NASA Centennial Challenges Program: A crowdsourcing tool to advance life support technologies for future NASA missions

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NASA’s first and biggest prize program

Established to conduct prize competitions in support of NASA programs

Inspired by Orteig Prize and Ansari X Prize, among others

Established (per NASA Prize Authority, 51 USC 20144): “to stimulate innovation in basic and applied research, technology development, and prototype demonstration that have the potential for application to the performance of the space and aeronautical activities of the Administration.”
NASA Crowdsourcing Initiatives

- **Centennial Challenges**
  - Duration: Years
  - Awards: $100K+ to $Ms
  - Products: Technology demos
  - Who: US-led (to win prize)
  - Authority: NASA prize authority

- **NASA Mix Challenge**
  - Duration: Months
  - Awards: $1K to $250K
  - Products: Ideas, design, software
  - Who: Worldwide; US-led (COMPETES)
  - Authority: Procurement; COMPETES Act

- **International Space Apps Challenge**
  - Duration: Days/Weeks
  - Awards: Recognition
  - Products: Software apps/tech concepts
  - Who: Worldwide
  - Authority: Space Act

- **Citizen Science**
  - Duration: Months
  - Awards: Recognition
  - Products: Scientific observations and analysis
  - Who: Worldwide
  - Authority: Amer. Innov. and Competitive ness Act

- **NASA Education**
  - Duration: Months
  - Awards: Varies
  - Products: Design
  - Who: Students (US)
  - Authority: Space Act; grants & cooperative agreements

- **NASA@Work**
  - Duration: Weeks
  - Awards: Recognition
  - Products: Ideas, info
  - Who: NASA
  - Authority: N/A

These opportunities can be accessed at www.nasa.gov/solve
Completed

3D-Printed Habitat
$3,150,000
Additive construction technology for space
- $2,060,000 awarded
- 120 teams
- Allied Organization: Bradley University, Sponsors: Caterpillar Inc., Bechtel Corp, Brick and Mortar Ventures

Active

Cube Quest
$5,000,000
Flight-qualified CubeSats near and beyond the moon
- $460,000 awarded
- 15 U.S. teams
- Innovative propulsion and communication
- 3 payload slots on SLS EM-1
- NASA Led Challenge

Vascular Tissue
$500,000
Viable thick tissue for research
- 13 U.S. teams currently registered
- Innovation in engineered tissue that can stay viable for more than 30 days
- Allied Organization: New Organ Alliance

CO₂ Conversion
$1,000,000
Bio-manufacturing from in-situ resources
- $250,000 awarded (Phase 1)
- 17 teams
- Phase 2 target open date August 2019
- HEOMD collaboration
- NASA-led Challenge (STMD/HEOMD)

Space Robotics
$1,900,000
Advance robotics software for full autonomous operations
- Multi-robotic systems working together in short-term and long-term ISRU missions.
- Phase 2 target open date in August 2019
- Allied Organization: Space Center Houston

History of Challenges 2005-2019

Team Breakdown

Geographical Team Distribution (by region)
Centennial Challenge Program*
(Dedicated NASA Team)
Stimulate innovation in basic and applied research, technology development, and prototype demonstration that have potential NASA applications.

*NASA Prize Authority

Who is in charge?
NASA
• Leads
• Prize Purse
Allied Organization/
No-Profit
• Registrations
• Runs competition
• Judges

Evaluation Criteria
Clearly defined before competition opens

Who designs the Challenge?
• NASA
• Allied Organization
• SME’s (NASA, Other Gov Agencies, industry)

What is different?
• Insurance and Indemnification obligation
• Fed Register Notice
• NASA has no rights in solutions

NASA Senior Management approves development of the competition
Innovation challenges can help us leverage the crowd to overcome our biggest hurdles

- **Proven tool** for innovation for >300 years
- **Inspire** and **incentivize** positive action
- **Focus communities** and **foster collaboration**
- Leverage funding and **investment**
- Democratize innovation and **encourage new ideas**
- **Reduce risk**
- Influence **public perception** and activate the public
Competitions & Prizes: Best Target Areas

