NATIONAL SPACE GRANT FOUNDATION

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Moon to Mars eXploration Systems and Habitation (M2M X-Hab) Academic Innovation Challenge – FY26 Solicitation

Sponsored by:

NASA Mars Campaign Office

Release Date:	March 14, 2025
Proposals Due:	April 28, 2025
Anticipated Award Date:	May 26, 2025
Program Website:	https://www.spacegrant.org/xhab/

X-Hab 2026 Academic Innovation Challenge Solicitation

1. Funding Opportunity Description - Synopsis

The Moon to Mars eXploration Systems and Habitation (M2M X-Hab) 2026 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.

Innovation is the keystone to this challenge. Universities and investigators not normally associated with the aerospace industry are encouraged to consider their potential contribution to changing the way the space industry views the solution space.

NASA's Mars Campaign Office (MCO) anticipates offering multiple awards of up to $15k - $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 1Figure 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 MCO mentors in May 2026. Universities may form collaborations to perform as a single distributed project team.

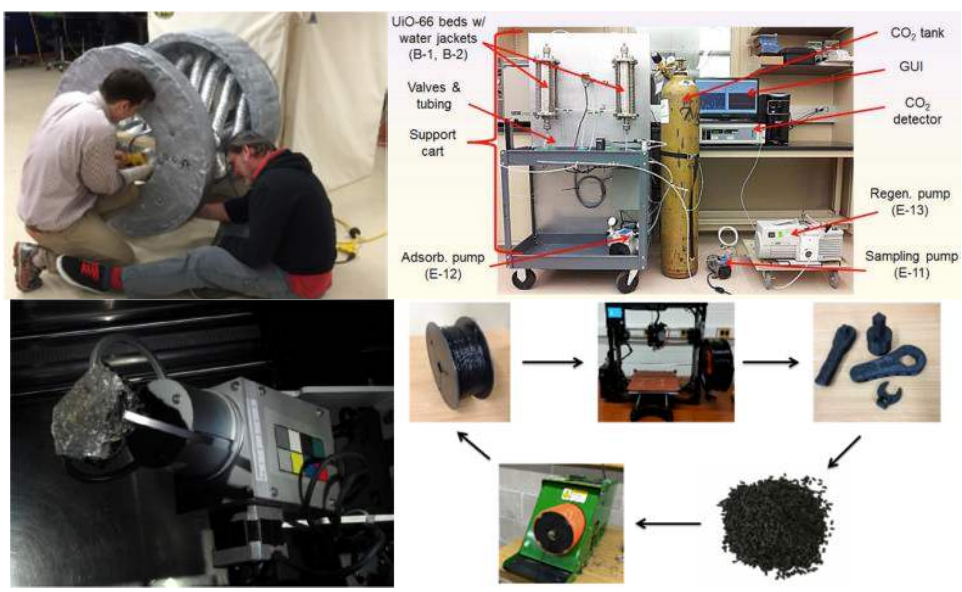


Figure 1. Previous X-Hab Projects (from top left, clockwise): Deployable Airlock, Closed Environment Air Revitalization System Based on Metal Organic Framework Adsorbents, Carbon-fiber/Fused Deposition Modeling Spacecraft Structural Fabrication System, Sample Handling System for GeoLab Glovebox (Image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

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 Academic Innovation Challenge 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 Academic Innovation Challenge. For the current “Controlled Countries” list, reference EAR Part 768.1d

3. Funding Opportunity Description - Details

3.1 Description

NASA’s multicenter MCO is requesting proposals for the Moon to Mars eXploration Systems and Habitation (M2M X-Hab) 2026 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 2026 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 MCO 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 2025 and spring 2026 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 2025-2026 academic year.

NASA understands that the funding awarded as part of this solicitation may not be sufficient to meet all requirements; 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, as described in their proposal. 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.

NASA's MCO anticpates multiple awards of $15k - $50k per award.

