NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)
Phase 3 Competition Rules

Rules prepared in coordination with
CANADIAN SPACE AGENCY (CSA)
& IMPACT CANADA INITIATIVE

For full details on the NASA-managed competition webpage visit
https://www.deepspacefoodchallenge.org
For full details on the CSA-managed competition webpage visit
https://impact.canada.ca/en/challenges/deep-space-food-challenge

Contents

1 Revision Tracking Log

Section	Revision #	Description	Date
	0	Original Document	

2 Definition of Collaborators and Challenge Administrators

National Aeronautics and Space Administration (NASA): Is an independent agency of the U.S. Federal Government responsible for the civilian space program, as well as aeronautics and space research.

Methuselah Foundation: Is a non-profit organization that strives to advance human health and longevity. They develop and partner with programs and organizations to accelerate breakthroughs in these areas. NASA Centennial Challenges has partnered with Methuselah Foundation to help execute the Challenge.

The Ohio State University: Is a public research university, serving more than 68,000 undergraduate, graduate, and professional students located in Columbus, Ohio. Ohio State has partnered with the Methuselah Foundation to host and support the Phase 3 demonstrations for the Challenge at the George Washington Carver Science Park's Starlab Terrestrial Analog Facility.

The George Washington Carver Science Park's (GWCSP) Starlab Terrestrial Analog Facility (TAF): The GWCSP, established by Voyager Space Holdings, is a core research ecosystem and infrastructure supporting Starlab, Voyager's future commercial space station being developed as part of a joint venture with Airbus. The permanent TAF will be located in a Voyager-owned, purpose-built facility in the GWCSP at The Ohio State University Airport. Currently, a temporary TAF is operating within the Agricultural Engineering Building on the Ohio State University campus and is devoted to space research. It is a systems replica laboratory of the Starlab space station, and enables researchers to prepare, evaluate, validate, and test parallel ground and spaceflight experiments and activities. It also serves as a key focal point for STEM education and outreach, stakeholder engagement, and business development functions for Starlab and GWCSP.

Canadian Space Agency (CSA): Is a Canadian federal agency responsible for managing all of Canada's civil space-related activities. The CSA is responsible for advancing the knowledge of space through science and using its discoveries for the good of Canadians and all of humanity.

Privy Council Office (PCO): Supports the Canadian Prime Minister and Cabinet. Led by the Clerk of the Privy Council, the department helps the Canadian government in implementing its vision, goals, and decisions in a timely manner.

Impact Canada: Housed within the Privy Council Office, is a Government of Canada-wide effort to help accelerate the adoption of innovative funding approaches to deliver meaningful results to Canadians. Challenge Prizes, Pay-for-Success projects and Behavioral Science are its key business lines.

3 Definition of Terms

Concept of Operations: A document describing the operations of a proposed system from a user's perspective, through a complete production cycle, including cleanup and any activities required to prepare for the following production cycle.

Food Production Cycle: The period of time and activities required for the food production technology to produce a food output. A production cycle is a stage of the technology life cycle.

Judging Panel: A panel of professionals and subject matter experts from government, academia, and industry who will evaluate and score all submissions.

Kitchen Level: A level of technology development roughly equivalent to Technology Readiness Level (TRL) 4.

Phase: A stage of the Challenge representing a key step in the development of food production technologies for feeding crews on long-duration space exploration missions. This Challenge will have up to three Phases.

Simunaut: An individual selected to play the role of "astronaut" during a simulated crew mission.

Simunaut Crew: Group made up of individual Simunauts.

Team: An individual, group of individuals, or a group of individuals represented by an Entity that have officially registered and are approved to compete in the Challenge (U.S., International).

Technology Cycle: The various stages required and/or conducted over the use of the food production technology, including (but not limited to) set up, food production, harvesting, shutdown, and cleaning.

Technology Readiness Level (TRL): A method for estimating the maturity of technologies. The use of TRLs enables consistent, uniform discussions of technical maturity across different types of technology.

4 Challenge Background and Objectives

International collaborations have been key to the success of countless space missions. This Challenge represents a first of its kind coordination between the National Aeronautics Space Administration (NASA), the Canadian Space Agency (CSA) and the Privy Council Office (PCO) in the organization of parallel prize competitions to support the space policies of the respective United States Government and the Government of Canada while having broader terrestrial benefits. For more information on the CSA prize competition visit: *https://impact.canada.ca/en/challenges/deep-space-food-challenge*

Food is a critical component of human space exploration missions. When humans return to the lunar surface, the early missions will use prepackaged foods similar to those in use on the International Space Station (ISS) today. But extending the duration of lunar missions requires reducing resupply dependency on Earth. Thus, testing a sustainable system on the Moon that meets lunar crews' needs is a fundamental step for lunar sustainability and will also support a transit mission to, and further exploration of, Mars This requires a focus on how to furnish crew members with a viable system that produces food for all long duration space missions.

Solutions from the Deep Space Food Challenge could be part of the larger food system as an integrated solution that:

- Provides all daily nutritional needs
- Provides a variety of palatable and safe food choices
- Enables acceptable, safe, and quick preparation methods
- Limits resource requirements with no dependency on direct periodic resupply from Earth over durations increasing from months to years

In short, future crew members will require nutritious foods they will enjoy eating within all the constraints of current technology for life away from Earth. The process to create, grow, and/or prepare food must not be time consuming or unpleasant. Although there are many food systems on Earth that may offer benefits to space travelers, the ability of these systems to meet spaceflight demands has not yet been established. The DSFC seeks to bridge this gap via innovative technologies that promote a more sustainable food production future for space while simultaneously offering benefits for people back on Earth who deal with unique food challenges of their own.

4.1 Terrestrial Intersection

Food insecurity is a significant chronic problem on Earth in urban, rural, and harsh environments and communities. In places like the Arctic and Canada's North, the cost of providing fresh produce on the shelves can be incredibly high. In addition, many northern communities can only be accessed by aircraft or receive infrequent shipments of food, often resulting in a decrease in quality. While the production of fresh foods cannot address Northern food insecurity caused by isolation, controlled environment food production technologies have advanced rapidly over recent decades and the cost-benefit ratio for their application, even to harsh environments such as the Arctic, are now becoming feasible. This can also support greater food production in other milder environments, including major urban centers where vertical farming, urban agriculture and other novel food production techniques can play a more significant role.

Disasters can also disrupt supply chains which people depend on, and further aggravate food shortages. Developing compact and innovative food system technologies can enhance local production and reduce food supply chain challenges, providing new solutions for humanitarian responses to floods and droughts and new technologies for rapid deployment following disasters.

The Deep Space Food Challenge seeks to create novel food production technologies or systems that require minimal inputs and maximize safe, nutritious, and palatable food outputs for long-duration space missions, and which have potential to benefit people on Earth.

The Deep Space Food Challenge will identify food production technologies that can:

- Help fill food gaps for a crew of four for a three-year round-trip mission with no resupply
- Improve the accessibility of food on Earth via production directly in urban centers and in remote and harsh environments
- Achieve maximum food output with minimal inputs and minimal waste
- Create a variety of palatable, nutritious, and safe foods that requires little processing time for crew members

This Challenge seeks to incentivize Teams to develop novel technologies and/or systems for food production that need not meet the full nutritional requirements of future crews but can contribute significantly to and be integrated into a comprehensive food system.

4.2 Baseline Information

Information describing NASA's current food system capabilities, including inputs and outputs is provided in the Reference Materials section of this rules document. This will serve as a baseline reference for Teams, to help them envision whether their food production technology could offer an improvement to the current prepackaged food system. Examples of possible opportunity areas for new food production technologies are also included in the Reference Materials section.

In the past, proposed technologies have not been able to address the full range of considerations for a potential food system. For example, a technology may fill the nutritional needs of the crew but may not be very appealing to prepare and/or consume. The Deep Space Food Challenge is interested in food production technologies that address multiple considerations.

