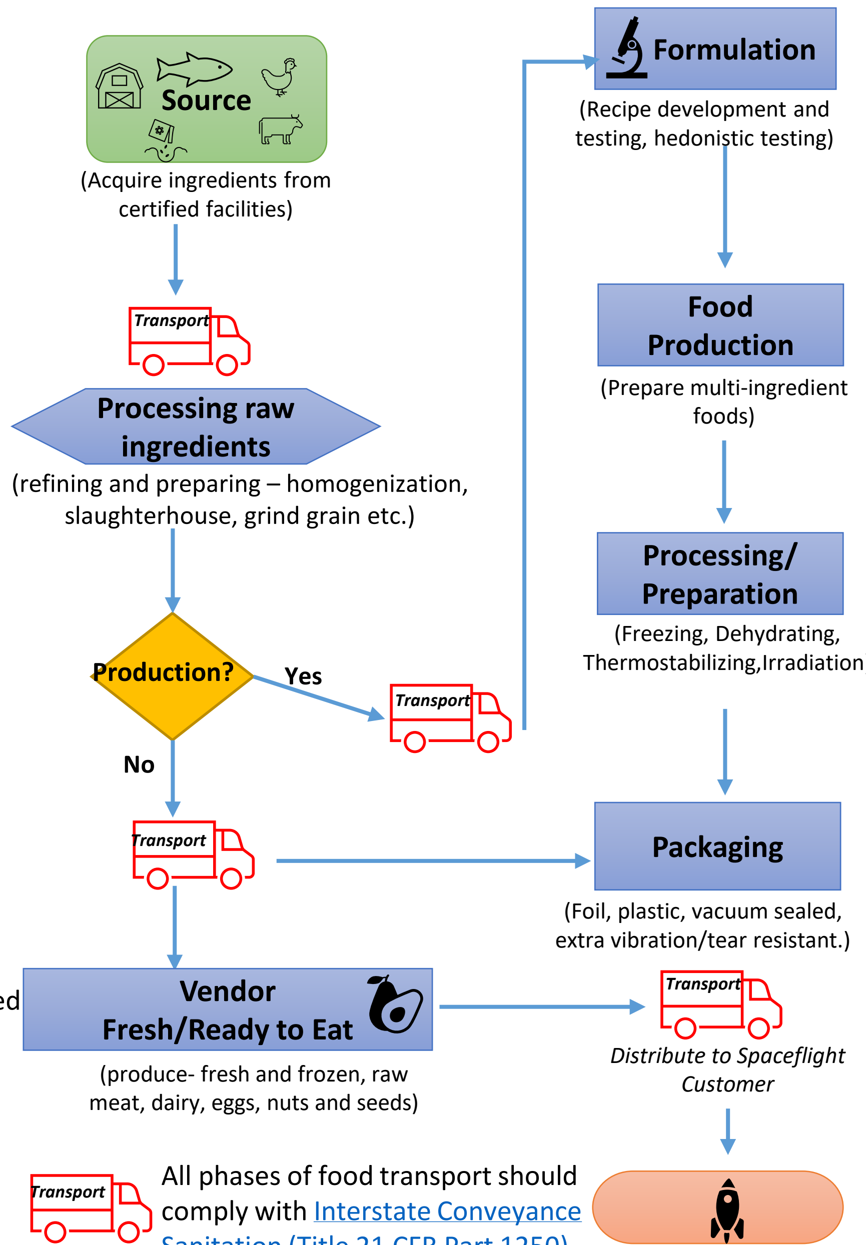
- Individual vs group meals
- Packaging considerations prior to production
- Fresh food cleansing and packing
- Shelf life
- Extra processing/testing
- Can packaging withstand launch, spaceflight environment
- Reduce air/liquid to conserve volume/mass
- Labeling
- Ability to be stowed easily

Preparation (environmental microgravity)

- Training on equipment
- Training for consumption
- Minimize foreign object debris (FOD)

Vehicle

- Stowage/Access pre- and in-mission (freezer, soft bag)
- Meal prep equipment (hot water, food warmer etc.)
- Access to replace expired food if needed
- Waste (packaging/food waste)
- Waste (human waste)[2]
- Portion control
- Cleaning of equipment



1. [OCHMO-TB-007 Mission Duration Technical Brief](#)
2. [OCHMO-TB-042 Body Waste Management Technical Brief](#)

Application

Space Food System Design – Food and Galley In-Flight

Considerations:

- Impacts to ECLSS and waste management system
- Flameless cooking
- Water (hot and cold)
- Food warmer
- Drinking containers (use of straws, bags)
- Cleaning materials (wipes, etc.)
- Stowage volume (food items, packaging & food waste)
- Refrigeration or freezer capabilities
- Food types that are compatible with microgravity and partial gravity scenarios

FDA Food Code
and
Control of Communicable Diseases (Title 21 CFR Part 1240)
and
Interstate Conveyance Sanitation (Title 21 CFR Part 1250)