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 2025 – Requirements and System Definition Review (SDR)
- 10 Nov 2025 – Preliminary Design Review (PDR)
- 19 Jan 2026 – Critical Design Review (CDR)
- 08 Mar 2026 – Progress Checkpoint Review
- 06 May 2026 – 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: MCO

- Project Title: Autonomous Charging Service Capability for Surface Rovers and Systems
- Project Title: Lightweight Active Surface Tunnel Elements for Pressurized Transfer
- Project Title: COOLER – Cryogenic Operations for Off-gassing Losses and Efficient Recovery
- Project Title: What to do with all this CO2? Regeneration in a Martian Environment
- Project Title: Medical Eyewash Redesign
- Project Title: Mechanical Sealing of a Cryogenically Cold Circular Interface in a Vacuum
- Project Title: R&D for Lightweight Space Suit Portable Life Support System (PLSS)
- Project Title: Smart Textiles for Space Applications

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 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 to address NASA problems and advance technology development in a flexible way for technological breakthroughs.

The MCO 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 challenge 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 MCO 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. Universities and investigators inexperienced with an X-Hab cycle are highly encouraged to reach out to ask questions and apply for consideration.

3.4 Online Technical Interchange Forum

Prior to the proposal submission deadline, an online Technical Interchange will be posted for NASA MCO 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, 2025.
Responses will be posted on April 11, 2025.

3.5 Pertinent Dates

Proposal Phase

14	Mar	2025	Date of Announcement and Release of RFP
03	Apr	2025	Questions for online Technical Interchange due
11	Apr	2025	Responses to submitted questions published online
28	April	2025	Proposal due
26	May	2025	Award announcements

Award Phase

Summer - Fall 2025			Design phase
Sept 2025			Kickoff meetings
06	Oct	2025	Requirements and System Definition Review (SDR)
10	Nov	2025	Preliminary Design Review (PDR)
19	Jan	2026	Critical Design Review (CDR)
08	Mar	2026	Progress Checkpoint Review
06	May	2026	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.

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, 2025, to May 31, 2026. 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 2026 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. This is an academic challenge and is treated as such.

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 2026 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 2026 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.
    - *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 2026 Academic Innovation Challenge will be implemented during the 2025-2026 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 MCO objectives.
- Demonstrate an innovative or non-traditional approach.
- 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.
- **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 requesting funding in excess of 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 2025**. *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 2025.

4.4 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 challenge, 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 Title: Autonomous Charging Service Capability for Surface Rovers and Systems

Scope of the challenge:
The scope of this project challenge includes design and pilot demonstration of an autonomous charging station servicing a rover. The systems involved include a charging station and a rover, both with charge and communication interfaces.

Detailed Description:
Autonomous operations on the surfaces of the Moon and Mars will require power charging of many assets, including rovers. For context, a nominal scenario could involve a (1) charging station (e.g. located either next to a power generation station or on a lander) and (2) rovers, that when batteries get low (i.e. battery charge exhausted from performing activities), will need to charge. This challenge seeks to develop and demonstrate technologies for autonomous charging of rovers. The following elements need to be addressed:

1. A rover with capability to execute charging tasks in collaboration with a charging station.
2. A charging station with capability to execute charging tasks in collaboration with a rover.
3. ConOps for the autonomous charging activity.
4. A use-case scenario that captures challenges for the charging station and rover to perform autonomous charging, considering a range of circumstances i.e, assessment of system health and management of resources (such as power, navigation, and other).

Expected Product (delivery item/concept):

- Rover with capabilities for autonomous charging
- Charging station with capabilities for autonomous charging service
- ConOps for autonomous charging
- A scenario to demonstrate autonomous charging
- A demonstration of autonomous charging

Relevance to Exploration:
Sponsoring the project addresses the following MCO New Start focus area, Surface Systems & Environments, area of interest in

3.1 Power Management and Distribution between Surface Elements (PMAD)

- 3.1.1. Surface Power Management integrated hardware and software system
- 3.1.4 Surface Element Power Exchange Interface design

Student Skills Required:
Student teams will benefit from participation in a variety of disciplines, including topics such as engineering, computer science, intelligent systems, autonomous systems, systems engineering and other associated technologies in support of implementing the NASA Design Review Process for developing a technology.

