National Space Grant Foundation

1645 9th Avenue SE Suite 149
Albany OR 97322
202-536-3030 • 202-536-3089 (fax)
https://www.spacegrant.org/

eXploration Systems and Habitation (X-Hab) Academic Innovation Challenge – FY20 Solicitation

on behalf of

NASA Headquarters
Human Exploration & Operations Mission Directorate

Sponsored by:

The Advanced Exploration Systems (AES) Division

Release Date:	February 25, 2019
Proposals Due:	April 26, 2019
Anticipated Award Date:	May 24, 2019
Program Website:	https://www.spacegrant.org/xhab/

X-Hab 2020 Academic Innovation Challenge Solicitation

1. Funding Opportunity Description - Synopsis

The eXploration Systems and Habitation (X-Hab) 2020 Academic Innovation Challenge is a university-level challenge designed to develop strategic partnerships and collaborations with universities. It has been organized to help bridge strategic knowledge gaps and increase knowledge in capabilities and technology risk reduction related to NASA's vision and missions. *In 2016, the X-Hab Challenge scope was formally extended to include other areas of Exploration Systems as well as habitation topics*. 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 $15k - $50k each to design and produce studies or functional products of interest to the AES Division (see Section 3.2, *X-Hab Proposal Topic List*) as proposed by university teams according to their interests and expertise. The prototypes produced by the university teams (examples of which are shown in Figure 1) may be integrated into existing NASA-built operational prototypes. Universities interested in participating will submit X-Hab proposals, which will be reviewed by technical experts; subsequent down-selection will determine which projects will be funded. X-Hab university teams will be required to complete their products for evaluation by the AES Division in May 2020. Universities may form collaborations to perform as a single distributed project team.

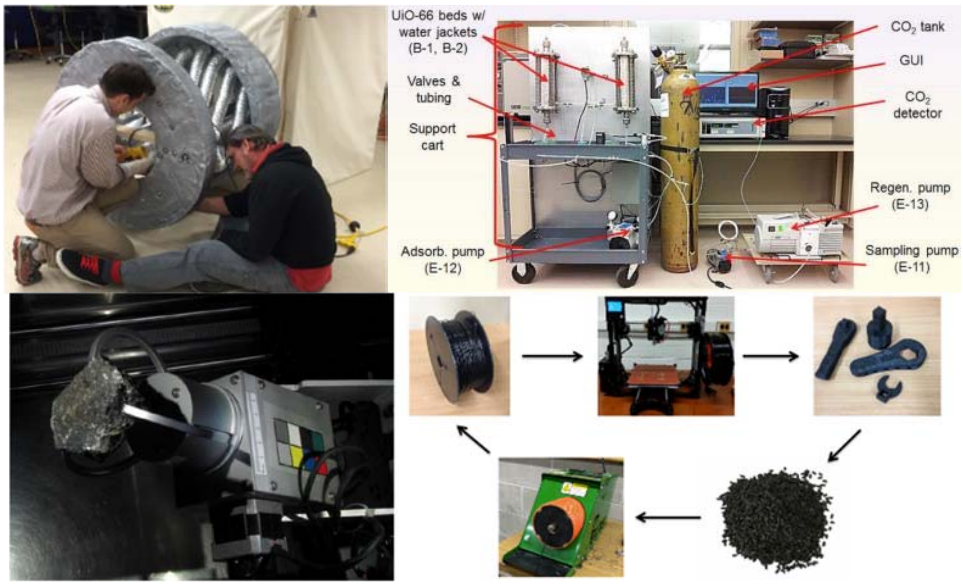


Figure 1: Previous X-Hab Projects (from top left, clockwise): Deployable Airlock, Closed Environment Air Revitalization System Based on Metal Organic Framework Adsorbents, Carbon-fiber/Fused Deposition Modeling Spacecraft Structural Fabrication System, Sample Handling System for GeoLab Glovebox (Image credit: 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 alongside NASA researchers. Teams are required to go through a series of NASA-standard assessments as other NASA engineering products, including a System Definition Review (SDR), a Preliminary Design Review (PDR), and a Critical Design Review (CDR). With this approach, NASA is putting a great deal of responsibility on the students. This in turn gives the students a bigger stake in the development of space technologies that likely will form the basis for future systems and technologies that will be flown in space.

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 and Fellowship Program, or other US accredited university. Multidisciplinary, multidepartmental, 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.

In order to fully comply with the United States Department of Commerce, Bureau of Industry and Security (BIS) Export Administration Regulations (EAR), *participation in the X-Hab program by citizens of controlled countries, as defined in Part 768.1.d is prohibited*. This restriction applies to all faculty members, staff, students, consultants, and any other individual that participates in the X-Hab program. For the current "Controlled Countries" list, reference EAR Part 768.1d

3. Funding Opportunity Description - Details

3.1 Description

NASA's multicenter AES Division is requesting proposals for the eXploration Systems and Habitation (X-Hab) 2020 Academic Innovation Challenge. The X-Hab Challenge is a university-based challenge to provide real world, hands-on design, research and development opportunities to university teams. Teams will design, manufacture, assemble, test, and demonstrate functional prototypical subsystems and innovations that enable increased functionality for human space exploration missions. The projects and products of the challenge will be evaluated by NASA subject matter experts currently working in the topic area and may be integrated into prototypes for the purpose of operational and functional evaluation opportunities. Alternatively, the products of the challenge may be used in other NASA studies or analyses of exploration architectures. In previous X-Hab rounds, products have been tested and evaluated at NASA's Johnson Space Center (JSC), Marshall Space Flight Center (MSFC), Kennedy Space Center (KSC), NASA's Desert Research and Technology Studies (D-RATS) analog field tests, and school campuses. The products and technologies produced by the universities for the X-Hab 2020 challenge may be improved upon for next-generation exploration systems, and may eventually provide the basis for future flight demonstrations and exploration missions.

