National Space Grant Foundation

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eXploration Habitat (X-Hab) 2016 Academic Innovation Challenge Solicitation

on behalf of

NASA Headquarters
Human Exploration & Operations Mission Directorate

Sponsored by:

The Advanced Exploration Systems (AES) Division
And
Exploration Augmentation Module (EAM) Project

Release Date:	March 11, 2015
Notice of Intent Due:	April 4, 2015
Proposals Due:	April 30, 2015
Anticipated Award Date:	May 29, 2015
Program Website:	http://www.spacegrant.org/xhab/

X-Hab 2016 Academic Innovation Challenge Solicitation

1. Synopsis

The eXploration Habitat (X-Hab) 2016 Academic Innovation Challenge is a university-level challenge designed to develop strategic partnerships and collaborations with universities to help bridge strategic knowledge gaps and increase knowledge in capabilities and technology risk reduction related to NASA's vision and missions. The competition is intended to link with senior- and graduate-level design curricula that emphasize hands-on design, research, development, and manufacturing of functional prototypical subsystems that enable functionality for space habitats and deep space exploration missions. NASA will directly benefit from the challenge by sponsoring the development of innovative concepts and technologies from universities, which will result in novel ideas and solutions that could be applied to exploration. The Advanced Exploration Systems (AES) Division will offer multiple awards of $10k - $30k each to design and produce functional products of interest to the AES Division (see 3.2 topic list) as proposed by university teams according to their interests and expertise. The prototypes produced by the university teams may be integrated onto existing NASA-built operational prototypes (examples shown in Figure 1). X-Hab proposals will have a proposal submittal, where down-selection will determine which projects will be funded. X-Hab university teams will complete their products for evaluation in May-June 2016 by the AES Division. Universities may collaborate together on a project team.

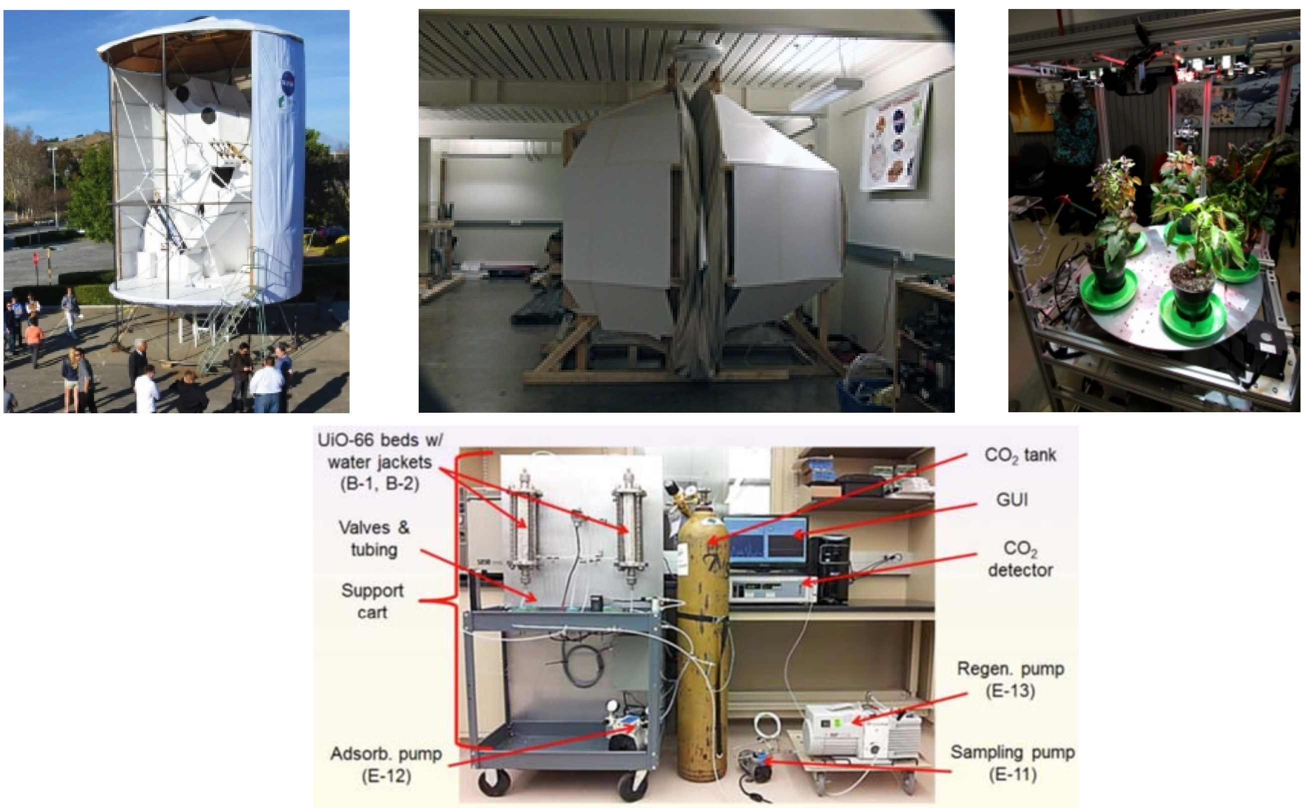

Figure 1: 2010-2013 Previous X-Hab Projects (from top left): Vertically Oriented Habitat Mockup, Expandable Habitat Demonstration, Robotic Plant Growth System, Air Revitalization System prototype (Courtesy: NASA).

Students in the Critical Path: The X-Hab Academic Innovation Challenge has a unique approach to student involvement, in that the student team is placed in the NASA mission critical path for the product or technology that they develop. The student team is considered equal with all the other subsystem teams, as Principal Investigator (PI) for their particular project. They are required to go through NASA System Definition Review (SDR), Preliminary Design Review (PDR), and Critical Design Review (CDR) on a similar footing as other NASA engineered products. In doing so, the NASA team is putting a great deal of responsibility on the students, and in turn gives the students a bigger stake in the future development of space technologies that likely will become heritage to actual systems and technologies that will be flown in space in the years and decades to come.

2. Eligibility

Proposals will be accepted from faculty who are U.S. citizens and currently teach an Accreditation Board for Engineering and Technology (ABET) accredited engineering senior or graduate design, industrial design, or architecture curriculum teaming course at a university affiliated with the National Space Grant College (if applicable) and Fellowship Program, or other US accredited university. Multi-discipline, multi-departmental, and/or multi-institutional teaming collaborations are highly encouraged.

Historically Black Colleges and Universities, Tribal Colleges and other minority serving educational institutions are particularly encouraged to apply. Proposals from women, members of underrepresented minorities groups, and persons with disabilities are highly encouraged.

3. Funding Opportunity Description

3.1 Description

NASA’s multi-center Advanced Exploration Systems Division and Exploration Augmentation Module Project are requesting proposals for the eXploration Habitat (X-Hab) 2016 Academic Innovation Challenge. The X-Hab Challenge is a university-based challenge to design, manufacture, assemble, test, and demonstrate functional prototypical subsystems and innovations that enable functionality for human space exploration missions. The awarded projects and products of the challenge will be evaluated and may be integrated into prototypes for the purpose of operational and functional evaluation opportunities. Alternately, the products of the challenge may be used in NASA studies or analysis of exploration architectures. In previous X-Hab rounds, products have been tested and evaluated at NASA Johnson Space Center (JSC), at Marshall Space Flight Center (MSFC), at Kennedy Space Center, at NASA’s Desert Research and Technology Studies (D-RATS) analog field tests, and at school campuses. The products and technologies produced by the universities for the X-Hab 2016 challenge will be improved upon for a next generation exploration systems, and may eventually become heritage for future flight demonstrations and exploration missions.

NASA's Advanced Exploration Systems Division and Exploration Augmentation Module Project are inviting university faculty who teach design courses to submit a proposal based on a topic that coincides with the faculty’s interest and the topic list (see below), for a two-semester design course. Design projects are intended to stimulate undergraduate and graduate research on current NASA exploration activities and to bring out innovative and novel ideas that can be used to complement those currently under development at respective NASA Centers. Additionally, such academic involvement will improve the prospects for graduates to pursue additional studies and to seek careers in the space industry. The design courses should be relative to exploration systems and missions. It is understood by NASA that the funding awarded to manufacture some test articles may not be sufficient and thus it may require teams to obtain supplemental sponsored funding from university sources or industry partners in order to design, manufacture, assemble, test, and demonstrate a functional and operational test article. Additionally, the supplemental funding may enable the teams to enhance the quality or scope of the proposed work. As part of this solicitation the universities are encouraged to seek additional, innovative sponsorship and collaborations (Project Teaming) with other universities and organizations (including institutional support, industry, space grant consortiums, etc.) to meet the design requirements and test objectives. Each proposal must include a signed letter of commitment from the university faculty, collaborators, and their potential sponsor(s) to ensure their commitment to the project.

