Penetrometer: Group 18

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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 Midterm I paper, Team 18 discusses the research, design and performance specifications, decision matrix and 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 weigh less than 50 pounds. It is also important that the design be wireless with capabilities of relaying the information back to an Android device. It has been asked by NPS that the penetrometer reach depths upwards of 25 feet. The finished project should successfully identify to an archeologist on site whether or not there is midden present. In order for this project to take place in an efficient and flowing manner, a Gantt chart was created as seen in the appendix. The team also provided a decision matrix for the possible options for design and discusses the criteria of choosing the most reasonable and reliable design of the device.

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. The team will implement a decision design matrix in order to properly choose the most reliable design for the National Park Services.

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]

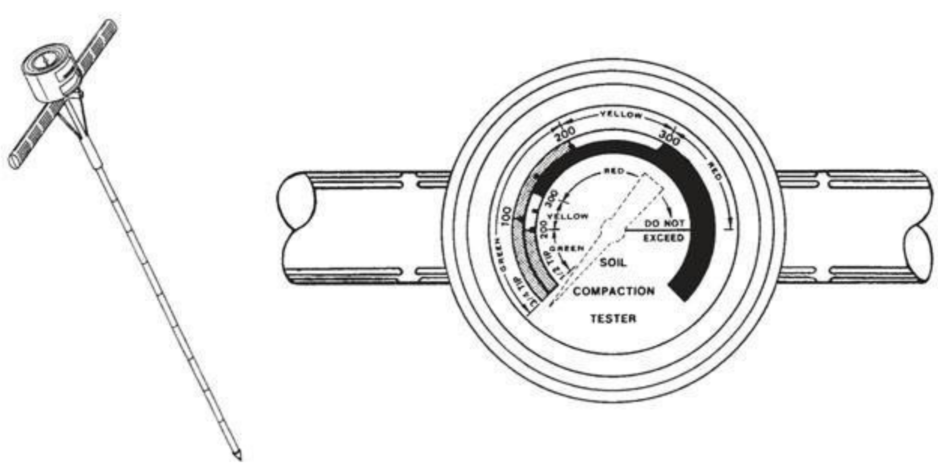

Figure 1. Standardized Penetrometer Design[2]

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]

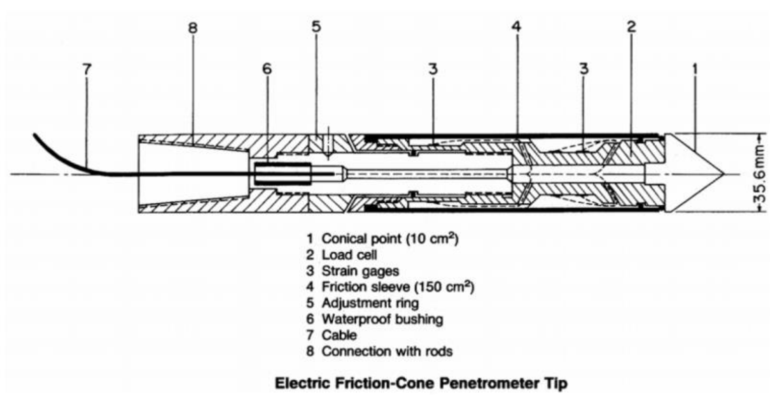

Figure 2. Electric Components of the Penetrometer Tip[3]

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.

2.4 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 Design and Analysis:

3.1 Functional Analysis

Penetration Shaft

The penetration shaft is one of the most important components of this device. While the shaft penetrates the ground, it will be exposed to debris, rocks, and shells in the soil. The shaft must be strong enough to withstand the applied load that will force it into the ground, and also must not fracture while breaking through shells or rocks. The load cells or strain gauges will be placed either on the bottom of the penetration shaft or in a housing near the handle. If extensions are added while using the penetrometer, they will be added between to the top of the penetration shaft.

