2019

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 **2019 RASC-AL Special Edition: Moon to Mars Ice & Prospecting Challenge** provides undergraduate and graduate students with the 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/Scenario 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.**

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Participating team members take on the role of astronauts who monitor and control drilling operations. Using a combination of autonomous operation and remote control, 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-on" crew interaction with the prototype will be restricted. During all phases of the competition, the teams will be able to use a control system to "remotely" operate the water extraction system.

Moon to Mars Ice & Prospecting Challenge Overview

Through the ***2018 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 Martian subsurface ice. Multiple teams will be chosen through a proposal and down-select process that assesses the teams' concepts and progress throughout the year.

Up to 10 teams will become finalists and travel to the NASA Langley Research Center in Hampton, VA during the summer of 2019 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 the 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 overburden 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:

1. **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.
2. **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 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. Scoring will be based on total water extracted and collected each day, the accuracy of the digital core, adherence to NASA requirements, a technical paper capturing paths-to-flight, innovations and design, and the technical poster presentation.

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 to offset the cost of traveling to the event.

Simulated Mars Subsurface Ice Test Station

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

TEST STATION : Bonar Ice Chest Model PB2145

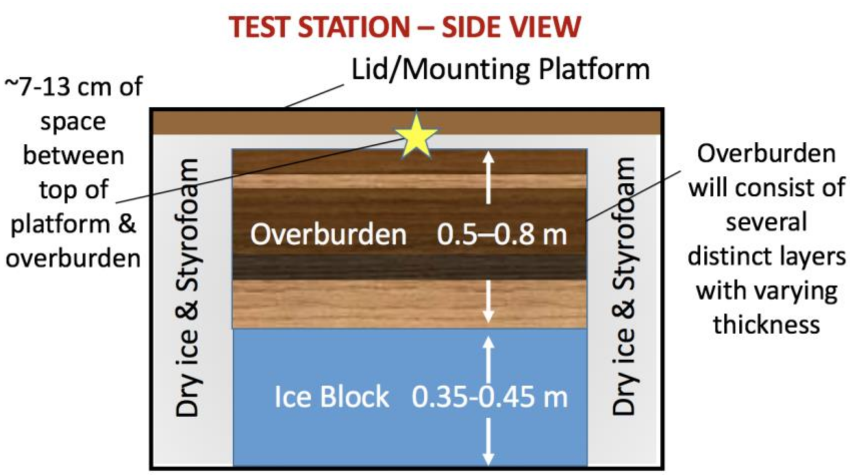
PB2145 / (35) Cube				
Capacity: (258) Gal/(993) liters/ 35 cu.ft.				
Box Weight: (164) lbs. / (74) KG				
Lid Weight: (38) lbs. / (17) KG				
Dimensions	External		Internal	
	cm	inches	cm	inches
Length:	123	48	110	43
Width	109	43	97	38
Height	120	47	101	40
Height w/lid	125	49		

Test Station

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

- 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 0.35 m and 0.45 m
- 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):
    - Dry Sand
    - Clay mixed with 20% sand and 10% gravel
    - Clay mixed with 20% sand
    - Clay mixed with rocky inclusions
    - Solid/consolidated rock or stone
    - Aerated concrete
    - Crushed cinderblock

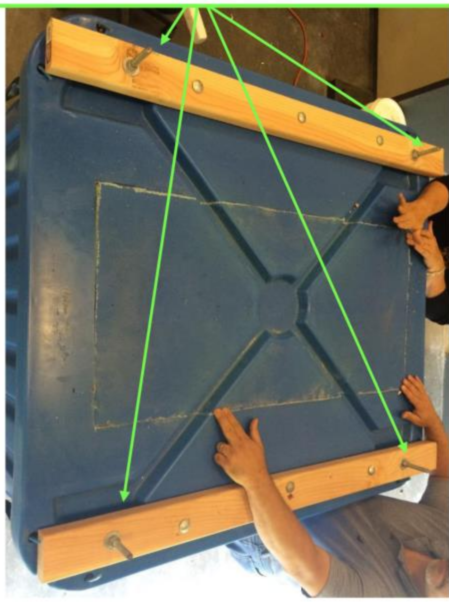
  - The hardest layer will have an unconfined compressive strength of ~25 MPa
  - The total overburden depth will be between 0.5 and 0.8 m. The range in depths is intended to simulate the variability in regolith overburden inherent in natural environments and the resulting needed adaptability of the water 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.
- 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)

