



**Moon to Mars eXploration Systems and Habitation
(M2M X-Hab)
Academic Innovation Challenge – FY27
Solicitation**

Sponsored by:
NASA Mars Campaign Office

Release Date: March 12, 2026
Proposals Due: May 1, 2026
Anticipated Award Date: June 5, 2026
Program Website: <https://www.spacegrant.org/xhab/>

X-Hab 2027 Academic Innovation Challenge Solicitation

1. Funding Opportunity Description - Synopsis

The Moon to Mars eXploration Systems and Habitation (M2M X-Hab) 2027 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 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 2027. Universities may form collaborations to perform as a single distributed project team.

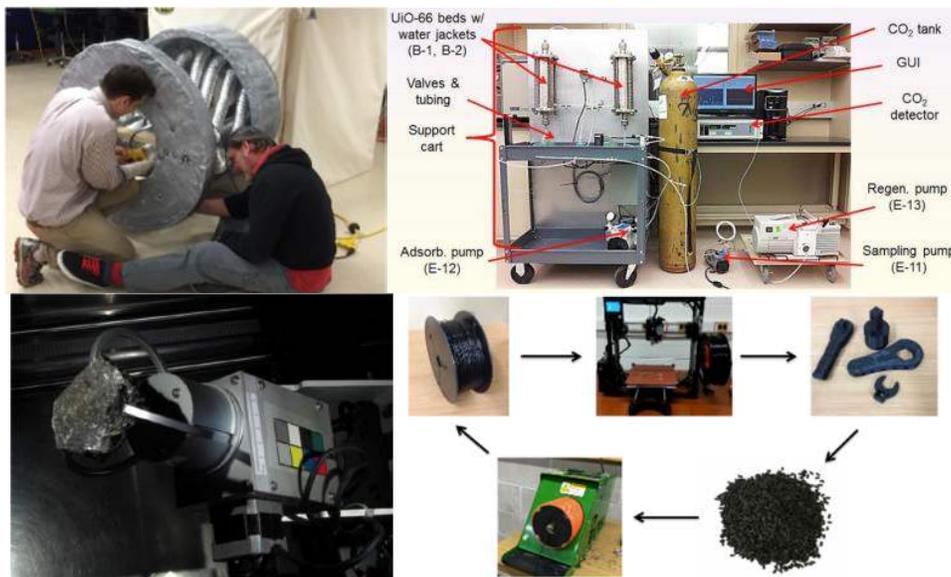


Figure 1. Previous X-Hab Projects (from top left, clockwise): Deployable Airlock, Closed Environment Air Revitalization System Based on Metal Organic Framework Adsorbents, Carbon-fiber/Fused Deposition Modeling Spacecraft Structural Fabrication System, Sample Handling System for GeoLab Glovebox (Image 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) 2027 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 2027 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 2026 and spring 2027 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 2026-2027 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 anticipates 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 2026 – Requirements and System Definition Review (SDR)
- 10 Nov 2026 – Preliminary Design Review (PDR)
- 19 Jan 2027 – Critical Design Review (CDR)
- 08 Mar 2027 – Progress Checkpoint Review
- 06 May 2027 – 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 NASA's Moon to Mars Program will also be considered. Detailed topic descriptions are located in Appendix B.

Project Sponsor: MCO

- Project Title: Utilizing Space Temperatures for Atmosphere Management
- Project Title: Dust-Tolerant Life Support, Are Filters Enough?
- Project Title: Getting Outside the Box: Unpacking and Integrating Outfitting into Lunar Infrastructure Modules

- Project Title: The Galactic Garage: Structures and Capabilities to Support Inspection, Maintenance, and Repair on the Lunar Surface
- Project Title: Automated Medical Inventory System
- Project Title: Space Exploration Bathing Concepts
- Project Title: Thriving in Space on Exploration Long Duration Mission
- Project Title: Enhancing markerless motion capture using asynchronous cabin video
- Project Title: Health monitoring flexible wearables for space application
- Project Title: Temperature regulating wearable textiles for space application
- Project Title: Extravehicular Activity (EVA) Mission Objectives for a Lightweight Spacesuit on Mars
- Project Title: Intra-vehicular Activity (IVA) Suit Bladder Refurbishment and Extra-vehicular Activity (EVA) Outer-Layer Repair Kit for Lunar/Mars Surface Operations

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 innovative 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, 2026.
Responses will be posted on April 11, 2026.

3.5 Pertinent Dates

Proposal Phase

18 Mar	2026	Date of Announcement and Release of RFP
03 Apr	2026	Questions for online Technical Interchange due
10 Apr	2026	Responses to submitted questions published online
01 May	2026	Proposal due
05 Jun	2026	Award announcements

Award Phase (dates are approximate)

Summer - Fall	2026	Design phase
Sept	2026	Kickoff meetings
06 Oct	2026	Requirements and System Definition Review (SDR)
10 Nov	2026	Preliminary Design Review (PDR)
19 Jan	2027	Critical Design Review (CDR)
08 Mar	2027	Progress Checkpoint Review
06 May	2027	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, 2026, to May 31, 2027. 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 2027 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 2027 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 2027 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 2026-27 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 through 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 2027 Academic Innovation Challenge will be implemented during the 2026-2027 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, 01 May 2026**. *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 05 June 2026.

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: Utilizing Space Temperatures for Atmosphere Management

Scope of the challenge:

Advantage the extreme temperatures on the Lunar and/or Martian surface to improve the performance of a thermal-swing air revitalization method.