Additionally, resource requirements should also be considered by the Teams. If the resource requirements of a food production technology are greater than those currently achievable with existing space systems, that technology may not transfer well to a spaceflight environment. If resource requirements of a food production technology are comparable, there should be a beneficial trade in other areas, such as nutritional stability, acceptability, safety, health and performance promotion, and crew considerations such as time and ease of use.

4.3 Flexible Food Systems

The types and durations of future exploration missions are constantly evolving and maturing based on new technological advances and scientific input. Space agencies will need to address long-duration lunar missions and how to provide these future lunar crews with safe and nutritious food while in lunar orbit or on the lunar surface. At the same time, they are looking ahead to how a lunar food system can help enable a Mars mission for a crew traveling with their entire food system. Additionally, the speed at which technology is being developed is increasing. As such, space agencies are interested in flexible and modular food production technologies that adapt to changing needs and mission architectures. The intent is to use modular and flexible technologies and build them into systems that meet the unique needs of each mission type or specific mission. This Challenge provides a set of performance criteria and asks Teams to produce the best food production technology they can within those criteria.

The scoring criteria recognize that a combination of technologies will be used together in an overall food system and rewards those technologies (submissions) that are likely to contribute to multiple mission scenarios. Examples of mission scenarios are included in Appendix A.

5 Challenge Description

5.1 Competition Overview

The Deep Space Food Challenge is designed to be composed of three phases:

- ***Phase 1: Design. (COMPLETED)*** Required Teams to design a novel food production technology concept and provide a detailed explanation of how it meets the Challenge goals and performance criteria.
- ***Phase 2: Kitchen Demonstration (COMPLETED).*** Requires Teams to build a food production technology prototype (equivalent to a TRL 4) and demonstrate the prototype during a Kitchen-Level demonstration at a designated facility. Teams will also provide samples of food outputs (e.g., tangible nutritional products) from the prototype, and will be asked to provide a vision for future commercialization of the technology.
- ***Phase 3: Full System Demonstration.*** Requires Teams to build a full-scale food production technology and demonstrate the technology at a designated facility. Teams are asked to provide documentation that shows the potential Impact of the demonstrated technology for Earth-based applications.

This rules document covers Phase 3 of the Deep Space Food Challenge.

Phase 3 offers prize purses of $1,500,000 USD from NASA, to be awarded as described in Section 7. Phase 3 will last approximately eleven (11) months (see Competition Calendar in Section 6).

5.2 Phase 3 Scenario

The following scenario serves as a backdrop to support the continued development and demonstration of the Phase 3 food production technologies.

In the not-too-distant future, a crew of “Simunauts” awaits the arrival of the components of a food system for an analog mission. The Teams delivering these different components have developed a range of food production technologies and will train the Simunaut crew on how to operate and maintain their technology, and will guide them through Ground Test Validation. Once this training is complete and the doors to the analog have closed, the Simunaut crew will begin Simulated Flight Operations to determine the functionality possible for the food production systems with the limited resources provided.

The Simunauts are not an extension of the Team, but act as the “crew” for the duration of the mission tasked with operating the food production technologies in the same way a future astronaut crew may operate them during a long-duration space exploration mission. This includes:

- maintaining the systems
- following the provided operating procedures for producing product(s)
- converting the product(s) into menu items for the crew
- cleaning the food production technologies

Similar to real-life mission planning, the Simunaut crew’s time is not dedicated to solely food production activities. A future astronaut crew schedule is a full-day schedule of activities including Extravehicular Activities (EVA) and exploration missions, research and science experiments, cleaning, maintenance, supporting public engagement requests, personal time, self-care, exercise and meals. The Simunaut crew will have a scheduled amount of time for meal preparation, and a separate scheduled amount of time to maintain, clean and operate the food production system. The Teams will coordinate the schedules for the Simunaut crew in advance of the demonstration.

The Teams will deliver and set up their technologies in the analog facility and can monitor or remotely command their technologies from external consoles. Teams will be able to have contact with the Simunauts to answer questions and guide them through repairs if needed; however, this contact will follow the process and procedures detailed in these Official Rules. Additionally, the amount of contact between the Teams and the Simunauts will be tracked and will influence the Simunauts’ evaluation.

At the completion of the Simulated Flight Operations, the Simunauts’ mission logs will be part of the overall evaluation of the food production technology as described in these Official Rules.

5.3 Submission Summary

The Phase 3 demonstration is analogous to Technology Readiness Level (TRL) 5[1]. Teams will further develop their initial Phase 2 prototype of their proposed food production technology and deliver it to a designated facility. Details and instructions for the required testing are included in Sections 10 of these Official Rules.

The food production technology must:

- Stay within the operational considerations described in Table 1 (below)
- Meet the overall criteria (Table 4) and performance criteria (Table 5) as described in Section 8

Table 1. Operational Considerations

Item	Description
Gravity	Earth gravity (9.81 m/s²) and ambient atmospheric conditions of 101,325 Pascals, 22 degrees Celsius, and 50 percent relative humidity.
Simunaut Crew Time	All Simunaut crew activities must occur between 8am-6pm ET, 7 days per week and are not to exceed 2 hours per day. Responsibilities and constraints are further explained in Sections 10 and 12.

Per Table 2 (below), Phase 3 will consist of three (3) submission requirements from the Teams leading up to the Demonstration Period.

- Development Schedule & Milestones
- Operations Document Package
- Final Determination of Technology Readiness

[1] Technology Readiness Levels as defined here: https://www.nasa.gov/pdf/458490main_TRL_Definitions.pdf

The full details of each submission requirement is described in Sections 10.

Table 2: Phase 3 Submission Requirements

Submission Requirement	Description
1. Development Schedule & Milestones: *Report the schedule for scaling the Team's Phase 2 prototype to be ready to ship for the for the demonstration, including key milestones*	
October 2023	● Teams will submit a development schedule & milestones and additional information about their food production technology to support the preparations for the demonstration facility. ● Link to the online submission form will be provided by Methuselah Foundation ● **Submission is not scored** o *Submissions reviewed by the Judging Panel and Challenge Administrators and feedback will be provided as appropriate.*
2. Operations Document Package: *Develop the supporting plans and manuals to support the requirements of the demonstration.*	
Draft Operations Document Package January 2024	● Teams will submit a Draft Safety Plan, Draft Crew Procedures Manual, Draft Inventory of Resources and Draft Production Schedule ● Links to upload the documents will be provided by the Methuselah Foundation. ● **Submission not scored** o *Submission reviewed by the Judging Panel and feedback will be provided as appropriate*
Final Operations Document Package April 2024	● Teams will submit a Final Safety Plan, Final Crew Procedures Manual, Final Inventory of Resources and Final Production Schedule ● Link to upload the documents will be provided by Methuselah Foundation ● **Submission is not scored; however final documents will contribute to the overall determination of technology readiness to ship to the demonstration facility.**
3. Final Determination of Technology Readiness: *Prove the food production system is ready for the full system demonstration*	
Virtual Walkthrough April 2024	● Virtual presentation with an Evaluation Panel that will consist of members of the Judging Panel, the Challenge Administrators, and the demonstration facility Managers to determine readiness of the food production system to be shipped for the demonstration. ● Methuselah Foundation will schedule the day and time for each Team's Virtual Walkthrough ● **Submission not scored, however technology readiness will either be Approved, Conditionally Approved, or Rejected** ○ Conditionally Approved technologies will be permitted to resubmit

6 Competition Calendar

Table 3 below is an overview of the expected timeline for Phase 3 of the Challenge.

Table 3. Competition Calendar

Date/Deadline	Event

September 15, 2023	Phase 3 Opens
October 6, 2023	Intent to Compete and Development Schedule Due
September 2023 - April 2024	Teams scale their technologies and work towards technology readiness for the demonstration
January 16, 2024	Draft Document Package Due
April 1,2024	Final Document Package Due
April 9-10, 2024	Virtual Walkthroughs
April 16, 2024	Final Determination of Technology Readiness
May 20-25, 2024	Teams deliver the food production systems to the designated facility and prepare for the demonstration
May 27-June 1, 2024	Teams Arrive at the TAF for Technology Setup
June 3-4, 2024	Simunaut Crew Operational Training
June 5 - July 31, 2024	Demonstration Period *June 5-18 - Ground Test Validation* *June 19-July 31 - Simulated Flight Operations*
August 5-16, 2024	Judging Panel Evaluation & Final Summit to determine winners
August TBD, 2024	Phase 3 Winners Announced & Industry Day Event
August TBD, 2024	Teams Remove Technologies from the TAF

7 Phase 3 Prize

U.S. Teams must meet the eligibility requirements for the NASA Prize in order to receive a prize from NASA. These criteria are defined on the Official Challenge Website (deepspacefoodchallenge.org).