NASA's AES Division is inviting university faculty who teach design courses to submit proposals for a two-semester design course based on a topic that is congruent with the faculty members' interests and the topic list provided in Section 3.2. Design projects are intended to stimulate undergraduate and graduate research on current NASA exploration activities and to bring forth innovative ideas that can be used to complement those currently under development at NASA field centers. Additionally, such academic involvement will provide a hands-on space systems project development experience to enhance the scientific, technical, leadership, and project management and participation skills for the selected student teams, thereby improving the prospects for graduates to pursue additional studies and to seek careers in the space industry. The design courses should be related to existing or planned exploration systems and missions.

The selected project teams will implement the design course during the fall 2019 and spring 2020 semesters. Applicants are required to apply a systems engineering approach in the design course. For reference, please see the NASA Systems Engineering Handbook NASA SP-2007-6105. Further, all teams must provide proof that the course has been approved to be taught at their institution and the selected professor must be available for technical assistance to the implementing university team in 2019-2020 academic year.

NASA understands that the funding awarded to manufacture some test articles may not be sufficient; thus, NASA may require teams to obtain supplemental sponsored or leveraged funding from university sources or industry partners in order to design, manufacture, assemble, test, and demonstrate a functional and operational test article. Any savings from reducing or waiving overhead costs at universities may count as leveraged funding in the proposals. Additionally, the supplemental funding may enable the teams to enhance the quality or scope of the proposed work. As part of this solicitation, universities are encouraged to seek additional, innovative sponsorships and collaborations (project teaming) with other universities and organizations (including institutional support, industry, space grant consortia, 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.

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

- 08 Oct 2019 – Requirements and System Definition Review (SDR)
- 11 Nov 2019 – Preliminary Design Review (PDR)
- 21 Jan 2020 – Critical Design Review (CDR)
- 11 March 2020 – Progress Checkpoint Review
- 06 May 2020 – Project Completion and Evaluation by NASA

Additional information on the listed reviews is found in Appendix E: *NASA Review Requirements and Checklists*

Interactions with NASA personnel are not limited to these meetings. 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

Proposals addressing the following topics will be given priority consideration. Proposals that address other areas in direct support of the Advanced Exploration Systems Division will also be considered. Detailed topic descriptions are located in Appendix B.

Project Sponsor: AES Life Support Systems

- Project Title: *High Efficiency Heat Exchanger to Achieve Low-Power CO_2 Deposition*

Project Sponsor: Solar System Exploration Research Virtual Institute (SSERVI)

- Project Title: *Integration of Field Results into Virtual and Augmented Reality Environments*

Project Sponsor: AES Life Support Systems

- Project Title: *Microgravity Gas-Liquid Separator for the Liquid Amine CO_2 Removal System*

Project Sponsor: Space Life and Physical Science Research and Applications

- Project Title: *Volume Optimization for Food Product During Deep Space Exploration*

Project Sponsor: AES In-Space Manufacturing Project

- Project Title: *Development of a Design Database for the In-Space Manufacturing Project*

Project Sponsor: AES NASA Platform for Autonomous Systems Project

- Project Title: *User Interfaces for Gateway Autonomous Operations*

For reference information on the sponsoring projects at NASA, please refer to the NASA Techport database at http://techport.nasa.gov.

For specific Advanced Exploration Systems projects, visit here

For additional information on Space Life and Physical Sciences, visit here

For additional information on Strategic Knowledge Gaps to improve human and robotic exploration, visit here.

3.3 Academic Innovation Challenge Background and Purpose

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 is dedicated to creating a capability-driven approach to technology and foundational research that enables sustained and affordable off-Earth human and robotic exploration. NASA has a long history of working with universities in 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 its

missions, thereby benefiting the nation and humankind. Using innovative approaches to problem solving—such as challenges and collaborations—NASA seeks to stimulate innovators, thereby creating diverse pools of problem solvers that address NASA problems and advance technology development in a flexible way for technological breakthroughs.

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 universities.
2. Teams will analyze and solve complex design and integration issues from an interdisciplinary perspective, exercising their innovation skills 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, but with an eye toward integration with NASA activities.
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. Teams' support under this program will adhere to NASA's commitments in its *Strategic Plan* to "maintain strong partnerships with academia" and to "engage and inspire students."

Pursuant to these objectives, NASA's AES Division focuses on advanced design, development, and demonstration of exploration capabilities to reduce risk, lower life cycle cost and validate operational concepts for future human missions to deep space. AES leads development of new approaches to project and engineering management, such as rapid systems development or alternative management concepts, open innovation, and collaboration. Specifically, AES Division activities are uniquely related to crew safety and mission operations in deep space, and are strongly coupled to future vehicle development. The activities fall under five primary domain areas: Crew Mobility Systems, Habitation Systems, Vehicle Systems, Foundational Systems, and Robotic Precursor Activities. NASA is also extending human presence deeper into space with the Moon for long-term exploration and utilization by first establishing a Lunar Gateway in cislunar space. The purpose of the X-Hab Academic Innovation Challenge is to leverage funding, capabilities, and expertise within and outside of NASA to overcome technology barriers and advance technology in these areas. Topic areas are summarized as follows:

Crew Mobility Systems

Systems to enable the crew to conduct “hands-on” surface exploration and in-space operations, including portable life support systems, and extravehicular activity tools.

Habitation Systems

Habitation systems provide a safe place for astronauts to live and work in space and on planetary surfaces. They enable crews to live and work safely in deep space, and include integrated life support systems, radiation protection, fire safety, and systems to reduce logistics and the need for resupply missions.

Vehicle Systems

Vehicle systems include human and robotic exploration vehicles, including advanced in-space propulsion, extensible lander technology, modular power systems, and automated propellant loading on the ground and on planetary surfaces.