Detailed Description:

The Lunar and Martian environments are alien compared to Earth. The lack of or thin atmosphere can cause temperatures to be extremely cold, to from -130 °C to -220 °C in permanent lunar shadows. Therefore, special design considerations are required to enable humans to live and work on the surface. However, these extreme cold temperatures can also be leveraged to aid in things like thermal management and cryogenic storage. Regenerable life support systems can also utilize the cold environment as many require thermal cycling or heat rejection to function. One CO₂ removal system being developed investigates a direct interface to generate a cold surface for deposition, but other methods such as sorbent-based systems can utilize this cold environment as well. Often, sorbent systems operate between ambient temperature for uptake and elevated temperature for regeneration. However, operating at sub-ambient temperatures can greatly enhance sorbent uptake and improve overall performance. Therefore, the systems can be smaller and use less power. The goal is to test a representative system to determine if leveraging the extreme environment of the Lunar or Martian surface is worthwhile. An additional benefit is investigating potential startup from dormancy if systems are not thermally regulated without crew present. The system tested could be for humidity control, CO₂ removal, trace contaminant control, or another aspect of the air revitalization string.

Expected Product (delivery item/concept):

Design, build, and test a regenerable sorbent-based air revitalization method in a simulated cold environment and compare its performance to nominal ambient operation. The comparison may be to the same system or an existing air revitalization system. Deliver analysis, design, and test results, as well as expected system scaling to either 4-crew scale or spacesuit scale.

Relevance to Exploration:

Optimizing air revitalization systems to leverage extreme environments addresses either or both Mars surface EVA suits in Martian atmosphere and dormancy recovery for water management.

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:

The level of funding can be up to \$30k to perform modeling, prototype fabrication, and testing. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

Project Title: Dust-Tolerant Life Support, Are Filters Enough?

Scope of the challenge:

Develop a dust-tolerant air revitalization subsystem not reliant on upstream mitigation methods.

Detailed Description:

One of the largest challenges to overcome to enable sustained human presence on the Moon or Mars is dust. The particulates can be jagged and electrically charged, making them especially difficult to mitigate. The dust is harmful to both humans and various systems, including life support systems. For example, the original Carbon Dioxide Removal Assembly on ISS had degraded performance from generated dust increasing pressure drop and clogging valves. High efficiency filters are currently being developed and tested to prevent dust intrusion into the air revitalization string. However, it is vital to ensure the robustness of the critical systems downstream in the undesirable event any breakthrough occurs. The systems in the air string including humidity control, trace contaminant control, and CO₂ removal would be most at risk. The goal is to design and stress test a subsystem of the air revitalization string so that it is able to withstand any potential dust intrusion. The resulting design would improve the overall reliability of the Lunar and Martian life support systems.

Expected Product (delivery item/concept):

Design, build, and test a dust-tolerant air revitalization method or component and determine its robustness against a simulated breakthrough regolith dust input. Deliver analysis, design, and test results, as well as recommendations for integration into 4-crew scale habitat systems.

Relevance to Exploration:

Optimizing air revitalization systems to tolerate dust directly informs both lunar dust-tolerant systems and dust mitigation and Mars dust-tolerant systems and dust mitigation.

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:

The level of funding can be up to \$30k to perform modeling, prototype fabrication, and testing. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

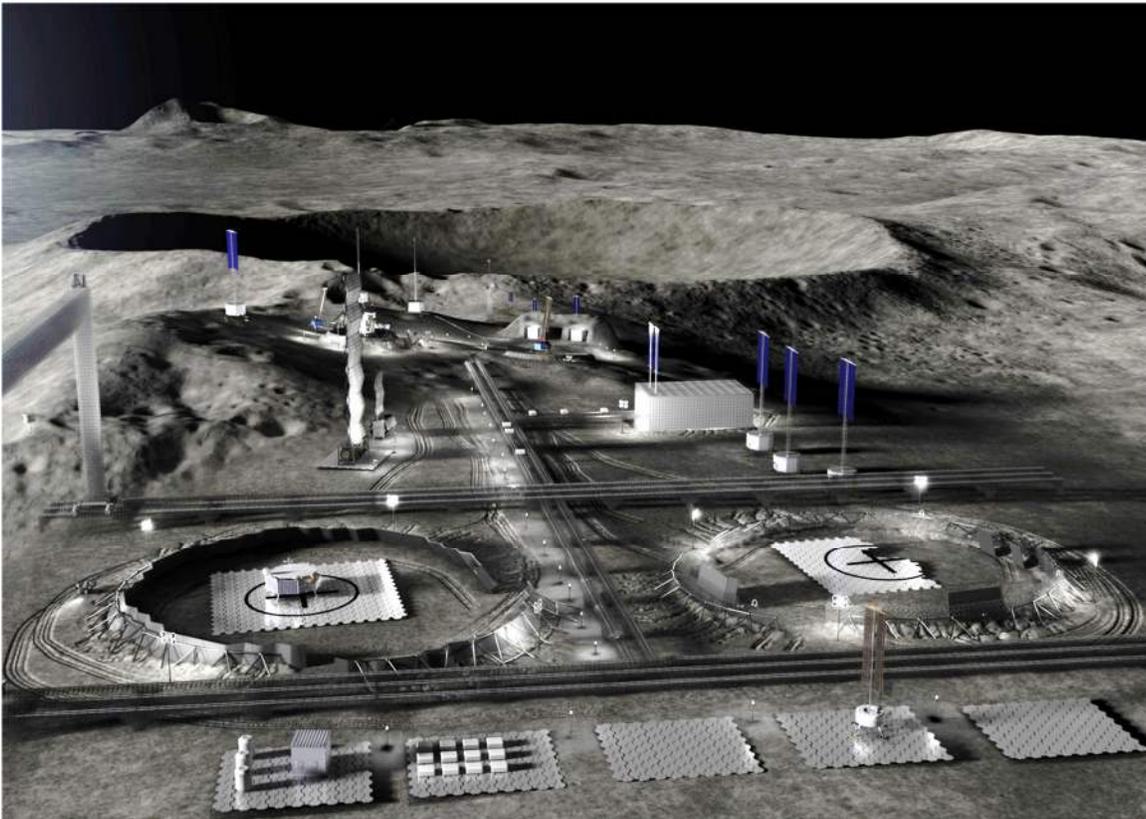
Project Title: Getting Outside the Box: Unpacking and Integrating Outfitting into Lunar Infrastructure Modules

