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Automated Core Removal System for the NASA/BHI Mars Drill

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Texas Space Grant Consortium Design Challenge
Topic #6, Mars Drill Automation

Automated Core Removal System for the NASA/BHI Mars Drill

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Abstract

NASA is in the process of developing an autonomous drill for use in an unmanned mission to Mars. NASA along with Baker Hughes, Inc. (BHI) has designed a drill capable of drilling a core sample from as deep as twenty meters below the Martian surface. Since the mission is unmanned, an automated process for removal of drilled material from the drill is needed. The Trinity Tigernauts T.N.G. design group is working on an automation system for the Mars drill that will assist in recovery of these core samples. These samples could be analyzed for signs of water and life. The team researched space automation, interplanetary automation, and automated interplanetary drilling, and visited related collaborators. Ultimately, the Tigernauts developed a prototype system on paper for this removal process. Next semester the team plans to construct and test this prototype design.

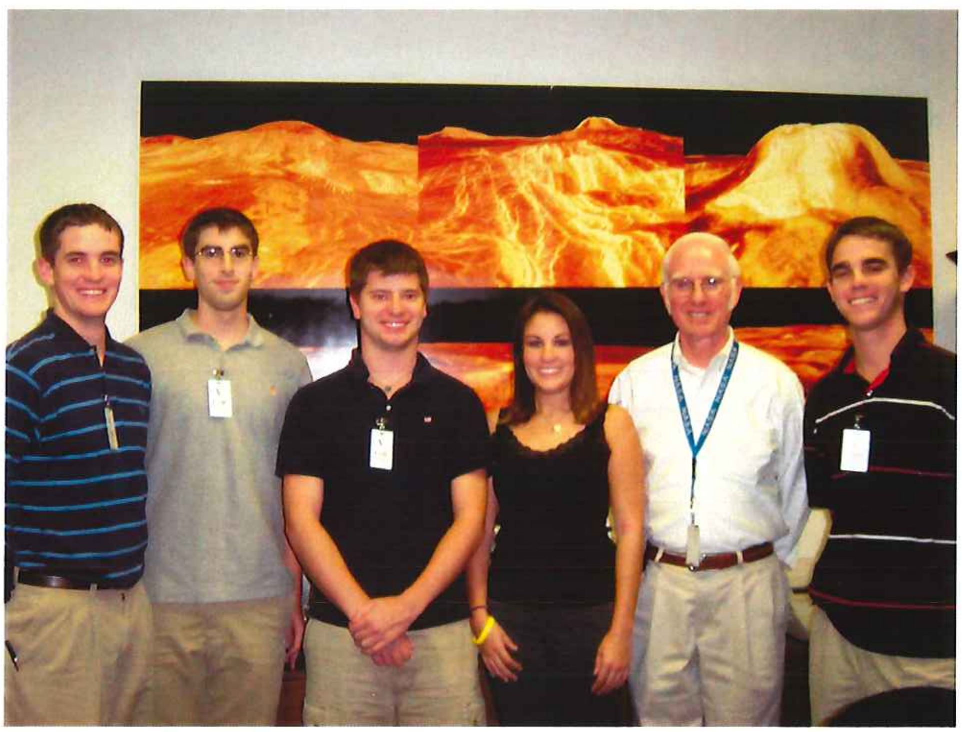

Figure 1: From Left to Right: Jeffrey Bennett, Konrad Izbinski (Team Leader), Eric Mullen, Lindsay Wetzel, Humboldt Mandell (Group Mentor), Michael Pickford

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1 Mentor and Research Group Identification

To accomplish the design goal, the Trinity Tigernauts T.N.G. worked with Dr. Humboldt Mandell at the Center for Space Research. Dr. Mandell specializes in developing new programs, cost analysis tools, and studying and implementing organizational change for NASA. The Center for Space Research is located in Austin, Texas at:

The Center for Space Research
3925 West Braker Lane #200
Austin, Texas 78759-5321

2 Collaboration

In addition to visits and interviews with Dr. Mandell concerning the nature of the project and the drill, the team collaborated with Jeffrey George and Brian Derkowski of NASA, Roger Fincher of Baker Hughes, Inc, and Michael Yockey of iSky Factory Automation. Mr. George and Mr. Derkowski are in charge of the drill development at NASA along with Mr. Fincher, the BHI contact. Mr. Yockey, an expert on industrial automation, helped the group research the possibility of using a Programmable Logic Controller for the design's control system.

3 Team Identification

The Trinity Tigernauts T.N.G. participated in the TSGC Design Challenge as part of their senior design course, Design and Analysis VII (ENGR 4381). This course serves as a capstone design experience with small groups of students advised by a faculty member. The major considerations of the class were the establishment of objectives and criteria, synthesis, analysis, safety, aesthetics, and robust product design. The course also placed a focus on formal written and oral presentations, and project management.

Last year, a senior design group from the Trinity University Engineering Department worked on the Mars Rover TSGC Design Challenge project. That team picked their name because Trinity's mascot is the Tiger and the project dealt with space; thus their name Trinity Tigernauts. This year, the team selected the name Trinity Tigernauts T.N.G. (The Next Generation) as a continuation of last year's group name. The group will not be working on the same project, but felt that this name was appropriate for the team. The faculty advisor for the Trinity Tigernauts T.N.G. is Dr. Kevin Nickels of the Trinity University Engineering Department.

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The Trinity Tigernauts T.N.G. consists of five senior engineering science majors, with concentrations in electrical and mechanical engineering:

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Eric Mullen, EE, Eric.mullen@trinity.edu
Jeffrey Bennett, EE, jbennett@trinity.edu
Michael Pickford, ME, konrad.izbinski@trinity.edu

There were two basic roles of the team members: group leader and team member. The role of the group leader was to ensure that the project ran smoothly and that all group goals and deadlines were being met. The group leader also served as a medium of communication between the faculty advisor and the group. Each team member took on the role as the group leader for some portion of the total project time (some will not assume the role until next semester). The role of the remaining four group members is to conduct the research and construction, set forth by the group, while meeting all goals and deadlines set forth by the group leader. These deadlines were determined by the group leader after negotiating with the TSGC, the faculty advisor, and the course administrator so that all requirements were covered with minimal redundancy. The position of group leader rotated so that each team member has the opportunity to be group leader during the course of the year.