NASA is building and testing prototype systems that will be utilized to advance NASA's understanding of alternative mission architectures, requirements definition and validation, and operations concepts definition and validation.

University professors and their teams that are interested should propose an X-Hab 2016 Academic Innovation Challenge proposal for innovations and/or technologies that they would like to develop (see topic list). They must conform to the end-product design requirements, schedule, and meet the evaluation criteria.

The selected project teams will implement the design course during the fall 2015 and spring 2016 semesters. All teams must provide proof that the course has been approved to be taught at their institution in 2015-2016 academic year. The selected professor must be available for technical assistance to the implementing universities during the 2015-2016 academic year.

Applicants are required to apply a systems engineering approach for the design course. For reference please see the NASA Systems Engineering Handbook NASA SP-2007-6105.

The following project review milestones will take place with participation from the NASA Project Team, for the awarded university projects (dates are approximate):

- 1 Oct 2015 – Requirements and System Definition Review
- 11 Nov 2015 – Preliminary Design Review
- 20 Jan 2016 – Critical Design Review
- 9 March 2016 – Progress Checkpoint Review
- 11 May 2016 – Project Completion and Evaluation by NASA

Additional meetings for more technical interchange can be requested by the teams but are not required as a milestone.

3.2 X-Hab Proposal Topic List

The following list contains test articles, demonstrations, and studies for each of seven potential project sponsors for this solicitation. Detailed descriptions appear in Appendix B.

1.0 Exploration Augmentation Module Project

Crew Systems
1.1 Deep Space Mission Food Storage
1.2 Deep Space Mission Exercise Equipment
1.3 Deep Space Mission Telepresence Capabilities

Structures
1.4 Inflatable/Deployable Airlock Structure for either EVA or IVA
1.5 Deployable and Reconfigurable Internal Secondary Structures for Space Habitats

Habitat Layout
1.6 Deep Space Mars Transit Habitat Layout Studies

Power
1.7 Photovoltaic Power System Demonstration for the Exploration Augmentation Module
1.8 120 VDC Dual-Source Power Distribution Unit

2.0 Space, Life, and Physical Sciences (SLPS)

2.1 Microgravity plant watering system
2.2 Assessing performance and refining a space plant growth system
2.3 A Microgravity Food Production System utilizing radial acceleration for water and nutrient delivery

3.0 Logistics Reduction Project

3.1 Oxygen-Based Clothing Sanitation System

4.0 Nuclear Thermal Propulsion (NTP) Project

4.1 Advanced Nuclear Thermal Propulsion (NTP) systems

5.0 Life Support Project

5.1 Optimization of Carbon Dioxide Removal Systems for Mars Missions

6.0 In-space Manufacturing Initiative

6.1 Technology Development of Low-Power Required Manufacturing of Metals for the Zero-Gravity Environment

7.0 Autonomous Propellant Loading Project

7.1 Automated Umbilical Project for Surface Systems

3.3 Background and Purpose

NASA is dedicated to creating a capability-driven approach to technology and foundational research that enables sustained and affordable human and robotic exploration. NASA has a long history of working with universities in the pursuit of joint interest research and technology development efforts. Drawing on talent from industry and academia, NASA delivers innovative solutions that dramatically improve technological capabilities for our mission and the Nation. Using innovative approaches to problem solving such as challenges and collaborations NASA harnesses innovators, creating diverse pools of solvers that address NASA problems and advance technology development in a flexible way for technological breakthroughs. This announcement maps to NASA Strategic Plan Objective 2.3: Optimize Agency technology investments, foster open innovation and facilitate technology infusion, ensuring the greatest national benefit.

NASA's Advanced Exploration Systems (AES) Division is pioneering new approaches for rapidly developing prototype systems, demonstrating key capabilities, and validating operational concepts for future human missions beyond Earth orbit. AES activities are uniquely related to crew safety and mission operations in deep space, and are strongly coupled to future vehicle development.

The purpose of the X-Hab Academic Innovation Challenge is to leverage funding, capabilities and expertise within and outside of NASA to address technology barriers and advance technology.

The AES Division has five main objectives for the Academic Challenge:

1. Teams will learn by putting into practice the knowledge and skills they have gained throughout their years at their respective university.
2. Teams will analyze and solve complex design and integration issues from an interdisciplinary perspective, exercising their innovation and initiative as they deal with conflicting requirements and make appropriate trade-offs.
3. Teams will develop skills in project planning, teamwork, leadership, critical thinking, and decision-making in an academic environment.
4. Teams will produce a test article and a final report that will be made widely available to space agencies, aerospace companies and universities.
5. This support will adhere to NASA's commitments in its Strategic Plan to "maintain strong partnerships with academia" and to "engage and inspire students."

3.4 Online Technical Interchange Forum

Prior to the proposal submission deadline, an online Technical Interchange will be posted for the NASA AES Division to answer questions about the project. Questions pertaining to this effort shall be submitted to xhab@spacegrant.org four days prior to have them included in the response. Answers will be published on the solicitation website.

Schedule:

Questions due April 4, 2015
Responses posted: April 11, 2015

3.5 Pertinent Dates

Proposal Phase

11 Mar 2015	Date of Announcement / Release of RFP
4 Apr 2015	Questions for online Technical Interchange Due
11 Apr 2015	Responses for questions published online
30 April 2015	Proposal Due Date
28 May 2015	Award Announcements

Award Phase

Summer - Fall 2015	Design Phase
Sept 2015	Kickoff meetings
1 Oct 2015	Requirements and System Definition Review
11 Nov 2015	Preliminary Design Review
20 Jan 2016	Critical Design Review
9 March 2016	Progress Checkpoint Review
11 May 2016	Project Completion and Evaluation by NASA
May - June 2016	Integration with NASA test bed (if applicable)
Aug - Sept 2016	Testing (if applicable)

3.6 Documentation and Deliverables

Award recipients will provide the following deliverables:

1. Work Plan and Implementation Schedule
2. Participation in Milestone Progress Reviews (WebEx & Telecon)
3. Report on Educational Outreach activity
4. Demonstration articles for the X-Hab development studies
5. Technical Final Report

<u>Systems Definition Review (SDR) checklist:</u>
The SDR examines the proposed system architecture/design and the flow down of Level 1 requirements to all functional elements of the system. SDR is conducted to prepare for, and access readiness for the Preliminary Design phase.

SDR Objectives: the objectives of the review are to:

1. Ensure a thorough review of the team, processes, and products supporting the review.
2. Ensure the products meet the success criteria.
3. Ensure issues raised during the review are appropriately documented and a plan for resolution is prepared.

SDR Results of Review: as a result of successful completion of the SDR, the system and its operation are well enough understood to warrant proceeding to PDR. Approved specifications for the system, interfaces, and preliminary specifications for the design of appropriate functional elements may be released.

SDR Agenda (each academic team to present):

1. Identify Team Members
2. Review Vision, Mission, Goal and Objectives of Project
3. Review System Architecture (includes system definition, concept and layout)
4. Review Level 1 Requirements
5. Review Traceability of requirements “flow down”
6. Review Work Breakdown Structure (WBS)
7. Review preferred system solution definition including major trades and options. CAD model of physical components of system if available.
8. Review preliminary functional baseline
9. Review draft concept of operations
10. Review preliminary system software functional requirements
11. Review risk assessment and mitigations approach
12. Review analysis tools to be used
13. Review Cost and schedule data
14. Review software test plan (approach)
15. Review hardware test plan (approach)

SDR Success Criteria:

1. Systems requirements (based on mission as described by NASA) are understood, defined, and form the basis for preliminary design.
2. All requirements are allocated, and the flow down (subsystems, etc.) is adequate.
3. The requirements process is defined and sound, and can reasonably be expected to continue to identify and flow detailed requirements in a manner timely for development of project, post SDR.
4. The technical approach is credible and responsive to the identified requirements.

5. Technical plans have been updated, as necessary, from initial proposal.
6. Trades have been identified, and those planned prior to PDR/CDR adequately address the trades/options.
7. Any significant development or safety risks are identified, and a process exists to manage risks.
8. The ConOps is consistent with any proposed design concepts and is aligned with the Level 1 requirements.
9. Review demonstrates a clear understanding of customer and stakeholder needs.

Preliminary Design Review (PDR) Checklist:

During the PDR, the team should demonstrate that activities have been performed to establish an initial project baseline, which includes a formal flow down of the project-level performance requirements to a set of system and subsystem design specifications. The technical requirements should be sufficiently detailed to confirm schedule and cost estimates for the project are being met. While the top-level requirements were baselined at SDR, the PDR should identify any changes resulting from the trade studies and analyses since SDR.