NASA Prize Purse for U.S. Teams
Each U.S. Team that proves technology readiness as determined by the Judging Panel and is approved to ship their food production technology to the demonstration location, will be awarded $50,000 USD.

Up to one (1) top scoring U.S. Team will be named the U.S. winner of Phase 3 and will receive $750,000 USD from NASA. Up to two (2) U.S. runners up will each receive $250,000 USD from NASA.

U.S. Teams must meet the eligibility requirements to participate in the Challenge and receive a prize award from NASA.

Recognition for International Teams
One top scoring International Team will be recognized as the international winner of Phase 3, and up to two (2) international runners up will also be recognized.

International Teams must meet the eligibility requirements to participate in the Challenge and be recognized as winners.International Teams are not eligible to be awarded prize money from NASA.

8 Assessment Criteria

Teams' submissions will be assessed by a panel of Judges and evaluated using a set of overall criteria and specific performance criteria.

The overall criteria are described in the below Table 4.

Table 4. Overall Criteria

Category	Description
Design Approach and Innovation	Do the operations of the system make the technology work as a human factor and ease of use? ● Approaches to the operational procedures to make the technology more user-friendly including: ○ Set up ○ Startup/shut down ○ Daily maintenance and cleaning ○ Harvesting ○ Food prep ○ All other tasks ● Examples could include: ○ Autonomy ○ Ease of use ○ Automation
Terrestrial Potential	Teams should explain the feasible scenario for the potential use of their food production technology within terrestrial food systems. ● How would this food system be useful on Earth? ● What communities do you see this system benefiting? Ex: food deserts, remote communities, restaurants) ● How would your system benefit these communities?- What specific factors is the technology impacting? ● Does it help solve food security issues found in extreme environments, or post disaster scenarios?

The performance criteria are described below in Table 5.

Table 5. Performance Requirements

Category	Description

Acceptability	<u>**Acceptability of the Food Production Process**</u> ● ***Target: The current target for Astronauts is 1 hour per meal for a crew of 4 (30 minutes for preparation, 30 minutes after the meal to clean, dispose, or reconfigure the device for the next production cycle).*** ● *NOTE: The process must be something crew members could be expected to accomplish in a reasonable amount of time, on a daily basis in a small kitchen-like space after a busy workday.* o Teams must provide detailed descriptions in the crew procedures manual of all the operations processes and procedures, including (but not limited to): o Food production technology set up o Food production cycle, including steps to produce food products o Food handling, processing procedures and collection of food products o Shutdown, cleaning, and/or stowage procedure(s) o An estimate of the overall crew time to operate and maintain the technology <u>**Acceptability of the Resulting Food Product**</u> ● ***Target: A NASA food item achieving an overall acceptability rating of 6.0 or better on a 9-point hedonic scale for the duration of the mission is considered acceptable.*** ● The food production technology should produce a food output that will be assessed on: o **Desirability** – The degree to which a person is motivated to consume the food item as soon as it is seen o **Appearance** - Color and color combinations, size and shape, visual attractiveness, eye appeal, signs of freshness. o **Aroma** - The smell or aroma such as tangy, herby, earthy, etc. o **Palatability** - Sensory capacity to stimulate ingestion of the food product o **Flavor/Taste** – The direct contact of food with stimuli on the tongue to determine the quality of the ingested food. The basic tastes include umami, sour, sweet, bitter, and salty. o **Texture** - Qualities felt by touch such as mouth feel, hand and/or finger feel
Safety	**NOTE: No pathogens that could result in illness are permitted to exist within the food technology or its outputs. Teams must take this into account.** ***Technologies that fail to account for pathogens will receive a "zero" score on the Safety category.*** <u>**Safety of the Food Production Process**</u> ● ***Targets: Environmental & process safety:*** ***o Avoidance of hazardous compounds or materials used or produced (e.g., microbes, off-gassing, toxic components)*** ***o Avoidance of hazards associated with cleaning this technology prior to and/or after use*** ***o Avoidance of physical, chemical, or biological hazards associated with the hardware or the process*** ***o Clear mitigation strategies to address the aforementioned risks*** ● Teams must provide a HACCP Plan that addresses the safety of the food production processes and addresses and mitigates identified risk(s), including: o Identifying the critical control points and establish critical limits o Establish monitoring procedures and corrective actions o Establish verification procedures and record-keeping and documentation procedures. o Teams should demonstrate an understanding of food safety procedures on their own or through the consultation of industry/academic food scientists and similar experts as necessary <u>**Safety of the Food Product**</u>

	• ***Targets: Consumption safety: Resulting food product safe is for repeated human consumption as defined by NASA-STD-3001 (see Reference Materials)*** • The food production technology will produce a food output that meets the safety requirements for repeated human consumption. • Samples will be collected and tested in a laboratory for pathogens that could result in illness. • *NOTE: A food product deemed unsafe for human consumption will affect the ability of the Food Sensory Lab to conduct the hedonic-scale testing and ultimately affect the score for the acceptability of the food product.*

Resource Inputs & Outputs	**<u>Inputs and Outputs in Relation to Quantity of Food Produced</u>**
	• ***Targets:***
	  o ***Maximum quantity food output relative to quantity of system inputs***
	  o ***Maximum quantity food output relative to quantity of waste output***
	• Teams will provide a list of inputs to their food production technology to be used for the duration of the demonstration period, and the expected food outputs associated with the technology.
	  o Inputs may include: Raw materials, energy, water, or other materials that enter the system
	  o Waste Outputs may include: Waste (cleaning water and chemical agents), heat (latent and sensible), and other unusable product exiting the system, including liquid and gaseous process flows (*e.g.*, water vapor, low-molecular weight organic and inorganic compounds, water, oils, etc.)
	  o Food Outputs may include: Food products and other useful products exiting the system (e.g., feedstock for another part of the technology or system)
	• The inputs used in a production cycle will be measured before the production cycle begins.
	• The waste outputs associated with the technology will be measured as they are incurred during the technology cycle.
	• Both inputs and waste outputs will be measured against the resulting quantity of nutritious food output.
	  o food outputs / (inputs + waste)
	
	<u>Nutritional Food Outputs</u>
	• ***Targets:***
	  o ***Maximum macronutrients supplied, as a percentage of complete dietary needs for a crew of four***
	  o ***Maximum micronutrients supplied, as a percentage of complete dietary needs for a crew of four***
	  o ***Maximum variety of nutrients supplied***
	• Teams must maintain or exceed the baseline nutritional makeup as established in Phase 2 lab testing including:
	  o The Food and Drug Administration (FDA) Nutrition Labeling and Education Act (NLEA)
	  o Vitamins C, B1 and K
	
	<u>Water Inputs and Outputs</u>
	• ***Targets:***
	  o ***No more than 40 L at startup***
	  o ***No more than 1 L per day "water added over time"***
	  o ***No more than 5 L for cleanup***
	• Teams will set a baseline for net water consumption during the initial setup of their food production technology.
	  o The technology must maintain or improve on the set baseline for each production cycle.
	• Net consumption of water is measured by the following equation:

	○ C_{Net} = (Initial water input + water added over time + water used for cleaning – condensed/recovered water provided back to crew) ● In this calculation: ○ Do not include water recycled by your system in the “water added over time” ○ Do not subtract the water remaining in your system after the food has been collected ○ Do not subtract water lost to the vehicle environment (e.g., water evaporated into the vehicle’s air)
Reliability / Stability	<u>**Reliability of the Food Production Technology**</u> ● ***Targets:*** ***o Amount of time required to maintain and clean the system should not exceed an average of 60 minutes per 7-day week.*** ***o Mass of spare parts and cleaning materials should not exceed the estimated mass of the total system.*** ***o Less than 10% loss of functionality or food production throughout a three-year mission.*** ● The food production technology must remain operational for the entirety of the demonstration period. ● Reliability of the technology considers any loss of functionality including downtime and breakdown that result in loss of food production. <u>**Stability of the Input Products and Food Outputs**</u> ● ***Targets:*** ○ ***Stability of inputs should be three (3) years*** ○ ***Stability of the food outputs should be at least three (3) days*** ○ ***Both inputs and food outputs must remain safe, without any significant loss of nutritional value or quality at ambient conditions*** ● The input products provided by the Teams must remain safe, without any significant loss of nutritional value or quality for the duration of the demonstration period. ● Teams will provide guidelines in the operational manual for the storage and estimated time for consumption (shelf-life) of the food product outputs.

