Penetrometer: Group 18

Deliverable Name: Project Plan and Product Specification

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Authors: Carren Brown (Mechanical Engineering), Peter Hettmann (Mechanical Engineering), Sean Kane (Electrical Engineering), Natalie Marini (Mechanical Engineering), Mitchell Robinson (Electrical Engineering), and Maritza Whittaker (Mechanical Engineering)

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Abstract

In the project plan and product specification report, Team 18 covers the research, design and performance specifications, and the scheduling of the overall project. By researching penetrometers, it is found that they are mostly used for testing soil compaction. This project entails creating a penetrometer that can determine actual soil type so archeologists at the National Park Service can identify midden or archeological remains in the ground. Midden is soil that contains domestic waste and artifacts of past human occupation. NPS requires that the penetrometer is portable and weighs under 50 pounds, wireless and can relay the information back to an Android device, and it must reach depths upwards of 25 feet. The finished project should successfully be able to tell an archeologist in the field whether or not there is midden and how deep the midden reaches.

In order for this project to take place in an efficient and flowing manner, a Gantt chart was created as seen in the appendix. This Gantt chart includes the class requirements, staff meetings, and the tasks the team has identified themselves in order to break down the project into manageable stages. Following this method along with each individual's assigned area of the project to focus on should result in a successful project and a good learning experience. As seen in the schedule, the team will proceed from this report to present the project and then move into the design face of the final design. Each member will be contributing to the project's success.

1 Introduction

The objective of this project is to design and build an instrument that can identify midden in remote locations and differentiate soil types at various depths. The prototype must be relatively lightweight, have strength in compression, and be portable. The penetrometer was originally used as an agricultural tool to determine the soil compaction, which helped farmers decide if the soil could be used for crop production. Due to varied results from site to site, a standard design of the penetrometer was developed. Archeologists use penetrometers to locate soil midden levels as well as determine how deep it runs below the ground. This information can assists archeologists in verifying if there is organic material present at the test site. Team 18 will develop a prototype of a penetrometer that is portable, wireless, and easy to use in the field. This penetrometer prototype will determine the type of soil by calculating the friction coefficient of the soil. The prototype should produce reliable data that can be transmitted to a handheld device.

In order to stay on task, the team will develop a Gantt chart that will be updated throughout the semester. Certain members in the team will have different areas to focus on in order to successfully manage and complete the team's goals and tasks at hand. Staff and group meetings will be held weekly and biweekly to keep everyone involved.

2 Project Definition

2.1 Background research

A penetrometer is a basic force instrument in design and simple in use. However, it cannot be effectively used by a novice for precise results. Originally, a penetrometer was used by agricultural personnel for penetration of the ground soil on several acres of land to determine the soil compaction and how viable the soil will be for crop production. Before a standardized penetrometer, results could vary from farm to farm and with different surveying teams. Depending on the varying level of experience by the surveying team, these results can either be interpreted as good or bad soil results. To account for this inexperience during surveying of the ground, calculations will be used to be unbiased in the testing of the soil composition and compaction before any ground comparisons need to be done via a computer.

The standard design of a penetrometer was adopted by the American Society of Agricultural Engineers in 1999 and with this standard design the comparison of data across a wide range of locations could be compared and used for soil compaction. This design calls for a 30 degree cone angle and the use of a 1/2 inch or 3/4 inch base cone. These dimensions more closely resemble a root growing and penetrating the ground as it grows and with certain ground compaction can yield higher or lower crop turn out. [1]

