NATIONAL SPACE GRANT FOUNDATION

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# Moon to Mars eXploration Systems and Habitation (M2M X-Hab) Academic Innovation Challenge – FY25 Solicitation

**on behalf of**

## NASA Headquarters
## Human Exploration & Operations Mission Directorate

***Sponsored by:***

## NASA Exploration Capabilities

Release Date: March 6, 2024
Proposals Due: April 26, 2024
Anticipated Award Date: May 24, 2024
Program Website: https://www.spacegrant.org/xhab/

# X-Hab 2025 Academic Innovation Challenge Solicitation

## 1. Funding Opportunity Description - Synopsis

The Moon to Mars eXploration Systems and Habitation (M2M X-Hab) 2025 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.

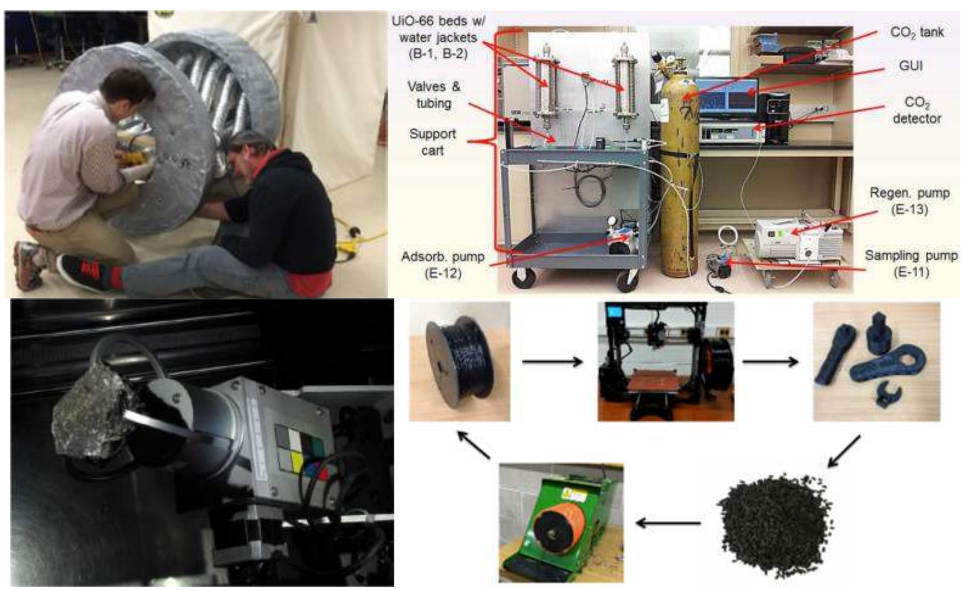



**Figure 1.** Previous X-Hab Projects (from top left, clockwise): Deployable Airlock, Closed Environment Air Revitalization System Based on Metal Organic Framework Adsorbents, Carbon-fiber/Fused Deposition Modeling Spacecraft Structural Fabrication System, Sample Handling System for GeoLab Glovebox (Image 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) 2025 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 2025 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 2024-2025 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**):

- 04 Oct 2024 – Requirements and System Definition Review (SDR)
- 08 Nov 2024 – Preliminary Design Review (PDR)
- 17 Jan 2025 – Critical Design Review (CDR)
- 07 Mar 2025 – Progress Checkpoint Review
- 05 May 2025 – 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: Autonomous Robotic Assembly and Construction of Artemis Base Camp 2040. What would that look like?

- Project Title: Rack and Stack: Design of Payload Racks to Support Future Habitation Platforms and Exploration Missions

- Project Title: Crew Mobility Modalities inside Moon/Mars Habitats

### 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, 2024.
Responses will be posted on April 12, 2024.

### 3.5 Pertinent Dates

**Proposal Phase**

| | | | |
|---|---|---|---|
| 06 | Mar | 2024 | Date of Announcement and Release of RFP |
| 03 | Apr | 2024 | Questions for online Technical Interchange due |
| 12 | Apr | 2024 | Responses to submitted questions published online |
| 26 | April | 2024 | Proposal due |
| 24 | May | 2024 | Award announcements |

**Award Phase**

| | | | |
|---|---|---|---|
| Summer - Fall 2024 | | | Design phase |
| Sept 2024 | | | Kickoff meetings |
| 04 | Oct | 2024 | Requirements and System Definition Review (SDR) |
| 08 | Nov | 2024 | Preliminary Design Review (PDR) |
| 17 | Jan | 2025 | Critical Design Review (CDR) |
| 07 | Mar | 2025 | Progress Checkpoint Review |
| 05 | May | 2025 | 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, 2024, to May 31, 2025. 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 2025 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 2025 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 2025 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 2024-25 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 2025 Academic Innovation Challenge will be implemented during the 2024-2025 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, 26 April 2024**. *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 2024.