Foundational Systems

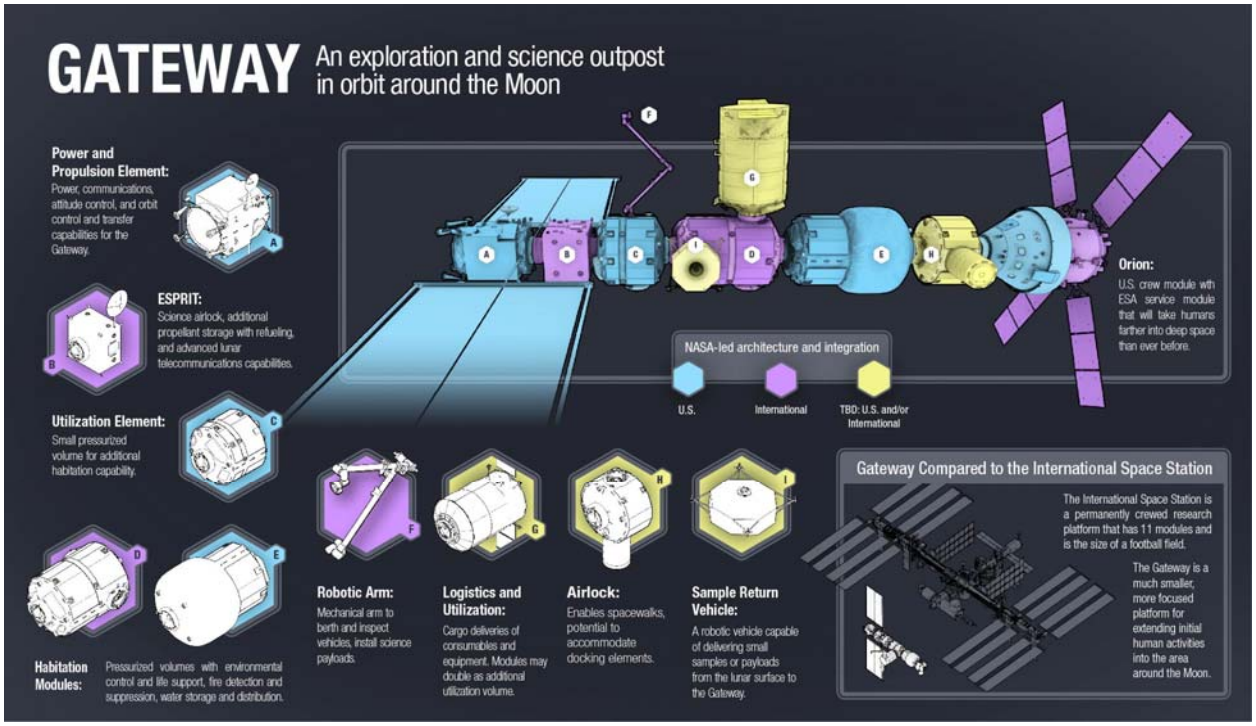
Foundational systems provide more efficient mission and ground operations and those that allow for more earth independence. These systems foster autonomous mission operations, *in situ* resource utilization, in-space manufacturing, communication technologies, and synthetic biology applications.

Robotic Precursor Activities

Robotic missions and payloads acquire strategic knowledge about potential destinations for human exploration. They inform systems development, including prospecting for lunar ice, characterizing the Mars surface radiation environment, radar imaging of near-Earth asteroids, instrument development, and research and analysis.

Gateway

Gateway establishes a platform to mature necessary short- and long-duration deep space exploration capabilities through the 2020s. It will be assembled in a lunar orbit where it can be used as a staging point for missions to the lunar surface and destinations in deep space, providing a flexible human exploration architecture. Gateway can be evolved for different mission needs (exploration, science, commercial and international partners). Initial functionality will include several main elements: a Power and Propulsion Element (PPE), habitation elements, two airlock elements (one to enable human Extra-Vehicular Activities (EVA), one to pass science hardware and experiments), utilization, and required logistics element(s). The element containing a science airlock will also house additional propellant storage and advanced lunar telecommunications capabilities.



3.4 Online Technical Interchange Forum

Prior to the proposal submission deadline, an online Technical Interchange will be posted for NASA AES Division representatives to answer questions about the project. Questions pertaining to this effort shall be submitted to xhab@spacegrant.org no less than four days prior to the deadline to have them included in the response. Answers will be published on the solicitation website.

Schedule:

Questions are due by April 2, 2019.
Responses will be posted on April 9, 2019

3.5 Pertinent Dates

Proposal Phase

25 Feb 2019	Date of Announcement and Release of RFP
02 Apr 2019	Questions for online Technical Interchange due
09 Apr 2019	Responses to submitted questions published online
26 April 2019	Proposal due
24 May 2019	Award announcements

Award Phase

Summer - Fall 2019	Design phase
Sept 2019	Kickoff meetings
08 Oct 2019	Requirements and System Definition Review
12 Nov 2019	Preliminary Design Review
21 Jan 2020	Critical Design Review
11 March 2020	Progress Checkpoint Review
06 May 2020	Project Completion and Evaluation by NASA

3.6 Documentation and Deliverables

3.6.1 Project Documentation

For successful project completion, award recipients will provide the following deliverables:

1. Work Plan and Implementation Schedule by the SDR. milestone
2. Participation in Milestone Progress Reviews (Vidyo, WebEx and telecon) through the project execution
3. Report on Educational Outreach activity prior to Project Completion
4. Demonstration articles for X-Hab developmental studies prior to Project Completion
5. Technical Final Report prior to Project Completion. Universities must comply with the U.S. export requirements by submitting their final presentation/report to their University Export Control Office (ECO) for review prior to submission to NASA. If it is determined that export controls do not apply to the final presentation/report, the ECO will note the outcome and recommend that the final presentation/report be approved/accepted. A Scientific and Technical Information/Document Availability Authorization (STI/DAA) form NG1676B using the NASA Electronic Forms site (https://nef.nasa.gov/) should be

prepared for the final report submission to formally archive the final report for the NASA project sponsor.