Scope of the challenge:

Develop and demonstrate a benchtop system for packing, deploying, and robotically assembling modules equipped with integrated outfitting panels.

Detailed Description:

NASA's Autonomous Robotic Construction for Lunar Surface Infrastructure (ARC-LSI) groups are maturing the technologies necessary to build large-scale, functional lunar surface infrastructure. Student teams will design, analyze, and prototype packing schemes, deployment mechanisms, and robotic assembly operations. Solutions should emphasize functional integration—the outfitting panels must remain protected during packing, accessible during deployment, and correctly oriented during robotic assembly.



NASA will provide:

- A baseline module geometry and material system suitable for structural applications.
- A standard outfitting panel architecture (e.g., power/data routing, thermal layers, conduit pathways) designed to integrate directly into the module faces.
- Suggested reversible joining interfaces with tolerances, allowable loads, dust mitigation considerations, and manipulation features.
- Suggested packing, deployment, and assembly ConOps, including environmental assumptions (lighting, thermal cycling, regolith dust, robot payload limits).
- Interface information defining robot reach, module handling constraints, and end-effector compatibility requirements.

Expected Product (delivery item/concept):

Deliverables may include:

1. A packing strategy and validated packing layout for high-density transport of outfitted modules.

2. A deployment mechanism or concept enabling reliable module unpacking and staging for robots.
3. A robotic assembly concept aligned with NASA's provided ConOps, including sequencing, tolerances, and environmental considerations.
4. End-effector concepts or refinements ensuring reliable grasping, alignment, and placement of outfitted module components.
5. Hardware demonstrations (benchmark prototypes or mockups) may be included; teams may reserve travel funding for potential on-site demonstrations.

Relevance to Exploration:

Modular structures with embedded functional outfitting enable scalable, adaptable infrastructure that supports power routing, thermal management, sensing, and utility distribution across Artemis surface systems. This topic advances multiple Moon-to-Mars Architecture needs by maturing:

- Modular structural systems
- Robotic assembly technologies
- Autonomous multi-agent coordination
- Functional integration / outfitting for surface elements
- Mass-efficient deployment and construction operations

The work supports STMD/ESDMD gap areas including primary structures, modular robotic assembly, and multi-agent autonomy challenges.

Student Skills Required:

Depending on chosen focus:

Structures: materials, FEM, structural loads, thermal/dust effects.

Outfitting Panels: wiring/power routing, mechanical integration, protective encapsulation.

Reversible Joining: mechanism design, tolerances, dust mitigation.

Packing/Deployment: logistics engineering, packaging design, kinematics.

Robotics & End Effectors: grasping, alignment, motion planning.

Autonomy: multi-agent control, sequencing, throughput optimization.

Systems Engineering: requirements development.

Anticipated Funding Requirements:

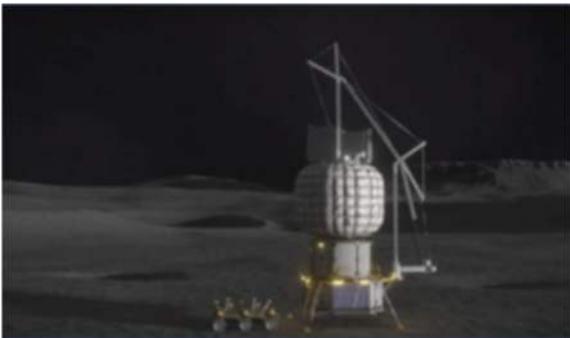
NTE \$25k–\$30k from X-Hab. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

Project Title: The Galactic Garage: Structures and Capabilities to Support Inspection, Maintenance, and Repair on the Lunar Surface



Scope of the challenge:

This challenge seeks to develop a design concept for a pressurized storage and maintenance space on the lunar surface. This structure will serve as a “lunar garage” to store systems (protecting them from additional long term environmental exposure), house inspection, maintenance, and repair (IMR) equipment, and perform IMR operations (which may be intravehicular or extravehicular, depending on the activity). The garage should use an expandable structural system, with the goal of achieving a larger volume with a single deployment/emplacement. The garage structure is intended to augment other assets which may not have adequate space or capabilities to support IMR. Teams will investigate options for structure size, deployment, and portability. As part of this challenge, teams should also layout the inspection, maintenance, and repair capabilities which could be housed in the garage and envision possible use cases for these technologies to support at least a 10 year life for lunar surface assets, including potential surface habitation capabilities, mobility platforms, and rovers (unpressurized or pressurized).