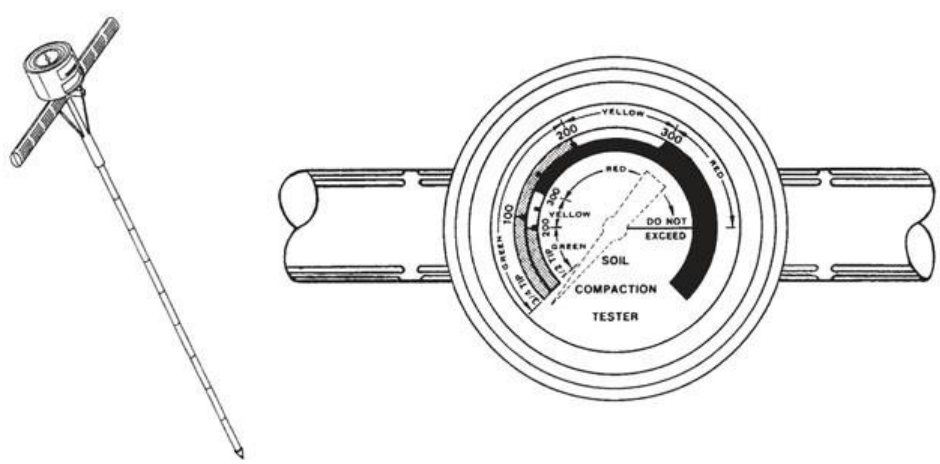

Figure 1. Standardized Penetrometer Design[2]

In the field of archeology, soil compaction and composition can save a lot of time and money from large excavation digging to uncover important soil types shallow or deep underneath the top soil. A penetrometer is being used to detect the location of midden, which is archeological soil type produced from decomposed artifacts that were tossed into the environment during the time of population in that certain location. The used method to determine the midden is a basic T-bar penetrometer that has several extendable rods that can allow for several meters of distance to map the location and depth of midden. When used by an experienced surveying team, the midden can be located based on the "feel" of the midden soil type as the compaction and compression is different than the surrounding soil types. This feel can be misinterpreted by an inexperienced surveyor and the data collected could be wrong. To account for this inexperience, load cells can be used along with a computer program to determine the depth and soil types.

One method closely related to our approach on the penetrometer is the cone penetrometer test (CPT) which incorporates an electronic friction cone and piezocone penetrometer. When used to test the soil composition and compaction, a computer logs the values from the cone and friction sleeve and uses the ratio to determine if the soil is suitable for use. Using this same concept of separating load cells to determine the friction ratio, archeological dirt can be determined several meters under the topsoil without digging several holes. The surveying team using the device with not need a high level of experience as the data collected will be based on calculated values to determine the actual soil that is being penetrated. [3]

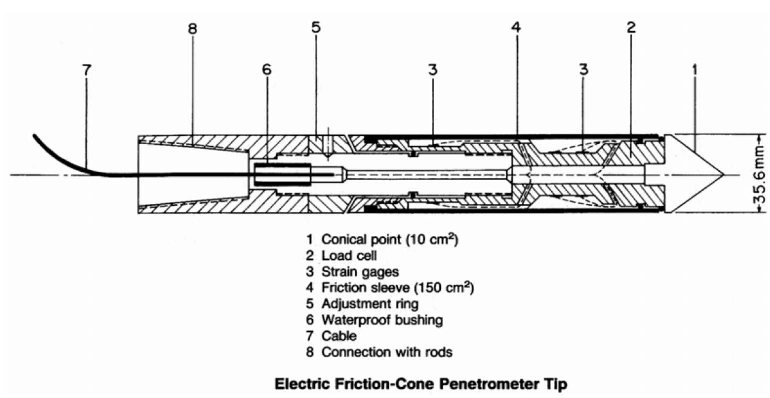

Figure 2. Electric Components of the Penetrometer Tip[3]

2.2 Need Statement

As an extension of the 2013-2014 senior design project, it is the object of Team 18 to redesign a penetrometer which will detect midden levels in the soil present at the Southeast Archeological Center & National Park Services' field testing site. This penetrometer will have portable and wireless capabilities in order to properly distinguish the type of soil present below the ground. It has been established that the sponsor is looking for a more reliable and easier-to-use system than the prototype designed by the previous senior design project. Currently, this year's project has been to redesign last year's design project. Team 18 has taken the prototype out into the field at the National Park Services' testing site. However, upon the first day of field testing, the epoxy failed and the tip of the penetrometer no longer took input readings. With the failed prototype as an example, Team 18 has gathered much information as what not to do with this year's design.