In general, teams should devote significant effort to discussing interface requirements and operational requirements (including test support, training products, repair products). The team should thoroughly define design and production requirements (if possible) during the PDR. PDR products should include comprehensive system and element requirements documentation, interface documentation, and technology validation.

The PDR should demonstrate the establishment of a functionally complete preliminary design solution (i.e., a functional baseline) that meets project goals and objectives. It should define the project in enough detail to establish an initial baseline capable of meeting the project needs.

PDR Objectives: the objectives of the review are to:

1. Ensure a thorough review of the team, processes, and products supporting the review.
2. Ensure the products meet the success criteria.
3. Ensure issues raised during the review are appropriately documented and a plan for resolution is prepared.

PDR Results of Review: As a result of successful completion of the PDR, the system and its operation are well enough understood to warrant proceeding to CDR. Approved specifications for the system, interfaces, and specifications for the design of appropriate functional elements may be released.

PDR Agenda (each academic team to present):

1. Review and updates of any documents developed and baselined since SDR
2. Review a matured ConOps
3. Review of any updates to any engineering specialty plans
4. Review risk management plan
5. Review cost and schedule data
6. Review top-level requirements and flow down to the next level of requirements since SDR
7. Review any design-to specifications (hardware and software) and drawings, verification and validation plans, and interface documents at lower levels. A CAD model is required at PDR stage for all physical components of the system.
8. Review any trade studies that have been performed since SDR and their results
9. Review any performed design analyses and report results
10. Review any engineering development tests performed and report results

11. Review and discuss internal and external interface design solutions (and any interface control documents needed). This includes interface information provided by NASA since SDR
12. Review system operations
13. Review any potential safety issues (or data) including test identification and test readiness criteria as applicable
14. Select a baseline design solution

PDR Success Criteria:

1. Systems requirements (based on mission as described by NASA) are understood and defined and form the basis for preliminary design.
2. All requirements are allocated, and the flow down (subsystems, etc.) is adequate.
3. The requirements process is defined and sound, and can reasonably be expected to continue to identify and flow detailed requirements in a manner timely for development of project, post PDR.
4. The technical approach is credible and responsive to the identified requirements.
5. Technical plans have been updated, as necessary, from the System Design Review.
6. Trades have been identified and executed, and those planned for PDR have been completed with appropriate rationale.
7. Any significant development or safety risks are identified, and a process exists to manage risks.
8. Plans are defined to address Test Readiness Criteria if applicable.
9. The ConOps is consistent with any proposed design concepts and is aligned with the Level 1 requirements.
10. Review demonstrates a clear understanding of customer and stakeholder needs.

Again, the PDR should demonstrate the establishment of a functionally complete preliminary design solution (i.e., a functional baseline) that meets project goals and objectives. It should define the project in enough detail to establish an initial baseline capable of meeting mission needs.

Design issues uncovered in the PDR should be resolved so that final design can begin with unambiguous design-to specifications. From this point on, almost all changes to the baseline are expected to represent successive refinements, not fundamental changes.

<u>Critical Design Review (CDR) Checklist:</u>

The team should finalize all their designs for the CDR, after having selected a preferred alternative among the trade studies. A CAD model of both the system and a CAD model showing how the system is integrated in with the overall habitat is required.

CDR Agenda (each academic team to present):

1. Review and updates of any documents developed and baselined since PDR
2. Review a finalized ConOps
3. Review of finalized engineering specialty plans
4. Review finalized risk management plan
5. Review finalized cost and schedule data
6. Review top-level requirements and flow down to the next level of requirements since PDR
7. Review finalized design-to specifications (hardware and software) and drawings, verification and validation plans, and interface documents at lower levels. A CAD model is required at CDR stage for physical components of the system and showing the system in with the larger habitat model.
8. Review finalized design analyses and report results

9. Review finalized engineering development tests performed and report results
10. Review and discuss finalized internal and external interface design solutions (and any interface control documents needed). This includes interface information provided by NASA since PDR
11. Review finalized system operations
12. Present the finalized baseline design solution that will be built

Once the CDR is completed, the majority of the design work should be over and the teams will concentrate on testing, building, procuring, and assembling the finalized system. The Checkpoint Review is a progress discussion to help the team along with the assembly and construction of the product. Teams may request additional meetings for technical interchange, but they are not required as a milestone.

3.7 Period of Performance

The period of performance for this award will be August 1, 2015 to September 30, 2016. The contract for the awarded teams may be extended to facilitate participation in testing as appropriate.

3.8 Facilities and Equipment

Facilities and equipment needed to conduct this X-Hab 2016 Academic Innovation Challenge are the responsibility of the proposing project team and respective Universities. No unique facilities, U.S. Government-owned facilities, industrial plant equipment, or special tooling are required.

4. Proposal and Submission Information

4.1 Proposal Format and Content

Proposals should be single-spaced on standard 8 ½ x11 paper, no smaller than 12 point font and with one inch margins throughout. All proposals must be prepared in the following format:

A. Title Page (not included in the page count) - Title of X-Hab 2016 Academic Innovation Challenge, name and contact information of proposing faculty (address, university affiliation, email address, phone number), and the local Space Grant Consortium (if applicable) in which faculty is affiliated.
B. Body of Proposal (8 pages maximum)
    - Proposal Synopsis -- description of the X-Hab 2016 Academic Innovation Challenge work plan, design challenge to the students, and complexity.
    - Significance -- description of the need and relevancy of the proposed design project for NASA, and how this course will benefit the university.
    - Content -- description of the course outline, framework, and the faculty outline. Applicants should describe the involvement of appropriate computer-aided tools in its design and analysis solution. Applicants should describe how a Systems Engineering process will be applied. Applicants should propose a preliminary notional concept for the proposed Head-to-head competition or X-Hab test article with the understanding the final design will occur during the fall semester.
    - Mechanisms for Integration -- description of how the X-Hab prototype will be integrated and tested at the affiliated university in academic year 2015-2016. Describe how the X-Hab work will be performed during regular courses. Applicants should also describe the feasibility of implementing the project team with other universities, if applicable.

- Diversity -- Demonstrate effort to attract a diverse group of student participants, including underrepresented and underserved minorities, women, and students with disabilities, along with multiple academic disciplines. Disciplines include engineering, industrial design, and architecture curriculums.
- Educational Outreach Plan -- plan for the engagement of K-12 students from the local community though presentations, team involvement, mentoring, etc. Note that NASA also has public relation specialists that will be available for assistance.
- Assessment Plan -- plan for evaluation approach of design course, lessons learned, and potential impacts.
- Past Performance -- demonstration of successful implementation of design courses that met ABET quality standards. Applicants should also demonstrate experience with a systems engineering process.
- Resources (Sponsors) -- includes sponsorships, leveraging opportunities, unique capabilities, matching funds, and in-kind support. Also may include collaborations with other Universities.

C. Schedule (not included in the page count) -- one-page overview of the proposed schedule should include the deliverables, expected dates of tangible outcomes, travel dates and final report to NASA.

D. Budget (not included in the page count) -- total NASA funding requested cannot exceed the funding level associated with the project title. Specific information should be given for salary, detailed expenses for supplies and materials for the course and for the project, expenses for workshop and travel. Specific information should be given pertaining to supplemental funding by sponsors.

E. Collaboration showing estimated expenditures. Reduction or full waiver of indirect costs are encouraged and may be considered to be a University contribution to the project.

F. Appendix (not included in the page count):
- Mandatory -- a signed confirmation of support of the proposal must include a signed commitment from the University faculty, collaborators, and their potential sponsor(s) to ensure their commitment to the project.
- Mandatory -- a signed confirmation from the university stating that the X-Hab 2016 Academic Innovation Challenge will be implemented during the 2015-2016 academic year.

4.2 Proposal Evaluation Criteria

The X-Hab Challenge is divided into two phases. Phase-1 solicits proposals that will be evaluated and TBD project teams selected for the Phase-2 challenge. Both phases will be evaluated based on appropriate predetermined evaluation criteria.

Phase-1 Evaluation Criteria

The following criteria will be used in the Phase-1 proposal evaluation process:

Logistics

- Identify Project Title
- Identify Project Team
- Identify the Principal Investigator (PI)
- Identify a Vision, Mission, and Concept of Operations
- Identify the Problem Statement, Functional and Performance Requirements
- Identify a Work Plan, Integration Testing Plan, Milestone Schedule, and Experience.
- Identify faculty institution and provide confirmation of commitment in appendix.

