

2018

RASC-AL Special Edition: Mars Ice Challenge



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



RASC-AL Special Edition: Mars Ice Challenge

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RASC-AL Background Information

The Revolutionary Aerospace Systems Concepts – Academic Linkages (RASC-AL) portfolio 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 2017 RASC-AL Special Edition: Mars Ice Challenge).

The **2018 RASC-AL Special Edition: Mars Ice Challenge** provides undergraduate and graduate students with the opportunity to design and build hardware that can extract water from simulated Martian subsurface ice. 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 and Scenario for the Mars Ice 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 just under the surface on Mars have Mars mission planners re-thinking how a sustained human presence on 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 Mars ice deposits. Once extracted, water must be isolated to prevent evaporation (or sublimation if still ice) from the low atmospheric pressures found on Mars. The purpose of this challenge is to explore and demonstrate methods to extract water from the Mars ice deposits.

Participating team members take on the role of astronauts on Mars who monitor and control drilling operations. Using a combination of autonomous operation and remote control, teams will extract as much water as possible. In order to demonstrate a wide range of water extraction 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.

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Mars Ice Challenge Overview

Through the **2018 RASC-AL Special Edition: Mars Ice Challenge**, NASA will provide university-level engineering students with the opportunity to design and build prototype hardware that can extract water 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 2018 to participate in a multi-day competition where the universities' prototypes will compete to extract the most water from simulated Martian subsurface ice over a two-day period. Each Martian simulated subsurface ice station will be comprised of layers, including overburden and solid blocks of ice. The total simulated subsurface ice depth will not exceed 1.0 meter. Teams may drill multiple holes. The water extraction 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 "path-to-flight" (how the design can be applied to an actual mission on Mars). Noting the significant differences between Mars and Earth operational environments, the mandatory path-to-flight discussion should describe essential modifications that would be required for Mars water extraction. This includes, but is not limited to, considerations for temperature differences, power limitations, and atmospheric pressure differences (i.e., challenges from sublimation).

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, adherence to NASA requirements, a technical paper capturing 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 invites may include an accompanying stipend to further advance development of team concepts and offset the cost of traveling to the event.

Designing the Prototype for Mars or Earth?

The 2018 Mars Ice Challenge is focused on ways to extract water from 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 on Mars, and then modify it for the Earth-based technology demonstration at Langley next summer.** Project plans should discuss the modification/trades that were made between the Mars-based design and the design as modified for use on Earth.

Even though the competition will take place here on Earth, please do not propose a concept with a blow-dryer and a shop vacuum, as that won't get very far in this competition.

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Competition Tasks

1. Penetrate through a top layer of overburden (comprised of pitcher mound clay, mixed with 10% by mass ~1" angular gravel)
 - The overburden depth will be between 0.3 and 0.6 m. The range in depths is intended to simulate the variability in regolith overburden inherent in natural environments and the resulting needed adaptability of a water drilling and extraction system.
2. Penetrate the ice.
3. Extract and transfer as much 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 right).
 - 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)
 - A standard garden hose will be able to 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.



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 water extraction system.

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

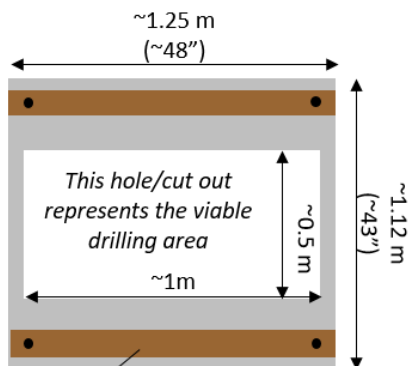
| PB2145 / (35) Cube | | | | |
|---|----------|--------|----------|--------|
| Capacity: (258) Gal/(993) liters/ 35 cu.ft. | | | | |
| Box Weight: (164) lbs. / (74) KG | | | | |
| Lid Weight: (38) lbs. / (17) KG | | | | |
| Dimensions | External | | Internal | |
| | cm | inches | cm | inches |
| Length: | 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 ice chest (Bonar ice chest, Model PB2145), consisting of:

- a layer of blocked ice (2 ice blocks stacked on top of each other, with a thin layer of water between the two to ensure one solid, frozen block of ice to work with)
 - total ice block dimension = $\sim 1 \text{ m} \times 0.5 \text{ m} \times 0.5 \text{ m}$ (L x W x D), followed by:
- a layer of overburden consisting of pitcher mound clay mixed with 10% by mass of $\sim 1''$ angular gravel;
 - overburden layer depth will be between 0.3 and 0.6 m
 - the overburden will be filled to the top of the container, however, due to the thickly insulated lids, teams should allow $\sim 7\text{-}13 \text{ cm}$ of space between the top of the mounting platform and the top of the overburden. While every effort will be made to pack each test bed the same, 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;

TOP VIEW of LID/MOUNTING PLATFORM



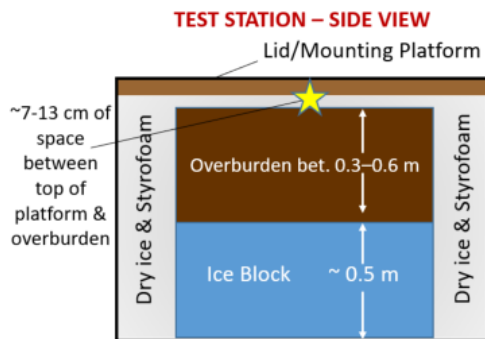
2"x 4" boards will be bolted onto long side of lid.

- 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 $1 \text{ m} \times 0.5 \text{ m}$). 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 system to this lid/mounting platform (if approved, NASA will assist in customizing your team's mounting platform on-site the first day of the competition)

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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.

Competition Environment and Thermal Management

The Mars Ice Challenge Forum will be inside Langley's Hangar facility. This is a well ventilated, shaded environment, but it is outdoors. 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. During the 2017 Mars Ice Competition, temperatures were approximately 35°C all week and the ice remained frozen solid inside the test beds at the end of the week.

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 to the ice interface at -10° C.

Daily Operations

Each team will have two separate attempts (6 hours on Day One and 6 hours on Day Two) to extract water from the simulated Martian subsurface ice.

- 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 will be allowed on the set-up day.
- Testing Day One:
 - On the first day, teams may perform unlimited human interventions, if needed.
- Testing Day Two:
 - **UPDATE:** On the second day, once the 6-hour countdown clock has started, teams will still be allowed as much hands-on time as needed. However, once the team is ready for operation and receives the authorization from a judge, they must operate autonomously or via remote control during the remaining time to collect any water that counts towards their scoring.

Collected water will be measured daily; the water collected on Day Two will be weighted by a multiplier of 3.

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Mars Water Extraction System Prototype Design Constraints & Requirements

1. The water extraction system must operate autonomously or via “remote crew-controlled” operations for the duration of the run. Either system operation is acceptable, as either could be used on Mars.
 - a. Definitions:
 - i. **Autonomous control** is “hands-off” once the system starts, no further operation from any crew is required.
 - ii. **Remote crew-controlled** allows for the use of a computer distinct from but able to communicate with the water extraction 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. Water extraction 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. Monitoring and making decisions in real-time based on the use of feedback from cameras and sensors is encouraged, but not required.
 2. Teams may utilize a corded or tethered system that serves as the digital link between humans and machine.
 3. 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 system and computer/control system, but must accept the risk of possible interference.
 4. The computer/control system will operate on a separate power supply from the water extraction system.
 - b. Once the water extraction system has been set up, teams will need to step back and allow their system to operate independently. If the system needs to be repaired after initial operation begins, judges will allow human intervention (i.e., mulligans) in accordance with the daily operations described above. An example of an allowable intervention is replacement of stuck drill bits.
2. The water extraction 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. Volume limits extend to all portions of the competition (i.e., the size of the water extraction system can never exceed the established volume limits), 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 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.**