Rendering of an example of a lunar surface habitat. Concept only.

Detailed Description:

NASA’s Artemis campaign seeks to return humans to the moon and establish a sustained presence there. The phases of exploration envisioned for the lunar surface are outlined in the agency’s Architecture Definition Document (Reference 1). Beyond the initial human lunar return phase, crew (and assets) may remain on the surface for longer periods (up to 28 days). The planned series of Artemis missions are anticipated to emplace multiple elements on the lunar surface in a stepwise manner; these assets will collectively support longer crewed durations and enable larger regions of exploration. Possible assets include landers for delivery of crew and cargo, an initial surface habitat, a pressurized rover, terrain vehicles to allow crew to traverse between sites of geologic and scientific interest, and rovers/mobility platforms to transport payloads, utilization equipment, and/or other assets.

To support these mission objectives, teams are asked to develop a concept for a deployable structural material system (the “lunar garage”) to support long term storage of equipment or supplies and the conduct of IMR activities. The garage structure could be used to store systems during periods of

dormancy/uncrewed operations to protect assets from the natural environment and maintain their readiness to support crew.

In designing the lunar garage concept, teams should optimize the size of the structure to support a variety of systems and activities. Teams can assess the efficacy of the structure to provide additional protection for systems from the lunar environment, including dust, thermal extremes, and radiation, via modeling and analyses (see Reference 3 for radiation effects and Reference 4 for more general information on the lunar surface environment as it relates to the Artemis campaign). Teams must present a concept of operations for use of the structure, including landing, deployment, ground mounting/staking, outfitting, deflation, any potential relocation capabilities, and disposal. Considerations should be made for the pressurization system required for any inflation, deflation, and atmospheric gas recycling needed when systems are moved in or out of the garage. Since one key purpose of the garage is to facilitate IMR, teams should select and layout (within the garage “footprint”) the IMR capabilities they may incorporate, including nondestructive evaluation/inspection techniques, welding, additive manufacturing, or cleaning. Through trade studies conducted in the first half of the study, teams should select technologies which can be scaled to a human spaceflight application and are suitable for the space environment. Trade studies should consider power/mass/volume, crew interaction required for the system (approaches may require crew to operate or may be conducted autonomously or via teleoperation), operational safety, and utility of an approach in supporting the use cases envisioned (i.e. scenarios the team identifies in which IMR capabilities would be used on the lunar surface). One key outcome of the work will be a recommendation of IMR capabilities to incorporate for lunar surface operations; teams should thus also characterize any potential impact to design of other surface elements in including these technologies in a mission scenario (for example, use of an additive manufacturing capability for spare part production requires that the parts being replaced are designed for/compatible with the process selected). Prototyping and development of models as part of the overall project, including garage structure design, is highly encouraged.

Expected Product (delivery item/concept):

The primary deliverable will be a final report with assumptions and development of requirements for the lunar garage and IMR capabilities. Teams will summarize development of their concept for a lunar garage, including material selection, mass and volume characteristics, strategy for protection from dust and debris, scalability of structure, and deployment mechanisms. The team must include a computer-aided design (CAD) rendering of the structure and supporting analyses to verify it will support the intended use scenario and survive in the lunar environment. The report will also include a concept of operations for use of the structure to a) support and enhance the lifecycle of lunar surface assets and b) enable crew to respond to contingency scenarios. The report will include a trade study of IMR technologies, use cases identified for IMR on the lunar surface, and a recommendation of IMR capabilities to incorporate. With the IMR aspect of the effort, teams may pick a specific technology and demonstrate how it would be implemented for a use case identified at a laboratory proof of concept level.

Other study outcomes include an assessment of risk for the concept and technology maturation needed to enable the concept within a certain timeframe assumed by the team. The team should include a layout of the garage footprint, which includes placement of systems and IMR capabilities. If teams plan to travel to a NASA center as part of the effort, this travel should be reflected in the project budget.

Relevance to Exploration:

This effort supports a new and interesting use for deployable structure technology and also serves to help develop strategies to support extended life of assets on the lunar surface. With the consideration of robotic IMR technologies, the study may serve to provide strategies for crew time reduction in maintenance and repair. The entire scope of the effort contributes to long term survivability of structures and humans in the harsh lunar surface environment.

Student Skills Required:

Students will need to develop requirements, conduct trade studies, select materials, develop designs and models, perform analyses (including structural analysis), and report-present technical findings and recommendations to NASA stakeholders. This is a multi-disciplinary engineering project which will require teams to use or develop knowledge in the materials, structure, manufacturing, and systems engineering.

Anticipated Funding Requirements:

NTE \$15k-20k from X-Hab. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

References:

1. Architecture Definition Document, Revision C. NASA. Link: [add-revision-c-20251211.pdf](#)
2. Online Tool for the Assessment of Radiation in Space (OLTARIS) user manual. NASA. Link: [OLTARIS | Documents](#)
3. M2M-30044: Moon2Mars Lunar Surface Data Book Baseline. NASA. Link: [Document Template](#)

Project Title: Automated Medical Inventory System

Scope of the challenge:

Design a means to log available quantities and locations of various durable and consumable medical items, that requires minimal user input, records inventory to a high degree of accuracy, and provides as close to real time data as possible for mission and ground use.