4 Background Information

According to Dr. Mandell [2], water is believed to lie a few meters below the Martian surface, most likely in the form of permafrost. Since water is a fundamental requirement for life, examining this permafrost could be a crucial step in determining if life exists or existed on Mars. It has been proposed that drilling below the Martian surface would be the most effective way to get to this water. Currently, interstellar drilling operations would be possible with the aid of humans. However, as a manned Mars mission is still far in the future, a manual drilling solution is not applicable for this project. Due to the large time delay between Earth and Mars, it is also not feasible to tele-operate the drill from Earth. This leaves a completely automated process for the operation of the drill as a possible design for the mission.

Background research included analyzing the report of Christopher Koci, Andrew Lynch, and Ashwin Madgavkar from the University of Texas at Austin [1]. These students participated in the TSGC Mars Drill Automation Design Challenge 2003, focusing on the core removal process. That group focused particularly on unlocking the J-lock mechanism by "hold[ing] the drill in place, while the drill does the necessary turns in combination with the wench, vertically translating the J-lock mechanism" [1]. In regards to the issue of removing the core sample from the sleeve, the report indicates this could be done with a minimum amount of effort by rotating the sleeve horizontally and pushing the core out of the sleeve. Figure 2 shows the design proposed by the University of Texas group in [1].

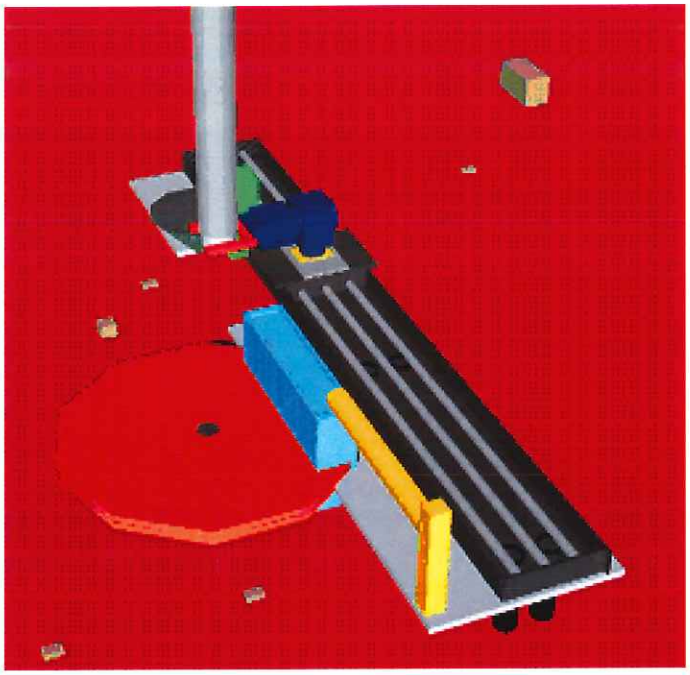

Figure 2: The core removal system previously proposed by [1].

5 Design Objectives

The Trinity Tigernauts T.N.G. spent the year developing an automation process for the NASA/BHI Mars drill. The team will simulate an automated core removal process, removing a mock core sample of diameter 0.019 meter (0.75 inches) from the raised drill and then storing it for analysis later. Currently, the Mars drill requires 4.35 Watts of power [3]. The automation system should operate around or be easily scalable to this power level. The system must also be able to withstand the journey to the surface of Mars and withstand the Martian climate. ??

6 Project Requirements & Restraints

The team focused on the automation of the core removal system. This system takes over once the drill has successfully drilled a core sample and returned from beneath the surface of Mars. The system needs to remove the core sample from the drill and prepare it to be delivered to mission specific analysis equipment on the mission's stationary platform. The system must also be able to restore the drill to operational status without damaging any equipment.

The system is based off of the NASA/BHI MkI drill, though modifications to non-integral parts, such as housings, are acceptable. However, a major change to the current drill's locking mechanism is required and expected for the final drill design [4]. The design must accomplish this by incorporating existing technology and parts. The design must be adaptable to future models of the NASA/BHI drill.

[1]Currently the The NASA/Baker-Hughes, Inc. MkI Drill, (shown in Fig. 3), consists of a 2 meter long cylinder with a drill bit at one end and a connection to a winch cable and umbilical cable at the other. The cylinder is about 3.8 cm in diameter. As can be seen in the drill diagram in Fig. 4, the drill contains a motor powered self-anchoring mechanism, a drill motor, a force-on-bit spring, and an auger with internal space for the core sample. Not shown in the diagram is the drilling bit, which can be seen in the lower right hand corner of Fig. 3.

Figure 3: The MkI drill [1].

The drill operates by using the anchoring mechanism to anchor itself to either its initial casing tube (spud tube) or the medium into which it is drilling. Using a motor to elongate itself as it drills, the drill slowly cuts out the core sample. Shavings are pulled up by the auger and stored while the core sample is guided into the hollow shaft of the auger. It is from this hollow shaft that the

[1]The information from this and the next paragraphs is derived from [2], [3], and [4]

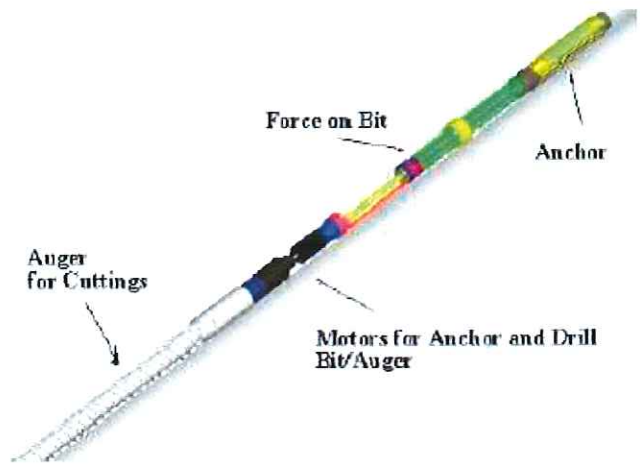

Figure 4: A diagram of the MkI drill [1].

core sample must be removed. Once the drill has cored a few inches (the length of the elongation), the drill removes its anchors, shrinks back to its original size, resets the anchors, and begins the drilling process again. An updated version of the drill, the MkII, is currently under development at NASA.