Stowage of Supplied Food Items

Fresh or Ready to Eat/Use | **Packaged Items**

No Cooking (Fruits, Veggies, Dairy, etc.) | **Cooking** (flameless)

Plating Food and Dining

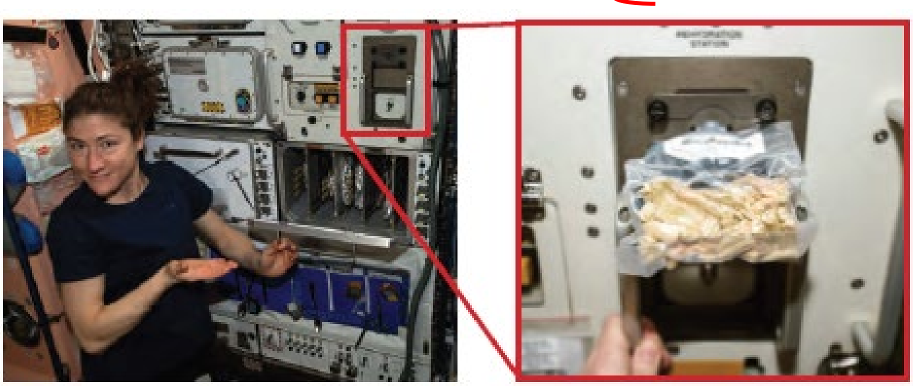
Cleaning

Food/Drink Products Disposal | **Non-Perishable Items, Packaging**

Stowage Trash

Stowage Perishable Items | **Stowage Non-Perishable Items**

The ISS Galley in the USOS includes a conduction food warmer and a Potable Water Dispenser with metered hot or ambient temperature water. NASA astronaut Christina Koch is heating pizzas, part of the limited shelf-life foods that may be included in some resupply provisions to the ISS. Inset: Example of a food package during rehydration. Photo Credits: NASA.



Current Good Manufacturing Practice (CGMP), Hazard Analysis, and Risk-Based Preventive Controls for Human Food (Title 21 CFR Part 117) is required throughout the food preparation and transport process. Federal, State, and Local applicable laws and regulations help ensure food safety.

Application

Food Safety

Food safety is important pre-flight to prevent any food borne illnesses from impacting the crew and mission during the ascent phase of flight and for preventing any infectious disease prior to or during the mission. Post-flight food safety is important for the health of the crew as they may return with impaired immune systems.

Staging of food should consider long duration storage and temperatures to ensure food quality and acceptability.

- Contingency planning
- Prepositioning or staging of foods
- Available fresh fruits/vegetables
- Crew preferences
- Stability of food micro- and macronutrients
- Preservation of food quality

Food Safety Modernization Act (FSMA)
FoodSafety.gov

Contamination Sources

Waste and Hygiene Areas – microbes that can lead to gastrointestinal illnesses (see OCHMO-TB-042 Body Waste Management Technical Brief)
Air – odors that are not properly contained
Water Sources – microbial contamination, leeching or biocides (see OCHMO-TB-027 Water Technical Brief)
Packaging – must be food grade
- Primary packaging will need to be uncompromised

Eating Utensils – forks, spoons, scissors, straws, etc.
Chemical Sources – cleaning materials used in the same area that leave a residue or have off-gassing
Physical Debris – dirt, regolith, wood, plastic and other small objects
Fresh Fruits and Vegetables – direct shipment from the ground, items that are picked and then eaten
- Recommendation of 30-second dip in a 200 parts per million chlorine solution (or approved equivalent), followed by a final potable water rinse and thorough air drying prior to stowage/storage, which should include a wrapping to maintain cleanliness

Opened Food Items - consuming food that was prepared and open past 2 hours

Top 5 Germs Causing Illness, Hospitalizations, and Deaths From Food Eaten in the United States
(source: CDC Food Safety)

Illnesses	Hospitalizations	Deaths
1. Norovirus	1. *Salmonella* (non-typhoidal)	1. *Salmonella* (non-typhoidal)
2. *Salmonella* (non-typhoidal)	2. Norovirus	2. *Toxoplasma gondii*
3. *Clostridium perfringens*	3. *Campylobacter*	3. Listeria monocytogenes
4. *Campylobacter*	4. *Toxoplasma gondii*	4. Norovirus
5. *Staphylococcus aureus*	5. *E. coli* 0157	5. *Campylobacter*

Application

Source: NASA-STD-3001 Volume 2, Revision C, Table 15 – Food and Production Area Microorganism Levels

Food Safety During Production

Food safety is defined by the absence of a health risk due to physical, chemical and microbiological contamination. Shelf stable food products will need to be processed in compliance with local, state, and federal codes and laws and NASA specific requirements, as well as follow FDA regulations, including but not limited to, visual inspections, vacuum integrity and microbial testing. This can also include testing items prior to or during use, empty pouches at receiving, septum adapter assemblies at receiving, and straw assemblies after cleaning. It is recommended that these tests are verified by inspection, as well as testing by a qualified ISO/IEC 17025:2005 accredited laboratory. Further guidance can be found in [Current Good Manufacturing Practice (CGMP), Hazard Analysis, and Risk-Based Preventive Controls for Human Food (Title 21 CFR Part 117)](https://www.ecfr.gov/current/title-21/chapter-I/subchapter-B/part-117).