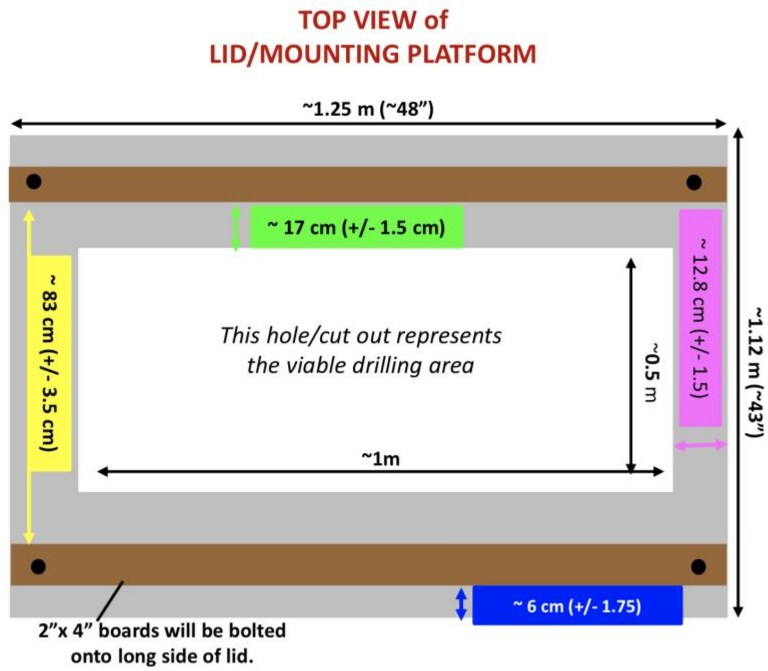


Note: The overburden layers portrayed in this image are for example only and do not represent the actual pattern that will be used for the competition.

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.*

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.





Competition Tasks

1. Mine through the various overburden layers
2. Create a digital core that contains the following information:
   - The number of overburden layers in their test station
   - A sequence of the layers in order from softness 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 tank

- The external accumulation tank will be a 22qt. bucket, 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 (see picture examples to the left).
- The external accumulation tank is 15" (38 cm) tall, with a 31 cm diameter.
  - As water nears the top of the 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 tank).
  - 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 outdoors when the hangar doors are open. Please keep in mind that temperatures average close to 30^0 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.

Daily Operations

Set Up Day: Prior to the first official competition day, teams will have a full day 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 on the set-up day.

Competition Days:

- Water Extraction: Each team will have two separate attempts (6 hours on Day One and 6 hours on Day Two) to extract water from the simulated planetary subsurface ice.
  - During the course of these 2 days, teams may operate their systems "hands-on" or "hands-off". **Water collected during "hands-off" operations will be worth 5 times the value of water collected during "hands-on" operations.**
    - Teams can begin "hands-on" operations as soon as the 6-hour countdown clock begins each day.
      - Before teams can conduct a "hands-off" run, they must receive approval from a judge. Approval will be granted after:
        - the judge has poured out, measured, and recorded any water collected during the "hands-on" period.
        - Teams reset/return their drill to its 'home' state (e.g., starting from a drill elevated over a pristine drilling area).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 pour out, measure, and record any water collected during the "hands-off" period before the team can revert to "hands-on" operations.
    - There is no limit to the number of times a team can operate "hands-off" over the 2-day competition.
    - Water collected during "hands-on" operations will be added cumulatively for each team over the course of the 2-day competition.
    - Water collected during "hands-off" operations will also be added cumulatively for each team over the course of the 2-day competition, weighted by a multiplier of 5.