"It is difficult to distinguish soil midden levels apart from other organic and mineral soil levels when field testing on site."

2.3 Goal Statement & Objectives

Goal Statement: "Design an instrument that can identify midden and differentiate soil types at various depths."

Objectives:

- Must be able to identify midden levels in remote locations.
- Must weigh less than 50 lbs.
- Must be able to reach depths past 20 feet.
- Should wirelessly display results to a handheld device.
- Device should be very portable.
- Weight should be minimized.

3 Constraints

Listed below are the constraints placed on the design. If a design does not meet the listed constraints, the design will not be considered.

- The prototype design must be easy to use.
- The prototype must be able to be used by one person in the field, without assistance.
- The diameter of the prototype must be small enough for the device to penetrate the ground easily.
- The material of the prototype must be strong enough for the device to penetrate the ground without fracturing.
- The prototype design must be able to determine the location of midden and how deep the midden runs.
- The prototype design must be wireless, allowing it to be portable.
- The weight of the prototype must not exceed 50 pounds.
- The data from the device must be reliable.
- The prototype design must allow for wireless data transmission to a handheld device.
- The total cost must not initially exceed $2,000.
    - The sponsor is able to expand the budget if it is deemed necessary by the team and the advisor.

3.1 Design Specifications

Below are the design specifications for the penetrometer device. The first section includes the mechanical specifications; the second section covers the electrical portion. The mechanical specifications come from the sponsor, Dr. Russo from National Park Services, the American Society of Agricultural Engineers, and the Senior Design team.

3.1.1 Mechanical Design Specifications

- National Park Services – Desired penetrometer dimensions
    - Capable of reaching 20 – 25 feet of depth in the soil.
    - Weighing less than 50 lbs. of total weight.
    - Standard diameter of the penetration rod and cone.

    - All in one compartment housing: battery, multi-meter, transmitter to wireless device and load cells.
    - T – bar handle for manual work and force applied.
    - Low power consumption for all day use.
- American Society of Agricultural Engineers - Standard Penetrometer Dimensions
    - ½ and ¾ inch diameter of rod.
    - 30° and 60° angle of penetration cone.
- Senior Design – Penetrometer Design Specifications
    - Multiple extension rods each at 3 feet of length.
    - Load cells capable of handling 300 lbs. of direct force.
    - Easy access housing for protection of multi-meter devices, Bluetooth transfer and data acquisition, and load cells.

3.1.2 Electrical Design Specifications

A 10 Volt rechargeable battery will supply power to two load cells. The 10 Volt battery will be chosen based upon a power analysis of the system. Several batteries will be researched and a specification matrix will be created to select the best option.

The output voltage of the load cells will be measured using a data acquisition device with Bluetooth capabilities. The battery along with the data acquisition device will be enclosed in a weatherproof housing to protect from rain, dirt, or any other factor that may affect the performance of these devices. The data acquisition device should be able to measure the output voltage from the load cells in the millivolt range. This data will be sent to an Android device running an application developed by the team to display and interpret the results in real time.

A laser range finder that also has Bluetooth capabilities will measure the depth that the penetrometer travels into the ground. Similar to the data acquisition device, the data from the laser range finder will be displayed on the Android device running the developed application.

Figure 3 illustrates a block diagram of the electrical design specifications.

