NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)
Phase 2 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

Revision Tracking Log

Section	Revision #	Description	Date
	0	Original Document	1/20/22
3.0 Competition Calendar	1	Update for Public Awards Annoucement	10/27/22
7.3.2 Bonus Prizes	1	Update point distribution	10/27/22

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 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.

Canadian Space Agency (CSA): Is a 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.

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.

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.

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 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.

1.0 Challenge Background and Objectives

International collaborations have been key to the success of countless space missions. This Challenge represents a first of its kind collaboration 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 both lunar sustainability and will also support Mars exploration. 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 the food must not be time consuming and not 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.

1.1 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 be accessed solely by aircraft or only receive infrequent shipments of food, often resulting in food of lesser quality. While the production of fresh foods cannot address Northern food security in 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, on which all people depend, and further aggravate food shortages. Developing compact and innovative food system technologies can further 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.

1.2 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.

1.3 Flexible Food Systems

The types and durations of future lunar 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.

2.0 Challenge Description

2.1 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.*** 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*.*** Would require Teams to build a full-scale food production technology and demonstrate the technology at a designated facility. Teams may be asked to provide a business plan for commercialization of the demonstrated technology.

This rules document covers Phase 2 of the Deep Space Food Challenge.

Phase 2 offers prize purses of $1,000,000 USD from NASA, to be awarded as described in Section 4.0. Phase 2 (including an initial registration period) will last approximately fifteen (15) months (see Competition Calendar in Section 3.0).

*The initiation of Phase 3 is contingent on the emergence of promising submissions in Phase 2 that demonstrate a viable approach to achieving the Challenge goals. The rules for Phase 3, if initiated, will be released prior to the opening of Phase 3.

2.2 Phase 2 Kitchen Demonstration

The kitchen-level demonstration is analogous to Technology Readiness Level (TRL) 4[1]. Teams will build a prototype of their proposed food production technology and conduct some of the required testing at their own facilities. Details and instructions for the required testing are included in Sections 7.0 and 8.0 of these Official Rules.

The food production technology must:

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

- Address the operational considerations described in Table 1 (below)
- Meet the overall criteria and performance criteria (Table 4) as described in Section 5.0

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.
Crew Time	**Maintenance & Operations of the Food System:** Teams should target a maximum crew time of four (4) person hours per week for operations of the food production technology for the entire crew of four (4) individuals. **Autonomy:** Minimizing crew time is valuable and one way to accomplish this is through autonomy or a simpler process. It is not necessary to automate everything for your demonstrations, manual steps may be used along with a description of how or how easily those steps might be automated..Teams should describe how their system achieves the goal of minimizing crew time and how it could be improved in a future design.

Per Table 2 (below), Phase 2 will consist of three submission requirements from the Teams

1. Progress Report
2. Video Demonstration and Safety Testing
3. Final On-Site Demonstration and Sample Collection

Each submission requirement will be reviewed by the Judging Panel and will serve as a gate Teams must pass in order to proceed. The full details of each submission requirement and scoring are described in Sections 7.0 and 8.0 of these Official Rules.

Table 2: Phase 2 Submission Requirements

Submission Requirement	Description
1. Progress Report: March – May 2022 *Report the current status of the Team's design and show the plans for the prototype build, demonstration, and the draft testing plan*	
Phase 1 Winning Teams	• Teams will submit a Progress Report • **Progress Reports for P1 Winning Teams are not scored** ○ Proceed to draft and submit the Team Pre-Testing Plan

Phase 1 Non-Winning Teams	• Teams will submit:
	  ○ Progress report
	  ○ Design report
	  ▪ *NOTE: Teams must highlight improvements and/or changes made to the design since the original submission in Phase 1.*
	  ○ Animation Video
	• **Progress reports scored by Judging Panel**
	  ○ Teams achieving threshold score proceed to draft and submit the Team Pre-Testing Plan
	  ○ Teams not achieving threshold score do not proceed

New Teams	• Teams will submit:
	  ○ Progress report
	  ○ Design report
	  ○ Animation Video
	• **Progress reports scored by Judging Panel**
	  ○ Teams achieving threshold score proceed to draft and submit the Team Pre-Testing Plan
	  ○ Teams not achieving threshold score do not proceed

2. Video Demonstration and Testing: August – December 2022 *Report and execute the Team's plan for demonstrating how the food production system meets the challenge criteria and conduct initial safety testing.*	

