2018 RASC-AL Special Edition: Mars Ice Challenge

Technical Report

West Virginia University

Statler College of Engineering and Mineral Resources

The Mountaineers

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1 Introduction

Liquid water provides many benefits for the exploration of Mars and other places past our terrestrial bounds. Benefits of extracting liquid water from the Martian environment go beyond simply fulfilling the biological needs of human beings—water retrieved can be used for rocket fuel when split into hydrogen, and oxygen and can provide shielding from radiation. Extraction of liquid water, however, can be seen as an intricate task due to the characteristics of the Martian environment such as its low temperature and pressure. Specially designed robotic systems can provide a solution to the formidable problem while maintaining low liabilities.

The Mountaineering Ice Drilling Automated System II (MIDAS II), developed by the West Virginia University Robotics Team, is completely redesigned from its 2017 RASC-AL Mars Ice Drilling Challenge award winning predecessor the Mountaineer Ice Drilling Automated System (MIDAS). Given the lessons learned from last year's competition MIDAS II displays a unique process that can undermine the complications of retrieving liquid water from Martian ice deposits. MIDAS II's functions will be demonstrated alongside other robots in the 2018 Revolution Aerospace Systems Concepts Academic Linkage (RASC-AL) Special Edition: Mars Ice Challenge at NASA's Langley Research Center (LaRC).

The process designed by the WVU Robotics team corroborates that a simple solution of working with the environment on Mars rather than fighting it can allow for the successful extraction of liquid water. It includes percussively ramming a custom designed all-in-one heating and water extracting bit into the Martian surface until it reaches an ice deposit where it will use a predetermined heating cycle to form a pressurized Rodriguez Well within the ice deposit. Once a well has been created from agitating the ice deposit with heat and has been pressurized, liquid water will be pumped and or vapor will travel up the extracting bit to a pressurized vessel where it will be available for use. MIDAS II's operations on Earth have been altered to accommodate energy use. Descriptions of Martian operations are listed in detail, along with potential additions, on the path-to-flight section of this paper. The rest of the paper describes the team's build details, challenges, and strategy to usher in a golden age of research and exploration with the completion of MIDAS II.

2 System Descriptions

2.1 Frame

The inspiration for the frame shape of MIDAS II is a general oil rig. This shape was chosen to allow for easy deployment of the probe and the easy storage of multiple devices. The structural components of MIDAS II consist of 1" x 1" and 1" x 2" t-slotted aluminum for ease of construction and device mounting. To prevent binding from causing discrepancies with weight-on-bit (WOB) readings while MIDAS II is in operation, a commercial grade Bosch Rexroth compact linear rail was chosen for vertical axis motion. An additional compact rail was also installed on the horizontal axis. The vertical rail is powered by a NEMA 23 stepper motor with a 16:1 gearhead while the horizontal rail is powered by a NEMA 24 stepper motor. MIDAS II, fits within a 98cm x 98cm x 158cm (1.5 cubic meters) bounding box with additional room vertically, if needed. Portable hinges on ground rails allow it to fold for transportation and storage purposes. When folded, MIDAS II fits within a 98cm x 60cm x 158cm (0.93 cubic meters) box. Figure 1 depicts the configurations of MIDAS II's frame when it is under operation and while it is being transported. To support the hinges during operation, 8-inch t-slots are added underneath the hinge shape to provide support and structure. Final mass of MIDAS II is 52.7 kg.

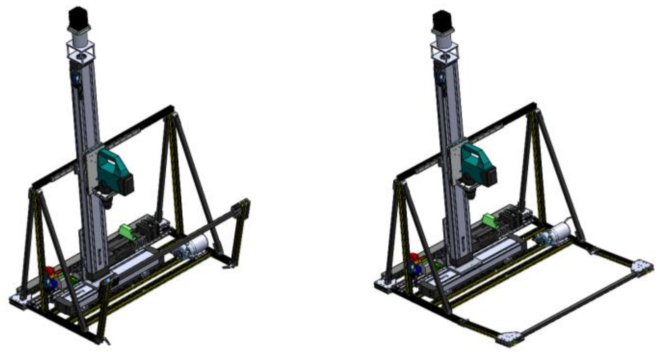

Figure 1. Different configurations of MIDAS II

2.2 All-in-One Heating/water Extraction Bit

2.2.1 Bit Ramming

MIDAS II employs only one probe via pipe-ramming action for the retrieval of water rather than using two systems featured in the previous version. Using just one probe simplifies and allows for faster operation. One probe will also maximize chances of the process of creating an ideally-shaped hole in the ice to minimize cave-ins from the above overburden. MIDAS II utilizes a smaller rotary hammer drill shown in Figure 2. During operation, only the hammering action of the drill will be actuated since the pipe ramming action requires no rotary action when going through the overburden and ice. Slip-rings and water-swivel are unnecessary due to the lack of rotation. The drill body is connected via a load cell assembly to a vertical linear actuator which will drive it down. During testing, holes were easily created in both the overburden and the ice layer using this method. WOB also did not exceed 100 N which is under the cap set by competition rules.