**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:**
NASA Autonomous Robotic Construction Projects - TLT, PASS, ARMADAS

**Project Title:**
**Autonomous Robotic Assembly and Construction of Artemis Base Camp 2040. What would that look like?**

**Scope of the challenge:**
*If in-space assembly and construction technologies were adopted and part of the critical path for the Artemis program, what would Artemis base camp look like in the year 2040?*

**Description:**
*NASA is developing robotic assembly and construction technologies for large Lunar infrastructure and needs help from students to develop a concept of operations for robotic assembly of the Artemis base camp. NASA is leveraging lessons learned from existing GCD/Polaris assembly projects (ARMADAS, PASS, TLT). This new start project will develop core assembly technologies, including Structures, Robotics, Autonomy, and Outfitting. This technology will lay the foundation for how we build infrastructure in space and will serve as the interface between many systems.*

*Students will be involved in early phase requirement definitions, trade studies, analysis, and concept of operations development. The development will continue to evolve and eventually guide implementation planning of these technologies with the Artemis base camp. Artemis base camp will require multiple functional structures for a sustainable lunar presence. Students should consider structures for power, shelters, blast shielding, and in-situ resource utilization (mining, refinement, and processing) and how these may be robotically assembled.*

*Various robotic assembly systems and technologies should be considered. A study of the structural requirements of Artemis base camp infrastructure should begin the effort. Followed by a survey of available technologies and/or approaches that may fulfill those needs. The available technologies and/or approaches will be traded considering figures of merit (Technology readiness level, system mass, power requirements, cost, assembly reliability, structural performance, assembly throughput, assembly scale etc.). Finally, a concept of operations (ConOps) detailing how the technologies may be implemented with the Artemis base camp will be developed.*

**Figure 1 NASA robotic assembly systems, a.) ARMADAS b.) PASS, and c.) TLT**

**Expected Product (delivery item/concept):**
*Expected deliverables include analysis, architecture studies, mission design, trade studies, and recommendations.*

**Expected Result (knowledge gained):**
*The sponsoring project would like to receive support infusing autonomous robotic construction system to Moon 2 Mars architecture and lunar infrastructure development. They would also like support in developing mission ConOps and trade studies.*

**Relevance to Exploration:**
*Construction of infrastructure for space exploration is critical in building a sustained presence on orbit, the Lunar surface, and beyond. This work will address gaps in TA 4,7,10,11,12, and 13. This highly integrated and cross cutting technology development will address many gaps NASA's STMD and ESDMD areas related to tower assembly (629, 618, 636, 630), robotic assembly of modular structure (513, 1409, 1471), autonomous multi-agent construction (1412) and many more. Work in this area will range from TRL 4 to 6.*

**Level of Effort for student team:**
*General tasks include systems engineering work of requirements development, conducting trade studies, mission design and analysis and more. Mechanical, electrical engineering, computer science, and robotics will be utilized in the analysis of systems to advance robotic construction technologies.*

**Level of effort for NASA team:**
*The NASA team will provide subject matter experts to mentor the students within key technical areas, including materials, structures, systems engineering, and robotics. For trade studies and concept development, NASA will assist the team by providing background information outfitting needs, and technology gaps. Ground rules and assumptions for future construction platforms will also be provided. NASA subject matter experts will hold bi-monthly tag-ups with student teams to ensure applicability of the work to the a*utonomous robotic construction project *and regular communication.*

**Suggestion for seed funding (~$10-$50k):**
*~15K from NASA. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.*

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

**Project Title:**
*Rack and Stack: Design of Payload Racks to Support Future Habitation Platforms and Exploration Missions*

**Scope of the challenge:**

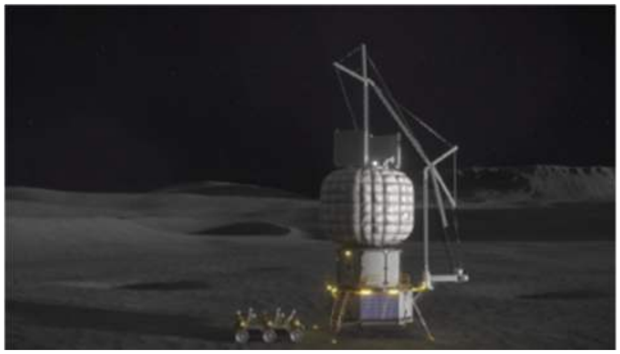
*NASA's Artemis program seeks to return humans to the Moon and establish a sustained presence there, with the goal of using the Moon as a proving ground to develop technologies and train crew to support future Mars missions. One of the key tenets of Artemis is using the moon and cislunar space to conduct science, with the goal of expanding knowledge in the areas of human research, heliophysics, planetary science and geology, astrophysics, and biological and physical sciences. Future habitation platforms, such as a lunar surface habitat, will contribute to these advancements by providing an internal volume for intravehicular (IVA) science operations and technology testing/maturation.*