Anticipated Funding Requirements:
NTE 30K from X-Hab. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

Project Title: Lightweight Active Surface Tunnel Elements for Pressurized Transfer

Scope of the challenge:
This challenge seeks to develop novel concepts for a lightweight pressurized tunnel system that can provide active positioning and berthing between crewed surface assets. Prototyping and demonstrations of concepts are highly encouraged.

Detailed Description:
NASA's Artemis campaign seeks to return humans to the lunar surface and establish a continuous presence there. The Artemis missions will be used to test technologies in the "lunar proving ground" and prepare for eventual human Mars exploration. Both NASA's lunar and Mars architectures are in development. This project asks teams to consider tunnels as a possible means of connecting elements on the lunar or Mars surface. Elements may include habitats, rovers, logistics carriers, or landers. Tunnels could enable crew to transfer between pressurized elements without conducting an extravehicular activity (EVA). In this case, tunnels serve to limit dust contamination inside habitable volumes and reduce radiation levels crew are exposed to in the transit between elements. Tunnels may also support aggregation of elements to support larger crew sizes and make logistics transfer between elements easier.

One challenge in tunnel design is that current active docking/berthing tunnel concepts are mass prohibitive. This is due to the required 6 degree of freedom (DOF) articulation of the active end and high loading in the actuation system when the element is pressurized for crewed access. The current baseline approach uses large and heavy linear actuators to address these requirements (Figure 1). This project seeks novel solutions to reduce the mass and volume of the tunnel system. Solutions should be extensible to different mission scenarios, maximizing scalability in connecting together pressurized surface elements in the most efficient manner. Elements to be connected by tunnels may include habitats, pressurized rovers (Figure 2), logistics carriers, and ascent/descent elements.

Considerations in the proposed work:
- Crew safety and ease of ingress/egress.
- Operation on the surface of the Moon/Mars in a gravity field and exposure to the thermal/dust environment.
- These systems could include a combination of active and passive elements, and trade coarse positioning + mechanical capture zones vs. fine positioning.
- Actuation/positioning of the tunnel should have minimal impact on the connected elements in terms of inducing additional loads/moments, i.e. self-reacting is preferred.
- Scalability: Consider impacts on design if tunnel needs to be 5-ft, 10-ft, 20 ft long, or if hatch/interface is different at each end.
- Reusability / relocatability. Optimality of modular vs. integrated approaches.

Expected Product (delivery item/concept):
The expected product is a final study report which summarizes the tunnel design(s) developed and any trade studies which informed the designs. Teams should document their assumptions and assess scalability of the design(s) (length of tunnel, differences in interfaces) and extensibility to connect different assets in a variety of mission scenarios. Detailed supporting analyses should be provided to justify design decisions. Computer-aided design (CAD) renderings and walkthroughs of CAD models showing the integration of tunnels with surface assets are also expected. Teams should capture the estimated mass/volume of their tunnel design and document materials selection. Deployment mechanics should also be assessed,

along with the ability to reuse and relocate tunnel structures to support different mission elements and dispersed locations for operations. Reporting should summarize all trades, analysis, and testing completed.

The development of a prototype demonstrator (sub-scale is appropriate) tunnel and actuation system, and control software is highly desired as part of the effort. Demonstrations can be performed at the university and videoed, to be presented with the final report and presentation.

