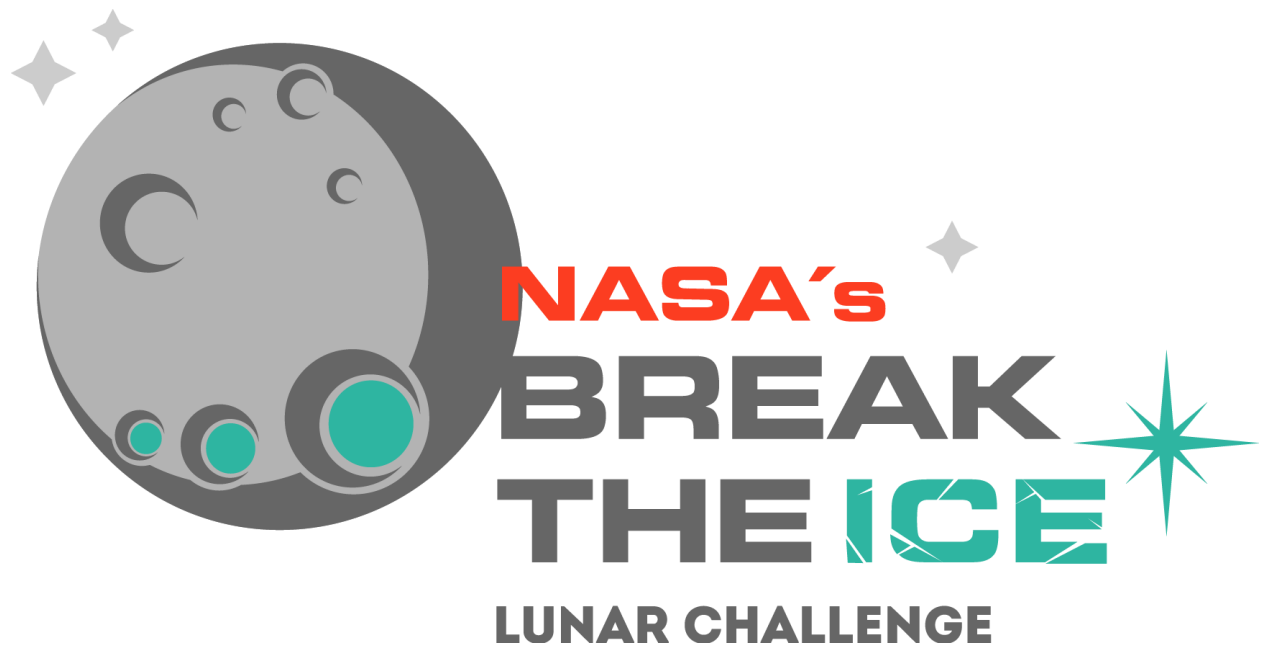


NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
(NASA)



Phase 2 Competition Rules
June 2022

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Revision Tracking Log

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| Baseline | | 6/2/2022 | Document Baseline |

1. Definition of Terms

Eligibility Requirements Document: A document that all Teams must sign in order to participate in the Challenge.

Ensemble: Ensemble is a contractor that provides challenge operations services. NASA has contracted with Ensemble to support the administration and promotion of this Challenge.

Excavation: The use of a tool or tools to remove in-situ material from a predetermined location.

Icy Regolith: In-situ regolith (see definition below) with a temperature between 40 Kelvin and 70 Kelvin that contains volatile materials with varying percentages of water content by weight.

Judging Panel: A panel of professionals and subject matter experts from government, academia, and industry who will evaluate and score Phase 2 submissions.

Ombudsman: A liaison available to help resolve disputes. Additional information regarding the ombudsman can be found in the Eligibility Requirements Document.

Permanently Shadowed Region (PSR): A general term describing a location on the lunar surface that does not receive any direct illumination or heat from the Sun and therefore is always dark and cold.

Prototype: A preliminary version of the excavation system that is built to test in laboratory conditions.

Regolith: Granular lunar material that contains no volatile materials and has a maximum grain size of 1 mm.

Team: Individual(s) or organization(s) who have registered to compete in the Challenge.

Team Leader: The person selected by each Team to interact with the Challenge contractor (Ensemble). The Team Leader will be responsible for compliance with the rules, and NASA will issue prize payments to the Team Leaders of the winning Teams.

2. Challenge Background and Objectives

As NASA works to extend human exploration of the solar system, a sustained presence on the Moon will be critical for developing and testing the technologies and systems needed for future missions to the Moon and beyond.

In situ resource utilization (ISRU)—the development of lunar materials for life support, fuel, energy, manufacturing, and construction—is necessary to limit the delivery of supplies from Earth.

One of the most important of these resources is water. Water supports all life on Earth and will be critical to supporting human exploration beyond Earth. On the Moon, water is trapped in icy regolith at the lunar poles, including inside permanently shadowed regions (PSRs).

The Break the Ice Lunar Challenge seeks to incentivize innovative approaches for excavating icy regolith and delivering acquired resources in extreme lunar environmental conditions. The Challenge seeks to incentivize solutions for maximizing resource delivery while minimizing energy use and the mass of equipment delivered to the lunar surface.

3. Challenge Overview and Technical Goals

3.1. Competition Overview

The Break the Ice Lunar Challenge has two phases and a total prize purse of \$3.5 million.

Phase 1 of the Break the Ice Lunar Challenge was focused on incentivizing new ideas and approaches to a system architecture for excavation and movement of icy regolith and water on the lunar surface. Phase 1 of the challenge opened in November 2020. Teams had six months to register and submit solutions for Phase 1. Phase 1 winners were announced in August 2021. Teams were awarded a total of \$500,000 in Phase 1 (<https://www.nasa.gov/feature/nasa-awards-500000-in-break-the-ice-lunar-challenge>).

The goal of Phase 2 is to further the development of technologies that can excavate and transport large quantities of icy lunar regolith and can address the technology gaps listed below. Phase 2 will not focus on ice/water delivery hardware or equipment (which was of interest in Phase 1). Through a prototype demonstration, Teams must show that their solutions address the reliability, durability, and traversability challenges these systems must overcome to operate for long durations.