- Identify a Research Assistant to provide leadership to the student project team (optional).
- Identify affiliated Space Grant Consortium (if applicable), Sponsor, or Affiliations.
- Identify NASA Technical Expert and provide signed statement of commitment in appendix (optional)
- Identify manufacturing, assembly, and pre-testing capabilities and facilities.
- Identify a preliminary notional concept of the demonstration article with the understanding the final design will occur during the fall semester.

Merit

- Demonstrate alignment with NASA HEOMD objectives.
- Describe work plan to implement and integrate project into university.
- Demonstrate alignment with ABET quality standards.
- Include systems engineering process in the course.
- Include appropriate computer-aided design and analysis tools in the course.
- Provide evidence of past performance of design courses that meet ABET quality standards.
- Provide feasibility of project teaming implementation with other universities.

Contribution to NASA Strategic Goals

- **Content:** Demonstrate ability to develop a meaningful, challenging, realistic hands-on Human Exploration and Operations Mission Directorate-relevant design project.
- **Continuity:** Demonstrate ability to create interest in NASA while connecting and preparing students for the workforce.
- **Diversity:** Demonstrate effort to attract a diverse group of student participants, including underrepresented and underserved minorities, women, and students with disabilities, along with multiple academic disciplines. Disciplines include an engineering, industrial design, and architecture curriculums.
- **Education Outreach:** Demonstrate effort to engage K-12 students in the local community
- **Evaluation:** Provide assessment plan including appropriate quantitative metrics and qualitative outcomes.
- **Budget:** Provide adequate, appropriate, reasonable, and realistic budget.

4.3 Proposal Submission

Electronic copies of proposals must be received no later than: **midnight Pacific Daylight Time, Wednesday, 30 April 2015**. Late proposals will not be considered. The proposal will be submitted online at https://secure.spacegrant.org/proposals/xhab/

Applicants will be advised by electronic mail when selections are made. It is anticipated that the award will be announced on 28 May 2015.

Appendix A: Budget Summary

From ________________ To __________________ *(performance period)*

	Funds Requested from Sponsor	Proposed Cost Sharing (if any)
1. Direct Labor	$ ______________	________________
2. Other Direct Costs:		
a. Subcontracts	$ ______________	________________
b. Consultants	$ ______________	________________
c. Equipment	$ ______________	________________
d. Supplies	$ ______________	________________
e. Travel	$ ______________	________________
f. Other	$ ______________	________________
3. Indirect Costs	$ ______________	________________
4. Other Applicable Costs	$ ______________	________________
5. Total	$ ______________	________________
6. Total Estimated Costs	$ ______________	

Budget Narrative

If the proposal contains cost sharing separate budget narratives should be included for the funds requested from the sponsor and the proposed cost sharing.

1. **Direct Labor** (salaries, wages, and fringe benefits): Should list numbers and titles of personnel, amount of time to be devoted to the grant, and rates of pay.

2. **Other Direct Costs**:
   a. **Subcontracts** - Describe the work to be subcontracted, estimated amount, recipient (if known), and the reason for subcontracting this effort.
   b. **Consultants** - Identify consultants to be used, why they are necessary, the time they will spend on the project, and rates of pay (not to exceed the equivalent of the daily rate for Level IV of the Executive Schedule, exclusive of expenses and indirect costs.)
   c. **Equipment** - List separately and explain the need for items costing more than $1,000. Describe basis for estimated cost. General purpose equipment is not allowable as a direct cost unless specifically approved by the sponsor.
   d. **Supplies** - Provide general categories of needed supplies, the method of acquisition, estimated cost. (For Example: Office Supplies, Lab Supplies, etc.)
   e. **Travel** - List proposed trips individually and describe their purpose in relation to the award. Also provide dates, destination, and number of people where known. (For example: Airfare, Hotel, Per Diem, Registration, Car Rental, etc.)
   f. **Other** - Enter the total direct costs not covered by 2.a through 2.e. Attach an itemized list explaining the need for each item and the basis for the estimate.

3. **Indirect Costs**

4. **Other Applicable Costs** - Enter the total of other applicable costs with an itemized list explaining the need for each item and basis for the estimate.

5. **Total** – The sum of lines 1 through 4.

6. **Total Estimated Costs** – The sum of the funds requested from the sponsor and the proposed cost sharing (if any)

Appendix B: X-Hab Topic Details

1.0 Exploration Augmentation Module Project
http://www.nasa.gov/exploration/technology/deep_space_habitat/

CREW SYSTEMS

Project Title:
1.1 Deep Space Mission Food Storage

Scope of the challenge:
Design of an efficient food storage system for a deep space mission.

Description:
This project entails the design of a refrigeration and/or freezer system sized to accommodate the food supply in support of a crew of four for a conjunction-class Mars transit mission, which utilize deep space temperatures as a passive means to maintain food storage temperature and minimize power usage. Take into account that the transit is broken into two pieces: the outbound trip to Mars transit and the earth return transit that are separated by a 500-day unmanned vehicle period during which the crew has their surface stay. Assume a 200-day transit period for each of the outbound and return legs. Guidelines for a balanced portfolio of in space food production and preservation capability should be included.

Expected Product (delivery item/concept):
Products could include an operational prototype as well as development algorithms, design/sizing, and overall modeling for inclusion in an integrated Mars vehicle transit simulation.

Expected Result (knowledge gained):
NASA will gain knowledge on potential innovations in food storage techniques and technology to provide crew with balanced nutritional portfolios on deep space missions such as a Mars transit mission.

Relevance to Exploration:
Work content is relevant to Tab 7.2.1.2 Food Production and Preservation under the Human Exploration Destination Systems Technology Area 7 (TA7) of the NASA Space Technology Roadmap.

Level of Effort for student team:
Medium. Involves research, creative thinking, procurement, testing, and reporting. Can include a variety of engineering disciplines, food storage and preservation expertise, and project management skills.

Level of effort for NASA team:
Minimal. Provide examples of past and current approaches for food storage (mass, volume, power, etc.) and consultation to facilitate the systems engineering development process.

NASA seed funding:
$15k from NASA. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

Project Title:
1.2 Deep Space Mission Exercise Equipment

Scope of the challenge:
Development of concepts and prototypes for integrated exercise-based countermeasure systems.

Description:
Define crew exercise equipment for microgravity during Mars transit that includes a very high-reliability, low-weight treadmill concept, but also takes into consideration vibration isolation as a design consideration/concern. Equipment should also include full body resistive exercise, whether via the same device or an independent device. Project should include small, robust equipment with high efficacy with high return for long duration missions

Expected Product (delivery item/concept):
Products could include an operational prototype(s) as well as development algorithms, design/sizing, and overall modeling for inclusion in an integrated Mars vehicle transit simulation.

Expected Result (knowledge gained):
NASA will gain knowledge on potential innovations in exercise systems and approaches deep space missions such as a Mars transit mission.

Relevance to Exploration:
Work content is relevant to section 2.3 Human Health and Performance under the Human Health, Life Support, and Habitation Systems Technology Area 6 (TA6) of the NASA Space Technology Roadmap.

Level of Effort for student team:
Medium. Involves research, creative thinking, procurement, testing, and reporting. Can include a variety of engineering disciplines, and exercise physiology.

Level of effort for NASA team:
Minimal. Provide examples of past and current approaches for in-space exercise systems (mass, volume, power, etc.) and consultation to facilitate the systems engineering development process.

NASA seed funding:
$15k from NASA. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

Project Title:
1.3 Deep Space Mission Telepresence Capabilities

Scope of the challenge:
Provide "hands-on" maintenance capabilities for the vehicle in a microgravity environment during long periods of no crew presence.

Description:
During a Mars transit mission, there may be extended periods without crew presence or when the crew is unavailable. For these times, it is a desired capability to have "hands-on" manipulation capability for vehicle maintenance, science activities, or other operations. These operations are complicated by the varying communications delay with a vehicle departing Earth, in the Mars vicinity as Mars tracks around the Sun, and in a returning vehicle to Earth from Mars. This project should investigate technologies and design approaches to facilitate such a capability including accounting for the relevant physics environment as well as senses including sight, sound, touch, and even smell.

Expected Product (delivery item/concept):
Products could include an operational prototype(s) as well as development algorithms, design/sizing, and overall modeling for inclusion in an integrated Mars vehicle transit simulation.

Expected Result (knowledge gained):
NASA will gain knowledge on potential techniques and approaches to enable a robust telepresence capability to supplement the crew on long, duration missions.

Relevance to Exploration:
Work content is relevant to a top technical challenge, entitled "Full immersion, telepresence with haptic and multi-modal sensor feedback" of Robotics, Tele-robotics, and Autonomous Systems (TA 4) of the NASA Space Technology Roadmap.