*For the past 24 years, the International Space Station (ISS) has served as the singular IVA testbed for microgravity science, and technology demonstration. While low earth orbit platforms like the ISS and future commercial capabilities will continue to provide orbiting laboratory spaces for science utilization and technology maturation, this challenge asks teams to consider the potential uses of future habitation platforms beyond low earth orbit for these same purposes. NASA is currently developing concepts for a lunar surface habitat, a Mars transit habitat, and a Mars surface habitat, which could provide volume allocations and payload accommodations for science and utilization activities, logistics, and general storage. Teams will consider science objectives and community documents related to the Artemis campaign alongside NASA's envisioned futures for technology development to help define use cases for future habitation platforms in the areas of science and utilization. Teams should consider the ISS-based International Standard Payload Rack and how this design could be adapted or modified to best support future surface habitation platforms. A standard payload rack design is typically paired with a standard payload housing (referred to as payload locker on ISS) to enable different kinds of payloads packaged in a standard design to be easily installed and removed as needed throughout the life of the habitat. The standard rack typically provides resources to payloads such as power, data, cooling, waste gas venting, and even access to potable water. Teams may generate entirely new rack designs and/or define improvements and recommendations for heritage payload rack designs which can better enable science and utilization activities for a lunar surface mission, with extensibility to the Mars surface. Designs for the payload enclosures that interface with the rack should also be considered. Layout studies and trades to optimize rack placement within the habitat may also be considered. Teams are strongly encouraged to build prototypes of their design(s) which are representative of the form and fit of the rack. Human factors studies to understand human-system interaction in partial gravity environments are also desired as part of the work. Special consideration should also be given to ease of maintenance and repair for systems housed within the racks and ease of affixing equipment with minimal tooling required to minimize the crew time burden.*

Image of EXPRESS rack with payloads from ISS.

**Description:**

*The International Standard Payload Rack (ISPR) design has heritage for ISS and Shuttle operations. As such, it has been a major driving interface for spacecraft systems and payloads. Before NASA adopts applying such a standard design to future spaceflight systems, it should be re-assessed with consideration to new habitation system design (including layouts enabled by alternative structural material options such as inflatable softgoods) and completely new operating environments, to include the partial gravity environments of the Lunar and Martian surface. Concepts for a lunar surface habitat would allow crew to extend their time on the moon's surface and conduct additional science. The lunar surface habitat concept pictured below consists of a metallic airlock for ingress/egress with an inflatable softgoods structure comprising the habitable volume. Inflatable softgoods are one structural material option for future habitation platforms. Inflatables represent a complex multi-material system which could enable a much greater volume per unit mass relative to traditional rigid metallic structures, potentially allowing for a larger portion of a habitat's interior volume to be allocated to utilization. A Mars Transit Habitat concept, which could support crew on an up to 1,200 day mission, may also leverage this material system. Some information on habitation conceptual designs can be provided to student teams for reference as they develop requirements and consider optimization of rack design for specific mission scenarios, including the most recently published version of ground rules and assumptions for habitation.*



Example of lunar surface habitat concept.

*In the course of the project, teams are expected to work with NASA mentors and subject matter experts to develop alternative rack geometries and interfaces which would be optimized for lunar surface habitation (1/6 gravity), with extensibility to Mars surface habitation (1/3 gravity). Teams may start with a baseline design for a microgravity rack interface, which could leverage heritage approaches, and identify modifications which might be needed to implement the rack in planetary surface mission scenarios. Teams should consider the effects of different gravity environments on servicing and rack replacement, recommending design modifications and operational accommodations. For lunar surface habitation, long periods of dormancy (up to three years) when no crew are present are possible, as well as high oxygen environments (up to 40% oxygen), and these constraints should be considered in the design. A Mars transit habitat will also likely experience periods of dormancy, with the length of these periods depending on the specific concept of operations. Racks could launch as initial mass within a surface habitat or be transferred into the habitat later on a subsequent mission. Launch loads and hatch sizes should thus also be a design consideration, as well as landing/atmospheric entry loads for rack systems that would be deployed on a planetary surface.*