Team Pre-Testing Plan August 2022	Report details:
	  ○ The Team's required food and equipment safety plan
	  ○ How the Team will conduct the required sample tests
	  ○ How the Team will conduct the initial demonstration
	  ○ How those meet the challenge evaluation criteria
	• All Pre-Testing Plans reviewed by Judging Panel
	• Pre-Testing Plans are either Approved or Rejected
	  ○ **Approved plans proceed**
	  ○ **Rejected plans do not proceed**
	  • *Teams may adjust and resubmit their Pre-Testing Plan for additional review before deadline*

Testing Report & Summary Video December 2022	Provide testing results and demonstrate the food production technology as described in the approved Pre-Testing Plan
	• All final testing reports and summary videos reviewed by the Judging Panel and scored
	• **Finalist Teams identified by score and move on to compete in the final demonstration event.**
	  ○ *Up to 10 U.S. Finalist Teams*
	  ○ *Up to 5 International Finalist Teams*
	• **Score from testing report and summary video will contribute to the Team's final score**

3. Final On-Site Demonstration and Sample Collection: January – March 2023 *Demonstrate the food production system in person and validate food output samples.*	

Final Demonstration	• Interactive presentation with the Judge to determine acceptability of the system • Assessment of the food output(s) by the Judge to determine acceptability • **Combined acceptability score will contribute to the Team's final score**
Sample Collection & Analysis	Sample collected under the supervision of the Judge and sent to a NASA-designated laboratory for testing • **Testing results will contribute to the Team's final score**

3.0 Competition Calendar

Table 3 below is an overview of the expected timeline for Phase 2 of the Challenge.

Table 3. Competition Calendar

Date/Deadline	**Event**
January 20, 2022 10:00 AM Central Time	Phase 2 Opens
February 28, 2022 5:00 PM Central Time	Phase 2 Registration Closes
March 28 - May 20, 2022	Submission & Evaluation Period for Progress Reports
August 1-31, 2022	Submission & Evaluation Period for Team Pre-Testing Plans
December 16, 2022	Testing Report and Summary Video Due
January 2023	Judging Panel Summit (virtual) to determine Finalists
	Finalists Announced
February - March 2023	Finalist Teams' On-Site Demonstrations & Sample Collection
	Judging Panel Summit (virtual) to determine winners
April 2023	Phase 2 Winners Announced

4.0 Phase 2 Prizes

All interested Teams must compete in one of two competitor categories: U.S. Team or International Team. Each competitor category has its own set of eligibility criteria to compete and win a prize. These criteria are defined on the Official Challenge Website (deepspacefoodchallenge.org).

NASA Prize Purse for U.S. Teams
Up to 10 top scoring U.S. Teams will be named "finalists" and will receive $20,000 USD each from NASA and will move on to compete in the final on-site demonstration.

After the final on-site demonstration up to 5 top scoring U.S. Teams will each be awarded $150,000 USD and be invited to compete in Phase 3 (should Phase 3 open for competition).

Additionally, a total of $50,000 USD will be available for bonus prizes for up to 5 U.S. Teams to be awarded when finalists Teams are announced. U.S. Teams do not need to be named as a finalist in order to be awarded a bonus prize.

U.S. Teams must meet the eligibility requirements for the NASA Prize in order to receive a prize from NASA.

Recognition for International Teams
Up to 5 top scoring International Teams will be recognized as "finalists" and will move on to compete in the final on-site demonstration. Up to 3 top scoring International Teams will be recognized as Phase 2 challenge winners.

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

5.0 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 include:

- **Design approach and innovation** - *Does the design approach the problem of food production technology for spaceflight in a novel and innovative way?*
- **Scientific and technical merit** - *Does the scientific and technical approach and design of the technology demonstrate merit?*
- **Feasibility of design** - *Is the proposed technical approach feasible? To what extent does the Team clearly understand and address any potential risks in their design submission?*
- **Terrestrial potential** - *To what extent does the Design Report present a feasible scenario for the potential use of the technology within terrestrial food systems?*

The performance criteria are described below in Table 4.