Food and Production Area Microorganism Levels (NASA-STD-3001 [V2 7007] Food Microorganism Levels)		
Area/Item	**Microorganism Tolerances**	
Food Production Area	**Samples Collected**	**Limits**
Surfaces	3 surfaces sampled per day[a]	3000 CFU/ft^2 (total aerobic count)
Packaging Materials	Before use	3000 CFU per Pouch, Septum, 25 cm^2 or base
Air	1 sample of 320 L monthly	113 CFU/320 L (Total aerobic count)
Food Product	**Factor**	**Limits**
Non-Thermostabilized[b]	Total aerobic count	20,000 CFU/g for any single sample (or if any two samples from a lot exceed 10,000 CFU/g)
	Enterobacteriaceae	100 CFU/g for any single sample (or if any two samples from a lot exceed 10 CFU/g). No detected serious or severe hazard human enteric pathogenic organism
	Salmonella	0 CFU/g for any single sample
	Yeasts and molds	1000 CFU/g for any single sample (or if any two samples from a lot exceed 100 CFU/g or if any two samples from a lot exceed 10 CFU/g Asperfillis flavus)
In-House Thermostabilized Products	Package integrity inspection	100% inspection for package integrity
	Incubation test	Test package must remain intact with no gas production following 10-day incubation at 35 ± 3°C
Commercial Thermostabilized Products	Package integrity inspection	100% inspection for package integrity
Irradiated Sterile Products	Package integrity inspection	100% inspection for package integrity
	Incubation test	Test package must remain intact with no gas production
	Total aerobic count	<10 CFU/g Note: test conducted on samples following incubation at 35°C for 10 days
	Yeasts and molds	<10 CFU/g Note: test conducted on samples following incubation at 35°C for 10 days

a. Samples collected before food processing on days that the food facility is in operation. Environmental samples will be collected when there is a 1-hour break in activity, or after five hours of continuous work.

b. Food samples that are considered "finished" products that require no additional repackaging are only tested for total aerobic counts.

Application

Types of Food and Packaging for Spaceflight		
Food/Packaging Type	ISS Example	Parameters
Thermostabilized – heating food to a temperature that renders it free of pathogens, spoilage microorganisms, and enzyme activity	Beef stew, Chocolate Pudding, Split Pea Soup, Tuna casserole, Red beans & rice	**Shelf life: 2.5-3.5** years **Packaging:** Multilayer aluminum-containing laminate pouch **Preparation:** None or heating **Mass:** 3.07 to 8.32 oz (87 to 236 g)
Irradiated – use of gamma rays, X rays, or electrons, and uses energy levels that ensure negative induction of radioactivity in the irradiated product. Irradiation controls naturally occurring processes such as ripening or senescence of raw fruits and vegetables, and is effective to inactivate spoilage and pathogenic microorganisms	Beef fajitas, Smoked turkey	**Shelf life: 4.5** years **Packaging:** Multilayer aluminum-containing laminate pouch **Preparation:** None or heating **Mass:** 3.03 to 6.94 oz (86 to 197 g)
Rehydratable – are drying with heat, osmotic drying, and freeze drying	Vegetables, Chicken salad, Cornbread dressing, Sausage patty, Shrimp cocktail	**Shelf life:** 2 years in interim cans; 2 years with overwrap; or 3 months with no overwrap **Packaging:** Multilayer laminate pouch with, vacuum packaged with gas flush, adapter for rehydration **Preparation:** Rehydration using hot or cold Water **Mass:** 0.88 to 3.40 oz (25.0 to 96.6 g)
Natural form – these foods rely on reduced water activity to prevent microbial activity	Cookies, Brownies, Nuts, Granola bars	**Shelf life:** 2 years with overwrap; 0.5 year with no overwrap **Packaging:** Multilayer laminate pouch **Preparation:** None **Mass:** 0.74 to 2.43 oz (21 to 69 g)
Extended-shelf-life bread products – the products must be specially formulated to a water activity level low enough to prevent the growth of anaerobic pathogenic bacteria	Tortillas, Wheat flat bread	**Shelf life: 3** years **Packaging:** Multilayer aluminum-containing laminate or packaged by Department of Defense **Preparation:** None
Fresh food – foods with a short shelf life and no processing	Fresh fruit and vegetables	**Shelf life:** 1 week **Packaging:** Vacuum packaged with gas flush, protection of structure and contamination **Preparation:** None
Beverages – either freeze-dried beverage mixes (e.g., coffee or tea) or flavored drinks (e.g., lemonade, orange drink, etc.)	Dehydrated (coffee or tea), Drink mix (lemonade)	**Shelf life:** 3 years **Packaging:** Multilayer aluminum-containing laminate pouch, adapter for rehydration, straw **Preparation:** Rehydration using hot or cold water **Mass:** 0.42 to 1.90 oz (12.0 to 54.0 g)

Source: Human Integration Design Handbook, Section 7.2.3.4 Food Types and Table 7.2-6: Types of Food and Packaging for Spaceflight with updates

Application

Factors to Ensure Consumption of Adequate Nutrition

Past experience and personal preference – The ability to choose and consume foods that are familiar, and the availability of personal favorites becomes more important in isolation and confinement; considerations are needed for international crews.

