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Moon to Mars eXploration Systems and Habitation (M2M X-Hab) Academic Innovation Challenge – FY24 Solicitation

on behalf of

NASA Headquarters
Human Exploration & Operations Mission Directorate

Sponsored by:

NASA Exploration Capabilities

Release Date:	March 7, 2023
Proposals Due:	April 28, 2023
Anticipated Award Date:	May 26, 2023
Program Website:	https://www.spacegrant.org/xhab/

X-Hab 2024 Academic Innovation Challenge Solicitation

1. Funding Opportunity Description - Synopsis

The Moon to Mars eXploration Systems and Habitation (M2M X-Hab) 2024 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. 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.

NASA's Exploration Capabilities (EC) Program will offer multiple awards of $13k - $50k each to design and produce studies or functional products of interest to NASA (see Section 3.2, *M2M 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 M2M X-Hab proposals, which will be reviewed by technical experts; subsequent down-selection will determine which projects will be funded. M2M X-Hab university teams will be required to complete their products for evaluation by NASA EC mentors in May 2024. Universities may form collaborations to perform as a single distributed project team.

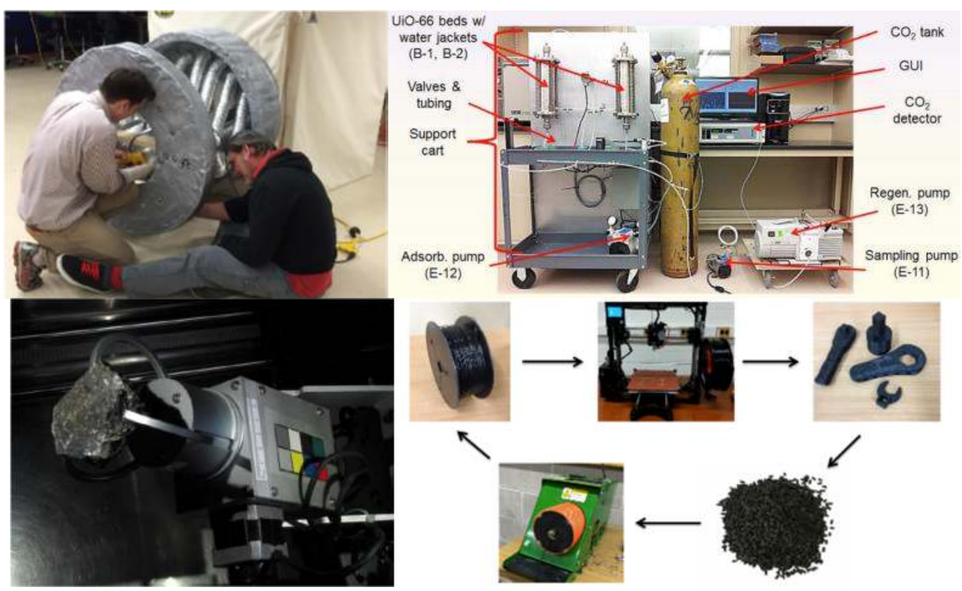

Figure 1. Previous X-Hab Projects (from top left, clockwise): Deployable Airlock, Closed Environment Air Revitalization System Based on Metal Organic Framework Adsorbents, Carbon-fiber/Fused Deposition Modeling Spacecraft Structural Fabrication System, Sample Handling System for GeoLab Glovebox (Image credit: NASA).

Students in the Critical Path: The M2M 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, 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.

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 M2M 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 M2M 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 EC Program is requesting proposals for the Moon to Mars eXploration Systems and Habitation (M2M X-Hab) 2024 Academic Innovation Challenge. The M2M X-Hab Challenge is a university-based challenge to provide real world, hands-on design, research and development opportunities to university teams. 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 M2M X-Hab 2024 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 EC Program 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, 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. It is expected that students will perform the majority of the work and the Principal Investigators are there to guide and direct. 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 2023 and spring 2024 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-2016-6105 Rev2. 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 2023-2024 academic year.

