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)

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Table of Contents

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.

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.

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.

TEST STATION : Bonar Ice Chest Model PB2145

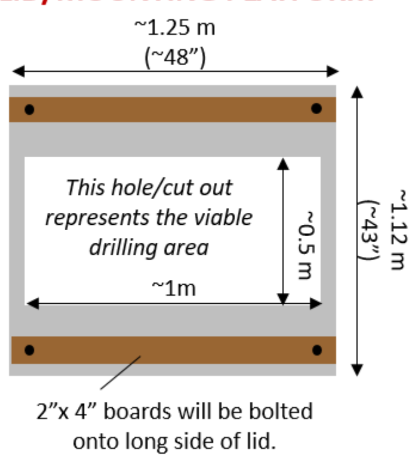
PB2145 / (35) Cube				
Capacity: (258) Gal/(993) liters/ 35 cu.ft.				
Box Weight: (164) lbs. / (74) KG				
Lid Weight: (38) lbs. / (17) KG				
Dimensions	External		Internal	
	cm	inches	cm	inches
Length:	123	48	110	43
Width	109	43	97	38
Height	120	47	101	40
Height w/lid	125	49		

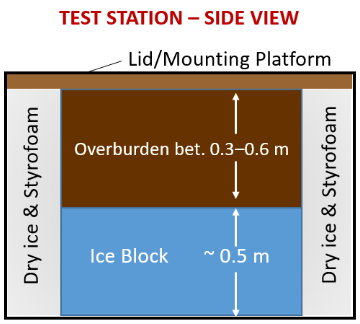
Test Station

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 = ~ 1 m x 0.5 m x 0.5 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 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 ~7-13 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;
  - 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 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)

TOP VIEW of LID/MOUNTING PLATFORM





***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^{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. During the 2017 Mars Ice Competition, temperatures were approximately 35^{o}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:
  - On the second day, teams will be allowed as much hands-on time as needed at the start of the day for setup. However, once the team is ready for operation and receives the

authorization from a judge, they must operate hands-off 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.

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.**
    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 water extraction system) **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 system must be capable of operating on limited power supply, either via limited amperage on 120 VAC or via a finite amount of power stored in a battery. Details to be announced soon. One way or the other, power supply will be restricted to closely simulate conditions on Mars.
    a. Augmenting the system's power supply via batteries, solar power, etc. is **not allowed**.
    b. This power limitation only applies to the water extraction 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. Failure to provide a WOB data logger that can provide real-time data will result in a penalty.
    d. 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 97.8 cm (38.5 inches) to avoid drilling through the bottom of the cooler.
7. The water extraction system should be able to penetrate:
    a. Between 0.3 and 0.6 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 water extraction system must be capable of handling temperatures as low as -26° Celsius.
9. Each team's water extraction system should include solutions to:
    a. Deal with 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.

RASC-AL Special Edition: Mars Ice Challenge

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 13, 2017	NOI deadline for university teams
October 17, 2017	Q&A Webinar for teams with Mars Ice Challenge Steering Committee
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

RASC-AL Special Edition: Mars Ice Challenge

Notice of Intent

Notice of Intent deadline: 11:59 p.m. ET on October 13, 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

- 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 in their Project Plan proposals that thoroughly details any improvements, upgrades, enhancements, approaches, and modifications being made.

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)

RASC-AL Special Edition: Mars Ice Challenge

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.

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	STACY DEES PROGRAM MANAGER	VICTORIA (TORI) O'LEARY PROGRAM SPECIALIST
		
Tel 757-325-6732 shelley.spears@nianet.org	**Tel** 757-218-8313 stacy.dees@nianet.org	**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

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