Detailed Description:

Currently, inventory of medical consumables and durables (medications, treatment aids, diagnostic equipment, etc.) is a manual process whereby crewmembers reach out to their flight surgeon to relay when items are used. The flight surgeon then must relay this information to the appropriate persons to decrement the inventory and resupply items if needed. Often, crew forget to inform the ground when items are used. Over time, the inventory of medical items becomes inaccurate, and items get moved from their initial location, which can jeopardize finding and using items in a timely manner. Currently, performing a full inventory of the medical system is time intensive and ground teams spend large amounts of time manually updating and keeping inventory systems as up to date as possible. For LEO missions, which have long durations and large medical systems but frequent resupply and immediate evacuation capabilities, accurate inventory management is not as crucial. Additionally, even lunar missions, which will have limited resupply and evacuation capabilities, counterbalance their risk of misplacing or mismanaging medical system components by nature of their short mission duration and small medical kits. However, as exploration progresses to long duration missions with little to no resupply or evacuation capabilities, maintaining an accurate account of inventory and location for medical systems across the mission will become increasingly critical. A new system must be developed to meet the need for a crew-facing, real-time method of managing medical inventory for future exploration missions.

The system will primarily be composed of a database, and the hardware and software allowing for input, output, manipulation, and storage of inventory data. The database will be populated with inventory datasets initially on ground, and these data will also be editable during mission and in-flight. The system is also expected to operate with significant communication delay and multiple simultaneous users.

The system (or sub-systems) that scan the inventory to locate and track available quantities will be utilized across all mission phases and locations including in-flight vehicles, as well as on the ground during system validation and verification as well as preparations for flight.

Expected Product (delivery item/concept):

The team will deliver a summary of findings of different technologies used to track inventory and analysis on which would work best for AMIS. They will also deliver a functional prototype of the inventory system including the software and hardware that allows for accurate inventory of medical items across all mission phases of a Mars mission.

Relevance to Exploration:

This project maps to ESDMD Gap #0405 Exploration Medical Capabilities for Deep Space Missions, ESDMD Gap #1002 Autonomous Monitoring for Exploration Missions, and the below M2M Objectives:

- RT-3 Crew return safely
- RT-4 Maximize crew time
- RT-8 Leverage LEO
- TH-3^L Systems for crew to operate and live on Lunar surface or orbit
- TH-7^M Systems for crew to operate and live on Martian surface
- OP-1^L Conduct Tech Demos on Earth, LEO, cislunar, surface of moon
- OP-2^{LM} Optimize operations and interaction between team on Earth, crew members, and Martian surface team

Student Skills Required:

Desired skills include analysis using decision matrices, prototyping, database manipulation, engineering drawings, coding.

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: Space Exploration Bathing Concepts

Scope of the challenge:

Develop a method for astronauts to bathe in microgravity and/or reduced gravity on the Moon/Mars that improves hygiene & reduces time of current wipe down methods used on the International Space Station (ISS).

Detailed Description:

Bathing in space is one of the many challenges astronauts face while living aboard the ISS because of the reduced gravity and expense to launch and manage water. Astronauts have historically used wet wipes to clean themselves - a long and arduous process that results in a final cleanliness that pales in comparison to a shower or bath here on Earth. As NASA sets its sights on the Moon and Mars, missions will become increasingly longer than any thus far experienced and hygiene will be an important factor for astronaut health – both physically and mentally. With the crew's health in mind and paying note to the expense of consumables, develop a method to bathe on the Moon and/or Mars that improves upon existing methods. The method should be low mass, take up minimal space within a spacecraft, minimize time to bathe, maximize cleanliness, and be efficient in microgravity/reduced gravity. The system should also be entirely self-contained. For example, if water is used as part of the concept, a method to recycle the greywater separate from current water recycling systems on ISS must be developed.

Expected Product (delivery item/concept):

The end product should be a report detailing how the system would operate on the Moon/Mars and a delivery of a prototype of the solution to JSC.

Relevance to Exploration:

Provide the context for how improving the knowledge and capability in this area will address Moon to Mars Objectives or Technology Gaps, as identified in the publicly available Moon to Mars Architecture Definition Document, Rev. B.

Moon to Mars Architecture Definition Document, Rev. B.

1.3.2.1.3 Habitation Systems

Student Skills Required:

We are looking for students full of creativity and the ability to think outside the box. Engineering and/or prototyping backgrounds may be particularly useful for this task.

Anticipated Funding Requirements:

NTE \$10k-\$50k from X-Hab. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

Project Title: Thriving in Space on Exploration Long Duration Mission

Scope of the challenge:

Develop a concept and prototype of a method to make space flight more like living instead of only surviving. The effects of stress, isolation, and the unknown can wear on a human. Provide ideas of ways to make the experience more enjoyable and relaxing.

Detailed Description:

Current efforts in space travel focus heavily on the survival of crew members in the space environment. While that is still critical of course, the importance of the human mental condition will be brought to the forefront with long-duration space travel. When it takes a year to reach the destination, it will take a new type of space environment to support these travelers. They will have a huge list of responsibilities, but they will also have downtime and regular daily routines that should bring them some comfort and connection.