The specific NASA technology gaps that Phase 2 aims to address include:

- Excavate large quantities of icy regolith
- Delivery of large quantities of acquired resources
- Hardware and equipment that is lightweight and energy efficient
- Hardware and equipment that is reliable and durable

- Hardware and equipment that operates well in extreme lunar environmental conditions, including:
 - Reduced gravity
 - Complex terrain including rocks, craters, slopes, and loose granular soil

In Phase 2, Teams will be asked to design, build, and test their icy regolith excavation system and their icy regolith transportation system. Phase 2 contains three levels and will last for 23 months (including judging) and offers a total prize purse of \$3 million.

3.1.1 Mission Scenario

In the Break the Ice Challenge, teams design, manufacture, and test equipment to support a hypothetical lunar ISRU mission. The details of this hypothetical mission are described in the Rules for Phase 1 of the Challenge (<https://breaktheicechallenge.com/wp-content/uploads/2021/01/Break-the-Ice-Challenge-Phase-1-Rules-Rev-B.pdf>).

In Phase 1, Teams designed system architectures to excavate icy regolith and to deliver water based on the locations and sites, environmental conditions, terrain, icy regolith specifications, and hypothetical NASA assets described in the Mission Scenario.

In Phase 2, Teams will design technologies that can excavate and transport large quantities of simulated icy lunar regolith and can operate in lunar relevant conditions and scenarios. Phase 2 of this Challenge will not focus on processed ice/water delivery nor the equipment required to perform this function. However, details of water delivery are shown in the hypothetical Mission Scenario to provide full mission context.

3.2. Phase 2

3.2.1 Eligibility and Registration

Any individual, groups of individuals, and/or organizations or entities that meet the eligibility criteria provided in Section 4 may enter Phase 2. Participation in Phase 1 is not a requirement to compete in Phase 2.

All interested Teams must register by September 30, 2022 (11:59 PM Eastern) and meet the eligibility requirements in order to participate in Phase 2.

The registration process will be administered by Ensemble. Registration will take place through the official challenge website: <https://breaktheicechallenge.com/>. Additional details regarding the process for registration will be available on the Challenge website.

3.2.2 Structure and Timeline

Phase 2 contains three levels. In this Phase, Teams will design, build, and test terrestrial analog full-scale prototypes of robotic icy regolith excavation and transportation systems. Downstream ice and/or water delivery equipment described in Phase 1 of this Challenge will not be considered in Phase 2 of this Challenge. Figure 1 provides a snapshot of the Phase 2 structure.

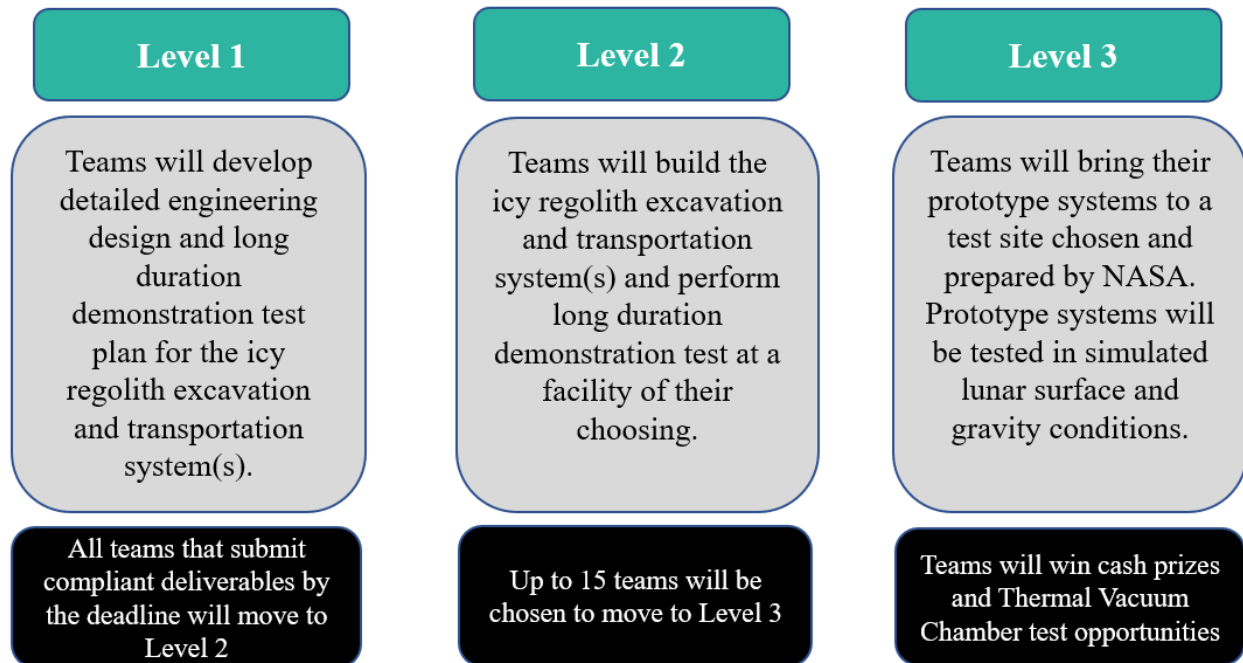


Figure 1. Phase 2 Structure

In Level 1, Teams will develop detailed engineering designs and long-duration demonstration test plans for their prototype systems. Section 3.2.3 provides the equipment requirements. Section 3.2.4 provides the demonstration test requirements. Level 1 will offer up to \$0.5M in prizes. Level 1 deliverables, prize distribution, and judging criteria are provided in the following sections. All Teams that submit compliant deliverables by the deadline will move to Level 2.

In Level 2, Teams will build their prototype systems and perform long-duration demonstration testing (refer to section 3.2.4) at a facility of their choosing. Excavation will be demonstrated by extracting simulated icy regolith from a test bed as described in Section 3.2.5. Transportation will be demonstrated by hauling excavated icy regolith simulant over a surface which simulates certain physical characteristics of the expected lunar surface as described in Section 3.2.6. Level 2 will offer up to \$1M in prizes. Level 2 deliverables, prize distribution, and judging criteria are provided in the following sections. Up to 15 Teams (including the Level 2 winners and runners up) that score above a minimum score (refer to section 3.2.11) will be invited to compete in Level 3.