NASA understands that the funding awarded to manufacture some test articles may not be sufficient; thus, NASA encourages 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**):

- 06 Oct 2023 – Requirements and System Definition Review (SDR)
- 10 Nov 2023 – Preliminary Design Review (PDR)
- 19 Jan 2024 – Critical Design Review (CDR)
- 08 Mar 2024 – Progress Checkpoint Review
- 06 May 2024 – 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 M2M 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: Exploration Capabilities

- Project Title: Sub-scale Air Cooled Temperature Swing Adsorption and Compression (AC-TSAC) Heat Pipe Based Canister Re-design

- Project Title: Volatile Organic Compound (VOC) Management for the CO2 Deposition System

- Project Title: Mars Campaign Development (MCD) Division Exploration Capability (EC): NASA Platform for Autonomous Systems (NPAS) Project

- Project Title: Bring the Heat: Design of Radiator Systems for Lunar Surface Habitation

3.3 Academic Innovation Challenge Background and Purpose

This announcement maps to [NASA Budget Documents, Strategic Plans, and Performance Reports] where NASA identifies, establishes, and maintains a diverse set of partnerships to enable collaborations of mutual benefit to NASA and academia. 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. It 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 EC Program 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 EC Program focuses on advanced design, development, and demonstration to reduce risk, lower life cycle cost and validate operational concepts for future human missions to deep space. EC leads development of new approaches to project and engineering management, such as rapid systems development or alternative management concepts, open innovation, and collaboration. Specifically, EC Program 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 six primary domain areas: Crew Mobility Systems, Habitation Systems, Vehicle Systems, Foundational Systems, Robotic Precursor Activities, and

Human Spaceflight Architecture Systems. NASA is also extending human presence deeper into space with Moon to Mars for long-term exploration and utilization by first establishing a Lunar Gateway in cislunar space. The purpose of the M2M 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.

Human Spaceflight Architecture Systems (Artemis focused)

Gateway establishes a platform to mature necessary short- and long-duration deep space exploration capabilities through the 2030s. 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), and 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 EC Program 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 3, 2023.
Responses will be posted on April 11, 2023.

3.5 Pertinent Dates

Proposal Phase

07 Mar 2023	Date of Announcement and Release of RFP
03 Apr 2023	Questions for online Technical Interchange due
11 Apr 2023	Responses to submitted questions published online
28 April 2023	Proposal due
26 May 2023	Award announcements

Award Phase

Summer - Fall 2023	Design phase
Sept 2023	Kickoff meetings
06 Oct 2023	Requirements and System Definition Review (SDR)
10 Nov 2023	Preliminary Design Review (PDR)
19 Jan 2024	Critical Design Review (CDR)
08 Mar 2024	Progress Checkpoint Review
06 May 2024	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 (using any one of a number of video teleconferencing tools) through the project execution.
3. Report on Educational Outreach activity prior to Project Completion.
4. Demonstration articles for M2M X-Hab developmental studies prior to Project Completion.
5. Technical Final Report prior to Project Completion.
    a. Third party content will not be included in the final report, including materials protected by copyright or trademark. Third party content is any content created by an entity other than the awardee or NASA.
    b. Photos or videos included in the final report featuring the authors must include written permission to publish the photos/videos in any medium. Photos/videos featuring individuals other than the authors will not be incorporated into this final report.
    c. Any financial information included, as deemed necessary to the final report by the authors, will be incorporated into a separate appendix.
    d. Any included software code will be incorporated into a separate appendix.

e. 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.
f. If determined export controls do not apply, the ECO will note the outcome and recommend the final presentation/report be approved/accepted.
g. After ECO approval, the M2M X-Hab coordinator will file in Scientific, Technical and Research Information DiscoVEry System (STRIVES) to formally archive the report.
h. Project teams/advisors are expected to provide a list of authors and brief abstract in support of the Document Availability Authorization process.
i. No personal contact information will be included in the final report.

