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 contains several premier university engineering design challenges that address NASA's new approach for future human space exploration. In each of these university reach-back design challenges, students develop concepts that may provide solutions to design problems and challenges currently facing human space exploration.

- RASC-AL Classic – Aerospace Concepts is the forerunner of the NASA/NIA RASC-AL programs and serves as the foundation for the application-based nature of the other RASC-AL competitions. RASC-AL Classic offers graduate and undergraduate students the opportunity to develop innovative concepts and/or technologies for human space exploration system mission architectures and/or subsystems. Participating RASC-AL teams present their concepts and supporting analysis to a panel of NASA and industry experts at the annual RASC-AL Forum in Cocoa Beach, FL. The oral presentations are augmented by the submission of a technical paper and a research poster.
- RASC-AL Exploration Robo-Ops focuses on a specific system within an interplanetary mission – teleoperated robotics. Robo-ops annually invites collegiate students to build a planetary rover prototype and demonstrate its capabilities to perform a series of tasks in field tests at NASA's Johnson Space Center's (JSC) Rock Yard – completely via teleoperation. Student teams are required to submit a technical paper and poster, as well as conduct a dynamic public and stakeholder engagement component that demonstrates participatory exploration approaches for future NASA missions. (Robo-ops is taking a temporary hiatus in 2017).
- RASC-AL Special Edition: Mars Ice Challenge is a special edition competition that will be held in conjunction with 100th Anniversary celebration activities at NASA's Langley Research Center (LaRC) in 2017. RASC-AL has served as an integral part of LaRC's talent pipeline as well as an idea mine for many LaRC projects over the span of several decades. As a part of the centennial celebration activities at LaRC, NASA will highlight RASC-AL achievements by hosting a Special Edition Challenge focusing on technology demonstrations for In-Situ Resource Utilization (ISRU) capabilities on Mars, particularly extracting water from simulated Martian subsurface ice. Improving ISRU capabilities will be a focus for NASA over the next few decades, and the ***RASC-AL Special Edition: Mars Ice Challenge*** offers a unique way for NASA LaRC to recognize RASC-AL's important place in its history while also linking the competition to its future.

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 Earth independence 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 and temperatures found on Mars.

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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 operate their drills to extract as much water as possible. In order to demonstrate a wide range of drilling capabilities of interest to exploration and science, team member interaction with the drill 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 drill will be restricted. During all phases of the competition, the teams will be able to use a control system to "remotely" operate the drill system.

Mars Ice Challenge Overview

Through the ***RASC-AL Special Edition: Mars Ice Challenge***, NASA will provide university-level engineering students with the opportunity to design and build 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 8 teams will become finalists and travel to the NASA Langley Research Center in Hampton, VA during the summer of 2017 to participate in a multi-day competition where the universities' drilling hardware and software 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 drilling and 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 drilling 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 drill 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 8 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 the ability to drill through each layer of the simulated subsurface ice, total water extracted and collected each day, adherence to NASA requirements, a technical paper capturing innovations and design, and a 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 FY17 Mars Ice Challenge is focused on ways to extract ice and get it into 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 earth-based design and how that design would be modified for use on Mars.

Even though the competition will take place here on Earth, please do not propose a concept with a blow-dryer and a shop vacuum – that won't get teams very far in this competition. **Preference will be given to those teams that propose water extraction ideas that have merit for use on Mars. Your emphasis should be on Marian design, but then modify it to show us how it will work here on Earth.**

Competition Tasks

1. Drill through a top layer of overburden (comprised of pitcher mound clay, mixed with 10% by mass ~1" angular gravel)
    - The overburden depth will be approximately 0.5 m.
2. Drill into ice
3. Extract as much liquid water as possible and deposit into an external accumulation tank
    - The external accumulation tank will be a 22 qt. bucket and lid, located within 1 meter adjacent to the team's test station.
        - 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 transfer as much liquid water as possible into the provided tank.
    - Teams will need to design and bring water transfer equipment.
        - 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.
    - Teams will need to deliver a finished product (i.e., liquid water filtered from as much debris as possible) into the provided tank.
        - Designs should include a solution (i.e., filter) to collect any sediment, so that only water is delivered into the tank for measurement.
        - NASA will provide a secondary control filtration system 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, based on a ratio of water/debris collection.

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 drilling system.

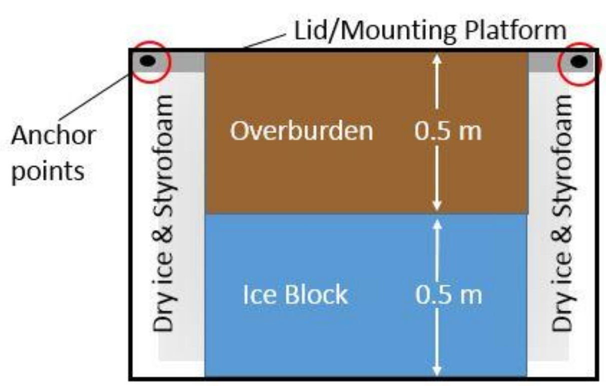
TEST STATION : Bonar Ice Chest model PB2145