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Eligibility

The **RASC-AL Special Edition: Mars Ice 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 Mars Ice Challenge.
 - Teams who do not have a faculty advisor present at the Mars Ice 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 Mars Ice 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 Mars Ice 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 2018 Mars Ice 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 19, 2017 | Q&A Webinar for teams with Mars Ice Challenge Steering Committee |
| November 15, 2017 | NOI submission deadline (extended) |
| November 16, 2017 | Project Plan submission deadline |
| December 4, 2017 | Teams are notified of their selection status |
| March 11, 2018 | Mid-Point Progress report deadline |
| May 1, 2018 | Deadline for Hotel Reservations at the Group Rate |
| May 1, 2018 | Deadline for online registration and payment for the Mars Ice Challenge Forum |
| May 20, 2018 | Technical Paper and Integration documentation submission deadline |
| June 5-8, 2018 | Mars Ice Challenge Competition at NASA Langley Research Center |



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Notice of Intent

Notice of Intent deadline: 11:59 p.m. ET November 15, 2017

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 Mars Ice Challenge website to complete the brief online NOI submission form.

Project Plan

Project Plan submission deadline: 11:59 p.m. ET on November 16, 2017

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 references)
 - A cover page is not required, but if your team chooses to use a cover page, it will not count toward the 8-page limit
 - 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
- 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 June)
- The relevant past experience and capabilities of the team's systems leads and facilities available for development of the water extraction system



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- The physical characteristics and functional capabilities of the proposed water extraction system (including filtration solutions)
- A 3-D view drawing or solid model representation and dimensions
- A description of how the proposed water extraction system 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 path-to-flight on a Mars mission. The path-to flight description must address the critical modifications that would be made to the design if it were trying to extract water on Mars, based on significant differences between Mars and Earth operations. 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.
- Clear adherence to the Design Constraints and Requirements
- **RETURNING TEAMS ONLY:** Teams who are re-competing may use any of their previous design concepts, 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.

Submitting the Project Plan

To upload your project plan (.pdf file), please visit the *Deliverables link* on the Mars 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 water extraction system will accomplish required tasks (Max – 25 points)
- Description of concept's anticipated "Path-to-Flight" (Max 25 points)
- 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.

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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 Report - 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 path-to-flight (how the design can be applied to actual Martian drilling/water extraction).
- Technical Poster Presentation
 - to be presented during the Mars Ice 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.

Mid-Project Review Guidelines

Mid-Project Review submission deadline: 11:59 p.m. ET on March 11, 2018

Prior to receiving the second stipend installment, each Mars Ice 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 Mars Ice Challenge Judges with evidence that the team is on-target to compete at the Mars Ice Challenge competition in Hampton, VA with a fully functioning water extraction 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 system at the 2018 Mars Ice 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 both overburden 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

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- **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 both 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 Mars Ice 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 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. Teams are encouraged to use the appendix section wisely.



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- 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 of presentation
- Photo of the water extraction 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's capabilities
 - 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
 - Filtration and Water Collection
 - Solution to deal with the overburden
 - 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
- **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 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 on their water extraction systems at least one time prior to arriving at NASA**, and include a paragraph or two about the integration. Please included photos.
- **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
- **Path-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 drill concept's



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anticipated path-to-flight (how the design could be applied to actual mission on Mars) – and how you came up with the concept. The path-to flight description must address critical modifications (design trades) that would be made to the design if it were trying to extract water on Mars, based on significant differences between Mars and Earth operations. This includes, but is not limited to, considerations for temperature differences, energy/power limitations, and atmospheric pressure differences (i.e., challenges with sublimation).

- **Budget:** Include a full budget for designing, building, testing, and transporting your water extraction system.
 - Recognize all sponsors and/or grants
 - Include estimated amounts for any parts received in-kind
 - Report the total amount of funding received outside of the Mars Ice Challenge Development Award.
- **References Cited**

Submitting the Technical Paper:

To upload your team's Technical Paper (.pdf file), please visit the *Deliverables Page* on the Mars Ice 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 water extraction system and operational strategy. Each team will be given one 6' table. Posters must be free standing and able to fit on this table. 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 how your Earth-based system would be modified for use in Mars.***

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

Evaluation/Scoring

Mars Ice Challenge Steering Committee/Judges

The Mars Ice Challenge Steering Committee is comprised of NASA experts who will evaluate and score the competition between participating teams. Mars Ice Challenge projects will be evaluated and judged based on adherence to the Design Constraints and Requirements and the criteria below. The ***2018 Mars Ice Challenge Scoring Matrix*** provides a detailed explanation of the scoring approach.