Figure 2. Light weight Rotary Drill

2.2.2 Extraction System

MIDAS II employs only one probe to reach the ice layer and extract liquid water from it. The main body of the probe is constructed using a hollow stainless-steel pipe, and copper is used for the construction of the tip. The horizontal rail will position the probe in a unique place each day. The probe works by being rammed into the overburden by the impact action from the drill and vertical linear rail. This is depicted in Figure 3 where MIDAS II's probe is rammed into a dirt sample during testing. A bit stabilizer is also located on the horizontal rail to protect the probe from swaying too much. The impact action minimizes WOB. During the ramming operation, the tip of the probe is heated to 150 °F to ensure less force is exerted onto the system by the hard ice layer. The plunging rate will be automatically adjusted if an influx of forces is sensed using the PID controller. Once the probe has rammed to a predetermined depth, heat will be blasted causing the melting of ice to occur. MIDAS II creates a Rodriguez Well within the ice sample to maximize water yields. A Rod-Well itself is cavity within an ice

Figure 3. MIDAS II's probe ramming through a dirt sample

deposit shaped in a certain "teardrop" shape. Testing showed that creating the shape is possible. Figure 4 shows the melting shape of a sample. Creating and using Rod-Wells is a technique for collecting and storing water employed in polar exploration operations since the 1960's [1]. It has proven to be highly effective at generating a large quantity of water in a relatively short amount of time. The formation of the well probe will also ensure the hole created in the overburden does not collapse. The blasting of heat at a given depth will also create an ice cavity that will reduce chance against mud from entering the ice layer and causing problems with retrieval. Test show that creating an ice cavity is doable with the correct rate of heating.

Figure 4. Sample showing a Rod-Well shape formed with the operations of MIDAS II

The current version of MIDAS II's tip includes a one-way-valve for the water to travel from the tip, shown in Figure 5, to the collection bin. A one-way-valve is a self-automated valve that allows flow in one direction and prevents flow in the other direction. The one-way-valve will protect against any debris from entering the probe. In some instances, the newly melted water will be able to travel to a steaming chamber where it will be vaporized. The vaporized water will then travel up the probe to a container where it will condense. Since conditions on Earth require a substantial amount of energy to be used for the state changing of water, a pump will also work in conjunction with the steamer to send melted water from the tip of the probe to the retrieval chamber. During testing, steam was present after the heating samples to a certain high temperature. An example of steam production can be shown by Figure 6. Estimates from the team conclude that only 127 ml of water per hour can be retrieved through steaming the ice while the rate of producing 3.23 L of water per hour can be accomplished using a pump along with the probe using only 400 Watts heaters.

Figure 5. Copper tip including a one-way-valve

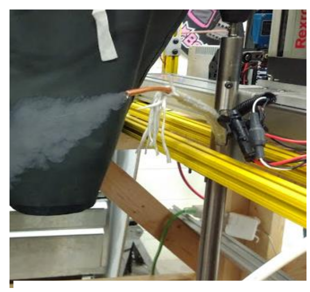

Figure 6. Steam produced by MIDAS II during testing

2.3 Anchoring

Similar to MIDAS I, MIDAS II will use a simple anchoring system. Oversized holes are bored on the corners of MIDAS II 36.5 inches apart. The size of the holes ensures that they fit over threaded rods protruding from pieces of 2x4 lumber on the ice chest. Wing nuts will lock MIDAS II into place.

2.4 Electrical System

The electronics subsystem, shown in Figure 7, is divided into several key components that work in unison to provide a stable control system for MIDAS II. The main power cable runs through a power switch and delivers AC to a power bank. That in turn provides power to the DC supply and the Programmable Logic Controller (PLC). High current relays provide power to the drill, the pump, and the heaters. The DC supply is routed to its own power bank and provides 24 volts to the stepper motor controllers and various sensors. The stepper controllers allow the PLC to enable/disable the steppers, set direction, configure the number of steps per revolution, and