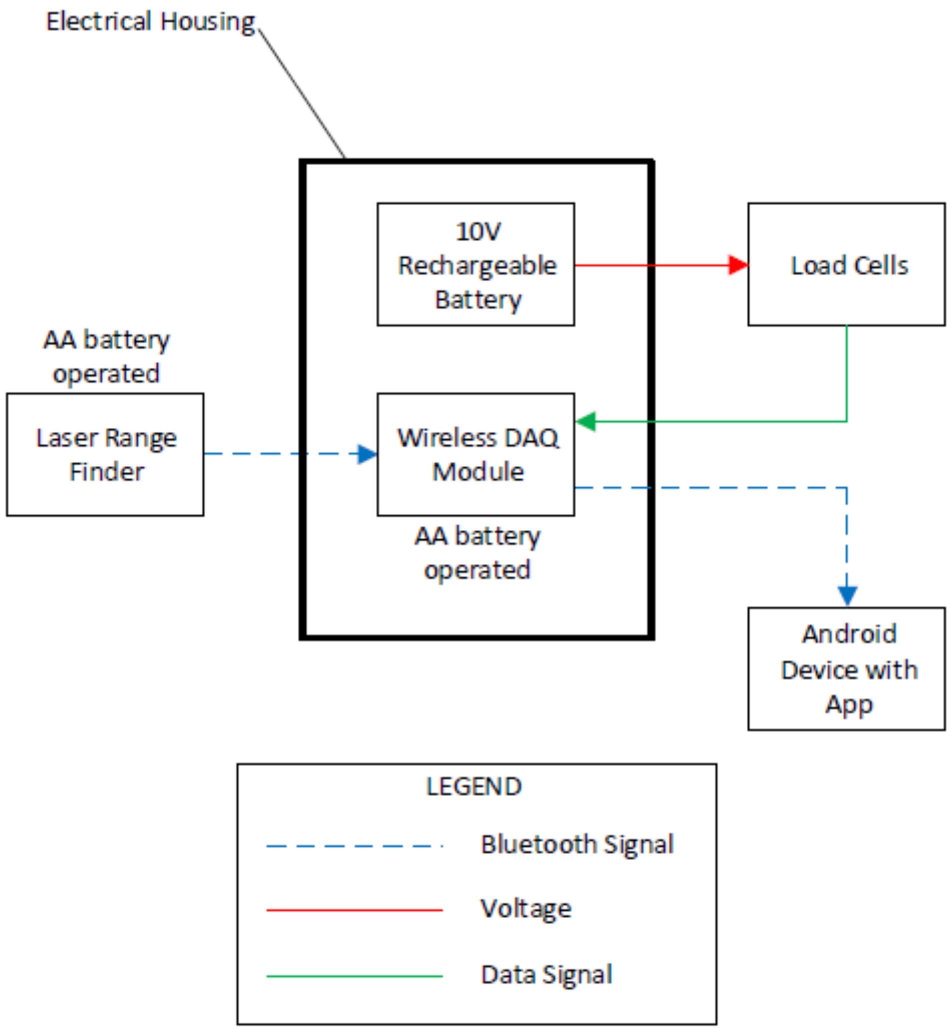

Figure 3. Block Diagram of Electrical Design Specifications

3.2 Performance Specification

Currently, the method archeologists use to locate midden is not an exact science. Archeologists use a T-bar static penetrometer to probe the ground and feel for the difference in the layers of soil. The device being designed must be more accurate and more precise than an archeologist with 20 years of experience in the field. This will eliminate any human bias and error present within the current method. The penetrometer device will be used by 1-2 people in the field on a daily basis. Therefore, the batteries used to power the device will last 8-9 consecutive hours, which is equivalent to one typical work day. These batteries will be rechargeable, and multiple can be taken to the work site to be interchanged when one battery dies. The device will not require more than 10 Volts. The material and diameter of the shaft will keep any bending or fracturing to a minimum. This is important because the device will be under repetitive compressive loads, and major repairs cannot be done in the field. The friction cone tip will be easily replaceable for quick, minor repairs in the field. The penetrometer will be able to reach at least 20-25 feet (6.1-7.6 meters) into the ground. The 3-foot (0.9 meters) extensions will be added to achieve this depth. The load cells inside the device will measure the friction coefficient of the soil and will correlate that to the type of soil present. The type of soil will be displayed on the handheld wireless tablet. The gathered data will also be displayed on the screen in a graphical or tabulated form.

