2021

RASC-AL Special Edition: Moon to Mars Ice & Prospecting Challenge

RASC-AL is managed by the National Institute of Aerospace (NIA) on behalf of the National Aeronautics and Space Administration (NASA)

Moon to Mars Ice & Prospecting Challenge

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RASC-AL Background Information

The Revolutionary Aerospace Systems Concepts – Academic Linkages (RASC-AL) suite of competitions consists of several premier university engineering design challenges that help inform NASA's approaches for future human space exploration and prompt collegiate students to investigate, plan, and analyze space exploration design at differing states of development. RASC-AL competitions fuel innovation for aerospace system concepts, analogs, and technology prototyping by engaging universities as partners in the journey.

Periodically, Special Edition RASC-AL programs are established to elicit students' fresh perspective on developing concepts that may provide full or partial solutions to specific design problems and challenges currently facing human space exploration. In the past, these special edition competitions have included design-build-test programs for subsystem and component level prototypes (i.e., the RASC-AL Exploration Robo-ops and RASC-AL Lunar Wheel Design challenges), as well as technology demonstrations for critical ISRU capabilities (i.e., the 2018 RASC-AL Special Edition: Mars Ice Challenge).

The **RASC-AL Special Edition: Moon to Mars Ice & Prospecting Challenge** provides undergraduate and graduate students with the competitive opportunity to design and build hardware that can **extract water and assess subsurface density profiles from a simulated off-world test bed to advance critical technologies needed on the surface of the Moon or Mars**. The "R" in RASC-AL – Revolutionary – is not just another word for advanced technology, it is about thinking outside the box, clever innovation, and challenging convention. NASA's investment in RASC-AL supports the future engineers, scientists, and explorers who make those revolutionary ideas a reality.

Context for the Moon to Mars Ice & Prospecting Challenge

NASA is embracing new paradigms in exploration that involve expanding our knowledge and leveraging resources as we extend our presence into the Solar System. Space pioneering and prospecting towards independence from Earth are necessary steps to achieving NASA's goal of extending humanity's reach into space.

Recent discoveries of what are thought to be large ice deposits under both lunar and Martian surfaces have mission planners re-thinking how sustained human presence on the Moon and/or Mars could be enabled by a "water rich" environment. Water is essential to enabling a sustained presence, as it could enable agriculture and propellant production, reduce recycling needs for oxygen, and provide abundant hydrogen for the development of plastics and other in-situ manufactured materials. Before the water can be used to support sustained human presence, it must be extracted from the ice deposits. However, getting to the water will be a formidable task due the variety of layers that can be encountered on top of that ice. The composition, density, and hardness of each of these layers presents different drilling challenges, and it is crucial that we develop systems that can identify different layers and understand what modifications need to be made to mine through them in order to reach the ice. **The purpose of this challenge is to explore and demonstrate methods to identify different layers using system telemetry, and ultimately extract water from lunar or Martian ice deposits.**

Participating team members take on the role of astronauts who monitor and control drilling operations. Using a combination of remote control and hands-on operations, teams will extract as much water as possible from the buried ice. In order to demonstrate a wide range of capabilities of interest to exploration and science, team member interaction with the prototype will be divided into a period where "hands-on" operation and repairs are permitted and a period where physical "hands-off" operations will take place. During all phases of the competition, the teams will be able to use a control system to operate the water extraction system.

Moon to Mars Ice & Prospecting Challenge Overview

Through the ***RASC-AL Special Edition: Moon to Mars Ice & Prospecting Challenge***, NASA will provide university-level engineering students with the opportunity to design and build prototype hardware that can extract water and assess subsurface density profiles from simulated lunar and Martian subsurface ice. Multiple teams will be chosen through a proposal and down-select process that assesses the teams' initial plans and progress throughout the year.

Up to 10 teams will become finalists and travel to the NASA Langley Research Center (LaRC) in Hampton, VA during the summer of 2021* to participate in a multi-day competition where the universities' prototypes will compete to extract the most water from an analog environment simulating a slice of a combined lunar and Martian surface, while simultaneously using system telemetry to distinguish between overburden layers and create a digital core of the various layers. Each simulated subsurface ice station will contain solid blocks of ice buried under various layers of overburden (terrestrial materials of varying hardness that represent possible materials found on lunar or Martian surfaces). Teams will be asked to provide a digital core that represents their knowledge and understanding of where each of the layers are, the general hardness of each different layer, and the thickness of each layer. The total internal depth of the simulated testbed will not exceed 1.0 meter. Teams may drill multiple holes. The water extraction and prospecting system is subject to mass, volume, and power constraints.

In addition to the test and validation portion of the project, teams will present their concepts in a technical poster session to a multi-disciplinary judging panel of scientists and engineers from NASA and industry. Poster presentations will be based on the team's technical paper that details the concept's "paths-to-flight" (how the design can be modified for use on an actual mission on the Moon or Mars). This includes, but is not limited to, considerations for temperature differences, power limitations, and atmospheric pressure differences.

The paths-to-flight description will be broken into two distinct sections:

- **Water extraction on Mars:** teams will discuss the significant differences between Mars and Earth operation environments and describe essential modifications that would be required for extracting water from subsurface ice on Mars.
- **Lunar prospecting for a digital core:** teams will discuss the significant differences between the Moon and Earth operational environments and describe essential modifications that would be required for prospecting on the Moon.

Based on initial Project Plan Proposals, up to 10 qualifying university teams will be selected to receive a $10,000 stipend to facilitate full participation in the competition, including expenses for hardware development, materials, testing equipment, hardware, software, and travel to Langley for the competition. Final scoring will be based on total water extracted and collected each day, the accuracy of the digital core, adherence to NASA requirements, a technical poster presentation, and a technical paper capturing paths-to-flight, innovations, and design.

Top performing teams may be chosen to present their design at a NASA-chosen event. Subject to the availability of funds, such invitations may include an accompanying stipend to further advance development of team concepts and/or offset the cost of traveling to the event.

*As the coronavirus (COVID-19) situation continues to evolve, NASA and NIA will closely monitor and follow guidelines from federal, state, and community officials regarding the onsite competition at NASA LaRC next summer. Protecting the health and safety of team members, staff, and judges is our primary priority.

Simulated Martian & Lunar Subsurface Ice Test Station

**TEST STATION :
Bonar Ice Chest Model PB2145**

During the on-site portion of the competition, each team will be provided with their own workstation, which will include workbench style tables, chairs, wastebasket, and a test station with the simulated Martian/lunar subsurface ice. A lid/mounting platform with **open access** to the simulated overburden and subsurface ice will be located directly on top of the test station; this platform will be a staging area for the prototype system.