3.6.2 Formal Review Activities and Requirements

As noted elsewhere, submitted projects will undergo formal NASA review and assessment. Descriptions of the individual review components, their purposes, and checklists to help teams prepare for the reviews are found in Appendix E: *NASA Review Requirements and Checklists.*

3.7 Period of Performance

The period of performance for this award will be August 1, 2019, to May 31, 2020. 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 2020 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 is required.

4. Proposal and Submission Information

4.1 Proposal Format and Content

Proposals should be single-spaced, formatted to fit on standard 8½" x11" paper, no smaller than 12-point font, with one-inch margins throughout. All proposals must be prepared in the following sequence of sections:

A. **Title Page** (not included in the page count) - Title of the X-Hab 2020 Academic Innovation Challenge project, university name, name and contact information of proposing faculty member(s) (address, university affiliation, email address, and phone number), and the local Space Grant Consortium faculty affiliation (if applicable).
B. **Body of Proposal** (12 pages maximum)
   - *Proposal Synopsis* – Description of the X-Hab 20120 Academic Innovation Challenge work plan, design challenge to the students, and scope of the proposed effort.
   - *Significance* – Description of the need and relevance 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 their design and analysis solutions. Applicants should describe how a systems engineering process will be applied. Applicants should propose a preliminary notional concept for the proposed study or test article with the understanding that the design should occur during the fall semester.
   - *Administration* – Description of project administration approach including the facilitation of cross-campus or other partnership collaborative efforts.
   - *Mechanisms for Integration* – Description of how the X-Hab prototype will be integrated and tested at the affiliated university in the 2019-20 academic year.

Describe how the X-Hab work will be performed during regular courses. Describe the feasibility of implementing the project team with other universities, if applicable.

- *Diversity* – Demonstrate efforts to attract a diverse group of student participants, including underrepresented and underserved minorities, women, and students with disabilities, along with multiple academic disciplines. Some applicable disciplines include engineering, industrial design, and architecture curricula.
- *Educational Outreach Plan* – Provide a plan to engage K-12 students from the local community though presentations, team involvement, mentoring, etc. Note that NASA also has public relations specialists that will be available for assistance.
- *Assessment Plan* – Provide a plan that describes the evaluation approach for the design course, lessons learned, and potential impacts.
- *Past Performance* – Demonstrate successful implementation of design courses that have met ABET quality standards. Demonstrate experience with a systems engineering process.
- *Resources (Sponsors)* – Include 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) – Present a one-page overview of the proposed schedule. This should include the deliverables, expected dates of tangible outcomes, travel dates, and date of final report to NASA.
D. **Budget** (not included in the page count) –Note that total requested NASA funding 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, and expenses for workshops 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* – Confirmation of support for the proposal must include signed documents from the university faculty, collaborators, and their potential sponsor(s) to ensure their respective commitment to the project.
    - *Mandatory* – Include a signed confirmation from the university, stating that the X-Hab 2020 Academic Innovation Challenge will be implemented during the 2019-2020 academic year and will comply with all pedagogical requirements.

4.2 Proposal Evaluation Criteria

The X-Hab Challenge is divided into two phases. Phase 1 solicits proposals that will be evaluated for selection and Phase 2 is the project execution of the selected teams, the actual 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 pretesting 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 Human Exploration and Operations Mission Directorate objectives.
- Describe work plan to implement and integrate project into university activities.
- 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 within 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 could include (but are not limited to) engineering, industrial design, and architecture curricula.
- **Education Outreach:** Demonstrate efforts 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, Friday, 26 April 2019**. *Late proposals will not be considered.* The proposal will be submitted online at https://spacegrant.net/proposals/xhab/

Applicants will be advised by electronic mail when selections are made. It is anticipated that the award will be announced on 24 May 2019.

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): List numbers and titles of personnel, number of hours 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 number of hours 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 (*e.g.,* office supplies, lab supplies, etc.), the method of acquisition, and estimated cost.
   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. Include where appropriate airfare, hotel, per diem, registration fees, 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** - Since the project is related to academic course work and not research, the indirect cost rate should not exceed your university's negotiated rate for that category. Waived indirect cost is encouraged.

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

Project Sponsor:
Advanced Exploration Systems (AES) Life Support Systems

Project Title:
High Efficiency Heat Exchanger to Achieve Low-Power CO_2 Deposition

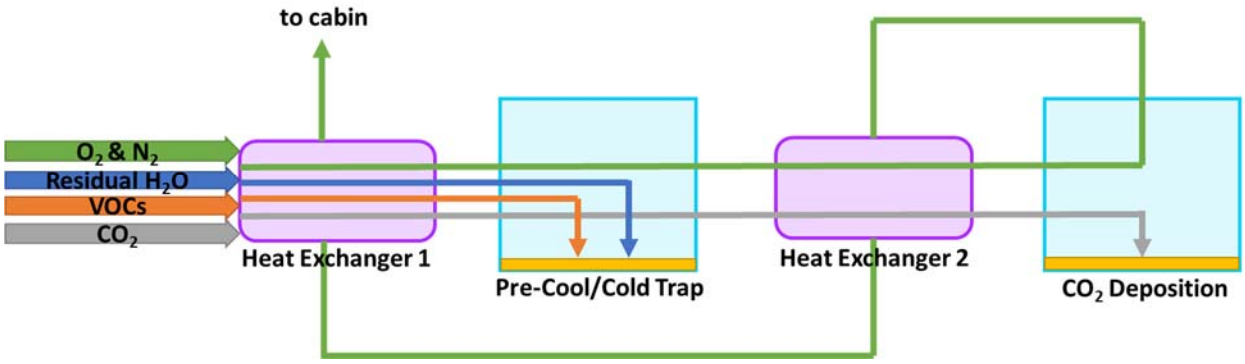
Scope of the challenge:

Characterize the achievable efficiency of an air to air heat exchanger in order to cool air for CO_2 removal utilizing phase change properties.