7 Design Plan

The team researched the NASA/BHI Mars drill, the final design report from last year's TSGC Mars Drill Automation project [1], and the basics of automation (particularly previous extraterrestrial automations and drilling automations). The group also considered the use of a Programmable Logic Controller (PLC) to work as the brain of the automation process. Next semester the team will also design and construct a working prototype of the automation system. The success of the project will be gauged by evaluations from TSGC, Dr. Mandell, and the Trinity Engineering Department as well as the prototype's ability to withstand several test simulations.

The automation process will be tested with a mock core sample, which the team will manufacture to represent the estimated weight, size, and density of a Martian core sample (see Appendix A). The prototype must be able to remove the mock core sample from a mock drill setup, also constructed by the team, and place the sample into a container. The prototype will also be subjected to vibration tests to simulate the long journey to Mars.

8 Final Design Concept

After deliberating over the design concepts, the group decided on a prototype that incorporates concepts and methods of individual ideas, as well as new ideas developed by the group as a whole. When the drill has finished drilling a core sample, it will be pulled up back to the surface in order to remove the core sample. Because the spud tube is not resting on the Martian surface, once the drill has been pulled up all the way, only about 3 in. of the drill (mainly just the drill bit) is exposed. Once the drill has been pulled up from beneath the Martian surface, a motor will begin to rotate a small gear attached to the base of the rover. This gear will use the grooves on the outside of the spud tube to lift the tube while keeping the drill stationary relative to the spud tube. Fig. 5 shows the gear which lifts the spud tube. Once the drill has been raised slightly higher than the top surface of the Martian rover, the core removal system will engage.

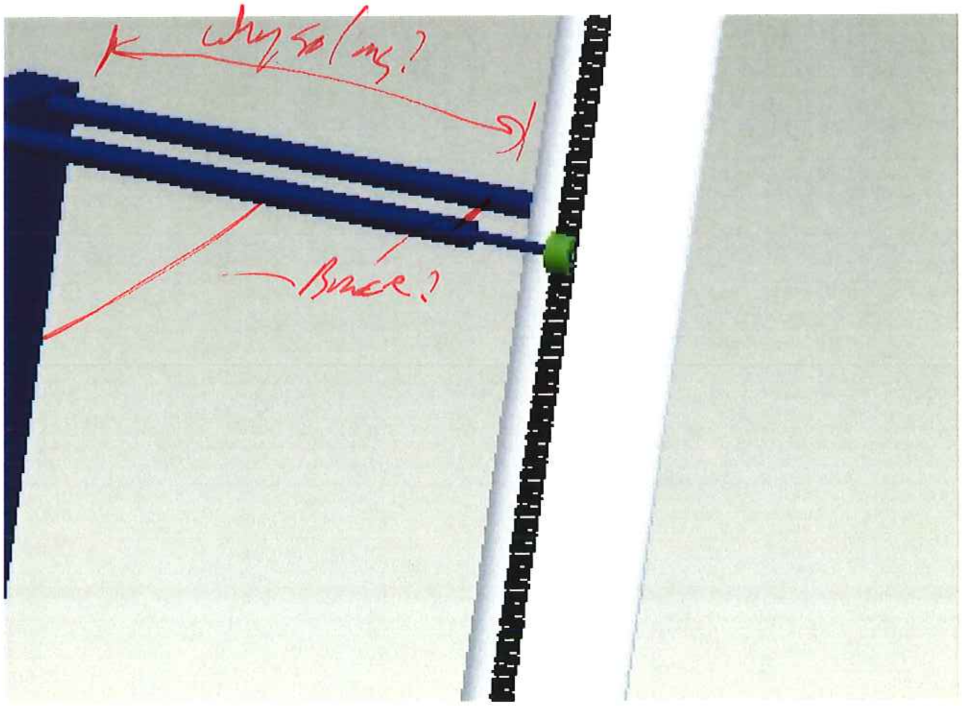

Figure 5: The Spud tube lift assembly.

The assembly of the core removal system consists of four main parts. The first part is a small, vertically-standing pole 2 ft. tall. This pole is referred to as "the Beanstalk" and is able to move through a curved crevasse allowing the core sample to be deposited without interfering with the rest of the assembly. The beanstalk has small rack gears and a notch to allow for and guide arm assembly's move vertically motion. The second part of the system is a small box (attached to the Beanstalk), known as "Jack". A motor will allow Jack to move up and down the Beanstalk whereas another motor will allow the L-shaped arm, or "the Goose", to move horizontally through Jack. The Beanstalk, Jack, and Goose assembly can be seen in Fig. 6. On one end of the Goose is the robotic gripper, known as "the Beak", which is responsible for grasping onto the drill bit once the drill and spud tube have been lifted. A motor is attached to the end of the Goose which enables the Beak to rotate 180 degrees in order to allow the core sample to be removed from the drill bit.