4 Methodology

To begin the project, the team will research existing penetrometer designs that are relevant to the project. The team shall also review the progress made on the project by last year's team; this includes reviewing their reports and testing their prototype. The team will then determine the range of values that need to be read by the device, based upon the wants of the sponsor. The team shall also discuss with the sponsor what he would prefer in the design for performance, reliability, and portability. Simultaneously, the team will explore various wireless data acquisition components and charging methods that could possibly be used in the design. After extensive research has been done, the team will develop and evaluate multiple ideas. The cost of materials shall be estimated for each design. Then, the team will create a decision matrix in order to compare all designs without bias. A final design shall be chosen from this matrix.

After the design has been validated, the team will simulate the design using a computer program. Final decisions on the type and cost of materials will be made. This will all be discussed with the sponsor in order to obtain his approval. After obtaining approval, materials and equipment will be purchased and the prototype will be constructed. After the construction is complete, the prototype will be tested in the field, and the test data will be analyzed, with the assistance of the sponsor. After the test performance and results have been analyzed, the team will reevaluate the design and decide upon any necessary or desired changes to the prototype. This may include, but is not limited to, multiple improvements and partial redesign. After these changes have been decided upon, the final prototype shall then be built and test in the field, in the same manner as the previous prototype. Again, the team will discuss the performance and results with the sponsor. If the sponsor approves the prototype, the team will compose the final report of the project and present the final model to the sponsor and advisor, and at the open house event in April 2015.

4.1 Schedule

After much discussion and planning, a detailed schedule was created to ensure that Group 18 stays on task and up to date on the project's needs. Included in the Gantt chart which can be found in the appendix are three different categories of tasks. They include class deliverables which is what the team actually has to submit for grading and evaluation, team deliverables which are tasks that the team has discussed would help us reach our goals and milestones, and there is also a category for our staff and sponsor meetings. The class deliverables are in red, the team deliverables are in green, and the meetings are shown in blue. Each task has been assigned specific team members that will help to complete the tasks goals. Some tasks such as the Needs Assessment included everyone in the team, but others are more specific to team member's roles in the group. As a deliverable comes closer, more detail will be added in subcategories as to who is doing which part of the task at hand. Having this detailed schedule will ensure we have a clear path on what is to be done at all times. Changes will be made throughout the semester as new tasks arise and members shift into the roles they feel comfortable in.

4.2 Resource Allocation

Throughout this project, allocated roles will be given to each team member. It can be seen in the table above which specific team member will be assigned to each task throughout the semester. As a whole, it has been decided by the team to work on each deliverable in equal amounts. However, both Sean and Mitchell have the specific tasks of completing any electrical aspect of the project while it is Carren, Peter, Natalie and Maritza's role to complete the mechanical aspects of this project.

As mentioned in the code of conduct, Natalie Marini was allotted the role of Team Leader. This means that she is responsible for enforcing deadlines, keeping team members on task, and developing a plan for optimal project completion. All documents will be finalized and approved by the team leader. She is responsible for communicating effectively between the team members, faculty advisor, and team sponsor. Therefore, she will have the majority of the responsibility of each task that is presented in the Gantt Chart. (see appendix)

Peter Hettmann was chosen as Team Treasurer, meaning that he must maintain all records of purchases from the project account and a copy of all receipts. Purchasing information and analysis of the budget before purchasing is the treasurer's appointed job. He will be presented with the majority of the responsibility of any and all money-related issues.

Carren Brown is the team's Ambassador. This includes the responsibility of maintaining correspondence between the ME team members and the ECE team members. She will also coordinate all meetings with team members and keep the group calendar updated with meeting times, due dates, and presentations.

Maritza Whittaker is the team's Secretary and Webmaster. It is her responsibility to serve as the main record keeper and email correspondent. She is to correspond emails between the team and sponsors/advisors/professors throughout the design project. The secretary is also responsible for keeping a record of all meeting minutes and noting what was accomplished during the meeting. As the Webmaster, she is to maintain and run the team's website throughout the design project. She will be responsible for any and all allocated tasks pertaining to the website.

Sean Kane and Mitchell Robinson are the ECE liaisons. They must ensure that ECE tasks are completed on time, responsible for keeping all documentation that pertains to the electrical aspect of the project, and maintains communication with the ME team leader, ECE Coordinator, and ECE Advisor of the project.

