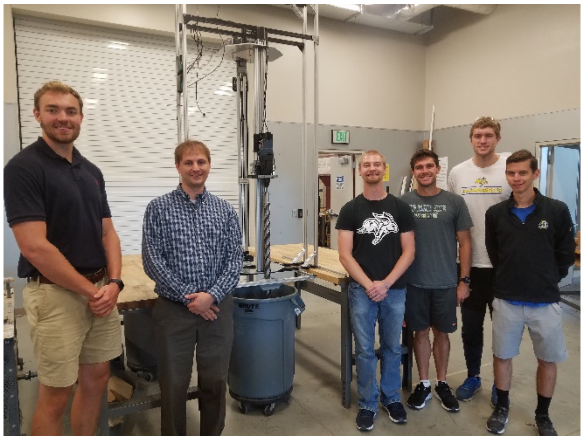
2021 RASC-AL SPECIAL EDITION:
MOON TO MARS ICE AND PROSPECTING CHALLENGE
Technical Paper
August 31, 2021



JAMMER: **J**ackrabbit **A**utomated **M**oon to **M**ars **E**xtractor and prospecto**R**

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Executive Summary

The JAMMER system provides four basic functions: 1. Drill through overburden layers to reach icy layers, 2. Prospecting during the drilling process to determine overburden materials and depths, 3. Remove ice (in water form) through the drilled hole and deliver to a filtration system, and 4. Filter particulate contamination from the water stream. To accomplish these tasks, a rotary system was designed where one side has a hammer drill with an inner/outer drill assembly and the other side has a 3d printed heater core that causes swirling in the water, which then promotes faster melting and eventually more water uptake. The digital core prospecting has several components, which can be analyzed post-drilling to determine overburden layers and depths. Vibrations on the drill are monitored and compared to a database of known values for known materials and a camera monitoring the spoils from the drilling process help identify major changes to material. In addition, drill current and vertical speed (drill power kept as constant as possible) are also monitored as another data stream to compare to the database.

A small amount of water is used to prime the system to help get fast melting started. The water is pumped through the heater core, slightly warming it, but mostly spraying it out the sides to ensure swirling within the hole. The swirling action, in addition to the water continually circulating through the heater core and back into the hole ensures that water temperature is more uniform (not hot spots near the heater core) and promotes fast melting. Water is removed from the hole as the hole widens to the maximum diameter with the given heater power and ambient conditions. This water is pumped through a series of filters to clean out almost all particulate matter. A Sawyer water filter is used to remove the smallest of the particles; however, this small filter can become clogged. A backwashing system is used to clean out the Sawyer filter and that water is filtered through disposable paper filters, which are the only part that needs to be replaced. All other filters and be cleaned out and reused.

The system is controlled by a series of Arduino microcontrollers that control relays to turn on pumps, valves, drills, etc. as needed. To ensure ease of operation for the users and simple troubleshooting, the Arduinos are connected by USB cable to a custom designed software package to adjust performance parameters as needed. In this system, all necessary sensor values are recorded on internal storage to be analyzed post-use.

System Description

Mounting Method

Starting with the most basic function of the system, mounting to the ice container, the JAMMER system is secured to the wood platform in several locations as shown in Figure 1 and Figure 2. While we have not been able to test on the exact model of ice/overburden container, this mounting system has worked well on our simulated testing system.