Description:

In order to meet the challenges posed by deep-space manned exploration, innovative, reliable, and cost-effective solutions must be developed in order to close the loop in human life support. In the realm of air revitalization, the current sorbent-based architecture aboard the ISS has proven to be sensitive to contaminants and mechanical failures. It has been demonstrated that use of cryogenic coolers can be an effective method to remove CO_2 from process flow via deposition. However, cryogenic coolers are energy-intensive. So, to reduce the power required to operate the system, the cold, CO_2-free air will be used to pre-cool the inlet air via air to air heat exchangers.

Challenges to overcome are:
1. Reaching a high efficiency (95%+) with a small pressure drop
2. Robustness to potential condensing air contaminants



Expected Product (delivery item/concept):

Design an air to air heat exchanger that operates in at least one of two required temperature ranges: 190-296K and/or 130-190K. Model its performance to predict its efficiency and scalability to different air flow rates. Build a prototype of the design for testing at the university and/or ARC. Deliver modeling results and recommendations, including required operating parameters, pressure drop, temperature gradient, and condensing species (if any).

Expected Result (knowledge gained):

This project will aid in designing the full-scale system as a candidate for future deep space exploration air revitalization. The results will influence the definition of standard operating conditions and procedures and affect long-term system stability testing, dynamic input environment testing to prove system robustness, and analysis of potential failure modes.

Relevance to Exploration:

This project will continue the exploration of deposition onto a cold surface as an alternative technology pathway to removing CO_2 and other contaminants from the cabin air environment. Proving out and developing an air revitalization system based on deposition can potentially operate as a full standalone system or can be integrated into other existing air revitalization subsystem segments.

Level of Effort for student team:

Design, thermal, and flow modeling of the heat exchanger component of the CO_2 deposition to demonstrate expected thermal efficiency and operation. Possible build and delivery of the prototype design.

Level of effort for NASA team:

Requirements definition, system design assistance, data-sharing

Suggestion for seed funding:

$50,000 to perform both modeling and prototype fabrication. Proposers are encouraged to seek additional funding or other contributions from their institutions, industry, space grant consortiums, and others

Project Sponsor:
Solar System Exploration Research Virtual Institute (SSERVI)
SSERVI addresses basic and applied scientific questions fundamental to understanding the Moon, Near Earth Asteroids, the Martian moons Phobos and Deimos, and the near space environments of these target bodies. SSERVI acts as a bridge between science, exploration, and technology, and seeks new lines of research that integrate interdisciplinary endeavors. As a virtual institute, SSERVI funds investigators at a broad range of domestic institutions, bringing them together along with international partners via virtual technology to enable new scientific and technical efforts.

Project Title:
Integration of Field Results into Virtual and Augmented Reality Environments

Scope of the challenge:

New datasets from missions and field analogs are desired to be integrated into virtual and augmented reality environments so that scientists in the field or here on Earth can more accurately and efficiently identify samples/areas of interest.

Description:

SSERVI has a focus on the interaction of robotics, planetary surface science, human exploration, ConOps, and analog field science. The integration of augmented reality and virtual reality with surface datasets can enhance each of these areas of research by creating visual linkages between datasets and the local environment. This also allows for new and powerful field techniques for obtaining samples, and eventually new approaches for human exploration of planetary surfaces. This opportunity seeks a team of university scientists and engineers who can create a pipeline for data input into a working VR/AR environment (e.g. implementation of a "Field Trek" application based on the MoonTrek program: https://trek.nasa.gov/moon/). For example, LIDAR data can be combined with X-Ray Fluorescence data and overlain into an augmented reality environment for scientists in the field.

A headset with 3D and GPS positioning should be utilized and integrated with either artificial or real world data (either analog or mission-based). Subsequent years' efforts (or this year provided rapid prototyping success) could involve travel and field testing the equipment, with real-time data input.

Expected Product (delivery item/concept):

The expected deliverable will be a program that can be integrated into the Field/Trek MoonTrek suite of software tools. A final presentation to SSERVI/MoonTrek management that involves feasibility, recommendations, and/or demonstrations will be expected as well.

Expected Result (knowledge gained):

Integration of exploration data into scientific investigations is of importance as we begin the process of returning humans to other planetary surfaces. The integration of data into real time operations increases the efficiency with which we can process actions in the field.

Relevance to Exploration:

With the Gateway underway and remote operations of lunar surface assets being a big part of the human presence on Gateway, a dedicated method of integrating datasets from various sources into an AR/VR environment can improve exploration-related operations. This effort can directly inform several Strategic Knowledge Gaps (SKGs: https://www.nasa.gov/exploration/library/skg.html) including lunar SKGs I-C, I-D, I-E, III-B.

Level of Effort for student team:

It is expected that the student teams will perform computer programming, data handling, and have an understanding of the needs of the scientific community who will ultimately utilize the end solution.

Level of effort for NASA team:

Several interactions with SSERVI NASA Ames/JPL team members as well as SSERVI teams focused on similar work is expected through telecoms and videocoms. There is the opportunity for additional mentoring and data sharing.

Suggestion for seed funding:

$15,000. Proposers are encouraged to seek additional funding or other contributions from their institutions, industry, space grant consortiums, and others.

Project Sponsor:
Advanced Exploration Systems (AES) Life Support Systems

Project Title:
Microgravity Gas-Liquid Separator for the Liquid Amine CO_2 Removal System

Scope of the challenge:

Design and characterize the operation of a phase separator that operates in microgravity and both species are recoverable.