8.1 Phase 3 Judging

The Challenge will have distinct Judging Panels for U.S. and Canadian Teams, and a combined Judging Panel for Other International Teams. The Judging Panels will communicate and collaborate throughout the entirety of the Challenge. Each Judging Panel has discretion in the assessment and scoring of submissions and in selecting the winners.

Following the demonstration period, the Judging Panels will review the Simunaut Mission Logs along with results from the Sensory Testing and Lab testing, and discuss, evaluate, and rank the entries. Table 6 shows the distribution of points across the evaluation criteria. The Judging Panel's evaluation of the food production technology will be informed according to the sources listed in this same Table 6.

Teams can earn points in all categories, with the exception of Reliability/Stability. Teams can incur a penalty of up to 6 points for loss of functionality of the food production technology as compared to the required 2.5kg food output.

A penalty for loss of functionality will be applied to the Team's overall score as described below:

- Minor (2-point penalty): 10-15% loss of production
- Moderate (4-point penalty): 16-20% loss of production
- Significant (6-point penalty): Greater than 20% loss of production

Teams can incur a penalty of up to 6 points for loss of inputs due to limited stability.

A penalty for loss of inputs will be applied to the Team's overall score as described below:

- Minor (2-point penalty): All inputs are not stable for more than 4-6 weeks at ambient temperatures
- Moderate (4-point penalty): All inputs are not stable for more than 2-4 weeks at ambient temperatures
- Significant (6-point penalty): All inputs are not stable for 2 weeks or less at ambient temperatures

Table 6. Scoring

Criteria	Source			Judging Panel	Points
	Simunaut Mission Logs	Sensory Testing	Lab Testing		
Design Approach and Innovation				**X**	**5**
Terrestrial Potential				**X**	**5**
Acceptability				**X**	**10**
Process	*Qualitative*				*5*
Food Product		*Quantitative*			*5*
Safety				**X**	**10**
Process	*Qualitative*				*5*
Food Product			*Quantitative*		*5*
Resource Inputs / Outputs				**X**	**25**
Quantity of Inputs to Outputs	*Quantitative*				*17*

Nutritional Content of Outputs			*Quantitative*		*8*
Reliability/Stability				**X**	**10**
Cleaning & Maintenance	*Quantitative*				*10*
Loss of Functionality	*Quantitative*				**Penalty only (Up to 6 points total)*
Stability of Inputs	*Quantitative*				**Penalty only (Up to 6 points total)*
Contribution:	**Mixed Data**	**Quantitative Data**	**Quantitative Data**	**Informed by Quantitative Data, Apply Qualitative Scoring & Validate Final Ranking**	**Total: 65 points**

**Penalties will be applied to the overall score*

9 Eligibility and Registration Requirements & Process

The Phase 3 competition is only open to Phase 2 winners. NASA will not accept new registrations for Phase 3. Phase 2 winning Teams should indicate their intent to compete by signing a Phase 3 Team Agreement no later than October 6, 2023, and are only required to submit documents to confirm eligibility if adding new Team members.

Teams will be officially registered to compete after the Team Agreement is co-signed by the Methuselah Foundation and the Team Leader. Until registration is confirmed by Methuselah Foundation, a Team is not considered registered.

10 Submission Requirements

All Teams will provide the required information described below via online submission portal provided by Methuselah Foundation. All reports, applications, documents, and videos must be submitted in English. No submissions will be accepted outside of the stated deadlines.

- **Development Schedule & Milestones**
- **Operations Document Package:**
  - Terrestrial Business Strategy
  - Safety Plan
  - Crew Procedures Manual
  - Inventory of Resources
  - Production Schedule
- **Determination of Technology Readiness**
  - Virtual Walkthrough

10.1 Development Schedule & Milestones

Teams will provide a technology Development Schedule that reflects the current status of their food production technology and describes the necessary steps and key milestones for scaling their Phase 2 prototype to the required technology readiness level for the final demonstration period. This report will be submitted through an online form and is due no later than October 6, 2023. The Development Schedule will also support the preparations for the demonstration facility and can be changed/edited by the Teams as needed.

The Development Schedule should include:

- **Technology Requirements for the Demonstration Facility**
  - Power – overview of the technology's power system, quality & quantity of the power needed, types and quantity of plugs
  - Wi-Fi and data transfer
  - Water – volume, pressure & flow, quality, second stream
  - Compressed Air (yes/no)
  - Mounting/set up of the hardware (on a table, on the floor, calibrated level surface, vibration isolation)
  - Hardware temperature, humidity, environmental boundaries
  - Layout drawing of the technology that gives the measurements of the technology
    - Low fidelity, block diagram
    - Include any "keep out" space needed around the technology
    - Indicate where facility interfaces will go (List - power, water, etc.)
  - Refrigeration – type, size
    - Storage requirements for inputs (amount, temperature, humidity)
    - Storage requirements for food outputs (amount, temperature, humidity)
  - Wish List for Pantry (ex: cooking utensils)
- **Production Schedule**
  - Length of production schedule
  - Length of time a food output can be stored before spoilage
  - Estimated amount of in-person technology monitoring required
- **An overall status report of the food production system development efforts indicating progress on:**
  - Description of baseline prototype technology
  - Plan for scaling/adjusting technology
  - Description of approach
  - Block diagram or system-level report of the process to scale
- **Current Status:**
  - Percentage complete
  - Summary description of what's going well, what's proving to be challenging, and estimated completion date of the build
- **Target completion date**

The Development Schedule and Milestones will be reviewed by the Judging Panel and the Challenge Administrators and feedback will be provided as appropriate.

10.2 Operations Document Package

10.2.1 Terrestrial Use Strategy

The Terrestrial Use Strategy is a one-page overview of how and where the food production technology could be adapted, implemented and utilized on Earth. Teams should explain the feasible scenario for the potential use of their food production technology within terrestrial food systems.

- How would this food system be useful on Earth?
- What communities do you see this system benefiting? Ex: food deserts, remote communities, restaurants
- How would your system benefit these communities?- What specific factors is the technology impacting?
- Does it help solve food security issues found in extreme environments, or post disaster scenarios?

10.2.2 Safety Plan

The Safety Plan is a continuation of the initial plan developed in Phase 2 and should give a complete picture of the processes in place to address the safety of the technology and potential risk to the individuals operating the technology and to the demonstration facility.

Teams must provide a HAACP Plan that addresses the safety of the food production processes and addresses and mitigates identified risk(s), including:

- Identifying the critical control points and establish critical limits
- Establishing monitoring procedures and corrective actions
- Establishing verification procedures and record-keeping and documentation procedures.
- Teams should demonstrate an understanding of food safety procedures on their own or through the consultation of industry/academic food scientists and similar experts as necessary

A Hazard Analysis and Critical Control Point (HACCP) plan is a systematic approach to the identification, evaluation, and control of food safety hazards. A HACCP plan is the written document which is based upon the principles of HACCP, and which delineates the procedures to be followed.