In Level 3, Teams will bring the prototype system(s) they built and tested in Level 2 to a designated test facility to compete against other teams. The facility will be chosen and prepared by NASA. Expected testing includes excavation under reduced gravity (using gravity off-loading) and transportation over complex terrain (including rocks, craters, slopes, turns, and loose granular soil). More information about Level 3 including detailed testing requirements and judging criteria will be made available at a later date on the challenge website. Level 3 will offer up to \$1.5M in cash prizes. In addition to the cash prizes, NASA will also award opportunities to test concepts in a dusty Thermal Vacuum Chamber (TVAC) that will simulate the temperature

and atmospheric pressure conditions at the lunar south pole, which is the most thoroughly investigated region on the Moon using robots and is a target location for future exploration.

The following is an overview of the expected timeline for Phase 2 of the Challenge.

| Date | Description |
|---|--|
| June 2, 2022 | <ul style="list-style-type: none"> ● Phase 2 opens |
| June – September 2022 | <ul style="list-style-type: none"> ● Webinars to support registered Teams and potential Teams ● Promotional activities and/or other support for registered Teams |
| September 30, 2022 | <ul style="list-style-type: none"> ● Phase 2 registration deadline ● Eligibility Requirements document and Proof of Insurance submission deadline |
| November 4, 2022 | <ul style="list-style-type: none"> ● Level 1 submission deadline |
| December 5, 2022 | <ul style="list-style-type: none"> ● Level 1 winners’ announcement ● Announcement of all Teams that will move to Level 2 |
| September 15, 2023 | <ul style="list-style-type: none"> ● Deadline to start long duration testing |
| October 27, 2023 | <ul style="list-style-type: none"> ● Level 2 submission deadline |
| December 2023 | <ul style="list-style-type: none"> ● Level 2 winners’ announcement ● Selection and announcement of all Teams that will move to Level 3 |
| March 2024 | <ul style="list-style-type: none"> ● Deadline for Teams to confirm Level 3 participation |
| May 2024 | <ul style="list-style-type: none"> ● Level 3 competition and winners’ announcement |
| <i>Note: All deadlines are at 11:59 PM Eastern on the specified date.</i> | |

3.2.3 Equipment Design Requirements

Terrestrial analog full-scale prototypes of robotic icy regolith excavation and transportation systems must meet the following design requirements:

- All hardware and equipment must be designed at full scale:
 - Total system mass must be less than 10,000 kg
 - Total system must notionally fit inside a 6-meter-diameter, 10-meter-long cylinder
 - Total system includes:
 - all icy regolith excavation equipment
 - all icy regolith transportation equipment (can be the same robot that conducts excavation)
 - any spare parts that might be needed during the long-term durability demonstration test regimen
 - any tools and equipment that might be needed for repair and maintenance during the long-term durability demonstration test regimen
 - any tools and equipment that might be needed to maintain the test area during the long-term durability demonstration test regimen
- Icy-regolith excavation and transportation equipment:
 - Must not use wired umbilical power. Only onboard power sources will be allowed (e.g., batteries)

- Must not use wired communications. Only wireless communications equipment will be allowed (e.g., WiFi, Bluetooth, RF)
- Must not employ any fundamental physical processes, gases, fluids or consumables that would not work in a lunar environment. For example:
 - pneumatic systems are allowed only if the gas is stored and supplied onboard the robot itself
 - hydraulic fluid systems are not allowed unless the power and mass for a fully encapsulating heating system is included that would be capable of keeping the fluid from freezing in the extreme environmental conditions on the lunar surface
 - air-filled or foam filled rubber tires are not allowed, as they would not maintain their integrity in the vacuum of the lunar surface
 - ultrasonic sensors are not allowed, as they would not function in a vacuum

Electronic and mechanical components are not required to be space qualified for lunar atmospheric, electromagnetic, or thermal environments. The Challenge is intended to demonstrate off-world plausible system functionality but the components do not have to be traceable to a space-qualified, radiation-hardened version.

Examples of allowable terrestrial components are: sealed lead-acid batteries, nickel metal hydride batteries, rubber or plastic parts, fan-cooled electronics, and motors with brushes. If a Team has a question about the acceptability of a specific terrestrial component, please send the question to admin@breaktheicechallenge.com to receive official guidance.

Since Teams will be performing their long-term durability demonstrations of their prototype systems at terrestrial locations under ambient environmental conditions, working thermal protection systems appropriate for an extreme lunar environment (i.e., motor heaters, electronics heaters, radiators, etc.) will not be required. Working onboard lighting systems appropriate for an extreme lunar environment will also not be required.

3.2.4 Durability Demonstration Test Requirements

Teams will perform a long-term durability demonstration test of their working prototype system per the following requirements:

- Durability demonstration must be performed at a terrestrial location of each Team's choosing.
- Demonstration must include both an excavation subsystem and a transportation subsystem. The transportation subsystem must haul only the material that was previously excavated by the excavation subsystem.
- Demonstration must be performed under ambient conditions (temperature, lighting, atmospheric pressure, naturally occurring dust levels, earth gravity, etc.).
- Teams will target operation of all prototype equipment over a period of 15 full, 24-hour long, earth days, or until equipment fails.
- The excavation subsystem must extract simulated regolith defined in Section 3.2.5.
 - Teams will target excavating 12,000 kg of simulated regolith.