Description:

In order to meet the challenges posed by deep-space manned exploration, innovative, reliable, and cost-effective solutions must be developed in order to close the loop in human life support. In the realm of air revitalization, the current sorbent-based architecture aboard the ISS has proven to be sensitive to contaminants and mechanical failures. One solution takes inspiration from CO_2 scrubbing in power plants and submarines by utilizing liquid amines. The liquid flow in microgravity is achieved by surface tension in interior angles, so crossflow gas absorption and heated desorption can be achieved.

The CO_2 captured is fed to a downstream conversion process, for example a Sabatier reactor, and therefore must be highly pure. But, during the desorption process in this system both the amine and water solvent evaporate, contaminating the CO_2 product stream. Once the product stream cools, the non-CO_2 components condense but still need to be separated from the gaseous CO_2 stream. The condensate can then be recycled back to the amine reservoir.

Expected Product (delivery item/concept):

Design and build a non-gravity-dependent benchtop-scale phase separator capable of separating incoming water and amine condensing from gaseous CO_2. Develop test plan capable of demonstrating non-gravity-dependence. Deliver experimental findings, scalability studies and recommendations. Include required parameters for operation, separation efficiency, and expected functionality in microgravity conditions.

Expected Result (knowledge gained):

This project will provide insight into a critical component of the Liquid Amine CO_2 removal system, which is currently lacking in maturity compared to the other subsystems. The results will directly inform the design and operation of the system.

Relevance to Exploration:

This project will continue the exploration of liquid amine absorption as an alternative technology pathway to removing CO_2 from the cabin air environment. The system capitalizes on industry-standard materials used to remove CO2, but approaches the microgravity fluid handling in a new and novel way to allow for the high-throughput flow required to remove sufficient CO_2.

Level of Effort for student team:

Design, build, and test a non-gravity-dependent phase separator for air revitalization utilizing liquid amines. Possible involvement in developing a 0-g test apparatus.

Level of effort for NASA team:

Requirements definition, system design assistance, and data-sharing.

Suggestion for seed funding:

$30,000. Proposers are encouraged to seek additional funding or other contributions from their institutions, industry, space grant consortiums, and others.

Project Sponsor:
Space Life and Physical Science Research and Applications

Project Title:
Volume Optimization for Food Product During Deep Space Exploration

Scope of the challenge:

Development of a system that provides optimum volume conditions for plant growth will significantly reduce mission cost while providing a healthy diet for crew members. Plants will be needed during Exploration missions lasting more than one year to provide nutrients and some calories to flight crews. Volume requirements change over the lifecycle of most plants grown for food and systems need to be developed to support plant needs while making the best use of available volume.

- Development of a modular, scalable infrastructure to support food production using as little volume as possible
    - Development of a fault tolerant architecture that can be reused multiple times and supports plant size changes over its life cycle.
- Develop a system that both optimizes total volume and minimizes hands on crew time requirements.

Description:

Deep Space Exploration by humans, e.g., Mars Missions, will require plant growth systems to produce food, both nutrients and calories for periods of three to five years. The time frame will dictate the reuse of this plant growth system many times, while consistently providing the expected output. The need for continuous production over time could require multiple independent volumes, or coordinated use of a common volume to accommodate different crops and stages of growth. The use of automation and AI should also be considered to reduce hands on crew requirements. Developing a system that produces the maximum output per unit volume will significantly reduce system mass. The system needs to include lighting, water and nutrient delivery, and air flow management, and hence should also consider mass and energy constraints.

Expected Product (delivery item/concept):

NASA would expect to see an operating system concept and an operating model of the proposed end product.

Expected Result (knowledge gained):

Students would become familiar with NASA's project management process, the issues of producing food in space, and the development of operating models. NASA would be training the next generation of space system developers and be reviewing ideas from a fresh perspective.

Relevance to Exploration:

The capability to produce a continuous supply of fresh food is critical to exploration. The system configuration needed to produce this desired output is wide open to new ideas. If we get three

or four good proposals and can get an equal number of end products, we will be closer to an end product which is critical to Exploration

Level of Effort for student team:

The team will need expertise in structures and mechanical systems, electrical and electronic systems, software development, plant growth, micro biology, and the integration of those systems into an operating product.

Level of effort for NASA team:

The NASA team will support five 2-hour telecom with the University team including kickoff meeting, SDR, PDR, CDR, and completion presentation and a site visit of one day for two team members.

Suggestion for seed funding:

The sponsor will provide up to $25,000 for this project which needs to support a demonstration visit to KSC for at least 2 members of the team. Proposers are encouraged to seek additional funding or other contributions from their institutions, industry, space grant consortiums, and others.

Project Sponsor:
Advanced Exploration Systems In-Space Manufacturing Project

Project Title:
Development of a Design Database for the In-Space Manufacturing Project

Scope of the challenge:

Develop a design database populated with parts (components of space systems, medical devices, and consumable supplies) that can potentially be made with in-space manufacturing capabilities.

Description:

The in-space manufacturing (ISM) project at NASA Marshall Space Flight Center seeks to develop the processes, skills, and certification framework to provide an on-demand manufacturing capability for long duration exploration missions. Current in-space manufacturing capabilities for International Space Station include two fused filament fabrication systems on ISS (the 3D Printing in Zero-G technology demonstration mission printer and the Additive Manufacturing Facility - AMF, a commercial facility developed and operated by Made in Space). An integrated fused filament fabrication printer and recycler, the Refabricator developed by Tethers Unlimited, was installed on space station in early 2019. The ISM project is also working toward a multimaterial fabrication laboratory for space station, a new ISS facility which will demonstrate manufacturing of metal materials in the microgravity environment and prove out manufacturing technologies for long duration exploration missions.

