NM STATE WERC ENVIRONMENTAL DESIGN CONTEST

Task 4. Request for Proposals:

2026

Survive the Night: The Lunar Logistics Challenge

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Introduction

You and your crew just landed at the Lunar South Pole for a 28-day mission. Conditions are extreme in this region, where temperatures can range from 54°C (130°F) in sunlight to -203°C (-334°F) in permanently shadowed areas.

Your life-support supplies, including food, water, medications, and critical equipment, were delivered 30 days earlier. They are stored in pressurized, temperature-controlled logistic containers positioned outside your habitat. This setup allows you to access only the items you need, optimizing the small space in the habitat while keeping the remaining supplies protected.

Knowing that any failure in the container's temperature or pressure controls could compromise critical life support supplies, you have been monitoring the data logging system to ensure that interior temperatures and pressures of the containers are maintained as they rest on the lunar surface. The data logger reports "conditions nominal," and you access the container, knowing your food, water, medications, and maintenance supplies are in good condition and will sustain you throughout your mission, thanks to the engineering teams—perhaps even students who competed in the WERC Environmental Design Contest—that designed these robust pressurized logistics containers.

Problem Statement

Note: Terms used in this problem statement are defined in the Background section, below.

Your task is to research, design, and demonstrate a prototype logistics container solution that can be scaled up to support a crew of four for a 28-day mission. The full-scale container design must accommodate 130 Cargo Transfer Bags (CTBs), which together hold 1,965 kg (4332 lb) of logistics items.

Throughout its journey aboard a lander from Earth to the lunar surface, the container must maintain internal temperatures between 4 and 21°C (39 - 70°F) and pressures between 101 kPa and 56 kPa (14.7 and 8.2 psi) until it is opened on the lunar surface. To ensure safe access within the 56 kPa (8.2 psi) habitat environment, the container must be equipped with a pressure-relief valve or equivalent mechanism that equilibrates its internal pressure with the habitat prior to opening. Additionally, the container must include equipment capable of recording, storing, and transmitting real-time temperature and pressure data to the lunar surface crew and to Ground Control.

Your team may choose to design the prototype as either a single container capable of holding all logistics items or as multiple smaller containers. If you opt for a single container, it must be scalable to connect with the shirt-sleeve habitat through a 1 x 1.5 m (40 x 60 in.) hatch, at which point it will function as a pressurized walk-in area. If you opt to design smaller containers, they may be uniform or vary in size. Each of these smaller containers must be manageable by a single crew member during an EVA and support transport into the habitat, either by hand or with the assistance of a mobility aid, through a hatch of size of 1 x 1.5 m (40 x 60 in.).

The logistics container design should optimize storage capacity while minimizing overall mass, and balance tradeoffs across the packing, launch, landing, transport, and unpacking phases. Design decisions should weigh the benefits and limitations of using one large container or any combination of smaller container sizes.

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The containers must be made of materials that are sufficiently durable to withstand the stresses of launch, landing, and lunar transport with minimal shifting of contents. They must resist lunar dust accumulation, as needed; maintain a narrow range of internal temperatures and pressures; be equipped to record and report temperature and pressure data; be compatible with the specified habitat hatch size; and facilitate repurposing and or reuse.

The scaled-up design should accommodate CTBs primarily sized at 1 CTBE, with some CTBs as multiples of 1CTBE. Full-scale containers will store dry goods such as food, medical supplies, clothing, crew supplies, operational supplies, and spare parts, but the bench-scale containers will serve only as placeholders and will not contain actual supplies. The container design must provide internal flexibility to store both CTBs and other components that do not conform to standard CTB dimensions.

Background

To help us better understand how humans can live beyond Earth in harsh conditions, NASA's Artemis Program is preparing to send crews to the Lunar South Pole to conduct extravehicular activities (EVAs) [1, 2]. NASA's plans for a long-term sustainable presence on the Moon include a progressive increase in habitation capability that will eventually support crews of four for 30 days or longer.

Life Support at the Lunar South Pole

The extreme conditions at the South Pole – from hot sunlit areas to extremely cold shadowed regions—make it a compelling location for deep-space exploration and discoveries that could prepare us for further solar system exploration. At the lunar South Pole, the sun lies at near-horizon level—sometimes above and sometimes below the horizon. During sunlit periods, temperatures can soar to 54°C (130°F), yet, due to the low angle of the sun and dramatic topographic changes, many regions are in constant darkness and have not been exposed to sunlight in billions of years. Temperatures in those perpetually dark areas can be as low as -203°C (-334°F) [3].

Under Pressure

On the lunar surface, which lacks an atmosphere, the pressure felt on a body will be nearly zero (13 kPa or 1.9×10^{-4} psi). For comparison, on Earth, atmospheric pressure at sea level is 101 kPa (14.7 psi), and for the highest city on Earth, La Rinconada, Peru (elevation 5100 m or 16,730 ft), it is approximately 54 kPa (7.8 psi).