- The principles and guidelines of a HACCP plan are described by the U.S. National Advisory Committee on Microbiological Criteria for Foods (NACMCF) and the associated prerequisite programs (where applicable): https://www.fda.gov/food/hazard-analysis-critical-control-point-haccp/haccp-principles-application-guidelines#princ

10.2.3 Crew Procedures Manual

The Crew Procedures Manual is an instructional document that describes in detail the suite of operational processes associated with the technology including (but not limited to) setting up, operating, cleaning, tearing down the food production technology and producing, collecting/harvesting, and processing the food output. The Team will train the Simunaut crew using this manual, and the Simunaut crew will use and refer to this manual for all operations of the food production technology during the demonstration period.

The Simunaut crew will not conduct any procedures not included in the manual.

The manual will be submitted in a single PDF format (no page limit), and may include text, pictures, diagrams, graphics, tables, etc. Hyperlinks and videos are permitted as supplemental to the written procedures.

The manual must provide detailed descriptions of all the operations processes and procedures, including (but not limited to):

- Technology set up
- Food production cycle
  - Steps to produce food products
  - Operations cycle time (i.e., the amount of time for one production cycle)
- Food handling, processing procedures and collection of food products
  - Teams will provide three different recipes the Simunauts will use to process the food output into a consumable component of a meal.
    - A minimum of 30% of the total mass of the ingredients in each recipe is required to be a food output or food outputs produced by the food production technology.
    - The recipe should include measurements for each ingredient and clearly describe each step.
      - For example, if this product needs to be mixed with another product, it must be outlined for how long (i.e. 30 seconds) it should be mixed.
    - Teams will provide all ingredients (except what is utilized from the space pantry) as part of their inputs
    - Each Team will be provided with a “space pantry” (Further described in Section 10.2.3) that may be used by the Simunaut crew to enhance the food output products. The space pantry will be identical for each team.
  - Packaging and storing food outputs
- Maintenance and cleaning processes and procedures including:
  - Maintenance schedule (i.e.How often will it need maintenance?)
    - Which component(s)/element(s) require maintenance or replacement (i.e., what components will need to be replaced, and when?)

        - Critical spare parts for the duration of the demonstration period and longevity of those spare parts
    - Which component(s)/element(s) require cleaning
        - Cleaning schedule (i.e. How often will it need cleaning?)
            - Cleaning per use
            - Deep cleaning the full system
                - What is needed to fully clean the system (i.e., water, chemicals, etc.)
- Time estimates
    - An estimate of the overall crew time to operate and maintain the technology (per day and per week)
    - Amount of time it takes to perform the required maintenance (per task and overall, per day and per week)
    - Amount of time required to perform the system cleaning (per task and overall, per day and per week)
- Shutdown, cleaning, and/or stowage procedure(s)

10.2.4 Inventory of Resources

Teams will provide enough resources for their food production technologies to maintain functionality for the duration of the Demonstration period.

An inventory of these resources will also be provided by the Team and should include the name, description, and amount (kg) of each item.

- Inputs to the food production technology
- Additives to the food outputs contributing to the processing and preparation for consumption (i.e., spices, flavorings, condiments)
- Cleaning materials
- Replacement parts

Each Team will be provided with a “space pantry” that may be used by the Simunaut crew to enhance the food output products, and utilized in the operations, maintenance, and cleaning processes as needed.

The space pantry will be identical to each team and will include:

- Condiments: Ketchup, Mustard, Hot Sauce, Salt, Pepper
- Housekeeping Supplies: Paper towels, gallon-size resealable bags, aluminum foil, garbage bags,
- Personal Protective Equipment: Nitrile Gloves, Safety Goggles and Coats, N95 Masks, Hair nets/Head covering

Condiments and housekeeping supplies will be provided in limited quantities. Personal Protective Equipment will be provided in unlimited quantities. Teams are free to use the space pantry items for any aspect of their processes. Any quantities that are included in the space pantry will not be included in a team’s scoring. If a team needs more of any item that is included in the space pantry than is provided, those additional quantities will be included as inputs and/or waste in their scoring.

The Challenge Administrators will notify the Team in writing of any additions to the Space Pantry and will provide measurements for each pantry item prior to the demonstration period.

10.2.5 Production Schedule

The Production Schedule lays out the daily and weekly schedule for the Simunaut crew operating the Team’s technology. Teams will enter their production schedule into an electronic form provided by Methuselah Foundation.

The schedule should map out which operational procedures should be conducted daily and weekly. This includes:

- Food production operational procedures
    - Processes and procedures needed for preparing the system to produce food. Example: Procedures for planting and harvesting
    - Food production schedule
        - Teams must indicate two or more points during the demonstration period where their food production technology will produce a food output.
- Post-production meal preparation, processing and general clean up
    - *Target: The current target for Astronauts is 1 hour per meal for a crew of 4 (30 minutes for preparation, 30 minutes after the meal to clean, dispose, or reconfigure the device for the next production cycle).*
- General Maintenance and Full System Cleaning
    - *Target: Amount of time required to maintain and clean the system should not exceed an average of 60 minutes per 7-day week.*

<u>All activities must occur between 8am-6pm ET, 7 days per week and are not to exceed 2 hours per day.</u>

Teams will provide two versions of the schedule:

- **Detailed weekly schedule**: Daily tasks for the Simunaut crew to conduct
- **Overview schedule**: High-level overview schedule for the duration of the demonstration

Any emergency situations outside of the Simunaut Crew hours will be addressed by the TAF management.

An emergency is defined as an issue or problem with the food production technology that cannot be addressed during the next Simunaut crew shift and will directly result in a significant loss of production and/or total system failure.

10.2.6 Operations Document Package Review:

10.2.6.1 Draft Operations Document Package

A draft of each document in the Operations Document Package must be submitted via an online form no later than January 16, 2024. The Judging Panel will conduct the review of each Team's draft package to ensure all requirements listed are met and all potential safety risks are addressed and provide feedback as appropriate.

NOTE: The draft Operations Document Package will also support the preparations for the demonstration facility.

10.2.6.2 Final Operations Document Package

A final version of each document in the Operations Document Package must be submitted via an online form no later than April 1, 2024. The Judging Panel will conduct a review of the final document package and will include this evaluation as part of the determination of technology readiness to ship to the demonstration facility.

Draft and final document packages will not be accepted after the stated deadlines.

10.3 Determination of Technology Readiness

10.3.1 Virtual Walkthrough

Each Team will participate in a 1-hour virtual walk-through with an Evaluation Panel that will likely consist of members of the Judging Panel, the Challenge Administrators, and the Ohio State TAF Managers.

The Virtual Walkthrough will be made up of two parts:

- **Part One: Determination of Technology Readiness -** The purpose is for the Teams to show the status of their technology, address any questions and concerns from the Evaluation Panel, and prove the technology is ready to ship to the demonstration facility.

- **Part Two: Review of Facility Needs and Inventory -** The purpose is to review the inventory of resources the Teams will provide and make any adjustments to the technology requirements for the TAF.

The first 45-minutes of the virtual walk-through will be dedicated to the Determination of Technology Readiness and will include:

- Overview of the Technology - Since the Phase 2 prototype, what has changed, what has stayed the same, etc.
- Review of Requirements - Review of the requirements for the demonstration period (ex: providing food output samples) and how the technology will achieve those requirements.
- Risk Assessment - Identify potential technical challenges, operational bottlenecks, safety concerns and other issues that could hinder a successful demonstration and/or potentially cause damage to the TAF.
- Review of Operations Document Package - Review Judge's feedback and answer any remaining questions and/or concerns.

The final 15-minutes of the virtual walk-through will be dedicated to the Review of Facility Needs & Inventory and will include:

- Review of the original technology requirements for the demonstration facility - Changes from the original requirements, additional requests
- Review of Inventory - Review of the resources and amounts the teams will be providing in support of their food production technology and any requirements necessary to support those resources.