Table 4. Performance Requirements

Category	Description
Acceptability	• **Acceptability of the food production process** o Teams must demonstrate the operations processes and procedures, including (but not limited to): ▪ Operational footprint (i.e., how much space is needed for the solution and its related processes?) ▪ Food production technology set up ▪ Food production cycle, including steps to produce food products ▪ Food handling, processing procedures and collection of food products ▪ Shutdown, cleaning, and/or stowage procedure(s) ▪ An estimate of the overall crew time to operate and maintain the technology o Teams must provide an assessment (using industry standards and/or existing research) that their technology processes are likely to be user friendly and acceptable to crew. o *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.* • **Target: Teams should consider 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).**

	• **Acceptability of the resulting food product**
	  ○ Teams must provide a food output that will be assessed on appearance, aroma, palatability, flavor, and texture.
	  • **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.** [2]

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. *Prototypes that fail to account for pathogens will receive a "zero" score on the Safety category.***
	
	• Participants must demonstrate the safety of the food production process and demonstrate an understanding of the risk(s), including any operational risks for the technology, and potential mitigation.
	  ○ Demonstrate relevant food safety procedures
	  ○ Participants 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
	  • **Targets: Environmental & process safety:**
	  ▪ **Avoidance of hazardous compounds or materials used or produced (e.g., microbes, off-gassing, toxic components)**
	  ▪ **Avoidance of hazards associated with cleaning this technology prior to and/or after use**
	  ▪ **Avoidance of physical, chemical, or biological hazards associated with the hardware or the process**
	  ▪ **Clear mitigation strategies to address the aforementioned risks**
	
	• Participants must provide a sample of the food output (to be tested in a laboratory) that will meet the safety requirements for repeated human consumption.
	  • **Targets: Consumption safety:**
	  ▪ **Resulting food product safe is for repeated human consumption as defined by NASA-STD-3001 (see Reference Materials)**

Resource Inputs & Outputs	• Participants must show the resource inputs and outputs associated with the technology; and demonstrate the quantity of nutritious food output in relation to the quantity of inputs and quantity of waste output. It must be shown that mass of all inputs equals the mass of all outputs to demonstrate the system process is understood.
	  ○ Inputs may include: Raw materials, energy, water, or other materials that enter the system
	  ○ Outputs may include: Food products, waste (cleaning water and chemical agents), heat (latent and sensible), and other useable or 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.)
	  ○ Describe and demonstrate how the food production technology achieves the greatest amount of food output in relation to the quantity of inputs and quantity of waste output
	  • **Targets:**
	  ○ **Maximum quantity food output relative to quantity of system inputs**
	  ○ **Maximum quantity food output relative to quantity of waste output**

[2] The hedonic scale is a quantitative method that is accepted throughout the food science industry as a means to determine acceptability. Further information regarding methods for determining food acceptability can be found in resources such as Meilgaard, Morten C., B. Thomas Carr, and Gail Vance Civille. *Sensory evaluation techniques*. CRC press, 2006.

	• Participants must provide the nutritional potential of food produced with their technologies.
	• The nutritional content of the food output samples will be assessed against the Food and Drug Administration (FDA) Nutrition Labeling and Education Act (NLEA) by an independent laboratory. In addition, Vitamins C, B1 and K will be measured.
	  • **Targets:**
	  ○ **Maximum macronutrients supplied, as a percentage of complete dietary needs for a crew of four**
	  ○ **Maximum micronutrients supplied, as a percentage of complete dietary needs for a crew of four**
	  ○ **Maximum variety of nutrients supplied**
	
	• Participants must show the net water consumption of their food production technology.
	• 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)
	  • **Targets:**
	  ○ **No more than 40 L at startup**
	  ○ **No more than 1 L per day "water added over time"**
	  ○ **No more than 5 L for cleanup**

Reliability / Stability	• Participants must demonstrate how the technology is reliable to provide its intended function
	  ○ Operational cycle time (i.e. the amount of time for one production cycle)
	  ○ System lifespan (i.e., how many cycles can the system perform before requiring replacement parts?)
	  ○ Maintenance and cleaning processes and procedures
	  ▪ Maintenance schedule (i.e., how often will it need maintenance and/or cleaning?)
	  ▪ Which component(s)/element(s) require cleaning
	  • Cleaning per use
	  • Cleaning the full system
	  ▪ Amount of time required to perform the system cleaning
	  ▪ What is needed to fully clean the system (i.e. water, chemicals, etc.)
	  ▪ Which component(s)/element(s) require maintenance or replacement (i.e., what components will need to be replaced, and when?)
	  ▪ Amount of time it takes to perform the required maintenance
	  ▪ Critical spare parts for a three-year mission and longevity of those spare parts
	  ▪ Estimated additional mass needed for replacement parts and cleaning materials
	  ▪ Estimated total time needed per month, per 6 months, and per year for maintenance and cleaning
	  • **Targets:**
	  ▪ **Amount of time required to maintain and clean the system should not exceed an average of 60 minutes per 7-day week.**