NASA is planning for the shirt-sleeve lunar habitat to have a pressure of 57 kPa (8.2 psi) with 36% oxygen concentration. This is to minimize crew pre-breathe time as they transition from the habitat to the lunar surface to perform EVAs (a principle similar to the needs of scuba diving to avoid the bends). NASA defines a "shirt-sleeve environment" as a pressurized area with a breathable air mixture that is temperature- and humidity-controlled and protected from radiation and micrometeoroids, allowing the crew to wear regular clothing without needing spacesuits.

The logistics container(s) will be packed and sealed at sea level. A fully sealed container at this altitude should retain the approximate 101 kPa sea level atmospheric pressure upon arrival on the lunar surface. If the seal is compromised, whether intentionally or unintentionally, internal pressure will drop to ambient lunar conditions. Thus, if pressure is released inside the habitat, the container's internal pressure will equilibrate to 57 kPa.

Logistics Containers and CTBs

A key requirement for human exploration of the lunar South Pole is ensuring that essential life-support supplies are safely stored and maintained in logistics containers. NASA uses the term "logistics items" to describe cargo that is necessary to sustain life, ensure ongoing system functionality, and support human exploration [4]. Logistics items include food, medicine, water, tanks of breathable air, spare parts for critical systems, and equipment needed for scientific activities. These items must be stored in thermally conditioned, pressurized containers.

Logistics containers usually hold a set of smaller containers, called cargo transfer bags (CTBs). CTBs have been used to organize, stow, and carry supplies and equipment in space since the 1990s, when they were designed for the Shuttle and Spacehab. Traditionally, CTBs have been multipurpose fabric bags that are foldable and used as shelving, etc., when not carrying cargo. See [5] for a history of the CTB and [6] for an example of how they were implemented in the ISS. Note that the dimensions given in [6] differ from those in this design challenge.

CTBs were originally designed to hold a volume of 0.053 m^3 (1.9 ft^3), and this became a standard unit of measure called the Cargo Transfer Bag Equivalent (CTBE) that is still used today. CTBs have historically been produced in sizes that are one-third, one-half, two times, three times, 20 times, 70 times, etc., that of the CTBE. Each of these sizes is referred to, respectively, as ⅓CTBE, ½CTBE, 2CTBE, 3CTBE, 20CTBE, 70CTBE, etc.

For this design challenge, teams shall base most of their CTBs on the standard 1CTBE size. However, not all logistics items can fit within the traditional 1CTBE proportions. These include odd-sized equipment and even the cooling suit that is worn underneath the EVA space suit. Teams should research potential items that need to be stored in odd-sized CTBs, and plan for a limited number (two or three) of CTBs with sizes or proportions different from the standard design.

Although dimensions reported in the literature vary for CTBs, our SME (Subject Matter Expert) has provided the dimensions for a typical CTB with a volume of 0.053 m3 (1.9 ft3) to be 50.2 cm X 42.5 cm X 24.8 cm and a mass of 0.89 kg (or 20 in. x 17 in. x 10 in. and a mass of 1.96 lb.). Teams should use these proportions when designing their CTBs.

The space industry is developing new CTB designs for future lunar missions because current CTBs, placed directly on the lunar surface in past missions, accumulate significant amounts of lunar dust (a.k.a. *lunar regolith*), causing subsequent damage to mechanical equipment in the habitat and endangering the health of the crew. In the future, if most CTBs are stored inside logistics containers, the requirement for dust-resistant materials will shift from the CTBs to the containers themselves.

Logistics Container Uses, Needs, and Design Considerations

The logistics container(s) will be packed on Earth, loaded on a lander, land on the lunar surface, and be transported from the landing site to an area near the habitat. The container(s) will remain outside the shirt-sleeve environment until the crew needs to retrieve items. The primary design considerations are to minimize container weight and mass, ensure that logistics items maintain their integrity, enable transport into the habitat, maintain crew safety, and provide organized and accessible storage for all logistics items.

The size of your selected logistics container(s) should optimize storage for a crew of four on a 28-day mission, accommodating about 1,965 kg, or 4332 lb., of logistics supplies packed in 130 standard 1CTBE CTBs. NASA encourages teams to explore various container sizing strategies to determine the most efficient approach – whether one large container to hold all 130 CTBs or multiple smaller containers that may be uniform in size or varied to suit specific handling and storage needs.

A single large container would connect to the habitat through a hatch, effectively serving as a walk-in storage module once its pressure is equalized with the habitat. Because of its size and mass, it would be transported from the landing site and positioned at the hatch using mechanical aids such as a crane or other heavy-handling equipment. Proper alignment with the hatch is always challenging, and at the lunar south pole it may be especially difficult because NASA's current docking systems rely on visual alignment methods, which can be hindered if they are affected by full or partial shadows. In this configuration, the habitat would require two hatches: One dedicated to the logistics container and a separate hatch for crew ingress and egress for EVAs.

Smaller containers would be stored in proximity to the habitat and require an EVA to retrieve them. Their size and dimensions should allow efficient CTB storage, support handling by one crew member either by hand or with the assistance of a mobility aid, and be transported by the crew member through the same hatch that is used for EVAs.