The Evaluation Panel will make one of two determinations based on the evaluation of the final operations document package and the virtual walkthrough:

- **Rejection:** A Team's technology readiness will be rejected if it meets any or all of the following conditions:
  - The Team has not provided the required information and/or documentation as described in the Official Rules
  - The Team has not provided proof to the Judging Panel to accurately determine whether the Team's technology has progressed from the Phase 2 prototype to accomplish the requirements of the demonstration period and meet each evaluation criteria as stated in the Official Rules.
  - Safety concerns are present and not addressed including safety risks to the facility, team, and/or Simunaut Crew.
- **Conditionally Approved:** A Team's technology readiness will be conditionally approved if it meets one or all of the following conditions
  - The Team has provided partial information and/or documentation as described in the Official Rules
  - The Team has not provided enough proof to the Judging Panel to accurately determine whether the Team's technology has progressed from the Phase 2 prototype to accomplish the requirements of the demonstration period and meet each evaluation criteria as stated in the Official Rules.
  - There are safety concerns not included, and/or are not adequately addressed including safety risks to the facility, team, and/or Simunaut Crew.
  - **Teams will have 5 business days to address the concerns of the Evaluation Panel and resubmit for review.**
    - **If the Team has not met all of the conditions for approval (stated below), their technology will be rejected and the Team will not continue in the competition.**
- **Approval:** A Team's technology readiness will be approved if it meets all of the following conditions:
  - The Team has provided the required information and/or documentation as described in the Official Rules
  - The Team has provided enough proof to the Judging Panel to accurately determine whether the Team's technology has progressed from the Phase 2 prototype to accomplish the requirements of the demonstration period and meet each evaluation criteria as stated in the Official Rules.

- The has satisfied and addressed any safety concerns including safety risks to the facility, team, and/or Simunaut Crew.

Teams will be notified of the decision of the Evaluation Panel via email no later than April 16, 2024.

The Judging Panel's determination on the acceptance or rejection is final.

11 Prizes Awarded - Technology Readiness

Each U.S. Team that achieves approval from the Judging Panel for their food production technology's readiness to proceed to the Ohio State TAF for the demonstration period will receive a prize of $50,000 USD.

12 Pre-Demonstration

12.1 Technology Delivery & Set Up

Teams are responsible for shipping their Food Production Technology to the Terrestrial Analog Facility at the Ohio State University including all components of the technology and all supporting materials and inputs listed in the previously submitted inventory per the schedule below. Teams are responsible for all shipping costs.

All shipping containers must be clearly labeled with the Team Name and the Team Leader's Name. Teams will provide a tracking number for the shipment to the Challenge Administrators. NASA, Methuselah Foundation and The Ohio State University are not responsible for any damages to the technology during shipping and receiving.

May 20-25, 2024: HARDWARE ARRIVES AT OSU

Teams will ship all hardware associated with their Food Production Technology including:

- Food Production Technology
- Replacement parts
- Cleaning materials and supplies
- Inputs to the technology
- Additives to the food outputs contributing to the processing and preparation for consumption (i.e., spices, flavorings, condiments)

NOTE: Teams may be permitted to ship or bring their inputs and/or additives with them closer to the demonstration period. Teams should contact the Challenge Administrators to arrange this if necessary.

Teams will be permitted to enter the TAF and begin setting up their technology at 8am ET on May 27, 2024 and must complete their setup by 6pm ET on June 1, 2024.

12.2 Simunaut Crew Training

Teams will conduct a training for the Simunaut crew that will be guided by the crew procedures manual. Simunaut crew will be provided with the Teams' crew procedures manual for review in advance.

Each Team will coordinate with the Methuselah Foundation to schedule the initial training and general overview for up to 2 hours of time on either June 3 or June 4, 2024.

Additional hands-on training will occur during the Ground Test Validation of the demonstration period as described in Section 13.

13 Demonstration Period

The Phase 3 demonstration period will take place in-person and on-site at the Ohio State University George Washington Carver Science Park's Terrestrial Analog Facility (GWCSP TAF) in Columbus, Ohio (USA) and will run for 8 weeks. The demonstration period will begin on June 5, 2024, at 8am ET, and will end on July 31, 2024, at 6pm ET.

The regular operations of the food production technologies will be conducted by a crew of Simunauts for the duration of the demonstration period. Teams are permitted to monitor their technologies external to the facility and will be available for the Simunauts to contact with questions.

The demonstration period will consist of Ground Test Validation and Simulation Flight Operations and requires the food production technology to complete three cycles: one technology cycle and two food production cycles (see Section 3 for Definition of Terms).

- **Ground Test Validation - June 5-18, 2024 (2 Weeks)**
    - Teams will continue mentoring the Simunaut crew in-person at the TAF in completing the all stages of the technology cycle
        - Teams may guide and instruct the Simunaut crew
    - **Cycle #1 - Baseline for Reliability**
        - Must demonstrate all the steps of one full technology cycle, including:
            - Start the production system
            - Verify its performance and operability to the satisfaction of the Team
            - Perform a complete shutdown and full system cleaning
            - Restart/reset the technology for the remainder of the demonstration period
        - Producing a food output in Cycle #1 is desired, but not required
            - Any food produced will be discarded
            - All inputs and outputs for Cycle #1 will not be considered in the Teams' score
    - Once the Ground Test Validation is complete, the Teams will leave the TAF and will not have physical access to operate their technologies for the Simulated Flight Operations.
- **Simulated Flight Operations - June 19-July 31, 2024 (6 Weeks)**
    - Simunauts will operate the food production technology to complete two production cycles and produce food outputs
        - **Cycle #2 - Safety & Nutritional Analysis**
            - Produce a food output no less than 500g for safety and nutritional testing
        - **Cycle # 3 - Safety Testing & Sensory Evaluation**
            - Produce a food output sample no less than 2kg for safety testing and sensory evaluation

13.1 Data Collection and Reporting

The Simunaut crew will submit mission logs after every interaction with the technology.
These logs will include an assessment of the following activities:

- Routine Maintenance (i.e., daily check, daily/weekly cleaning)
- Critical Maintenance and/or repair
- Harvesting and/or producing food
- Processing and/or preparing food
- Sample and/or culture collection

The mission logs will contribute to the assessment of the following evaluation criteria:

- Acceptability:
    - Ease/ difficulty of use
    - Time required
    - Ease/ difficulty in processing the food output using the provided recipe
    - Overall food production experience
    - Satisfaction with the food item(s)
    - Ease of cleaning system and time required
- Safety

    - Processes associated food production, cleaning, and maintenance
- Resource inputs and outputs
    - Material inputs and sources of the materials
    - Water usage
    - Quantity of inputs and outputs
    - Sourceability of the inputs

The Simunaut crew will not taste or consume the food output or the processed food product as part of their evaluation. A Sensory Evaluation (described in Section 13.2.3) will contribute to the evaluation of the acceptability of the food product.

13.2 Lab Testing

13.2.1 Safety Testing

Lab testing to determine the safety of the food production system and resulting food output from Cycle #2 and Cycle #3 will include:

- Microbial pathogens (i.e., bacterial pathogens)
- Salmonella spp.
- Escherichia coli O157:H7
- Listeria monocytogenes
- Total aerobic plate counts and Enterobacteriaceae counts as an indicator of sanitary production

The outcomes from the safety tests will be considered in the safety score. Additionally, if a Team's technology fails to meet the requirements for safety in Cycle #2 (as described in Table 5), a complete system shutdown, cleaning and reset is required.

If a Team's technology fails to meet the requirements for safety in Cycle #3 (as described in Table 5), the food product cannot be used in the Sensory Evaluation which will be reflected in both the score for safety and the score for acceptability (as specified in Table 6).

13.2.2 Nutritional Testing

Lab testing to determine the nutritional makeup of the food outputs will include:

- The Food and Drug Administration (FDA) Nutrition Labeling and Education Act (NLEA)
- Vitamins C, B1, and K

The outcomes from the tests will be considered in the resource input/output score as described in Table 5 specified in Table 6.

13.2.3 Sensory Evaluation

A sensory evaluation of the food output will be conducted using a 9-point hedonic scale that will be conducted by the Ohio State Department of Food Science and Technology Food Sensory Lab.

- The Sensory Evaluation will be conducted using one of the three recipes the Team provided
    - The Team will select which of the three recipes will be used
- Prior to the Sensory Evaluation, the food product will undergo safety testing (as described above in Section 13.2.1) to ensure the safety of the food product for human consumption.

