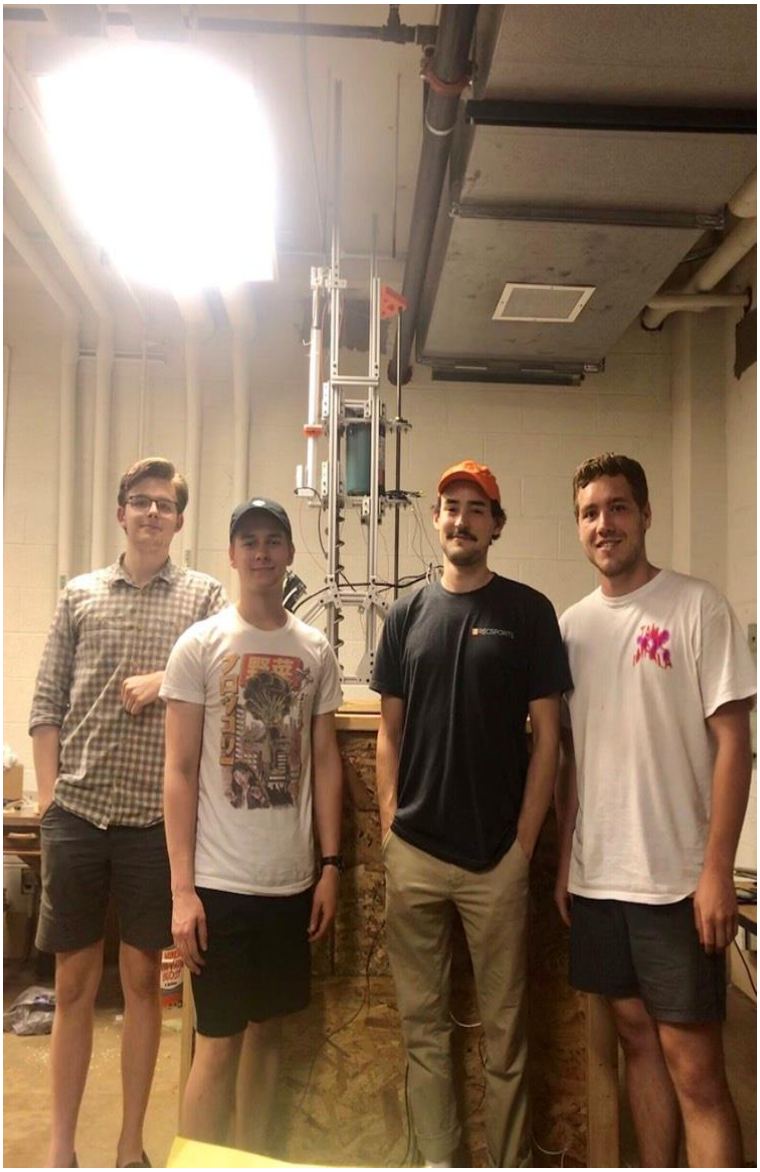
TINAD

This Is Now A Drill



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1.0 Introduction

The University of Tennessee, Knoxville team has developed the machine, TINAD (This Is Now A Drill) in order to fulfill the objectives put forth by the RASC-AL Special Edition Moon to Mars Ice and Prospecting Challenge. This system accomplishes its objectives of prospecting, excavating, melting, and pumping through the use of a single tool head.

2.0 System Description

TINAD uses pumping and heating equipment contained within the hollow core of its auger to melt and pump water directly from the tip of the drilling hardware. Digital core data is collected by monitoring the amp-consumption data received from the auger's motor and comparing it to data collected from drilling in similar materials during tests prior to the competition. The machine can then correlate these data to determine the type of material encountered during drilling. Sudden changes in this amperage feedback indicate that the drill has entered a new type of material. This design, though complex, cuts down on the volume of hardware and number of operation steps necessary to achieve the dual goals of prospecting and pumping water.

Last year, TINAD's design consisted of two primary modules: the auger, and the heating a pumping module. This year, the team combined all primary functions into one single tool head. The team made this decision for several reasons. First of all, since sand is one of the materials present in this year's selection of overburden materials, there was the possibility of sand layers collapsing and re-filling holes drilled by the auger and preventing the heating module from accessing the ice layer. \team circumvented this potential problem by deploying heating and pumping hardware directly in to the ice from the auger's tip, eliminating the possibility of interference between the heating and pumping stages.

2.1 Mounting System

The mounting system features two-axis translation of the integrated tool head over the excavation area and is composed of two primary sections: the base and the tool head housing tower. The base has four feet that screw into the wood of the mounting platform. The base is effectively composed of two beams which span the distance between two rails. The beams are connected to the rails by dry bearings which are also attached to a system of lead screws and stepper motors which move the beams in the x-axis over the length of the rails. The team decided to use dry bearings rather than lubricated roller bearings like last year in order to minimize the chance of bearing seizure in the dusty environment.

Figure 1: Tool Head Housing Tower

The integrated tool head housing tower sits atop these beams, extending vertically 150 cm above the chassis feet. This housing tower supports all hardware necessary for digging, melting, prospecting, and water collection. The primary auger, its actuation system, and the actuators that move the auger's interior components all sit in the center of the housing tower, while the electronics board, peristaltic pump, and water filter all hang from the side of the tower.

2.2 System Excavation Operations

TINAD utilizes an integrated heating, water extraction, and drilling tool head to determine overburden layer data, penetrate overburden, melt subsurface ice, and retrieve the resulting water. This is made possible by the hollow shaft employed in TINAD's auger. The outermost shaft of the auger, sporting the stainless steel flightings and tungsten carbide bits, is attached to the primary 3-phase AC motor via 1.4:1 two-gear train in the auger housing tower. This allows power to be transferred from the motor to this outer shaft while providing a 40% increase in the torque to the auger. The team decided to gear up the auger's torque due to the addition of harder overburden layers to this year's selection of materials.