Things that the crew members will miss from home are endless, but what kinds of things or experiences can help them thrive on their journey or even add to their accomplishments? We are looking for joy, satisfaction, familiarity, or calm. Humans have breaks, humans have hobbies, but the limitations of mass and the focus on survival have left an opportunity for a unique development that will change the game. Suggested areas of focus include but are not limited to: a better hygiene solution such as a shower or other methods, wellness center including a massage station, gaming for group participation, and dining environments suitable for all crew members to eat as a group.

Expected Product (delivery item/concept):

The end-product deliverable includes a report detailing how the idea(s) would operate on the Moon/Mars and an optional delivery of a prototype of the solution to JSC.

Relevance to Exploration:

Provide the context for how improving the knowledge and capability in this area will address Moon to Mars Objectives or Technology Gaps, as identified in the publicly available Moon to Mars Architecture Definition Document, Rev. B.

Moon to Mars Architecture Definition Document, Rev. B.

1.3.2.1.3 Habitation Systems

Student Skills Required:

We are looking for a team of students full of creativity and thinking outside the box. We believe the students have a critical perspective on the current beat of wellness and would love to have insight into their ideas for long duration missions. We expect to receive real development on a concept to help humans thrive in a small space for a long period of time. The possibilities are open since this is not a common subject yet. We know it will be critical to maintain the wellness and positive engagement of our crew members to achieve new and amazing things on these long journeys to come.

Anticipated Funding Requirements:

NTE \$10k-\$20k funding from X-Hab. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

Project Title: Enhancing markerless motion capture using asynchronous cabin video

Scope of the challenge:

This project will utilize open source pose estimation software to characterize monitoring of head and body motion using multiple asynchronous cabin video sources.

Detailed Description:

Markerless motion capture (MoCAP) provides an unobtrusive methodology to capture crew activity during intravehicular activity within a crew cabin during lunar landings or shortly after landing. While most commercial MoCAP systems rely on multiple cameras that are synchronized, during some exploration missions we may be required to leverage cameras that are not synchronized. This project will characterize head and body MoCAP with one to multiple asynchronous cameras, test methods that can be used to perform calibrations and “best effort” offline synchronization (e.g., LED flash that is captured by all camera recording simultaneously) and quantify the accuracy of the tracking during different types of motion relative to other “gold standard” references (e.g., marker-based MoCAP or inertial measurement units).

The intended crew activity to be captured can include seated suit activity involving interactions with displays and inceptors for manual control, and/or unsuited activity involving natural motion in the cabin navigating steps, stepping over obstacles, rising from a seat or lying position, reaching for objects and using exercise equipment.

Expected Product (delivery item/concept):

The expected deliverable will be demonstration of the hardware prototype system used (camera /calibration / synchronization hardware as well as the “gold standard” system utilized for comparison), demonstration of the software developed for the pose estimation, and a summary of recommendations that should be considered for future exploration mission cabin video architecture. The prototype hardware and software can be demonstrated remotely using a video conference presentation without requiring travel to a NASA center.

Relevance to Exploration:

This technology has been identified in the publicly available Moon to Mars Architecture Definition Document, Rev. B under gaps enabling crew health and performance for crew mission(s) in deep space and/or Mars vicinity. Specifically, this is outlined in the higher priority gap for monitoring sensorimotor countermeasures to support extended habitation in space (ESDMD #0402).

Student Skills Required:

A mixture of general engineering skills such as electrical and computer science is required. Experience with kinematic tracking and access to a maker-based motion capture system or IMUs to provide a gold-standard reference would be preferred.

Anticipated Funding Requirements:

NTE \$20k funding from X-Hab. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

Project Title: Health monitoring flexible wearables for space application

Scope of the challenge:

This project will investigate the design, fabrication and optimization of a smart textile prototype engineered for continuous, non-invasive physiological monitoring of astronauts performance in microgravity. This work will focus on building flexible sensors directly into clothing with the objective of tracking astronauts health data in real-time using the embedded sensors. The collected data can be used as indicators of the astronauts physical strain which can aid in making data driven decisions regarding fatigue management and overall mission safety.

Detailed Description:

The objective of this project is to engineer a sensorial fabric or garment tailored for the Intra-Vehicular Activity (IVA) environment. This advanced smart prototype moves beyond basic wearable electronics to embedding a network of flexible, textile-integrated sensors designed for medical-grade data acquisition and early-warning safety systems. The technical approach can be divided into multiple core pillars.

The first pillar can focus on integrating a suite of sensors and electrodes to monitor biomarkers that indicate astronaut's physiological stability in oxygen enriched environment. Further, these sensors and electrodes can be utilized so that it is possible to capture real-time data such as ECG and heart rate in addition to monitoring blood-oxygen saturation levels, providing a primary defense against Hypoxia. Moreover, the integration of sensors at strategic locations like the thoracic and abdominal regions can assist in monitoring breathing rate and volume. Rapid and shallow breathing patterns can be an early indicator of Decompression Sickness (DCS) which poses a life-threatening risk in oxygen-rich environment.

The second core pillar can focus on building hierarchical textile architecture with an efficient signal integrity. This covers ensuring consistent sensor to skin contact which is a major challenge in the "floating" environment of microgravity. Keeping sensors stabilized against the body is crucial for maintaining a clean signal and protecting the sensitive biological signals during the physical movements associated with exercise or emergency response.

The third pillar should address the data utility. This encompasses the analysis process and establishing a correlation between the collected data so that it is possible to employ the sensorial garment as an early-warning system. This can help in detecting the subtle physiological precursors leading to DCS or Hypoxia before the astronaut notices physical symptoms.