Load Cells

Load cells are measuring devices that create an electrical signal directly proportional to the force being applied to the cell. In this project's application, load cells can potentially be used to measure the load applied to the soil. When measuring the results with two load cells in a friction sleeve, the friction of the soil can hypothetically be found. This will enable the penetrometer to identify what type of soil it is penetrating into. Last year's design group attempted to use load cells but ran into trouble due to the size of the cells. If smaller, more accurate cells can be found, load cells can prove to be very valuable to the success of this project.

Strain Gauges

A strain gauge consists of a backing and metallic foil that is insulated by adhesive material such as cyanoacrylate. The strain gauge is fixed to the surface of the material that is experiencing strain and as the material deforms the strain gauge deforms with the material and this change in resistance is measured using a Wheatstone bridge. As the strain gauge is deformed in the vertical or horizontal direction, the internal conductance of the foil will stretch or be compressed and this allows for a difference in voltage to be measured in the Wheatstone bridge configuration. In this configuration the four resistors must be matched while at equilibrium and by changing each resistor with the exact same resistive strain gauge the sensitivity and accuracy of the Wheatstone bridge will increase and be able to measure more strain to the specimen.

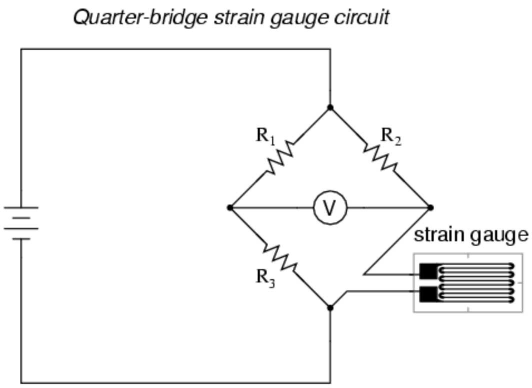

Figure 3. Wheatstone Bridge Configuration

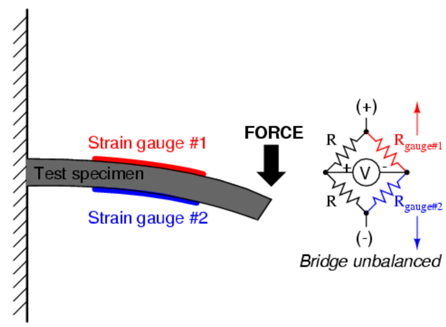

Figure 4. Force Displacement

For the needed friction coefficient being calculated for in field testing, two separate but comparable voltages must be read: one due to the impact force from the load striking the rod and one measurement from the ground reactive force. To be able to accurately measure the strain being produced on the rod, a four strain gauge Wheatstone bridge will be explored, with each strain gauge 90 degrees from each other on the strained rod. As the weight impacts the center rod, the rod will deflect slightly due to the force and material type and this deflection will be measured by the strain gauges attached to the rod. In order for the rod to experience a deflection, a slight clearance will have to be calculated so the rod will deflect due to the force. This voltage will be taken as the control and compared to the later voltage from the secondary Wheatstone bridge. On the other end of the rod, the cone will have a force applied to it that is near identical to the force struck at the top and the cone will penetrate the ground. As the cone penetrates the ground the rod will experience a deflection due to the compaction of the soil. If the soil is softer, dirt or soft sand, the cone will have less resistance, have a lower deflection, and less voltage will be created from the Wheatstone bridge. If the ground is hard, clay or shells, the cone will experience a high resistance to penetrating the ground. The force being measure will almost be equal to the applied force. This difference in the voltages will be used to determine the separation of soil compaction types and their depths below the top soil.

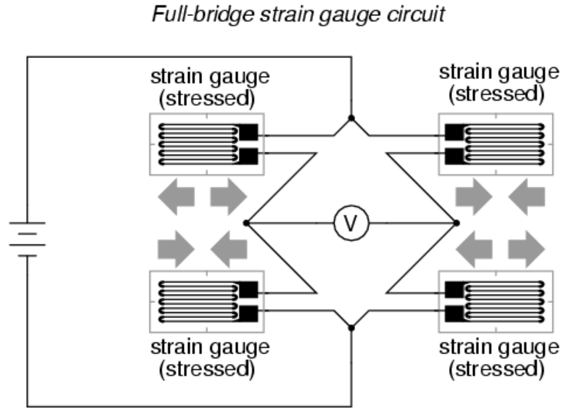

Figure 5. Strain Gauge Circuit

For the strain gauge design, the strain deflection of the material can be in either the horizontal direction or the vertical direction. These two directional deflections will be explored in design C and design D below. The bottom strain gauge reads the penetration cone at the bottom of the rod. The two diagrams below show the two different methods that can be explored, the top force applied will be from the drop weight that will be a constant force and the applied force for the bottom elastic material will be from the penetration cone and given the compaction of the soil this will yield a different force to the strain gauges.