- Complex opportunity that may require multiple attempts
- Opportunity that is not being solved in the marketplace or by governments quickly enough; lack of relevant incentives?
- The means by which the problem or opportunity will be solved are unknown or too speculative for traditional research, contracts, or grants
- Opportunity where it is not known who will develop the best solutions or where the best solutions will come from
- Opportunity that is not purely regulatory or political
Competitions & Prizes: Best Design Practices

- Define the problem, not the solution
- Define an audacious but achievable target
- Offer a clear measure of success
- Design to have a media-friendly winning moment, and tell great stories along the way
- Design for after the prize is won
- Make it easy for you to operate
- … And rewarding and simple for teams to compete
Provide more than a prize purse

HARD INCENTIVES
- Industry validation
- Third-party verified data
- Testing
- Expertise
- Media exposure
- Brand promotion
- Business plans
- Pitch sessions
- Crowdfunding
- Market studies
- Capital infusion
- Partnership opportunities
- Regulators

SOFT INCENTIVES
- The cause
- Making a difference in the world
- Interesting work
- Industry
- Company
- Building a market (during and after the competition)
- Glory and prestige
- Pride
- It’s fun!
- Attention
- Experts
- Networking
- Collaboration
- Community
- New team members
What motivates people to compete?

- Guts
- Glory
- do Good
- Gold
Challenges in Formulation

**StarHab**
$4,000,000
**GOAL:**
Addressing technology gaps in nutrition and life support systems for future planetary missions.

**Lunar ISRU**
$5,000,000
**GOAL:**
In Situ Resource Utilization (ISRU) competition targeting a large scale, end-to-end demonstration.

**Planetary Protection**
$250,000
**GOAL:**
Detection of microorganisms to confirm compliance with planetary protection requirements.

**Lunar Power**
$5,000,000
**GOAL:**
Portable energy storage competition to enable powering a rover through several cycles of lunar daylight and darkness.
How do we provide astronauts with:

• A viable food system for long duration missions?

• An approach that meets their daily nutritional needs in a confined space?

• A palatable diet with limited or no dependency on Earth resupplies?

• A ‘harvest’ that provides a variety of fresh food choices?
Why A Prize-based Challenge?

This challenge competition seeks to leverage open-source innovations in areas like genetic modification of crops to address nutrition optimization and food production.

The problems can be approached from numerous angles and with a broader pool of potential solutions

• Attract new “eyes” and new perspectives from new and sometimes unexpected places
• Solvers dedicate their own resources and NASA only awards the prize funds for successful outcomes
• Develop techniques to optimize indoor agriculture that will be useful on Earth as well as in space
NASA Technology Gaps

• Stored food degrades over time; vitamins and micronutrients are space labile. Enjoyable, desirable food is critical for crew physical and mental health, but processing (dehydration, retort) change texture and palatability

• Current crews frequently get fresh food delivered with stored food, but the cost of this type of resupply is not sustainable.

• ISS payloads are small scale, science focused, and only sometimes are used to produce food crops.

• Growing food crops in space has had mixed success, and is not yet reliable or predictable enough to be a critical system in the spacecraft

• Limited number of crops have been demonstrated, and models and predictions are limited.

• Spacecraft do not currently accommodate mass, volume and water needs of food production

• Stored food dominates logistics needs for space missions, but using existing NASA technologies is not a positive mass trade.
StarHab Formulation Process

**STEP ONE: Assessment of the Current State-of-the-Art Technology**
- We interviewed experts internal and external to NASA
  - *Centennial Challenge Program Team*
  - *Plant Research Team at KSC*
  - 17 Experts from NASA, industry and academia
  - *Relevant literature and internal NASA documents*
- Purpose: to identify potential areas of opportunity to help frame the discussions at the Ideation Workshop

**STEP TWO: Ideation Workshop**
- 36 Experts from NASA, industry and academia were invited to KSC on December 4, 2018
- Purpose: to discuss, validate and prioritize the potential areas of opportunity from the assessment

**STEP THREE: Outcomes**
- Based on outcomes from the Workshop, we developed three (3) options for the topic and potential structure of the StarHab Challenge
- Purpose: to identify a potential Challenge based on researched, vetted, and validated topic areas
Overview Of Workshop Results

Technology areas selected through the formulation process included:

1. **FOOD PRODUCTION EFFICIENCY**
   - Cost effective
   - Energy efficient
   - Optimization of height/volume/density, water, nutrients, light
   - Automation and control
   - Efficient use and recycling of water

2. **PLANT MODIFICATION**
   - Optimized for nutrition
   - Effectiveness, efficiency
   - Engineer plants to fit a given environment
   - Plant sensing
   - Molecular farming

3. **VERIFIED MODELS FOR MARS PLANNING**
   - Modeling ECLSS and air/water/plant integration
   - Big data analysis
   - Develop models and applications for remote operations

From these, the team was able to identify potential StarHab challenges that are based on researched, vetted and validated topic areas.
StarHab: Proposed Challenge Options

• Concept #1: Comprehensive
  • Two phases
  • First phase lays the groundwork for the full development of the teams’ solutions in the second phase
  • The same teams would continue throughout the entire competition and NASA would commit to launching the entire competition.

• Concept #2: Staged
  • Large-scale, staged competition with phases
  • Each of the phases builds upon the previous phase
  • Could be launched through just the first phase, through the first and second phases, or through all three phases
  • Phases are designed to build upon each other to eventually reach an audacious outcome
  • Teams can choose to participate in all phases that are launched or exit or enter at any phase

• Concept #3: Building Blocks
  • Multiple separate challenges that can run simultaneously or one at a time
  • Although designed to be independent of each other (and therefore can be launched in parallel or sequentially and any can be launched with or without the others), they are also designed to complement each other
  • If more than one is launched, the aggregate value will exceed the value of the individual challenges
**Proposed Competition Structure**

**PHASE ONE: IDEATION CHALLENGE**

Large segments of the public will compete in one or a series of ideation competitions. Submissions will be scored and prizes awarded.

**PRIZE PURSE:** $100,000  
**DURATION:** 6 months

Food must be considered as a system-level issue

Key formulation question: What parts of the diet are set as fixed by NASA?

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**PHASE TWO: SUBSCALE PROTOTYPE**

Teams will design system models, validate key items, and be scored. Top teams will be awarded a prize and be invited to compete in Phase 3.

**PRIZE PURSE:** $1,500,000  
**DURATION:** 12 months

Developers will have to make trade-offs

Key formulation question: How do we weight multiple performance parameters?

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**PHASE THREE: DEMONSTRATION**

Selected Teams from Phase 2 will develop full size prototypes of their systems and operate over a given duration for multiple cycles.

**PRIZE PURSE:** $2,000,000  
**DURATION:** 18 months

Reliability & human acceptability are critical

Key formulation question: How long is the demo and can people safely eat the products?
Status and Plan Forward

• The challenge competition was approved by STMD Senior Management to start the process of development

• NASA customers will be working with the Centennial Challenge Program team to develop a path forward that will be presented to STMD to start the looking for an Allied Organization

• If approved by management after the challenge is developed, it is expected to open for registration late summer/early fall
Daring you to ask

What if?
What will home look like ... on Mars?

www.nasa.gov/3DPHab
3DPH Challenge Phase 1: Design
7/2015-9/2015
Prize Purse: $50,000/$40,000 awarded
Develop state-of-the-art architectural concepts that take advantage of the unique capabilities offered by 3D printing.

3DPH Challenge Phase 2: Material
6/2016-5/2017
Prize Purse: $1,100,000/$701,000 awarded
Autonomously 3D Print structural components using terrestrial/space based materials and recyclables.

3DPH Challenge Phase 3: Build it
11/2017-5/2019
Prize Purse: $2,000,000/$1,320,000 awarded
Level 5: Demonstrate an autonomous additive manufacturing system that can create a complete habitat.
The PSU construction approach utilized two robots, one for placement of components and one for printing the concrete-like structure.

Habitat crush test. Notice excavator treads off of the ground!

Completed Habitats
3D Printed Habitat Recap
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Questions?

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www.nasa.gov/winit
What if a long-distance call could reach a new world?

www.nasa.gov/cubequest
What if your coworkers came with **batteries**?
What if space held the key to revolutionizing medicine for better health?

www.nasa.gov/tissueprize
What if creating a new material started with a single breath?

www.nasa.gov/co2challenge