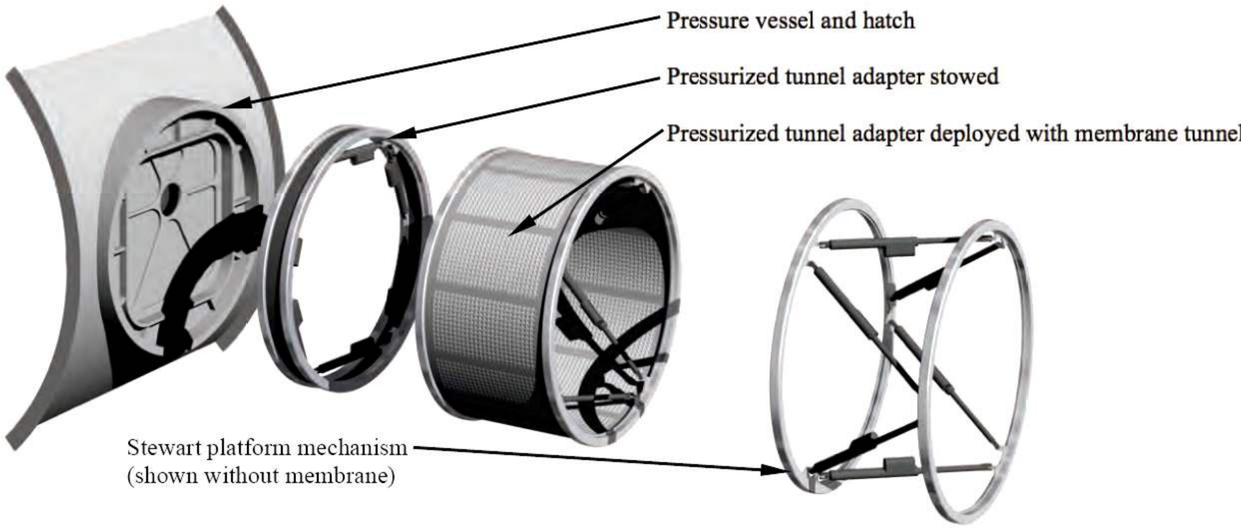


Figure 1 – Articulated Tunnel Concept JPL[2]

Figure 2 - Mars Tunnel Concepts[3]

Relevance to Exploration:

This work aligns with and addresses several technical gaps identified for surface exploration: a) docking and berthing between surface elements on the Moon and Mars, and b) high-reliability actuators, sensors, and interfaces. Artemis campaign and Moon-to-Mars architecture can benefit from the development of compliant berthing between surface elements, especially in regard to increasing mission productivity / efficiency by reducing the number of required EVAs. The development of a lightweight, stowable, articulating pressurized tunnel element is a potentially high impact, enabling technology for all of NASA's future surface exploration mission architectures.

Student Skills Required:
Students are asked to investigate the trade-space of tunnel designs, and based on the derived assumptions, generate possible solutions, with supporting analyses of promising concepts using closed form structural analysis and FEM where appropriate. Design and fabrication of a prototype(s) to test concept(s) and control schemes for positioning, and software development and testing is strongly desired. Roles/skills would include: team leadership, technical integration across engineering disciplines, CAD competencies, structural analysis, manufacturing/fabrication, software development, testing, and technical writing/communication.

Anticipated Funding Requirements:
$20-30K from X-Hab dependent upon scope. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

REFERENCES

[1] Moon to Mars Architecture Definition Document, Revision B. NASA/TP-20240015571. NASA Exploration Systems Development Mission Directorate.

[2] Rucker et al., "Mars surface tunnel element concept," 2016 IEEE Aerospace Conference, Big Sky, MT, USA, 2016, pp. 1-12.

[3] Howe, A.S., "A Modular Habitation System for Human Planetary and Space Exploration", 45th International Conference on Environmental Systems (ICES2015), Bellevue, WA, USA, 2015.

Project Title: COOLER – Cryogenic Operations for Off-gassing Losses and Efficient Recovery

Scope of the challenge:
Design a passive storage system that efficiently recaptures and recondenses cryogenic fluid boil-off. Note: No prototype is required for this effort

Detailed Description:
During long-duration space travel, the cryogenic storage of liquids and propellants is essential for life support, propulsion, and scientific applications. However, a natural byproduct of storing cryogenic fluids is boil-off, where a portion of the liquid phase transitions into gas due to ambient heat and system inefficiencies. Over time, this leads to a gradual loss of valuable resources, increasing mission risk and resupply needs.