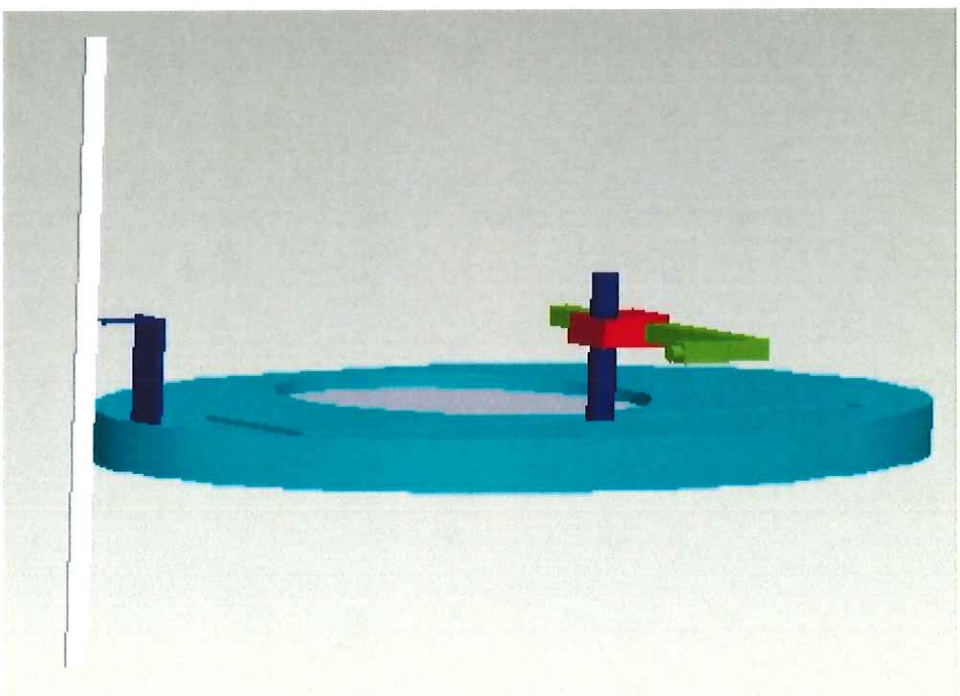

Figure 6: The sytem assembly.

Once the spud tube has been lifted, Jack will climb down the Beanstalk so that it is level with the drill bit. The method for determining this level has not yet been decided, though possibilities include light sensors on the drill or spud tube or an inertial system of some kind. Using one of

✓ Again, how known?

the motors in Jack, the Goose will move horizontally until it is flush with the drill bit. The Beak will then grasp and remove the drill bit from the main drill assembly. The Goose will then move horizontally back to its original position. Once the Goose is in place, the Beanstalk will then move through the crevasse in order to deposit the core sample. Once the Beanstalk has moved completely through the crevasse and the drill bit is in position to remove the core sample, the Beak will rotate so the drill bit is horizontal. Once the drill bit is horizontal the core sample may be removed.

The core sample is held in the drill bit by small, flexible, finger-like protrusions from the bottom end of the bit that keep the core sample inside the drill bit. The core sample may pass through these fingers easily while travelling upwards through the drill, and when the drill is being pulled out of the bore hole the fingers will prevent the core sample from falling out of the drill [2].

This leads to a problem when trying to remove the sample from the tube by pushing it out with a rod. The same forces that keep the sample in the tube will also keep the rod in the tube. To prevent this, a smaller rod could be used. Unfortunately, unless the rod provides a uniform force to the bottom of the sample, the sample may crack, or more likely, if the sample is not completely solid, the thin rod would only remove part of the sample. To avoid this problem an umbrella-like device is being developed. This device, shown in Fig. 7, would consist of a relatively thin hollow tube. From one end of this tube three or four prongs can be pushed out of, or drawn into, the thin tube with prongs and a solenoid. These prongs will be shaped so that they bend away from the centerline of the tube, effectively increasing the area spanned by the prongs. When the prongs are retracted into the tube, they will compress towards the centerline of the tube and retract into the tube. A foldable, solid membrane is strung between these prongs. When the prongs are extended, they would expand this membrane creating a surface area about equal to that of the tube. The rod, now having a full size head, can adequately push the sample out of the tube. Once the sample is removed from the tube, the prongs retract and return to a diameter able to fit back through the fingers as the rod is removed from the drill bit. The extension and contraction of the prongs would be short enough to be activated by a small solenoid.

Once the core sample has been removed, the process that the core removal system went through to deposit the sample will be reversed in order to reattach the drill bit in order for more samples to be acquired.

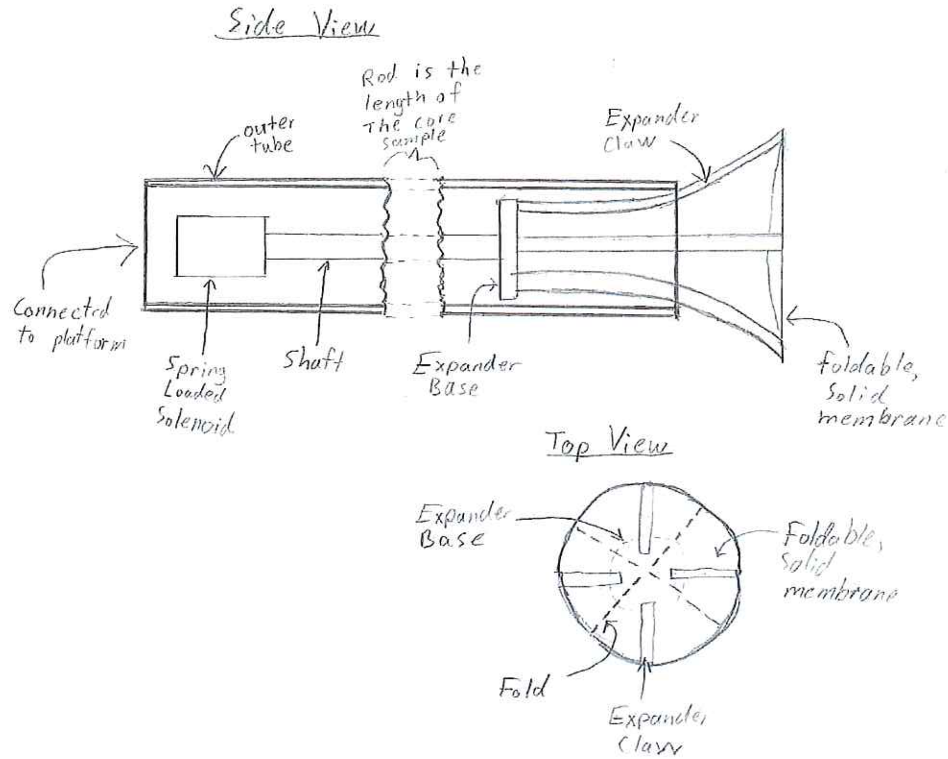

Figure 7: The rod to remove the core sample from the hollow shaft. The membrane and claws will shrink in diameter as the rod shaft is brought towards the rear of the rod by the solenoid.