- 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 6-hour 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.

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.***
   a. Definitions:
      i. **Autonomous control** refers to no human intervention after the system starts; no further operation from any crew is required at all.
      ii. **Remote crew-controlled** 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.
         1. During "Hands-off" operations, teams will not be permitted to provide verbal guidance for the operator while they are physically watching the extraction system.
         2. 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.
         3. Teams may utilize a corded or tethered system that serves as the digital link between humans and machine.
         4. There will be no local WiFi 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.
         5. 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.
   a. System volume limits represent launch vehicle packaging limits.
   b. 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 chords and computers used beside the test station.
   c. 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.
   a. 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.) **– all of this counts towards mass and power limit.**

    i. 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 limitations.**

  b. 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.
    a. **New this Year:** Teams will be required to incorporate a 9 A fast-blow fuse into their circuitry
    b. 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.
    c. Augmenting the system's power supply via batteries, solar power, etc. is **not allowed**.
    d. 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.
    a. Teams are required to provide a WOB data logger to monitor and record their load limits throughout the competition with at least 30% accuracy. It is therefore advisable to limit WOB to 100N to allow for error margin.
    b. The WOB data logger must display critical parameters **in real-time** (i.e., it is not acceptable to provide a solution that involves removing an SD card to be read in a computer).
    c. The above does not apply if the system provides passive (dead weight) WOB. However, in that case, the weight of the excavation system interacting with a soil and ice should be less than 150 N.
6. The length of any drill bits used is limited to 99.06 cm (39 inches) to avoid drilling through the bottom of the cooler.
7. The prototype should be able to penetrate:
    a. Between 0.5 and 0.8 meters of overburden layers that have differing hardness and density profiles
        i. The hardest layer will have an unconfined compressive strength of ~25 MPa
    b. Up to 0.45 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:
    a. Deal with different layers within the overburden as well as the regolith/ice interface, minimizing the amount of dirt in the water collected.
        i. 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.
        ii. 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).
    b. 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.
    c. Melt the ice so that it can be delivered to the external tank, where total water volume is collected.
    d. Filter debris from the water.

Moon to Mars Ice & Prospecting Challenge

Eligibility

The ***RASC-AL Special Edition: Moon to Mars Ice & Prospecting Challenge*** is open to full-time 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.

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 2019 Moon to Mars Ice & Prospecting Challenge.**

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.**

October 12, 2018	NOI submission deadline
Mid-Late Oct., 2018	Webinars and Q&A Session for teams with Steering Committee
November 15, 2018	Project Plan submission deadline
December 4, 2018	Teams are notified of their selection status
March 14, 2019	Mid-Point Progress report deadline
Early May, 2019	Deadline for Hotel Reservations at the Group Rate

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May 5, 2019	Deadline for online registration and payment for the Moon to Mars Ice & Prospecting Challenge Forum
May 19, 2019	Technical Paper and Integration Video submission deadline
June 3-7, 2019	Moon to Mars Ice & Prospecting Challenge Competition at NASA Langley Research Center

Notice of Intent

Notice of Intent deadline: 11:59 p.m. ET October 12, 2018

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 link* on the Moon to Mars Ice & Prospecting Challenge website to complete the brief online NOI submission form.

Project Plan

Project Plan submission deadline: 11:59 p.m. ET on November 15, 2018

General Project Plan Formatting Instructions

Teams are responsible for the formatting and appearance of their project plan. Figures and tables must be in digital format. We recommend that teams use image file formats that provide acceptable resolution without being huge (for example, please don't use a 1-MB TIFF file when a 250-K GIF file will do).