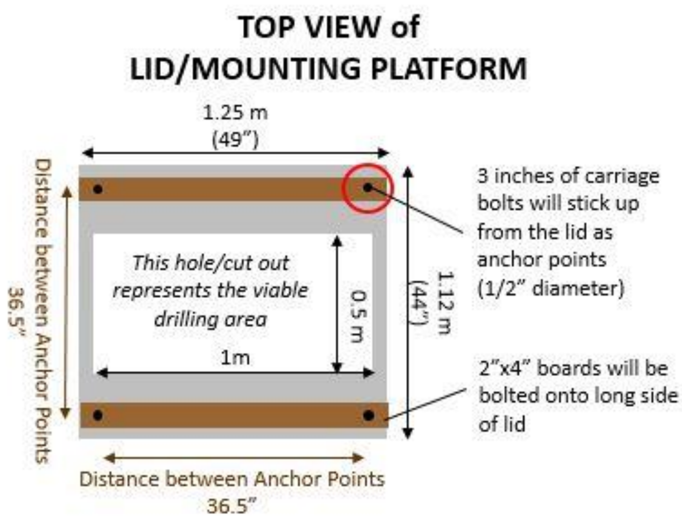
Test Station

The simulated Martian subsurface ice (aka, test station) is contained within a large ice chest/cooler (Bonar ice chest, model PB2145), consisting of:

- a layer of dry ice on the bottom, followed by:
- a layer of blocked ice
  - ice block dimension = 1 m x .5 m x .5 m (L x W x D), followed by:
- a layer of overburden consisting of pitcher mound clay mixed with 10% by mass of ~1" angular gravel;
  - overburden layer depth will be approximately 0.5 m
  - the overburden will not exceed past the natural height of the ice chest
- a lid that sits directly on top of the overburden, which also serves as the drill 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 .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 drilling into dry ice and foam insulation
  - each team's drill will sit directly on this mounting platform
  - several anchoring points (3" carriage bolts) will be available at the corners of the platforms, 36.5 inches apart – as well as 2'x4' wooden boards for mounting (see diagram below)
    - teams will design solutions that propose the best way to anchor the drill to this lid/mounting platform

TEST STATION – SIDE VIEW





Competition Environment and Thermal Management

The competition will be held indoors, in a climate controlled room.

Dealing with ice at atmospheric conditions is non-trivial. Teams are encouraged carefully consider thermal management in the design and operation procedures. During this indoor competition, teams can expect the simulated Martian subsurface ice will have non-uniform temperature. Teams should assume that the atmospheric temperature is going to be ~ 20 °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 drill and extract water from the simulated Martian subsurface ice.

- Set Up Day:
  - Prior to the first official competition day, teams will have an afternoon to set up their drilling system, undergo inspection (safety, volume check, weigh-in, etc.), and conduct mechanical, electrical, and communications testing. No actual drilling will be allowed on the set up day.
- Testing Day One:
  - On the first day, teams will receive unlimited human interventions, if needed.
    1. Standing water in the cooler will be drained overnight.
- Testing Day Two:
  - On the second day, teams will be allotted with 30 minutes for human interventions at the start of the day, and then must be "hands-off" for the remainder of the day (i.e., the drills must operate autonomously or via "remote crew-controlled" operations for the last 5.5 hours of the 2nd competition day).

Collected water will be measured each day, and the water collected on Day Two will be weighted by a multiplier of 3.

Mars Drilling System Prototype Design Constraints & Requirements

1. The drilling system must operate autonomously or via "remote crew-controlled" operations for the duration of the run. Either system operation is acceptable, as either would/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 the drilling system that talks to the drill (if desired, connected by a cable or Bluetooth, point-to-point, etc. to the drilling system) to operate the drilling system (e.g. to control the speed of the drill).
    b. Once the drilling 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. Example of allowable intervention is replacement of stuck drill bits.
    c. "Remote crew-controlled" operations indicate that the crew will be nearby their test station (within line of site) and can figure out when problems occur and can address those problems remotely. Drills should not be built that will require human intervention, instead, they should be built to work on their own while being controlled remotely.
        i. Teams are encouraged to utilize a corded or tethered system that serves as the digital link between humans and machine.
        ii. There will be no local WiFi access available to the teams for this competition. Teams may implement a direct, localized wireless connection between their drill and computer/control system, but must accept the risk of possible interference.
        iii. While the drill is limited to 10 amps, a separate power supply will be available for the computer/control system.
2. The drilling 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 drilling 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 these dimension limits will result in disqualification and development stipends subject to refund to NIA.***
3. The drilling system (and everything used on the system, including the water transfer equipment) must have a mass less than or equal to 50 kg.
    a. Clarification: Anything that sits on top of the lid as part of your drill system must meet the mass, power, and volume constraints. **Anything that is intrinsically part of the drill system** (the drill components, heating elements, command & control computers, power cables, filtration system, pumps, hose, anchoring system, etc.) **– all of this counts against 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 drill) **are not included in your overall system mass or power limitations.**