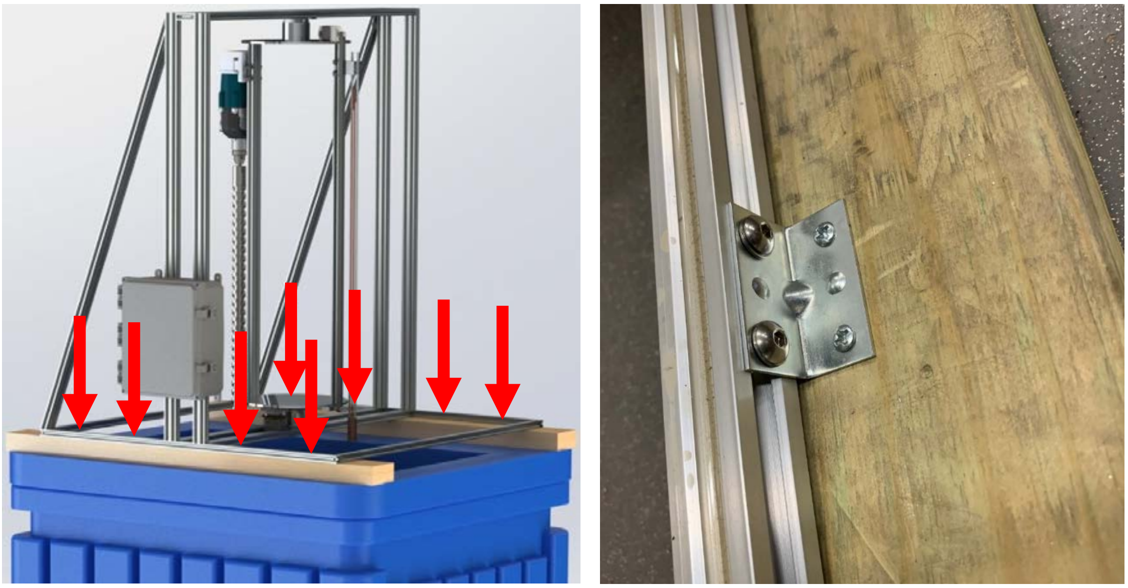

Figure 1. (Left) Attachment Plan, (Right) Attachment Method Prototyped (one location shown)

Drilling System (plus digital core and first step of filtration)

The drilling system as it is currently designed and implemented, acts as the first round of protection from debris in the water and as a method for retrieving part of the information about the digital core prospecting. The drilling system utilizes a unique method of an inner and an outer drill. The inner drill is a long shaft driven by a Bosch hammer drill, with a drill tip mounted on the end of the long shaft. The shaft uses a system of radial keys that connect to slots on the outer drill and these keys drive the outer drill. The outer drill is a custom-machined auger type drill bit meant to clear loose overburden from the hole and prevent loose debris from entering the hole. The tip of the outer drill is a repurposed drill tip typically used for rock climbing applications. These details are shown in Figure 3.

As the drill progresses through the overburden layer, the speed of the drill rotation and the amount of power supplied to the drill will be kept as constant as possible (near max). The variable in the system is the vertical drill down speed allowed by the overburden. As expected, softer materials allow the drill to progress quicker than harder materials. The drill is moved downward by powerful stepper motor, geared down by a worm gear reducer, which then turns a leadscrew, moving the drill attached to bracket/nut. The worm gear reducer prevents the system from moving vertically during drilling operations and allows us to conserve power (turn off stepper driver motor) while not using it (during heating/pumping phase). Because stepper motors require continuous power to maintain holding torque, this is a significant power savings and will allow us to produce more water.

After the hole has been drilled to the necessary depth, the inner drill disengages (the drill rotates in the opposite direction) and the pins are removed from the slots in the outer drill. The inner drill is then free to move vertically on it's own and the JAMMER slowly raises the inner drill out of the outer drill. The outer drill stays in place to hold back as much drilling debris as possible so the hole is not contaminated. After the maximum amount of water has been removed from the hole, the inner drill is re-inserted into the outer drill, the pins re-engage, the drill slowly rotates to loosen the outer drill from its current location, and the entire drill bit system is pulled up and out of the hole. The system can then be moved to another location to collect more water.

Before settling on a full-scale drill design, three half-size prototypes were developed and tested. Because this was manufactured in-house by inexperienced machine operators, several test patterns were cut on inexpensive PVC pipe materials to test the manufacturing process and G-code generated to perform the cutting. The final two practice prototypes before the Mid-Point review were able to successfully drill through partitioned samples of sand, gravel, dirt and concrete. Since then, the final outer drill has been manufactured and has been tested in a variety of overburden types to help build the digital prospecting database and to prove efficacy of the system.


Figure 2. JAMMER prototype mounted on simulated ice box in below -20C outdoor conditions

By testing several versions of the outer drill with varying screw designs/styles and from two different materials (steel and aluminum), it was determined that an aluminum outer drill is acceptable because it is only clearing loose debris and not directly drilling into hard materials. This is a significant mass savings; however, it does cause some problems when joining the drill tip and the outer drill. In the final version of the outer drill, the drill tip is attached via a setscrew that is locked into place using Loctite.

Testing the drill has proven to be valuable for overall strategy development. For instance, large spikes in starting amperage (when drill is at or near full speed) would cause violations to the maximum amount of current allowed. Therefore, the drill will be started at a low speed and slowly incremented until reaching normal drilling speed.

The outer drill has shown to be an effective first filter, in some overburden configurations. In configurations that have hard/dense materials in contact with the ice, the outer drill acting as a filter has been most effective. When the layer of overburden contacting the ice is small particles (sand), the outer drill acting as a filter is less effective, though we don't have supplies to test without the outer drill filter, so it could still be significantly effective in this case.