- Teams must start the demonstration using an undisturbed slab of simulated regolith.
- The transportation subsystem must be performed in an area that complies with the requirements of Section 3.2.6.
 - The transportation component must haul material that was excavated during the excavation component of the demonstration.
 - Teams will target transporting and delivering 12,000 kg of simulated regolith.
 - Transportation equipment must haul material 500 meters (one way) to a delivery location.
 - Transportation equipment must return 500 meters back to the excavation location following delivery of material.
 - This 500-meter one-way distance is representative of the distance between the Excavation Site and the NASA Water Extraction Plant detailed in the Mission Scenario.
 - Please note per Section 3.2.6 that the 500-meter travel distance requirements can be met inside a small area as long as the equipment's onboard odometry sensor accurately reads 500 meters per each one-way trip.
- Human intervention with the prototype icy regolith excavation and transportation equipment is allowed during the long-term durability demonstration with the following caveats:
 - prototype icy regolith excavation and transportation equipment can be either remotely controlled by human operators or fully autonomous or anywhere in-between
 - in case of excessive wear or breakdown, manual repairs and parts replacement are allowed, provided worn parts are saved for inspection and details of excessive wear and breakdowns are included in the final Durability Demonstration Test Report, as detailed in section 3.2.9.2
 - any spare parts that might be needed during the test:
 - must have been identified in the Durability Demonstration Test Plan
 - must be on hand throughout the Durability Demonstration
 - must have been weighed and their mass counted as part of the total mass of equipment
 - examples of spare parts include spare tires, swapped out batteries, spare electronics, spare digging teeth, redundant robots, redundant subsystems, etc.
 - any tools and equipment that might be needed for repair and maintenance of prototype icy regolith excavation and transportation equipment during the test:
 - must have been identified in the Durability Demonstration Test Plan
 - must be on hand throughout the Durability Demonstration
 - must have been weighed and their mass counted as part of the total mass of equipment
 - energy consumed by tools and equipment during prototype icy regolith excavation and transportation equipment repair and maintenance will not be collected nor reported as part of the total energy used by the system

- examples of tools and equipment for repair and maintenance include jacks, cranes, toolboxes, power tools, hand tools, etc. (humans using the tools and equipment do not need to be weighed and counted)
- the 15-day timer must not pause for any prototype equipment repair and maintenance activities
- if equipment fails prior to the end of the 15-day durability demonstration test and no spare parts are available for repair, the durability demonstration must be terminated early

3.2.5 Icy Regolith Simulant

The simulated icy regolith utilized by Teams for long duration excavation demonstration shall meet the minimum requirements provided below. Teams shall submit mixture design, certified test report, and a geometry sketch of their icy regolith simulant for review per deliverables in section 3.2.9 and schedule in section 3.2.2.

Concrete materials will be used to simulate the assumed mechanical properties of 4% water weight lunar icy regolith. The 10% water weight icy regolith detailed in the Phase 1 Rules of this Challenge will not be simulated nor utilized in Phase 2.

- Simulated icy regolith shall be made from Controlled Low Strength Materials (CLSM) following the guidance provided in the American Concrete Institute report, ACI 229R Report on Controlled Low-Strength Materials (available at <https://www.concrete.org>).
 - There are no specific requirements or testing of bulk density or tensile strength.
 - Lightweight aggregates are not permitted.
- Simulated icy regolith shall be proven to have an unconfined compressive strength of 1.5 to 2.0 MPa at the start of the Durability Demonstration Test.
 - ASTM C39 Compression Test of 150 mm by 300 mm cylinders are recommended for verifying compressive strength.
- The geometry of the icy regolith simulant is as follows:
 - The depth of the simulated material to be excavated shall be no more than 80 cm.
 - The width and length shall be any dimensions necessary to accommodate the equipment under test. Any shape (square, rectangular, circular, etc.) is also acceptable.
 - A minimum of 20 cm of additional buffer area (an area not to be excavated) shall surround the volume to be excavated in order to minimize the likelihood of a crack that propagates through the boundary of the deposit. See Figure 2.
- Simulated material to be excavated shall be placed in a continuous process lasting no longer than 8 hours.
- Dry (0% water) overburden shall not be simulated.

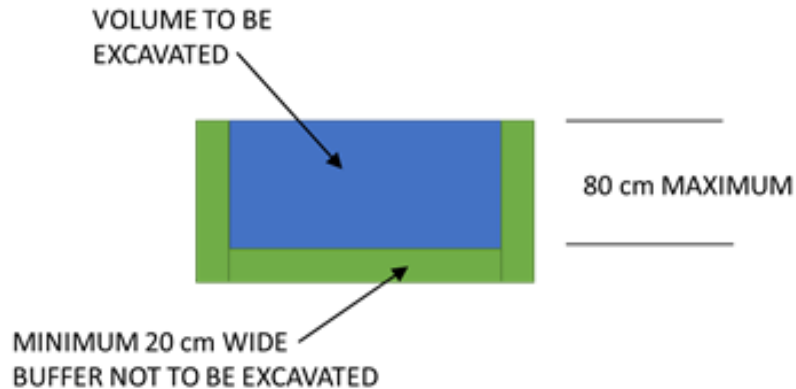


Figure 2. Side view of icy-regolith simulant bed, buffer area shown in green

3.2.6 Transportation Demonstration Area

Rather than prescribing a specific track size, shape, length, roughness, layout, slope, track surface makeup, particle shape, mineralogy, size distribution, and compaction, this Challenge allows each Team to create their own transportation demonstration area capable of demonstrating and testing terrestrial analog full-scale prototypes of robotic icy regolith transportation systems continuously for 15 days. Teams must explain and justify the extent to which their transportation demonstration area simulates the physical and environmental details of the anticipated lunar surface.

The area used for long duration transportation demonstration shall meet the minimum requirements provided below. Teams shall submit plans and specifications for their transportation demonstration area for review per deliverables in section 3.2.9 and schedule in section 3.2.2.

- The minimum one-way travel distance shall be 500 meters from simulated Excavation Site to simulated Water Extraction Plant.
 - This 500-meter travel distance can be performed inside a small area by following multiple paths that are less than the one-way distance, as long as the equipment’s onboard odometry sensor accurately reads 500 meters per each one-way trip.
- Transportation equipment shall drive in the transportation demonstration area in both directions equally. In other words, equipment will drive in one direction to get to the simulated Water Extraction Plant and then drive in the opposite direction to return to the simulated Excavation Site
- The surface of the transportation demonstration area should simulate the surface conditions the Team assumed in designing the icy-regolith transportation system.
- The prototype robotic icy regolith transportation system must repeatedly drive on the same path throughout the Durability Demonstration Test.
- Teams must simulate the regolith delivery to the Water Extraction Plant (detailed in the Mission Scenario) to the following fidelity:
 - The designated delivery location for the simulated regolith must be capable of receiving and weighing the material that was hauled and delivered by the prototype robotic icy regolith transportation system.

