NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)
Phase 1 Competition Rules

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

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

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Revision Tracking Log

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	0	Original Document	01/12/2021
Submission & Judging	1	Correct % of Score for Design Animation (original 66/34, update to 67/33)	01/20/2021
Phase 1 Design Submission	2	Requirement added for submissions to be in English	01/29/2021
Competition Calendar	3	Extended registration for U.S. & International teams	05/17/2021
Insurance and Indemnification	4	Remove $5,000 USD liability insurance requirement for Phase 1	06/14/2021

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., Other International).

Technology Readiness Level (TRL)[1]: A method for estimating the maturity of technologies. The use of TRLs enables consistent, uniform discussions of technical maturity across different types of technology.

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

Per Space Policy Directive 1 ("To the Moon, then Mars"), NASA will:

> *"Lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities. Beginning with missions beyond low-Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations…"*

[1] 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

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. The food system will need to be 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 of 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.

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 advanced 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 three-year round-trip mission with no resupply
- Feed a crew of four (4)

- Improve the accessibility of food on Earth, in particular, via production directly in urban centers and in remote and harsh environments
- Achieve the greatest amount of 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.

Baseline Information

Information describing 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 game-changing food system technologies.

Additionally, 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.

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 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 constraints and asks Teams to produce the best food production technology they can within those constraints. . The scoring criteria recognizes 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.

Challenge Description

Competition Overview

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

- ***Phase 1: Design.*** Requires 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.*** Would require 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 would also provide samples of food outputs (e.g., tangible nutritional products) from the prototype, and may 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 1 of the Deep Space Food Challenge.

Phase 1 offers prize purses of $500,000 USD from NASA, to be awarded as described below. Phase 1 (including an initial registration period) will last approximately six (6) months (see Competition Calendar below).

The initiation of Phase 2 is contingent on the emergence of promising submissions in Phase 1 that demonstrate a viable approach to achieving the Challenge goals. In Phase 2, Teams would build and demonstrate prototypes of their proposed food production technology. The rules for Phase 2 will be released prior to the opening of Phase 2.

The initiation of Phase 3 is contingent upon the outcomes of Phase 2.

Phase 1 Prize Purses

All interested Teams must select to compete in one of three competitor categories: U.S. Team, Canadian Team, or Other 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 20 top scoring U.S. Teams that achieve a score in five or more of the scoring categories will receive $25,000 USD each from NASA and be invited to compete in Phase 2 (should Phase 2 open for competition). Teams must meet the eligibility requirements for the NASA Prize in order to be eligible to receive a prize from NASA.

Recognition for Other International Teams
The 10 top scoring Teams will be recognized as Challenge winners. Teams must meet the eligibility requirements for participating in the Challenge.

Phase 1: Design

Each Team admitted to Phase 1 of the Challenge will generate a robust design for an innovative food production technology that fits within the set of constraints in Table 1 below.

Table 1. Constraints

Item	Constraint
Volume	• Food production technology must: ○ Be ≤ 2 cubic meters ○ Pass through a doorway that is 1.07 m wide and 1.90 m tall ○ Fit in a room that is: 1.829 m X 2.438 m X 2.591 m (W x D x H)
Power	• Maximum draw of 3,000 Watts • Average draw of <1,500 Watts
Water	• Net consumption of water is not constrained, but greater net water consumption may result in a lower score on the Resource Inputs & Outputs performance requirement described in Table 3 • Net consumption of water is measured by the following equation: • C_{Net} = (Initial water input + “new water” added over time) • In this calculation: ○ Do not include water recycled by your system in the “new water” ○ 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)
Mass	• Not constrained, but greater mass may result in a lower score on the Resource Inputs & Outputs performance requirement
Data Connection	• In Phase 1, the technology may be designed to transmit operational data and limited video to a remote location outside of the technology itself, and receive periodic operational commands. Future phases of this Challenge will require greater autonomy.
Crew Time	• Maintenance & Operations of the system: Not constrained, although Teams should target a maximum crew time of 4 hours per week for operations of the food production technology for the entire crew of 4 individuals.
Operational Constraints	• Earth gravity (9.81 m/s^2) and ambient atmospheric conditions of 101,325 Pascals, 22 degrees Celsius, and 50 percent relative humidity.