Grant disbursements – 40% at SDR, 50% at CDR, then final 10% after final presentation and final report submitted.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, 2023, to May 31, 2024. 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 M2M X-Hab 2024 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 M2M X-Hab 2024 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 M2M X-Hab 2024 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 M2M X-Hab prototype will be integrated and tested at the affiliated university in the 2023-24 academic year. Describe how the M2M 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 M2M X-Hab 2024 Academic Innovation Challenge will be implemented during the 2023-2024 academic year and will comply with all pedagogical requirements.

4.2 Proposal Evaluation Criteria

The M2M 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 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 Exploration Systems Development 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 Exploration Systems Development 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. Proposals exceeding the allocated budget will not be considered.

4.3 Proposal Submission

Electronic copies of proposals must be received no later than **midnight, Pacific Daylight Time, Friday, 28 April 2023**. *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 26 May 2023.

5. Disqualification

Ethical competition practices are expected. The solicitation of NASA collaborators for no other purpose than current or prior involvement with X-Hab and the management thereof may result in disqualification without the proposal being evaluated. Similarly, listing collaborators without their knowledge or consent will result in immediate disqualification and may be reflected in future X-Hab evaluations.

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: M2M X-Hab Topic Details

Project Sponsor:
EC Life Support Systems

Project Title:
Sub-scale Air Cooled Temperature Swing Adsorption and Compression (AC-TSAC) Heat Pipe Based Canister Re-design

Scope of the challenge:
Design, build, and test new canisters, specifically incorporating heat, pipes for a temperature swing CO_2 compression system for air revitalization.

Description:
To meet the challenges posed by deep-space crewed exploration, innovative, reliable, and cost-effective solutions must be developed to close the loop in human life support. AC-TSAC is an alternative gas compression system that uses packed beds of regenerable bulk sorbents and heat cycles to compress the low pressure CO_2 from the cabin air CO_2 removal system to a sufficiently high pressure required for downstream conversion to useful products.

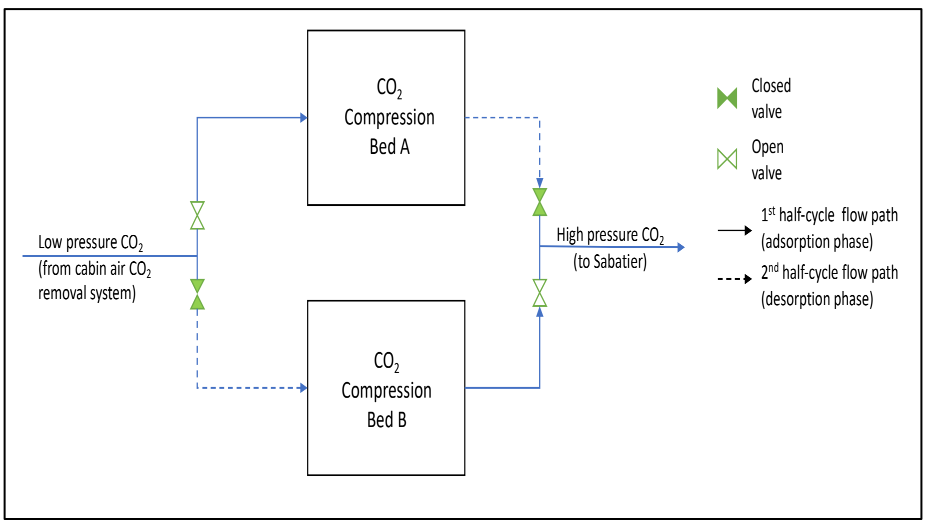

Figure 1. Schematic for AC-TSAC system that uses temperature swing adsorption to pressurize captured CO2 for processing.

The existing AC-TSAC design has been successfully tested for many years in the lab, including being integrated with both past and current CO_2 removal system designs used on the International Space Station. However, the current method of using resistive heaters and air cooling to cycle the system between adsorption and desorption can be improved. Heat pipes are promising due to their superior efficiency. This project aims to design, build, and test a new AC-TSAC geometry that incorporates heat pipes to improve canister performance that could be scaled up in future iterations to meet the performance, temperature, and power requirements of a full-scale AC-TSAC system.