- Once delivered, material must be weighed either automatically or manually within the designated delivery location.
 - Once weighed, material may be removed either automatically or manually from the designated delivery location.
 - Teams must target a delivery rate of 800 kg every 24 hours.
 - A daily delivery that is within plus or minus 10% of the target rate is acceptable. Deliveries greater than or less than the target range will have a negative effect on scoring.
- Human intervention with the transportation demonstration area is allowed during the long-term durability demonstration with the following caveats:
 - robotic maintenance equipment can be either remotely controlled by human operators or fully autonomous or anywhere in-between
 - only robotic maintenance of the transportation demonstration area is allowed – human held tools and equipment are not to be used to maintain or repair the transportation demonstration area once the Durability Demonstration Test has started
 - robotic maintenance equipment that might be needed for transportation demonstration area repair and maintenance during the test:
 - must have been identified in the Durability Demonstration Test Plan
 - must be on hand throughout the Durability Demonstration
 - must have been weighed and their mass counted as part of the total mass of equipment
 - energy consumed during transportation demonstration area repair and maintenance will not be collected nor reported as part of the total energy used by the system
 - examples of robotic maintenance equipment for repair and maintenance of transportation demonstration area include earth moving equipment, surface preparation equipment, soil compaction equipment, rock moving equipment, etc.
 - the 15-day timer must not pause for any transportation demonstration area repair and maintenance activities
 - if robotic maintenance equipment fails prior to the end of the 15-day durability demonstration test and the transportation demonstration area conditions can no longer be sufficiently justified as simulating the physical and environmental details of the anticipated lunar surface, the durability demonstration must be terminated early

3.2.7 Data Collection

During the long-term durability demonstration, the following data must be collected by the Team:

- At least one live 1080 line or better resolution video stream that is either publicly accessible or is privately accessible to the NASA Judging Panel
 - This live feed must be broadcast during the entire 15-day duration of the durability demonstration test
 - Separate video feeds focusing on each major piece of hardware and equipment being demonstrated (excavator, regolith transporter, etc.) are required

- Detailed photos of each major piece of hardware and equipment performing normal operations
- Mass of each piece of equipment, including spare parts and repair and maintenance tools on standby whether used or unused during the demonstration, plus total system mass
- Energy used by each piece of prototype icy regolith excavation and transportation equipment, plus total system energy
 - Energy usage must be collected using commercial-off-the-shelf energy data logger devices.
 - Each energy data logger device must be installed in series (inline) with the robot's energy source (battery pack) in order to track total energy used by the robotic system.
 - Energy consumed by tools and equipment during prototype icy regolith excavation and transportation equipment repair and maintenance will not be collected nor reported
 - Energy consumed by tools and equipment during transportation demonstration area repair and maintenance will not be collected nor reported
- Runtime of each piece of equipment, plus total system runtime, plus total number of icy regolith excavation and transportation robots
 - Runtime can be collected using commercial-off-the-shelf sensors, or it can be logged manually by test staff
 - Runtime is defined as any motion of the equipment under test (for example, digging, driving, dumping, etc). Down time, idle time, and recharge time is not considered runtime.
- Total distance traversed by icy-regolith transportation equipment during transportation of material from the excavation location to the delivery location, plus total number of icy-regolith transportation equipment round trips between simulated Excavation Site and simulated Water Extraction Plant
 - Distance traversed can be collected using commercial-off-the-shelf sensors, or it can be logged manually by test staff
 - Number of round trips can be collected automatically by proximity or other applicable sensors, or it can be logged manually by test staff
- Compressive strength of icy regolith simulant at the beginning and end of the 15-day test period.
- Total amount (kg) of icy regolith simulant excavated and delivered
 - A daily record (at the end of each 24 hour period) of the mass of regolith delivered.
 - Any material processed by the excavation equipment which is not also transported and delivered by the transportation equipment will not be scored and should not be reported.
- Log of parts replaced, breakdowns, issues requiring human intervention, along with job-hours spent on repairs and maintenance on the prototype icy regolith excavation and transportation equipment.
- Log of any maintenance or repair to the Transportation Demonstration Area.

3.2.8 Onsite Observation Visits

The Break the Ice Challenge judging staff will visit all the Teams that are eligible to win prizes during the course of long-term durability demonstrations. Notice of an on-site observation visit will be provided to the Team Lead at least 24 hours prior to arrival of the judging staff. Each site visit is expected to be completed within the span of two days. Teams must satisfy the following requirements relating to onsite visits:

- Notify the Break the Ice Lunar Challenge organizers of anticipated start date of durability demonstration a minimum of 28 days in advance of anticipated start date. Any changes to the start date of the test after sending this notification must be immediately communicated with a justification for the change. All notifications must be sent to admin@breaktheicechallenge.com.
- Upon arrival, provide the Break the Ice Lunar Challenge judging staff with the following:
 - Appropriate personal protective equipment
 - Detailed tour of testing site, including excavation component, transportation component, icy-regolith simulant
 - Detailed tour of the hardware and equipment under test
 - Detailed tour of planned spare parts and repair tools

3.2.9 Deliverables/Submission elements

Teams will submit the below deliverables. Refer to the competition calendar in Section 3.2.2 for the submission deadlines. Teams that fail to submit the Level 1 submissions before the deadline will be disqualified and will not be allowed to continue further in the competition.

3.2.9.1 Level 1 Deliverables

The following Level 1 deliverables will be evaluated by the Judging Panel in the order they are received to determine whether they are compliant with the requirements detailed in this rules document. Each Team Lead will then be notified regarding their compliance status. This evaluation of Level 1 deliverables and Team compliance notification will take at least two full weeks from submission.

If a Team is considered not compliant, they will be notified of the areas of design that require additional attention. If the deadline for Level 1 submission has not passed, non-compliant Teams may then resubmit Level 1 deliverables for further assessment and evaluation. There is no limit on the number of times a Team may resubmit material before the Level 1 submission deadline (provided in Section 3.2.2). However, each submission requires at least two full weeks for evaluation by the Judging Panel.

- **Submission Title:** Please provide a title that may be displayed on the competition website and other media post-submission.
- **Team Information:** Submit a Curriculum Vitae and headshot for each Team Member.
- **Technical Abstract:** Provide a brief description of the excavation and transportation system(s). Focus on delivering a compelling overview so that the Judging Panel members

assigned to score your application will want to read more. This is your opportunity to make a strong first impression, so make every word count!