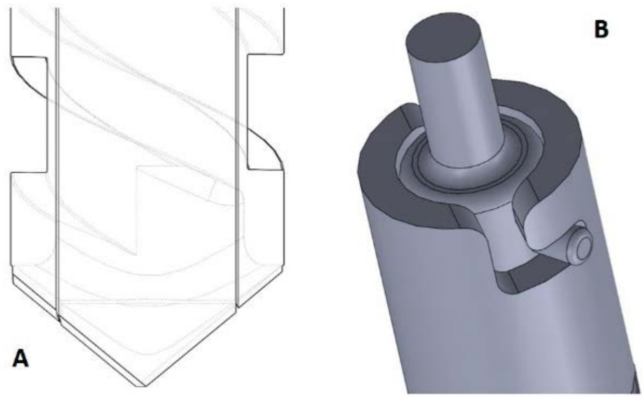

Figure 3. A) Inner/Outer Drill details B) Inner drill pins to drive outer drill

Figure 4. Drill prototypes (top 3), full scale final (bottom)

Digital Core

In the original proposal, we suggested a digital core mapping technique that used a monitoring system for drill vibrations to provide data for comparison to an experimentally validated database. In the midpoint review, we had built a small (non-hammer) drill prototype and shown some success monitoring vibrations in drastically different materials, one at a time. This concept for determining the core layers is used as one of the key indicators of the core material and depth. While this one stream of data isn't enough information to definitely determine all parameters as we had hoped, this data in conjunction with several other indicators still allows us to have an understanding of the core material properties and depths of the overburden.

In addition to drill vibration data, the power supplied to the drill is also monitored. By monitoring the drill power, changes in overburden layers can be detected. The vertical speed of the drill will be relatively slow so the vertical drill down speed will be as constant as possible. When all other factors are held as constant as possible (drill speed), the drill power can be used as an indicator of overburden material. Comparing this data to our experimental database of individual materials also helps provide some information to determine material characteristics of each overburden layer.

As a last method to help discern discrepancies in the data, camera mounted on JAMMER, monitoring the hole can be used to estimate what is coming out of the hole and drill depths. This is made easier when there are dramatic changes in granularity, hardness, and/or color.

Water Extraction System and Technique

The JAMMER system using a water from ice mining technique called the “Rodwell” technique. Essentially, a hole is drilled into the ice layer and a heating device is inserted. The heating device warms the ice, melts it into a liquid form and the water is pumped out for use. This technique has been used in Arctic and Antarctic regions to supply water for humans for decades. While this scenario is not exactly the same as the expected scenario on Mars, it is very similar and will prove to be highly effective. A diagram of our procedure is shown in Figure 5.

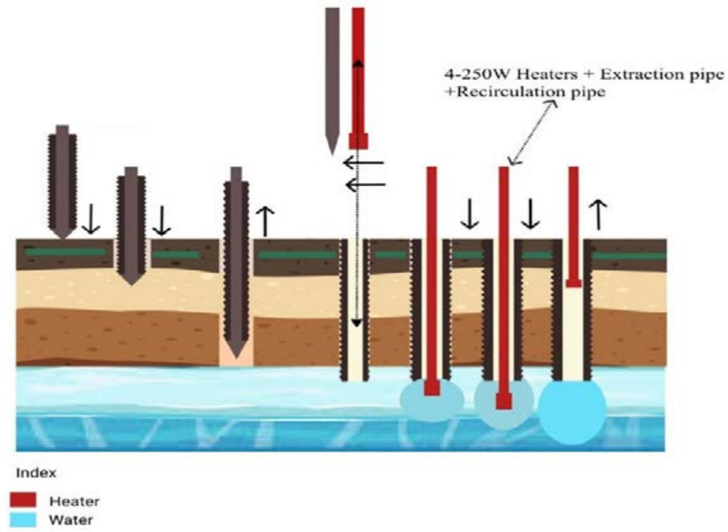

Figure 5. Drilling and Rodwell heating procedure

In the JAMMER system, the drill first drills a hole and leaves the outer drill in the overburden layers, extending into the ice. The turntable then rotates 180 degrees to orient the “heater core” to be lowered into the outer drill and into the ice hole. The “heater core” is an aluminum 3d printed component that was designed to produce swirling in the ice hole under the surface (see Figure 6). The heater core has space for four individual heater cartridges that use nearly the maximum amount of power allowed. These heater cores heat the aluminum heater core, causes nearby ice to melt and any water touching the heater core to heat. Nearly 1000 watts going into a 1 inch x 3 inch heater core does provide rapid heating and temperature increase. This is exactly why the water swirling technique was developed. After initial testing (with no swirling), it was noted that water near the heater core rapidly increased in temperature. Ideally, we would want the energy from the heater cartridges to move to the ice as quickly as possible. However, the energy was all going towards increasing the temperature of the water near the heater core.

The swirling concept serves two purposes: 1. Water is heated (slightly) as it is pumped through the heater core. 2. The water sprayed out the side holes of the heater core pushes the heated water away from the heater core and towards the ice walls. To create swirling, a pump/valve system is used to circulate water through the heater core/pump loop only. This means that one of the heater cartridges must be turned off to allow enough power for the pump, but still stay under the allotted power requirements. Therefore, the pump swirling motion will be used intermittently to allow for as much energy as possible to go into the water/ice melting process.