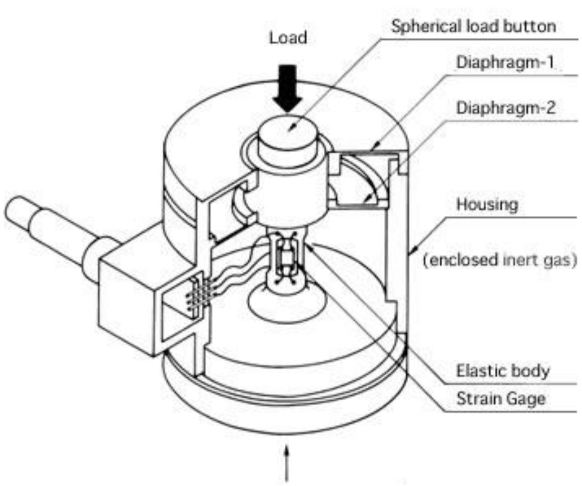

Figure 6. Stain Gauge Configuration

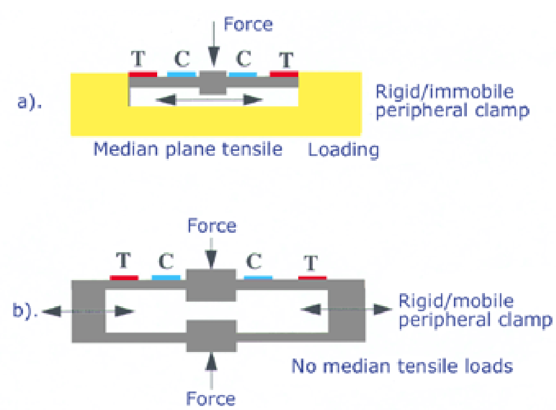

Figure 7. Strain Gauge Loading Displacement

Penetration Method

Two methods of penetration are currently being considered. The first method is manual penetration using a T-bar handle. This is the type of penetrometer the sponsor currently uses. The user would repetitively force the device into the ground using his or her own body weight. The current use of this method is not an exact science; the user will “feel” for changes in the soil when using a T-bar penetrometer. The addition of the data acquisition unit will allow for non-bias collection of data. This method is easy to transport and use, due to its lightweight and simple design, but the large applied load may be harsh on the electrical components.

The second method of penetration is using the drop weight method. This was the method implemented in last year’s design. In this method, a user would repetitively drop a weight of known mass from the top of the penetrometer to a second marked height, forcing the penetration shaft into the ground. With this design, the load cells or strain gauges would be placed at the bottom of the penetration shaft, just above the friction cone. Although this method provides a more consistent applied force, the drop weight would increase the overall weight of the device.

BTH-1208LS Wireless Multifunctional Data Acquisition (DAQ)

This DAQ acquires data over Bluetooth or USB connection. The device will record the output voltage from the load cells/strain gauges and relay the data to an Android device running an application that will be developed by the team through Bluetooth.

- Sample rate: 1 kS/s continuous, 47 kS/s burst mode
- Battery or USB power options
- Two 12-bit analog outputs
- Eight 11-bit SE or four 12-bit DIFF analog inputs

Figure 8. Wireless DAQ

Arduino Mega 2560 Microcontroller Board

The Arduino Mega 2560 Microcontroller Board acquires the data like the DAQ, but does not have the ability to transfer the data through Bluetooth. This board is very inexpensive and has many reference libraries to assist in the programming.