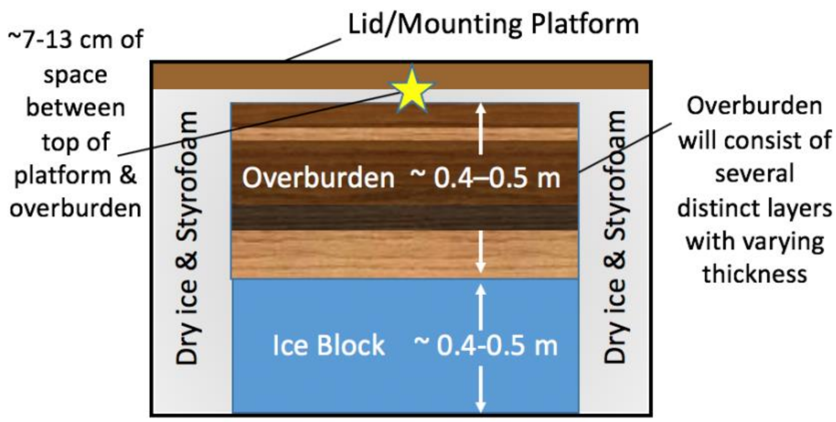
PB2145 / (35) Cube				
Capacity: (258) Gal/(993) liters/ 35 cu.ft.				
Box Weight: (164) lbs. / (74) KG				
Lid Weight: (38) lbs. / (17) KG				
Dimensions	External		Internal	
	cm	inches	cm	inches
Length:	123	48	110	43
Width	109	43	97	38
Height	120	47	101	40
Height w/lid	125	49		

The test station is a large, plastic, insulated ice chest (Bonar ice chest, Model PB2145), consisting of:

1. a layer of blocked ice at the bottom
   - this layer will consist of 2 separate ice blocks stacked on top of each other, with a thin layer of water between the two in an effort to facilitate one solid, frozen block of ice
   - total ice block dimension = ~ 1 m x 0.5 m (L x W); depth will be between 0.4 m and 0.5 m
2. several layers of differing overburden materials (terrestrial materials of varying hardness that represent possible materials found on lunar or Martian surfaces)
   - Teams can expect to encounter distinct overburden layers and each of these layers will be made up of material taken from the following list (Note: not all of these materials will be used and some of these layers may be in the form of a single block of the same horizontal area as the ice block. Some of the materials may be found in more than one layer)
     - Dry, fluffy play sand with rocky inclusions (between 3”- 6” in diameter)
     - Clay mixed with 20% sand
     - Solid/consolidated stone (i.e., single block of stone)
     - Solid/consolidated aerated concrete (single block)
   - The hardest layer will have an unconfined compressive strength of no more than 25 MPa
   - The total overburden depth (not including the ice) will be between 0.4 m and 0.5 m. The range in depths is intended to simulate the variability in regolith overburden inherent in natural environments and the resulting needed adaptability of the water extraction and prospecting system.
   - The overburden will be filled to the top of the container, however, due to the thickly insulated lids, teams should allow ~7-13 cm of space between the top of the mounting platform and the top of the overburden. Teams should expect minor variances in the distance between the mounting platform and the top of the overburden.
3. a lid, which also serves as the system’s mounting platform;
   - the lid/mounting platform will have a hole cut out that is equal to the size of the ice blocks beneath it (i.e., the opening will not exceed 1 m x 0.5 m). This hole will expose the entire viable drilling area, and only the viable drilling area, so that teams may drill multiple holes as desired without concern for penetrating the dry ice and/or foam insulation
   - Each team’s system will sit on this mounting platform. Two 2’x4’ wooden boards will be attached to the lid for mounting purposes (see diagram below)
   - Teams will design solutions that propose the best way to anchor their water extraction and prototyping system to this lid/mounting platform (if asked for and approved in advance, NASA will assist in customizing your team’s mounting platform on-site the first day of the competition)

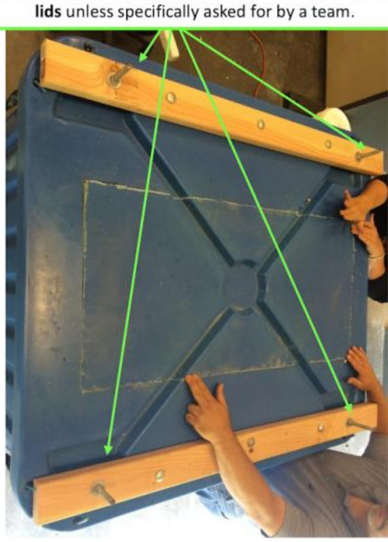
Note: *The overburden will be filled to the top of the container, however, due to the thickly insulated lids, teams should allow ~7-13 cm of space between the top of the mounting platform and the top of the overburden.*

TEST STATION – SIDE VIEW

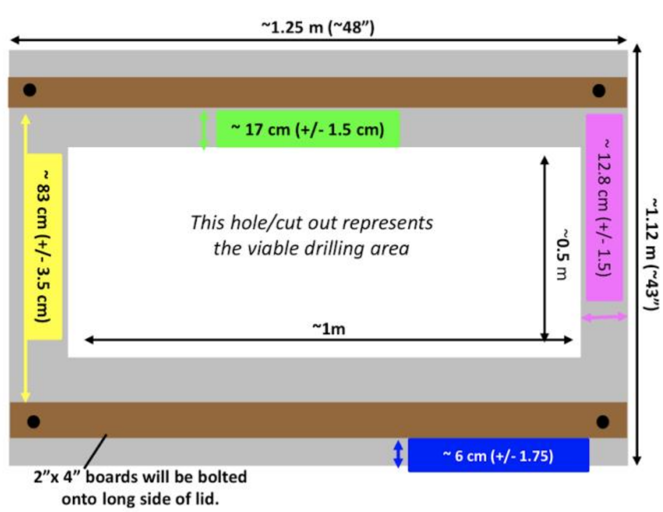


Note: The overburden layers portrayed in this image are for example only and do not represent the actual pattern that will be used for the competition.

2"x 4" boards will be bolted onto the long side of each lid, but note that **the 3" carriage bolts shown sticking up from the wood in the photo below WILL NOT be on any lids** unless specifically asked for by a team.