9 Conclusion

After research into previous interplanetary drilling operations, the team designed a system to remove the core sample from the NASA/BHI drill. The project proceeded as scheduled throughout the course of the semester (see Fig. 8). The design assumed the MkI design of the drill and that the drill can be successful extracted from the drill hole and anchored in the spud tube. The choices particular to this design were to keep the mechanism as simple as possible to ensure the system will work every time. This simplicity also helps in expediting the design and future construction process.

The design does not yet fully take into account the harsh Martian environment. Shieldings for electrical equipment and mechanical devices have not been developed though would be necessary on Mars. A stress analysis on each of the components has not yet been done, though is planned for next semester. Power for the prototype is expected to exceed the current power draw of the drill, primarily due to the PLC, though it is expected that the system power requirements could be reduced by using more expensive or custom devices.

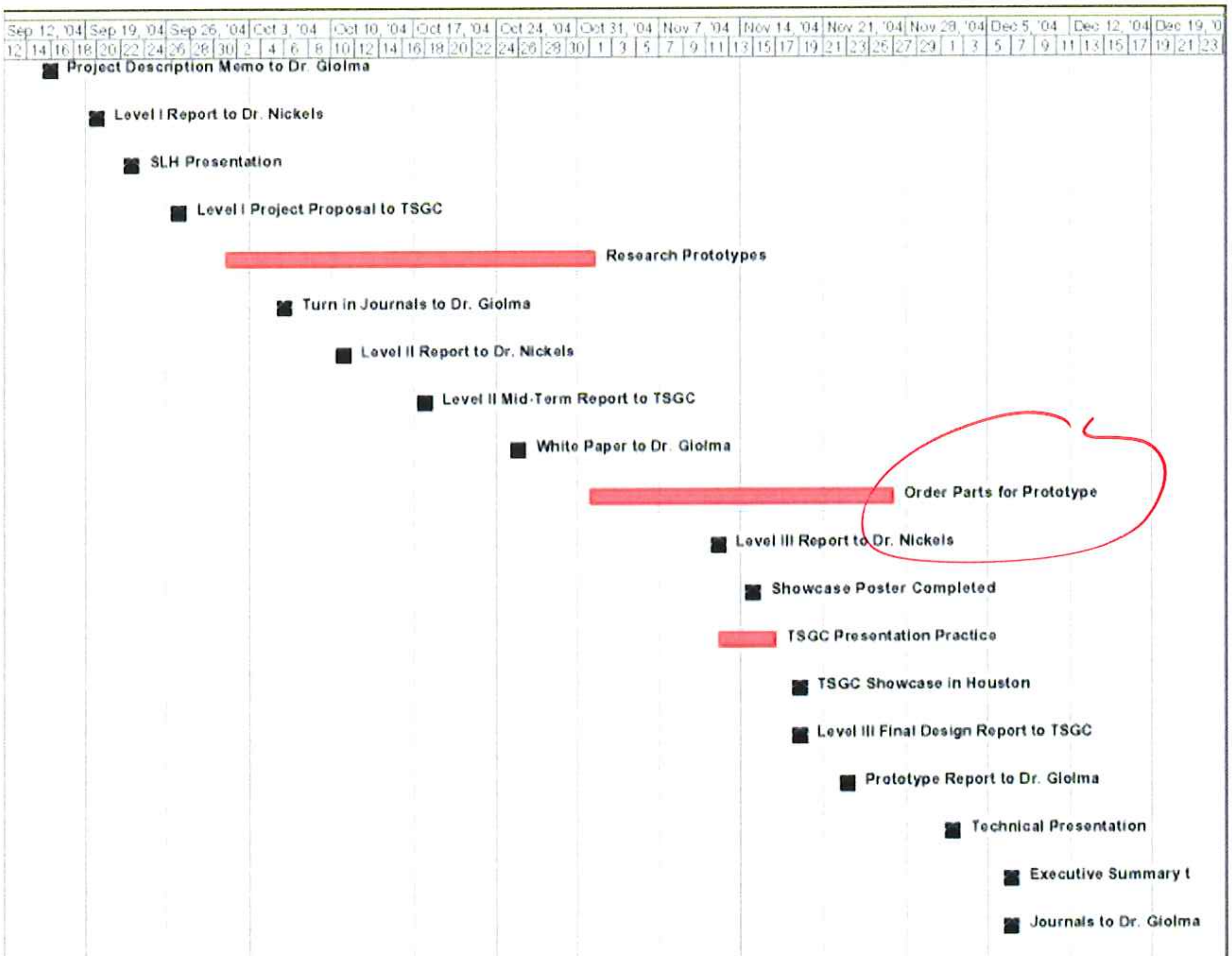

Figure 8: : Timeline for Semester I work

References

[1] Koci, Christopher, Andrew Lynch, and Ashwin Madgavkar. "Mars Drill Automation Process and Control" *TSGC Design Challenge Reports* University of Texas at Austin. 2004.

[2] Mandell, Humboldt. Personal Interview. Center for Space Research, Austin, Texas: 6 OCT 2004.

[3] Mandell, Humboldt. *Basic Drill Design Parameters.* PowerPoint Slide. 21 SEPT 2004.

[4] George, Jeffrey, et al. of the NASA/Baker-Hughes Design Team. Personal Interview. NASA Johnson Space Center: 22 OCT 2004.