For this scenario, assume the containers will receive power from their cargo lander until they are offloaded. Once offloaded, they will require an independent power source and/or a passive system capable of maintaining internal temperatures and pressures, as well as recording and storing this data. Although alternatives are currently being explored at NASA, assume the containers will be offloaded from the lander and positioned in sunlight near the habitat 30 days before the crew's arrival. The design must ensure that the containers remain within acceptable environmental parameters throughout this pre-deployment period without relying on lander power.

The primary design tradeoff to consider is the size and number of logistics containers. Here are some of the advantages and challenges of each. Your team will likely identify other factors:

Many Smaller Containers

Challenges:

- The tare mass of the containers compared with the mass of the total cargo might be higher than for a single container.
- Temperature maintenance and pressure equalization mechanisms are needed for every container.
- A single crew member must carry each container into the habitat from the outside.
- Dust removal in an airlock would be required prior to bringing the container into the habitat.
- Many small landers may be needed. *

Advantages:

- Heavy equipment is not required to position the containers on the lunar surface; mobility aids, if needed, would be simpler and require less mass than large-scale moving equipment.
- The habitat would require only one hatch.
- Containers are retrieved only when fresh supplies are needed.
- Supplies stored outside the habitat remain protected without strain on the habitat environment.
- Smaller containers might be more flexible for repurposing and/or reuse.

One Large Container

Challenges:

- Complex mobility and lifting aids are required to move the container into position.
- Temperature and pressure must be managed consistently throughout the container prior to opening.
- Alignment with the habitat may be challenging.
- A tight seal must be maintained at the hatch opening throughout the mission.
- The habitat would require two hatches.
- One of two choices must be made that may place a strain on either the habitat's or the container's environmental controls:
  - The habitat's environmental controls must extend into the container to maintain a shirt-sleeve environment for the entire 28-day mission, or
  - A hatch mechanism must be installed to seal the area when not in use. In this case, the container must resume maintaining its own temperature and pressure when the hatch is sealed off.
- A single, large lander is required. *

Advantages:

- The tare mass of one container is likely lower than the combined tare mass of multiple smaller ones.
- Crew members can carry CTBs directly into the habitat from the container.
- Dust removal is unnecessary when bringing CTBs into the habitat, unless the hatch seal is compromised.
- Only one container requires temperature control and pressure-relief mechanisms.
- Pressure equalization is required only once (if the hatch remains open throughout the mission).
- It is possible that no dust removal will be needed for the container's exterior. This depends on choices for repurposing and reuse.

*This may either be an advantage or a disadvantage, depending on the size of the container and the functionality of the lander.

The Hatch(es)
The habitat can be equipped with either one or two hatches of the same size (1x1.5 m or 60x40 in.). The main hatch is always dedicated to crew ingress/egress for EVAs. A second hatch is added only if your team chooses to connect a single large logistics container. In that case, the crew will access supplies through the container hatch, which will remain attached to the habitat for the duration of the mission. If your team designs multiple smaller containers, they will be carried in through the main hatch, and a second hatch would not be required.

Systems and Process Planning
This design challenge involves multiple objectives and numerous design variables. Containers must maintain proper temperatures and pressures to preserve logistics quality, while also minimizing overall volume and mass. They must be easy to open, allow for smooth pressure equalization with the surrounding environment, and be appropriately sized to avoid being too heavy or cumbersome for the crew. Balancing human-systems factors has been a long-standing challenge in the space industry. To address these complexities, teams are encouraged to engage industrial- and human-factors engineering students as a part of their team to help optimize usability, safety, and efficiency. For a comprehensive review of space-crew life support baseline values, see [7, 8].

Supplies will arrive on the lunar surface before the mission and will be staged outside the habitat. The crew will transfer a portion of these supplies into the habitat as needed. To provide context for expected use of the hatch, NASA currently anticipates that the crew will enter and exit the habitat once every other day to conduct scientific EVAs.

Since crew time is a scarce and costly resource, ideal solutions will minimize operational complexity to reduce the time required for training, use, maintenance, and repair. Designs must also prioritize crew safety (See NASA Technical Standards 6001 [7 - 10]) while minimizing energy requirements, material volume, and mass. Potential safety concerns include flammability due to elevated oxygen levels, material off-gassing, pressure relief, lifting and carrying hazards, and other risks your team may identify.

Technoeconomic Analysis and Equivalent System Mass: Evaluating Space Systems
In every engineering design, cost is a key factor. For this task, teams will determine capital expenses (CAPEX) using standard methods. To evaluate operational costs (OPEX), your team will evaluate the system's "equivalent system mass." Mass is used as the standard for this evaluation because launching mass into space is a major operational cost. Equivalent System Mass (ESM) reduces all elements of a technology into a single parameter stated in units of mass. ESM for space technologies typically includes mass, volume, power, cooling, and crew time.

Specifically for this project, NASA engineers developed the following ESM computation guidelines based on the *Advanced Life Support Equivalent System Mass Guidelines* [11] and *Advanced Waste Management Strategic Analysis: Human Lunar Return to Sustained Lunar Evolution* [12].