Variety – Food can lose its acceptability if eaten too frequently. Additionally, individuals will have favorite foods and avoid foods they do not like. In closed systems, a wide variety of foods helps support preferences that lead to intake of adequate nutrition.

-The US military limits the use of MREs to 21 consecutive days to prevent health and performance impacts due to inadequate food consumption.

Availability – Some foods requiring minimum preparation should be available, which is particularly important for high-energy-output tasks such as extravehicular activity (EVA) operations. Food overage is necessary in a closed system to help support preferences that lead to intake of adequate nutrition. Situations that risk losing food also risk losing crew (inadequate packaging or protection if the vehicle goes to vacuum; loss of crops if dependent on bioregenerative foods).

Food form – Food quality that is more familiar and "Earth-normal" will facilitate acceptability of the food and subsequent consumption.

Meal scheduling – Lack of consistent meal periods and time in the crew schedule can lead to skipped meals and undernourishment.

-Crew days are planned to ensure there is adequate time for meals, as well as time for dining together as a team.

-Meal scheduling will likely be impacted on days with EVAs and the specific needs of those activities.

Meal Preparation Time and Capability – Complexity of preparation, or availability of preparation equipment, including rehydration and heating, can lead to skipped meals or incomplete consumption due to time constraints from crew day scheduling, and presence of food items to increase acceptability and intake.

Microgravity environment – Anecdotally, some crewmembers have reported that changes occur in their taste and odor perception of foods during space flight, which may be influenced by factors such as bodily fluid shift, changes in air circulation, and competing odors in the closed spacecraft. Condiments are flown to allow the crewmembers to individually alter the flavors of the foods.

-Some crew have noted that spicier foods are desired due to the lack of smell or taste.

Waste management facilities – Inadequate body waste management facilities have discouraged food consumption.

-Previous crew comments have noted that odors from the waste management system has caused a decrease in appetite.

Space Adaptation Sickness (SAS) – Control of SAS is essential for a healthy appetite.

-Crew have medications available to them to help mitigate this occurrence, as well as having the flexibility to consume less solid food while maintaining hydration with the available water quantities.

Atmospheric contaminants – Buildup of background odors during missions could contribute subliminally to a decrease in appetite and consumption.

-This could include the stowage of trash, as well as the off-gassing from various chemicals used or payloads.

Application

Space Food System Design

Development of Food Products – Food products are developed with consideration for nutritional content, safety, and acceptability, as well as:

- storage duration (based on mission duration plus the time required to process, test, and ship the foods for launch) and shelf life (based on each food's composition, preparation and processing method, packaging, and storage conditions)
- packaging type is essential for maintaining safety, nutritional quality, and acceptability throughout shelf life – food packaging must meet safety and gaseous barrier specifications and mass/volume limitations
- suitability for use in microgravity, for example, foods that produce crumbs (such as crackers) should be provided in bite-sized pieces to minimize debris and foods that easily break and crumb should not be used; meal items should contain enough moisture to stay in the package or on a utensil through surface tension

Mission Requirements – Missions up to three days in length may have mass and power constraints that do not support certain types of foods, such as rehydratables and heated foods. As mission length increases menu cycle length must increase to provide variety, which promotes consumption.

Risk of Performance Decrement and Crew Illness Due to Inadequate Food and Nutrition

Menu Development (personal preference vs standard menu) – Personal preference coupled with providing a standard menu for use by all crew is considered based on launch and crew selection timelines.

Food Reserves - Sufficient supply will also need to be considered for planning. For example, the reserve for ISS USOS crewmembers is 4-month worth of food for 4 crewmembers.

Food Stowage – Food may be stowed in various configurations, as long as the packages are protected from chemicals, puncture or damage during transport and in mission.

Product Packaging on System Compatibility and Crew Safety – Other considerations should include flammability of the packaging, avoiding the use of fragile materials, off-gas testing and limiting foreign object debris (FOD).

Expertise and Facilities

Expertise – NASA utilizes the following expertise to develop and provide a food system:

- **food scientists** develop process and food specifications, confirm safety, confirm shelf life, and suitability
- **registered dietitians** develop menus and confirm nutritional content
- **engineers** develop and test package integrity (sealing and vacuum) of packaged foods
- **logistics specialists** develop stowage procedures and monitor food inventory
- **system engineers** design food processing equipment to rehydrate and heat food

Facilities – Proper facilities such as an analytical lab, food processing plant, packaging room, sensory facility and stowage room are needed to maintain the food quality and safety.