	▪ **Mass of spare parts and cleaning materials should not exceed the estimated mass of the total system.** ▪ **Less than 10% loss of functionality or food production throughout a three-year mission.** • Participants must demonstrate the stability of both the input products used and food product outputs. Teams must provide rationalization of the estimated time the inputs and outputs will be fit for use and/or consumption (i.e. shelf-life). • **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**

5.1 Phase 2 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.

Following the deadline for each submission requirement, the Judging Panels will review the submissions and discuss, evaluate, and rank the entries. Each Judging Panel has discretion in the assessment and scoring of submissions and in selecting the winners.

The Judging Panels will evaluate designs according to the following criteria (Table 5).

Table 5. Scoring

Criteria:	**Submission Requirements:**		
	Design Report & Animation (Phase 1 non-winning Teams & New Teams)	**Testing Report & Summary Video**	**On-Site Demonstration & Sample Analysis**
Design Approach and Innovation	15 points	15 points	
Scientific and Technical Merit	15 points	10 points	
Feasibility of Design	15 points	10 points	
Terrestrial Potential	15 points	10 points	
Acceptability	10 points	10 points	40 points

Safety	10 points	25 points	30 points
Resource Inputs / Outputs	10 points	20 points	30 points
Reliability/Stability	10 points	10 points *(Reliability Only)*	
Design Animation Accuracy	10 points		
Design Animation Engagement	5 points		
Maximum Points:	**115 points**	**110 points**	**100 points**

6.0 Registration Requirements & Process

6.1 Registration

The registration process will be administered by the Methuselah Foundation.

NASA will accept registration from interested U.S. and non-Canadian International Teams only. CSA will not accept new registrations for Phase 2.

All interested Teams must register for the Challenge by the deadline and meet the eligibility requirements in order to participate in the Challenge. Phase 1 winning Teams should submit an "Intent to Compete" and sign a Phase 2 Team Agreement but are not required to submit documents to confirm eligibility unless adding new Team members.

To officially register, Teams are required to:

1. **Submit an "Intent to Compete" –** Teams will submit a notice that they intend to compete to the Methuselah Foundation management via an online form on the Challenge website (deepspacefoodchallenge.org).

   The Intent to Compete must include:
   a. **Team Information:** Teams will submit the name and nationality of the Team Leader, along with a summary description of the makeup of the Team which could include:
      i. Curriculum Vitae or resume for each Team Member
      ii. Biography and headshot for each Team Member
      iii. Team logo or Team photo. *Photographs and logos submitted will only be used in connection with media material prepared and distributed for the promotional purposes of the Challenge.*
   b. **Title of Submission (≤10 words):** This title may be displayed on the competition website post-submission.
   c. **Concept Description (≤50 words):** Provide a brief summary description of the proposed food production technology.

Intent to Compete forms will be reviewed by the Methuselah in a timely manner, and a registration link will be provided to the Team Leader to submit the required information in step #2 (below).

2. **Submit registration documents –** Teams will submit the required registration documents and proof of eligibility through the registration link provided by the Methuselah Foundation. A Registration Checklist for U.S. Teams and Other International Teams is available in Appendix B. Teams should refer to the Challenge website (deepspacefoodchallenge.org) for a full description of the registration process and eligibility requirements.

After Teams have submitted their registration and proof of eligibility, Methuselah Foundation will verify the Team meets the eligibility requirements. Teams will be officially registered to compete after the eligibility of the Team has been confirmed and 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.

7.0 Submission Requirements

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

7.1 Progress Report

Teams will provide a mandatory Progress Report that reflects the current status of their project and the draft testing plan. This report will be submitted through an online form beginning March 28, 2022 and is due no later than May 20, 2022.