Level of Effort for student team:
Medium. Involves research, creative thinking, procurement, testing, and reporting. Can include a variety of engineering and computer science disciplines.

Level of effort for NASA team:
Minimal. Provide examples of past and current approaches for exercise systems (mass, volume, power, etc.) and consultation to facilitate the systems engineering development process.

NASA seed funding:
$15k from NASA. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

STRUCTURES

Project Title:
1.4 Inflatable/Deployable Airlock Structure for either extra-vehicular activity (EVA) or inter- vehicular activity (IVA)

Scope of the challenge:
Inflatable/deployable structures are critical to the future evolution of space exploration; potential mass savings, and/or volumetric efficiency, as demonstrated by either a sub-scale, or full scale airlock, would be required.

Description:
- Define a concept which shows deployability, which could be inflatable, and which is capable of accommodating two suited astronauts at a time.
- Concept basics would involve a breathable atmosphere, allowable leakage rates, operability and an ability to be volumetrically efficient (ratio of stowed versus deployed volume).
- Risk mitigation, in the context of potential crew loss via use of such a structure must be assessed thoroughly; i.e. if catastrophic depressurization occurs, what
- possible solution(s) could be demonstrated?

Expected Product (delivery item/concept):
A. Demonstrate efficient deployability, inflatability, and appropriately designed structural geometry with analytical results.
B. What joints will be demonstrated, and of what type will they consist? What are the figures of merit for such joining sections?
C. Leakage rates should be assessed, hopefully via either a sub-scale, or full scale prototype.

Expected Result (knowledge gained):
A. Assessments of deployability, ability to retain pressure, efficiency of the joints, or joining techniques in the approach;
B. ability to accommodate two suited crew within the chamber at the same time
C. risk mitigation strategy for potentially depressurizations, etc

Relevance to Exploration:
Of enormous relevance to advanced space exploration for the agency; solutions to problems of this nature may well mean the difference between success and failure of continued Space Exploration evolutionary efforts.

Level of Effort for student team:
Structural Engineering, pressure vessel design, mechanisms, electrical and environmental control and life support systems (ECLSS), and other sub-systems type knowledge; a very multi- disciplinary team is required for such an effort.

Level of effort for NASA team:
Collaboration of subject matter experts to mentor the students associated with each of the areas required for the various sub-system solutions.

NASA seed funding:
$15k from NASA. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

Project Title:
1.5 Deployable and Reconfigurable Internal Secondary Structures for Space Habitats

Scope of the challenge:
Develop sub-scale, or full scale prototype concepts of deployable internal secondary structures such as crew quarters, air beam supports, space furniture, reconfigurable lattice type supports and other volumetrically efficient and repurpose constructs.

Description:
Concept designs and prototypes for nominal geometries of typical sized space habitats and/or the International Space Station. Requires a specific focus on volumetric efficiency (stowed vs. deployed volume), mass savings and which are potential reconfigurable….would require a substantial increase in the current state of the art for such approaches.

Expected Product (delivery item/concept):
Demonstration of a system at Langley Research Center, Hampton, VA and such concept prototypes, if constructed, would have to address the issues as outlined – deployability, stowability, volume efficiency (the ration between stowed/deployed) . Would also need to demonstrate an ability to support secondary structural items (air beam usage) and also space furniture for the crew.

Expected Result (knowledge gained):
Feasibility of conceptual approaches and the ability to demonstrate a first level Design and Analysis Cycle.

Relevance to Exploration:
Addressed strategic knowledge gap for volumetrically & mass efficient structures utilizing fabric material (or others) and their applicability and integration into a State of the Art Space Habitat. Addresses needs in NASA Space Technology Roadmap areas – Technology Area 07 (TA07) – Human Exploration Destination Systems and Technology Area 12 (TA12) – Materials, Structures, Mechanical Systems, and Manufacturing.

Level of Effort for student team:
Conceptual design, analysis and fabrication (prototypes) of the outlined type of structures; mechanical design/engineering, Ergonomics design, Electrical and Sensors design and integration, analyses via FEMs, pressure vessel design, joints and mechanisms

Level of effort for NASA team:
Subject matter expertise to support the outlined engineering skills and approaches.

NASA seed funding:
$15k from NASA. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

HABITAT LAYOUT

Project Title:
1.6 Deep Space Mars Transit Habitat Layout Studies

Scope of the challenge:
Perform mockup studies for architectural layouts in vertically or horizontally oriented cylindrical Deep Space Habitats. Universities that already have mockup facilities for performing habitat layout studies are welcome to apply, as are universities that plan to create unique facilities specifically for this study.

Description:
Vertical and/or horizontal interior layout transit habitation studies, with creative/resourceful interior architecture volume and mass efficiencies that comply with NASA-STD-3001 and also take into account a requirement to provide a minimum of 20 g/cm2 of effective radiation shielding throughout the spacecraft using the structure, subsystems, logistics, and general provisioning that would already be required to support/supply a long duration transit to Mars.

A radiation analysis is not actually expected, but rather a general sense of layout and provisioning arrangement to help promote meeting the effective shielding need. A use analysis of logistics and general provisioning is expected to verify that any relocatable items used for radiation shielding (e.g. food, clothing, trash, etc.) still support the minimum 20 g/cm2 effective radiation shielding at all times, while minimizing spacecraft mass and maintaining the habitability of the spacecraft interior environment.

Expected Product (delivery item/concept):
Design reports and layout usability studies. Design reports shall fully specify the mockup design, NASA-STD-3001 compliance, and effective radiation shielding analysis. Usability studies shall measure crew member efficiency, effectiveness, and satisfaction with appropriate human factors evaluation tools.

Expected Result (knowledge gained):
Gain an understanding of a variety of internal layouts for a vertically- or horizontally oriented cylindrical volume.

Relevance to Exploration:
Appropriate for insight into potential layout options for a crewed vehicle for a Mars transit mission.

Level of Effort for student team:
Layout studies can be performed in appropriately oriented cylindrical volumes developed by or already available to the university teams. University teams will use a variety of low to medium - fidelity materials (wood, foam core, sheet metal, etc.) to create working layouts within which the students can perform simulated missions for specified durations, to provide feedback to
NASA design teams.

Level of effort for NASA team:
Minimal. Participation in reviews, site visits and advisement on previous studies and current exploration architecture options.

NASA seed funding:
$15k from NASA. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

POWER

Project Title:
1.7 Photovoltaic Power System Demonstration for the Exploration Augmentation Module

Scope of the challenge:
Students will design and build a lightweight, deployable photovoltaic array power system to supply on the order of 0.5 kW of supplemental power to the EAM.

Description:
An operational power system based on a photovoltaic array would be constructed from off-the- shelf components to provide power to the EAM through one of the PV power input ports on the power-conditioning cart. The power system design will include a battery pack, inverter, charge controller and solar array. The solar array will be the main focus of the deign effort. Options for the array would be to make it lightweight and deployable and configured similar to that of a space array. Commercial flexible array blankets can be utilized. The output power of the array would be on the order of 500 W (depending on size and the type off blankets utilized.) The array would be capable of tracking in a single axis. The array must be able to be transported to the test site, and operate independently with appropriate safety features.

Expected Product (delivery item/concept):
A standalone photovoltaic array power system with a single 120 VAC power output.

Expected Result (knowledge gained):
Students will learn the principles of solar energy power systems, mechanics of deployment systems and project management.

Relevance to Exploration:
The energy created by the array will be combined with other sources to provide more spacecraft-like electrical characteristics for the EAM test systems and experiments.

Level of Effort for student team:
Tasks: Design, development, manufacture, assembly, test, project management (requirements, schedule, budget, performance reviews and validation)

Level of effort for NASA team:
Tasks: Requirements development, mentoring, progress assessment

NASA seed funding:
$15k from NASA. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

Project Title:
1.8 120 VDC Dual-Source Power Distribution Unit

Scope of the challenge:
To produce a power distribution unit (PDU) for the distribution of 120 VDC power with two selectable input sources.

Description:
The project consists of developing a PDU that will be capable of switching between two 120 VDC input power sources and distributing it to various loads. The PDU will need to have the following capabilities:

- The capability to switch between the sources within 400ms
- The capability of switching power on and off to each load output
- The ability to monitor current to each load output
- The ability to current limit the output to each load
- The total input power for the PDU will be 30 amps at 120 VDC.
- There will be a total of 10 outputs with a maximum output current of up to 15 amps on any of the outputs (note the total output still cannot exceed 30 amps).
- Have control software and an Ethernet based interface for monitoring the PDU and controlling the switching capability.