Expected Product (delivery item/concept):
Design, build, and test a benchtop heat pipe based CO_2 compression system. Model its performance to predict performance and scalability for up to 4kg CO_2/day. Deliver modeling results, experimental testing results, and operational recommendations for both heat pipe and canister design. Students will also provide design suggestions and/or alternative solutions.

Expected Result (knowledge gained):
This project will aid in redesigning the full-scale system as a candidate for future deep space exploration air revitalization. The results will influence the selection of an alternative CO_2 compression system for deep space transit to Mars. Mechanical, chemical, thermal, fluid, and electrical engineering disciplines will work together to succeed in this project. Practical systems engineering and project management skills will be developed.

Relevance to Exploration:
This project will continue the redesign and refinement of the AC-TSAC system as it moves toward a more flight like system. AC-TSAC is being designed to be an alternative, solid state, more reliable compression system in the air revitalization process. Heat pipe based AC-TSAC canisters can potentially improve sorbent heating and cooling rates in the beds and allow for more uniform temperature distributions. A more homogeneous temperature distribution could more efficiently use the sorbent present in the bed, allowing for decreased mass, volume, and energy requirements for the canisters.

Level of Effort for student team:
Design, thermal-flow modeling, build, and test of their new heat pipe based AC-TSAC canisters to determine heat pipe's capability to heat and cool zeolite beds for solid state CO_2 compression.

Level of effort for NASA team:
Requirements definition, system design assistance, and data-sharing.

Suggestion for seed funding (~$10-$50k):
$50K to perform modeling, prototype fabrication, and testing.

Project Sponsor:
EC Life Support Systems

Project Title:
Volatile Organic Compound (VOC) Management for the CO_2 Deposition System

Scope of the challenge:
Design, build, and characterize the VOC capture system to be used in conjunction with the CO_2 deposition system for air revitalization

Description:
A CO_2 capture system is being developed to improve the efficiency and reliability of air revitalization systems for long-duration human space exploration. One approach to improve reliability is the removal of sorbents entirely from the system, as they have limited life, and use a purely thermal capture approach. The CO_2 deposition (CDep) system utilizes cryogenic coolers to remove CO_2 from the air stream through deposition onto a cold surface, but VOCs also present in the spacecraft that have a condensation or deposition temperature in this temperature range (>130K) get trapped as well, as seen in Figure 1. The goal is to remove these VOCs before the CO_2 stream is sent to the Sabatier reactor or other CO_2 conversion system to prevent contamination, which can be done either upstream of the CO_2 deposition process or removed from the sublimed CO_2 product. The main challenge in designing this system is to integrate it into the current CDep architecture while minimizing its mass, volume and power requirements.

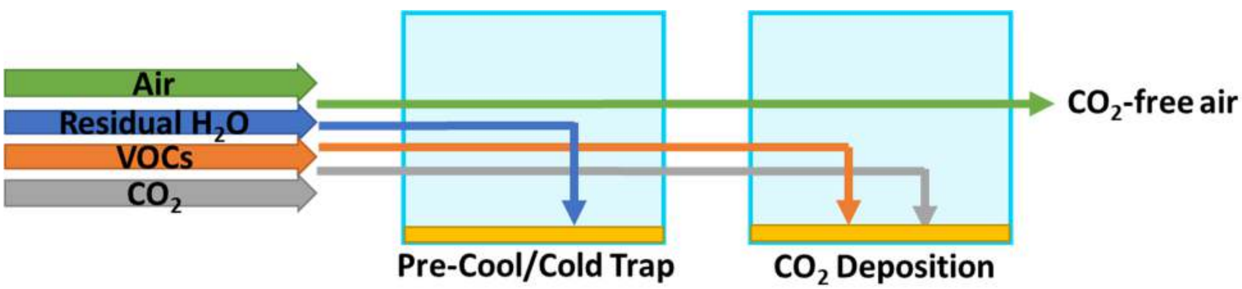

Figure 1. Basic Operation of the CDep system, cold surface represented by yellow block at base of box.