TOP VIEW of LID/MOUNTING PLATFORM



Competition Tasks

1. Mine through the various overburden layers
2. Create a ***digital core**** (a written description that represents the team's knowledge and understanding of where each of the layers are, the general hardness of each different layer, and the thickness of each layer. Finalist teams will use the Digital Core Form provided on-site to record the following information:
   - The number of layers in their test station
   - A sequence of the layers in order from softest to hardest
   - The thickness of each layer

   *The digital core should result from information garnered using system telemetry and not via placing a ruler down the hole. Teams may not touch the layers to determine hardness.
3. Extract and transfer as much clean liquid water as possible into the provided external accumulation tanks
   - The external accumulation tanks consist of two (2) 22qt. buckets (one for water collected during "hands-on" operations, and one for water collected during "hands-off" operations, located within 1 meter adjacent to the team's test station. At each team's discretion, the tank can be located on the ground, or on a near-by table.
   - The external accumulation tanks are 15" (38 cm) tall, with a 31 cm diameter.
     - As water nears the top of either bucket, it will be measured and poured out to allow for additional water collection.
   - Teams have the freedom to design creative solutions to melt the extracted ice.
   - Teams will need to design and bring water transfer equipment (i.e., hosing that can connect to the external accumulation tanks).
     - Teams are encouraged to bring at least 3 meters of hose.
   - The water delivered to the provided tank is the final product and should be filtered from debris and as clean as possible.
     - Teams are encouraged to design innovative filtration systems that provide a long-term solution to collect any sediment, so that only water is delivered into the tank for measurement. Filtration with no means of regeneration or back wash is not a viable long-term solution.
     - NASA will provide a secondary control filtration system (i.e., a Nut Milk Bag) at the accumulation tank to capture any additional debris.
       - Any sediment captured in the secondary filtration system will be collected and measured. There will be a score penalty associated with sediment collected.

Competition Environment and Thermal Management

The Moon to Mars Ice & Prospecting Challenge Forum will be held inside Langley's Hangar facility. This is a well ventilated, shaded environment, but it is open to the outdoors when the hangar doors are open. Please keep in mind that temperatures average close to 30° C in Hampton, VA during June, generally with high humidity. The test beds are well insulated and will utilize enough dry ice to keep the ice in a solid, frozen state throughout the entire competition.

Dealing with ice at these atmospheric conditions is non-trivial. Teams are encouraged to carefully consider thermal management in the design and operation procedures. During this indoor competition, teams can expect that the simulated Martian subsurface ice will have non-uniform temperature. Teams should assume that the atmospheric temperature is going to be between 25-35 °C; the overburden will have a gradient from 20° C at the surface to -10° C at the ice interface.

On-site Competition Operations

Set Up:

Prior to the first official competition run, teams will have approximately 8 hours to set up their water extraction system, undergo inspection (safety, volume check, weigh-in, etc.), and conduct mechanical, electrical, communications, and integration testing. No actual drilling/water extraction/prospecting will be allowed during set up.

Competition Rules:

- **Water Extraction:** Each team will have 12 hours total to extract water from the simulated planetary subsurface ice (i.e., 6 hours on two separate days; or a 4-hour run on one day and an 8-hour run on another day - TBD).
    - During the course of these 2 days, teams may operate their systems "hands-on" or "hands-off". **Water collected during "hands-off" operations is weighted more heavily than water collected during "hands-on" operations.** (See "Scoring for Water Collection" below.)
        - Teams can begin "hands-on" operations as soon as the countdown clock begins each run. Before teams can conduct a "hands-off" run, they must receive approval from a judge. Approval will be granted after:
            - the judge moves the connection hose from the "hands-on" water collection bucket to the "hands-off" water collection bucket.
            - Teams reset/return their drill to its 'home' state (e.g., starting from a drill elevated over a pristine drilling area). Note: Teams must create a new hole each time they move into "hands-off" operations. Similarly, on the final day of the competition, teams will not be allowed to reuse a hole created on the previous day.
            - Teams may manually move/reposition their drills between subsequent "hands-off" operations without penalty***. However, if a team plans to use manual repositioning, careful consideration should be taken in the path-to-flight section of their Project Plan Proposal to articulate how this would translate into operations off-Earth.***
        - If something breaks during a "hands-off" run, or if another issue requires teams to revert back to "hands-on" operations, a judge must be notified immediately. The judge will move the connection hose from the "hands-off" water collection buck to the "hands-on" water collection bucket before the team can revert to "hands-on" operations.
        - There is no limit to the number of times a team can operate "hands-off"
    - Scoring for Water Collection:
        - Water collected during "hands-on" operations will be added cumulatively for each team over the course of the competition.
        - Water collected during "hands-off" operations will also be added cumulatively for each team over the course of the competition
        - A team's Scoring Volume will be equal to their hands-on water volume plus five times their hands-off water volume. **(Scoring Volume = Total Hands-On Water + (5 x Hands-Off Water)**
            - The Scoring Volume will then be normalized to a 150-point scale **[so the team with the most Scoring Volume will receive 150 points for Water Collection and the other teams will receive points for Water Collection based on the following equation: (Team's Scoring Volume/x*150)]**
- **Prospecting for a Digital Core:** Teams will be asked to provide a digital core that represents their knowledge and understanding of where each of the layers are, the general hardness of each different layer, and the thickness of each layer. Note: individual layers will have a uniform thickness horizontally across each test station, with depths that vary among each layer.
    - The digital core will include:

  - Identifying the correct number of layers (including the ice)
  - Sequencing the layers in order from softest to hardest
  - Estimating the thickness of each layer in centimeters (cm)
- The Digital Core Form (provided on site) must be presented to a judge prior to the end of the competition run on Day Two. Once the form has been handed to a judge, it is considered a final submission of the team's digital core.

Optional Subsystem Demonstrations:

On the final day of the on-site competition, teams will have the opportunity to participate in small challenges designed for teams to showcase their systems' unique capabilities. **While participation in these challenges is completely voluntary and they do not count toward the overall score**, they do provide the opportunity for systems to show-off. Certificate awards will be presented for the winner of each subsystem demonstration category during the Awards Ceremony. During the subsystem demonstrations, teams can operate in hands-on mode.

Subsystem Demonstrations May Include the Following Challenges:

- Filtration
- Fastest Penetration
- Speed: First to get to the Ice
- Pure Rodwell

More information about the subsystem demonstrations will be made available to the finalist teams.

Prototype Design Constraints & Requirements

1. The water extraction system must be capable of operating autonomously or via "remote crew-controlled" operations during the competition. Either system operation is acceptable, as either could be used on the Moon or Mars. Autonomous control and remote crew-controlled operations are considered ***"Hands-Off" operations.***

Autonomous Control vs. Remote Crew-Control

- **Autonomous control** refers to no human intervention after the system starts; no further operation from any crew is required at all.
- **Remote crew-control** allows for the use of a computer distinct from but able to communicate with the water extraction and prospecting system (e.g., connected by a cable or Bluetooth, point-to-point, etc.) to operate the water extraction system (e.g., to control the speed of a drill). "Remote crew-controlled" operations indicate that the crew will be nearby their test station (within 5 feet and within line of site), can figure out when problems occur, and can address those problems remotely. Systems should not be built that will require human intervention; instead, they should be built to work on their own while being controlled remotely.