In parallel with development of potential manufacturing technologies for space applications, the ISM project has worked extensively with exploration systems designers to identify parts in space systems which could be manufactured on space flight missions. The objective of the proposed project is to curate these parts in the format of a database which could be used by both space system designers and potentially even a crew on a deep space exploration mission. Each entry in the database should include a link to the part's CAD file, an image of the part, material(s), a description of the part and its use scenario, and other fields to be defined by the database development team in conjunction with NASA. The XHab team does not have to populate this information themselves, but should generate a framework which the NASA team can use to create entries corresponding to parts currently identified from work with systems designers. Features to facilitate semi-automated transfer of existing data into the database framework is desired. The database may also link to a manufacturing system, enabling an engineer or crew member to select a tool and print it via only the database interface.

Expected Product (delivery item/concept):

As part of this project, teams should develop a part database for the in-space manufacturing project capable of storing and distributing previous data and incorporating new data. Teams must demonstrate the functionality of the database to the NASA project customer at design reviews. The database should facilitate entry of parts and requisite information (STL file, part image, material information, use scenarios and restrictions on use, life limits, etc.) by NASA team members. The database will initially include hundreds of parts from space systems, disposable and customizable items (ex. biomedical supplies and food consumables), and crew personal items. The final product should be available as a web application and as an application for mobile device (tablets are sometimes used by crew on ISS). Teams are encouraged to incorporate novel

software features to facilitate the most efficient use of the database by the NASA engineering team and potentially spaceflight crew.

Expected Result (knowledge gained):

The expected result is a database to support the in-space manufacturing project's ongoing research activities as well as utilization of current and future in-space manufacturing systems on-orbit.

Relevance to Exploration:

This project directly supports the tasks of the in-space manufacturing project, which is focused on enabling sustainable long duration exploration by reducing logistics and enhancing crew safety by offering on-demand manufacturing capabilities in a crewed environment.

Level of Effort for student team:

Student teams should have experience in 3D printing and software design and development. If teams do not have 3D printing equipment or software to support this activity, it may be purchased through the project funds.

Level of effort for NASA team:

The NASA team will assist with requirements definition, example part files for the database, and defining a work plan to achieve outcomes that are of benefit to NASA and have a clear infusion point for NASA projects and programs. NASA personnel will participate in all design reviews and serve as a resource for the student team throughout the course of the project.

Suggestion for seed funding:

$20,000. Proposers are encouraged to seek additional funding or other contributions from their institutions, industry, space grant consortiums, and others.

Project Sponsor:
AES NASA Platform for Autonomous Systems Project
https://techcport.nasa.ov/view/94884

Project Title:
User Interfaces for Gateway Autonomous Operations

Scope of the challenge:

Explore and design user interfaces for autonomous operations of the Gateway (including, all modules) while in crewed and un-crewed mode, which includes applicability for interface accessibility from the ground support.

Description:

The NASA Gateway will consist of multiple modules, as described in Figure 1 below.

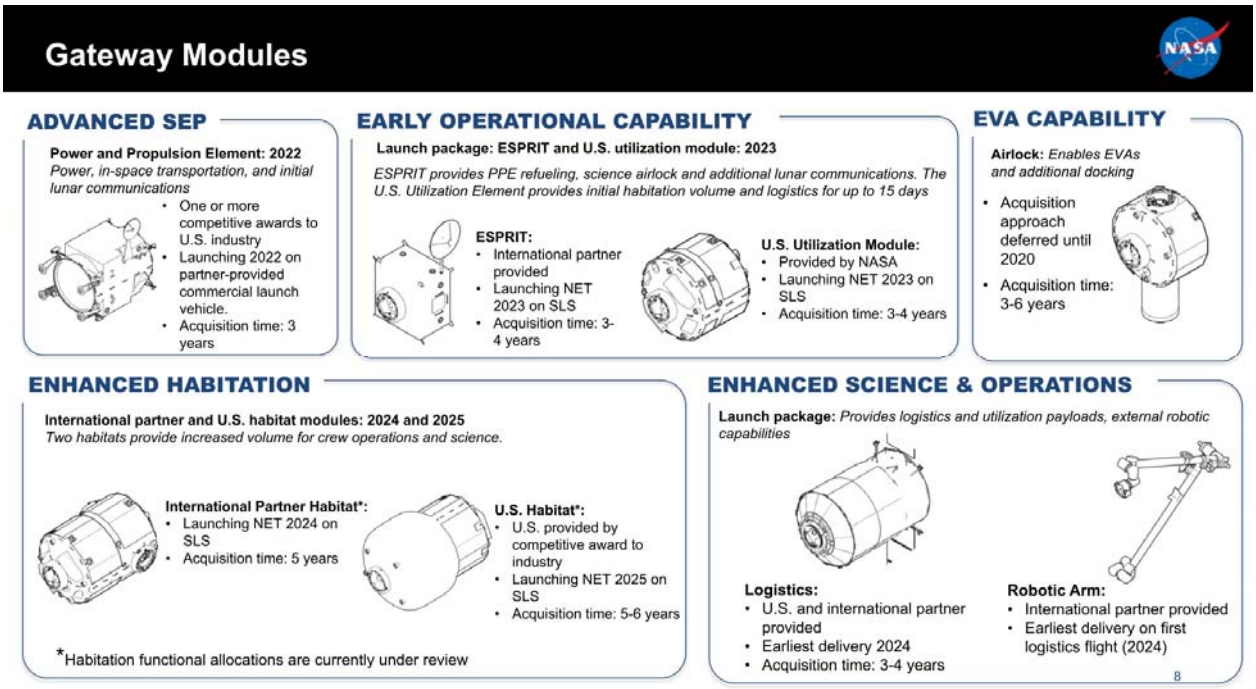


Figure 2. Gateway Modules

Additional information regarding Gateway design and purpose is provided at

https://www.nasa.gov/topics/moon-to-mars/lunar-outpost

While in lunar orbit, Gateway is being designed to operate autonomously; respectively, there will be both periods of time when the spacecraft is crewed, and other often long periods of time when it is un-crewed. Gateway is expected to operate fully autonomously when un-crewed; share autonomy with the crew, when crewed; and then, also share autonomy with ground support, as needed.