Expected Product (delivery item/concept):
A 120 VDC power distribution unit with the capabilities as described above contained in a single housing suitable for testing within a laboratory environment

Expected Result (knowledge gained):
Students will learn the principles of power control equipment design, layout and construction. They will also gain experience in control software development and integration.

Relevance to Exploration:
The development of this PDU will further the implementation of a 120 VDC power system within the Exploration Augmentation Module and could provide a basis for the development of additional PDUs for exploration missions.

Level of Effort for student team:
Tasks: Design, development, manufacture, assembly, test, project management (requirements, schedule, budget, performance reviews and validation)

Level of effort for NASA team:
Tasks: Requirements development, mentoring, progress assessment

NASA seed funding:
$15k from NASA. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

2.0 Space, Life, and Physical Sciences (SLPS) Project
http://www.nasa.gov/directorates/heo/slpsra/index.html

Project Title:
2.1 Microgravity plant watering system

Scope of the challenge:
Develop a plant watering or nutrient delivery system that works in microgravity. System should be passive or use very little energy, should be reusable, require little crew involvement

Description:
For space food production, watering plants in microgravity has been the biggest challenge, since plant roots require both water and oxygen. Successful microgravity plant watering systems have been active, requiring power for pumps, solenoids and moisture sensors. Systems have also been planted on Earth, and used rooting modules have to be returned for cleaning or refurbishment and replanting. Ideally we would like a system that is reusable under microgravity conditions and requires little or no energy and little crew time and low launch mass. Using capillary wicking and vanes may be a desirable way to distribute water or a nutrient solution. 3-D printing technologies in space could be used to print root systems in situ. Roots or inedible plant biomass could be used as a substrate for future crops, potentially broken down and printed into a new matrix.

Expected Product (delivery item/concept):
One or more functional microgravity or gravity independent plant watering/nutrient delivery system. Students might propose to test system or scale model in parabolic flight opportunities program. A list of key science questions and engineering challenges that have an impact on success.

Expected Result (knowledge gained):
Novel solutions to plant watering in microgravity.

Relevance to Exploration:
Reducing mass, volume, power, cooling and crew time is an important goal for transitioning technologies beyond low Earth orbit. Food production capabilities are currently being tested
on ISS and expanding these will be important as humans live off Earth for longer durations and travel farther.

Level of Effort for student team:
Design, modeling, prototype development, construction, assembly, testing and reporting of one or more systems.

Level of effort for NASA team:
Providing subject matter expertise plant growth systems and information and consultation to facilitate the systems engineering development process.

NASA seed funding:
$10k from NASA. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

Project Title:
2.2 Assessing performance and refining a space plant growth system

Scope of the challenge:
Using an already developed plant growth system such as a robotic gardening system, a deployable greenhouse, or a commercial plant growth system, system performance would be assessed with different crop types and refinements to the hardware would be made based upon lessons learned.

Description:
For space food production, reduction of mass, volume, power, cooling and crew time is desired while optimizing plant growth and increasing capability. An existing system may have capabilities for growing some plant types, but increasing the plant types to be grown, testing and refining performance and increasing plant harvest index while decreasing launch and energy costs is critical to the evolution of enhanced technologies. The first system built is rarely the best, but testing and making trades of technologies can lead to dramatic improvements in system design. The challenge is taking an existing system and making it better, and this could involve reexamining all key elements that contribute to launch and use costs.

Expected Product (delivery item/concept):
Test data showing productivity gains or performance improvements. An improved plant growth system for space. A list of key science questions and engineering challenges that have an impact on success.

Expected Result (knowledge gained):
Improved knowledge of criteria for evaluating the capabilities of plant growth systems for space applications

Relevance to Exploration:
Reducing mass, volume, power, cooling and crew time is an important goal for transitioning technologies beyond low Earth orbit. Food production capabilities are currently being tested on ISS and expanding these will be important as humans live off Earth for longer durations and travel farther. Designing incrementally better systems through testing is critical.

Level of Effort for student team:
Testing of existing hardware with plants, identifying subsystems where improvements can be made, design, modeling, prototype development, construction, assembly, testing of new components and reporting of improvements and test data.

Level of effort for NASA team:
Providing subject matter expertise plant growth systems and information and consultation to facilitate the systems engineering development process.

NASA seed funding:
$10k from NASA. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

Project Title:
2.3 A microgravity food production system utilizing radial acceleration for water and nutrient delivery

Scope of the challenge:
Design and prototype a rotating plant growth system for food production in microgravity.

Description:
Plant food production for microgravity missions is challenging to implement due to the physics of delivering water and nutrients in a microgravity environment. Microgravity makes supplying adequate moisture and oxygen in the root zone difficult, and plant growth will be hindered by conditions of anoxia, hypoxia or insufficient moisture. This proposal asks for ideas on how to have an "artificial gravity" to improve the technology readiness of higher order plant production in a microgravity long duration mission. The prototype system should be able to utilized for ground testing by incorporating ways to minimize dripping water, brace typical plants from moving while they rotate around the wheel, and be scaled to a size for practical transport (fit through a doorframe).

Expected Product (delivery item/concept):
Develop a prototype plant food production system that utilizes a rotating system for water and nutrient delivery to plants. Automation of an on-board plant root moisture monitoring and nutrient delivery system that can be remotely monitored and controlled is highly desired. A list of key science questions and engineering challenges which have an impact on success.

Expected Result (knowledge gained):
Better understanding of the threshold level of gravity needed to adequately distribute water/nutrient solution; the feasibility of a rotating plant growth system for microgravity.

Relevance to Exploration:
A stable water delivery system for plants in microgravity is very challenging and having a gravity-like acceleration could increase the reliability and technology readiness of bioregenerative systems. This could be used in transit missions and orbital habitats.

Level of Effort for student team:
Design, modeling, prototype development, construction, assembly, and reporting.

Level of effort for NASA team:
Providing subject matter expertise plant growth systems and information and consultation to facilitate the systems engineering development process.

NASA seed funding:
$20k from NASA. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

3.0 Logistics Reduction Project
http://www.nasa.gov/directorates/heo/aes

Project Title:
3.1 Oxygen-Based Clothing Sanitation System

Scope of the challenge:
Perform survey of clothing sanitation technology based on the use of molecular or ionic oxygen (ex. ozone, negative oxygen ions, hydrogen peroxide, etc.) in a contained environment. Down select to one technology, design and develop a functional prototype, and demonstrate effectiveness on fabric.

Description:
Long-distance space travel will require astronauts to be able to launder clothing in space. There are currently few or no efficient means of washing clothing within the micro-gravity or low gravity of space since terrestrial cleaning processes cannot be directly applied. Use of water- based laundry systems have a greater impact on spacecraft resources including water and power.

The student team is asked to conceive a method of clothing sanitation that relies on molecular or ionic oxygen in a contained environment. The sanitation system would enable clothing to be reused several times but not necessarily indefinitely as with conventional terrestrial laundry systems. It is the intent that this limited cleaning capability will significantly decrease laundry complexity and the impact on spacecraft resources, including water, consumables, and power. The mass of the sanitation system equipment plus the required spacecraft resource mass to sanitize the clothing must be significantly less than the mass of the extra clothes needed without the sanitizing system.

The sanitation method shall sanitize fabrics of all sorts (towels, clothing, socks, under garments, etc.) in space. Current clothing materials include cotton, cotton/poly blends, wool, modacrylic, elastic bands, metallic zippers, metallic snaps, Velcro®, Nomex®, Gore-Tex®, and will likely expand to include fabrics present in many current athletic garments.

The sanitation system shall be tested with several types of soiling compounds (refer to staining materials in ASTM D4265) and across a range of operating conditions (range of exposure times, levels of active oxygen,

The following criteria should be considered with developing an oxygen based clothing sanitation system:

1) Molecular or ionic oxygen (ex. ozone, negative ion, hydrogen peroxide, etc.) and water vapor
   a) System shall use the ambient air available in the environment and generate the active oxygen species
   b) A catalyst may be required to neutralize the ozone before opening the sanitizing chamber
   c) Using ozone technology without water vapor has proven to be ineffective
2) System shall be a self-contained unit, which does not release any hazardous by-product to the spacecraft cabin environment (operating and non-operating)
3) Accommodate a clothing load of 1-2 kilograms
4) Each clothing item in a load shall be sanitized
   a) However, precise placement of clothing by crew members or manual operation is undesirable because crew time is a very limited resource
5) Does not require liquid water or other liquid phase medium as the oxygen agent carrier
6) System mass and volume are not defined as hard requirements but the team should minimize both parameters. The team should provide an estimate of the mass and volume along with materials of construction assumptions. As a guideline, the system should be limited to one quarter of an ISS rack volume [18-in x 22-in x 21-in (45.7cm x 55.8cm x 53.3cm) – Width x Height x Depth].