A Mars Fact Sheets

Quick Facts about Mars

Comparisons	Mars	Earth	% of Earth
Mass (kg)	6.4185×10^{23}	5.9736×10^{24}	10.7%
Volume (km^3)	16.318×10^{10}	108.321×10^{10}	15.1%
Total surface area (m^2)	1.4441×10^{14}	5.1025×10^{14}	28.3%
Land surface area (m^2)	1.4441×10^{14}	1.4796×10^{14}	97.6%
Acceleration due to gravity (m/s^2)	3.7	9.8	37.8%
Surface pressure (mbar)	6 to 8	1013	0.59%-0.79%
Planetary equilibrium temperature (K)	210 (-63°C)	256 (-17°C)	82.0%
Mean scale height (km)	10.8	7.5	144%
Speed of sound (m/s)	229	321	71.3%
Equitorial radius (km)	3397	6378	53.3%
Escape velocity (km/s)	5.03	11.19	45.0%
GM (km^3/s^2) (gravitational parameter)	4.283×10^4	3.986×10^5	10.1%
Solar irradiance (W/m^2)	589.2	1367.6	43.1%
Black-body temperature (K)	216.6 (-56.4°C)	247.3 (-25.7°C)	87.6%
J_2 (effects of nonspherical/homogeneous body)	1960.45×10^{-6}	1082.63×10^{-6}	181%
Semi-major axis (km)	227.92×10^6	149.60×10^6	152%
Mean orbital velocity (km/s)	24.13	29.78	81.0%
Min orbital velocity (km/s)	21.97	29.29	75.0%
Max orbital velocity (km/s)	26.50	30.29	87.5%
Axis inclination (deg)	25	23.5	106%
Orbit inclination (deg)	1.85	0.00	-
Orbit eccentricity	0.0935	0.0167	560%
Sidereal rotation period (hrs)	24.62 (1.03days)	23.93 (.997 days)	103%
Specific heat at constant p (J/K/kg)	860	1000	86.0%
Solar day (s)	88775 (1480 min)	86400 (1440 min)	103%
Planetary rotation rate (1/s)	0.7088×10^{-4}	0.7294×10^{-4}	97.2%
Sun-planet distance (AU)	1.38-1.67	0.98-1.02	141%-164%

Atmospheric Composition		
	Mars	Earth
CO_2	95.5%	0.03%
N_2	2.7%	78%
Ar	1.6%	0.90%
O_2	0.15%	21%
CO	0.07%	Trace
Trace Gases:*		
H_2O	210ppm	x
NO	100ppm	
Ne	2.5ppm	x
HDO	0.85ppm	
Kr	0.3ppm	x
Xe	0.08ppm	x
H		x
O_3		x
CH_4		x
He		x

*Not all amounts found
x = found in atmosphere

Surface Material

Material	Size	Cohesion	% of field
Drift	0.1-10.0 μm	1.6 1.2 kPa	14% (VL-1)
Crusty to Cloddy	0.1-10.0 μm	1.1 1.2 kPa	86% (VL-2)
Blocky	0.10-1500 μm	5.5 2.7kPa	78% (VL-1)
Rocks	35000-240,000 μm	1000-10,000kPa	8% (VL-1) 14% (VL-2)

VL-1 Viking Lander 1 VL-2 Viking Lander 2

References: Kaplan, David (ed.), "Environment of Mars, 1988", NASA Technical Memorandum 100470, October, 1988.
Kieffer, H.H (ed.), MARS, The University of Arizona Press, Tucson, 1992.
"Mars Fact Sheet" (Online) "http://nssdc.gsfc.nasa.gov/planetary/factsheet/marsfacts.html"

Erica Walsh
Exploration Office

EXPLORATION

Quick Facts about Mars

Climate
- Average global temp: 210K (-63°C)
- Min. temp recorded: 92K (-181°C) at 80km alt.
- Daily temp range: 184K to 242K (-89°C to -31°C)
- Northern hemisphere has moderate seasons, while south has harsh, long winter and short, warm summer
- Surface winds:

	Mars	What it would feel like on Earth
Summer	2-7m/s 4.5-15.6mph	0.3-0.9m/s 0.6-2mph
Fall	5-10m/s 11-22mph	0.6-1.3m/s 1.5-3mph
Dust Storm	17-30m/s 38-67mph	2.2-3.8m/s 5-9mph

Atmosphere
- Comparable to Earth's stratosphere, but where Earth's is very dry, Mars is saturated with water (even though this is the case, it still feels very thin and cold)
- Constant magnetic (iron composite) dust in air (similar to foggy/smoggy day on Earth)
- Air pressure is less than 1% of Earth's
- Atmospheric density: ~0.020 kg/m^3

Surface
- Soil is oxidized and very oxidizing (but oxidation process takes longer than normal because of the cold temps)
- Surface area is about the same as dry surface area on Earth
- Surface material density: 1.2 to 2 g/cm^3

Dust Storms
- Typical dust storm is 200m-600m in diameter and 1-3km tall
- All recorded storms were observed between 2 and 3pm local time
- Temperature maximums occur during dust storms (because of low pressure)
- Storm season: northern fall & winter
- 3 possible ways a storm begins:
  - saltation: small particles carried short distances and transferring KE to larger particles (need at least 30 m/s winds)
  - dust devils: may be the vertical pressure gradient force within a dust devil
  - electric forces: unexplored

Electrostatic Discharge
- Two forms of discharge:
  - Short-scale (fluorescence)
  - Longer 'filamentary' (lightning)
- Low pressure on Mars favors arching or discharging between differential potentials
- Electric fields are expected to be in the 10kV/m range
- Dust storms comparable to rainstorms on Earth
  - Storm will tend to form electric dipole
  - Lighter particles will carry negative charge and be elevated
  - Heavier particles will carry positive charge and be lower to surface
- Storms may be detectable by radio

Topography
- Northern hemisphere is relatively flat
  Average elevation: -1 to -3 km
- Southern hemisphere very mountainous
  Average elevation: 4 km
- Vallis Marinaris is Grand Canyon of Mars
  - 8-10 km deep (Grand Canyon is 1.5 km)
  - 4000 km long (Grand Canyon is 446 km)
- Mons Olympus is 3 times taller than Mt. Everest at a height of 27 km

Miscellaneous
- Mars is 187 times farther from Earth than the moon
- Conversion of solar power to heat on Mars is about 15-20% efficient, compared to Earth's 30-40%
- Mars has two moons:
  - Phobos: seen 3 times a day
  - Deimos: seen every 1.25 days
- Ozone does not occur in enough concentrations to make a difference in atmospheric radiation
- Ozone gets destroyed when water vapor returns to Mars atmosphere in high latitudes during the spring (same thing happens on Earth)
- Seasonal condensation and sublimation of CO_2 in polar regions; up to 25% of total atmospheric mass
- Total atmospheric water:
  - on Mars: ~1-2 km^3 of ice
  - on Earth: ~13,000 km^3 of ice
- If a micro dust particle was lifted 50 km, it would take 50 Martian days to settle to the surface
- Magnetic field is very small and non-uniform.