- During "Hands-off" operations, teams will not be permitted to provide verbal guidance for the operator while they are physically watching the extraction system.
- Monitoring and making decisions in real-time based on the use of feedback from cameras attached to the system (**excluding external** hand-held cameras/cell phone cameras) and sensors is encouraged, but not required.
- Teams may utilize a corded or tethered system that serves as the digital link between humans and machine.

- There will be no local Wi-Fi access available to the teams for this competition. Teams may implement a direct, localized wireless connection between their water extraction and prototype system and computer/control system but must accept the risk of possible interference.
- The computer/control system will operate on a separate power supply from the water extraction and prospecting system.

2. The water extraction and prospecting system (and everything used on the system during the competition) must be no larger than 1m x 1m x 2m tall.
    - System volume limits represent launch vehicle packaging limits.
    - The system, while operating, needs to remain within the horizontal area encompassed by the test station, with the exception of the water transfer equipment that connects to the accumulation tank and the remote-control cords and computers used beside the test station.
    - ***Systems exceeding the volume dimension limits will result in a penalty.***
3. The water extraction and prospecting system (and everything used on the system, including the water transfer equipment) must have a mass less than or equal to 60 kg.
    - Clarification: Anything that sits on top of the lid as part of the water extraction system must meet the mass, power, and volume constraints. **Anything that is intrinsically part of the water extraction system** (the extraction components, heating elements, command and control computers, power cables, filtration system, pumps, hose, anchoring system, etc.) **counts toward mass and power limits.**
        - The interface used in remote crew-controlled operations (i.e., any cables used for tethering to the system for communication, or computers used to communicate with the prototype) **are not included in the overall system mass or power limits.**
    - ***Teams with a system exceeding the mass limit will result in a penalty.***
4. The water extraction and prospecting system must be capable of operating on limited power supply. Teams will be provided with 120 VAC (GFCI protected) power, via an outlet.
    - Teams will be required to incorporate a 9 A fast-blow fuse into their circuitry.
    - Teams will be required to monitor and log their electrical current usage via the same data logger that is monitoring and recording the WOB load limits.
    - Augmenting the system's power supply via batteries, solar power, etc. **is not allowed.**
    - This power limitation only applies to the water extraction and prospecting system itself. Separate power sources (i.e., a standard wall outlet) will be supplied for the remote crew-controlled computer/control devices for the system. The control system may not provide power to the water extraction system.
5. The drill force (also called Weight on Bit or WOB) should be limited to less than 150 N.
6. The length of any drill bits used is limited to 96.52 cm (38 inches) to avoid drilling through the bottom of the cooler.
7. The prototype should be able to penetrate:
    - Between 0.4 and 0.5 meters of overburden layers that have differing hardness and density profiles
        - The hardest layer will have an unconfined compressive strength of no more than ~25 MPa
    - Between 0.4 and 0.5 meters of solid ice
8. The prototype must be capable of handling temperatures as low as -26° Celsius.
9. Each team's water extraction and prospecting system should include solutions to:
    - Deal with different layers within the overburden as well as the regolith/ice interface, minimizing the amount of dirt in the water collected.
        - Solutions should not involve options to "blow" the overburden away from the test station, unless acceptable abatement solutions are provided. All abatement issues are subject to the approval of the NASA Safety review committee.

  - Teams may move overburden anywhere on the lid/mounting platform, but overburden should only be deposited onto the floor outside the container within the limits of the tarp under each station (which extends approximately 4 feet on all sides of each test station).
- Manage the temperature changes to prevent any drill bits (if used) from freezing in the ice, and/or how to deal with this situation should it occur.
- Melt the ice so that it can be delivered to the external tank, where total water volume is collected.
- Filter debris from the water.

Eligibility

The ***RASC-AL Special Edition: Moon to Mars Ice & Prospecting Challenge*** is open to undergraduate and graduate students majoring in science, technology, engineering, mathematics and related disciplines at an accredited U.S.-based university. Teams may include senior capstone courses, robotics clubs, multi-university teams, multi-disciplinary teams, etc. Undergraduate and graduate students may work together on the same team.

University Design Teams Must Include:

- Team sizes vary widely, but must contain, at a minimum, one US citizen faculty or industry advisor with a university affiliation at a U.S.-based institution, and 2 US citizen students from a U.S.-based university. Multi-disciplinary teams are encouraged.
- A faculty advisor is ***required*** to attend the onsite portion of the competition with each team and is a condition for acceptance into the Moon to Mars Ice & Prospecting Challenge.
  - Teams who do not have a faculty advisor present at the Moon to Mars Ice & Prospecting Challenge Forum will be disqualified from competing and stipends will be subject to return to NIA.

Team Size and Composition

- There is no limit to the number of participants on each team, however, **a maximum of 5 students and 1 faculty advisor may attend the onsite portion of the Moon to Mars Ice & Prospecting Challenge Forum held at NASA Langley Research Center.**
  - Please note that due to prohibitive restrictions and ever-changing NASA security regulations**, foreign nationals will not be able to attend the Moon to Mars Ice & Prospecting Challenge Forum on-site at NASA.** There will be no exceptions to this policy.
- Teams will be comprised of a minimum number of 2 US citizen students.

Special Eligibility Considerations

- An individual may join more than one team.
- A faculty advisor may advise more than one team.
- A university may submit more than one Project Plan Proposal.

Foreign Universities

Because this is a NASA-sponsored competition, eligibility is limited to students from universities in the United States. **Foreign universities are not eligible to participate in the Moon to Mars Ice & Prospecting Challenge.****

**RASC-AL Program staff are only able to respond to questions presented by eligible students and faculty from accredited colleges and universities in the United States (and international team participants formally affiliated with a US-based university team).

Dates and Deadlines

Note: all deadlines must be met by 11:59 p.m. Eastern Time (ET) on the dates specified below. **Late deliverables will not be accepted.**

Date	Description
October 1, 2020	NOI deadline for university teams
October 20, 2020	Q&A Session with interested teams
November 24, 2020	Project Plan Proposal submission deadline
December 14, 2020	Teams are notified of their selection status
Late December, 2020	1st installment of development stipend sent to universities
March 15, 2021	Mid-Point Progress Report and video submission deadline
April 2, 2021	Teams notified of pass/fail status & 2nd installment stipends sent as appropriate
May 2, 2021	Hotel reservations and online registration & payment deadline for Forum
May 18, 2021	Technical Paper and Integration Video submission deadline
June 2-4, 2021	Competition at NASA LaRC

Notice of Intent

Notice of Intent deadline: 11:59 p.m. Eastern on October 1, 2020
Interested teams are encouraged to submit a Notice of Intent (NOI) to compete by the deadline in order to ensure an adequate number of reviewers. Please visit the Deliverables Page on the Moon to Mars Ice & Prospecting Challenge website to complete the brief online NOI submission form.