The Progress Reports should include:

- An overall status report of the food production system development efforts indicating progress on:
    - Design status:
        - Percentage complete
        - Block diagram or system level report of the build process
    - Status of Prototype Build:
        - Percentage complete
        - Summary description of what's going well, what's proving to be challenging, and estimated completion date of the build
    - Draft test plan for prototype and for food inputs and outputs
    - Draft plan for verifying food safety including what measures will be used

In addition to this information, non-winning Teams from Phase 1 (not Phase 1 Winners) and new registered Teams will provide the required information and a video as described below via an online application form. The form will prompt the Team to provide inputs for each of the criteria except for Scientific & Technical Merit and Feasibility of Design, which will be evaluated based on the overall submission.

Phase 1 winning Teams will not submit the additional information and video for scoring as these requirements were already submitted, reviewed, and scored in Phase 1. All Phase 1 winning Teams will progress to draft and submit the Team Pre-Testing Plan.

- **Design Abstract (≤250 words)**: Provide a brief summary description of the food production technology. Focus on delivering a compelling overview so that the Judging Panel members assigned to score your submission will want to read more. This is your opportunity to make a strong first impression, so make every word count! In the abstract, Teams should address:
    - What is your proposed food production technology?
    - What is novel, sustainable, and innovative about your proposed food production technology?
    - What foods does your food production technology create?
    - How are you minimizing inputs and maximizing food outputs?

- **Design Report that includes the following information:**
    - Description of the food production technology
        - What the food production technology is, what it does, how it functions, and how the crew will interact with the technology / system.
        - Include descriptions of major hardware components and processes
    - Initial Concept of Operations, including descriptions of:
        - Describe the basic operations concept of the food production technology. Describe assumptions required of operation. For example, is a sterile/aseptic environment needed? Are special steps required between production cycles? Must fluids or materials be removed or added to prime/inoculate a system?
    - Description of what makes the food production technology novel, innovative and sustainable
    - Description of how the food production technology addresses the performance criteria, described in detail above:
        - Acceptability of the Process and the Food Products
        - Safety of the Process and the Food Products
        - Resource Inputs/Outputs (including mass balance calculations to show inputs and outputs are accounted for)
        - Reliability/Stability
    - Description of how the food production technology may have the potential to improve terrestrial food production
    - Supporting Material
        - Any preliminary data or calculations that support the design and operation of the food production technology
        - A visual representation of the food production technology, which may include models, schematics, or drawings

- **Design Animation** (5-minute maximum length) showing the food production technology under operation and including the following elements:
    - Setup
    - Operations from a user perspective
    - Inputs and outputs
    - Shutdown and cleaning

- **Intellectual Property**: Teams must explain who owns the intellectual property of the proposed food production technology. If the technology is built on existing or off-the-shelf technology, Teams should detail the permissions (if applicable) they have to use that technology. If a Team is part of an organization, the submission should indicate which Team Members own the intellectual property.

The Progress report, Design Report and Animation will be evaluated by the Judging Panel and assigned a score. Teams must meet a threshold score of 85 in order to proceed. Teams that achieve the threshold score will be invited to draft and submit the Team Pre-Testing Plan. Teams that do not meet the threshold score will not proceed. The Judging Panel's decisions are final.

7.2 Team Pre-Testing Plan

The Team Pre-Testing Plan covers the details of how the Team will conduct their demonstration and satisfy the testing requirements. The Team Pre-Testing Plan must be submitted via an online form no later than August 31, 2022. The Judging Panel will conduct the review of each Team's Pre-Testing Plan to ensure that all requirements listed below are met.

7.2.1 Team Pre-Testing Plan Submission:

Each Team will submit a Team Pre-Testing Plan. This document will be reviewed by the Judging Panel to ensure that the Team's demonstration tests will provide adequate data for the review of all Evaluation Criteria and that the Team meets all Safety requirements as stated in the Rules.

The Team Pre-Testing Plan must include:

- **Overall Status:** An overall status report of the food production system prototype development efforts indicating progress on the building and testing of the Team's system.
    - Preliminary results, predicted and/or produced
    - Video/photographs/diagrams of existing system components
- **Development timeline & key milestones:**
    - A development timeline identifying key milestones for completing the prototype build.
- **Process Description:**
    - A step-by-step description of all details in the food production system's process and in conducting the Team's demonstration testing including (as applicable):
        - Setup and prep
        - Food production and processing
        - Cleanup and stowage
- **Proposed Demonstration:**
    - Description of the proposed demonstration the Team will perform in the Summary Video and explanation of how that demonstration will satisfy the criteria in this Rules Document.
        - *NOTE: The Demonstration and Process descriptions combined must provide sufficient detail to allow for the Judging Panel to verify whether all criteria have been successfully met.*