Each team member must effectively communicate the thoughts and ideas beneficial to the project as well as stay up-to-date on material and goals of the project. It was the consensus of the entire group to consistently help one another whenever another may deem fit.

Table 1. Assigned Tasks List for Team 18

Category	Task Name	Duration	Start	Finish	Resource Names
ME Deliverable	Needs Assessment	5 days	Sat 9/20/14	Thu 9/25/14	Carren Brown, Maritza Whittaker, Natalie Marini, Peter Hettmann, Sean Kane
Team Meeting	1	1 day	Tue 9/30/14	Tue 9/30/14	Carren Brown, Maritza Whittaker, Mitchell Robinson, Natalie Marini, Peter Hettmann, Sean Kane
Team Meeting	2	1 day	Tue 10/28/14	Tue 10/28/14	Carren Brown, Maritza Whittaker, Mitchell Robinson, Natalie Marini, Peter Hettmann, Sean Kane
Team Meeting	3	1 day	Tue 11/11/14	Tue 11/11/14	Carren Brown, Maritza Whittaker, Mitchell Robinson, Natalie Marini, Peter Hettmann, Sean Kane
ME Deliverable	Project Plans and Product Specs	11 days	Fri 9/26/14	Fri 10/10/14	Carren Brown, Maritza Whittaker, Mitchell Robinson, Natalie Marini, Peter Hettmann, Sean Kane
ME Deliverable	Midterm Presentation I	7 days	Mon 10/6/14	Tue 10/14/14	Carren Brown, Natalie Marini, Sean Kane
ME Deliverable	Midterm Report I	9 days	Tue 10/14/14	Fri 10/24/14	Carren Brown, Maritza Whittaker, Mitchell Robinson, Natalie Marini, Peter Hettmann, Sean Kane
Team Deliverable	Initial Web Page Design	2 days	Mon 10/6/14	Tue 10/7/14	Maritza Whittaker
Team Deliverable	Rough Draft of Webpage	6 days	Fri 10/17/14	Fri 10/24/14	Maritza Whittaker
ME Deliverable	Final Web Page Design	28 days	Fri 10/17/14	Tue 11/25/14	Maritza Whittaker
ME Deliverable	Peer Evaluation	1 day	Tue 10/28/14	Tue 10/28/14	Carren Brown, Maritza Whittaker, Mitchell Robinson, Natalie Marini, Peter Hettmann, Sean Kane
ME Deliverable	Midterm Presentation II	11 days	Tue 10/28/14	Tue 11/11/14	Maritza Whittaker, Mitchell Robinson, Peter Hettmann
ME Deliverable	Peer Evaluation	1 day	Tue 11/25/14	Tue 11/25/14	Carren Brown, Maritza Whittaker, Mitchell Robinson, Natalie Marini, Peter Hettmann, Sean Kane
ME Deliverable	Final Design Presentation	6 days	Tue 11/25/14	Tue 12/2/14	Carren Brown, Maritza Whittaker, Mitchell Robinson, Natalie Marini, Peter Hettmann, Sean Kane
ME Deliverable	Final Report	9 days	Tue 11/25/14	Fri 12/5/14	Carren Brown, Maritza Whittaker, Mitchell Robinson, Natalie Marini, Peter Hettmann, Sean Kane
Team Meeting	Design Discussion with Sponsor	1 day	Tue 10/14/14	Tue 10/14/14	Natalie Marini
Team Deliverable	ProE Designs	11 days	Mon 10/6/14	Mon 10/20/14	Natalie Marini, Peter Hettmann
Team Deliverable	EE Design Drawings	11 days	Mon 10/6/14	Mon 10/20/14	Mitchell Robinson, Sean Kane
Team Deliverable	Material Selection	14 days	Tue 10/28/14	Fri 11/14/14	Carren Brown, Maritza Whittaker, Natalie Marini, Peter Hettmann
Team Deliverable	Budget Summary	14 days	Tue 10/28/14	Fri 11/14/14	Peter Hettmann
Team Deliverable	Purchasing of all Materials and Parts	17 days	Fri 11/14/14	Mon 12/8/14	Natalie Marini, Peter Hettmann
Team Deliverable	Machining of Parts	7 days	Wed 12/3/14	Thu 12/11/14	Carren Brown, Maritza Whittaker, Natalie Marini, Peter Hettmann
Team Deliverable	Construction of Design	7 days	Wed 12/3/14	Thu 12/11/14	Carren Brown, Maritza Whittaker, Mitchell Robinson, Natalie Marini, Peter Hettmann, Sean Kane
Team Deliverable	Testing and Evaluation	16 days	Thu 1/8/15	Thu 1/29/15	Carren Brown, Maritza Whittaker, Mitchell Robinson, Natalie Marini, Peter Hettmann, Sean Kane
Team Deliverable	Analysis on Tested Results	6 days	Thu 1/29/15	Thu 2/5/15	Carren Brown, Maritza Whittaker, Mitchell Robinson, Natalie Marini, Peter Hettmann, Sean Kane
Team Deliverable	Redesign (if necessary)	11 days	Thu 2/5/15	Thu 2/19/15	Carren Brown, Maritza Whittaker, Mitchell Robinson, Natalie Marini, Peter Hettmann, Sean Kane
Team Meeting	Testing at site with Sponsor	1 day	Thu 3/5/15	Thu 3/5/15	Carren Brown, Maritza Whittaker, Mitchell Robinson, Natalie Marini, Peter Hettmann, Sean Kane
ME Deliverable	Reporting Final Results	14 days	Thu 3/5/15	Tue 3/24/15	Carren Brown, Maritza Whittaker, Mitchell Robinson, Natalie Marini, Peter Hettmann, Sean Kane