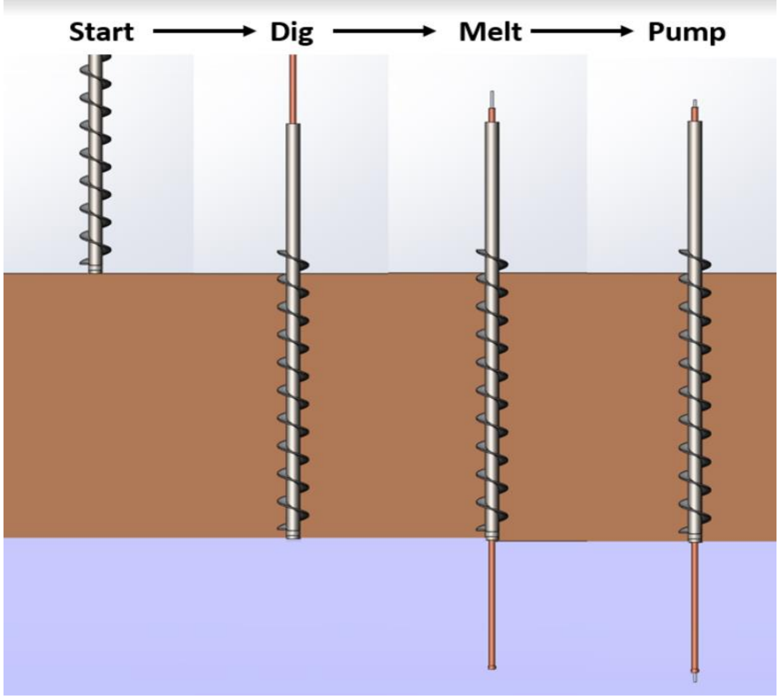


Figure 2: Excavation Process

Moving inward, there is a copper pipe housed within the auger shaft. This pipe is secured in position inside the outermost auger shaft by two high-temperature, dry running sleeve bearings which allow the copper pipe to both rotate and extend/retract vertically with respect to the outermost auger shaft. This allows the copper pipe to remain stationary while the outermost auger shaft spins during excavation and prospecting operations. Moving inward again, there is a thin aluminum pipe that sits within the copper pipe. This aluminum pipe remains stationary with the copper pipe during excavation and prospecting operations. The copper pipe acts as a stationary housing for the auger's interior components: the heating element and the pumping pipe (aluminum pipe). This nichrome wire heating element occupies the space between the copper and aluminum pipe for the six inches

Figure 4: View of Integrated Auger Tip

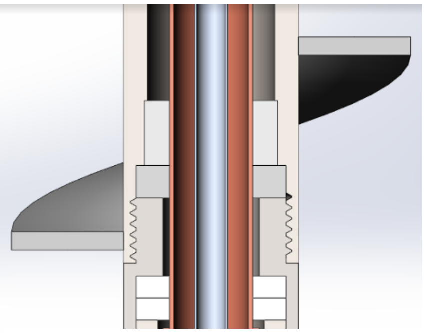
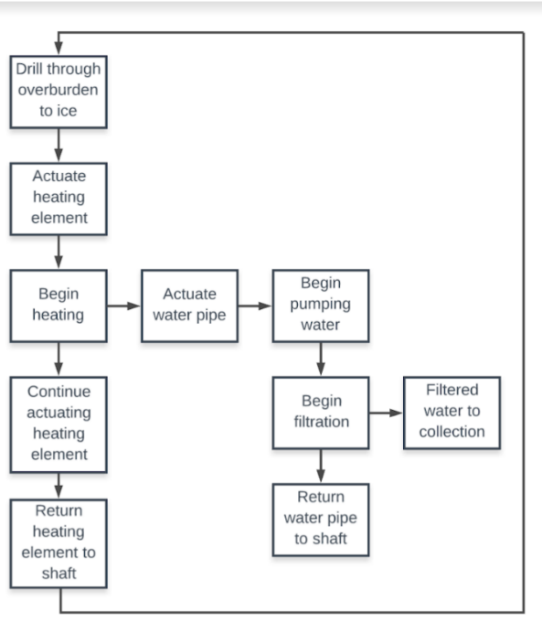


Figure 3: Integrated Auger Section View

nearest the bottom tip of the auger. The wires necessary to power this heating element run the length of the copper pipe and exit out of the top along with the aluminum pipe. When the auger reaches the ice layer and excavation ceases, the heating element is activated, melting the surrounding ice. The heating element then slowly extends out of the end of the outermost auger shaft and down into the ice layer. As it melts through the ice, the aluminum tube extends a few centimeters out of the end of the copper pipe, exposing the hole in its side at its tip. This hole is used to collect and pump water up to the water filter.

2.3: Water Collection

Water is extracted from the ice using a nichrome heating element and water collection tube housed within the auger. This heating element is composed of nichrome wire threaded through hollow alumina ceramic tubes that sit between the copper and aluminum pipes inside the auger. Once the auger has reached the ice layer, the copper pipe which houses the heating element and the water collection pipe extends down into the ice, melting as it goes. During this process, the aluminum pipe extends slightly from the end of the copper pipe, exposing the water collection hole on its side, allowing it to collect water.