Teams may design any food production technology that meets the goals of the Challenge within the constraints above and the performance criteria described in Table 2 below.

Teams will describe the process and all the inputs entering and outputs exiting the food production technology. They will also describe the full operational process including, but not limited to, how many crew members will be needed to operate the system, how the system is operated, and how long the process will take to produce their defined outputs.

Assessment Criteria

Teams' submissions will be assessed on a set of overall criteria and specific performance criteria.

The overall criteria are described in detail under *Phase 1 Judging*, and include:

- Adherence to constraints
- Design approach and innovation
- Scientific and technical merit
- Feasibility of design
- Terrestrial potential

The specific performance criteria are described below in Table 2. Additional information on the current standards for food systems as they relate to the below targets can be found in NASA-STD-3001 provided in the Reference Materials.

Table 2. Performance Criteria

Category	Description
Acceptability	• **Acceptability of the food production process** ○ Teams will describe the operations processes and procedures, including (but not limited to) how a person will set up and use the solution ▪ 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 ○ 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. ○ 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 (30 minutes for preparation, 30 minutes for the meal itself).** • **Acceptability of the resulting food product** ○ Teams must provide an assessment (using industry standards and existing research) that the food outputs of their technology is likely to meet the acceptability target/rating described below. ○ NOTE: This assessment should include appearance, aroma, palatability, flavor, and texture. ○ **Target: A NASA food item measuring 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]

[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

<table>
<tr><td>Safety</td><td>NOTE: No pathogens are permitted to exist within the food technology or its outputs. Teams must take this into account in their Phase 1 designs. Designs that fail to account for pathogens will receive a "fail" score on the Safety category.

Participants need to explain 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.

Describe relevant food safety procedures.
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 need to explain the safety of the resulting food products.

Targets: Consumption safety:

Resulting food product safe is for repeated human consumption as defined by NASA-STD-3001 (see Reference Materials)

</td></tr>
<tr><td>Resource Inputs & Outputs</td><td>
Participants need to show resource inputs and outputs associated with the technology; and the quantity of nutritious food output in relation to the quantity of inputs and quantity of waste output

Inputs may include: Raw materials, energy, water, or other materials that enter the system
Outputs may include: Food products, waste, 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 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

Participants need to provide the nutritional potential of food produced with their technologies. They can use values based on reasonable literature information that they can reference. For example, as defined by NASA-STD-3001 (see Reference Materials).

Targets:

Maximum macronutrients supplied, as a percentage of a crewmember's complete dietary needs
Maximum micronutrients supplied, as a percentage of a crewmember's complete dietary needs
Maximum variety of nutrients supplied

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<tr><td>Reliability / Stability</td><td>
Participants must show how the technology is reliable to provide its intended function
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</table>

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

	○ Operational lifespan (i.e., how long is the solution designed to last?) ○ Maintenance processes and procedures ▪ Maintenance schedule (i.e., how often will it need maintenance?) ▪ Component/element maintenance or replacement (i.e., what components will need to be replaced, and when?) ▪ Critical spare parts for a three-year mission ○ **Targets:** ▪ **Less than 10% loss of functionality or food production throughout a three-year mission.** • Participants will describe the stability of both the input products used and food product outputs. Description should include rationalization of the estimated time the inputs and outputs will be fit for use and/or consumption (i.e. shelf-life). ○ **Targets:** ▪ **Longest possible shelf-life of the ingredients and food products. They must remain safe, without any significant loss of nutritional value or quality at ambient conditions**

Competition Calendar

The following is an overview of the expected timeline for the Challenge. A detailed competition calendar for Phase 2 will be finalized as part of the Phase 2 rules.

Date/Deadline	Event
January 12, 2021 9:00 AM Central Time (GMT -05:00)	Phase 1 Opens for Registration & Submission for all Teams
February 2021 – July 2021	Webinars to support registered Teams and potential Teams in developing concept design NASA/Methuselah Foundation promotional activities and/or other support (TBD) for registered Teams
June 25, 2021 5:00 PM Central Time (GMT -05:00)	Phase 1 Registration Closes for U.S. and International Teams
July 30, 2021 5:00 PM Central Time (GMT -05:00)	Phase 1 Submissions Due for all Teams
August 2021	Judging Panels review and score submissions
September 2021	Judging Panels Summit (virtual) to determine Winners
September 2021	All Phase 1 Winners Announced

Submissions and Judging

Registration

All interested U.S. and International Teams will register for the Challenge by the deadline and meet the eligibility requirements in order to participate in the Challenge and win a prize. For all Teams, the registration links will be provided through the official Challenge website**:** (deepspacefoodchallenge.org). A Registration Checklist for U.S. Teams and non-Canadian International Teams is available in Appendix A.