- **Intellectual Property:** Explain who owns the intellectual property of the proposed system. If the system is built on existing or off-the-shelf technology, detail the permissions (if applicable) they have to use that technology. If a Team is part of an organization, the submission should indicate which Team Members own the intellectual property.
- **Team Introduction Video:** Submit a short video to introduce the Team. This video can also optionally summarize the Team's plans for Phase 2.
- **Legal and other required documentation, as described in Section 4 and the eligibility requirements document**
- **Detailed Design Report:** Detail the Team's terrestrial analog full-scale prototypes of robotic icy regolith excavation and transportation systems. This report must address the suitability of the design for lunar conditions and how the design complies with the requirements of Section 3.2.3.
 - Report must provide a summary description of the conceptual design for the following subsystems:
 - Electrical
 - Mechanical
 - Power
 - Thermal
 - Communication
 - Software
 - Report must provide a detailed description of the following subsystems, that is sufficient to understand the design intent for the systems that are being tested in the durability demonstration:
 - Excavation
 - Regolith movement/conveyance
 - Mobility and Traction
- **CAD Models and/or Drawings:** Include 3D CAD models or 2D drawings of the full-scale prototypes of robotic icy-regolith excavation and transportation systems. These models/drawings may utilize simple placeholders for any sensitive or proprietary design details that a Team wishes to keep internal. However, the overall length, width, and height of systems and equipment must be shown.
- **Durability Demonstration Test Plan:** Detail the Team's plans for performing a long-term durability demonstration of their working prototype system. The test plan must include the following details:
 - Planned durability demonstration site address and entry instructions

- Primary and backup points of contact for judging staff entry into demonstration site (name, title, email address, phone number)
- Planned demonstration start date and planned schedule of high-level tests
- Plans for operating of each piece of prototype equipment over the 15-day test period.
- Plans for creating and placing regolith simulant, including a simulant mixture design and sketch of the deposit geometry.
- Proposed drawing of transportation demonstration area layout, including applicable excavation location, delivery location, and path of travel in-between
- Plans for delivery location including transfer and weighing of transported regolith simulant material
- Plans and justification for emulating physical and environmental details of anticipated lunar surface
- Plans for creating transportation demonstration area
- Planned runtime for each piece of prototype equipment (excavator, transporter, etc.)
- Planned distance traversed by each piece of prototype equipment
- Planned amount of icy regolith simulant to excavate and transport
- Planned flow rate (kg per hour, kg per day, etc.) and trip frequency (trips per hour, trips per day, etc.) of regolith simulant into simulated Water Extraction Plant
- Planned spare parts, if any
- Tools and equipment and plans for repair and maintenance of each piece of prototype robotic equipment
- Tools and equipment and plans for repair and maintenance of Transportation Demonstration Area
- Plans for recharging and/or battery swapping
- Plans for data collection and video streaming
 - Note that the link to the live video stream must be provided on the test start date to admin@breaktheicechallenge.com.

Summary of Level 1 Submission Elements Limits

| Phase 2 Submission Level 1 Element | Form Field Character Limit | Narrative Page* Limit | Limit on Attachments (such as data files, illustrations, video, etc.) |
|---|-----------------------------------|------------------------------|--|
| Submission Title | ~5 words/ 30 characters | | |
| Technical Abstract | ~250 words/ 1,500 characters | | |
| Intellectual Property | ~50 words/ 300 characters | | |
| Team Information | | | 25 pages in Portable Document Format (PDF) |

| | | | |
|---|---------------------------|----------|---|
| Team Introduction video | | | Maximum of four (4) minutes uploaded to an online platform that should be accessible by judges. |
| Legal and other required documentation | ~100 words/500 characters | | 25 pages in Portable Document Format (PDF) |
| Detailed Design Report | | 25 pages | |
| CAD models/drawings | | | 3D CAD model and 2D drawings viewable in freely available CAD viewer |
| Durability Demonstration Test Plan | | 25 pages | |
| Layout Drawing of Transportation Demonstration Area | | | A single sheet PDF drawing that when printed full sized is no larger than an E size Drawing format. |

*A “page” is defined as Letter size paper (8.5 x 11 inches) with 12-point font (Times New Roman) and one-inch margins. Information contained in any excess pages beyond the page limit will be ignored.

3.2.9.2 Level 2 Deliverables

- **Durability Demonstration Test Report:** Detail the Team’s long-term durability demonstration of their working prototype system. This document must include the following details:
 - Demonstration start date, duration, and as-run schedule of tests
 - Sequence for operating and exercising each piece of prototype equipment
 - Description of any changes in the Demonstration Test Plan from that submitted in Level 1
 - Description of any changes to the prototype robot design submitted in Level 1.
 - Photos of each major piece of hardware and equipment performing normal operations
 - Log of parts replaced, breakdowns, issues requiring human intervention, along with job-hours spent on repairs on the prototype icy regolith excavation and transportation equipment.
 - Log of any maintenance or repair of the Transportation Demonstration Area
 - Post demonstration inspection results

- Details of icy regolith simulant bed used in demonstration:
 - mixture design
 - certified compressive strength test report at the beginning and end of the 15-day test period
 - geometry sketch
- The following information shall be provided in a table:
 - Mass (kg) of each piece of equipment, including spare parts (whether used or not) and repair and maintenance tools (whether used or not), plus total system mass (kg)
 - Energy used by each piece of prototype icy regolith excavation and transportation equipment (kWh), plus total system energy (kWh)
 - Not counting energy used during repair and maintenance of prototype icy regolith excavation and transportation equipment nor repair and maintenance of transportation demonstration area.
 - Runtime (hours) of each piece of equipment, plus total system runtime, plus total number of icy regolith excavation and transportation robots
 - Total distance traversed (km) by icy-regolith transportation equipment, plus total number of icy-regolith transportation equipment round trips between simulated Excavation Site and simulated Water Extraction Plant
 - Total mass (kg) of icy regolith simulant excavated and delivered
 - Any material processed by the excavation equipment which is not also transported and delivered by the transportation equipment will not count towards the Team's score.
 - Daily (at the end of each 24-hour period) log of the mass of simulated icy regolith delivered
- **Durability Demonstration Time-Lapse Video:** Must show a minimum of 3 full cycles of excavation, transportation, and delivery from each piece of equipment recorded during the Team's long-term durability demonstration of their working prototype system. For equipment operating continuously without discrete cycles, a minimum of 2 hours of operation from that equipment is acceptable.
- **Safety analysis:** Identify any potentially hazardous material or other safety concerns related to the terrestrial analog full-scale prototypes. This safety analysis must specifically consider future possible transport and operation of your equipment in a test facility (NASA or other) and potential interactions with humans (i.e. NASA judging staff).