Water is extracted through the hole at the bottom of the aluminum pipe at the center of the auger assembly. This is the longest of any of the pipes at 90 cm and therefore extends out of the top of the copper pipe. The upper end of the aluminum tube is connected to a pipe which, through a series of pressure fit connectors and adapters, leads into the peristaltic pump. This pump uses its rotating fingers to create a vacuum on the intake side of the pump and excess pressure on the outflow side of the pump. Furthermore, this pump's direction of flow can be inverted enabling the pump to alleviate clogging issues by using water in the to wash out troublesome particles. The pump then feeds water into an active carbon filter. Last year, the UT team experienced significant issues with the filter clogging and overflowing, causing much of the collected water to leak out of the filter and leave the system. This year, the filter is housed in a larger cylinder. This way, if the filter overflows the cylinder will still collect the water since turbid water is better than no water at all. That said, testing with this filter indicates that overflow will not be a problem unless the water collection rate vastly exceeds expectations

2.4 Developing the Digital Core

The digital core will be developed by monitoring the amperage consumption of the primary 3-phase AC motor. The motor maintains a constant rotational velocity under a constant voltage, but the power consumption changes as the auger drills through materials of varying hardness. This causes the current draw to vary as the overburden substrate varies. Test data gathered from running the drill in various materials beforehand is used to establish how the amperage values relate to the material being tested. This data can then be used to determine approximately what sorts of materials are being encountered in competition. When the drill enters a new layer of overburden, the amperage values jump suddenly, either upwards or downwards, thereby indicating the layer change. The depth of the drill at beach point will be measured by counting the steps taken by the stepper motor actuating the vertical motion, and calculating how the number of rotations translate to vertical distances.

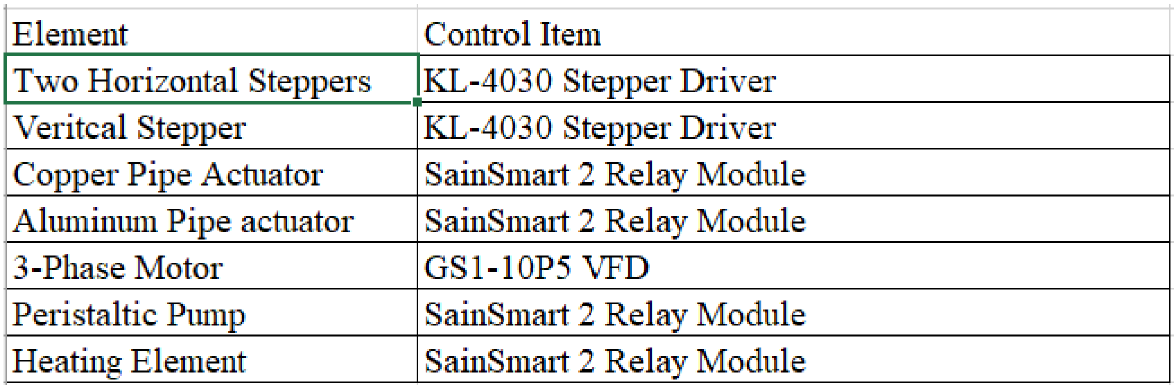
2.5 Freeze Protection

TINAD's integrated tool head design enables it to heat its way out of any frozen conditions since the heating element is housed within the tool head itself, occupying the area between the two interior pipes along the final six inches of the auger. This heating element can activate any time the drill is no running. If at any point the drill gets frozen, the heating element can be activated for several minutes to melt the obstructing ice. Since nearly all components of the auger are metals, the heating element, though located at the core of the auger, will be able to heat the exterior via conduction.

2.6 Electronics and Control

2.6.1 Control and Communication System

TINAD is controlled by an Arduino mega board that receives codes over serial input from a connected computer. These codes are translated into a specific action that the Arduino then sends to the mounted components. A GUI written in Python simplifies the process of sending these codes for the user by directly linking a code with a corresponding action.

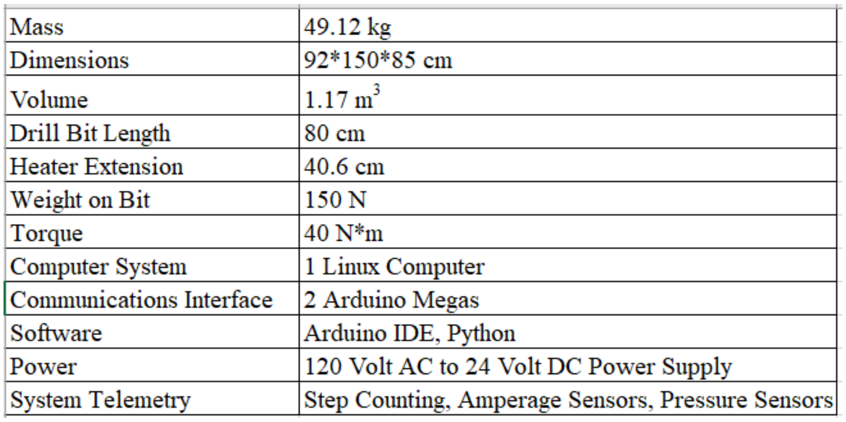


Element	Control Item
Two Horizontal Steppers	KL-4030 Stepper Driver
Veritcal Stepper	KL-4030 Stepper Driver
Copper Pipe Actuator	SainSmart 2 Relay Module
Aluminum Pipe actuator	SainSmart 2 Relay Module
3-Phase Motor	GS1-10P5 VFD
Peristaltic Pump	SainSmart 2 Relay Module
Heating Element	SainSmart 2 Relay Module

2.6.2 Data Logging

Weight on bit and current usage are recorded using a second Arduino board that employs an ACS712 Hall Effect current sensor and four FlexiForce Piezoresistive sensors mounted at the four feet of the device. These sensors will output analog signals which are sent to a computer through serial output where they are then mathematically converted into an amperage and weights respectively.

3.0 Technical Specifications



Mass	49.12 kg
Dimensions	92*150*85 cm
Volume	1.17 m^3
Drill Bit Length	80 cm
Heater Extension	40.6 cm
Weight on Bit	150 N
Torque	40 N*m
Computer System	1 Linux Computer
Communications Interface	2 Arduino Megas
Software	Arduino IDE, Python
Power	120 Volt AC to 24 Volt DC Power Supply
System Telemetry	Step Counting, Amperage Sensors, Pressure Sensors

4.0 Design Changes/Improvements:

TINAD has undergone several primary design changes since mid-project review: the adoption of an improved auger, the alteration of the filtration system, the fortification of the ventral chassis beams and joints, and the ninety-degree rotation of the tool head housing tower with respect to the chassis base.