Rodwell water harvesting (with no swirling) has shown that the hole will increase in diameter when the heater core is at that elevation. However, there is a limit to the maximum diameter that can be created like this, dependent on the power put into the heater core and the temperature of the ice block. When the maximum diameter (or chosen diameter if wide holes are not desired) has been reached, the heater core can be lowered deeper into the hole to create a deeper hole and produce more water. Typically, the maximum diameter must be reached before moving downward because it is difficult, if not impossible, to widen the hole after the water has been removed and the heater core has been lowered. Because this is difficult to simulate without having a similar testing container/conditions, or being able to simulate exact conditions, part of this timing/strategy will be left for real-time decision-making. An endoscopic camera will be attached to the system that lowers the heater core into the hole to attempt to view the interior of the hole while heating/pumping water. In our simulated small scale testing (5 gallon buckets of ice), this concept has been more difficult. However, we hope with a larger ice block and bigger ice box, this camera will be more useful.

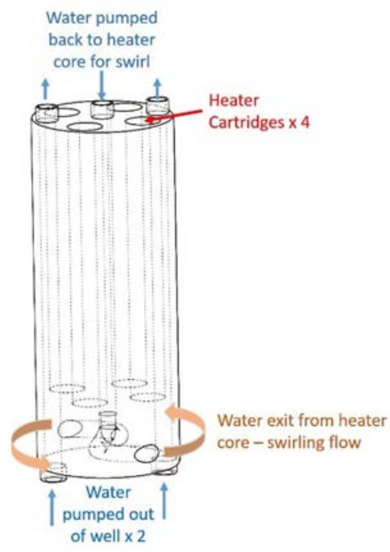

Figure 6. 3d Printed Aluminm Heater Core

Water Filtration and Collection

The water filtering system in the original proposal has been refined and improved as testing has progressed. The current filtering system uses a series of pumps and valves and intermediate water collection tanks to ensure the filtering system can clean itself, if necessary. Figure 7 shows a picture of the actual filtering system.


Figure 7. Full Filtration System

The filtering system consists of two types of main particulate filters and a process to clean the finest filter if it becomes clogged. To accomplish this, three pumps and four valves are toggled as necessary to produce flow in the proper areas of the loop and directions through the system.

The main particulate filters, responsible for filtering out large particulate matter, are a series of mesh screens mounted in a 3d printed housing. The housing is easily disassembled and the mesh filters can easily be cleaned out by dumping the contents out (this system is very similar to a series of progressively smaller sieves). The water coming out of these mesh filters is free of large particulate matter, but likely still has fine dusty particulate matter. To remove as much of the fine dust as possible, the next step in the filtration process is a Sawyer drinking water filter, typically used for hiking/camping gear to allow you water from lakes/streams to be used for drinking water. Water passes through this filter and is temporarily stored in a small tank. The Sawyer filter does a great job of removing significant amount of particulate, but it eventually become clogged and needs to be backwashed to be usable again. To backwash the Sawyer filter, water from the intermediate holding tank is pumped backwards through the Sawyer filter. However, this time, a valve above the Sawyer filter is closed, forcing the water to be diverted to a series of disposable paper filters to collect the dirty water. The cleaner water is then allowed to go back to the Sawyer filter to be filtered again. When the intermediate collection tank is full, the water is allowed to go to the final collection point. This water filtration system has proven to be relatively simple and effective during preliminary testing, however, we do not have a method to measure turbidity of the filtered water.

Control and Communications System

Power comes into the system at a central location, with a current sensor and fuse before the point of energy being drawn. Power is then split into the necessary voltage for the various systems (110V AC, 12V DC, 20V DC, and 5V DC). All components are controlled by Arduino microcontrollers and relevant electronics (relays, sensors, etc.). The Arduinos are connected to the computer via a hardwired (USB) connection. A custom software package was developed for JAMMER to allow users to control all aspects of operations from a central on-screen location. This software also incorporates data logging and camera feeds to allow the users the maximum amount of information available when real-time decisions must be made. A screenshot of the software is shown in Figure 8.

The computer software was developed in Visual Studio as a Windows Forms App in the C# programing language. The interface communicates with the two Arduino Megas via serial connection. The interface sends a string command based on what buttons the user selects, and the Arduino parses each of the characters in the string to determine actions. The program also receives data from the Arduinos for current, weight on bit, and stepper locations in a similar manner. All camera output is displayed in the interface window, when attached.