The following information will be requested on the NOI submission form:

- College/University name
- Partnering universities (if any)
- Contact information for the faculty advisor
- Contact information for the team lead

Project Plan Proposals

Project Plan Proposal submission deadline: 11:59 p.m. Eastern on November 24, 2020

General Project Plan Proposal Formatting Instructions

Teams are responsible for the formatting and appearance of their Project Plan Proposals. Figures and tables must be in digital format. We recommend that teams use image files with a minimum dpi of 150.

- 8 pages maximum (including figures, tables, and charts)
    - Cover page, references and appendices are ***excluded*** as a part of your 8-page total limit. They do not count toward the minimum or the maximum page limitations.

    - Appendices do NOT count toward the maximum page limit and are **limited to references only.** The judges are not obligated to read appendices, nor will the content of any appendix be considered in the overall Project Plan Proposal evaluation.
    - A table of contents is unnecessary
- Project Plan Proposals should be single spaced
- Please use fonts common to Macintosh and PC platforms, i.e., Times, Times New Roman, Helvetica, or Arial for text; Symbol for mathematical symbols and Greek letters.
- Font size can be either 11 or 12 pt.
- Margins should be a standard 1" (2.54 cm) all the way around (top, bottom, left, and right)
- Project Plan Proposals should be submitted in PDF Format
- File size cannot exceed 80 MB

Cover Page must include:

- University name
- Title/name of prototype
- Full names of all team members along with their respective specialties and/or team role, major course of study, and academic level (undergraduate or graduate)
- Faculty/industry advisor's full name(s)
- Graphic/Image of proposed system

Special note from the judges about Project Plan Proposals:

The Moon to Mars Ice & Prospecting Challenge is focused on ways to assess subsurface depth and density profiles, mine through those layers and into ice deposits beneath, harvest water from that ice and collect it in a container. **Whatever designs teams come up with to accomplish that goal, the technology should be designed as if it would be feasible for use off-Earth, and then modify it for the Earth-based technology demonstration at Langley next summer.** NASA sponsors are looking for concepts that realistically demonstrate a system that could be used on the Moon or Mars. For example: even though the competition will take place here on Earth, please do not propose a concept with a 'blow-dryer and a shop vacuum', which would not be effective on the moon or Mars.

Teams must submit a detailed Project Plan Proposal outlining:

- Team's design of the following systems:
    - mechanical
    - electrical
    - programming
    - control
- The physical characteristics and functional capabilities of the proposed water extraction and prospecting system (including filtration solutions)
- A 3-D view drawing or solid model representation and dimensions of the overall system
- A description of how the proposed prototype will mount to the lid/mounting platform.
- A description of how the proposed system will successfully accomplish the competition tasks, including contingency plans
- A detailed timeline including development, testing, and integration of all required systems (integration must be conducted prior to technical paper submission deadline)
- The relevant past experience and capabilities of the team's systems leads and facilities available for development of the water extraction and prospecting system

- A brief discussion on the concept's anticipated paths-to-flight on a mission to the Moon and Mars. Through this challenge, NASA sponsors are looking for concepts that ***realistically demonstrate*** a system that could be used on the Moon or Mars. Based on significant differences between on- and off-Earth operations, the paths-to flight description must address the critical modifications that would be made to the design if it were trying to: (1) extract water on Mars, and (2) prospecting for a digital core on the Moon. This includes, but is not limited to, considerations for temperature differences, energy/power limitations, and atmospheric pressure differences (i.e., challenges with sublimation). Several paragraphs will suffice.
  - The paths-to-flight description should be broken into two distinct sections:
    - **Water Extraction on Mars:** teams will discuss the significant differences between Mars and Earth operation environments and describe essential modifications that would be required for extracting water from subsurface ice on Mars.
    - **Prospecting on the Moon:** teams will discuss the significant differences between the Moon and Earth operational environments and describe essential modifications that would be required for prospecting for a digital core on the Moon.
- Teams are also asked to propose suggested methods/mechanisms/approaches for making their individual testbeds a more accurate analog for better proof-of-concept testing (i.e., more "flight-like," conditions). This could include, but is not limited to pressurizing your hole, adding vibration isolators to simulate a mobile platform on a rover, etc.
  - **Note:** these are theoretical proposed improvements to the analog testing environment only. If selected as finalists, teams will NOT be required to implement the improvements.
- Clear adherence to the Design Constraints and Requirements
- **RETURNING TEAMS ONLY:** Teams who are re-competing may use any of their previous design concepts for water extraction and/or prospecting for the digital core, but are asked to document any improvements, upgrades, enhancements, approaches, and modifications made to the overall design.
  - A returning team is defined as "returning" if they are using **any part** of a design their university previously used during an on-site technology demonstration for a previous RASC-AL Special Edition Challenge.
  - This section of the proposal is limited to 2 pages max and will not count toward the 8-page limit.

Submitting the Project Plan Proposal

To upload your Project Plan Proposal (.pdf file), please visit the Deliverables Page on the Challenge website to complete the online Project Plan Proposal submission form. Teams are encouraged to review the Design Constraints and Requirements section to better understand what your system must accomplish as a part of the competition.

No revisions can be accepted after submission, so please proof your Project Plan Proposal file very carefully before submitting. If there are any technical problems with the content of your Project Plan Proposal (for example, your file was corrupted), we will try to contact you immediately, so it is very important that you provide us with up-to-date contact information on the submission form.

Late Project Plan Proposals will not be accepted, and the submission form will close promptly at midnight.

The following information will be requested on the Project Plan Proposal submission form:

- College/University name
- Partnering universities (if any)
- Contact information for the faculty advisor(s)
- Contact information for the team lead
- Project Title (Name of team's prototype)
- File upload for PDF Project Plan Proposal document
- Description of System in 400 characters or less (see Examples)

- Signed MMIP Letter of University Support* from the Dean of Engineering (or appropriate alternative authority from the lead university)
- Mailing address for stipend checks (for use if a team is selected as a finalist in the competition). We can mail stipend checks to the university location of your choice (i.e., Office of Sponsored Programs, Departments of Engineering, etc.)
- Vendor W9 Form* for the lead university (to be completed by the accounting department at the university).

*MMIP Letter of University Support and Vendor W9 Forms can also be downloaded from the *Resources page* under "Project Plan Proposals."