Application

Additional Considerations

Packaging – The food packaging needs to provide the capability to maintain food safety and limit environmental contamination during all nominal and contingency phases of the mission.

Personnel – All personnel working directly with food intended for human consumption will need to receive food handling training equivalent to or exceeding the requirement for obtaining a food handler's permit from the local health authority (ServSafe® certification, or the equivalent). Additionally, the personnel need to avoid personal behaviors that can contaminate food, properly wash and care for hands, wear proper PPE (e.g., disposable lab coat, hair nets, face mask, gloves, and beard nets when applicable are required when handling exposed food and packaged food for flight).

Facility – The facility where food is prepared, processed, packaged, stowed, and stored will need to:

- Comply with applicable federal/state/local laws and regulations and industry Good Manufacturing Practice standards.
- Limit access to prevent food adulteration.
- Have temperature and FOD control.
- Control for microbial and particulate contaminants.

Crew Training – Crewmembers will need to have understanding and training of in-flight food safety (proper food preparation, consumption, and clean up; food hardware's reuse frequency; etc.).

Documentation – Maintain records that demonstrate compliance with federal food regulations and laws for inspection at any time. Documentations such as standard operating procedures, technical specifications of food, and applicable drawings are to be in place to ensure consistent and quality work.

Technical Challenges for Moon to Mars

- Nutrient-dense, shelf stable foods that meet overall nutritional, safety, and sensory acceptability metrics
- Menu items with at least a 5-year shelf life
- Partial gravity cooking processes that minimize microbial risk
- High-barrier, low-mass, & process compatible packaging materials that help extend shelf-life to five years
- Packaging that can withstand vibration, acceleration loads, radiation, various environmental factors (i.e., temperature, humidity, zero-pressure and decompression)

Sourcing – All food and ingredients are sourced from a major chain grocery store or food companies with a quality assurance system in place that audits their suppliers for compliance with federal, state, and local food regulations and laws including but not limited to FSMA, Current Good Manufacturing Practices (CGMP), and Hazard Analysis, and Risk-Based Preventive Controls in accordance with the Code of Federal Regulations (CFR) Title 21 and Title 9 as applicable. Any items that are imported into the United States will need to meet all the requirements of the FDA FSMA rule on the Foreign Supplier Verification Program (FSVP), according to the federal government import requirements.

Processing – Shelf-stability is the standard used product type. This can include the processing methods of freeze drying, thermostabilizing, and irradiation.

Inventory Control –This includes maintaining, tracking, tracing, and recalling all food items that are subject to a recall.

Back-Up

Major Changes Between Revisions

Rev C → Rev D

- Added new requirements currently under consideration for addition to NASA-STD-3001.
- Included regulatory references and guidance information

Rev B → Rev C

- Modified layout to be consistent with new formatting
- Additional content added for clarity and guidance throughout
- Corrected Food and Production Area Microorganism Levels table

Rev A → Rev B

- Updated information to be consistent with NASA-STD-3001 Volume 1 Rev B and Volume 2 Rev C

Original → Rev A

- Modified Dietary Reference Intakes (DRIs) exceptions
- Added protein and deleted B6 adjustment
- Added note that DRIs may be tailored
- Added Considerations for Off-Nominal Events
- Added Packaging Considerations to "Technical Challenges" section on slide 8
- Added Back-Up slides to include Standard details

Reference Information

Food and Water Intake for Previous Spaceflight Programs and Expeditions

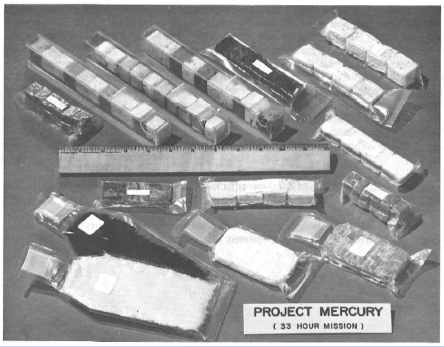
Updated nutrient intake data for several space programs are reported below. For ISS, we report the data on nutrients available from the Food Frequency Questionnaire analysis. Data on planned ISS menu content and information on a wider range of nutrients are available online at https://www.nasa.gov/hhp/education.