Expected Product (delivery item/concept):
A functional sanitation system prototype shall be delivered to JSC at the conclusion of the project. Delivery to NASA Johnson Space Center should be reserved in the budget.
Team shall also deliver a report that documents the following:

- Initial survey of oxygen-based sanitation technologies and the rationale for down select
- Concept of operations, functionalities, design, and specifications of the prototype system
- Effectiveness of the technology and system in sanitizing various clothing materials.
- Sanitation effectiveness could be measured by microbial colony counts remaining on the clothing after the treatment
- Testing Results
- Any lessons learned from the project

Expected Result (knowledge gained):
The project should capture knowledge on how to design a sanitation system using molecular and ionic oxygen base agent, and the effectiveness of such technology in sanitizing different clothing materials.

Relevance to Exploration:
A clothing sanitation will reduce the mass and volume of clothing that will need to be manifested for a long duration mission. Aligns with NASA Space Technology Roadmap Technology Area 06 (TA06) 6.1.4.6:

6.1.4.6 Laundry Freshening System (Simple Laundry)
Freshening system to extend clothing life. Removes odors from clothing and restores fresh smell. Minimal cleaning capability.

The current Technology Readiness Level (TRL) is 3 for this technology and the goal is to develop to a TRL 7. This effort is expected to increase the TRL to a 4 or 5.

Level of Effort for student team:
Student team would need to perform an initial survey of technologies to determine the type of molecular or ionic oxygen technology to develop. Tasks also include design, modeling, prototype development, assembly, testing, and reporting.

Level of effort for NASA team:
NASA sponsors would consult throughout the project especially during the initial survey of technologies and requirements development phase to assist with design parameters. NASA sponsors will participate in reviews and provide feedback.

NASA seed funding:
$20k from NASA. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

4.0 Nuclear Thermal Propulsion (NTP) Project

http://www.nasa.gov/directorates/heo/aes

Project Title:
4.1 Advanced Nuclear Thermal Propulsion (NTP) systems

Scope of the challenge:
Building on knowledge and capability that has (or will be) gained from first generation NTP systems, devise concepts and perform experiments related to advanced NTP systems.

Description:
Fission has over 10 million times the energy density of the best chemical reactions. First generation Nuclear Thermal Propulsion (NTP) systems will use that energy to directly heat a hydrogen propellant that will then be used to generate high thrust at a specific impulse of ~900 s. First generation NTP systems will help enable rapid, affordable crew transport to a variety of solar system destinations. The experience gained from first generation systems could then be used to help develop advanced NTP systems.

The student project will have the flexibility to focus on a variety of advanced NTP systems, including bimodal (both thermal and electric propulsion), two-pass cores with electric "superheat", liquid core engines, gas core engines, and/or others. The student team will devise and perform appropriate experiments.

Expected Product (delivery item/concept):
The product will include findings and recommendations related to one or more advanced NTP systems. At least one supporting experiment will be devised and performed.

Expected Result (knowledge gained):
The AES NTP project hopes to gain insight and ideas related to advanced NTP systems.

Relevance to Exploration:
The AES NTP project is focused on first generation NTP systems. These systems are designed to be safe; and as simple and affordable as possible while still significantly enhancing or enabling missions of interest. Advanced NTP systems could be truly game changing, and enable not only rapid transport but also sustained, affordable exploration and development of many destinations throughout the solar system. The student project's combination of analysis and experimentation could increase the TRL of certain advanced NTP concepts.

Level of Effort for student team:
The student teams will require a variety of skills, particularly skills related to science and engineering. Experimental interest and capability will also be required.

Level of effort for NASA team:
The NASA AES NTP project team will be available to mentor the student team in any way possible. This would include describing potential concepts and assisting with the design of appropriate experiments.

NASA seed funding:
The sponsoring project (AES NTP) would provide $10k of seed funding to assist with experimental and computational work performed by the student team. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

5.0 Life Support Systems Project
http://www.nasa.gov/directorates/heo/aes

Project Title:
5.1 Optimization of Carbon Dioxide Removal Systems for Mars Missions

Scope of the challenge:
Traditional chemical engineering approaches to material selection and process optimization have been shown to fail when applied to complex systems. For Mars spacecraft applications, optimization and robustness are paramount, thus new system-level optimization approaches and technology improvements must be implemented.

Description:
In order to be successful, the overall system-level optimization approach will:

- Incorporate analytical techniques to characterize sorbents
- Incorporate novel adsorption cycles
- Include computer simulations of adsorption cycles

Also, system-level optimization will evaluate the overall benefit of improvements that are being made to state-of-the-art systems to prepare for a long-term mission to Mars, including:

- Improvements to CO_2 and H_2O sorbent capacity
- Reduction of sorbent dusting
- Reduction of sorbent capacity losses due to contaminants

Expected Product (delivery item/concept):
Participating university teams will be expected to contribute in one of three ways: (1) Development of overall system-level optimization approaches, or (2) more focused efforts on one of the components of system-level optimization from the first list above, or (3) directed technology developments from the second list above

Expected Result (knowledge gained):
New insights and approaches to system-level optimization and technology developments are anticipated to come from the university faculty/student teaming arrangements, as well as valuable information on novel sorbents.

Relevance to Exploration:
Carbon Dioxide removal system development has been identified as an “enabling need” for future long duration space missions by the NASA System Maturation Team.

Level of Effort for student team:
Tasks include development of system analysis tools, mathematical models and computer simulations, and laboratory work characterizing sorbent candidates

Level of effort for NASA team:
NASA would provide background, consulting, and collaboration at a low level of effort, and review of the project presentations

NASA seed funding:
$30k from NASA. Total level of funding should be sufficient to support graduate students in a chemical engineering department, and computing and/or material costs. Potential leveraged funding sources could include commercial space companies, commercial companies that produce specialty sorbents, and space grant consortiums.

6.0 In-space Manufacturing Initiative
http://www.nasa.gov/mission_pages/station/research/experiments/1115.html

Project Title:
6.1 Technology Development of Low-Power Required Manufacturing of Metals for the Zero- Gravity Environment

Scope of the challenge:
Several techniques currently exist of subtractive and additive manufacturing of metallic parts. These techniques in their current form have not been optimized for usage in a zero-gravity environment. In addition to the challenge of the zero-gravity environment, for metallic manufacturing to be feasible for space exploration missions, processes need to be more automated and require fewer resources such as volume and power.

Description:

Investigate the different manufacturing process (and potential manufacturing processes) of metals and their alloys that could be used in a zero-gravity environment and perform a trade study to identify the manufacturing process(es) and metal or alloy that could be used for future technology development. The trade study should at least consider the following factors: power requirement for operation, structural properties of as-manufactured materials, level of automation, and volume requirement for operation.

After a trade study has been completed, if possible, characterizing the processes' manufacturing accuracy and repeatability is preferred by the build and operation of different systems.

Expected Product (delivery item/concept):
A technical report (preferably a referenceable publication) with general assumptions on how to manufacture a metallic part in a zero-gravity environment while reducing power and volume requirements and increasing material property strength and level of automation. The technical report should also include the ground rules of the trade study, what factors were considered, and if/how the factors were weighed. From the trade study and testing, recommendations for future technology development should be provided. Additionally, the general assumptions for parts need to be backed up with test data of components made with the recommended process(es) and should also be included in the final report.

If a demonstration of a recommended manufacturing process is completed, pictures, videos, or samples provided to Marshall Space Flight Center are anticipated.

Expected Result (knowledge gained):
The results of this research effort should demonstrate how processes can be balanced between resource needs such as power and volume and material strength in ways not currently adapted for the zero-g environment. It should also help in understanding material properties associated with the method of production, reusability of previously utilized material (demonstrate an in- situ manufacturing capability), and responses of the part given various simple and complex stress states.

Relevance to Exploration:
The importance of low-power metal manufacturing to future development of space craft structures lies in the ability to balance resource needs and structural strength while developing processes that can be performed in a zero-g environment. This ability will become more critical as Habitats travel further out into the solar system.

Level of Effort for student team:
Broad based multi-disciplinary team is warranted: structures, manufacturing, material characterization, experimental methods and analysis, etc... It is expected that the university point of contact will be able to help determine the degree of scope in the context of resources provided joint by NASA and those which are university derived.

Level of effort for NASA team:
Minimal. Provide subject matter expertise in-space manufacturing and consultation to facilitate the systems engineering development X-Hab process.

NASA seed funding:
$20k from NASA. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

7.0 Autonomous Propellant Loading Project
http://www.nasa.gov/directorates/heo/aes

Project Title:
7.1 Automated Umbilical Project for Surface Systems

Scope of the challenge:
Develop a dust tolerant umbilical plate for connecting pneumatic, liquid, power and data systems across a standardized umbilical interface.