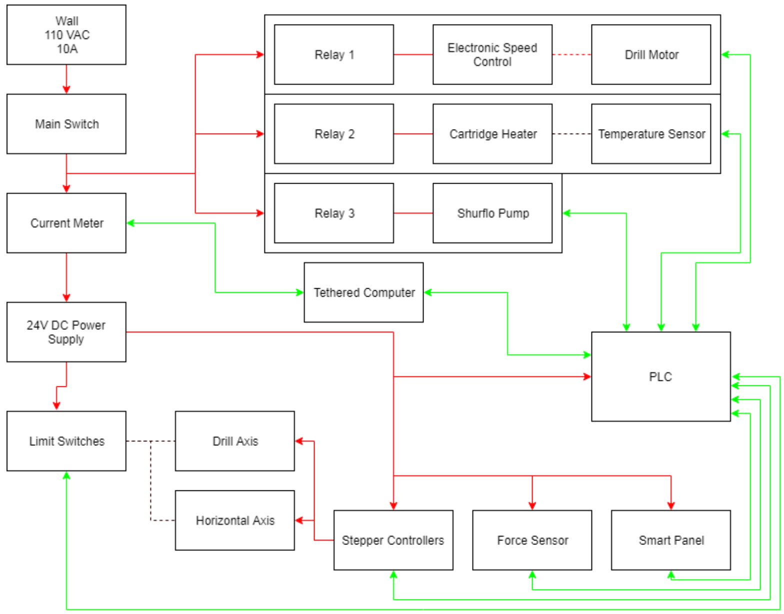

Figure 7. Electrical system diagram

send pulses to move the motors. Parts compatible with a DIN rail were procured for ease of use and neatness when considering this system. As seen in Figure 8, from left to right on the DIN rail are two stepper controllers, a 24V power distribution buses, load cell amplifiers, the PLC, power relays, AC power distribution buses, power/voltage/current Meter, main power switch, and the 24-volt DC supply. Additionally, all the wire pairs and cables are routed through a raceway duct with a cover for better organization and cable management.

Figure 8. Electrical wiring of MIDAS II

2.4.1 Sensory System

Safety Limit switches ensure that the rig does not travel beyond its parameters, and also serves to home the drill/probe during initialization. The S-beam load cell connecting the drill mount assembly to the linear rail measures the weight on bit as it plunges into the sample. The mechanism that attaches the drill to the load cell and the load cell to the plate is constructed in a way to allow minimal binding interference by other parts, shown in Figure 9. A built-in thermocouple inside of the probe heaters will also measure the temperature of the tip heater.

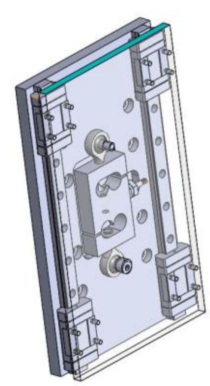

Figure 9. Load Cell mounting assembly

2.4.2 PLC and Communications

PLCs, such as the one shown in Figure 10, are used heavily in industry for process automation. PLCs operate using ladder logic. Commands are input into the PLC using a touch LCD display with a custom interface. These commands control the different functions of MIDAS II. The PLCs output ports are connected to each component of the rig, and it operates each of those components based on the current commands. Additionally, the PLC can display data from MIDAS II, such as weight on bit, heater temperature, and power usage.

Figure 10. Programmable Logic Controller

2.5 Software

The PLC is controlled using the ladder logic code. In order to operate MIDAS II, the code first goes through an initialization phase to prepare the controller to accept inputs. The manual control of the system parameters can be done by input into the PLC, and by MIDAS II's moving, drilling, heating, and pumping operations. There will also be an automated drilling mode. The manual controls are currently implemented, and the automated part of the code is being finalized. Figure 11 shows a control diagram MIDAS II will follow.

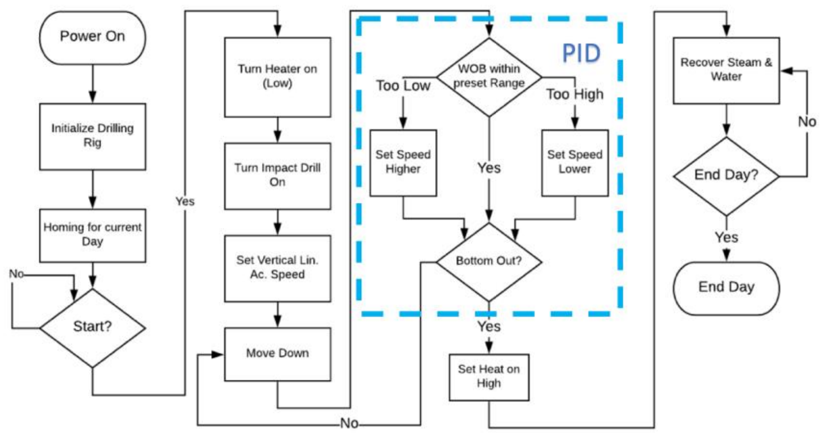

Figure 11. Automated control diagram

3 Design Changes/Improvements

The tip of the extraction bit was modified because of problems caused by the wax motor. In early designs an increase of heat during the heating process would cause a wax motor to expand causing the tip to move outward from the probe revealing space for the water to go through as shown by Figure 12. Unfortunately, the wax motor wasn't able to actuate enough due to limitations with off-the-shelf wax motors acquired and the amount of heat required under the chill water. Several prototypes led to either a premature opening of the wax motor and too much heat led to an explosive opening of the wax motor, forcing some elements of the bit several inches up the shaft. While we are confident in the wax motor's effectiveness for this problem, due to limited time and funding, we are not able to order a custom wax motor. A simple mechanical one-way valve was constructed within the copper tip to replace the wax motor as described in the Section 2.2.2. It will only open once the suction from the pump is applied to prevent clogging up the nozzle during ramming through the overburden.