Expected Product (delivery item/concept):
Design, build, and test a benchtop-scaled VOC capture system that can be used in conjunction with the current CDep system so that the CO_2 product is purified. The system may be implemented either upstream of the CO_2 deposition cold surface and remove VOCs from air or in the EC CO_2 product line to remove captured VOCs from CO_2. Deliver modeling results, experimental testing results, operational recommendations, and scaling expectations for future designs. Students will also provide design suggestions and/or alternative solutions.

Expected Result (knowledge gained):
This project will influence the design of a full-scale CDep system that can be used for future deep-space exploration air revitalization. It will give students a broad understanding of air revitalization methods, as well as the technical requirements for environmental control and life support systems (ECLSS). Participants will have the opportunity to work in interdisciplinary teams, combining expertise in mechanical, chemical, thermal, fluid, and electrical engineering to successfully complete the project. Additionally, students will gain valuable experience in practical systems engineering and project management.

Relevance to Exploration:
This project will delve further into the potential of using cold surface deposition as a method for removing CO_2 and other contaminants from the cabin air environment. The goal is to demonstrate and improve upon this technology, which has the potential to function as a standalone system or as an addition to existing air revitalization subsystems. By successfully completing this project, it could lead to improving the function of downstream CO_2 conversion systems and/or the elimination of separate trace contaminant control systems in future air revitalization architecture.

Level of Effort for student team:
Design, model, build, and characterize a benchtop VOC capture system to be used in conjunction with CO_2 deposition system for air revitalization.

Level of effort for NASA team:
Requirements definition, system design assistance, data-sharing. A list of a representative concentration of VOCs commonly found on the ISS will be provided.

Suggestion for seed funding (~$10-$50k):
$50K for analysis, prototype fabrication, and testing.

Project Sponsor:
NPAS NASA Platform for Autonomous Systems
Mars Campaign Development (MCD) Division Exploration Capability (EC): NASA Platform for Autonomous Systems (NPAS) Project
https://techport.nasa.gov/view/94884

Project Title:
Intelligent Devices/Equipment/Instruments (IDEI) for Enabling Crew Health and Performance on Mars

Scope of the challenge:
The scope of this challenge is the development of prototype Integrated Intelligetn Devices/Equipment/Instruments (DEI) that could be used for implementing integrated system health management for Crew Health and Performance (CHP) required for crew living on Mars for extended periods of time (longer than one Earth year). The IDEIs should operate autonomously and be designed as analogs for DEIs that are used on Earth to train, for example for hanging and/or rock-climbing.

Description
CHP aligns under the NASA Human Research Program (HRP) which is working to improve astronauts' ability to collect data, solve problems, and remain healthy during and after extended space travel and missions, and help address the challenges and demands that astronauts will face.

If systems do not accommodate for human capabilities and limitations, a disconnect can occur between these systems and what humans can manage and/or support, which could result in system failures and potentially loss of life. Incorporating these considerations as part of the systems engineering process is referred to as Human Systems Integration (HSI). A key principle of HSI is that all humans interacting with systems must be considered in the operation of the systems.

On Mars, crew will be kept alive by artificial life support systems (LSS), either inside habitats or within a space suit while outside of the habitat. The LSS will incorporate resource management systems (RMS) and Crew Health and Performance Managers (CHPM) for each crew member. CHPM will provide, in real-time, complete awareness to the crew about the individual’s health and performance, as well as provide this same awareness to the RMS and LSS to ensure required consumables are available and are provided to the crew.

This project is looking for the development of a concepts of operation and design of a prototype that could be used for implementing IDEIs, encompassing an ontology, architecture, and autonomous operations; to enable integrated system health management and oversight of human health beyond support that is currently provided by mission control on the ground.