	Apollo	Skylab	Shuttle	ISS (E1-13)	ISS (E14-25)	ISS (E26-34)
N	33	9	32	19	19	17
Energy, kcal/d	1880 ± 415[a]	2897 ± 447	2090 ± 440	2313 ± 514	2317 ± 591	2444 ± 536
Energy, %WHO	64.2 ± 13.6	99.1 ± 8.2	74.2 ± 16.0	79 ± 18	83 ± 17	84 ± 15
Protein intake, g/d	76.1 ± 18.7	111.0 ± 18.4	78.0 ± 18.8	102 ± 25	96 ± 34	109 ± 30
Protein intake, % of kcal	16.3 ± 2.1	15.7 ± 2.1	14.9 ± 2.4	18 ± 2	16 ± 2	18 ± 2
Carbohydrate intake, g/d	268.9 ± 49.1	413.3 ± 59.3	304.0 ± 67.3			
Carbohydrate intake, % of kcal	58.1 ± 7.1	57.5 ± 9.1	58.4 ± 5.0			
Fat intake, g/d	61.4 ± 21.4	83.2 ± 13.8	64.0 ± 17.8			
Fat intake, % of kcal	28.9 ± 5.5	26.8 ± 8.6	27.2 ± 4.4			
Calcium, mg/d	774 ± 212	894 ± 142	826 ± 207	878 ± 274	944 ± 258	1074 ± 205
Phosphorus, mg/d	1122 ± 325	1760 ± 267	1216 ± 289			
Magnesium, mg/d		310 ± 58	294 ± 74			
Iron, mg/d			15.0 ± 3.9	18 ± 5	18 ± 5	20 ± 5
Zinc, mg/d			12.0 ± 2.9			
Sodium, mg/d	3666 ± 890	5185 ± 948	3984 ± 853	4601 ± 1239	4658 ± 1593	3823 ± 785
Potassium, mg/d	2039 ± 673	3854 ± 567	2391 ± 565	3315 ± 513	3214 ± 863	3559 ± 784
Water, g/d	1647 ± 188[b]	2829 ± 529	2223 ± 669	2012 ± 462	2142 ± 387	2320 ± 581

Source: Human Adaptation to Spaceflight: The Role of Nutrition, 1st Ed by Smith, Zwart and Heer.

[a] All data are mean ± SD. Empty cells show where data were not available.

[b] n=3 for water intake during Apollo missions.



See the OCHMO OCHMO-TB-027 Water Technical Brief for additional information.

Regulatory Considerations and Guidance Sources

Food Safety Modernization Act (FSMA) - FDA has finalized nine major rules to implement FSMA, recognizing that ensuring the safety of the food supply is a shared responsibility among many different points in the global supply chain. The FSMA rules are designed to make clear specific actions that must be taken at each of these points to prevent contamination.

- Agricultural Water
- Accredited Third-Party Certification
- Food Traceability
- Foreign Supplier Verification Programs (FSVP)
- Laboratory Accreditation for Analyses of Foods (LAAF)
- Mitigation Strategies to Protect Food Against Intentional Adulteration
- Preventive Controls for Human Food
- Produce Safety
- Sanitary Transportation of Human and Animal Food
- Voluntary Qualified Importer Program (VQIP)

CDC List of the A-Z Index for Foodborne Illness

Food Safety - Four simple steps to prevent food poisoning: clean, separate, cook and, chill.

- Safe Minimum Cooking Temperatures
- Cold Food Storage Chart
- Meat and Poultry Charts

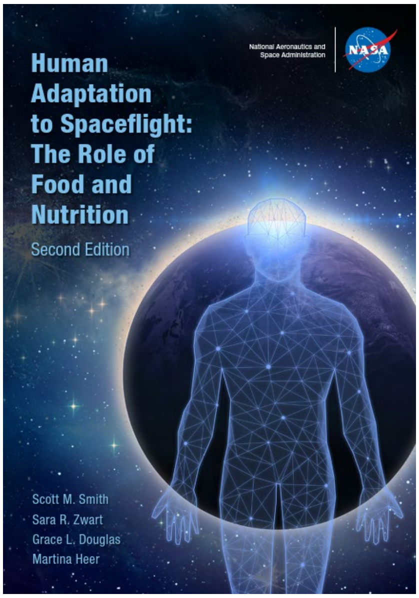
Foodborne Illness and Disease - Illness that comes from eating contaminated food, which and the onset of symptoms may occur within minutes to weeks and often presents itself as flu-like symptoms, as the ill person may experience symptoms such as nausea, vomiting, diarrhea, or fever.

Control of Communicable Diseases (Title 21 CFR Part 1240) – Requirements on prevention and food handling for interstate shipments.

Interstate Conveyance Sanitation (Title 21 CFR Part 1250) – Requirements on food and drink preparation, storage, handling and service. This is also intended to be in accordance with Title 21 CFR Part 1240.

Food Hygiene for Businesses - Food hygiene requirements for your business and how to keep your food safe. From the Food Standards Agency in the United Kingdom.

Food Hygiene Certification – as required by the UK for those who will be working with or around food to ensure food safety for the consumer or customer. For situations involving a chef or cook, the Level 3 certification is required in UK associated kitchens.



Regulatory Considerations and Guidance Sources

Hazard Analysis Critical Control Point (HACCP) - HACCP is a management system in which food safety is addressed through the analysis and control of biological, chemical, and physical hazards from raw material production, procurement and handling, to manufacturing, distribution and consumption of the finished product.

Retail & Food Service HACCP - Specific information is provided to assist the regulator and industry in meeting the needs for providing safe food to the consumer.

Current Good Manufacturing Practice (CGMP), Hazard Analysis, and Risk-Based Preventive Controls for Human Food (Title 21 CFR Part 117) – Requirements for establishing qualifications for individuals who manufacture, process, pack, or hold food.