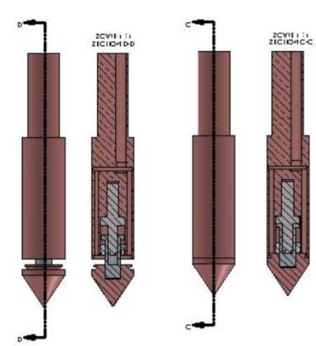

Figure 12. Copper tip design which includes a wax motor

4 Challenges

There have been several challenges faced by the team. The first challenge was the complexity of the extractor bit's tip. As stated in the Design Changes/Improvements section, the team had trouble producing a wax motor tip that worked. However, a different type of tip design was later chosen.

Another challenge came in the form of measuring the weight on bit. The load cell assembly works well. The issues came from the hammering of the drill near the 150 N WOB limit while plunging into the ice samples, killing the load cell in the process. The solution to this is to stay well below the WOB limit. Figure 13 shows the WOB of the probe after corrections were made. It is noted that the WOB did not exceed 57 Newton at 50 Newton set point.

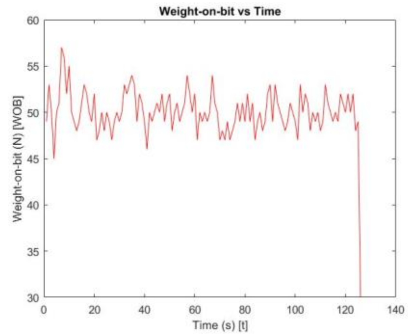

Figure 13. A graph displaying the WOB over time during a test

5 Overall Strategy for Competition

The team plans to create two holes, one each day, during the course of the competition. The holes will be made by first ramming through the overburden until there is a significant increase in the WOB indicating that the ice has been reached. Once the ice has been reached the heater will be turned on to a relatively low temperature to prevent the top of the hole from expanding too greatly. Once a target depth has been reached the heat will be increased greatly in order to begin forming the Rod-Well. After about 15 minutes a small amount of water will be extracted to lower the water level in the cavity. This has been proven to help prevent melting of the cavity's ceiling. After the small amount of water has been extracted the heat will be reapplied and continue to heat as water is pumped at predetermined intervals. Before each run, the components of MIDAS II will be checked for faults and other problems. The team plans to record data during the first run to optimize the operations during the second run.

6 Summary of Integration and Test Plan

Testing for MIDAS II is crucial for the development of its many components and general testing is needed to validate the structure of the robot. The team prepared multiple samples to test different components such as the load-cell and ramming-probe in a cylindrical five-gallon bucket. Samples included ones with just ice, ones with just the clay mixture, and one with clay overlapping ice. To test the durability of MIDAS II and to see how it would operate during conditions similar to the ones during competition, the team produced large samples within a 35 gallon trash can. Figure 14 shows MIDAS II's probe plunging into an ice-only sample and Figure 15 shows the team testing a large scale sample. The height at which the sample took inside the bucket was recorded. When preparing the nonhomogeneous sample, a five-gallon bucket with no base containing the clay mixture was laid on top of a five-gallon bucket with the ice. In order to simulate a similar condition in which the team will face in competition each clay sample was frozen. To track depth, the probe was marked with specific heights. During every test, observations about the rig and the hole it rammed were taken alongside the gathering of analytical data.

Figure 14. MIDAS II's probe plunging into an ice sample while the tip is heated

The team used analytical data taken from multiple organized tests to program MIDAS II for inerrant operations. One of the variables tested was rate of heating and the different size holes each plunge created can be shown in Figure 16. Because the depth of the Rod-Well has to be maximized without the top layer failing and creating a mush solution with the melted water, the hole which the heating cycle creates on top of the ice sample has to be as small as possible. Temperature given off by the heater during a test is shown in Figure 17. Different heating rates were tested to produce the best results. To keep the WOB underneath the allotted value, different rates of ramming were tested to find the ideal rate. This involved timing each run and recording values of WOB, depicted in Figure 18. The structure of the rig was also altered to minimized vibrations and unwanted movement by the frame of MIDAS II.