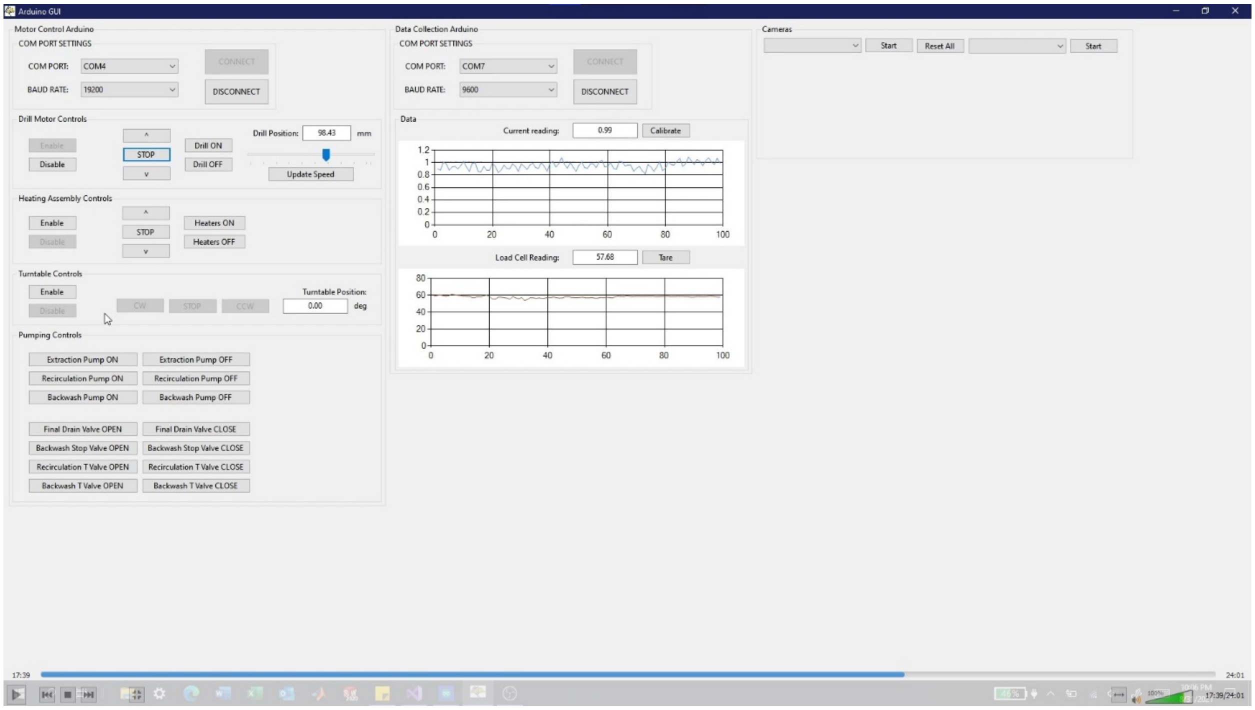

Figure 8. Custom Developed JAMMER software

Datalogging

Data is logged in two ways for backup purposes in case of malfunctions. Data is logged in the custom designed software on the PC. Log files are stored locally on the computer running the software for each data stream. In addition, another copy of the data is kept on the Arduino running the operation on an SD card. This data redundancy allows a mistake to happen (power failures) without affecting the mission (determining the core materials).

Data collected from the data collection system is:

- Weight on bit
- Camera feeds
- Current (amperage) usage
- Drill vibrations
- Drill power
- Drill depth
- Heater core depth

All of this real-time information can also be seen on the screen at all times.

JAMMER Technical Specifications

- Overall Mass: 57.6kg
- Overall Dimensions: 1m x 1m x 2m
- Length of drill bit: 36 inches
- Weight on Bit: design for maximum, will keep 10N below maximum to avoid penalties
- Max Drilling Speed: 1300 RPM
- Max BPM: 5800
- Computer System: Custom developed software running on Windows
- Communications Interface: Arduino and custom software, via USB connection
- Software: Custom developed
- Power: Max current allowed during drilling operations and heating operations
- System telemetry: USB cable, Arduino, custom software

Design Changes since Mid-Point Review

Building the Mid-Point Review prototype and beginning to test it provided valuable insight to develop the final prototype. A list of design changes and a brief description of each design change are listed below:

- Frame stiffness – After drilling several holes in very hard materials (concrete blocks), it was determined that the overall system stiffness had to increase. Larger aluminum extrusions were used and more cross braces were used. Stiffness improved, but mass increased.
- Rails/Carriages – Similar to the overall system stiffness, it was determined that the rails also needed to be stiffer. Bigger rail systems were used and stiffness problems were resolved. Again, required mass increased.
- Heater core – At the midpoint review, we did not have the 3d printed aluminum heater core yet. There were some difficulties attaching the piping to the 3d printed heater core, however, those problems were resolved and the system seems to be fine now.
- Software – At the midpoint review, all components and subsystems were controlled individually using individual pre-programmed Arduinos. Since then, a custom software was created to control all aspects of the project. This software system allows the operator to manage all data streams, view all cameras, and control all systems on one screen.
- Filtering system – The backwash system was not implemented at the Mid-Point review. The addition of the backwash system required additional holding tanks, pumps, and valves. One seemingly small and simple change required significantly more hardware and space, which increased the mass required.