        - Description of the access the Teams will give to the judging panel for the final demonstration
            - Teams should describe:
                - Plans for an in-person option (e.g. on-site visit)
                - Plan for a virtual option(s) (e.g. live stream)
    - **Materials list:**
        - A table listing all materials used in the food production system, including inputs and outputs, as well as those used in the demonstration.
    - **Safety Plan & Sample Analysis:**
        - A safety plan modeled after a Hazard Analysis and Critical Control Point (HACCP) plan for the safety of the system's food outputs and a laboratory testing plan to validate the measures in the safety plan.
            - HACCP 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 Team's Safety Plan should follow the principles and guidelines of a HACCP plan as 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
                - A sample outline for the safety plan is included in Appendix C.
        - Lab Testing for Safety:
            - Team will provide a formal agreement for testing with an accredited lab to conduct the required safety tests on the food output
            - Teams may select a lab of their choice that meets the following requirements:
                - Accredited to the International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC) standard 17025:2017(E)
                - Capable of conducting the required tests as shown below
            - The Team will also include a description of the process for sample collection, packaging, and shipping.
            - Testing should be appropriate to the food output, but must include:
                - Salmonella spp.
                - Escherichia coli O157:H7
                - Listeria monocytogenes
            - Teams must obtain total aerobic plate counts and Enterobacteriaceae counts as an indicator of sanitary production.

7.2.2 Team Pre-Testing Plan Review:

The Judging Panel will review the Team Pre-Testing Plan and make one of two determinations based on their review:

- **Rejection:** A Team's Pre-Testing Plan will be rejected if the Team has not provided the information listed above or has not provided adequate tests required in their demonstration to accurately determine whether the Team has met all criteria by the Judging Panel.

    - Pre-Testing Plans rejected by the Judging Panel may be adjusted and resubmitted for secondary review before the August 31, 2022 deadline.
- **Approval:** A Team's Pre-Testing Plan will be approved if the Judging Panel determines that a Team has developed a process capable of meeting all the requirements in the rules, and a Team has included sufficient tests to determine whether or not the Team has successfully met all criteria.

Team Pre-Testing Plans will not be accepted after the stated deadline. After the deadline, the Judging Panel's determination on the acceptance or rejection of a Team's Pre-Testing Plan is final.

7.3 Testing Report and Summary Video

The Team will produce a final report for the Judging Panel including the results of all tests performed and the procedures used throughout the testing period. Teams will submit the testing report and summary video no later than December 16, 2022.

The Testing Report must be submitted through an online form provided by the Methuselah Foundation and should include:

- Summary description of the food production technology
    - What is novel, sustainable, and innovative about the food production technology?
    - What foods does your food production technology create?
    - How are you minimizing inputs and maximizing food outputs?
- Explanation of the testing processes, measurements, and experiments from the accepted Team Pre-Testing Plan.
- Outcomes and results of the aforementioned accepted tests, measurements, and experiments
- Description of inputs including:
    - What the inputs are
    - The source, amounts and mass of the inputs
    - Any processes applied to the inputs resulting in alterations or changes to the original input
    - A list of any known allergens
- Description of the outputs including:
    - What the outputs are (e.g. food, water streams, waste streams)
    - Quantity of food outputs and mass (mass balance of inputs and outputs)
    - A prediction or demonstration of the nutritional composition of the food output as well as the basis and assumptions for the predictions.
- Explanation of how the food production technology may have the potential to improve terrestrial food production

The Summary Video will be narrated and no longer than five (5) minutes.
The Summary Video must include:

- Demonstration of the food production technology
    - What it does
    - How it functions
    - How the crew will interact with the technology / system including
        - Setup
        - Operations from a user perspective
        - Inputs and outputs

        - Shutdown and cleaning
        - Any steps required between production cycles
    - Demonstration of the major hardware components and processes
    - Describe the quantity of food output per production cycle
- Explanation of how the food production technology addresses the performance criteria in Table 4:
    - Acceptability of the Process and the Food Products
    - Safety of the Process and the Food Products
    - Resource Inputs/Outputs
    - Reliability
- Explanation of how the test(s) and the demonstration video meets all criteria defined in the Rules.