Summary of Level 2 Submission Elements Limits

| Phase 2 Submission Level 2 Submission Element | Form Field Character Limit | Narrative Page* Limit | Limit on Attachments (such as data files, illustrations, video, etc.) |
|--|-----------------------------------|------------------------------|--|
| Durability Demonstration Test Report | | 30 pages | A PDF with photos of each major piece of hardware and equipment performing normal operations that is less than 25 MB |
| Durability demonstration time-lapse video | | | Maximum of four (4) minutes uploaded to an online platform that should be accessible by judges. |
| Live feed of testing** | | | A link to an online streaming platform that is accessible by the judges |
| Safety Analysis | | 3 pages | |

*A “page” is defined as Letter size paper (8.5 x 11 inches) with 12-point font (Times New Roman) and one-inch margins. Information contained in any excess pages beyond the page limit will be ignored.

**Note that the link to the live feed testing must be provided on the test start date to admin@breaktheicechallenge.com.

3.2.9.3 Level 3 Deliverables

Invited Teams will bring their prototypes of robotic icy regolith excavation and transportation systems (along with all spare parts and maintenance equipment) to a NASA designated test facility to compete with other teams. More information about Level 3 including detailed testing requirements and judging criteria will be made available at a later date on the challenge website.

3.2.10 Judging Criteria

Level 1 deliverables will be evaluated by the Judging Panel in order to determine whether they are compliant with the requirements detailed in this rules document. Teams will receive a go or no-go decision from the Judging Panel. The Judging Panel will follow a set rubric to score each Team’s Level 2 submission according to the below criteria:

| Criteria | Description | Maximum Score |
|---------------------------|---|----------------------|
| Mass Efficiency | Total regolith simulant excavated and delivered per total landed mass. A factor will be applied that takes into account how closely the Team's prototype robotic icy regolith excavation and transportation systems meet the target delivery rate of 800 kg every 24 hours throughout the entire 15-day Durability Demonstration Test. | 40 |
| Energy Efficiency | Total regolith simulant excavated and delivered per total energy used. A factor will be applied that takes into account how closely the Team's prototype robotic icy regolith excavation and transportation systems meet the target delivery rate of 800 kg every 24 hours throughout the entire 15-day Durability Demonstration Test. | 30 |
| Reliability & Durability | The extent to which the Team's prototype robotic icy regolith excavation and transportation systems handle the operational challenges of the long-term Durability Demonstration Test. Reliability & Durability will be judged based on information provided by the Teams in their Durability Demonstration Test Report. | 15 |
| Lunar Simulation Fidelity | The extent to which the Team's Transportation Demonstration Area simulates the physical and environmental details of the anticipated lunar surface. Lunar Simulation Fidelity will be judged based on information and justification provided by the Teams in their Durability Demonstration Test Plan and Durability Demonstration Test Report. | 15 |

Level 3 judging criteria will be provided at a later date and will be available on the challenge website.

3.2.11 Prize Purse

Phase 2 will offer a total prize purse of up to \$3 million for U.S. Teams.

Level 1: All Teams that submit compliant deliverables by the deadline and are eligible to win the prizes will be awarded an equal share of the \$500,000 prize purse up to a maximum of \$75,000 per Team. All Teams that submit compliant deliverables by the deadline will move to Level 2, regardless of whether they earn prize money.

Level 2: Below table provides prize purse distribution for Level 2 for the Teams that are eligible to win prizes. In order to receive a prize, a Team must score a minimum of 40 points in Level 2. Placing will be determined based on Teams' overall Level 2 scores.

| Level 2 Prize Purse | |
|---|--------------------|
| 1 st Place | \$300,000 |
| 2 nd Place | \$200,000 |
| 3 rd Place | \$125,000 |
| Up to 5 (five) Runners Up (\$75,000 each) | \$375,000 |
| Level 2 Total | \$1,000,000 |

Up to 15 Teams (including the winners and runners up) that score above the minimum score will be invited to compete in Level 3.

Level 3: Level 3 will offer up to \$1.5M in cash prizes split between the 1st place (\$1M) and 2nd place (\$0.5M) Teams which are eligible to win prizes. In addition to the cash prizes, NASA will also award opportunities to test concepts in a dusty TVAC that will simulate the temperature and atmospheric pressure conditions at the lunar south pole. Detailed Prize Purse Distribution and scoring requirements to be eligible to receive the prize will be provided at a later date and will be available on the challenge website.

Recognition for International Teams

Up to 3 top scoring International Teams will be recognized as winners in Level 2 and in Level 3. Teams must score a minimum of 40 points to be recognized as winners in Level 2. Criteria to be considered a winner in Level 3 will be provided at a later date on the challenge website. International Teams must meet the eligibility requirements to participate in the challenge and be recognized as winners. International Teams are not eligible to be awarded prize money or TVAC testing opportunities.

4. Legal Requirements

4.1. In General

Teams are responsible for understanding and complying with all Challenge rules and requirements as stated below and detailed in the Eligibility Requirements Document. The following sections below summarize key elements of the Eligibility Requirements Document. Teams should review the Eligibility Requirements Document for additional details.

4.2. Eligibility

NASA welcomes applications from individuals, groups of individuals, and/or organizations or entities that meet the eligibility requirements provided below.

In order to participate in the Challenge, each individual, whether acting alone or as part of a Competitor Team must identify their nationality.

- No individual competitor shall be a citizen of a country on the NASA Export Control Program list of Designated Countries List Category II: Countries determined by the Department of State to support terrorism. The current list of designated countries can be found at <http://oiir.hq.nasa.gov/nasaecp>. Please check the link for the latest updates. This includes individuals with dual citizenship unless they are a U.S. citizen or a lawful permanent U.S. resident (green card holder).
- While China is not a Category II designated country, pursuant to Public Law 116-6, Section 530, NASA is prohibited from participating, collaborating, or coordinating bilaterally in any way with China or any Chinese-owned entity. Team members who are citizens of China but not affiliated with a Chinese entity may be permitted to participate on a Team.
- Subject to the conditions set forth herein, foreign nationals and foreign national Teams can participate in the Challenge. However, they are not eligible for a cash prize, and must acknowledge acceptance of this by signing and submitting a Foreign Participant Acknowledgement Form.
- A Team-designated lead shall be responsible for both compliance with the rules (including prize eligibility rules) and the actions of all members of the Team. The lead shall be a member of the Team.