Challenges

As with all projects, some new challenges were faced after the mid-point review. The team has worked hard to mitigate these challenges and come up with the best alternative solutions possible.

- Graduation and employment schedules – All four original members of the team graduated in May 2021. Summer and full time employment schedules and decreased shop availability during summer hours decreased the amount of useful time the group had to resolve problems and conduct testing. Essentially, three of the four team members were unable to continue with group after graduation.
- Addition of new team members – New team members were brought into the team to help fix bugs in the system and to help conduct testing. The new team members very quickly learned about the competition, the JAMMER design, and how to use JAMMER.
- Realistic Testing Environment – Our testing environment (outdoors in frigid South Dakota winters) works well in January and February, but does not allow for full scale testing in any other month. Testing since February has been completed using 5-gallon buckets of ice and 5-gallon buckets of simulated overburden. While we believe we have most of the bugs out of the system and have collected a database of materials that should help determine the digital core, there is still a possibility that something we could not prepare for or simulate will cause problems when integrated onto the large icebox.

Overall Strategy

When developing the overall strategy for the project, we wanted to focus on delivering as much clean water as possible, while still collecting enough data for a digital core. The early focus was to develop methods and strategies that promote as much melting as possible and reduce drilling time as much as possible. With that in mind, our strategy is to drill a single hole each day of the competition and melt as wide of a hole as possible, using our swirling technique, then pump some of the water out and lower the heater core to promote downward melting. The hole in the ice should collect water in the center under the heater core. At the end of the day, the heater core will be lowered to the bottom of the ice hole and the water will all be pumped out of the hole. On the second day of testing, the machine will be repositioned on the other side of the box to allow the hole size to increase to its maximum, without potentially interfering with the width of the first hole.

Digital core data will be collected during both hole-drilling procedures. Data from both holes will be analyzed individually and independent predictions of the digital core will be made. When data agrees, the sensor data will be used in our official prediction. If the data disagrees, the endoscopic camera will be lowered into the hole (assuming it does not collapse) after the outer drill is removed. This allows us visual confirmation of the layers of the overburden and some amount of measuring as the camera will be lowered by stepper motor rotations, indicating depth.

The filtering system can run independent of the other systems. Some water will be used to prime the system and get the water melting process started quickly (so there is water to swirl right away). The intermediate water tank will only hold enough water to ensure successful backwashing of the sawyer filter. Excess water will be immediately moved to the final collection point.

Summary of Integration and Test Plan and Results

The integration dry run shown in the video shows a demonstration of the machine performing all functions, in the correct order of operations, but not in an icebox. A bucket of water is used to demonstrate the functionality of the heater core water swirling and pumping. The system is also mounted on a similar type of icebox that was used for outdoor testing during the winter months.

Because we don't know the makeup of the overburden for the competition ahead of time, it's difficult to predict or simulate perfect scenarios. We do know that the drill system will drill through all of the materials we have tested (concrete blocks, rocks, gravel, sand). Preliminary testing has given us some guidelines for drill vertical speed, but these may also be adjusted as necessary at the competition to ensure a quick drilling process.

In 5-gallon bucket testing, the heater core has performed well; however, we acknowledge that the container used for testing is not a very realistic scenario. The bucket is much smaller than the icebox, creating different heat transfer and potentially flow effects. In addition, the bucket is uninsulated, so the ice is warming the entire time it is not in the freezer. Because of this, it is also difficult to judge the rate that the heater core can be lowered into the hole and the maximum diameter of hole the heater core can create. The endoscopic camera will help gauge both of these processes in the real competition testing.

Filtration testing has gone very well. The mesh filters are able to filter the large particulate matter extremely well. Basically, the only particles that make it past the mesh filters is the fine dust, which the Sawyer filter then removes. During "normal" dirty water testing, the Sawyer filter has not clogged, but it has clogged when we have put in very dirty water on purpose to test the filtration system. The backwash system was able to remove the Sawyer filter clogs and the system went back to performing as expected. As with the other systems, without being able to test in fully similar conditions (outer drill holding back dust from getting into the hole), we are not entirely sure how this will behave at the competition, but we do think it will perform well.

Tactical Plan for Contingencies/Redundancies

Testing and tweaking the design have mitigated many of the previously concerning risks. A risk of losing digital core data due to power failure or otherwise is mitigated by having more than one data storage system. Data will be stored on the computer and remotely on the Arduino SD card data logger. Spare parts of all 3d printed components and other mission critical components (within budget) and essential tools for repairs will be brought to the competition in case of shipping damages or other last second repairs.