Teams shall use the following equation for determining ESM for their container:

$$ESM = M + V \times E_v + P \times E_P + C \times E_c \qquad (1)$$

Where M = total mass of the team's concept (kg)
V = total pressurized volume of the system
P = required power of the team's concept (in kW)
C = any cooling needed for the team's concept (in kW)
E_V = 17.6 kg/cubic meter
E_P = 70.3 kg/kW
E_C = 95 kg/kw

Article [11] explains these terms in detail, noting that most of the power consumed by environmental support systems is ultimately rejected as heat, making subsystem cooling needs roughly equivalent to subsystem power needs. For initial studies, setting P equal to C is therefore a reasonable approximation, though your team may refine these variables if appropriate. Crew time is omitted in equation 1, since teams are unlikely to reach a level of analysis sufficient to incorporate it into the ESM.

Contest Logistics Container Specifications

To ensure the safe preservation of life-sustaining dry goods, logistics containers must meet specific performance and safety requirements. Full-scale key parameters discussed earlier in this document are summarized below. These will be proportionally scaled down for the bench-scale demonstration, as indicated.

- **Container Contents and Sizing:** Explore the tradeoffs between larger quantities of smaller containers vs. smaller quantities of larger containers. Smaller containers need not all be the same dimensions.
    - Propose the full-scale logistics container dimensions based on the need to store 130 CTBs, most being the standard 1CTBE size. This will supply a 4-crew, 28-day lunar mission with 1,965 kg (4332 lb.) of logistics supplies.
    - *Bench-scale prototype for this design challenge:*
        - The volume of the scaled-down logistics container shall be 0.113 m^3 (4.0 ft^3).
        - The container materials shall align with the specifications listed in the following section.
        - The mass of the contents within the prototype should be proportionally scaled to match the container's reduced size.
        - The container shall be demonstrated using CTBs that are scaled to the standard 1CTBE dimensions. For example, a 1/3CTBE should measure 16.73 cm × 14.17 cm × 8.27 cm (6.7 in × 5.7 in × 3.3 in). For practicality, these dimensions may be rounded or chopped – for example, to 7 in x 6 in x 3 in., but be consistent across the scaled-down container, mass, and CTB sizes.
        - Identify two to three items that do not fit within the standard 1CTBE. Design custom CTBs for these items and ensure they can be packed efficiently alongside standard CTBs. Provide a rationale for the dimensions selected.
        - Configure the logistics container to allow flexibility in internal CTB arrangements and/or sizes. All items must be securely restrained to prevent shifting during transport.

- **Materials:** Select one or more materials for the container, tailored to the unique needs of the interior and exterior. Options may include hard goods, fabric, and soft goods that are abrasion- and impact-resistant, durable, and suited for use in space. Provide supporting evidence for your selections in the technical report.
  The materials should (as applicable to your design):
    - Provide sufficient rigidity to support the planned use without collapsing or deforming.
    - Withstand impacts and resist abrasion from sharp lunar regolith and repeated crew handling.
    - Resist the adhesion of lunar dust, as needed. [See 13].
    - Ensure crew safety during handling and storage in the confined habitat (e.g., non-toxic, low off-gassing, fire-resistant).
    - Incorporate organizational dividers and/or tethers to prevent content shifting.
    - Tolerate extreme temperatures, up to 54°C (130°F) and as low as -203°C (-334°F), and endure rapid thermal cycling without loss of integrity.
    - Protect against degradation from exposure to solar radiation.

- **CTB Contents:** For the bench-scale prototype, the CTBs should be scaled in proportion to the prototype container. They do not need to hold actual supplies or be constructed from specific materials. However, they should be used to simulate the mass distribution required to meet the container's volume and weight limitations.
    - Maintain the same dimensional proportions as full-scale CTBs.
    - Full-scale CTB parameters:
        - Volume: 0.053 m^3 (1.9 ft^3)
        - Dimensions: 50.2 cm X 42.5 cm X 24.8 cm (20in. x 17in. x 10in.)
        - Empty mass: 0.89kg (1.96lb)
        - Weight limit: 27.2 kg (60 lb.)

- **Packing/Unpacking:** The containers will be loaded on Earth and unloaded on the lunar surface. The CTBs containing dry goods should be securely stored within the container to minimize shifting during launch, landing, and transport across the lunar surface. Include a plan for orderly item arrangement to help the crew quickly locate and access needed supplies.

- **Total Mass:** Total full-scale mass to consider includes:
  - Logistics supplies 1,965 kg (4332 lb.);
  - CTB empty mass (0.89kg (1.96lb) each;
  - Any power-generating equipment and supplies;
  - Thermal control equipment;
  - Structural materials, protective materials, handling hardware, securing hardware, etc.;
  - Pressure-relief equipment;
  - Data recording/logging equipment;
  - Estimated mass of lander(s) needed for your design;
  - Other support equipment, as identified by your team.