5 Conclusion

The goal of Team 18 is to successfully build a functioning penetrometer that can work within all the constraints provided by the sponsor. The penetrometer is to measure midden (archeological remains) and report back to the user how deep the midden appears and where it is located. Design specifications from the sponsor include having a penetrometer that can reach depths upwards of 25 ft, the penetrometer must weigh less than 50 pounds, it must have low power consumption, and it must be a T-bar device that is user-friendly. The electrical design specifications include researching a rechargeable battery to supply power to the load cells used to take the readings as well as find a Bluetooth data acquisition device that is able to transmit data to an android device. Following the design specifications, the performance specifications include designing a penetrometer that only requires one or two people to operate, it can be used continuously for 8 to 9 hours, it has minimum bending in the device due to repetitive compressive loads, all of the parts must be replaceable, and extensions would be preferred so the device can easily reach great depths.

Team 18 wishes to complete their goals to the best of their ability and this causes for detailed scheduling. The team collectively discussed goals and broke up the goals into smaller tasks. This information was all combined into a Gantt chart that shows the Team's plan to meet the class deliverables, the team deliverables, and how often the Team needs to keep up to date with our sponsor and mentors. Each member of the team will be utilized to the best of their ability and will be assigned an area of the project to focus on. Future work will be organized, well scheduled, and the Team will be moving into the design phase within the next two weeks.

6 References

1 Fee, Rich. "Soil Penetrometers." Probing for Compaction (2005). Successful Farming. Web. 25 Sept. 2014. <http://www.specmeters.com/assets/1/7/soil_penetrometers.pdf>.

[2] McCauley, Amy, and Clain Jones. "Water and Solute Transport in Soils." Soil and Water Management. Montana State University, 1 Jan. 2005. Web. 26 Sept. 2014. <http://landresources.montana.edu/SWM/PDF/final_SW4_proof_11_18_05.pdf>.

[3] "NOTES on the CONE PENETROMETER TEST." Web.mst.edu. Advanced Engineering Geology & Geotechnics, 1 Jan. 2004. Web. 25 Sept. 2014. <http://web.mst.edu/~rogersda/umrcourses/ge441/Cone Penetrometer Test.pdf>.

8. Appendix

Figure 4. Gantt Chart for Team 18