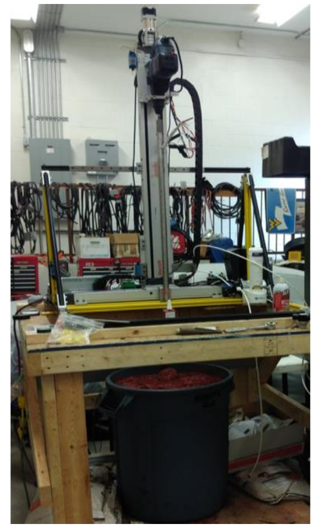

Figure 15. Large scale sample

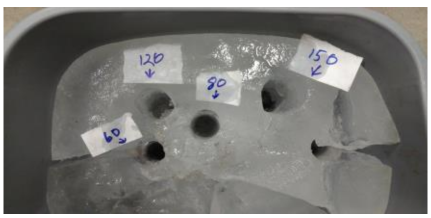

Figure 16. Different diameter holes created by different rates of heating

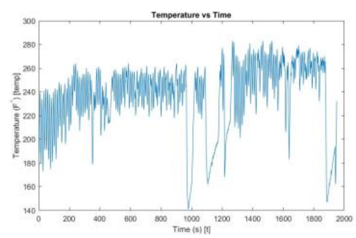

Figure 17. Temperature of the tip heater during a test

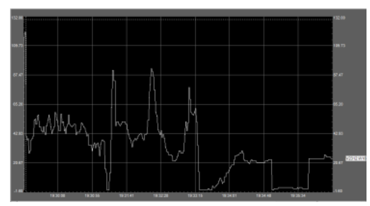

Figure 18. WOB recorded in real time and displayed through a computer monitor

7 Tactical Plan for Contingencies/Redundancies

There are multiple heating elements and thermocouples inside the all-in-one bit. If one malfunctions, the heater/thermocouple are still functioning with some reduction in power output. As our common practice, our contingency plan is to have spare parts for all sub-systems in the event of part failures. However, there is no contingency during the second day of the competition. If a critical part fails on the second day, there is no way to replace it due to the hands-off rule.

8 Project Timeline

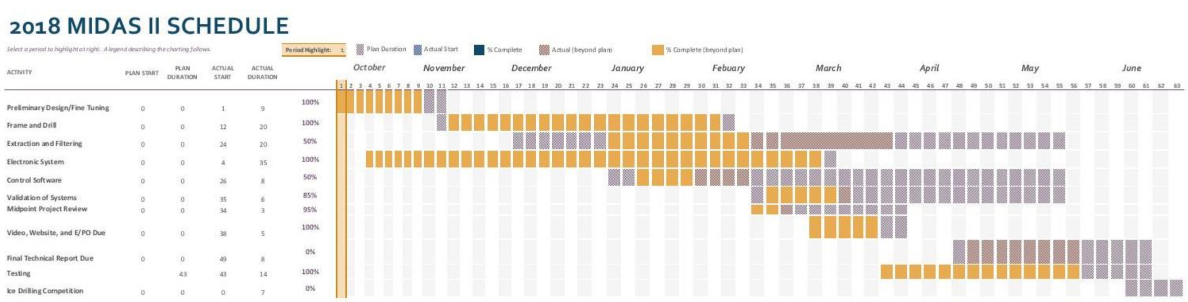

Figure 19. The team's updated schedule for the rest of the project

9 Safety Plan

The most prevalent safety concern with the MIDAS II drilling rig is the noise created by the hammer drill. Hearing protection is a must if one is in close proximity to the system. The team wants to prevent hearing loss and allow for comfortable viewing. With high impact plunging, another potential hazard is always aerial projectiles from the process, no matter how unlikely they may seem. The team strongly recommends safety glasses to avoid eye injury. With the heating elements' capability to reach temperatures in excess of a few hundred degrees Celsius, no hands, feet, limbs, or other objects are allowed within the rig's frame. For user and observer safety, in the unlikely event that control of the drill is lost or if some other unforeseen issues arise, the PLC has E-stop capabilities and there is a large kill switch on the back of MIDAS II.

10 Path to Flight

As stated in the introduction, water can play a pivotal role in future Martian missions or other interplanetary operations. It is a recourse that can optimize efficiency of operations by providing fuel and other necessities. However, low atmospheric pressure, extremely low temperatures and other factors cause a serious impediment for successful robotic retrieval of water. Although the version of MIDAS II demonstrated on Earth has components that would render it useless on Mars, such as a pump or pneumatic drill, MIDAS II's concept of sublimating water and using resultant pressure to retrieve it is ideal for Martian Operations. Changes on the robot to make it more adaptable with the properties of space and its planets can make MIDAS II an enabler of future space endeavors.