7.3.1 Testing Report and Summary Video Review

The Team's Testing Report and Summary Video will be used to determine whether or not the Team has successfully met all Evaluation Criteria. Determination of success and scoring will be completed virtually by the Judging Panel.

Up to 10 top scoring U.S. Teams and up to 5 top scoring International Teams will be named "Finalists" and move on to compete in the on-site final demonstration and sample collection at the Team's location. Determination of success is at the sole discretion of the Judging Panel.

7.3.2 Bonus Prizes – System Adaptability for Space Mission Application

In order for food production systems to be integrated into possible mission scenarios, they may need to function from small to large scales. Therefore, systems will be assessed based on their ability to adapt to different space mission applications. These could include, for example, the need for bigger or smaller systems, the need for longer shelf-life food products, and/or the need for more variety in the food products provided to crew. For the purposes of this Challenge, proposed methods and approaches for the adaptability of the systems will be compared to the tested configuration of the prototype and will focus on the food production system's ablility to be:

- Scaled up or down to produce more or less volume of food
- Adapted to produce food products with a longer or shorter shelf life
- Adapted to produce a greater or lesser variety of food products

For the purposes of the bonus, Teams should provide the following information as part of their Testing Report:

- Description of how the food production technology could be adapted to meet potential mission scenarios for transit and/or planetary and lunar surface operations including mitigation plan for adjusting the food production system to scale for volume, power, and mass.
- Description of the stability of both the input products used and food product outputs and how the inputs could be adapted to achieve a 3-year stability. *(Refer to Stability section in Table 4: Performance Requirements)*
- Description of how the technology could be adapted to provide fewer or additional variety or varieties of food products.

This information will be used by the Judging Panel to assess the system adaptability for future application in space missions. A total of $50,000 USD will be available for bonus prizes for up to 5 U.S. Teams.

Bonus points will be allocated as deemed appropriate by the Judges based on the Team's explanation of the adaptability and scalability:

- Volume, Power and Mass (up to 15 points)
- Stability (up to 20 Points)
- Variety (up to 25 Points)

Up to five (5) U.S. Team will each receive $10,000 USD. A minimum score of 20 bonus points is required to be eligible for a bonus prize. U.S. Teams do not need to win one of the Challenge prizes to be awarded a bonus prize.

8.0 Final Demonstration & Sample Collection

Final demonstrations will take place in-person and on-site at the Team's location. Finalist Teams will receive a site visit checklist to complete prior to scheduling their on-site demonstration. The Team Leader will be contacted by a Challenge representative via email to schedule a call with an assigned Judge to review the checklist and determine the readiness of the Team for a site visit. Upon review and acceptance of the Team's completed checklist, a site visit will then be scheduled.

8.1 On-Site Demonstration of Food Production System

The Team must perform an interactive demonstration with the Judge and collect a sample of the food output and a culture sample from the food production system per the descriptions in Sections 8.1 and 8.2.

Specific processes and procedures for the onsite visit will be sent to the Team Leader once the travel for the Judge is confirmed.

8.1.1 Acceptability of the food production technology

The Team will conduct an interactive presentation and demonstration with a member of the Judging Panel. The presentation should be hands-on with the Judge acting as the main operator of the food production technology under the guidance of the Team Leader or designated presenter.

Each Team will have a time limit of 20 minutes time to complete the presentation allowing an additional 10 minutes for questions from the Judge. Teams do not need to use the entire allotted time but will not exceed the time given. A penalty will be applied to the Team's score as shown below for exceeding their time limit. Maximum penalty is 20% of score for acceptability of the system.

- 5% for exceeding time by up to 5 minutes
- 10% for over by up to 10 minutes
- 15% for over by up to 20 minutes
- 20% for over 20 minutes

The Team Leader or designated presenter will be notified when their time is up and when they will begin to incur penalties.

8.1.2 Acceptability of the food output

The Team will provide a sample of the food output from their food production technology to be evaluated by a panel of Judges. The Team must provide a minimum of 200g of food output for evaluation.

The acceptability of the food output will be assessed on appearance, aroma, palatability, flavor, and texture.

8.2 Sample Collection and Analysis

The Team must collect a product sample from the food production system's resulting food outputs and a culture sample from the food production system to be sent to a NASA-designated laboratory for testing. Results of the laboratory testing will validate the sample's nutritional composition and safety of the food production system. The sample testing results will be scored, and that score combined with the outcomes of the on-site acceptability testing.