- 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.
    - A table of contents is unnecessary
- Project plans 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
- Project plans should be submitted in PDF Format
- File size cannot exceed 1.5 MB

Project Plan files must include:

- Title/name of prototype
- Full names of all team members, along with their specialties and/or team role
- University name
- Faculty/industry advisor's full name(s)

Teams must submit a detailed Project Plan outlining:

- Your design of the following systems:
    - mechanical
    - electrical

  - programming
  - control
- A detailed timeline including development, testing, and integration of all required systems (integration must be conducted prior to technical paper submission on May 19th, 2019)
- The relevant past experience and capabilities of the team's systems leads and facilities available for development of the water extraction and prospecting system
- 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
- 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 brief discussion on the concept's anticipated paths-to-flight on a mission to the Moon and 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.
  - Special Note: The paths-to-flight description should be broken into two distinct sections:
    - **<u>Water Extraction on Mars</u>**: 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.
    - **<u>Prospecting on the Moon</u>**: 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.
- 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, but must demonstrate (and document) some improvement to the overall design.
  - These teams must include a 'Lessons Learned' section (2 pages max) in their Project Plan proposals that thoroughly details any improvements, upgrades, enhancements, approaches, and modifications being made.
  - The Lessons Learned section will not count toward the 8-page limit.

Special Note: The 2019 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.** 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.

Submitting the Project Plan

To upload your project plan (.pdf file), please visit the *Deliverables link* on the Challenge website to complete the online project plan 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, so please proof your project plan file very carefully before submitting. If there are any technical problems with the content of your project plan (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 proposals will not be accepted, and the submission form will close promptly at midnight.

Project Plan Evaluation Criteria

- Adherence to project plan guidelines (Max – 10 points)
- Description of how prototype system will accomplish required tasks (Max – 25 points)
- **New this year:** Description of concept's 2 anticipated "Paths-to-Flight" (Max 25 points)
    - Water Extraction of subsurface ice on Mars
    - Prospecting on the Moon
- Appropriateness of project plan (including lessons learned) (Max – 20 points)
- Project plan capability – degree to which team can accomplish tasks (Max – 20 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 10 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
    - **New this year**: In conjunction with the technical paper, teams will also be required to submit a video demonstrating full integration of their system
- 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

Additional details on each of these deliverables will be provided to the finalist teams.

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Mid-Project Review Guidelines

Mid-Project Review submission deadline: 11:59 p.m. ET on March 14, 2019

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 document
    - The written document 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 2019 Moon to Mars Ice & Prospecting Challenge Forum. It should outline:
        - Progress in developing each of the following systems:
            - mounting (for attachment to the mounting platform)
            - control (e.g. laptop computer, sensors on the drilling system)
            - operation of the system excavating through overburden layers and ice
        - Any challenges that have been encountered, and how the team is overcoming them (include how the team plans to address any anticipated challenges)
        - Any significant design changes resulting from further development and testing
        - Detailed integration and operational test plan
        - Tactical plan for contingencies and redundancies
        - 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
        - Updated schedule/timeline of tasks and deliverables

2. Submission of a video
    - Mounting system (for attachment to the mounting platform)
    - Control interface (e.g. laptop computer, sensors on the drilling system)
    - Operation of the system excavating through various layers of overburden and ice

    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.
    - Videos should be uploaded in MP4 format.
    - Videos are limited to a maximum of 4 minutes in length
    - File size is limited to 100 MB

The judges will review each team’s video and written document 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, 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 submission deadline: 11:59 p.m. ET on May 20, 2018

Technical Paper Guidelines:

- Papers should be single spaced
- 10 pages minimum; 15 pages maximum;
    - Cover page, 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

Cover page must include:

- Title/name of prototype
- Photo of the prototype water extraction and prospecting system
- Group photo of team members
- Full names of all team members
- University name
- Faculty/industry advisor's full name(s)

Body of Report Should Include:

- **Introduction**
- **System Description**
    - Brief description of the water extraction capabilities
    - Brief description of the capabilities to prospect for a digital core
    - 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)
- System excavation operations
- Water extraction system/technique
- System/technique utilized for prospecting for a digital core
- Filtration and water collection
- Solution to mine through the overburden layers
- 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)
  - **NEW THIS YEAR:** 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.
- **Tactical Plan for Contingencies/Redundancies**: What potential risks exist during your operation, and what are your plans to mitigate those risks
- **Project Timeline**
- **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.
- **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 Moon to Mars Ice & Prospecting Challenge Development Award.