It is assumed that the occurrence of water on Mars is in a solid form due to the atmospheric properties of Mars and by the observations of multiple satellites. As stated by author and Martian researcher Michael H. Carr, "Viking 1 landing site, at an elevation of 2 km (and a northern equatorial location), the pressure ranged from 6.9 to 9 mbar, less than one-hundredth of the atmospheric pressure at sea level on Earth" [2]. Temperature on the planet averages to an extreme -63 ^{o}C as stated from NASA's Mars Fact Sheet. As according to the phase diagram of water, Figure 20, water will be in solid form under average Martian environmental conditions. Increasing the temperature of the solid water while pressure is maintained at the same level will cause it to directly sublimate into a gaseous state if the pressure placed on the solid water is not increased. However, the resultant increase in gas will raise pressure causing the water to change into a liquid form. The entirety of the probe will have to be heated or insulated to a certain degree to save the water molecules traveling up the probe deposing into a solid form. This should be simple to accomplish with the addition of correct materials. Liquid water from the pressurized Rod-Well formed by MIDAS II can be pumped to a suitable pressurized vessel.

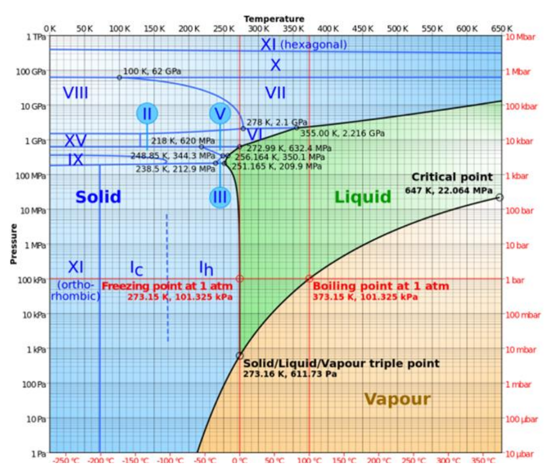

Figure 20. Phase diagram of water - http://wordpress.mrreid.org/2015/12/21/phase-diagrams/

MIDAS II's process uses this property of water to extract the water from the ice. Because of this, regular methods of taking solid ice chunks and melting them in a melting pot run the risk of losing samples to exposer and a low yield of liquid water. Tremendous amounts of energy can be wasted when trying to contain a water source within a given apparatus. The process shown by MIDAS II requires the solid ice to sublimate and requires less energy. The process also allows for water to be stored in the Rod-Well if the well is pressurized to a point to permit the presence of liquid water at whatever temperature it might be.

If the Rod-Well is pressurized to a point where water is present inside the formation of the cavity, a connection to a pressurized vessel can allow for liquid water to be pumped. The probe in this instance will also have to be heated or insulated from the environment due to the nature of water. The pressurized vessel can be located inside of a larger pressurized environment, such as astronaut habitation, to allow for easy access of the water retrieved. The retrieved water can also help with operations inside the habitation vessel by providing a gaseous material to fill the air inside of it. Water collected from the rig can be piped in through a series of pipes to minimize caving in of the ground. MIDAS II and or its process can be located within a Mars habitat. MIDAS II can use the preexisting pressure to pump any liquid water or provide means in creating sufficient pressure within the habitat.

Endeavors in space, due to the shear complexity of their nature and need of time management, require autonomy in robots performing redundant and or basic tasks. Lack of communications and high lag times hinder any operations from Earth based sites. MIDAS II has been designed to work independently from human interaction and can be programmed to work alongside human operators. The rig can be allocated to work for high periods of time to produce the most yield in water. For a better operation on Mars or other celestial bodies, more sensors and programming could be added to the rig so that it can maximize its yield in water given an anomaly. Sensors such as pressure gauges located on the tip of the probe can be used to calculate the amount of pressure in the Rod-Well allowing the robot to make any changes in heating or ram speed to maximize operations. A loss of pressure indicated from the pressure gauges could also alert the robot of any leakage of pressure from the Rod-Well. A microbial sensor added to the filtration/condensing part of the robot can assure its users that the water being consumed is not tainted with any space bugs. Since the robot's operation is considered mundane when compared to other operations, an increase in its autonomous functions can allow MIDAS II to be assured as an asset. It should be noted that any device sent to Mars requires the hardening of electronics as it must be protected from solar radiation and the large amount of dust that can occur on the Martian atmosphere.

The probe relies on a wax motor and/or spring to actuate in order for water to enter the probe's internal tubing. Because of the low temperature on Mars, the wax motor on MIDAS II's probe will need to be specifically designed for the Martian Climate. Other mechanical components of MIDAS II will have to powered by an energy source other than heat. Electrical systems on MIDAS II can be powered by sufficient batteries which can be charged by solar panels and or nuclear fuel.

The need of a filtration system can also add to the security of processing clean water. Currently MIDAS II has a filtration system whose cartridge can be easily replaced by hand. MIDAS II should have something similar for Martian operations.