To address this challenge, develop a passive storage system that minimizes boil-off losses by efficiently recapturing and recondensing the evaporated cryogenic fluid. The solution should leverage deep space cooling, heat exchangers, mechanical relief valves, reduce the reliance on cryogenic pumps, and minimize system complexity.

Expected Product (delivery item/concept):
Deliverables:

1. System Design & Schematic – A detailed engineering design of the proposed passive storage system, system architecture, and schematics illustrating key components and functionality.
2. Procedural Operations – A step-by-step outline of how the system operates, including fluid dynamics, thermal management, and passive recovery processes in relevant space environments.
3. System Calculations – Analytical and numerical justifications of the design, including:
    - Expected boil-off rates and recovery efficiency
    - Thermal management and heat transfer calculations
    - Mass, volume, and power constraints
    - Materials selection and longevity considerations
4. Final Presentation – A professional presentation summarizing the team's findings, design rationale, key performance metrics, and potential applications. This will be presented to a panel of subject matter experts.

Relevance to Exploration:
Development of this technology will aid in enabling deep space exploration by allowing NASA to reduce its required propellant upmass by 15 ~ 20%. The reduction in upmass allows for tremendous initial cost savings while also decreasing the need for future resupply missions. The knowledge learned may be applicable to future cryogenic systems on the Moon and Mars.

Student Skills Required:
Participants with knowledge of Thermodynamics, Systems engineering, Pressure systems, Fluid mechanics, Mechanical, Chemical, and Aerospace Engineering are considered to be idle candidates for this project.

Anticipated Funding Requirements:
NTE $15K from X-Hab. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

Project Title: What to do with all this CO_2? Regeneration in a Martian Environment

Scope of the challenge:
Determine an optimal method to manage CO_2 for crew when encompassed by a pure CO_2 atmosphere.

Detailed Description:
For humans to live and work on the surface of Mars, the life support systems used to enable said exploration must perform in a unique environment. Mars has an atmosphere made up of nearly entirely CO_2. This resource could be utilized to generate O_2 or other useful products by collecting the CO_2 for conversion. However, CO_2 must also be removed in crewed environments to maintain health, including habitats and space suits. Several regenerable methods of removing CO_2 have been developed, but many of them require a vacuum to complete the regeneration process. Space vacuum is readily available in orbit, transit, or on the Moon, but the Martian CO_2 atmosphere would prevent any ejection of CO_2. This project aims to investigate effective ways to work around, or even capitalize on, this CO_2 equilibrium problem. Optimally maintaining atmospheric CO_2 concentrations, providing useful CO_2 products, or both via CO_2 removal and in-situ resource utilization (ISRU) are all desired to minimize mass required to explore Mars.

Expected Product (delivery item/concept):
Investigate and analyze regenerable CO_2 removal methods able to efficiently eject waste gas into a low-pressure, pure CO_2 atmosphere. Consider scaling required to implement as solutions may be applicable to suits, habitats, and/or ISRU. Develop and test a viable regeneration method, ideally utilizing a simulated environment. Deliver analysis, design, and test results, as well as expected system scaling.

Relevance to Exploration:
Optimizing how CO_2 is managed and utilized on Mars directly addresses continuous CO_2 removal systems for Mars surface EVA suit in Martian atmosphere, and could support Mars atmosphere collection and processing for ISRU.

Student Skills Required:
Students skilled in several areas of engineering, including chemical, electrical, fluids, materials, mechanical, thermal, process, systems, etc. will perform modeling, analysis, design, assembly, testing, and data interpretation. Project management of an interdisciplinary team will be key to success.

Anticipated Funding Requirements:
$15K-30K - Depending on the scope of the proposal(s), the level of government funding can be from $15K for an in-depth trade study/analysis up to $30K for building and testing of hardware in a CO2 environment.