- **Pressure:** The container(s) will be packed on Earth at 101k Pa (14.7 psi). They must:
  - Maintain an internal pressure of at least 56 kPa (8.2 psi) during transport to the Moon and while on the lunar surface, until pressure is relieved by the crew.
  - Be equipped with a pressure-equalization mechanism that allows the crew to safely adjust the container's internal pressure to match the 56 kPa (8.2 psi) habitat environment.

- **Temperature:** The container(s) must maintain an internal temperature between 4 and 21°C (39 - 70°F) until opened. This will maintain the integrity and stability of sensitive dry goods.

- **Data Monitoring, Logging, and Transmission**:
  - Each container must continuously monitor its internal pressure and temperature.
  - Temperature and pressure data must be logged in real time and stored securely to ensure data is available for review and analysis at any time.
  - Each container must be capable of transmitting these records to verify that the temperature and pressure remained within acceptable limits throughout the entire mission – from launch, through retrieval, and until pressure relief by the crew.
  - Your team will select appropriate data logging and transmission protocols to send updated information to both the lunar surface crew and Ground Control.

- **Power:** Your system must provide for all power needs from lunar touchdown until the crew opens the containers. For this design challenge, assume a 58-day duration (30 days pre-crew and 28 days crewed), and design for at least 68 days of autonomous operation in case of mission delays. The system must support:
  - Temperature and pressure maintenance within each container;
  - Continuous data logging of temperature and pressure, along with periodic telemetry for monitoring and verification.

- **Delivery and Handling:** Each container will be delivered to the lunar surface on its own lander 30 days prior to the crew's arrival.
    - Consider how one large container or multiple small containers will be positioned for crew access, accounting for the total mass of the selected design and the equipment needed for placement. Handling requirements for one large container may require cranes or other mechanical aids, whereas multiple smaller containers could be moved by a single crew member with minimal equipment.
        - Lander(s): Since NASA has not yet finalized lander designs, teams shall make reasonable assumptions based on past lander concepts. While lander design itself is not part of this task, the technical report shall address how the number and size of landers could affect the mission's total CAPEX and ESM.
        - Support Equipment: Container concepts should identify, detail, and estimate the relative CAPEX and ESM contributed by support equipment needed to pack/unpack, load/offload, and/or transport the containers. These could include lifts, carts, cranes, hoists, etc.
    - As a value-added component, teams may propose container design features that would aid in the delivery of their container(s).
    - Address crew safety, ease of access while in space suits, stability on uneven terrain, and the ability to reposition containers if required by mission operations. WERC's SMEs emphasize that all equipment handling on the lunar surface must be executable by a single crew member, as multi-operator manipulation of large payloads has been demonstrated to be impractical under lunar conditions.

- **Interface with the Habitat:** The crew must bring their logistics supplies into the shirt-sleeve habitat through a hatch that is 1x1.5 m (60x40 in.) in full scale. For all container configurations, pressure equalization and CTB removal shall occur within the shirt-sleeve environment, permitting operations without protective gloves, unless specific hazards are identified that require their use. Your team may plan for one of two possible configurations:
    - <u>*One large container will attach to the hatch,*</u> allowing the crew to walk through and access items throughout the 28-day mission. The container will remain attached to the habitat for the duration of the mission. Special considerations: 1) aligning the container to the hatch, joining the two, and equalizing the pressures between the container and the habitat; 2) allowing crew to move through the hatch connection carrying CTBs; 3) maintaining a hatch seal that prevents lunar regolith from entering the connection; 4) choosing whether to keep the hatch open for the entire mission or to close and reopen as needed; 5) managing the empty container at the end of the mission.
    - <u>*Multiple smaller containers are brought through the hatch one at a time by a crew member.*</u> Each container must remain sealed until it enters the habitat. Once inside, a crew member must safely equalize the internal pressure to match that of the habitat, open the container, retrieve the CTBs and the supplies within them, and then manage the empty container. Special considerations:
      1) each container must be brought into the habitat before being opened; 2) lunar regolith must be removed from each container before it enters the habitat; 3) each container must have its own controls; 4) multiple empty containers must be managed.

- **Managing the Empty Container(s):** Empty containers may be stowed or repurposed, either inside or outside the habitat. Describe your team's proposed management plans. If feasible, demonstrate empty container management during the bench-scale demonstration.

  Current NASA concepts use containers to store trash and waste until disposal, but teams are encouraged to suggest other repurposing options after cargo removal. For a single large container, consider the effects of gradual emptying over time and the resulting growing unused internal volume. Although the article refers to CTBs, a NASA JSC white paper can provide inspiration for container repurposing [14].

Contest Design Requirements

Your proposed design should provide the following details and outcomes.