Safety Plan

During operation, team members should be able to operate JAMMER from a safe distance, or from behind a wall. If behind a wall, no safety gear is required. If working near JAMMER, safety glasses and closed toes shoes must be worn. All other standard shop rules must be followed at all times. Gasket making materials and JB weld used in construction were used in ventilated areas to mitigate breathing hazards. All chemicals are now fully cured. No other chemicals are required.

Paths-to-Flight

Most of the system was designed with the eventual required application (use on the Moon and/or Mars) in mind. Therefore, few changes will need to be made, however, the changes that are required are extremely important and some are likely difficult to implement properly, consistently, and efficiently. Some design decisions were made because testing is taking place on earth and realistic space conditions are not available for testing. The items listed and described below are listed in order of least difficult to implement to most difficult

- Shipping constraints on a rocket (both moon and Mars)
  Currently, the design takes up a significant amount of volume if shipped assembled, has heavy objects located at difficult to support locations, and has long beams and electronics/sensors susceptible to vibrations. This competition is interesting because in a very small way, we simulate launching our system on a rocket when it has to be shipped to the site. After the prototype leaves our campus, it will be susceptible to random vibrations (big and small), and potentially drops/impacts during its long journey from South Dakota to Virginia. As the designers and operators of the system, we have to design a shipping method to keep it safe during the journey too. The decision whether to disassemble and reassemble on-site or to ship it as one large machine (or a combination of the two approaches) is difficult.

  We have decided to disassemble the system and reassemble on-site, which we would also suggest for use on the Moon or Mars. However, we anticipate needing several hours to reassemble all of the pieces of the system, reconnect wires that were disconnected, and do preliminary testing of the machine. Because we have not disassembled and reassembled the machine yet, we expect there to be some unknown complications with re-alignment upon reassemble. With this in mind, a redesign of the frame, mounting for critical systems/sensors/cameras would be necessary. We anticipate using beams and connectors that allow "snap together" type connections that make reassemble as simple as possible for (less experienced and less knowledgeable about the JAMMER system) astronauts in a difficult environment. Other simple cues, such as color-coding, will be used to help astronauts quickly find appropriate parts. While this task is not difficult, it was not extremely necessary for this competition and was not a focus of our design process.

- Materials (both moon and Mars)
  (In some ways, material selection is also a part of the previous design change) Some materials used in our design would not be appropriate for use in space environments and would need to be recreated using another more appropriate material. For instance, we have used many polymer based 3d printed components made from inexpensive PLA filament. These components work perfectly fine in most earth environments, but would probably not last long in lunar conditions or harsh Mars conditions. Similarly, a wood panel is used to mount the filtration system to the frame. This would also be an inappropriate material to be used in space applications, but is perfectly fine for earth use.

  The aluminum extrusion used for the entire frame and many components of the JAMMER system may or may not be ideal for space applications. In lunar conditions and lunar dust, we know the dust plume created will be significant and the materials may not withstand the abrasiveness of the dust in critical locations. There are several options available to solve this problem, such as using a material that is more resistant to dust abrasiveness or designing dust shields or other dust mitigation strategies (electrostatic shielding) to protect critical components and wear locations. Likely, this design decision would come down to reduction of risk and overall mass savings for either option. However, this was also not a focus of this design, with the thought that these design options could be implemented relatively easily later if the system performed well otherwise.

- Electronics (both Moon and Mars)
  It is likely that all of the electronics would either need to be protected from the elements, or replaced with similar components that can be exposed to space conditions. The simplest solution is to enclose all of the electronics in an insulated and radiation shielded box, with a small heat source. All wires entering and leaving the box would have to have appropriate shielding from radiation damage and be properly insulated. For testing on earth only, none of these precautions were necessary to determine efficacy of the overall system.

- Dust Mitigation (mostly the moon, but Mars too)
  A very significant problem on both the Moon and Mars is dust mitigation. With the reduced gravity of both bodies, dust plumes are more significant than we are used to on earth. In addition, depending on the location, the dust is very fine, very light, and extremely abrasive. Other rovers or operations far from the JAMMER could produce dust plumes that could affect the operation of this system. This fact was not considered in the design of JAMMER.

  Several methods could be used to mitigate dust problems, ranging from simple and mostly effective to complex and more effective. The simplest solution is to implement dust shields throughout the design in critical locations. Dust shields could be foam filters, mesh filters, sheet metal barriers, or other similar protection. If that is not sufficient, or difficult to implement in some locations, a thin sheet metal cover could be designed to cover the entire Jammer and allow a small hose to deliver water to the next point of use. More complex solution would include electrostatic mitigation systems that use the charge of the particles to repel the dust from the areas of interest.