The team elected to enhance the auger following extended testing against rock and ice. The new auger is made of stainless steel and features a thicker outer wall as well as a larger interior diameter, making it both more robust and more accommodating of internal components. Furthermore, large tungsten carbide bits have been added to its tip to better equip the auger the penetrate rock and ice.

The design for the filtration system has been altered in the interest of avoiding the troubles that plagued last year's TINAD design, namely the extensive leakage caused by the clogging of the filter. The new filtration system has been designed such that the filter is now housed within a cylinder that has an outlet for water at the bottom. With this design, if the filter clogs and overflows, the spillage will still be collected by the cylinder. Nonetheless, an effort will be made to minimize the chance of overflow by pumping in intervals such that the rate of inflow to the filter does not exceed the rate of outflow.

The ventral support beams and joints were fortified after the first round of integrated testing. The two original 25*25mm 80/20 beams deformed under the full weight of the motor and auger assembly. Furthermore, the joints that attached the beams of the tool head housing tower to the ventral support beams were apt to bend and twist. In order to combat these issues, the width of the ventral support beams has been doubled. This increase in size also provides more attachment sites at the base for additional joint supports to be added. This new reinforced version of the chassis is substantially sturdier and does not visibly deform. The reinforced joints are considerably more resistant to both bending and twisting and enhance to overall stability of the chassis.

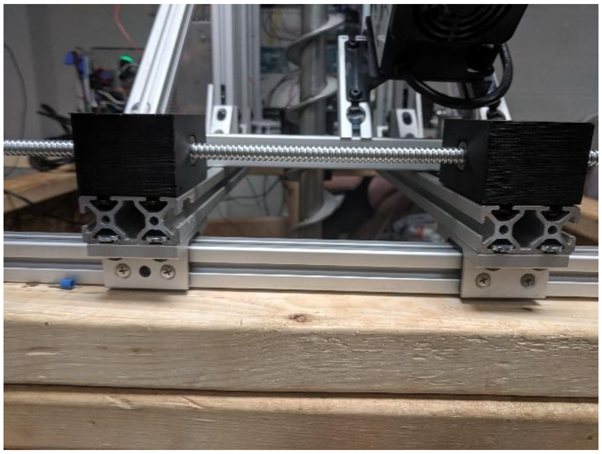


Figure 5: Double Wide Ventral Support Beams Side View

The tool head housing tower was rotated ninety degrees with respect to the chassis base in order to situate all of the heaviest elements of tool head actuation and driving (the auger, the motor, and the vertical lead screw) along the axis of the ventral support beams. Before this alteration, the center of mass of these elements in the tool head housing tower was not centered over the ventral support beams, causing the tower to sag to the side. After this alteration, all of the aforementioned heavy elements in the housing tower are aligned co-linearly along the axis of the ventral support beams.

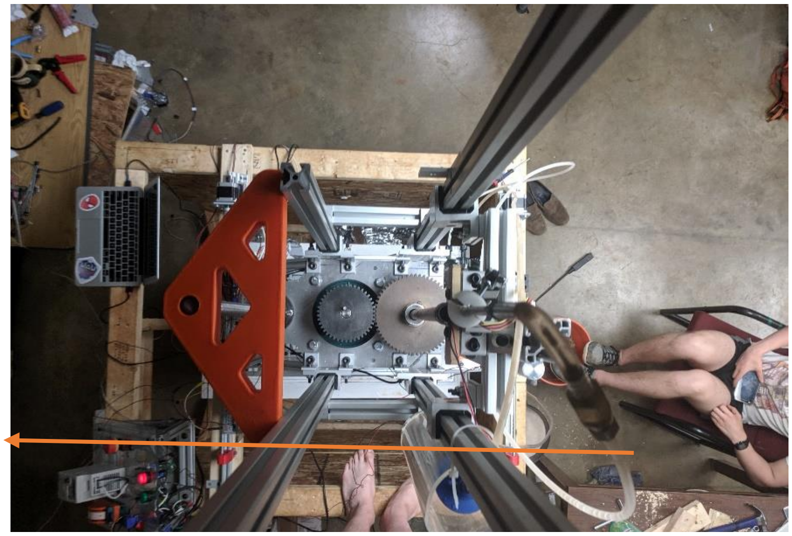


Figure 6: Heavy Elements Aligned Colinearly along Ventral Support Beams

5.0 Challenges:

The challenges involved with the completion of this project took one form: delays resulting from design changes. The first and most debilitating challenge was the need to redesign the motor system after discovering that the hollow-bore motor that the team had originally planned to use had a 20-week lead time (this information was made available to the team as part of a weeks-late quote that the team received after the project proposal was submitted) which was not at all compatible with the production timeline for the project. This resulted in the team being forced to redesign the machine to operate with a regular motor which in turn required the development and testing of a gearing system used to offset the primary auger tube from the motor so as to provide access to the top of the hollow tube, thereby facilitating the manipulation of interior auger components like the heating element and the water collection tube. This necessary change pushed back the development of the auger, the most complex and resource-intense part of the machine, by roughly a month. This change necessitated newly designed precision machined, gears, pipes, bearings, and mounting plates. This change was costly, both to the budget and project timeline.

The collection of the data used to develop the digital core has also proven difficult. The team originally attempted to take the required amperage readings from a point between the motor and the variable frequency drive. The readings taken from this point experienced considerable interference, causing the data to be unintelligible. Through trial and error, the team discovered that comprehensible amperage readings could be taken from the relevant wire before to entering the variable frequency drive, allowing the collection of useful data capable of developing the digital core.