Project Plan Proposal Evaluation Criteria

- Description of how prototype system will accomplish required tasks (Max – 20 points)
- Description of concept's 2 anticipated "Paths-to-Flight" (Max 20 points)
  - Water Extraction of subsurface ice on Mars
  - Prospecting on the Moon
- Technical merit and feasibility of Project Plan Proposal (including lessons learned) (Max – 20 points)
- Project Plan Proposal capability – degree to which team can accomplish tasks (Max – 20 points)
- Adherence to Project Plan Proposal guidelines (Max – 10 points)
- Proposed "flight-like" testbed enhancements (Max 5 points)
- Innovation (Max 5 points)

Please note: all design solutions are subject to review by NASA safety and Center Ops, and as a result, designs may be required to be modified. These reviews will happen immediately following selection of the finalist teams, with mitigations due at the mid-term.

Deliverables for Final Teams

Teams selected to participate in the on-site Forum will be responsible for the following Project Deliverables:

- Mid-Project Status Review
  - Submit a 3-5 page mid-project status review paper demonstrating the system's ability
  - Submit a short video demonstration of the system's ability
- Technical Paper - due two weeks prior to the actual competition at NASA
  - A 10-15 page technical paper to be judged by Steering Committee, detailing the concept's 2 paths-to-flight
  - In conjunction with the technical paper, **teams will also be required to submit a video demonstrating full integration of their system (via a YouTube link).**
- Technical Poster Presentation
  - to be presented during the Moon to Mars Ice & Prospecting Challenge Forum
- Fully functioning water extraction system that meets the Design Requirements

Mid-Project Review Guidelines

Mid-Project Review submission deadline: 11:59 p.m. Eastern on March 15, 2021

Prior to receiving the second stipend installment, each Moon to Mars Ice & Prospecting Challenge team must successfully pass a mid-project status review that demonstrates where they are in the development process.

The purpose of the review is to provide the Moon to Mars Ice & Prospecting Challenge Judges with evidence that the team is on-target to compete at the Moon to Mars Ice & Prospecting Challenge competition in Hampton, VA with a fully functioning water extraction and prospecting system that can complete the tasks outlined in the design constraints and requirements. Teams must pass this review to receive the remainder of their stipend. Failure to pass this review may lead to delays in receiving the stipend, or withdrawal of invitation to the competition.

The Mid-Project Review is a Pass/Fail review and will initially consist of two submissions demonstrating prototype functionality:

1. A 3-5 page written report
    a. The written report should provide a narrative of where you are in the development process, and whether you feel confident that you will have a functioning water extraction and prospecting system at the Moon to Mars Ice & Prospecting Challenge Forum. It should outline:
        i. Progress in developing each of the following systems:
            1. mounting (for attachment to the mounting platform)
            2. control (e.g. laptop computer, sensors on the drilling system)
            3. operation of the system excavating through overburden layers and ice
        ii. Any challenges that have been encountered, and how the team is overcoming them (include how the team plans to address any anticipated challenges)
        iii. Any significant design changes resulting from further development and testing
        iv. Detailed integration and operational test plan
        v. Tactical plan for contingencies and redundancies
        vi. Safety Plan (including hazards of operating system and planned mitigations, such as Personal Protective Equipment, if needed)
        vii. List all chemicals or hazardous materials being used
        viii. Updated schedule/timeline of tasks and deliverables
2. Submission of a video
    a. Mounting system (for attachment to the mounting platform)
    b. Control interface (e.g. laptop computer, sensors on the drilling system)
    c. Operation of the system excavating through various layers of overburden and ice
    d. Videos should be uploaded in MP4 format.
    e. Videos are limited to a maximum of 4 minutes in length
    f. File size is limited to 100 MB

    Note: the video is not expected to be a "finished" product, nor to be lengthy. It just simply needs to demonstrate the systems identified above.

The judges will review each team's video and written report to evaluate the team's progress towards competition readiness. If there are any concerns regarding a team's prototype or scheduled timeline, that team may be asked to conduct a follow-up "face-to-face" meeting with the judges via Skype or a webinar. At that point, the judges may request that improvements be made prior to moving the team to the next phase of the competition.

Submitting the Mid-Project Review

To upload your team's Mid-Project Review Paper and video files, please visit the Deliverables Page on the Moon to Mars Ice & Prospecting Challenge Website to complete the online submission form.

No revisions can be accepted after submission, so please proof your files very carefully before submitting it. If there are any technical problems with the content of your paper or video file (for example, a file was corrupted), we will try to contact you immediately, so it is very important that you provide us with up-to-date contact information on the submission form.

Late submissions will not be accepted, and the submission form will close promptly at midnight.

Technical Paper and Integration Video Guidelines

Technical Paper and Integration Video submission deadline: 11:59 p.m. Eastern on May 18, 2021

Technical Paper Guidelines:

- Papers should be single spaced
- Paper will consist of the following sections:
  - Cover Page
  - Executive Summary
  - Body of Report
  - Appendices
- Body of Report is limited to 10 pages minimum; 15 pages maximum ***(submission of a Technical Paper that exceeds this page limit will be considered non-compliant).***
  - Cover page, Executive Summary, References and Appendices are ***excluded*** as a part of your 15-page total limit. They do not count toward the minimum or the maximum page limitations.
  - The appendices are not included in the page limitation; however, it is important to note that the Steering Committee is not obligated to consider lengthy appendices in the evaluation process. **Appendices should be for references only.**
- Please use fonts common to Macintosh and PC platforms, i.e., Times, Times New Roman, Helvetica, or Arial for text; Symbol for mathematical symbols and Greek letters.
- Font size should be either 11 or 12 pt.

Cover page must include:

- University name
- Title/name of prototype
- Photo of the prototype water extraction and prospecting system
- Group photo of team members
- Full names of all team members and their respective major course of study and academic level (undergraduate or graduate)
- Graphic/Image of proposed system
- Faculty/industry advisor's full name (s)

Executive Summary must include:

- Brief description of the method to:
  - drill through the layers
  - prospect for a digital core
  - extract water
  - filter water
- Method of hardware control (avionics/software)

Body of report (10-15 pages max) must include:

- **System Description**
  - For the following, please provide visual (i.e., photos/drawings) and written descriptions, where appropriate, as well as explanations behind your design decisions.
    - Mounting system: (attachment to the mounting platform)
    - Solution to mine through the overburden layers
    - System/technique/methodology utilized for prospecting for a digital core
    - Water extraction system/technique
    - Filtration and water collection
    - Process for managing temperature changes to prevent drill from freezing in the ice
    - Control and communication system
    - Datalogger (including its ability to monitor and record WOB load limits and electrical current usage in real time)
  - **Technical Specifications**: Overall mass, overall volume, length of drill bit, weight-on-bit/drill force, rated load, max drilling speed, torque, on board computer system, communications interface, software, power, system telemetry
- **Design Changes/Improvements:** Include justification for any design changes made since the mid-project review
- **Challenges:** Describe any challenges you faced and how you mitigated them
- **Overall Strategy for the Competition:** How does your system accurately prospect for the digital core and maximize the water acquired
- **Summary of Integration and Test Plan:** Include testing results (simulated or otherwise)
  - Teams are ***required to conduct a fully integrated dry run of all their systems working together at least one time prior to arriving at NASA***. This includes a paragraph or two about the integration in the Technical Paper, as well as an accompanying video demonstration of the integration at the time of Technical Paper submission (as a YouTube link, please).
- **Tactical Plan for Contingencies/Redundancies**: What potential risks exist during your operation, and what are your plans to mitigate those risks
- **Safety Plan:** Including hazards of operating system and planned mitigations, such as Personal Protective Equipment, if needed.
  - List all chemicals or hazardous materials being used
- **Paths-to-flight:** This is one of the most important aspects of the technical paper, and teams are expected to devote ***at least 4 pages to this section***. Provide a clear and detailed discussion of your prototype concept's anticipated paths-to-flight (how the design could be applied to actual mission to the Moon and Mars) – and how you came up with the concept. The paths-to flight description should be broken into two distinct sections:
  - **3 pages should be devoted to water extraction on Mars**: teams will discuss the significant differences between Mars and Earth operation environments and describe essential modifications that would be required for extracting water from subsurface ice on Mars.
  - **1 page should be devoted to Lunar prospecting**: teams will discuss the significant differences between the Moon and Earth operational environments and describe essential modifications that would be required for prospecting for a digital core on the Moon.
- **Project Timeline**
- **Budget:** Include a full budget for designing, building, testing, and transporting your water extraction system.
  - Recognize all sponsors and/or grants. Report the total amount of funding received outside of the $10,000 Development Award, and include estimated dollar value for any parts received in-kind.

Appendices:

Appendices should be for references only.

Submitting the Technical Paper and Integration Video:

To upload your team's Technical Paper (.pdf file) and Integration Video (Youtube link), please visit the Deliverables Page on the Moon to Mars Ice & Prospecting Challenge Website to complete the online technical paper submission form.

No revisions can be accepted after submission, so please proof your Technical Paper file very carefully before submitting it. If there are any technical problems with the content of your paper (for example, your file was corrupted), we will try to contact you immediately, so it is very important that you provide us with up-to-date contact information on the submission form.

Late papers will not be accepted, and the submission form will close promptly at midnight.

Poster Presentation Guidelines

Digital poster file submission deadline: 11:59 a.m. Eastern on May 30, 2021

Poster Guidelines:

Each team is required to present a paper poster describing their paths-to-flight and operational strategy for water extraction and prospecting for a digital core. **Posters should be 48" x 36."** Each team will be given an easel for poster display. One tri-fold foam/cardboard poster board will also be made available for each team to use, as well as thumbtacks/tape to secure posters to the tri-fold boards.

Digital Poster File Guidelines:

Each team is also required to submit the digital file of their poster. Digital posters will be displayed on the Moon to Mars Ice & Prospecting Challenge Website, and as such, will need to follow some standard guidelines:

- Digital poster files must match the printed poster
- Posters must be 48" x 36" (9600 pixels x 7200 pixels) and horizontal
- Poster file size limit is 100MB
- Poster file should be submitted as a PDF file
- Images and graphs should be clear, legible, and appropriately sized for the poster
    - Images and graphs embedded within the poster should be "print-ready," with a minimum DPI of 150 whenever possible
- Links or redirects in the body of their poster are not permitted
    - This includes redirecting to a webpage, video, or any other content.
    - All content should be included in the text or directly embedded within the PDF
    - If the poster has a References section, links may be included in that section only.
        - Include a text link (Ex: http://rascal.nianet.org) vs hyperlinking text.

The Poster Session provides teams with an opportunity to informally interact with the judges and answer any questions the judges have about the prototype water extraction system. **Posters should be a summary of your Technical Paper, with the emphasis of discussion being on the paths-to-flight.**

All members are expected to participate and engage with the judges during the Poster Session.

Final Evaluation/Scoring

The Moon to Mars Ice & Prospecting Challenge Steering Committee is comprised of NASA experts who will evaluate and score the competition between participating teams. Moon to Mars Ice & Prospecting Challenge projects will be evaluated and judged based on adherence to the Design Constraints and Requirements and the criteria below.

The 2021 Scoring Matrix provides a detailed explanation of the scoring approach and can be found on the Deliverables page of the Moon to Mars Ice & Prospecting Challenge website.

Teams are responsible for thoroughly reviewing the Design Constraints & Requirements as well as guidelines for Deliverables above to ensure compliance in each area.

Final scores will be determined based on the following categories:

- Water extraction — 40% of overall score
- Prospecting: Drilling Telemetry — 20% of overall score
- Technical Paper — 30% of overall score
- Technical Poster Session — 10% of total score

Note: To be eligible for 1st or 2nd overall prize, teams must collect at least 50 mL of water.

Overall Competition Score

The maximum possible point value for the overall competition is **490.**

Water Extraction – 40% of overall score

A maximum of **180** points will be awarded for the water extraction portion of the competition. Each team's water volume will be collected (separately for hands-off and hands-on periods) and measured at the end of each day. Silt that has settled to the bottom of the containers will also be measured at the end of the day and subtracted from the water volume measurements to give each team their total water volume for that day's hands-off and hands-on collections.

Scoring for water collection (Max of 150 points)

- A team's Scoring Volume will be equal to their hands-on water volume PLUS five (5) times their hands-off water volume: **Scoring Volume = Total Hands-On Water + (5x Hands-Off Water)**
- The highest total Scoring Volume collected over the 2-day period by any one team = "z":
    - The Scoring Volume will then be normalized to a 150-point scale so the team with the most Scoring Volume will receive 150 points for Water Collection and the other teams will receive points for Water Collection based on the following equation:
      (Team's Scoring Volume/z *150)

Scoring for water clarity (Max of 30 points): Teams will be awarded up to 30 points based on the clarity of the water extracted. Turbidity tests will be conducted at the end of each day, with points being awarded to each team's sample with the best clarity over the 2-day period.