The registration requirements specific to U.S. Teams and Other International Teams can be viewed in Appendix B. All Teams should refer to the Challenge website (deepspacefoodchallenge.org) for a full description of the registration process and eligibility requirements.

Phase 1 Design Submission

Submission Requirements

All Teams will provide the required information and a video as described below via an online application form. Applications must be submitted in English. No application forms will be accepted after the Submission Deadline.

The form will prompt you to provide inputs for each of the criteria except for Scientific &Technical Merit and Feasibility of Design, which will be evaluated based on your overall submission.

- **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 and/or confirmation of how the food production technology design adheres to the constraints[3]

[3] *In Phase 1, Adherence to Constraints is not meant to determine whether the Design Report itself is complete in including all the required information. This question is meant to ensure that Teams have considered the constraints, and that the food production technology design, at a minimum, falls within those constraints. In future Phases, Teams' food production technologies will be evaluated and scored on whether or not the design stays within the constraints so that it ultimately can meet NASA and CSA's needs and deliver value.*

- 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
    - 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.

Phase 1 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 Phase 1 submission deadline, 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.

DESIGN REPORT (100 Points Maximum)			
Category	**Description**	**Maximum Points**	**Percent of Score**
Overall Criteria:			
Adherence to Constraints	Does the food technology design adhere to the constraints described in Table 1?[4]	Y/N	0%
Design Approach and Innovation	Does the design approach the problem of food production technology for spaceflight in a novel and innovative way?	15	15%
Scientific and Technical Merit	Does the scientific and technical approach and design of the technology demonstrate merit?	15	15%
Feasibility of Design	Is the proposed technical approach is feasible? To what extent does the Team clearly understand and address any potential risks in their design submission?	15	15%
Terrestrial Potential	To what extent does the Design Report present a feasible scenario for the potential use of the technology within terrestrial food systems?	15	15%
	Subtotal:	60	60%
Performance Criteria:			
Acceptability	Acceptability of the food production process; and Acceptability of the resulting food products	10	10%
Safety	**NOTE:** ***Designs that fail to account for pathogens will receive a "fail" score in the Safety category.*** Safety of the food production process, including environmental safety; and Safety of the resulting food products, including safety for human consumption.	10	10%
Resource Inputs / Outputs	Resource requirements of the food production process (inputs) and all outputs; the amount of food output in relation to the inputs and waste; and nutritional quality of the resulting food products	10	10%
Reliability/Stability	Stability and quality of the inputs and outputs; reliability and availability of the technology with less than 10% loss of functionality or food production	10	10%
		40	40%
Total		100	**100%**

DESIGN ANIMATION (15 Points Maximum)			
Criteria	**Description**	**Maximum Points**	**Percent of Score**
Accuracy	Does the Design Animation present an accurate visual representation of the food production technology described in the Design Report and its operation?	10	67%
Engages the Public	Is the Design Animation engaging for a public audience?	5	33%
Total		**15**	**100%**

Should Phase 2 open, all Teams selected as winners and/or awarded a prize purse in Phase 1 will also be invited to advance to Phase 2. Additional Teams (whether they participated in Phase 1 or not) may also register to participate in Phase 2 once it opens.

Teams that did not participate in Phase 1 will be required to submit additional information about their proposed technology/approach (consistent with the submission requirements for Phase 1) to be considered for participation in Phase 2. All Phase 2 registration requirements must be met by the registration deadline. The Judging Panel will assess the proposed submission for new Teams, and qualify them for participation in Phase 2. This review and qualification process is mandatory for new Teams entering Phase 2.

Challenge Requirements

In General
Teams are responsible for understanding and complying with these Requirements.

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 Competitor Team must identify their nationality.