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Teams are responsible for thoroughly reviewing the Guidelines for Deliverables above to ensure compliance in each area.

Final scores will be determined based on the following categories:

- Water extraction – 50% of overall score
- Technical paper – 40% of overall score
- Technical Poster Session – 10% of total score

Half of the team's score will be related to water extraction. The remaining fifty percent will be related to the technical paper, and poster presentation.

Overall Competition Score

The maximum possible points for the overall competition is 240.

The detailed **Mars Ice Challenge Scoring Matrix** can be found on the *Deliverables* page of the Mars Ice Challenge website.

Water Extraction – 50% of overall score

A maximum of **120** 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.

The most volume collected by any one team = "x" for that day.

Day One Scoring: The team with the most water collected is given a score of 30. Other teams' points are scaled linearly: $[(\text{Team volume}/x) * 30]$

Day Two Scoring: Water collection on Day 2 is worth 3 times the water collected on Day 1. The team with the most water collected is given a score of 90. Other teams' points are scaled linearly: $[(\text{Team volume}/x) * 90]$

Technical Paper – 40 % of overall score

A maximum of **96** 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 (including rationale behind various trades and critical modifications made to the Mars-based system) (Max **40** points)
 - Technical quality, feasibility, innovation of design for the Mars-based system (Max **30** points)
 - Quality of summary of production and testing approach (Max **16** points)
 - Adherence to Technical Paper guidelines (Max **10** points)

Poster Presentation – 10% of overall score

A maximum of **24** 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.

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- Key elements that the Poster Presentation will be evaluated on are:
 - Discussion of the Earth system (How we got from here to the Mars-based system) (Max 10 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 in Mars.
 - Technical content, style, and coherence of poster (Max 7 points)
 - Engagement with judges (all team members should participate) and quality of answers to questions (Max 7 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 5 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 10 points of their total score for every kg of extra weight over 60 kg
3. Exceeding Current limit of 10A (at supplied 120VAC)
 - a. Teams will lose 1-point per 1 amp for each minute over the established limit
 - b. Current data will be collected every 10 seconds by the teams datalogger
 - c. Linear Scale: we will subtract 1 point per Amp for each minute spent over 10.0A.
 - i. For example, if current is 10.1A for 10 minutes, 1 point will be deducted.
4. Exceeding Newton limit of 150 N
 - a. 0.5-point multiplier times the average Newtons above the established limit over the course of the 2-day competition
 - b. Force data will be collected every 10 seconds – if the average of the force data is above 150 N over the course of the 2-day competition, teams are penalized based on the number of Newtons beyond the allowable limit
 - c. Linear Scale: we will subtract “0.5” points per Newton over 150 Newtons
 - i. For example, if a teams averages 50 Newtons above the limit, their penalty score will be:
 1. $50 \times .5 = 25$ -point penalty off their total score
5. Failure to provide a WOB data logger that can provide real-time data
 - a. 40 points off the total score and disqualification for the top prize
6. 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 120 points off the total score (at the discretion of the judges)
7. Solid Debris collected in secondary filtration bag
 - a. Reduce total score by 1 points per 10 grams
8. 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

Resources

Teams are encouraged to build off of the successes and failures of last year's competition. For more information on lessons learned from 2017, please visit the *Resources* section on the Mars Ice Challenge website homepage.

Contact Information

For Mars Ice Challenge inquiries, please contact the RASC-AL Program Team at rascal@nianet.org:

SHELLEY SPEARS
PROGRAM DIRECTOR



Tel 757-325-6732
shelley.spears@nianet.org

STACY DEES
PROGRAM MANAGER



Tel 757-218-8313
stacy.dees@nianet.org

VICTORIA (TORI) O'LEARY
PROGRAM COORDINATOR



Tel 757-325-6926
victoria.oleary@nianet.org

National Institute of Aerospace

RASC-AL Program Office
100 Exploration Way
Hampton, VA 23666
<http://specialedition.rascal.nianet.org>



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