    - Include estimated dollar value for any parts received in-kind
- **References Cited (in Appendix)**

Submitting the Technical Paper and Integration Video:

To upload your team's Technical Paper (.pdf file), 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, 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

Each team is required to present a poster describing their paths-to-flight and operational strategy for water extraction and prospecting for a digital core. Each team will be given an easel for poster display. One tri-fold foam/cardboard poster board will be made available for each team to use at no charge. Posters should be 48" x 36." Thumbtacks will also be available to secure posters to the tri-fold boards.

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.

Evaluation/Scoring

Moon to Mars Ice & Prospecting Challenge Steering Committee/Judges

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 ***2019 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 & Requirement 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

New this year: To be eligible for 1st or 2nd overall prize, teams much collect at least 50 mL of water.

Overall Competition Score

The maximum possible point value for the overall competition is **490** (including 40 potential bonus points available in the Prospecting component of this challenge).

Water Extraction – 40% of overall score

A maximum of **180** points will be awarded for the water extraction portion of the competition. Water volume will be measured at the end of each day. Silt that has settled to the bottom of the container will also be measured and subtracted from the water volume to give each team their total water volume for that day.

In the scenario below, the most total volume collected over the two-day period by any one team in the following modes of operation = "x":

Scoring for hands-on water collection (Max of 25 points): The team with the most water collected during hands-off operations is given a score of 25. Other teams' points are scaled linearly: [(Team volume/x) *25]

Scoring for hand-off water collection (Max of 125 points): The team with the most water collected is given a score of 125. Other teams' points are scaled linearly: [(Team volume/x) *125)]

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.

Prospecting: Drilling Telemetry – 20% of overall score

A maximum of **90** points will be awarded for the regular prospecting portion of the competition, plus the potential for 40 additional bonus points. Teams will use drilling telemetry (penetration rate, depth, power) to deliver a digital core (formation strength vs depth) 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 receive **10 points** for identifying the correct number of overburden layers
  - 0 points are awarded if not exactly correct.
- Teams will be asked to list the layers in order from softest to hardest, scoring **up to 40 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.
  - Up to 40 bonus points will be awarded if teams can accurately determine the true hardness of individual layers in terms of MPa (within a 10% margin of error).
- 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

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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 oral Poster Presentation. Teams will be required to bring a poster (48”x36”) to display during the Poster Presentation Session.

- 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 will emerge as the winner).

Penalties

Penalties will be given for the following conditions:

1. Exceeding the Volume limit
    a. Teams will lose 10 points of their total score for every 1 cm over the size limit of 1m x 1m x 2m tall
2. Exceeding the Mass limit
    a. Teams will lose 20 points of their total score for every kg of extra weight over 60 kg
3. Exceeding 9 A Current/Amperage limit by blowing a fuse
    a. 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
    a. 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
    a. Up to 200 points off the total score (at the discretion of the judges)
6. Solid Debris collected in secondary filtration bag
    a. Reduce total score by 1 point per 10 grams
7. Excessive dirt ‘thrown’ outside of the 12’ x 12’ tarp under team test station
    a. Up to 20 points off the total score (at the discretion of the judges)

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Awards

Awards will be given for the following:

- First Place Overall
- Clearest Water
- Lightest System Mass
- Most Water Collected
- Best Technical Paper
- Most Accurate Digital Core

Resources

Teams are encouraged to build on the successes and failures of last year's competition. For more information on lessons learned from 2017 and 2018, 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:

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