- Follow all parameters listed in the section *Contest Logistics Container Specifications.*
- Review available literature on logistics containers and human factors. Generate concepts for your solution, narrow to a few options, then prototype, test, and iterate.
- Design a logistics container to store CTBs that balances: minimizing crew time for setup, training, operation, and maintenance; ensuring crew safety; enabling efficient transport and positioning on the lunar surface; resisting dust and abrasion; providing durability; storing and/or generating power; and minimizing mass, volume, footprint, and ESM.
- Include one or more complete process flow diagrams in your technical report showing all inputs, outputs, and processes, including maintaining temperatures and pressures, how pressure will be equalized, and how data is collected, stored, and reported.
- In addition to other items listed in this document, include in the Technical Report (and poster, as applicable):
    - Labeled diagrams that illustrate a full-scale design of your logistics container(s).
    - Predicted full-scale power usage, volume, and mass;
    - Expected maintenance of the containers;
    - Modularity of parts in the event of repairs, maintenance, etc.;
    - Documented applicability in ⅙ Earth's gravity at the lunar surface;
    - *Concept of Operations* for how the container will be managed and support the crew from the time of landing on the moon until it is accessed by the crew. Consider the expected effect on:
        - Crew workload (direct interaction, time, convenience, etc.) during landing, setup, hatch interfacing, accessibility of logistics items, etc.
        - Crew safety, including carrying weight or awkward dimensions, potential pressure-relief failures, exposure to lunar dust, off-gassing, flammability, or other hazards.
- Present a Techno-Economic Analysis (TEA) to construct your logistics container(s) to supply a four-person crew for 28 days.
    - Capital expenses (CAPEX):
        - Include all materials, equipment, electronics, pipes, pumps, meters, and other items needed to build the container(s).
        - Calculate the predicted CAPEX for lander(s) and positioning equipment; report these separately and as a combined total with the container's CAPEX.
        - Do not include costs of buildings in which the logistics containers will be manufactured.
    - Operating expenses (OPEX):
        - Calculate as the cost for launch, based on the total ESM.
        - Calculate the predicted ESM of lander(s) and positioning equipment; report these results separately and as a combined total with the container's ESM.
    - Visualization tools: Use tools such as sensitivity analyses, graphs, and other visuals to illustrate how key parameters impact system performance and economics.
- Contest Testing: follow the Bench-scale Demonstration criteria, below, for building and testing the bench-scale prototype logistics container.
- Address safety aspects of your design. Safety issues for the full-scale design should be included in the technical report. Safety issues for the bench-scale demonstration should be addressed in both the written report and the Experimental Safety Plan (ESP).

Bench Scale Demonstration

Teams will demonstrate a bench-scale design for a logistics container prototype according to the details below. Keep in mind that the contest is held in a banquet facility, without typical lab resources (e.g., no fume hoods, ovens, etc.). WERC can provide your team with an 8-foot folding table and access to 120V power. See the Team Manual for more bench-scale setup constraints.

Teams will provide at the contest:

- One prototype logistics container that shall:
  - Have a volume of approximately 0.113 m^3 (4.0 ft^3);
  - Maintain temperatures between 4 and 21°C and pressures between 14.7 and 8.2 psi;
  - Provide a means of relieving pressure within the container to equal ambient pressures;
  - Include means of measuring and recording temperatures and pressures, and communicating this information to the team's device(s) of choice;
  - Be equipped with the team's proposed interior and exterior materials, handling gear, tethering, compartments, etc., including the ability to be re-configured to hold an item that cannot fit within one CTBE;
  - Demonstrate the repurposing or stowage configuration;
  - Accommodate transfer of items from the container into the habitat:
    - If prototyping a single large container: Include the sealed hatch interface, demonstrate its pressure-relief mechanism, and illustrate (theoretically or schematically) how it would connect to a habitat. No full habitat or habitat hatch is required.
    - If prototyping one example of multiple smaller containers: Demonstrate that it would be maneuverable by a single person and able to pass easily through a hatch size opening that can be scaled up to 1x1.5 m (60x40 in.);
- CTB mock-ups that scale with your logistics container.
  - These are needed only to illustrate the functionality of the interior of your container. They do not need to hold supplies or be constructed from specific materials.
  - They should be properly scaled to the prototype container size. When possible, their weight should be used to simulate the expected mass distribution while remaining within the container's weight limitations.
  - Teams may use their judgment in selecting the number of CTBs for the demonstration. It is not required that storage of the full 130 CTBs be demonstrated at the bench scale. In the 30% Project Review, describe the size and number of CTB mock-ups you will bring and how you will use them to demonstrate the functionality of your container.

WERC will provide at the contest:

- Conditions that simulate near-lunar temperature and pressure variations:
  - Temperature: containers will be exposed to cycles below freezing and above 50°C (122°F).
  - Pressure: containers will be placed under a partial vacuum (pending the availability of a vacuum chamber large enough to hold your container).
- A "spare part" to be placed into your team's logistics container. This part will be scaled to the size of your team's CTB. Watch for more information after we review your 30% Project Review.
- Lunar regolith simulant to test dust resistance (LHS-1 from Space Resources Technologies/Exolith Labs, [15]).
- Additional items requested by your team, if needed. Although teams will provide the majority of items needed for the bench-scale demonstration, you may submit requests to WERC in the 30% Project review by January 30, 2026 (*See Team Manual*). These may include materials not safe to ship (such as pressurized gas cylinders) or bulky, low-cost items (such as kiddie wading pools) that are impractical to ship to the contest.