NTU (Nephelometric Turbidity Unit): Measurement of Reflected Light from a Sample
Note: All samples with an NTU above 1,000 will be calculated using a dilution

Turbidity (NTU)	Points
Less than 5 NTU (Minimum Standard for Wastewater)	30 points
5.1 – 50 NTU	25 Points
51 – 1,000 NTU	20 Points
1,001 – 5,000 NTU	15 Points
5,001 – 25,000 NTU	10 Points
25,001 – 50,000	5 Points
Greater than 50,000	0 Points

Prospecting: Drilling Telemetry – 20% of overall score

A maximum of **90** points will be awarded for the regular prospecting portion of the competition. Teams will use drilling telemetry (penetration rate, depth, power) to deliver a digital core that represents their knowledge and understanding of where each of the layers are, the general hardness of each different layer, and the thickness of each layer. Note: layers will have a uniform thickness horizontally across each test station, with depths that vary among each layer.

- Teams will be asked to identify the correct number of layers and list the layers in order from softest to hardest, scoring **up to 50 points** for getting all layers in the correct order in the sequence.
  - Partial points will be awarded if teams can correctly identify some of the correct spots for the layers sequence.
  - For each layer greater than or less than the current number of layers, teams will lose 50/N points (***where N is the true number of layers***). Each layer will be compared with the correct layer sequencing to determine accuracy of the team's suggested order. An error term will be calculated based on how far off the team's remaining ordering is from the true ordering (based on the square of the difference between team's suggested ordering and the correct ordering), and remaining points will be scaled based on how large the error term is.

$$Error = \sum_{i=1}^{N} (Correct\ Layer\ Order_i - Your\ Layer\ Order_i)^2$$

$$Points\ Deducted = \frac{Error}{Max\ Possible\ Error} * Remaining\ Points$$

- Teams will be asked to estimate the thickness of each layer, scoring **up to 40 points** if the estimate of the layers are determined within the established margin of error (MOE) for each layer (i.e., some layers will have a 1.27 cm (0.5 inch) MOE, while others will have a 2.54 cm (1.0 inch) MOE).
  - Partial points will be awarded for estimates that are slightly outside the MOE
  - Starting from the top, the suggested thickness of each layer will be compared to the actual thickness of that layer.

- If the estimate is within the MOE for that layer, teams will receive 40/N points ***(where N is the true number of layers).***
- If the estimate is within 2 * MOE for that layer, teams will receive 40/(2N) points (half-credit).
- If the estimate is greater than 2 * MOE for that layer, zero points will be given for estimating the thickness of that layer.

- This process will continue until the judges have checked all estimates against the true number of layers, regardless of whether the team estimated fewer or more layers (i.e., if there are 6 layers but a team only estimates thicknesses for 4, their estimate for the thicknesses of layers 5 and 6 will be treated as 0 cm, and no points will be awarded for estimating the thickness of unidentified layers).

Technical Paper – 30 % of overall score

A maximum of **135** points will be awarded based on the quality of the Technical Paper.

- Key elements that the Technical Paper will be evaluated on are:
  - Quality of Path-to-Flight description (Max **45** points); including rationale behind various trades and critical modifications made to the system for:
    - Extracting water from sub-surface ice on Mars
    - Prospecting on the Moon
  - Technical quality, feasibility, innovation of design for use off-Earth (Max **35** points)
  - Quality of integration video and summary description (Max **30** points)
  - Quality of summary of production and testing approach (Max **15** points)
  - Adherence to Technical Paper guidelines (Max **10** points)

Poster Presentation – 10% of overall score

A maximum of **45** points will be awarded based on the quality of the Poster Presentation. Teams will be required to bring a poster (48”x36”) to display during the Poster Presentation Session and submit a digital poster file.

- Key elements that the Poster Presentation will be evaluated on are:
  - Discussion of the Earth-based system and how you got from here to the off-Earth system) (Max **25** points)
    - Posters should be a summary of your Technical Paper, with the emphasis of discussion being on how your Earth-based system would be modified for use off-Earth in the following manner:
      - Extracting water from sub-surface ice on Mars
      - Prospecting on the Moon
  - Technical content, style, and coherence of poster (Max **10** points)
  - Engagement with judges (all team members should participate) and quality of answers to questions (Max **10** points)

Note: in the event of a tie, total water volume collected may become the deciding factor (i.e., the team who collected the most water in the tie will emerge as the winner).

Penalties

Penalties will be given for the following conditions:

1. Exceeding the Volume limit
   - Teams will lose 10 points of their total score for every 1 cm over the size limit of 1m x 1m x 2m tall
   - Penalties will be determined by rounding up or down to the nearest whole cm.
2. Exceeding the Mass limit
   - Teams will lose 20 points of their total score for every kg of extra weight over 60 kg.
   - Penalties will be determined by rounding up or down to the nearest whole kg.

3. Exceeding 9 A Current/Amperage limit by blowing a fuse
   - 80 points off the total score and disqualification for the top prize
4. Failure to provide a WOB data logger that can provide real-time data
   - 60 points off the total score and disqualification for the top prize
5. Misalignment between the system brought to the competition and the system described in the Mid-Project Review and/or Technical Paper submissions
   - Up to 200 points off the total score (at the discretion of the judges)
6. Solid Debris collected in secondary filtration bag
   - Reduce total score by 1 point per 10 grams
7. Excessive dirt 'thrown' outside of the 12' x 12' tarp under team test station
   - Up to 20 points off the total score (at the discretion of the judges)

Awards and Honors

Awards may be given for the following:

- First Place Overall
- Second Place Overall
- Most Water Collected
- Best Technical Paper
- Clearest Water
- Lightest System Mass (will only be awarded to a team who produces water)
- Most Accurate Digital Core

Development Stipends

Each finalist team will receive a $10,000 stipend to facilitate full participation in the competition, including expenses for hardware development, materials, testing equipment, hardware, software, and travel to Langley for the competition.

Stipends will be awarded to the finalist teams in two phases. The first half of the $5,000 stipend will be sent immediately after selection notifications in December so that teams may begin development of their prototypes. Each finalist team will receive the second $5,000 stipend installment only after successfully passing their mid-project review in March.

Moon to Mars Ice & Prospecting Challenge stipends **may not be used to**:

- directly support travel or research stipends for federal employees acting within the scope of employment (this includes co-op students with civil servant status).
- directly support travel or research stipends for foreign nationals.

Resources

Teams are encouraged to build on the successes and failures of previous competitions. For more information on lessons learned from previous challenge years, please visit the Resources section on the Moon to Mars Ice & Prospecting Challenge website homepage.

Contact Information

For inquiries about the RASC-AL Special Edition: Moon to Mars Ice & Prospecting Challenge inquiries, please contact the RASC-AL Program Team** at rascal@nianet.org:

Moon to Mars Ice & Prospecting Challenge

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**RASC-AL Program staff are only able to respond to questions presented by eligible students and faculty from accredited colleges and universities in the United States (and international team participants formally affiliated with a US-based university team).

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RASC-AL
Revolutionary Aerospace Systems Concepts Academic Linkage

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