Erica Walsh
Exploration Office

Figure 9: Data about Mars and the Martian Atmosphere (citations included in figures).

B Team Patch

The shape of our team patch is a pentagon because there are five members on our design team. The picture is of Marvin the Marian because he is the most famous animated Martian. In his left hand he is holding a hand-held drill. Even though our project uses a more sophisticated drill, the hand-held drill is used to convey the message that drilling will be involved. Marvin is leaning against the Trinity University tower. This was included because it is the symbol of our school. On the Mars surface Trinity Tigernauts T.N.G. is written because it is our team's name. Finally the background of the patch is space with a few stars and planets

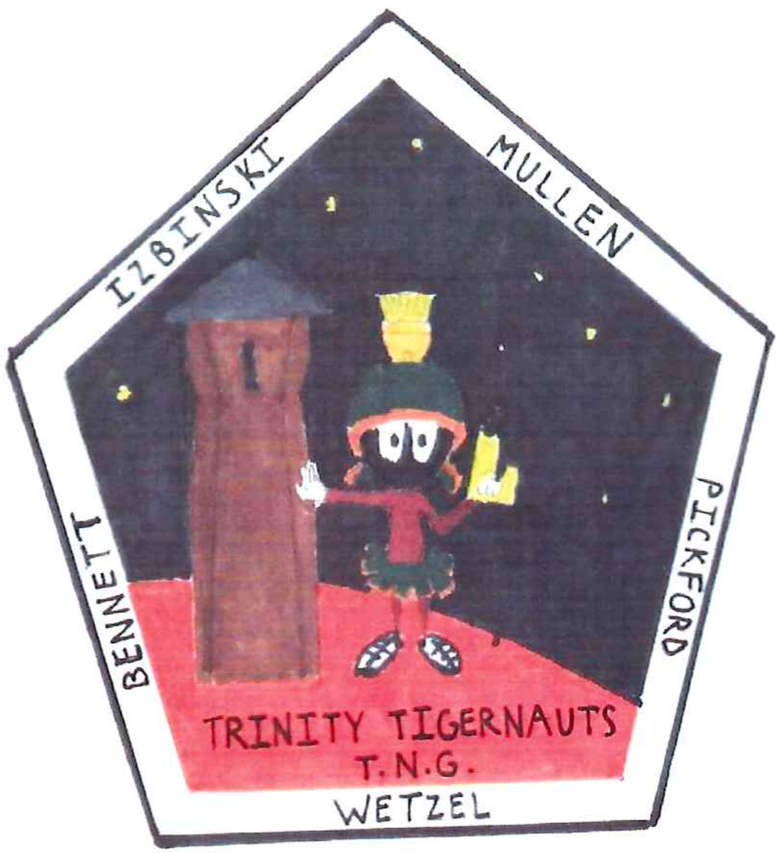

Figure 10: The Trinity Tigernauts T.N.G. team patch.

C Budget Report

TEXAS SPACE GRANT CONSORTIUM
DESIGN CHALLENGE

BUDGET REPORT
FALL 2004

INST	Trinity University	LEADER LAST NAME	Trinity Tigernauts T.N.G.

Teams are required to provide a Budget Report as an Appendix to each of the required reports for Level I [FDPP/SOW], II [mid-term] and III [final report]. The Budget Report will provide an overview of team expenditures for the time period preceding report submission. Ideally, it will help the team keep its budget in check.

COMPLETED	LEVELS @ $125 ea	OPTION AREAS @ $125 ea	TRAVEL OPTION / GRANT @ $500	BONUS @ $400
	☒ I ☒ II ☒ III	☐ I ☐ II ☐ III	☐ IV ☐ GRANT	☐ YES

TEAM EARNINGS TO DATE	$375.00	TEAM EXPENSES TO DATE	$392.21
		FUNDS REMAINING	$-17.21

REPORT TIME PERIOD COVERED: ☐ I FDPP /SOW ☐ II Mid-term ☒ III Final Rpt

ITEM NAME	USE	RECPT?	COST
Trip Expense - CSR	Transportation, Team Dinner	☒	$155.81
Trip Expense - JSC	Transportation, Meals, Parking, Space Center Houston Admission, Toll Road Fares	☒	$236.40
		☐	$
		☐	$
		☐	$
		☐	$
		☐	$
		☐	$
		☐	$
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		☐	$
		☐	$
		☐	$
		☐	$
		☐	$
		☐	$
		☐	$
		TOTAL FOR THIS REPORT	$392.21

Was the available funding adequate for team's project needs during this period?	☐ YES ☒ NO

BUDGET REPORT
FALL 2004

D Trip Reports

D.1 Center for Space Research Trip

On October 6, 2004, the Trinity Tigernauts T.N.G. visited the Center for Space Research in Austin, Texas. The team traveled to Austin to be briefed by Dr. Humboldt Mandell on the Johnson Space Center and Baker Hughes, Inc. Mars drill. Previous to the trip, the team understood very little concerning the construction and functionality of the drill, making the design process near impossible. Dr. Mandell was able to explain the workings of the drill as well as the work done by previous design groups in detail, which was very valuable to the progress of the project. The team has since formed a design solution which will be compatible with the current drill specifics. The field trip to Austin also gave the team a chance to meet Dr. Mandell, which will be valuable to the rest of the project.