Project Title: Medical Eyewash Redesign

Scope of the challenge:
Redesign the current ISS medical eyewash hardware for possible ISS operations and future exploration missions.

Detailed Description:
The current ISS medical eyewash hardware, pictured below, includes long tubing with a large mass/volume footprint, is single-use, and requires connection to the Russian water dispenser. Coordination with the Russian segment is necessary to use it, and once used, another must be flown up for replacement. The eyewash is intended to flush the eye in the case of chemical exposures. The goal of this project is to redesign the medical eyewash hardware to make it lower mass/volume and minimize consumables. The device must function in the spaceflight/microgravity environment. It also cannot allow contamination from one eye to the other, nor can it contaminate the potable water supply.

Don Pettit demonstrating fit of the current ISS eyewash system

Expected Product (delivery item/concept):
Deliverables include a prioritized list of available COTS solutions from a brief market survey and a recommendation on whether to purchase COTS or build a functional prototype. Depending on recommendation, the team will either deliver a functional prototype or purchase the device and assess its ability to replace the current eyewash station. Depending on route taken, funding may need to be reserved for travel to JSC.

Relevance to Exploration:
This project maps to a requirement for Medical Capabilities for Deep Space Missions and directly addresses the ability to return the crew safely, provide for maintainability and reuse.

Student Skills Required:
Desired skills include analysis using decision matrices, experience with CAD, and rapid prototyping. Engineering drawings may be necessary for functional prototype. Students will also need to be able to assess and test COTS solutions.

Anticipated Funding Requirements:
NTE $20K from X-Hab. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

Project Title: Mechanical Sealing of a Cryogenically Cold Circular Interface in a Vacuum

Scope of the challenge:
Demonstration by analysis or test of a mechanical seal of an approximately 0.50-1.0m wide tubular container and circular lid against vacuum and lunar dust using a mechanical interface at cryogenic temperatures.

Detailed Description:
Analyze and/or design a sealing mechanism between a metallic circular lid and a metallic tubular container against vacuum and lunar dust, in a lunar surface environment that is approximately 20 Kelvin. This sealing mechanism can be a one-time sealing operation, not required to re-seal once the lid is removed from the container after the initial seal is made.

Expected Deliverables include but are not limited to:

- Drawings of the mechanical interface(s)
- Data sheets on the materials used for the sealing interface
- Analysis of the seal strength regarding vacuum and lunar dust resistance
- Possible demonstration of the seal against near-vacuum and/or lunar dust simulant

Expected Product (delivery item/concept):
A detailed mechanical analysis report includes data sheets, mechanical models, drawings, and plots, as well as assumptions, inputs and outputs, data resolution, data confidence, or other descriptive or pertinent information related to the analysis.
If a physical demonstration is proposed, a materials list to include mechanical properties would be desired, as well as a description and documentation of the test hardware and setup.

Relevance to Exploration:
The cryogenic sample return portfolio, which includes FROSTE, is focused on providing the Science community with cryogenic core sample extraction and mobile deep cryo cold stowage to be utilized on the lunar surface, as well as providing environmentally controlled accommodation back to Earth for scientific research. Prevention of sample contamination due to exposure to vacuum or lunar dust ingress is critical to this goal. The Moon to Mars objectives including the Lunar/Planetary Science Goals are listed below:

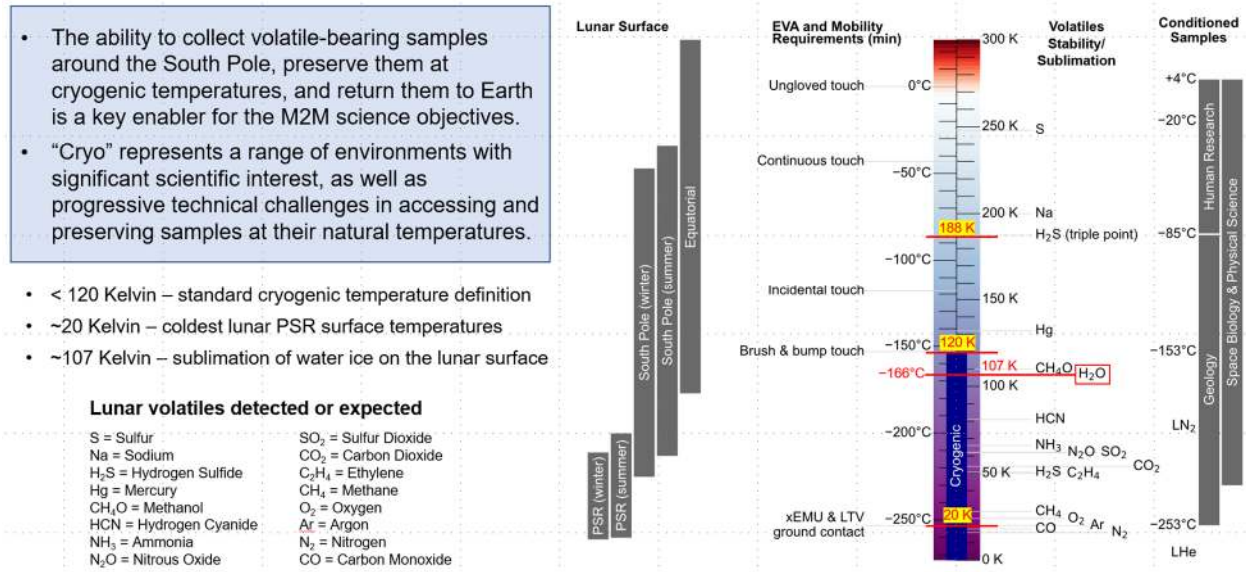
- **LPS-1:** **(*LM)** Uncover the record of solar system origin and early history, by determining how and when planetary bodies formed and differentiated, characterizing the impact chronology of the inner solar system as recorded on the Moon and Mars, and characterize how impact rates in the inner solar system have changed over time as recorded on the Moon and Mars.

- **LPS-2:** **(*LM)** Advance understanding of the geologic processes that affect planetary bodies by determining the interior structures, characterizing the magmatic histories, characterizing ancient, modern, and evolution of atmospheres/exospheres, and investigating how active processes modify the surfaces of the Moon and Mars.

- **LPS-3:** **(*LM)** Reveal inner solar system volatile origin and delivery processes by determining the age, origin, distribution, abundance, composition, transport, and sequestration of lunar and Martian volatiles.

***LM = Both Lunar and Mars Missions**

The Science driving the analysis is based on the desire to understand the volatiles contained within the Lunar surface.



Student Skills Required:
Students should be proficient in mechanical and materials analysis including modeling or other analytical techniques, as well as test requirements and planning.

Anticipated Funding Requirements:
\$15-30k funding from X-Hab depending on scope. Teams are encouraged to leverage commercial and university partnerships.

Project Title: R&D for Lightweight Space Suit Portable Life Support System (PLSS)

Scope of the challenge:
Develop design modifications to reduce the mass of the PLSS to meet Mars mission requirements.

Detailed Description:
The Exploration External Mobility Unit (xEMU) is more than 380lbs, with the PLSS at a little over 210lbs. This will not meet Mars mass requirements. The goal is to focus on reducing the weight through innovative packaging and materials on the PLSS. The PLSS uses cutting edge technology and methods, however there is room improvement in the overall PLSS assembly. As it currently makes up ~2/3rds the weight of the Space Suit, any efficiencies have a huge impact. Specifically, NASA is seeking to reduce PLSS mass to be at or less than 140lbs in 1g while maintaining functionality, safety, and backup systems as best as possible.

The goal for this project would be study either different configurations, materials or other efficiencies that could lower the weight of the suit. Additionally, system engineering approaches may be researched to provide tools to help with size/mass reduction.