*While the type of payloads future exploration habitation platforms may need to support are not defined at present, teams may use ISS capabilities as an initial basis for reference. There is also a recently released white paper on potential utilization capabilities for commercial low earth orbit platforms. Typical resources required by payloads include power, data, cooling, waste gas venting, access to potable water, and mechanical interface attachment points to attach to the rack. At the project start, teams will work closely with NASA subject matter experts to define specific capabilities to focus on for exploration habitation applications and better define anticipated payload accommodations requirements.*

*The project should seek to understand if a single rack geometry and interface can meet the needs of multiple environments or whether multiple variations are needed. If multiple rack designs are developed, teams should identify where commonality in the design (for Moon and Mars scenarios) can be applied. Teams are expected to leverage NASA system engineering practices to arrive at conceptual designs, evaluate designs, and make recommendations for specific use scenarios. Teams are strongly encouraged to build prototypes and conduct proof of concept testing, to potentially include human factors testing and consideration of partial gravity environments. The ability to service payloads and systems within a rack and maintain systems is an important consideration for future missions. Crew time will be limited; thus design features that facilitate ease of access to systems housed within the rack and maintainability are desired.*

*There are also multiple options for rack configuration and placement within a habitat layout. Teams may consider trades of these options to determine an optimum layout for space* *allocated in a specific platform/mission scenario. Teams may also consider rearrangement/movement of racks to support different numbers of crew and a rack design's ability to accommodate changes in mission objectives, needs, and priorities over a habitat's operational life. With an inflatable habitat design, there are also particular considerations with packaging and deployment of racks which should be considered, as systems may not be able to launch pre-integrated as they could in a metallic module. Attachment of racks to inflatables poses a challenge, as the structure itself may not have a rigid attachment point on the interior – cantilevering off a metallic core structure may be one potential option for installation of these systems within an inflatable architecture.*

**Expected Product (delivery item/concept):**

*The expected product is a final study report covering the overall rack design, concept of operations for rack replacement and servicing, and extensibility of rack design to different mission scenarios and environments. Teams should focus on lunar surface applications initially, but consider extensibility of designs to the Mars surface. The team should provide computer aided design (CAD) renderings of recommended rack solutions and CAD walkthroughs showing the integration/configuration of racks in a representative habitat environment. In product reporting, teams should capture mass, volume, power, and other changes relative to the ISPR baseline. The concept of operations should also capture alternative uses/repurposing/disposal of racks at end of life if not returned to Earth. Teams are strongly encouraged to build low fidelity prototypes and perform human factors testing. Teams should develop recommended rack design requirements to support anticipated science objectives and accommodate payloads. The final report should summarize the design process used, alternatives investigated/analyzed, and solutions.*

**Expected Result (knowledge gained):**
*The knowledge gained from this study will assist NASA in developing rack designs and interfaces to support science and utilization on future missions.*

**Relevance to Exploration:**
*The studies under this topic have direct linkage to ongoing concept development for the lunar surface habitat, Mars transit habitat, and Mars surface habitation.*

**Level of Effort for student team:**
*The study team will complete the effort during the course of an academic year (September 2024 to May 2025). A team of students will consistently engage with NASA stakeholders and mentors in habitation and utilization. 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 strongly 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 habitat design, structural analysis, and human factors. For trade studies and concept development, NASA will assist the team by providing background information on habitation concepts currently in development, ISPR and other rack or pallet designs which have been previously studied, relevant environments payload racks would operate in, and current plans for science and utilization activities in exploration habitation platforms. Students will be provided*

*with a library of references as a starting point and will have access to NASA advisement throughout the course of the project.*

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

**Project Sponsor:**
Mars Campaign Office (MCO) Activity Portfolio

**Project Title:**
Crew Mobility Modalities inside Moon/Mars Habitats

**Scope of the challenge:**
Paradigm, infrastructure, and conceptualization of novel crew mobility modalities inside Moon/Mars habitats

**Description:**
Habitat designs for the Moon and Mars favor structures with small footprint and use of elevation for living, work, and activity spaces. One would typically think then that crew will move up and down using stairs. However, the weight of a person on the Moon is 16.5% and on Mars 34% of his/her weight on Earth. Therefore, mobility on the Moon or Mars can happen in novel ways as humans are much lighter than on Earth. It is possible then to change the paradigm of mobility from walking and using stairs to jumping, climbing, swinging, pole transportation, and other modes. These are more dynamic mobility modes and can also help maintain aerobic conditioning and mitigate muscle and bone density loss in a natural way, complementing scheduled exercise and increasing the efficiency of crew. These mobility modalities would also add a fun/entertainment component in the day-to-day.