Contest Analytical Testing:

Materials Requirements

The materials used in your prototype container should be technically and logistically feasible for the application, including being tear-, scratch-, and impact-resistant and structurally capable of maintaining its shape. Dust resistance should also be addressed. These properties will be evaluated based on the evidence your team presents in the technical report, bench-scale demonstration, and the judges' assessments of the material's integrity.

Analytical Testing During the Contest

Although details of the analytical testing will be determined when all teams have submitted their 30% Project Review, WERC currently plans for teams to bring their sealed* container to the contest, where it will be tested as follows.

- Teams will demonstrate to the judges how data are collected, logged, and transferred. Judges will evaluate system performance under environmental stressors as WERC subjects your container to:
    - Large temperature swings, as previously specified;
    - Partial vacuum conditions.
- Judges will observe the pressure-relief process and evaluate its ease of operation, effectiveness, and safety.
- WERC will independently verify the accuracy of your container's temperature- and pressure-monitoring devices.
- WERC will explore the option of sealing and re-sealing your container at the contest. In the 30% Project Review, indicate the feasibility of this option as it applies to your design.

* To satisfy WERC's curiosity (and perhaps your own), teams coming from lower altitudes are encouraged to bring or ship their sealed containers to WERC's altitude of approximately 1,433 meters (4,700 feet) and equalize internal pressure as a part of the bench-scale demonstration.

30% Project Review

Due in late January, or a date requested by your team, the 30% Project Review outlines the design, functionality, and details for how you plan to demonstrate and test your logistics containers during the contest in Las Cruces. The report does not include background research, the TEA, community engagement plans, or audits. Teams are allowed to change parameters after submitting the report.

The 2026 Team Manual gives general guidelines for the 30% review. Pay particular attention to the Process Flow Diagram (PFD) that serves as a robust outline of all processes and balanced inputs and outputs in your system.

Specific to this project:

- Include a complete PFD. This will be reviewed by SMEs from NASA.
- Submit a draft for your bench-scale setup. Provide a scaled 3-D view of both the interior and exterior of the logistics container prototype, with dimensions labeled. If applicable, include repurposing and/or stowage plans. Specify whether the draft represents a single large container or one example of multiple small containers. If a large container, include the hatch connection in the 3-D views.
- Explain the method of relieving pressure during the contest. This is a critical safety consideration.
- Describe how you would facilitate the repeated opening and sealing of the container at the contest.
- Include all bench-scale setup requests, such as indoor versus outdoor demonstration area, the potential need to run the process overnight (justify the needs and describe continuous monitoring, power needs, safety measures).
- Request auxiliary equipment and supplies needed, if any, such as sample LHS-1 regolith, pressurized gas cylinders, bulky items, etc. Provide justifications for each requested item.
- Indicate the number of CTBs you will bring to demonstrate your technology. Specify their dimensions, weight, and construction materials, including 2-3 odd-sized CTBs. If warranted by your project, you may request that WERC provide additional or specialty CTBs; provide justification for the request.
- Determine bench-scale testing parameters: Outline how you plan to demonstrate and have WERC test the container's ability to maintain and monitor temperatures and pressures, and to log and transmit this data.
- Describe how you plan to demonstrate crew interaction with the container.

Evaluation Criteria
Each team is advised to read *Evaluation Criteria* and *Contest Scoring* in the 2026 Team Manual to gain a comprehensive understanding of the contest evaluation criteria. For a copy of the Team Manual, Public Involvement Plan, Audits, and other important resources, visit the WERC website: Guidelines | werc.nmsu.edu.

In addition to the evaluation criteria that apply to every task, judges will evaluate your team's response to the problem statement, with consideration of the *Contest Logistics Container Specifications* and the *Design Requirements* listed above. In particular, judges will evaluate:

- The overall CAPEX and ESM for the project;
- Total mass of containers vs the mass of the dry goods carried (favoring more efficient designs);
- The perceived durability and abrasion resistance of the logistics containers under operational conditions;
- Appropriateness of the number, size, and dimensions of the container(s), relative to mission needs;
- The power needs vs the ability of the container to maintain temperature and pressure ranges;
- Ease of offloading, moving, positioning, and handling the containers while on the lunar surface and (if applicable) within the habitat;
- Human factors involved in packing and unpacking the dry goods, including accessibility and ergonomics;
- Simplicity of the concept of operations (with preference given to less complex systems).

Experimental Safety Plan (ESP) and Required On-Demand Short Course.
See team manual for details. Due date is listed below. Teams will not be able to run a bench-scale demonstration if the ESP is not received by the deadline. This document is submitted no later than March 1, 2026 (see dates below). Instructions for preparing the ESP are provided in the 2026 Team Manual, and your entire team is required to attend a mandatory short course that outlines the ESP process.