- No individual competitor 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 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

[4] *In Phase 1, Adherence to Constraints is not meant to determine whether the Design Report itself is complete in including all the required information. This question is meant to ensure that Teams have considered the constraints, and that the food production technology design, at a minimum, falls within those constraints. In future Phases, Teams' food production technologies will be evaluated and scored on whether or not the design stays within the constraints so that it ultimately can meet NASA and CSA's needs and deliver value.*

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.

Eligibility to Compete and Win Prizes from NASA

In order to be eligible to win a prize:

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. Competitor 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 (separate form) wherein he/she discloses his/her citizenship and acknowledge that her/she is not eligible to win a prize from NASA, AND

I. The foreign national is an employee of an otherwise eligible U.S. entity participating in the Challenge,
II. The foreign national is an owner of such entity, so long as foreign citizens own less than 50% of the interests in the entity,
III. The foreign national is a contractor under written contract to such entity, OR
IV. The foreign national is a full time student, during the time of the Challenge, of an otherwise eligible entity which is an accredited institution of higher learning, AND the student is during the Challenge in the United States on a valid student visa and is otherwise in compliance with all local, state, and federal 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 shall result in the Team being disqualified from winning a Prize from NASA.

U.S. government employees may enter the competition, 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, access, personnel, knowledge or other resources that are available to them as a result of their employment except for those resources available to all other participants 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 Competition 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 if any Team Member is a Federal entity or Federal employee acting within the scope of their employment. This includes any U.S. Government organization or organization principally or substantially funded by the Federal 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 shall 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 shall promptly be provided to the Methuselah Foundation.

Current employees, consultants, and students of the Methuselah Foundation may only participate as Team Members when the 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.

Team Roles and Responsibilities

Each Team will designate a Team Leader. The Team Leader shall 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 C.

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 D.

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 required by its local, state, or Federal governments to conduct any and all virtual activities related to or required by participation of Team and the Team Members in the Challenge.

Delay, Cancellation or Termination

The Competitor 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, shall 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.

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

NASA STD-3001: NASA Spaceflight Human-System Standard; Volume 2
Human Factors, Habitability, and Environmental Health:
https://www.nasa.gov/hhp/standards[5]

On the Hedonic Scale
Meilgaard, Morten C., B. Thomas Carr, and Gail Vance Civille. *Sensory evaluation techniques*. CRC press, 2006.

Possible opportunity areas for new food system technologies:

- *Macro- and micro-nutrients:* 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

[5] *NASA STD-3001 is currently pending approval for 2021 revisions. Note the following corrections: section 7.1.1.3 (page 76), and also in the Nutrition Requirements, Standards, and Operating Bands for Exploration Missions, pages 13, 14 & 117, the formula is to calculate EER for men >19 yo is: [EER (kcal/day) =* ***662*** *– 9.53 x Age [y] + 1.25 x (15.9 x Body Mass [kg] + 539.6 x Height [m]). Section 7.1.1.7 (page 79) correction to the Latin name of the fungi Aspergil**lus** flavus.*

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.

<u>Data for Terrestrial Applications</u>

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: 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 submit a concept design. 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 submit a concept design. Verification and confirmation of registration will be completed in a timely manner.

APPENDIX B: REGISTRATION REQUIREMENTS

U.S. & Other International Teams

• **Initial Concept Design Title (≤10 words)**: This title may be displayed on the competition website post-submission.
 	
• **Initial Concept Description (≤50 words)**: Provide a brief summary description of the proposed food production technology.
 	
• **Team Information**: Teams will submit a Curriculum Vitae or resume, biography, and headshot for each Team Member, and may submit additional Team information, such as a Team logo or Team photo. Photographs and logos will only be used in connection with media material prepared and distributed for the promotional purposes of the Challenge.
 	
• **Team Video Pitch (3 minute maximum)**: Teams must submit a short video to introduce the Team and pitch your initial food production technology concept. In the video, Teams should address:
  ○ Introduce yourself and your organization and/or Team.
  ○ What is your initial proposed food production technology?
  ○ What is novel, sustainable and innovative about your initial proposed food production technology?
  ○ How would your approach contribute to developing a successful/reliable long-duration food system for exploration missions?
 	
• **Legal and other supporting documentation as required for registration, and as described in the Challenge Rules**

APPENDIX C: 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 Data 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 10 scoring Teams will be announced and recognized as Challenge winners at the time of the public winners' announcement.

APPENDIX D: 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.