The high temperature variability on Mars would lead to concerns regarding structural materials. Much of the rig's frame is made of aluminum, which becomes brittle when exposed to low temperatures. To remedy this, the aluminum t-slots used in the frame of the rig could be fabricated with a more durable aluminum alloy. A possible alloy could include aluminum 2195, an aluminum-lithium alloy that possesses a high tensile strength and remains structurally sound up to minus 423 degrees Fahrenheit (20.37 Kelvin) [3]. Copper should serve as an ideal material for the heated tip of the drill. It possesses high thermal conductivity and high fatigue strength. This should allow the tip to withstand the stresses of the hammering action employed by the drill and the harsh environment of Mars.

MIDAS II uses a simple system with as few moving parts as possible. This will extend the longevity of the rig. The parts most likely to see wear and tear are the drill and the tip of the bit. Both of those can be designed in a way that will allow for easy removal and replacement. Parts of the rig could also be used in other operations if needed. The frame is also foldable making it easy to transport and storage as needed. Adding more folding elements can weaken the integrity of the frame so other components can be added to the frame to make it stronger and rigid when folded.

The process of MIDAS II can also be miniaturized for smaller operations. For the smaller deployment, the extraction element of MIDAS II will be attached to a rover. The purpose of this is to collect water from the smaller ice deposits across mars or from the very top of larger ice sheets that are present. In order to collect the water, a process similar to the one used on the Earth based MIDAS II will be used. Instead of pumping the liquid out, MIDAS II will rely on the sublimation of the water. To ensure that the water vapor does not escape, the hole formed from plunging can be covered and/or a pump can fixate a certain pressure within the ice deposit.

The condensing chamber on the Earth-based version of MIDAS II does not need to be pressurized or altered in any way because of the high pressure, when compared to Mars, of the planet's atmosphere. On Mars, however, the condensing chamber will need to be pressurized or altered in a way to accommodate the vapor and liquid water. One idea would be to use a condensing chamber made out of balloon like material that would expand once water vapor has entered it.

A rover's use of MIDAS II process would not yield high amounts of water, it would rather provide support as a precursor to preliminary research operations of the planet. If a rover's goal is to provide support for such operations, it would not have to produce a high amount of water. According to research presented in the "Mining" Water Ice on Mars presentation by Stephen Hoffman [4], a Martian surface crew of 4 will require 3.5 gallons of water per person per day if laundry is being taken in to account or 14 gallons a day. In an ideal setting, the rovers would only need to collect only 14 gallons of water if the water recycling process is perfect. Much more water is going to be needed if electrolysis will be used to produce oxygen ahead of the crew's arrival. Any liquid water needs to last until the astronauts have set up the larger deployment of MIDAS II.

MIDAS II relies on the formation of a Rodriguez Well like the one, shown in Figure 21, in the ice deposit it is probing. The large deployment of MIDAS II will be used to form a Rod-Well in a location near a proposed habitation site. The major requirement for a Rod-Well is that there is enough ice to create one, so a location near one of the larger ice shelves is required [1]. In order to form a Rod-Well on Mars, MIDAS II will plunge to a target depth.

The target depth will need to be below the overburden and deep enough into the ice so that the risk of collapse is minimal. Capping the hole will allow the pressure to rise enough so that the water melted will remain as liquid. As the water is warmed, it will melt the ice outwards and down forming a tear shape. As enough of a pool is formed, water can begin to be pulled out and used. The rate at which the water is pulled out needs to be monitored closely, for if too much water is pumped out, the well will cease to grow and stop generating water. How the water is pulled out of the Rod-Well is another question. One method could be a traditional pump. The pump would be simple and effective as long as the water remains liquid.

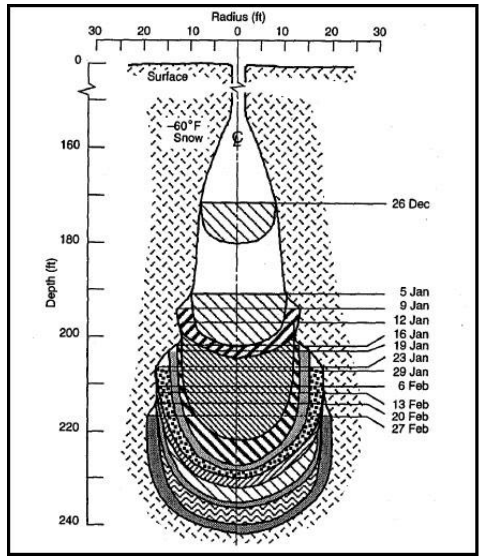

Figure 21. Rod-Well chart: http://www.southpolestation.com/trivia/rodwell/rodwell.html

As the well continues to grow, the tip of the extractor needs to be constantly lowered so it can continue to provide heat and extract water. This can be done using a method similar to an oil rig or a well drill where another section of drill that has the proper connections is placed on top and then allowed to continue. Another option for this is to have the tip of the extractor capable of detaching from the shaft and being lowered from where it begins forming the Rod-Well. The power and extraction lines would be on a reel with enough line to reach the bottom of the Rod-Well when it sinks to maximum depth. Some issues with these methods would be maintaining the pressure of the Rod-Well while lowering the tip of the extractor.