6.0 Overall Strategy for Competition:

TINAD will begin by prospecting. The auger will be activated at 120 RPM and descend into the overburden at a constant rate. Amperage data from the motor will be collected and analyzed as this occurs, developing the digital core contemporaneously. Once the auger makes contact with the ice layer, the auger will be deactivated. The heating element will then be activated for two minutes to accumulate heat while still housed in the auger. After this duration, it will be slowly lowered into the ice at intervals, melting as it goes. The water collection pipe will be actuated a centimeter beyond the end of the copper pipe, sucking water as the heating element melts the ice. The opposite end of the water collection tube is connected to the peristaltic pump, which provides the suction necessary for the water collection pipe to transport the water from the end of the water collection pipe and into the filter. After the heating element has reached its maximum depth of 124 cm, it will hold its position and remain active for several minutes, melting via convection and collecting any water that coalesces at the bottom. Once the rate of water collection becomes negligible, the water collection tube and heating element will retract back into the auger. The auger will resume rotation and will be lifted out of the hole. The chassis will move the auger to a new drilling spot, and the this entire process will be repeated. All digital core data from multiple holes will be compiled in order to develop more accurate figures for the development of the digital core.

7.0 Summary of Integration and Test Plan

The fully integrated test of all systems yielded useful information. Overall, the test was a success. TINAD demonstrated its ability to dig through rocky clay without issue. as well as actuate the tool head housing tower over the excavation area both vertically and horizontally. Additionally, the auger was able to dig through hard ice, an analog for rock, effectively, though slowly. During this integrated test against ice, we discovered that the auger operates effectively at higher RPMs than expected, and also need to be lowered more slowly when penetrating hard materials. Standard auger operation protocol will be altered as a result. The actuation for the copper heating pipe also worked smoothly. The only actuation issue we encountered was the Acutonix P16 actuator used to actuate the water collection pipe. It functioned properly several times immediately prior to integrated testing but failed during the test. More testing will be undertaken with a spare of the same model. The heating element and water collection worked flawlessly, melting rapidly and pumping water up into the filter. Furthermore, the team confirmed that the heating element is capable of heating the exterior tube and its bits to a temperature high enough to melt surrounding ice, allowing the auger to free itself should it become frozen.

The weight on bit sensors functioned, but at times provided strange and inconsistent readings. More testing and calibration will be necessary in the coming weeks.

The electronics and control system functioned well, controlling all electronics systems without delay or complication, barring the single faulty actuator. Though this system functioned effectively, the team discovered how difficult it is for a single operator to control the machine without communicating verbally with other team members. The team will focus on training the operator and developing a list of operation protocols to refer to in the event of an unexpected event prior to the competition. The data from motor used to develop the digital core was also gathered as planned and was consistent, but better calibration as well as testing against varied material substrates will be undertaken in the coming weeks in order to make the digital core as precise as possible.

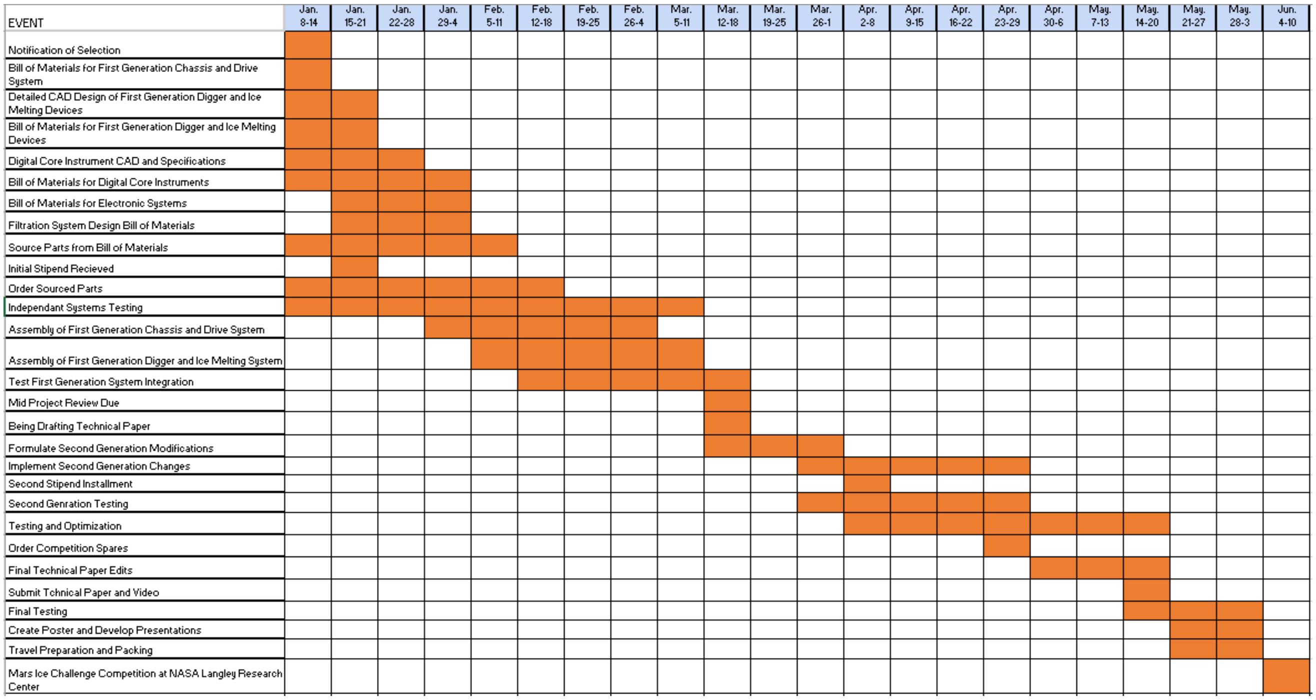
The chassis proved itself to be sturdy an exhibited minimal shaking, even when drilling through dense ice.