The outcomes of this evaluation will be considered in the overall acceptability score as described in Table 5 specified in Table 6.

13.3 Clean up & Removal
At the conclusion of the Simulated Flight Operations, the Simunaut Crew will complete a shutdown of the food production technologies per the instructions in the crew procedures manual.

Teams will be permitted physical access to their food production technologies at the completion of the demonstration period.

After the Winners' Announcement and Industry Day, Teams will have three days to remove their food production technology from the facility along with all remaining inputs, replacement parts, and cleaning materials.

14 Determination of Final Winners

The final winners of Phase 3 of the Challenge will be determined by both the total score achieved and the final rank by the Judging Panel.

15 Challenge Participation Requirements

Teams are responsible for understanding and complying with these Requirements.

15.1 Eligibility to Compete
In order to participate in the Challenge, each individual, whether acting alone or as part of a Team must identify their nationality.

No Team Member shall be a citizen of a country on the NASA Export Control Program list of Designated Countries List Category II: Countries determined by the Department of State to support terrorism. The current list of designated countries can be found at http://oiir.hq.nasa.gov/nasaecp. Please check the link for the latest updates. This includes individuals with dual citizenship unless they are a U.S. citizen or a lawful permanent U.S. resident (green card holder).

While China is not a Category II designated country, pursuant to Public Law 116-6, Section 530, NASA is prohibited from participating, collaborating, or coordinating bilaterally in any way with China or any Chinese-owned entity. Team Members who are citizens of China but not affiliated with a Chinese entity may be permitted to participate on a Team.

Subject to the conditions set forth herein, foreign nationals and foreign national teams can participate in the Challenge. However, they are not eligible for a cash prize, and must acknowledge acceptance of this by signing and submitting a Foreign Participant Acknowledgement Form.

15.2 Eligibility to Compete and Win Prizes from NASA
In order to be eligible to win a prize from NASA:
- Individuals must be U.S. citizens OR permanent residents of the United States, AND over the age of 18.
- Organizations must be an entity incorporated in AND maintaining a primary place of business in the United States.
- Teams must be comprised of otherwise eligible individuals or organizations AND led by an otherwise eligible individual or organization.
- Team Leader must be a U.S. citizen or permanent resident.

A Team may include foreign nationals and be eligible to win prize money as long as the foreign national signs and delivers a disclosure wherein they disclose his/her citizenship and acknowledge that he/she is not eligible to win a prize from NASA, AND the foreign national is:
- An employee of an otherwise eligible U.S. entity participating in the Challenge,

- An owner of such entity, so long as foreign citizens own less than 50% of the interests in the entity,
- A contractor under written contract to such entity, OR
- A full-time student who, during the time of the Challenge, (1) is enrolled in an accredited institution of higher learning, (2) has a valid student visa and (3) is otherwise in compliance with all local, state, and U.S. Government laws and regulations regarding the sale and export of technology.

Team Members must furnish proof of eligibility (including proof of citizenship or permanent resident status, for individuals, and proof of incorporation and primary place of business, for entities) which proof must be satisfactory to NASA in its sole discretion. A Team's failure to comply with any aspect of the eligibility requirements will result in the Team being disqualified from winning a Prize from NASA.

U.S. government employees may enter the Challenge, or be members of prize-eligible Teams, so long as they are not acting within the scope of their Federal employment, and they rely on no facilities, personnel, hardware, access, knowledge, information previously developed, or other resources that are available to them as a result of their employment except for those resources available to all other Teams on an equal basis.

U.S. government employees participating as individuals, or who submit applications on behalf of an otherwise eligible organization, will be responsible for ensuring that their participation in the Challenge is permitted by the rules and regulations relevant to their position and that they have obtained any authorization that may be required by virtue of their government position. Failure to do so may result in the disqualification of them individually or of the entity which they represent or in which they are involved.

Teams will be ineligible to win the prize from NASA if any Team Member is a U.S. Government entity or employee acting within the scope of their employment. This includes any U.S. Government organization or organization principally or substantially funded by the U.S. Government, including Federally Funded Research and Development Centers, Government-owned, contractor operated (GOCO) facilities, and University Affiliated Research Centers. Any such entity or individual will obtain prior written approval from their cognizant ethics officer that such participation does not violate federal personnel laws or applicable agency policy. A copy of this approval to participate in the Challenge will promptly be provided to the Methuselah Foundation.

Participants may not use Federal funds from a grant award, cooperative agreement, or other transaction award to develop their challenge submissions or to fund efforts in support of their challenge submissions.

Current employees, consultants, and students of the Methuselah Foundation may only participate as Team Members on a Team when that Team is not competing for the prize from NASA. Participation of such parties as Team Members on a Team will make a Team ineligible for any prize award from NASA.

15.3 Team Roles and Responsibilities

Each Team will designate a Team Leader. The Team Leader will be responsible for compliance with the rules, including prize eligibility rules, by all members of their Team. Prize funding will be released only to the Team Leader.

15.4 Intellectual Property Rights

Notwithstanding anything to the contrary in these rules, NASA and the Methuselah Foundation claim no intellectual property (IP) rights from the Team. All trade secrets, copyrights, patent rights, and software rights will remain with each respective Team. Additional details specific to U.S. Teams and Other International Teams are included in the table in Appendix C.

15.5 Insurance and Indemnification

Each Team Member agrees to assume any and all risks and waives claims against the Methuselah Foundation and the U.S. Government and its related entities, except in the case of willful misconduct, for any injury, death, damage, or loss of property, revenue, or profits, whether direct, indirect, or consequential, arising from each Team Member's participation in the Challenge, whether such injury, death, damage, or loss arises through negligence or otherwise. For the purposes of this section, the term “related entity” means a contractor or subcontractor at any tier, and a supplier, user, customer, cooperating party, grantee, investigator, or detailee.

Team agrees to obtain any and all insurance policies and coverage as stated in the Team Agreement and required by its local, state, or Federal governments to conduct any and all activities related to or required by participation of Team and the Team Members in the Challenge. In addition, Teams are required to obtain liability insurance in the amount of $500,000 USD minimum that covers each Team Member or otherwise demonstrate financial responsibility for that amount. The Team’s liability insurance will provide coverage for all claims by (A) a third party for death, bodily injury, or property damage, or loss resulting from an activity carried out in connection with participation in the Challenge, with the U.S. Government and the Methuselah Foundation named as an additional insured under the Team’s insurance policies; and (B) the U.S. Government, the Methuselah Foundation, and its contractors for damage or loss to Government or the Methuselah Foundation property resulting from or related to Challenge activities. The Team and all Team Members jointly and severally agree to indemnify the U.S. Government and the Methuselah Foundation against third-party claims for damages arising from or related to Challenge activities. Should an onsite activity be held all the Methuselah Foundation insurance requirements must be met.

Proof of insurance in such form as reasonably required by the Methuselah Foundation shall be provided to the Methuselah Foundation with the required Development Schedule due on October 6, 2023. The insurance coverage is required through the end of the competition (August 2024). The Team agrees that failure to meet this insurance requirement will result in the Team's removal from participation in the Challenge.

15.6 Delay, Cancellation or Termination

The Team acknowledges that circumstances may arise that require the Challenge to be delayed indefinitely or canceled. Such delay or cancellation, and/or the termination of the Challenge, will be within the full discretion of NASA and the Methuselah Foundation, and the Team accepts any risk of damage or loss due to such delay, cancellation, and/or termination.

16 Reference Materials

NASA Technology Readiness Level (TRL)

- https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html
- https://www.nasa.gov/sites/default/files/trl.png

Informational Article on Future Food Systems

- “Space Food for Thought: Challenges and Considerations for Food and Nutrition on Exploration Missions,” Douglas, G.L, and Zwart, S.R., and Smith, S.M., The Journal of Nutrition [online journal], Vol. 150, Issue 9

NASA Human Research Roadmap

- Evidence Report: Risk of Performance Decrement and Crew Illness Due to an Inadequate Food System

On the Hedonic Scale

- Meilgaard, Morten C., B. Thomas Carr, and Gail Vance Civille. *Sensory evaluation techniques*. CRC press, 2006.