FDA Food Safety Modernization Act (FSMA) and Small Business - The FDA Food Safety Modernization Act (FSMA) recognizes the role of small businesses in the food industry and provides for various ways to assist small businesses in meeting the new food safety requirements of the law. Specifically for several key provisions, the law mandates “plain language” guidance documents and phased-in effective dates.

Small Business Assistance - Units provide technical assistance to small companies, hold exchange meetings to hear the views and perspectives of small businesses, conduct educational workshops, develop informational materials, and provide an accessible, efficient channel through which small businesses can acquire information from the FDA.

Food Industry - Links and resources that includes information on outbreaks, recalls, industry systems, submission, registrations, CGMPs, etc.

How to Start a Food Business - This information provides a cursory overview of regulatory requirements that relate to starting a food business. In addition to the Food and Drug Administration’s (FDA's) requirements, food businesses are subject to other federal, state, and local requirements.

Sanitary Transportation of Human and Animal Food: What you need to Know About the FDA Regulation: Guidance for Industry - This guidance document is intended to assist small entities in complying with the rules set forth in 21 CFR Part 1, subpart O concerning Sanitary Transportation of Human and Animal Food. This guide was developed to inform shippers, receivers, loaders, and carriers engaged in transportation operations about the Sanitary Transportation rule and how to comply with it.

Bad Bug Book: Handbook of Foodborne Pathogenic Microorganisms and Natural Toxins (2nd Edition) - The second edition of the Bad Bug Book, published by the Center for Food Safety and Applied Nutrition, of the Food and Drug Administration (FDA), U.S. Department of Health and Human Services, provides current information about the major known agents that cause foodborne illness.

View the current versions of NASA-STD-3001 Volume 1 & Volume 2 on the OCHMO Standards website

Referenced Technical Requirements

NASA-STD-3001 Volume 1 Revision C

[V1 3002] Pre-Mission Preventive Health Care Pre-mission preventive strategies shall be used to reduce in-mission and long-term health medical risks, including, but not limited to: (see NASA-STD-3001, Volume 1 Revision C for full technical requirement list).

[V1 3003] In-Mission Preventive Health Care All programs shall provide training, in-mission capabilities, and resources to monitor physiological and psychosocial well-being and enable delivery of in-mission preventive health care, based on epidemiological evidence-based probabilistic risk assessment (PRA), individual crewmember needs, clinical practice guidelines, flight surgeon expertise, historical review, mission parameters, and vehicle-derived limitations. These analyses consider the needs and limitations of each specific vehicle and design reference mission (DRM) with particular attention to parameters such as mission duration, expected return time to Earth, mission route and destination, expected radiation profile, concept of operations, and more. In-mission preventive care includes, but is not limited to: (see NASA-STD-3001, Volume 1 Revision C for full technical requirement list).

[V1 3004] In-Mission Medical Care All programs shall provide training, in-mission medical capabilities, and resources to diagnose and treat potential medical conditions based on epidemiological evidence-based PRA, individual crewmember needs, clinical practice guidelines, flight surgeon expertise, historical review, mission parameters, and vehicle-derived limitations. These analyses consider the needs and limitations of each specific vehicle and design reference mission (DRM) with particular attention to parameters such as mission duration, expected return time to Earth, mission route and destination, expected radiation profile, concept of operations, and more. In-mission capabilities (including hardware and software), resources (including consumables), and training to enable in-mission medical care, and behavioral care, are to include, but are not limited to: (see NASA-STD-3001, Volume 1 Revision C for full technical requirement list).

[V1 3016] Post-Mission Health Care Post-mission health care shall be provided to minimize occurrence of deconditioning-related illness or injury, including but not limited to: (see NASA-STD-3001, Volume 1 Revision C for full technical requirement list).

[V1 3018] Post-Mission Long-Term Monitoring Crewmembers returning from spaceflight shall be monitored longitudinally for health, behavioral health, and well-being parameters in a standardized manner.

[V1 4019] Pre-Mission Nutritional Status Pre-mission nutritional status shall be assessed, and any deficiencies mitigated prior to launch.

[V1 4020] In-Mission Nutrient Intake Programs shall provide each crewmember with 100% of their calculated nutrient and energy requirements, based on an individual's age, sex, body mass (kg), height (m), and appropriate activity factor.

[V1 4022] Post-Mission Nutritional Assessment and Treatment Post-mission nutritional assessment and treatment shall be aimed at returning to pre-mission baseline.

View the current versions of NASA-STD-3001 Volume 1 & Volume 2 on the [OCHMO Standards website]

Referenced Technical Requirements

NASA-STD-3001 Volume 2 Revision D

[V2 3006] Human-Centered Task Analysis Each human spaceflight program or project shall perform a human-centered task analysis to support systems and operations design.

[V2 6026] Water Quality At the point of crew consumption or contact, the system shall provide aesthetically acceptable potable water that is chemically and microbiologically safe for human use, including drinking, food rehydration, personal hygiene, and medical needs.