8.0 Tactical Plan for Contingencies/Redundancies:

The UT team will be well equipped to to enact contingency plans should any of TINAD’s elements fail during the competition. The team will come to the competition with the parts and tools necessary to repair any part of TINAD except the shaft or flighting of the auger itself. The team will bring replacement electronics, motors -both for actuation and drilling-, 3D printed parts, structural beams, and screws. Furthermore, the tools necessary to perform any of these replacements will be brought as well. Though testing has not indicated that any of these failures have a high chance of occurring, the team wishes to be as prepared as possible. It is expected that electronic components have the highest likelihood of failure, so relevant replacements will be stocked multiple times.

Though the UT team is well outfitted and prepared to perform replacements, TINAD itself does not feature any built-in system redundancy in the interest of limiting weight. Any issues that arise will need to be dealt with by part replacement.

9.0 Project Timeline



EVENT	Jan. 8-14	Jan. 15-21	Jan. 22-28	Jan. 29-4	Feb. 5-11	Feb. 12-18	Feb. 19-25	Feb. 26-4	Mar. 5-11	Mar. 12-18	Mar. 19-25	Mar. 26-1	Apr. 2-8	Apr. 9-15	Apr. 16-22	Apr. 23-29	Apr. 30-6	May. 7-13	May. 14-20	May. 21-27	May. 28-3	Jun. 4-10
Notification of Selection	■																					
Bill of Materials for First Generation Chassis and Drive System	■																					
Detailed CAD Design of First Generation Digger and Ice Melting Devices	■	■																				
Bill of Materials for First Generation Digger and Ice Melting Devices	■	■																				
Digital Core Instrument CAD and Specifications	■	■	■																			
Bill of Materials for Digital Core Instruments	■	■	■	■																		
Bill of Materials for Electronic Systems		■	■	■																		
Filtration System Design Bill of Materials		■	■	■																		
Source Parts from Bill of Materials	■	■	■	■	■																	
Initial Stipend Recieved		■																				
Order Sourced Parts	■	■	■	■	■	■																
Independant Systems Testing	■	■	■	■	■	■	■	■	■													
Assembly of First Generation Chassis and Drive System				■	■	■	■	■														
Assembly of First Generation Digger and Ice Melting System					■	■	■	■	■													
Test First Generation System Integration						■	■	■	■	■												
Mid Project Review Due										■												
Being Drafting Technical Paper										■												
Formulate Second Generation Modifications										■	■	■										
Implement Second Generation Changes												■	■	■	■	■						
Second Stipend Installment													■									
Second Genration Testing												■	■	■	■	■						
Testing and Optimization													■	■	■	■	■	■	■			
Order Competition Spares																■						
Final Technical Paper Edits																	■	■	■			
Submit Tchnical Paper and Video																			■			
Final Testing																			■	■	■	
Create Poster and Develop Presentations																				■	■	
Travel Preparation and Packing																				■	■	
Mars Ice Challenge Competition at NASA Langley Research Center																						■

10.0 Safety Plan:

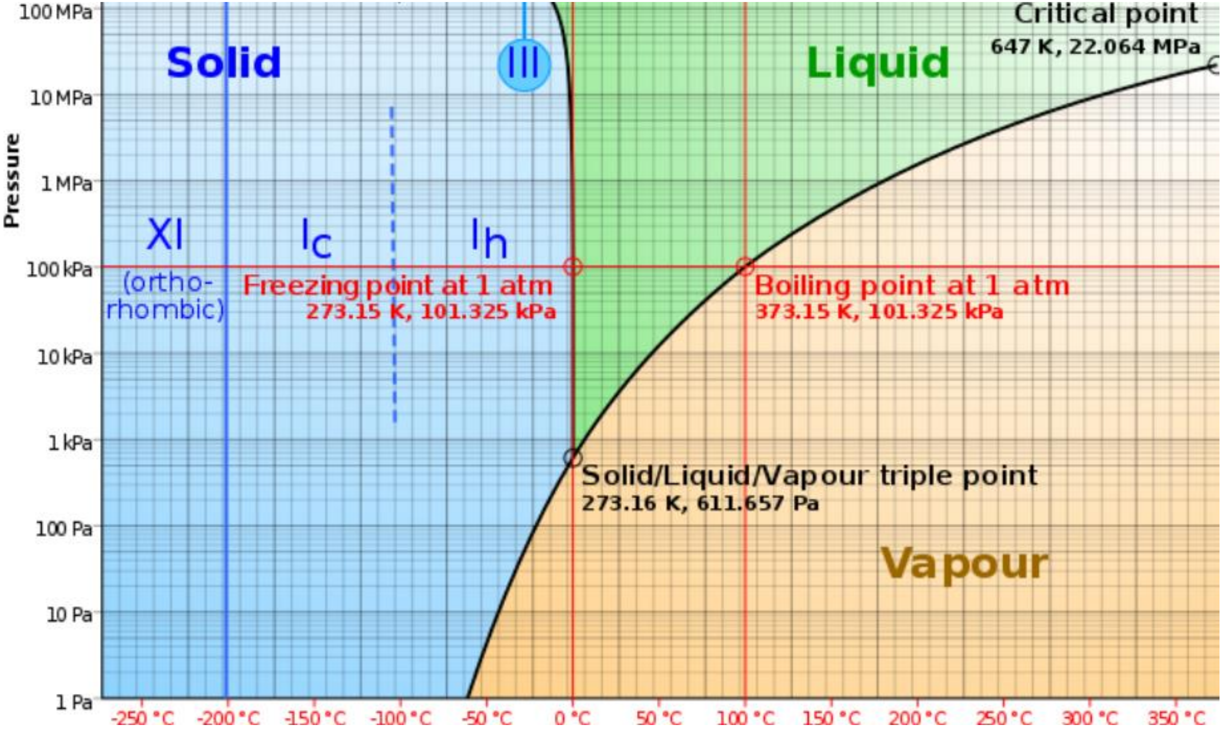
Effectively all hazards associated with TINAD's operation are related to part failures or misuse of the machine since TINAD employs no hazardous chemicals. Both during testing and during competition, all team members are required to stand at a safe distance from the machine, not able to make physical contact with any part of TINAD while the drill or the heating element are running. Furthermore, no team members are allowed to make contact with any of the electrical components of the machine while it is being powered. These issues aside, the only other potential for injury stems from part failures, though this is unlikely. The chassis is reinforced and stabilized far beyond what is necessary and is constructed from sturdy materials that have withstood lengthy testing without signs of failure. Furthermore, the auger will not be operated at high rotational velocities, instead running at a meager 120 RPM for the duration of excavation operations in order for the rotating carbide bits to take maximum effect. Additionally, the auger will be underground throughout the majority of its operation; the heating element will only be operated while the auger is completely ensconced in the overburden and ice. This means that even in the unlikely event that the drill fractures, the overburden/ice will shield spectators from injury. As described in the overall strategy, the heating element only leaves the auger when it is operating in the ice, and is housed inside the auger at all other times. Therefore, the heating element's hazardous high temperature will never have the opportunity to be in direct contact with operators or spectators.