The IDEI should embody autonomous behavior that is capable of interacting with crew, CHPM, RMS (all of which may require resources to function and/or support maintenance). Figure 1 represent the various systems involved.

An example concept for a IDEI implementation could address hanging and rock-climbing, which are activities that exercise the human body in a manner that optimizes muscle strength needed to have excellent control of one's body. It is also an activity that can be adapted with virtual reality or immersion content. The weight of a person on Mars is 0.375 times the weight on Earth (a little more than one third). The project could investigate creative ways to explore beyond what is normally done on Earth, that would serve as an analog for types of stress that humans would experience on Mars. This idea has up to 2 challenges: (1) to develop an Concepts of Operation for DEI prototype that is an analog to DEIs for an exercise activity i.e. Hanging And Rock-Climbing activity (HARC) IDEI on Earth – or some other strenuous activity; and (2) to develop the IDEI prototype.

The autonomous IDEI, that could be inspired by hangboards (Figure 2), should provide quantitative information regarding the exercise activity, which would be used to support the functions of the CHPM, LSS, and RMS. For example, in the case of the HARC IDEI, forces on fingers, kinematic movement, energy spent, and other data would be provided to the systems. The autonomous DEI should also be capable of autonomously providing state of health, report faults and maintenance needs, as well as report performance quality.

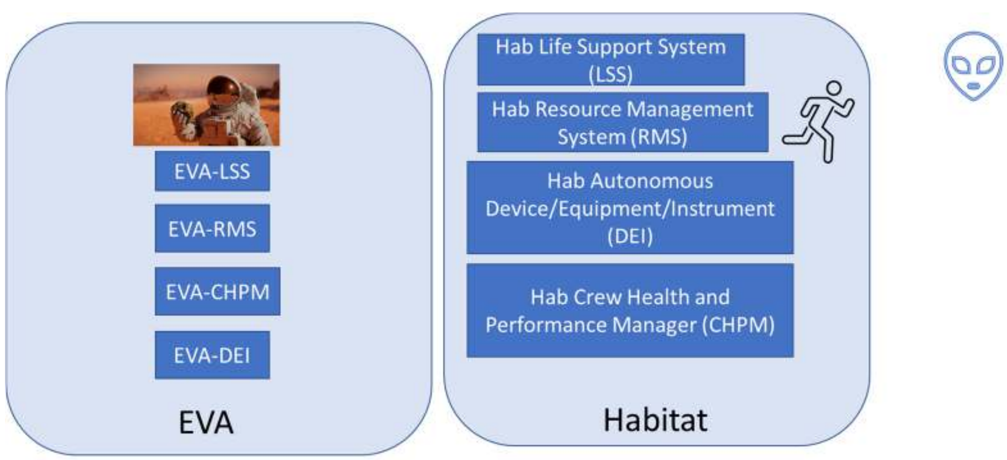

Figure 1. Autonomous IDEI in the context of systems for CHP inside a Habitat and during EVA

Figure 2. Typical Hangboard used for rock-climbing training

Expected Product (delivery item/concept):

- Design a prototype for implementing autonomous IDEIs in conjunction with an ontology, architecture, and concept of operations for autonomous IDEIs.
- Develop and build a prototype of one or more integrated DEIs that represent an analog of DEIs used on Earth to train i.e. for hanging and/or rock-climbing.

Expected Result (knowledge gained):

The MCD EC NPAS project is developing technologies and capabilities to enable autonomous operations of systems, and decision support, for developing and testing capabilities that will ensure crew health and performance during exploration EVA on Mars. The idea proposed will address how IDEIs could operate autonomously and integrate with software that monitors, evaluates, and manages CHP autonomously. In addition, the prototype will add a class of DEI that has not yet been conceived and that will encompass autonomous operations capability. The products expected address technology needs required to fill current CHP HEOMD Technology Capability Gaps.