[V2 6039] Water Dispensing Rate Water shall be dispensed at a rate that is compatible with the food system.

[V2 6040] Water Dispensing Increments To prevent overflow, water shall be dispensable in specified increments that are compatible with the food preparation instructions and time demands of the allotted meal schedule.

[V2 6109] Water Quantity The system shall provide a minimum water quantity as specified in Table 6.3-1—Water Quantities and Temperatures, for the expected needs of each mission, which are considered mutually independent.

[V2 6110] Water Temperature The system shall provide the appropriate water temperature as specified in Table 6.3-1—Water Quantities and Temperatures, for the expected needs of each mission and task.

[V2 7001] Food Quality The food system shall provide the capability to maintain food safety and nutrition during all phases of the mission.

[V2 7002] Food Acceptability The system shall provide food that is acceptable to the crew for the duration of the mission.

[V2 7003] Food Caloric Content The system shall provide each crewmember with an average of 12,698 kJ (3,035 kcal) per day, else an average energy requirement value is determined using Table 7.1-1—EER Equations and applying an activity factor appropriate to the mission gravity and planned level of physical activity.

[V2 7004] EVA Food Caloric Content For crewmembers performing EVA operations, the food system shall provide an additional 837 kJ (200 kcal) per EVA hour above nominal metabolic intake as defined by [V2 7003] Food Caloric Content, of this NASA Technical Standard.

[V2 7007] Food Microorganism Levels Microorganism levels in the food and production area shall not exceed those specified in Table 7.1-3—Food Microorganism Levels.

[V2 7008] Food Preparation The system shall provide the capability for preparation, consumption, and stowage of food.

All referenced tables and figures are available in NASA-STD-3001 Volume 2 Revision D.

View the current versions of NASA-STD-3001 Volume 1 & Volume 2 on the [OCHMO Standards website]

Referenced Technical Requirements

NASA-STD-3001 Volume 2 Revision D

[V2 7009] Food Preparation and Cleanup The food system shall allow the crew to unstow supplies, prepare meals, and clean up for all crewmembers within the allotted meal schedule.

[V2 7010] Food Contamination Control The food storage, preparation, and consumption areas within the vehicle shall be designed and located to protect against cross-contamination between food and the environment.

[V2 7011] Food and Beverage Heating The system shall provide the capability to heat food and beverages to a temperature appropriate for the given item.

[V2 7012] Dining Accommodations The system shall provide adequate volume and accommodations for crewmembers to dine together.

[V2 7014] Food Spill Control The system shall provide the ability to contain and remove food particles and spills.

[V2 7015] Food System Cleaning and Sanitizing The system shall provide methods for cleaning and sanitizing food facilities, equipment, and work areas.

[V2 7100] Food Nutrient Composition The system shall provide a food system with a diet including the nutrient composition that is indicated in the Dietary Reference Intake (DRI) values as recommended by the National Institutes of Health, with the exception of those adjusted for spaceflight as noted in Table 7.1-2—Nutrient Guidelines for Spaceflight.

[V2 7110] Food and Impacts to Environmental Systems Food items and packaging shall be evaluated for impacts on vehicle systems.

[V2 7111] Food Safety The program shall maintain flight food safety throughout product life cycle.

[V2 7112] Food Production Facility The facility where food is prepared, processed, packaged, stowed, and stored shall comply with applicable laws and regulations, or FDA equivalent, as well as industry Good Manufacturing Practice standards.

[V2 7052] Stowage Location All relocatable items, e.g., food, EVA suits, and spare parts, shall have a dedicated stowage location.

[V2 8001] Volume Allocation The system shall provide the defined habitable volume and layout to physically accommodate crew operations and living.

[V2 11025] Suited Nutrition The system shall provide a means for crewmember nutrition in pressure suits designed for surface (e.g., Moon or Mars) EVAs of more than 4 hours in duration or any suited activities greater than 12 hours in duration.

All referenced tables and figures are available in NASA-STD-3001 Volume 2 Revision D.

View the current versions of NASA-STD-3001 Volume 1 & Volume 2 on the OCHMO Standards website

Referenced Technical Requirements

NASA-STD-3001 Volume 2 Revision D

[V2 11029] LEA Suited Hydration The system shall provide a means for on-demand crewmember hydration while suited, including a minimum quantity of potable water of 2 L (67.6 fl oz) per 24 hours for the LEA suit.

[V2 11030] EVA Suited Hydration The system shall provide a means for on-demand crewmember hydration while suited, including a minimum quantity of potable water of 240 mL (8.1 fl oz) per hour for EVA suited operations.

[V2 11037] Suited Metabolic Rate Measurement The system shall measure or calculate metabolic rates of suited EVA crewmembers.

[V2 11038] Suited Metabolic Rate Display The system shall display metabolic data of suited EVA crewmembers to the crew.

All referenced tables and figures are available in NASA-STD-3001 Volume 2 Revision D.

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