If TINAD does experience an unexpected failure, there is a large red emergency stop button on the control panel which will cut power to all systems if pressed. This immediate power shut-off function should prevent injury.

11.0 Paths to Flight

11.1 Martian Water Collection

The methods for water extraction that employed by TINAD on Earth could be readily adapted for use on Mars with several key alterations necessitated by the Mars's pressure and temperature. Rotary drilling architectures such as augers and coring machines are decidedly the most effective tools for penetrating Martian regolith [0], so TINAD's integrated auger design will require minimal modification. Instead, modification efforts will need to be directed to the water extraction and melting procedures. Since Mars's atmospheric conditions comport with the triple point of water [3], H2O exists only in its solid and gas phases [2.5]. Therefore, when TINAD's heating element is activated, the ice will immediately sublimate and expand instead of melting and coalescing at the bottom of the hole. This means that the pumping system would have to be modified to pump gas at high velocity instead of liquid at low velocity. This new vapor pump



would need to be capable of pumping rapidly before the sublimated water vapor could diffuse into surrounding regolith. The pump will need to be altered in order to possess specialized qualities. The new pump will not have to deal with the high viscosity of liquid and sludge but will in turn have to pump at much higher rates and be equipped to filter dust. To accommodate this change the filter would need to be completely redesigned such that no portion of it relies on gravity, is capable of filtering high volumes of dust, and is sealed and insulated along its entire length. If the filter, pump, and vapor collection tube are not properly insulated, there would be a risk of the vapor cooling in the tube and reverting to its solid phase, thereby clogging the machine. In addition to insulation, we suggest that some form of heating be applied to the length of the vapor collection tube to ensure that no phase change occurs at any point prior to the liquefaction module (discussed later).

In order to collect liquid water, a new liquefaction module will need to be added to TINAD. This module would need to consist of a compressor capable of pressurizing the vapor above the triple point of water and cooled chamber where the water could be allowed to condense into liquid. This distillation process would also filter out the perchlorates and other contaminants present in the Martian soil [4]. This module would need to be well sealed to prevent the water from returning to its triple point and negating any efforts made towards the condensation of the water.

Modifications would also need to be effected on the actuation systems in order to protect them from becoming clogged with the dust thrown up from drilling operations. Dust is especially dangerous on Mars because of the planet's lower gravity, which is approximately ⅓ the strength of Earth's [2.5], meaning that dust will take roughly CUBEROOT3 the time to fall that it would on Earth. Since the dust will be expelled from the drilling hole with some momentum, this gives it more time to diffuse around the machine and reach components some distance from the hole itself. Some dust protection measures have already been enacted over TINAD's rotary bearings, but this protection would need to be considerably more extensive across the entire drilling platform for extended use on Mars. The lead screws and sliding carriages used to actuate the tool head in the X and Z directions would need to be shielded since dust buildup combined with the oil on the screws creates a harmful sludge that can permanently prevent the screws from turning properly and actuating the system. The same applies to the gearing system atop the drilling module. Over time, dust could build up in the gears and stifle the motion of the primary auger. Similarly, dust protection would need to be applied to all electronic systems components, including wires, connections, motors, and the control board. The dust insulation around the electronics components will also need to be sealed and heated to ensure that Mars's low temperatures do not freeze the electronics and prevent them from functioning. Additionally, the electronics would need to be shielded from radiation, since Mars's magnetic field is not strong enough to shield the planet from cosmic radiation. This can be accomplished using Radiation Hardened by Design (RHBD) [5].

TINAD would also require an energy source for extended operation. We think that solar panels would be ineffective since the machine is likely to clouded with dust during operation, hence occluding the panels and preventing energy collection. Power loss would be catastrophic since this would cause the electronics to be freeze and the vapor inside the machine to freeze, clogging and damaging the interior [1]. In the near future, an Advanced Stirling Radioscope

Generator (ASRG) could act as a suitable power source, given its efficiency of 26% and its long lifetime of seventeen years [2].

Furthermore, the electronics system would need to be enhanced considerably in order for it to function properly. The distance between Earth and Mars leads to considerable lag time between controller and machine. We suggest improving TINAD by equipping it with additional sensors, cameras for viewing by human operators, and the ability to perform self-diagnostics and incorporate some degree of automation [0].

Though TINAD's chassis has proven itself to be sturdy during testing, extended operation for weeks at a time could result in the degradation of the chassis rigidity. For this reason, we suggest replacing the aluminum beams with titanium or a custom-made composite that is resistant to extended stress. Furthermore, the wood components and 3D printed parts, made of ABS and PLA filament, would need to be replaced with machined titanium or printed aluminum since they are substantially less durable than the rest of the machine.

The team expects that the stainless steel and carbide composition of the auger and its bits would be strong enough to handle most regolith encountered near the surface during drilling operations. That said, the rock and ice would damage the bits over time, so the carbide bits would need to be removed and replaced periodically. TINAD is already capable of both bit replacement and the replacement of the last two inches of the auger which holds the bit pockets, meaning that the sections of the auger most prone to deterioration are replaceable, and therefore the system sustainable.