8.2.1 Sample Requirements for the Food Output Samples

Lab testing for food outputs will include:

- Nutritional makeup of the food product
- Estimated shelf life

8.2.2 Sample Requirements for the Food Production System

Lab testing for the food production system will include:

- Analysis of the safety of the system
    - Microbial pathogens (i.e. bacterial pathogens)
    - Total aerobic plate counts and Enterobacteriaceae counts as an indicator of sanitary production

8.2.3 Processes and Procedures for Collecting and Shipping Samples

Requirements for the collection and shipping of the food output samples (including size of and number of samples) will be released to the Team Leader prior to the on-site visit.

9.0 Determination of Final Winners

The Team's final score will be weighted as follows:

- 80% - Score achieved from the On-Site Demonstration and Sample Analysis
- 20% - Score achieved from the Testing Report and Summary Video

The final winners of Phase 2 of the Challenge will be determined by both the total score achieved and the final rank by the Judging Panel.

10.0 Challenge Participation Requirements

Teams are responsible for understanding and complying with these Requirements.

10.1 Eligibility to Compete

NASA welcomes applications from individuals, groups of individuals, and/or organization or entities that meet the eligibility requirements provided below.

- 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.

10.2 Eligibility to Compete and Win Prizes from NASA

In order to be eligible to win a prize from NASA:

1. Individuals must be U.S. citizens OR permanent residents of the United States, AND over the age of 18.
2. Organizations must be an entity incorporated in AND maintaining a primary place of business in the United States.
3. Teams must be comprised of otherwise eligible individuals or organizations AND led by an otherwise eligible individual or organization.
4. 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:

I. An employee of an otherwise eligible U.S. entity participating in the Challenge,
II. An owner of such entity, so long as foreign citizens own less than 50% of the interests in the entity,

III. A contractor under written contract to such entity, OR
IV. 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. No U.S. Government funds may be used to participate in the Challenge. 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.

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.

10.3 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 as detailed in Appendix D.

10.4 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 E.

10.5 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 $250,000 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 Testing Report due on December 16, 2022. The insurance coverage is required through the end of the competition (March 2023). Team agrees that failure to meet this insurance requirement will result in Team's removal from participation in the Challenge.

10.6 Delay, Cancellation or Termination

The Team acknowledges that circumstances may arise that require the Challenge to be delayed indefinitely or cancelled. 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.

11.0 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=6vVle67Tfjc

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=QY1Xyjsl70w

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 notial, 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 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 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 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 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: REGISTRATION CHECKLIST

U.S. Teams	Other International Teams
✓ Team Leaders should review eligibility requirements to participate and to win a prize from NASA to ensure Team is eligible to compete. ✓ Submit registration packet, including supporting documentation as required for proof of eligibility to participate and win a prize. ✓ Submitted information will be verified, eligibility confirmed, and Teams will be officially notified via email of their approval to compete. **NOTE:** Until registration and eligibility is confirmed, a Team is not considered registered and cannot make a submission. Verification and confirmation of registration will be completed in a timely manner.	✓ Team Leaders should review eligibility requirements to participate and ensure Team is eligible to compete. ✓ Submit registration packet, including supporting documentation as required for proof of eligibility to participate. ✓ Submitted information will be verified, eligibility confirmed, and Teams will be officially notified via email of their approval to compete. **NOTE:** Until registration and eligibility is confirmed, a Team is not considered registered and cannot make a submission. Verification and confirmation of registration will be completed in a timely manner.

APPENDIX C: SAFETY REPORT SAMPLE OUTLINE

- **Food Production System Description**
- **Production System Overview Flowchart**
- **Critical Point**
  - Hazard Description
  - Critical Limits
  - Monitoring Procedures
  - Deviation Procedures
  - Associated Documents

  Repeat for as many critical points as identified
- **Standard Test Record**
  - Purpose & Summary
  - Safety & Quality
  - Test Processes
    - *Preparation of Inputs*
    - *Verification*
    - *Setup, Maintenance & Collection Protocols*
    - *Storage*
    - *Cleanup & Turnover*
  - Closeout

Definition of Terms can be found at: *https://www.fda.gov/food/hazard-analysis-critical-control-point-haccp/haccp-principles-application-guidelines#princ*

APPENDIX D: 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 E: 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.