Relevance to Exploration:

The project will address the following HEOMD-Technology Capability gaps:

Gap ID	Capability Gap Title
06-22	EVA Crew Capabilities and Constraints
06-26	EVA Bioinformatics & Decision Support
06-107	Semi-autonomous Behavioral Health and Performance Technologies

Level of Effort for student team:

Student teams will benefit from participation in a variety of disciplines, including topics such as engineering, computer science, intelligent systems, autonomous systems, exercise devices/equipment/instruments, exercise physiology, health and performance, immersive environments, as well as graphical user interfaces, and other associated technologies.

Tasks include research and development of a prototype autonomous IDEI for Mars exploration.

Level of effort for NASA team:

The NASA team will provide knowledge and expertise related to the primary topic areas represented in this idea.

Suggestion for seed funding (~$10-$50k):

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

Project Sponsor:
NASA Marshall Space Flight Center, Habitation Systems Development Office

Project Title:
Bring the Heat: Design of Radiator Systems for Lunar Surface Habitation

Scope of the challenge:
This challenge focuses on concept development, design, and analysis of thermal control systems to support lunar surface habitation. The primary objective is to explore radiator design approaches to reduce heat loss during periods of lunar darkness. Student teams may consider both body-mounted and deployable radiator concepts over the course of the project. Deployable radiators are typically used for inflatable habitats while body mounted radiators can attach to metallic structure. Teams will design any mechanisms and control systems needed by the system (e.g., for deployment and stowage) and perform heat transfer analyses/simulations to assess predicted performance in the intended use environment (vacuum, periods of extremely low temperature ranges, and low solar elevation corresponding to reduced illumination). Operational considerations, such as dust mitigation strategies and operations in partial gravity, should also be accounted for in radiator design. This project will require multi-disciplinary engineering teams with expertise in heat transfer, mechanism design, materials, and analysis techniques which can be applied to thermal systems.

Description:
NASA is currently developing concepts for the lunar surface habitat (Figure 1). Surface habitat (SH) has a habitable volume consisting of a softgoods inflatable approximately 5m tall and 4m in diameter, which is attached to a metallic airlock for ingress/egress. As noted in the Ground Rules and Assumptions technical memorandum on habitation systems, SH is expected to support a crew of two for approximately 30 days with extensibility to 60 days. When the surface habitat operates in conjunction with another surface asset such as a pressurized rover, the habitat may need to support four crew temporarily during periods of swap-out or function as a safe haven in the event of an anomaly. While NASA anticipates a yearly cadence of missions to the lunar surface as part of the Artemis campaign, the SH will experience significant periods of quiescence, which could range from several months to up to three years. The habitat is assumed to be delivered by a cargo lander (upper limit for habitat mass is 12 metric tons) or cargo variant of a human lander. The habitat and its systems will be designed for a minimum life of 10 years with an objective life of 15 years.

Figure 1. Lunar surface habitat with lunar terrain vehicle operating in foreground and pressurized rover in background.

One of the most challenging aspects of lunar surface habitat design is the environment it will operate in. While Apollo missions were confined to the equatorial regions of the lunar surface, the Artemis missions will take crew to the lunar South Pole, a location of significant interest to the scientific and in situ resource utilization (ISRU) communities because of the high concentrations of volatiles and water located there. The South Pole experiences periods of extremely low temperatures and sustained darkness due to the low solar elevation. The temperatures in perpetually shaded regions at South Pole locations may drop below -240 C while local terrain may reach -210 C in shadow. Conversely, daytime environmental temperatures for local terrain at the South Pole can be much warmer, up to -50 C. This temperature swing drives the design for thermal radiators. The radiator must be sized to reject operational heat loads in the warm environment while minimizing losses to save power in the shadow. Incident solar energy upon the habitat (both direct and reflected) as well as re-radiated energy from the surroundings also factor into radiator performance in the warm, daytime environment.