Transporting TINAD to Mars will be difficult, but several changes can be made in order to ease the process significantly. Namely, the volume could be deceased significantly. In its present state, TINAD occupies a space of 1.17 cubic meters, treating it as a rectangular prism; however in actually, TINAD"s components likely occupy no more than ¼ that stated volume. If some sort of folding mechanism could be devised, TINAD could fit into a much smaller space, allowing for less propellant, a smaller rocket, and ultimately, decreased cost. Furthermore, TINAD's mass could be decreased, especially in the gearing system. Currently, the gears are carbon steel because they were readily available and relatively cheap. Similarly-sized gears composed of titanium could function properly at nearly half the weight of carbon steel. Also, the primary 3-phase motor could be downsized, saving mass.

11.2 Lunar Prospecting

Many of the same alterations necessary for operation on Mars would also apply for Lunar prospecting. Most notably, all of the insulation necessary on Mars to protect from dust, frigid conditions, and radiation would apply on the Moon as well. The Moon, having no atmosphere [6], entails that the that this insulation be capable of withstanding a hard vacuum. The Moon's considerably weaker gravity exacerbates the dust diffusion problem discussed in Section 11.1

making extensive dust insulation equally necessary for Lunar operations. Furthermore, the Moon's abject lack of atmosphere and even weaker crustal magnetic field make radiation shielding just as important as on Mars [6].

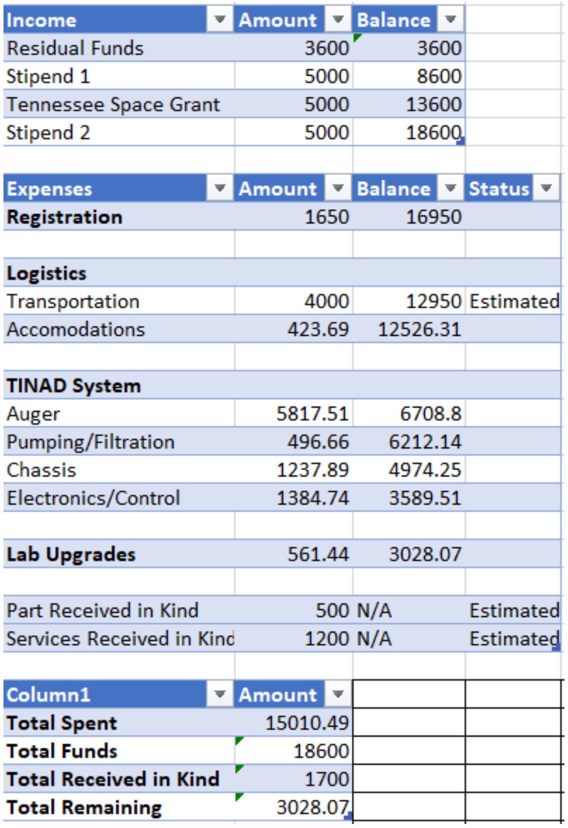
If used exclusively for the purpose of lunar prospecting, much of TINAD's hardware associated with water collection and filtration could be removed along with entire sections of the motor system. Since the prospecting capability of TINAD relies solely on feedback from the drill and not on TINAD's ability to collect water of soil samples, all hardware not pertaining to drilling, actuation, support, and control can be removed. This means the pump, filter, and water collection tubing can be removed. Furthermore, the ability to melt ice is irrelevant for prospecting so the heating element and its copper housing tube can be done away with. This is especially important since all of TINAD's most complex elements exist for the purpose of integrating and actuating these interior copper tubes. Without the need for the tubes used for melting and pumping functionality, there is no need for the gearing system atop the chassis. Removing the gears saves fourteen pounds, substantially decreasing the mass, and eliminates the problem of gears clogging due to dust buildup. With the gearing system and interior tubes gone, the auger can be attached directly to the motor. The absence of the interior tubing also allows for the removal of the two actuators that move the copper and aluminum tubes, along with the rails that this mechanism rests upon. This allows for the shortening for the two longest vertical beams. Furthermore, with both the interior actuation system and the gear system removed, one of the two aluminum support plates that support the elements in the tool head housing tower can be removed.

As with Mars, we do not anticipate any regolith constituents that necessitate the alteration of the auger, at least at the intended excavation depth since the majority of the lunar regolith present down to a depth of five meters is fine gray soil, with rock fragments interspersed. Though we anticipate that the auger will be fully capable of penetrating this regolith, it will still deteriorate over time, making the replacement of bits and tip of the auger a necessary feature.

The communication delay between Earth and the Moon is considerably less severe than that of the delay between the Earth and the Mars due to their relatively small proximity. This decreases the necessity for the extensive automation suggested for use on Mars.

In order to power TINAD, we suggest the same method put forth for Mars, the ASRG, given that the dust occlusion issue is even more likely on the Moon.

12.0 Budget



Income	Amount	Balance
Residual Funds	3600	3600
Stipend 1	5000	8600
Tennessee Space Grant	5000	13600
Stipend 2	5000	18600

Expenses	Amount	Balance	Status
Registration	1650	16950	
Logistics			
Transportation	4000	12950	Estimated
Accomodations	423.69	12526.31	
TINAD System			
Auger	5817.51	6708.8	
Pumping/Filtration	496.66	6212.14	
Chassis	1237.89	4974.25	
Electronics/Control	1384.74	3589.51	
Lab Upgrades	561.44	3028.07	
Part Received in Kind	500	N/A	Estimated
Services Received in Kind	1200	N/A	Estimated

Column1	Amount
Total Spent	15010.49
Total Funds	18600
Total Received in Kind	1700
Total Remaining	3028.07

Residual funds will be put towards next year's project in the form of direct funding and lab upgrades.

Appendix A: References

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