Description:
Future operations on the surface of the Moon or Mars will require the ability to permanently or temporarily connect one surface element to another to share power and transfer fluids and data. This is of particular interest to transfer propellants between an ISRU propellant production facility and the ascent vehicle or surface rovers that require those fluids to perform their jobs. Design an alignment (5 degree each axis) and dust tolerant set of umbilical plates and connectors to demonstrate fluid and electrical mate and transfer between two surface elements.

Expected Product (delivery item/concept):
Conceptual design (and prototype if possible) of a standardized umbilical plate with appropriate alignment and connector layout for connecting an ISRU plant delivering GH2 and GO2 to a mobile propellant liquefaction and storage element for the transfer of two fluids and power.

Expected Result (knowledge gained):
Minimal: provide requirements, quick disconnect components specifications and consulting from previous government efforts and possible approaches to satisfy envisioned needs.

Relevance to Exploration:
Umbilical system for exploration needs are still in the conceptual/laboratory phase (TRL 3-5). New ideas can have a significant impact on our ability to accomplish our goals of permanently working on the surface of the Moon and Mars.

Level of Effort for student team:
Medium: Mechanical, electrical and fluid system design and analysis and control systems development.

Level of effort for NASA team:
Minimal: provide concepts from previous government efforts and possible approaches to satisfy envisioned needs.

NASA seed funding:
$25k from NASA. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

Appendix C: Standard Education Grant / Cooperative Agreement

The following provisions of the Federal Code of Regulations are incorporated by reference

REFERENCE	TITLE
§ 1260.21	Compliance with OMB Circular A-110
§ 1260.22	Technical Publications and Reports
§ 1260.23	Extensions
§ 1260.24	Termination and Enforcement
§ 1260.25	Change in Principal Investigator or Scope
§ 1260.26	Financial Management
§ 1260.27	Equipment and Other Property
§ 1260.28	Patent Rights
§ 1260.29	Reserved
§ 1260.30	In full text
§ 1260.31	National Security
§ 1260.32	Nondiscrimination
§ 1260.33	Subcontracts
§ 1260.34	Clean Air and Water
§ 1260.35	Investigative Requirements
§ 1260.36	Travel and Transportation
§ 1260.37	Safety
§ 1260.38	Drug-Free Workplace
§ 1260.39	Buy American Encouragement
§ 1260.40	Investigation of Research Misconduct

Provisions listed above are contained in the Code of Federal Regulation (14 CFR Part 1260). The CFR can be accessed electronically at: http://www.gpoaccess.gov/cfr/index.html or copies are available in most libraries and for purchase from the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402. Provisions incorporated by reference have the same force and effect as if they were given in full text. The full text provision can be found via the NASA Grant and Cooperative Agreement Handbook web site: http://prod.nais.nasa.gov/pub/pub_library/grcover.htm. OMB Circulars referenced in the provisions can be assessed electronically at: http://www.whitehouse.gov/omb/circulars/ or may be obtained from the Office of Administration, Publications Unit, New Executive Office Building, Washington, D.C. 20503. An index of existing OMB Circulars is contained in 5 CFR 1310.

Appendix D: Certifications and Assurances

CERTIFICATION REGARDING DEBARMENT, SUSPENSION, AND OTHER RESPONSIBILITY MATTERS PRIMARY COVERED TRANSACTIONS

This certification is required by the regulations implementing Executive Order 12549, Debarment and Suspension, 34 CFR Part 85, Section 85.510, Participants' responsibilities. The regulations were published as Part VII of the May 28, 1988 Federal Register (pages 19160-19211). Copies of the regulations may be obtained by contacting the U.S. Department of Education, Grants and Contracts Service, 400 Maryland Avenue, S.W. (Room 3633 GSA Regional Office Building No. 3), Washington, D.C. 20202-4725, telephone (202) 732-2505.

A. The applicant certifies that it and its principals:

(a) Are not presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency;
(b) Have not within a three-year period preceding this application been convicted or had a civil judgment rendered against them for commission of fraud or a criminal offense in connection with obtaining, attempting to obtain, or performing a public (Federal, State, or Local) transaction or contract under a public transaction; violation of Federal or State antitrust statutes or commission of embezzlement, theft, forgery, bribery, falsification or destruction of records, making false statements, or receiving stolen property;
(c) Are not presently indicted for or otherwise criminally or civilly charged by a government entity (Federal, State, or Local) with commission of any of the offenses enumerated in paragraph A.(b) of this certification; and
(d) Have not within a three-year period preceding this application/proposal had one or more public transactions (Federal, State, or Local) terminated for cause or default; and

B. Where the applicant is unable to certify to any of the statements in this certification, he or she shall attach an explanation to this application.

C. Certification Regarding Debarment, Suspension, Ineligibility and Voluntary Exclusion - Lowered Tier Covered Transactions (Subgrants or Subcontracts)

(a) The prospective lower tier participant certifies, by submission of this proposal, that neither it nor its principles is presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from participation in this transaction by any Federal department of agency.
(b) Where the prospective lower tier participant is unable to certify to any of the statements in this certification, such prospective participant shall attach an explanation to this proposal.

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Organization Name

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Printed Name and Title of Authorized Representative

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Signature Date

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Printed Name of Principal Investigator/Program Director

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Proposal Title

CERTIFICATION REGARDING LOBBYING

As required by S 1352 Title 31 of the U.S. Code for persons entering into a grant or cooperative agreement over $100,000, the applicant certifies that:

(a) No Federal appropriated funds have been paid or will be paid by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, in connection with making of any Federal grant, the entering into of any cooperative, and the extension, continuation, renewal, amendment, or modification of any Federal grant or cooperative agreement;

(b) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting an officer or employee of any agency, Member of Congress, an or an employee of a Member of Congress in connection with this Federal grant or cooperative agreement, the undersigned shall complete Standard Form - LLL, "Disclosure Form to Report Lobbying," in accordance with its instructions.

(c) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers (including subgrants, contracts under grants and cooperative agreements, and subcontracts), and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by S1352, title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

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Organization Name

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Printed Name and Title of Authorized Representative

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Signature Date

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Printed Name of Principal Investigator/Program Director

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Proposal Title

Assurance of Compliance with the National Aeronautics and Space Administration Regulations Pursuant to Nondiscrimination in Federally Assisted Programs

The ____
(Institution, corporation, firm, or other organization on whose behalf this assurance is signed, hereinafter called "Applicant.")

HEREBY AGREES THAT it will comply with Title VI of the Civil Rights Act of 1964 (P. L. 88-352), Title IX of the Education Amendments of 1972 (20 U.S.C. 1680 et seq.), Section 504 of the Rehabilitation Act of 1973, as amended (29 U.S.C. 794), and the Age Discrimination Act of 1975 (42 U.S.C. 16101 et seq.), and all requirements imposed by or pursuant to the Regulation of the National Aeronautics and Space Administration (14 CFR Part 1250) (hereinafter called "NASA") issued pursuant to these laws, to the end that in accordance with these laws and regulations, no person in the United States shall, on the basis of race, color, national origin, sex, handicapped condition, or age be excluded from participation in, be denied the benefits of, or be otherwise subjected to discrimination under any program or activity for which the Applicant receives federal financial assistance from NASA; and HEREBY GIVES ASSURANCE THAT it will immediately take any measure necessary to effectuate this agreement.

If any real property or structure thereon is provided or improved with the aid of federal financial assistance extended to the Applicant by NASA, this assurance shall obligate the Applicant, or in the case of any transfer of such property, any transferee, for the period during which the real property or structure is used for a purpose for which the federal financial assistance is extended or for another purpose involving the provision of similar services or benefits. If any personal property is so provided, this assurance shall obligate the Applicant for the period during which it retains ownership or possession of the property. In all other cases, this assurance shall obligate the Applicant for the period during which the federal financial assistance is extended to it by NASA.

THIS ASSURANCE is given in consideration of and for the purpose of obtaining any and all federal grants, loans, contract, property, discounts or other federal financial assistance extended after the date hereof to the Applicant by NASA, including installment payments after such date on account of applications for federal financial assistance which were approved before such date. The Applicant recognizes and agrees that such federal financial assistance will be extended in reliance on the representations and agreements made in this assurance, and that the United States shall have the right to seek judicial enforcement of this assurance. This assurance is binding on the Applicant, its successors, transferees, and assignees, and the person or persons whose signatures appear below are authorized to sign on behalf of the Applicant.

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Organization Name

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Printed Name and Title of Authorized Representative

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Signature Date

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Printed Name of Principal Investigator/Program Director

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Proposal Title