- Reference for Consideration: *Ogilvie, R., Miller, S., & Hetherington, R., "Advanced Material Options for the Portable Life Support System," NASA JSC, International Conference on Environmental Systems, ICES-2024-127, July 2024.* *https://ttu-ir.tdl.org/items/1194b60a-7719-4cc3-8224-8900e2490101*

Expected Product (delivery item/concept):
A final presentation should include a recommended set of design changes to assist in meeting mass requirements. Market research of available technologies and materials, as well as a comprehensive study of current components, and potential repackaging will be expected. A PLSS mockup using new materials and methods could be invaluable. The PLSS is a complex system. Therefore, system engineering tools may be created to assist with size reduction.

Relevance to Exploration:
The weight of the space suit is critical to closing the overall mass requirement for launch and descent. Mars also has a much higher relative gravity compared to the moon (3/8 (Mars) vs 1/6 (Lunar) compared to 1g earth gravity. Therefore, while the heavy suits on the Moon is acceptable, reducing weight is critical for extended periods on Mars, especially given long term zero-g that may be required for transit.

Student Skills Required:
Students would be expected to be pursuing a degree in the engineering field focused on either Aerospace, Mechanical, or Materials. They would need to have or develop skills such as: design, modeling, prototyping, materials understanding, laboratory experience, research, literature review, and analysis.

Anticipated Funding Requirements:
NTE $30k funding from X-Hab. Teams are encouraged to leverage commercial and university partnerships.

Project Title: Smart Textiles for Space Applications

Scope of the challenge:
This research will investigate the design and fabrication of a smart textile protype for outer space application focusing on integrating stimuli-responsive polymers and/or sensors into textile architectures to enhance astronauts' thermal comfort and/or closely monitor their physiological performance. This project does not include engineering the base textile fibers themselves to meet NASA flammability requirements.

Detailed Description:
The main objective is to develop a smart textile prototype specifically designed for Intra-Vehicular Activity (IVA) environment. The core concept of the proposed protype focuses on integrating stimuli-responsive polymers (e.g., phase change materials PCMs) or other features to responds to astronaut's thermal needs in addition to incorporating sensors into the astronauts next-to-skin clothing with the purpose of assisting in maintaining an optimal microclimate condition next to the skin. Furthermore, the integration of flexible sensors directly into the textile structure may allow for continuous monitoring of key physiological parameters, such as skin temperature, heart rate, and perspiration levels. This real-time data acquisition is crucial for better understanding the astronaut's physiological response during practicing different IVA activities including exercising, which can assist in enabling optimized personalized thermal management strategies.

The smart textile prototype can be fabricated using traditional or advanced textile manufacturing techniques, such as seamless knitting or 3D weaving or the combination thereof to create a comfortable and form-fitting garment suitable for extended wear. The host textile structure has to be well engineered with a careful selection of the materials so that it is possible to maximize the effectiveness of the incorporated stimuli-responsive polymer and sensors, while also maintaining breathability, ease of movement, and durability.

Expected Product (delivery item/concept):
Expected product can be a functional smart textile prototype suitable for use in an intravehicular environment. This prototype can be a standalone garment or a layer to be integrated into existing IVA clothing constructed from traditional or advanced textiles incorporating stimuli-responsive polymers and integrated sensors.

Relevance to Exploration:
The outcome of the present study is expected to help gain better understanding of the astronauts' physiological performance during their prolonged stay in the reduced pressure environments planned for exploration (up to 40% O_2, 8.2 psi) and can assist in addressing their body needs in this new environment.

Student Skills Required:
A mixture of general engineering skills such as mechanical, materials, and electrical is required, and prior knowledge in polymers, textiles and wearable sensors would be advantageous.

Anticipated Funding Requirements:
NTE $20k funding from X-Hab. Teams are encouraged to leverage commercial and university partnerships.

Appendix C: Standard Education 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 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

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.