The payoffs of the Rod-Well are great. According to Brad Coutou [5], a typical well can produce up to one million gallons of water in seven years. Depending on the energy input to the well, about 98 metric tons (26000 Gallons) of water can be produced from -80C ice at 40kW in 20 days or the same amount in 220 days at 20kW from a single well as shown in Figure 22. Assuming that the water recycling is near 100% efficient, this is more than enough water to sustain many astronauts comfortably or allow for the expansion of agricultural efforts to reduce the need for using electrolysis to produce oxygen.

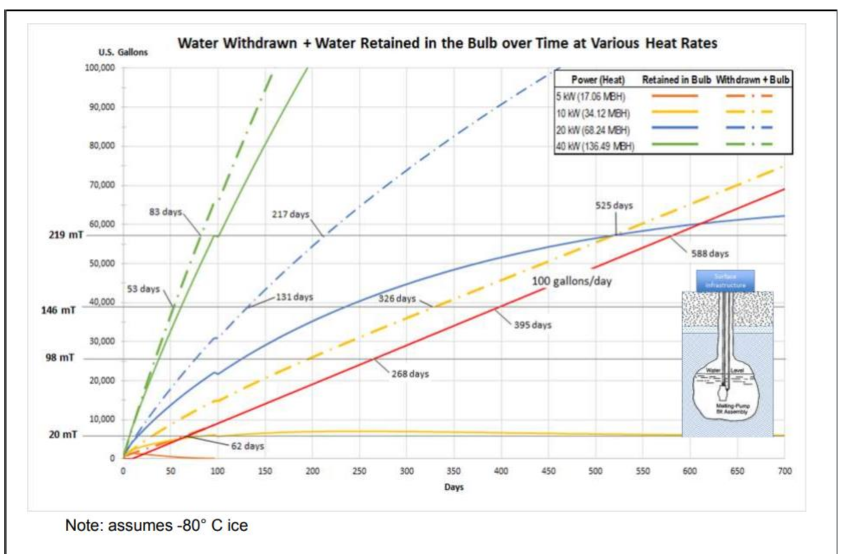

Figure 22. Water generation at different power levels

The reasoning behind MIDAS II is to show that retrieval of liquid water is a possibility on Mars and that it only requires rational outcomes from an able robot. The operations of MIDAS II simply uses the thermodynamic properties of water to change the state of the molecule in a workable process. For the process to be finalized more research must be done on the Martian environments effects on water, and the components of MIDAS II must be finalized. Development of autonomous robotic operations is also prudent for the success of any retrieval of water from the Martian subsurface.

11 Budget

The budget for MIDAS II was projected to be $15000. Funding was provided through generous sponsorship from the Statler College of Engineering and Mineral Resources, the Lane Department of Computer and Electrical Engineering, the Department of Petroleum and Natural Gas and the WV NASA Space Grant Consortium as well as the stipend received from NASA/NIA. With the NASA/NIA stipend covering $10,000, the remaining expenses were covered by our sponsors. The budget covers all costs associated with the fabrication and travel activities. All fabrication expenditures were tracked by the faculty advisor and the team's Chief Financial Advisor.

12 Conclusion

The West Virginia University MIDAS II Robotic Team worked diligently to fabricate a robot that meet all competition design constraints and adhered to the design described in the proposal and midpoint report. Lessons learned from testing and building the original MIDAS allowed the team to plan out and design a better system. Testing was also done to make sure that MIDAS II's subsystems worked properly. Preliminary test results show that MIDAS II can retrieve around 2 liters of water in an hour using 400 Watt heaters.

13 References Cited

[1] “Down the Hole--Rodwell Adventure Videos,” [online] Available at: http://www.southpolestation.com/trivia/rodwell/rodwell.html [Accessed 15 October 2018].

[2] Carr, M.H., “The Surface of Mars,” Cambridge: Cambridge University Press, 2007.

[3] "Super Lightweight External Tank," NASA Facts, April 2005. [Online]. Available: https://www.nasa.gov/sites/default/files/113020main_shuttle_lightweight.pdf. [Accessed Apr. 28, 2018].

[4] Hoffman, S., Andrews, A. and Watts, K., “Mining” Water Ice on Mars An Assessment of ISRU Options in Support of Future Human Missions. [online] Nasa.gov. Available at: https://www.nasa.gov/sites/default/files/atoms/files/mars_ice_drilling_assessment_v6_for_public_release.pdf [Accessed 5 May 2018].

[5] Profaizer, S., The Antarctic Sun: News about Antarctica - Rod well. [online] Antarcticsun.usap.gov. Available at: https://antarcticsun.usap.gov/features/contentHandler.cfm?id=1205 [Accessed 15 Oct. 2018].