Gateway must provide user interfaces to enable crew and ground-support to conduct nominal operational functions while Gateway operates with the highest possible level of independence. The user interfaces must provide complete awareness in an efficient and intuitive manner, while enabling crew or ground-support access to control for operations under circumstances when and as needed. Additionally, user interfaces must address all modules in Gateway. A prototype user interfaces for a Vehicle Manager (operating the entire vehicle), a Power System, and an Avionics System developed using SSC's NASA Platform for Autonomous Systems (NPAS) are shown in Figure 2 (below).

Figure 3. Prototype user interfaces for an autonomous habitat developed with NPAS.

Expected Product (delivery item/concept):

The project will deliver 2 products:

1. Implementation of graphics and tools used to validate design and operation of the user interfaces. If possible, an optimal validation opportunity would constitute immersive simulations, where crew members and/or ground-support are able to exercise user interfaces functionalities.

2. A final report describing the approach and methodology developed to create the user interfaces, including graphic examples. This document will assist in establishing guidance for design and implementation of user interfaces for autonomous systems.

Expected Result (knowledge gained):

Results from this project will help accrue knowledge and technology to successfully design user interfaces for Gateway and/or other autonomous spacecrafts, as well as for autonomous systems operating on planetary surfaces i.e., In-Situ-Resource-Utilization (ISRU).

Relevance to Exploration:

NASA, for the first time, is developing a spacecraft, Gateway, which must function with an elevated degree of autonomy. To date, user interfaces for autonomous systems is a technology area where knowledge, implementations, and associated concepts of operations are lacking. This shortcoming is now in the critical path for Gateway, Moon activities, exploration of Mars and beyond.

Level of Effort for student team:

Student teams will benefit from participation of members in a variety of disciplines, including topics such as human-machine interaction, human behavior, engineering, computer science, graphical and other technologies for human-machine interaction.

Level of effort for NASA team:

The NASA team will provide knowledge and expertise related to Gateway, Gateway concepts of operation, and theories and associated implementation of autonomous systems and operations.

Suggestion for seed funding:

$30K. Proposers are encouraged to seek additional funding or other contributions from their institutions, industry, space grant consortium and others.

Appendix C: Standard Education Grant or Cooperative Agreement

This award is made under the authority of 51 U.S.C. 20113 (e) and is subject to all applicable laws and regulations of the United States in effect on the date of this award, including, but not limited to 2 CFR Part 200 and Part 1800.

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

Location	Title	Date
Appendix A to 2 CFR Part 170	Reporting Subawards and Executive Compensation	Dec. 26, 2014
2 CFR 175.15	Trafficking in persons.	Dec. 26, 2014
2 CFR 182	Government-wide requirements for Drug-Free Workplace	Dec. 26, 2014
1800.900	Terms and Conditions	Dec. 26, 2014
1800.901	Compliance with OMB Guidance on Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal awards.	Dec. 26, 2014
1800.902	Technical publications and reports.	Dec. 26, 2014
1800.903	Extensions.	Dec. 26, 2014
1800.904	Termination and enforcement.	Dec. 26, 2014
1800.905	Change in principal investigator or scope.	Dec. 26, 2014
1800.906	Financial management.	Dec. 26, 2014
1800.907	Equipment and other property.	Dec. 26, 2014
1800.908	Patent rights.	Dec. 26, 2014
1800.909	Rights in data.	Dec. 26, 2014
1800.910	National security.	Dec. 26, 2014
1800.911	Nondiscrimination.	Dec. 26, 2014
1800.912	Clean air and water.	Dec. 26, 2014
1800.913	Investigative requirements.	Dec. 26, 2014
1800.914	Travel and transportation.	Dec. 26, 2014
1800.915	Safety.	Dec. 26, 2014
1800.916	Buy American encouragement.	Dec. 26, 2014
1800.917	Investigation of research misconduct.	Dec. 26, 2014
1800.918	Allocation of risk/liability.	Dec. 26, 2014

Unless otherwise specified, the terms and conditions in 2 CFR 1800.900 to 1800.918 and the requirements in 2 CFR 170, 175, and 182 apply and are incorporated by reference. To view full text of these requirements, terms, and conditions go to https://prod.nais.nasa.gov/pub/pub_library/srba/index.html

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.

_____
Organization Name

_____
Printed Name and Title of Authorized Representative

_____
Signature Date

_____
Printed Name of Principal Investigator/Program Director

_____
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.

Organization Name

Printed Name and Title of Authorized Representative

Signature Date

Printed Name of Principal Investigator/Program Director

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.

_____
Organization Name

_____
Printed Name and Title of Authorized Representative

_____
Signature Date

_____
Printed Name of Principal Investigator/Program Director

_____
Proposal Title

Appendix E: NASA Review Requirements and Checklists

NASA follows a strict adherence to a formal review process, as described earlier. The SDR, PDR, and CDR activities are further explained below, providing rationale, objectives, the information to be provided, and success criteria.

System Design Review (SDR)

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 assess readiness for the Preliminary Design phase.

SDR Objectives:

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):

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.

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.

PDR Objectives:

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.

Post-PDR, Pre-CDR Activities

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.

Critical Design Review (CDR)

The team should finalize all their designs for the CDR, after having selected a preferred alternative among the trade studies. The intent of the CDR during the X-Hab milestone process is to finalize the products seen in the SDR and PDR products and to reflect the changes and maturation since the earlier reviews but not to repeat the content seen earlier.

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.

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. As noted earlier, teams may request additional meetings for technical interchange, but they are not required as a milestone.