Finally, it is vital to ensure that the sensors integration does not compromise the comfort required for 24/7 wearability.

Expected Product (delivery item/concept):

The expected delivery is a functional smart fabric or garment prototype designed as a high-performance next to skin base layer. This product will feature a fully integrated network of flexible and textile-based sensors specifically calibrated and engineered to detect the onset of high-risk physiological conditions associated with low-pressure and oxygen-rich environments.

Relevance to Exploration:

The transition to the exploration atmosphere environment (up to 37% O₂, 8.2 psi) presents unique physiological risks to the crew. The intermittent traditional medical monitoring may not be suitable for the new environment and can leave gaps in safety. Hence, there is a need for a continuous and non-invasive monitoring system that functions as a "conformal second skin" to ensure that life-critical data is captured without interruptions.

Student Skills Required:

A mixture of general engineering skills such as electrical and materials and is required and prior knowledge in wearable sensors would be advantageous.

Anticipated Funding Requirements:

NTE \$20k funding from X-Hab. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

Project Title: Temperature regulating wearable textiles for space application

Scope of the challenge:

This research addresses the challenge of responding to astronaut's thermal needs during varied physical workloads. The project should focus on the design and fabrication of a smart textile prototype capable of enhancing astronaut's thermal comfort. Maintaining human body thermal balance is of prime importance as this can help prevent physiological and psychological discomfort that can significantly reduce human performance and stop thermal stress that may result in posing life-threatening risks.

Detailed Description:

The project's objective is to develop a smart thermal regulating textile prototype designed for Intra-Vehicular Activity (IVA) environment. The core concept of the proposed prototype should focus on active or/and passive thermal regulation techniques that can be integrated into textile architectures to maintain an optimal microclimate condition next to the skin. One example for passive thermal regulating techniques is stimuli-responsive polymers (e.g. phase change materials PCMs) that undergo rapid and drastic changes when subjected to external stimuli like temperature. PCMs can be programmed to absorb or release heat depending on the astronaut's needs. Thermoelectric coolers (TECs) is one example for active cooling techniques. TECs can pump heat from one side to the other via Peltier effect. Further, TECs are driven by electrical power and they have the advantages of being small in size, light weight in addition to the absence of moving parts and noise-free operation. Other passive or active thermal regulation technologies beyond these examples can also be considered.

The proposed thermal regulation technology can be incorporated at the polymer, fiber, yarn, or fabric level within the textile architecture. 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 comfortable and form-fitting garment suitable for prolonged wear time. The fiber type used in the proposed design shall be high performance fire-resistant in order to meet NASA's requirement for flammability. In addition, the proposed idea should not compromise the comfort required for 24/7 wearability.

Expected Product (delivery item/concept):

A functional and scalable temperature regulation textile prototype suitable for use in oxygen enriched spacecraft environment. This prototype can be a fabric or a finished garment.

Relevance to Exploration:

The outcome of this project is to select and optimize a thermal regulating technology capable of maintaining astronauts thermal comfort throughout the day during their prolonged stay..

Student Skills Required:

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

Anticipated Funding Requirements:

NTE \$20k funding from X-Hab. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

Project Title: Extravehicular Activity (EVA) Mission Objectives for a Lightweight Spacesuit on Mars

Scope of the challenge:

Develop and test mission objectives for a Mars Spacesuit. Review suit predicted capabilities and predicted mission profiles and requirements. Develop hardware, analogs, or mockups to demonstrate how suit systems may operate on Mars including consumable usage, airlock operations, rover usage, geology tasks, traverse, and consumable recharge in-situ. Review ways to reduce mass or mitigate mass concerns on Mars. Consider methods for repair, maintenance, and recharge of the suit between EVAs.

Detailed Description:

Current mission profiles for EVAs assume 1/6 to micro-gravity for either space or lunar environments. The Martian environment brings new challenges for weight of the suit and overall consumable time due to the weight restriction for launch as well as on-back mass. There are also other considerations, the temperature and pressure on Mars affecting the overall operation of the suit that are being investigated as well.

For this task, please consider the following objectives:

- Review published requirements and restrictions on suit usages and review analysis studies to evaluate suit capabilities
- Based on suit capabilities, review high level architecture that will be needed to support the suit.
 - Intravehicular Activity (IVA)/airlock needs, resupply, regeneration needs
 - Consumables needs in vehicle/rover
- For different EVA times based on reasonable suit/ Portable Life Support System (PLSS) capabilities, review methods to add items like a consumables cache on the ground, on rovers, umbilicals from the rovers, and buddy life support systems to increase EVA time and emergency walk back scenarios.
- Review terminate times/cases and methods to support those cases (like using a consumables cache on a rover as a lifeline) and/or illustrate maximum extents around a vehicle or rover for safety.
- Develop hardware, analogs, or mockups to demonstrate how suit systems may operate on Mars including consumable usage, airlock operations, rover usage, geology tasks, traverse, and consumable recharge in-situ.
- Review mobility of the suit and ways to improve mobility in the suit
- Review methods for repair, maintenance, and basic recharge/cartridge replacement
- Review methods to reduce mass and increase mobility on the PLSS or suit
 - Current Exploration Extravehicular Mobility Unit (xEMU) is 380lbs, with the PLSS at 210lbs. Mars Suit needs to be reduced to ~<230lbs total (~<140lbs PLSS)
 - Weight study could either different methods, processes, or materials that could lower the weight of the suit.