Dates, Deadlines, FAQs (*dates subject to change—watch website FAQs*)

This Fall	Email us to reserve a spot for your team and get on the email list for this task. Registration is limited.
Weekly	Check FAQs for updates: • Task-specific FAQs: 2026 Tasks/Task FAQs • General FAQs: 2026 General FAQs
November 1, 2025 - December 31, 2025	Early Bird Registration (discount applies)
December 1, 2025 – January 30, 2026	30% Project Review Due (or as arranged with WERC).
December 1, 2025 – February 16 ,2026	Mandatory On-demand Course: Preparing the Experimental Safety Plan. See Team Manual.
February 17, 2026	Final date to register a team w/o permission.
March 9 -13, 2026	Experimental Safety Plan (ESP) due to Juanita Miller. Include requests for chemicals, materials, etc.
April 2, 2026	Technical Report due
April 12 – 15, 2026	Contest in Las Cruces

Contacts:
ESP Questions: Safety Officer Juanita Miller, miljgh@nmsu.edu
All other correspondence: Ginger Scarbrough, werc@nmsu.edu

References

[1] Moon to Mars Overview. https://science.nasa.gov/toolkit/moon-to-mars/ (Accessed 7/10/2025).

[2] Artemis. https://www.nasa.gov/specials/artemis/ (Accessed 7/10/2025).

[3] Mahoney, E. Moon's South Pole is Full of Mystery, Science, Intrigue. 2022. https://www.nasa.gov/humans-in-space/moons-south-pole-is-full-of-mystery-science-intrigue/#:~:text=%E2%80%8BAt%20the%20lunar%20South,to%20rising%20and%20plummeting%20temperatures. (Accessed 7/14/2025).

[4] White Paper. Lunar Logistics: Drivers and Needs. 2023. https://www.nasa.gov/wp-content/uploads/2024/01/lunar-logistics-drivers-and-needs.pdf?emrc=4e168e (Accessed 07/31/25).

[5] Kitchmacher, G. Reply #7, Evolution of Stowage in US Spacecraft. https://forum.nasaspaceflight.com/index.php?topic=12018.0. (Accessed 9/16/2025).

[6] NASA Interim Directive (NID): Use of International Space Station (ISS) for Commercial and Marketing Activities. Associate Administrator for Human Exploration and Operations. 2019. https://www.nasa.gov/wp-content/uploads/2015/03/s1701746119060610280_1.pdf?emrc=e7a261#:~:text=4.2%20DEFINITIONS,Activity%20(Category%20A) (Accessed 9/10/2025).

[7] Ewert, M.K., Chen, T.T., and C.D. Powell. Life Support Baseline Values and Assumptions Document. 2022. NASA/TP-2015-218570/Rev2. *https://ntrs.nasa.gov/api/citations/20210024855/downloads/BVAD_2.15.22-final.pdf* (Accessed 7/11/2025).

[8] Lynch, C.S., K.E. Goodliff, C. Stromgren, J. Vega, and M.K. Ewert. Logistics Rates and Assumptions for Future Human Spaceflight Missions Beyond LEO. 2023. https://ntrs.nasa.gov/api/citations/20230012635/downloads/Logistics%20Rates%20and%20Assumptions%20Beyond%20LEO%20V5.pdf (Accessed 9/17/2025).

[9] NASA Space Flight Human-System Standard 3001. Vol. I, Rev. B. Crew Health. 2022. 2022-01-05-NASA-STD-3001-Vol1-Rev-B-Final-Draft-Signature-010522.pdf (Accessed 9/09/2025)

[10] Flammability, Offgassing, and Compatibility Requirements and Test Procedures. NASA-STD-6001. https://standards.nasa.gov/standard/NASA/NASA-STD-6001 (Accessed 07/31/25).

[11] Hanford, A.J. NASA: Advanced Life Support Equivalent System Mass Guidelines Document. September 2003. https://ntrs.nasa.gov/api/citations/20040021355/downloads/20040021355.pdf (Accessed 7/10/2025).

[12] Pitts, R.P., Alvarez, V.R., Ewert, M.K., and A.M. Spader. Advanced Waste Management Strategic Analysis: Human Lunar Return to Sustained Lunar Evolution" 2025 International Conference on Environmental Systems. July 7, 2025. Advanced Waste Management Strategic Analysis: Human Lunar Return to Sustained Lunar Evolution (Accessed 9/9/2025)

[13] Baccus, S., Broyan, J.L., and M. Borrego. Technical Report. 2016. Multipurpose Cargo Transfer Bags for Reducing Exploration Mission Logistics - NASA Technical Reports Server (NTRS) (Accessed 9/09/25)

[14] Abel, P.B., C. Calle, P.H. Dunlap, D.G. Fischer, S.A. Howard, K.M. Hurlbert, J.L. Jordan, D.R. Ludwiczak, E. Orndoff, F. Thomas, C. Wohl. Lunar Dust Mitigation: A Guide and Reference, First Edition (2021). NASA/TP-20220018746. https://ntrs.nasa.gov/api/citations/20220018746/downloads/TP-20220018746.pdf (Accessed 8/10/25).

[15] University of Central Florida CLASS Exolith Lab. https://sciences.ucf.edu/class/exolithlab/ (Accessed 9/10/25).