- Pressurizing and Insulating the Water Filtration System (Mars)

One of the most critical redesign tasks of the entire system is pressuring, sealing, and insulating the water filtration system. When used on Mars, the JAMMER system will likely be used in extremely cold locations, where the water is most likely to have pooled and turned into ice blocks under the surface layers of materials. At atmospheric pressures consistent with Mars, the water collected from the hole is likely to evaporate. In addition to evaporating, any water lines open to ambient conditions will likely become contaminated with Mars dust (either before or after it has been filtered). In our current system, most of our hoses and sealed, however, the backwash filter is open to the air, and the intermediate holding tanks are open to the air. These would need to be sealed and could easily be sealed – it was just not necessary for our system and earth testing. Additionally, if left to atmospheric pressure inside the sealed system, the water would still tend to evaporate and expand into a gas form, causing new problems. To counter this problem, the system will need to be pressurized to a point where the temperature/pressure combination keeps the water at a liquid state.

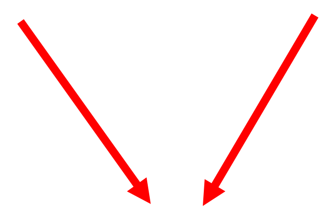

Figure 9. Location of required chemical sealant

- Pressurizing the hole (Mars)
  Similar to the point above, the entire hole below the surface of Mars will need to be pressurized to keep the water from sublimating and going straight from ice to vapor. This will likely need to be accomplished through several sealing methods. The area around the outer drill bit may need to have a sealing chemical applied on the exterior of the drill bit and Mars surface interface to ensure that gas does not escape between the drilled hole and the drill bit (see Figure 9). Along the same lines, the top of the outer drill bit will need to be sealed, but sealed in a way that still allows the heater core to enter and leave the hole. The tubes and wires that come along with the heater core will also cause some problems for the sealing procedure. There is no clear single solution to this problem. Likely, this would need to use a series of seals and the sealing chemicals may need to be applied after the heater core is insert into the hole and periodically after the heater core moves downward through the hole to create a deeper hole. This is likely the most difficult path to flight problem that needs to be resolved to use this method on Mars.

- Testing on fluffy, extremely dusty, and abrasive materials (Moon)
  Testing was not conducted on light, fluff materials that are similar to the surface of the lunar crust. Therefore, the database of sensor values does not exist yet for this type of material. Ideally, a lunar simulant material (or several varieties of lunar simulant) would be used. Because these simulants (and real lunar dust) as hazardous to breathe, this testing would have to be completed in a specialized environment to protect operators from the conditions. In addition, the amount of lunar simulant required to do a complete test of

JAMMER would be significant and very few locations exist that could accommodate the system. We would need to collaborate with a lab that has these environments and conditions available.

Project Timeline

- September 15 to December 15, 2020 – Develop strategy and design basic solution. Test innovative ideas to determine if they are functional.
- December 15, 2020 – Order many of the known supplies and materials
- January 2021 – Manufacture custom components in our shop. Assemble the small prototype JAMMER device. Assemble outdoor IBC tote testbed and begin filling with water. Assemble simple test electronics/automation on bench.
- Mid-January to mid-February 2021 – Begin outdoor ice drilling and melting testing.
- February – Begin overburden drilling preliminary testing into ice. Log relevant data to begin compiling database of material types for digital core processing.
- March 10, 2021 – Submit mid-point review
- March 15 to April 30, 2021 – Manufacturing full scale prototype parts as necessary. Begin assembling the full scale machine.
- April 30, 2021 – All four team members graduate
- July 2021 – Integrate new team members to replace graduated members.
- August 2021 – Full scale testing to develop database of overburden layers and ice melting strategies
- August 31 – Submit final Technical Paper and Integration video
- September 22 to 26, 2021 – Moon to Mars Ice and Prospecting Challenge
- October 2021 to May 2022 – Continue developing the system and test over the winter. MS student conducts fluid simulations to help simulate/predict melting models with swirling water.
- June 2022 – Publish MS student work related to fluid simulations of Rodwell melting process.

Budget

Travel for 5 people - $5050

- Registration - $1500
- Airline - $2000
- Taxi - $150
- Travel to Airport - $50
- Hotel - $1350

Preliminary JAMMER prototypes and drill concepts - $1500

Final JAMMER system - $2900

- Extrusion - $300
- Drill bits and tips - $450
- External machining costs to EDM cut hardened steel tips - $250

- Hammer Drill - $200
- 3d printed heater core - $300
- Electronics (Arduinos, relays, valves, pumps, etc) - $600
- Mesh filters - $100
- Cameras - $150
- Platforms and cutting - $100
- Ice box simulator - $150
- Sawyer filters - $50
- Miscellaneous Hardware/Parts - $250