The total distance travelled for the trip to the Center for Space Research from Trinity University was 186 miles. Including gas and car mileage, the transportation for the trip totaled $69.75. After the briefing, the team went to dinner at Cozymel's Mexican Grill as a team bonding experience. The total cost of dinner for all five team members was $86.06 and a copy of the receipt is attached. The total field trip cost the team $155.81.

Figure 11: Team members with Debbie Mullins

TEXAS SPACE GRANT CONSORTIUM
DESIGN CHALLENGE

TEAM TRIP REPORT

FALL 2004

INST	Trinity University	TEAM NAME	Tigernauts T.N.G.

A *Team Trip Report*, detailing actual circumstance and expenses associated with team travel undertaken during the semester, must be completed and attached as an Appendix to the appropriate Level report submission. Note that this report is for TSGC record purposes only; and does constitute a request that reimbursement be made. The team will submit a *Request for Travel Reimbursement*, with receipts, through the team's institution for reimbursement.

REPORT PERIOD	☐ LEVEL I	☒ LEVEL II	☐ LEVEL III

TRIP # 1	**DESTINATION: Austin, Texas**		
❑ **Dates of Travel**	From: October 6	To: October 6	
❑ **Method of Transportation**	☒ Private Car ☐ Rental Car	☐ Air ☐ Other	
❑ **Purpose of Travel**	Visit TSGC Mentor at The Center For Space Research		
❑ **Travelers**	Jeff Bennett	☒ Student ☐ Faculty ☐ Other	
# 5	Konrad Izbinski	☒ Student ☐ Faculty ☐ Other	
	Eric Mullen	☒ Student ☐ Faculty ☐ Other	
	Michael Pickford	☒ Student ☐ Faculty ☐ Other	
	Lindsay Wetzel	☒ Student ☐ Faculty ☐ Other	
		☐ Student ☐ Faculty ☐ Other	
		☐ Student ☐ Faculty ☐ Other	
		☐ Student ☐ Faculty ☐ Other	
		☐ Student ☐ Faculty ☐ Other	

❑ **Actual Expenses**	$	for	Accommodations	☐ Receipt
Total $155.81	$69.75	for	Transportation 186 miles round trip	☐ Receipt
	$86.06	for	Meals [Cozumel's]	☐ Receipt
	$	for	Parking	☐ Receipt
	$	for		☐ Receipt
	$	for		☐ Receipt
	$	for		☐ Receipt
	$	**TOTAL TRIP EXPENSES**		
	Notes:			

❑ **Description below.**   ☒ **Photo attached.**

Teams are encouraged to take and submit photographs during episodes of team travel.

D.2 Johnson Space Center Trip

The Trinity Tigernauts T.N.G. took a day field trip to the Johnson Space Center to meet with the Mars drill engineering design team. The Tigernauts were able to see a demonstration of the current Mars drill prototype as well as gain a better understanding of plans for future prototypes. The NASA design team was very helpful in answering all questions and was able to provide the team with valuable information concerning the drill specifics. The field trip was very important to the group in finalizing a design solution for the core removal process.

After the day at JSC, the group had the opportunity to have a nice lunch together at BJ's Restaurant and Brewary. Dr. Nickels and Mark then spent the rest of the day visiting the Space Center Houston. The group only had one small problem during the visit. The admission tickets to the Space Center Houston were supposed to be half price for all the TSGC design teams in attendance. However, when Dr. Nickels and Mark tried to purchase the tickets at this price, they were only being sold in packages of 20, and as a result, full price was paid. This was not a major problem, but the team felt that it should be noted.

Figure 12: Team members with Jeff George at NASA's Johnson Space Center.

TEXAS SPACE GRANT CONSORTIUM
DESIGN CHALLENGE

TEAM TRIP REPORT

FALL 2004

INST	Trinity University	TEAM NAME	Trinity Tigernauts T.N.G.

A *Team Trip Report*, detailing actual circumstance and expenses associated with team travel undertaken during the semester, must be completed and attached as an Appendix to the appropriate Level report submission. Note that this report is for TSGC record purposes only; and does constitute a request that reimbursement be made. The team will submit a *Request for Travel Reimbursement*, with receipts, through the team's institution for reimbursement.

REPORT PERIOD	☐ LEVEL I	☐ LEVEL II	☒ LEVEL III

TRIP # 2	DESTINATION: Johnson Space Center - Houston, TX			
❑ Dates of Travel	From:	10/21/04	To:	10/22/04
❑ Method of Transportation	☒ Private Car ☐ Rental Car		☐ Air ☐ Other	
❑ Purpose of Travel	Field Trip to Johnson Space Center to meet with Mars drill Design Team			

❑ Travelers	Dr. Kevin Nickels	☐ Student ☒ Faculty ☐ Other
# 7	Mark Nickels	☐ Student ☐ Faculty ☒ Other Advisor's son
	Lindsay Wetzel	☒ Student ☐ Faculty ☐ Other
	Eric Mullen	☒ Student ☐ Faculty ☐ Other
	Michael Pickford	☒ Student ☐ Faculty ☐ Other
	Konrad Izbinski	☒ Student ☐ Faculty ☐ Other
	Jeffrey Bennett	☒ Student ☐ Faculty ☐ Other
		☐ Student ☐ Faculty ☐ Other
		☐ Student ☐ Faculty ☐ Other

❑ Actual Expenses	$$0.00	for	Accommodations	☐ Receipt
Total $236.40	$$90.50	for	Transportation (Gas - two cars)	☒ Receipt
	$$122.00	for	Meals [BJ's Restaurant and Brewery, Burger King, Willie's Grill and Icehouse]	☒ Receipt
	$$4.00	for	Parking (Space Center Houston)	☒ Receipt
	$$16.15	for	Johnson Space Center Admission Tickets	☒ Receipt
	$$3.75	for	Toll Road Fares	☒ Receipt
	$	for		☐ Receipt
	$	TOTAL TRIP EXPENSES		
	Notes:			

❑ Description below. ☒ Photo attached.