From a thermal management perspective, the challenges of operating in the South Pole are unprecedented in human spaceflight. Radiators represent one piece of a thermal control strategy to help the habitat survive during eclipse periods. The primary objective of this project is variable geometry radiator design. Multi-disciplinary engineering teams are asked to develop and assess deployable and/or body mounted habitat thermal radiator concepts to mitigate heat loss during "survive the night" scenarios lasting up to 150 hours on the Lunar surface at the South Pole. Deployable radiator concepts might consider stowage, articulation and translation approaches as well as any special operational strategies to reduce heat loss. Body mounted radiator options might consider temporary MultiLayer Insulation (MLI) or other covers or hatches for the radiators as well as special operations. The approach would include any mechanism design and a control strategy to automatically stow or cover the radiators. The radiator working fluid as well as the operational habitat heat load will be decided at the beginning of the project in consultation with NASA subject matter experts. Lunar thermal environments may be found in the publicly available SLS-SPEC-159 (Revision I), *Cross Program Design Specification for Natural Environments (DSNE*). The intent of this project is to focus on variable geometry options and not necessarily consider other thermal control strategies such as variable emittance coatings, improved thermal control fluids or thermal switches.

Teams may also consider design optimizations or new approaches to reduce mass for Lunar Surface Habitat body mounted and/or deployable radiators. Approaches might consider but are not limited to: highly conductive face-sheets, core approaches with improved strength and reduced density, and improved heat transfer for pumped fluid loop systems or hybrid loop heat pipe system architectures. Deployable systems would also consider the mechanical design approach to deploy and stow a thermal radiator in partial gravity. In addition to a thermal design emphasis, a multi-disciplinary team to consider structural and mechanical aspects of the thermal radiator design is needed.

Teams should also conduct analyses to assess whether thermal fluids are maintained above the freezing point in approaches/designs considered and predicted performance of the system. Prototypes or laboratory proof of concepts (where feasible) are also value added. Teams may choose to focus more on certain aspects of the design and optimization activities listed previously. The scope of the effort will depend on the size of the team, their specific expertise and interests, and the resources available to them.

Expected Product (delivery item/concept):
The primary outcome expected (at a minimum) would be a study report covering the requirements for the radiator design, a trade study of various designs and approaches, a summary of design choices and rationale (including CAD models), considerations for operating the system in the lunar environment (including partial gravity, dust, and periods of eclipse), resource estimates, performance predictions, and modeling/simulation of the concept (structural models and thermal models). If time and resources are available, teams may build prototypes or develop a laboratory proof of concept to further explore their design.

Expected Result (knowledge gained):
The knowledge gained from this study will assist NASA in developing novel thermal approaches for operation in the challenging lunar surface environment. The project directly addresses NASA technology gaps for surface habitation in the area TX14: thermal management systems.

Relevance to Exploration:
The studies under this topic have direct linkage to ongoing concept development for the lunar surface habitat. Lessons learned may also be applicable to Mars transit habitat and/or Mars surface habitation. Improved radiator design is part of an effective thermal control strategy for enabling survival of planetary surface assets in the lunar night.

Level of Effort for student team:
The study team will complete the effort during the course of an academic year (September 2023 to May 2024). A team of students will consistently engage with NASA stakeholders and mentors in habitation and thermal analysis. Students will participate in reviews with NASA personnel, including a kickoff meeting, system requirements review, preliminary

design review, checkpoint review, critical design review, and final review, consistent with the X-Hab program requirements. The team's products will include a study report. Teams are also encouraged to develop supporting prototypes, simulations, and/or conduct human factors studies.

Level of effort for NASA team:
The NASA team will provide subject matter experts to mentor the students within key technical areas, including thermal engineering, materials, structures/mechanism design, and systems engineering. For trade studies and concept development, NASA will assist the team by providing background information on the lunar environment, information on previously published thermal design approaches, and technology gaps. Ground rules and assumptions for future habitation platforms will also be provided.

Suggestion for seed funding (~$10-$50k):
$20K from NASA. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, 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.

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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

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 Lunar 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.