Nutritional Needs of the Crew

- https://www.nasa.gov/hhp/standards
- https://www.nasa.gov/hhp/education

Evolution of Foods for ISS

- https://www.nasa.gov/feature/space-station-20th-food-on-iss

Processing and Packaging of Space Food

- Tasting Astronaut Food: Inside NASA's Space Food Systems Laboratory: https://www.youtube.com/watch?v=6vVIe67Tfjc

Current Systems & Standards:

- NASA STD-3001: NASA Spaceflight Human-System Standard; Volume 2: Human Factors, Habitability, and Environmental Health: https://www.nasa.gov/hhp/standards
- International Life Sciences Institute North America Mid-Year Meeting (2019): Developing a Safe, Nutritious & Palatable Food System in Space (Grace Douglas): https://www.youtube.com/watch?v=QY1XyjsI70w

NASA Human Research Roadmap

- Evidence Report: Risk of Performance Decrement and Crew Illness Due to an Inadequate Food System

Possible opportunity areas for new food system technologies:

- *Macro- and micronutrients:* Macronutrients are the nutrients a person needs in larger amounts, namely carbohydrates, protein, and fat. These provide a person with energy, or calories. Micronutrients are the nutrients a person needs in smaller amounts, which include vitamins and minerals. The quality of stored food degrades over time; some micronutrients are unstable; adequate macro- and micro-nutritional availability throughout the length of a mission is critical to maintain crew health and performance.

- *Desirable/palatable food:* Enjoyable, desirable, familiar food is critical for crew physical and mental health.

- *Sustainable fresh food production:* Current crews on the International Space Station (ISS) frequently get limited amounts of fresh food (e.g., apples, oranges) delivered along with prepackaged shelf-stable food. Although highly desired by crew, this type of resupply is much more expensive to deliver to the Moon and will not be available in extended exploration missions to Mars.

- *Reliable fresh food production:* Growing food crops in space is not currently reliable or predictable as a source of critical nutrients.

- *Water needs for food production:* Spacecraft do not currently support the mass, volume, and water needs of Earth-based food production. Even approaches that recycle water are too massive to supply water in the amounts typically used for terrestrial food production.

- *Power needs for food production*: Traditional controlled environment food production systems require high energy inputs that can make their application in larger scale production systems in space or on Earth impractical.

- *Resource logistics:* Food mass dominates life support logistics for extended space missions. It would be ideal to reduce all food system inputs and waste outputs in relation to nutritional output. This includes equipment, crew time, storage of ingredients, waste and waste processing, and safety or cleaning equipment (e.g., air monitors, microbiological tests, cleaning products).

- *Farm-to-table:* Current food systems use extensive repackaging of shelf stable foods, often requiring processed food to be prepared months to years in advance of the space mission. Innovative approaches to reduce the time from fresh food generation to consumption by the crew could help improve nutritional quality and palatability.

- *Optimization for health and palatability:* Nutrition, palatability, texture, and food safety are all important aspects to ensure the crew members consume enough food and that the food provides the necessary nutrients to protect health and performance.

- *Time limitations:* Crew members should not spend too much of their mission time in growing, preparing, and consuming food. Though necessary, any time so spent precludes spending time on mission objectives.

- *Acceptability of food systems:* Food production and preparation processes must be acceptable to the crew; if a process requires preparing and eating foods that are not acceptable or are too laborious or time consuming, then a crew member may choose not to use the food system or to eat the end product.

- *Terrestrial Applications:* The need for efficient use of volume, water, and other inputs for producing food could enable technologies with reduced impact on the resources needed for food production here on Earth, especially in extreme environments and resource-scarce regions. In addition to plant production, there are other advanced food systems (3D printing of food, aquaculture, cellular agriculture, etc.) that warrant exploration as they can also potentially address some of the challenges of terrestrial and space-based food systems.

Data for Terrestrial Applications

NASA Earth Sciences Division (ESD): Addressing Global Challenges:
https://www.nasa.gov/content/esd-food-security

ESD Earth Data: https://science.nasa.gov/earth-science/earth-data

ESD Earth Observations: https://appliedsciences.nasa.gov/

APPENDIX A: EXAMPLES OF MISSION SCENARIOS

The mission scenarios below are notional, and meant to describe a generous, potential, future mission. They are not meant to be constraints for the purposes of this challenge.

Transit Vehicle Food System

- A small space (roughly 0.25 m^3) will be allocated for the food system
- No more than 3000 W of power maximum draw
- It can connect to the space craft water system but cannot draw more than 1 L/ day from the system
- It does not need to supply all of the calories or food to meet the crew's needs, it is meant to supplement the packaged food system
- Scenario:
  - The unit will arrive on the Mars Transit Vehicle (MTV) six months to one year before the mission begins
  - It will be stowed at ambient "indoor" conditions during the wait with little but preferably no power
  - The chamber will be activated about 20 days into a 200-day journey to Mars on the Mars Transit Vehicle (MTV)
  - The crew will use the unit to provide fresh elements or novel flavors as well as nutrients to their packaged food diet
  - No additional time (beyond what is below) can be spent on the unit other than for setting it up or cleaning and stowing at the end of the production cycle. This amount of time needs to be quantified
  - Though the unit will likely operate only in microgravity, Teams in this competition only have to make sure their designs work in 1 g

Planetary and Lunar Surface Food System

- **Foundation Surface Habitat like operation**…
  - A small space (roughly 0.25 m^3) will be allocated for the food system
  - No more than 3000 W of power maximum draw
  - It can connect to the spacecraft water system but cannot draw more than 1 L/ day from the system
  - It does not need to supply all of the calories or food to meet the crew's needs, it is meant to supplement the packaged food system.
  - Scenario:
    - The unit will arrive on the habitat six months to one year before the mission begins
    - It will be stowed at ambient "indoor" conditions during the wait with little but preferably no power
    - The unit will be activated about 20 days into a 900-day surface mission
    - The crew will use the unit to provide fresh elements or novel flavors as well as nutrients to their packaged food diet
    - No additional time (beyond what is below) can be spent on the unit other than for setting it up or cleaning and stowing at the end of the production cycle. This amount of time needs to be quantified
    - At the end of the mission, it needs to be cleaned and stowed to await being used on the next mission
    - Though the unit will likely operate only in partial gravity, the contestants only have to make sure their designs work in 1 g

APPENDIX B: PRIZE DISTRIBUTION

U.S. Prize Purse Winners	Other International Winners
NASA will issue prize payments to the Team Leader(s) within 60 calendar days after the announcement of the winner(s) as determined by the Judging Panel. Each Team Member shall acknowledge by their signature in the Registration Package that NASA shall make Prize payments to the Team Leader. Any failure of the indicated Team Leader to make payments of any kind to Team Members is the responsibility of the Team Leader and not the responsibility of NASA.	The top scoring Teams will be announced and recognized as Challenge winners at the time of the public winners' announcement.

APPENDIX C: INTELLECTUAL PROPERTY

U.S. Teams	Other International Teams
To the extent the Team owns IP resulting from its participation in the Challenge, the Team agrees to negotiate in good faith with NASA for a grant of a nonexclusive, nontransferable, irrevocable license to practice or have practiced for or on behalf of the United States, the intellectual property throughout the world, at reasonable compensation, if NASA chooses to pursue such a license.	United States: To the extent the Team owns IP resulting from its participation in the Challenge, the Team agrees to negotiate in good faith with NASA for a grant of a nonexclusive, nontransferable, irrevocable license to practice or have practiced for or on behalf of the United States, the intellectual property throughout the world, at reasonable compensation, if NASA chooses to pursue such a license. Canada: To the extent the Team owns IP resulting from its participation in the Challenge, the Team agrees to negotiate in good faith with the CSA for a grant of a nonexclusive, non-transferable, irrevocable license to practice on behalf of the Government of Canada, the intellectual property throughout the world, if the CSA chooses to pursue such a license.