   b. ***Teams with a system exceeding the mass limit will be disqualified and development stipends subject to refund to NIA.***
4. The drilling system must be capable of operating on limited power supply - not more than 10 amps on 120 VAC
   a. Teams will be provided with a wall plug fitted with a circuit breaker to limit power draw.
      i. Augmenting the drill's power supply via batteries, solar power, etc. is **not allowed**.
   b. This power limitation only applies to the drilling system itself. Separate power sources (i.e., a standard wall outlet) will be supplied for the remote crew-controlled computer/control devices for the drill.
5. The drill force (also called Weight on Bit) should be limited to less than 100 N.
   a. Teams are required to provide a data logger to monitor and record their load limits throughout the competition.
6. The length of drill bits is limited to 38.5 inches to avoid drilling through the bottom of the cooler.
7. The drilling system should be able to drill through:
   a. Up to 0.5 meters of overburden (pitcher's mound clay mixed with 10% by mass ~1" angular gravel)
   b. Up to 0.5 meters of ice
8. The drilling system must be capable of handling temperatures as low as -26° Celsius.
9. Each team's drilling system should include solutions to:
   a. Deal with the overburden, minimizing the amount of dirt in the water collected.
      i. Solutions should not involve options to "blow" the overburden away from the test station.
      ii. Teams may move/deposit 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 the drill 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 can be collected.
   d. Filter debris from the ice/water.

Important Dates

October 14, 2016	NOI deadline for university teams
October 20, 2016	Q&A Webinar for teams with Mars Ice Challenge Steering Committee
November 17, 2016	Project Plan submission deadline
December 9, 2016	Teams are notified of their selection status
April 2, 2017:	Mid-Point Progress report deadline
May 30, 2017	Technical Paper submission deadline
June 13-15 2017	Mars Ice Challenge Competition at NASA Langley Research Center

Eligibility

The ***RASC-AL Special Edition: Mars Ice Challenge*** is open to full-time undergraduate and graduate students majoring in science, technology, engineering, or 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 in collaboration together on the same team.

University Design Teams must include:

- Team sizes vary widely, but must contain, at a minimum, one faculty or industry advisor with a university affiliation at a U.S.-based institution, and 2 students from a U.S.-based university. There is no limit to the number of participants on each team, however, a maximum of 4 students and 1 faculty advisor may attend the onsite portion of the Mars Ice Challenge held at NASA Langley Research Center.
- One 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 Competition will be disqualified from competing and stipends will be subject to return to NIA.

Foreign Students/Universities

Foreign universities are not eligible to participate in the Mars Ice Challenge. However, foreign students who are attending a U.S.-based university are eligible to participate with their team. Please note there is always the possibility that foreign nationals may not be granted access to attend the on-site competition at NASA Langley Research Center (LaRC), due to ever-changing NASA security regulations.

Notice of Intent

Notice of Intent deadline: October 14, 2016

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

Project Plan

Project Plan submission deadline: November 17, 2016

General Project Plan Formatting Instructions

You are responsible for the formatting and appearance of your project plan. Figures and tables must be in digital format. We recommend that you 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).
File size cannot exceed 1.5 MB.

- 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 should be between 11 and12
- Project plans should be submitted in PDF Format

Project Plan files must include:

- Title
- Full names of all team members
- University name
- Faculty/industry advisor's full name(s)

Teams must submit a detailed Project Plan outlining:

- The following systems requirements:
  - mechanical
  - electrical
  - programming
  - control
- A detailed timeline including development and testing of all required systems
- The relevant past experience and capabilities of the team's systems leads and facilities available for development of the drilling system
- The physical characteristics and functional capabilities of your proposed drilling system
- A 3-D view drawing or solid model representation and dimensions
- A description of how your proposed drill will mount to the lid/mounting platform.
- A description of how your proposed system will successfully accomplish the competition tasks, including contingency plans
- A brief discussion on drill concept's anticipated path-to-flight (how the design could be applied to actual mission on Mars). The path-to flight description must address an overview of 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

Submitting the Project Plan

To upload your project plan (.pdf file), please visit the *Requirements & Forms 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.

Project Plan Evaluation Criteria

- Adherence to project plan guidelines (Max – 10 points)
- Description of how drilling system will accomplish required tasks (Max – 20) points)
- Description of concept's anticipated "Path-to-Flight" (Max 20 points)
- Appropriateness of project plan (Max – 20 points)
- Project plan capability – degree to which team can accomplish tasks (Max – 30 points)

Deliverables

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

- Mid-Project Status Review
  - Submit a 3-5 page mid-project status review paper demonstrating drilling system's ability
  - Submit a short video demonstration of the drilling 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 drill concept's path-to-flight (how the design can be applied to actual Martian drilling).
- Technical Poster Presentation
  - to be presented during the Mars Ice Challenge
- Fully functioning drilling system that meets the Design Requirements

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

Scoring

Final scores will be determined based on the following categories:

- Water extraction – 70 % of overall score
- Technical paper – 20% of overall score
- Technical Poster Session – 10% of total score

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Contact Information

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

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