The challenge is then to design the elements in a habitat that accommodate the new mobility modalities, design the instrumentation (wearable and in the habitat) to measure parameters that enable assessment of health and performance that can be used by incorporating these mobility modalities in the habitat, as the crew go about their day activities moving around the habitat.

This project could have a validation component using the ARGOS system (Active Response Gravity Offload System) at JSC BekdashEtAl_ICES2020_ARGOS-Lunar-EVA-Simulation-Environment.pdf (usra.edu)

Figure 1. Kahn Yates - Phase 3: Level 1 of NASA's 3D-Printed Habitat Challenge
(https://youtu.be/a_BN_xJZMOk?si=sFW6746mV1UhY1rz)

Figure 2. AI SpaceFactory - MARSHA - Our Vertical Martian Future - Part One
(https://youtu.be/XnrVV0w2jrE?si=EULXNl9v358UCGfW)

**Expected Product (delivery item/concept):**
The team will create a complete solution that makes possible the novel mobility modalities, including:

- Conceptualize new mobility modalities for Moon/Mars habitats
- Define mobility paradigms and concepts of operations that may be desirable
- Define requirements
- Define and design the infrastructure needed to support these mobility modalities inside the habitats.
- Specify the design of the instrumentation (wearable and/or in the habitat) to measure parameters to assess health and performance as enabled by these mobility modalities in the habitat. If possible, develop prototypes that could be simulations.
- Develop physics dynamic models representing crew moving in the habitat in order to predict forces and aerobic motion (e.g. platforms, hanging infrastructure, hand-grips, and others).
    - This will help define form and function of the additional habitat infrastructure to support the movement modalities.
- Create visual representation of crew movement leveraging the physics simulations.
    - Run simulations of use-cases representing day-to-day crew movement.
- Define a concept of operations that integrates information from these crew movement modalities into autonomous capabilities of the habitat and crew health and performance systems

**Expected Result (knowledge gained):**
The MCO activity portfolio matures exploration capabilities to enable future missions to Mars through development activities on Earth and on the lunar surface. The MCO activity portfolio also addresses and fills high priority technology gaps that are identified by the Agency Strategic Capabilities and Leadership Teams (SCLT), Agency Principal Technologists, and Moon to Mars Programs.

The anticipated results from the project should represent a complete solution that enables the novel movement modalities and should include results from the Expected Product Section above.

The resultant products are expected to address technology needs required to fill current Moon to Mars Program Technology Capability Gaps described below.

**Relevance to Exploration:**
The project will address the following HEOMD-Technology Capability gaps:

| Gap ID | Capability Gap Title |
|---|---|
| 06-107 | Semi-autonomous Behavioral Health and Performance Technologies |

And STARPort Gaps:

| Taxonomy (TX) | | Gap IDs | | Basic Gap Information | |
|---|---|---|---|---|---|
| TX Level 1 | TX Level 2 | STARPort ID | FY21 ESTMD | Capability Gap Title | Gap Description |
| TX06 - Human Health, Life Support, and Habitation Systems | TX06.3 - Human Health and Performance | 724 | 3525 | Crew Health and Countermeasures Informatics Tool | Ground-based and in-flight informatics tools are needed to monitor and optimize crew health and performance capabilities via improving use of exploration countermeasures use during increasingly earth-independent, resource-constrained, and long-duration mission operations. An Integrated Data Architecture is needed to operationalize these tools and enable near real time feedback. |
| TX06 - Human Health, Life Support, and Habitation Systems | TX06.3 - Human Health and Performance | 771 | 2935 | Exercise System | Exercise countermeasures and assessment tools to maintain and monitor physical health and enable performance of critical exploration mission tasks during 0-gravity and reduced-gravity exploration missions. |

**Level of Effort for student team:**
The study team will complete the effort during an academic year (September 2024 to May 2025). General tasks include systems engineering work of requirements development, conducting trade studies, mission design and analysis and more. Mechanical, electrical engineering, computer science, and other appropriate engineering disciplines will be utilized in the analysis of systems to advance development of the proposed concepts. A team of students will consistently engage with NASA stakeholders and mentors in habitation and utilization. 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 and others as specified in the section above. Teams are also strongly encouraged to develop supporting prototypes, simulations, and/or conduct human factors studies.

**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.

## 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

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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

______________________________________________

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 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.