In order to be eligible to win a prize:

1. Individuals must be U.S. citizens or permanent residents of the United States and be 18 years of age or older.
2. Organizations must be an entity incorporated in and maintaining a primary place of business in the United States.
3. Teams must be comprised of otherwise eligible individuals or organizations and led by an otherwise eligible individual or organization.
4. Team leader must be a U.S. citizen or permanent resident.

A Team may include foreign nationals and be eligible to win prize money as long as the foreign national signs and delivers a disclosure (separate form) wherein he/she discloses his/her citizenship and acknowledge that he/she is not eligible to win a prize from NASA, AND

1. The foreign national is an employee of an otherwise eligible U.S. entity participating in the Challenge,
2. The foreign national is an owner of such entity, so long as foreign citizens own less than 50% of the interests in the entity,
3. The foreign national is a contractor under written contract to such entity, OR
4. The foreign national is a full time student, during the time of the Challenge, of an otherwise eligible entity which is an accredited institution of higher learning, AND the student is during the Challenge in the United States on a valid student visa and is

otherwise in compliance with all local, state, and federal laws and regulations regarding the sale and export of technology.

Teams selected for an award will be required to provide proof of citizenship/permanent residency, proof of primary place of business, proof of incorporation, and/or proof of student visa. Proof must be provided within 3 business days to be eligible for an award. Any Team or team member who submitted the required proof documents in Phase 1 and was deemed eligible to compete will not be required to submit this documentation again in Phase 2. Teams must indicate which documents from Phase 1 should apply to Phase 2 entry and provide confirmation that all documents are still valid. A Team's failure to comply with any aspect of the eligibility requirements shall result in the Team being disqualified from winning a prize from NASA.

U.S. government employees may enter the competition, or be members of prize-eligible Teams, so long as they are not acting within the scope of their Federal employment, and they rely on no facilities, access, personnel, knowledge or other resources that are available to them as a result of their employment except for those resources available to all other participants on an equal basis.

U.S. government employees participating as individuals, or who submit applications on behalf of an otherwise eligible organization, will be responsible for ensuring that their participation in the Competition is permitted by the rules and regulations relevant to their position and that they have obtained any authorization that may be required by virtue of their government position. Failure to do so may result in the disqualification of them individually or of the entity which they represent or in which they are involved.

Teams will be ineligible to win a prize if any Team Member is a Federal entity or Federal employee acting within the scope of their employment. This includes any U.S. Government organization or organization principally or substantially funded by the Federal Government, including Federally Funded Research and Development Centers, Government-owned, contractor operated (GOCO) facilities, and University Affiliated Research Centers. No U.S. government funds may be used to participate in the Challenge. Any such entity or individual shall obtain prior written approval from their cognizant ethics officer that such participation does not violate federal personnel laws or applicable agency policy. A copy of this approval to participate in the Challenge shall promptly be provided to Ensemble.

Current employees, consultants, and students of Ensemble may only participate as Team Members when the Team is not competing for a prize from NASA. Participation of such parties as Team Members on a Team will make a Team ineligible for any prize award.

4.3. Insurance and Indemnification

Each Team Member agrees to assume any and all risks and waives claims against Ensemble and the U.S. Government and its related entities, except in the case of willful misconduct, for any injury, death, damage, or loss of property, revenue, or profits, whether direct, indirect, or consequential, arising from each Team Member's participation in the Challenge, whether such injury, death, damage, or loss arises through negligence or otherwise. For the purposes of this section, the term "related entity" means a contractor or subcontractor at any tier, and a supplier,

user, customer, cooperating party, grantee, investigator, or detailee.

Team agrees to obtain any and all insurance policies and coverage required by its local, state, or Federal governments to conduct any and all virtual activities related to or required by participation of Team and the Team Members in the Challenge. In addition, Ensemble requires that each Team must obtain liability insurance in the amount of \$250,000 USD minimum that covers each Team Member or otherwise demonstrate financial responsibility for that amount. The Team's liability insurance shall provide coverage for all claims by (A) a third party for death, bodily injury, or property damage, or loss resulting from an activity carried out in connection with participation in the Challenge, with the Federal Government and Ensemble named as an additional insured under the Team's insurance policies; and (B) the Federal Government, Ensemble, and its contractors for damage or loss to Government or Ensemble property resulting from or related to Challenge activities. The Team and all Team Members agree to indemnify the Federal Government and Ensemble against third-party claims for damages arising from or related to Challenge activities.

Proof of insurance in such form as reasonably required by Ensemble shall be provided to Ensemble by the Level 1 Submission Deadline as outlined in Exhibit C of the Eligibility Requirements Document. Alternatively, if Team intends to fulfill this requirement by demonstrating financial responsibility in the requisite amount, Team shall submit to Ensemble in writing such information as demonstrates to Ensemble, in Ensemble's reasonable discretion, that Team has sufficient financial responsibility to cover the potential claims cited in the requisite minimum amount as outlined in Exhibit C of the Eligibility Requirements Document.

4.4. Use of Names, Trademarks, and Insignias

Team may not use the name, trademark or insignia of Ensemble, its contractors, collaborators, or NASA on its printed materials related to the participation of Team in the Challenge without Ensemble's or its contractor's, collaborator's, or NASA's prior written consent, whichever Party is applicable.

Team agrees that unauthorized use of such names, trademarks, and insignias shall result in elimination from participation in the Challenge if Team continues unauthorized use after being notified to cease and desist by Ensemble or NASA, as applicable.

4.5 Delay, Cancellation or Termination

The Team acknowledges that circumstances may arise that require the Challenge to be delayed indefinitely or canceled. Such delay or cancellation, and/or the termination of the Challenge, shall be within the full discretion of NASA, and the Team accepts any risk of damage or loss due to such delay, cancellation, and/or termination.