Teams may focus on the problem as a whole or dive into a subset of the above objectives.

ICES Paper for reference:

- [1] Lobmeyer, D. et. al “Martian Exploration Portable Life Support System Schematic Study”, NASA Johnson Space Center, ICES, ICES-2025-90
- [2] Ogilvie, R., Miller, S., and Hetherington, R., “Advanced Material Options for the Portable Life Support System,” NASA JSC, *International Conference on Environmental Systems*, ICES-2024-127, July 2024.
- [3] Ogilvie, R., Miller, S., and Chavez, J. “Advanced Materials Testing Plan for the Space Suit Portable Life Support System”, ICES NASA Johnson Space Center, *International Conference on Environmental Systems*, ICES-2026-128, July 2026 (To be released – JULY 2026)

- [4] Oliver, M. et. al., “Martian Exploration Portable Life Support System Schematic Study: Architecture Down-Selection” ICES-2026-158, NASA Johnson Space Center, International Conference on Environmental Systems, July 2026 (To be released – JULY 2026)
- [5] Ogilvie, R., Swartout B., McFarland S., Hoffmann B., Hickox, L., “Mars Spacesuit Mass Requirements”, NASA Johnson Space Center, International Conference on Environmental Systems, ICES-2026-127, July 2026 (To be released – JULY 2026)
- [6] Ogilvie, R., Chullen, C., Barrett, L., Oliver, M., And Conger, B., “Mars Portable Life Support System Status and Plan”, NASA Johnson Space Center, ICES, ICES-2026-126, 2026. (To be released – JULY 2026)

Expected Product (delivery item/concept):

A final presentation shall include a requirement decomposition and approach to answer the topics and objectives above. Chosen topics and objectives shall be covered in detail. Hardware prototypes, designs, and analogs, may be presented to demonstrate operations

Relevance to Exploration:

Understanding lightweight suit concept of operations is critical to developing the right hardware and helps inform decisions at an early stage. The weight on Mars is going to make the suit design more complicated than before and will require careful planning for Mars.

Student Skills Required:

Students would be expected to pursue a degree in the engineering field focused on either Aerospace, Mechanical, Systems Engineering, or Materials. They would need to have or develop skills such as design, modeling, prototyping, materials understanding, laboratory experience, research, literature review, and analysis. This project should include experienced seniors or grad students at the core.

Anticipated Funding Requirements:

NTE \$15- 30k funding from X-Hab. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

Project Title: Intra-vehicular Activity (IVA) Suit Bladder Refurbishment and Extra-vehicular Activity (EVA) Outer-Layer Repair Kit for Lunar/Mars Surface Operations

Scope of the challenge:

Develop and experimentally validate an integrated suit repair and maintenance approach that restores outer-layer structural integrity during EVA and enables preventative refurbishment of bladder coating wear during IVA between EVAs in lunar-relevant conditions.

Detailed Description:

Design and prototype an integrated 'Suit Repair and Maintenance Kit' that addresses two common, mission-impacting degradation modes:

1. Localized abrasion, cut, or puncture damage to exterior suit layers (e.g., Environmental Protection Garment (EPG) outer fabric systems) requiring EVA-capable structural patching.
2. Scuffing, thinning, or wear of urethane-based bladder coatings identified during inspection between EVAs, requiring IVA-applied preventative refurbishment to restore abrasion resistance and durability before subsequent surface operations.

The effort should focus on repair/refurbishment functionality, interfaces, and verification methods rather than flight qualification.

Suggested activities:

- (a) define representative damage archetypes and operational use cases;
- (b) develop and prototype structural patch concepts suitable for gloved application;
- (c) develop and prototype an IVA bladder coating refurbishment approach compatible with urethane/TPU materials;
- (d) establish inspection criteria and decision logic for repair versus replacement; and
- (e) execute a test plan quantifying effectiveness and durability under representative stressors (flex cycling, abrasion, contamination, thermal conditioning).

The bladder module is intended for preventative maintenance applied while the suit is doffed between EVAs—not emergency leak repair during EVA.

Expected Product (delivery item/concept):

- Prototype two-level repair and maintenance kit (EVA outer-layer patch + IVA bladder refurbishment concept).
- Defined inspection and decision workflow for repair/refurbishment applicability.
- Test fixtures and quantitative performance data demonstrating adhesion, durability, abrasion resistance, and compatibility.
- Demonstrated improvement in abrasion life and/or durability of worn bladder coating coupons following refurbishment.
- Risk assessment and prioritized maturation path.

If a hardware prototype is produced, the team should plan for delivery and final demo review at NASA JSC.

Relevance to Exploration:

Surface EVA architectures under Artemis and future Mars campaigns must support repeated EVA cycles with limited logistics mass and constrained spare component availability. Cumulative abrasion and coating wear can reduce durability margins and drive premature component replacement.

An integrated repair and preventative refurbishment capability enhances crew mobility system maintainability, reduces logistics burden, and supports sustained surface operations. By addressing both EVA structural damage tolerance and IVA lifecycle maintenance, this topic advances dust-tolerant systems and improves operational resilience for long-duration campaigns.

Student Skills Required:

Students would be expected to be pursuing a degree in engineering 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 \$30-50k funding from X-Hab. Proposers are encouraged to seek additional funding from their institutions, industry, space grant consortiums, and others.

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

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.