- Operating voltage: 5 V
- 54 Digital Input/Output Pins
- 256 kB Flash Memory
- 16 MHz Clock Speed

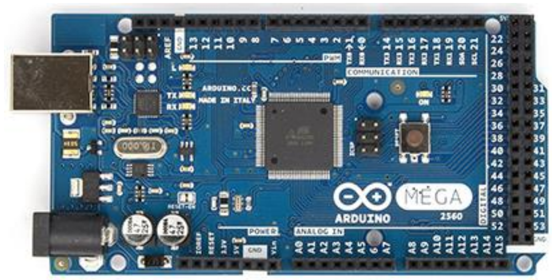

Figure 9. Microcontroller Board

Laser Range Finder

The laser range finder is a device from last year’s design. This device uses a laser and a reference point on the penetrometer. As the penetrometer travels into the soil, the reference point will move closer to the laser and measure the displacement. This displacement is the distance the tip of the penetrometer has traveled. This device measures and records the depth and sends the information to an Android device running an application developed by the company, Vertek.

Figure 10. Laser Range Finder

Arduino TFT LCD Screen

If the Arduino board is used, the results need to be displayed on an LCD screen. The Arduino TFT LCD Screen is 1.77” diagonal, with 160 x 128 pixel resolution. The LCD screen will have to be wired to the Arduino board, and a protective case will have to be made house the LCD screen.

Figure 11. Arduino TFT LCD Screen

3.2 Design Concepts

Mechanical Design A

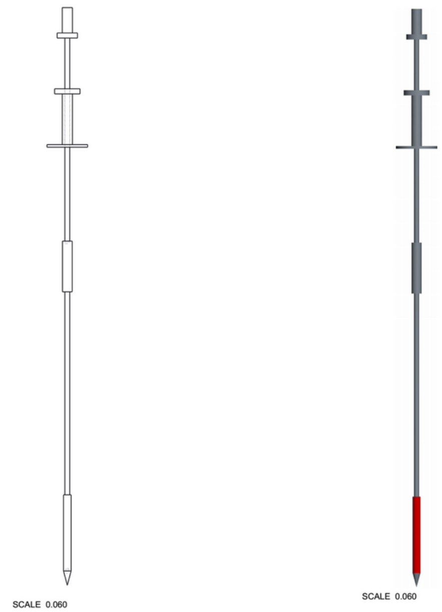

Figure 12. Mechanical Design A

Last year's prototype was not as successful as hoped. But revisiting last year's design and making a few alterations may produce a successful prototype. The design is based on the current drop weight penetrometers used by archeologist in the field. A weight of a known mass is placed on the top half of the shaft. The weight is repeatedly raised to the top of the shaft and then dropped in order to force the penetrometer into the ground. There are two stoppers on the shaft, one at the top to mark the height to which the weight will be raised, and one in the middle of the shaft to stop the weight from falling to the bottom. These two stoppers create a consistent distance for the weight to fall every time. Two load cells are placed at the bottom of the penetrometer just above the friction cone tip to obtain the voltage readings. The load cells are placed inside of a friction sleeve; this allows a fictional force to be read, which is used to calculate the friction coefficient of the soil.

To improve last year's design, changes need to be made mainly to the shaft, the load cell design, and the portability. The shaft of the penetrometer needs to be strong under repetitive compressive forces, but last year's design fractured multiple times in the field while in use. The compressive strength of the shaft needs to be increased, which can be done by choosing a stronger material, such as titanium, or by adding ceramic fibers. Ceramics are stronger under compressive loads than most metals, therefore in ceramic fibers were added into the metal shaft, the overall yield strength would increase. The load cells used for the prototype last year were large in size, forcing the shaft diameter to increase. Using smaller load cells would allow for a thinner penetrometer, which would permit easier entry into the ground. The wiring of the load cells was not housed, exposing it to any surrounding elements. The wires should be housed inside the penetrometer shaft or in a secure box at the top of the penetrometer. The prototype from last year was heavy and had to be carried in multiple parts, not making it portable. It also required a generator in the field for the multimeters to function. The weight of the penetrometer would need to be reduced significantly, and a different source of power, such as an internal battery, would need to be implemented.

Mechanical Design B

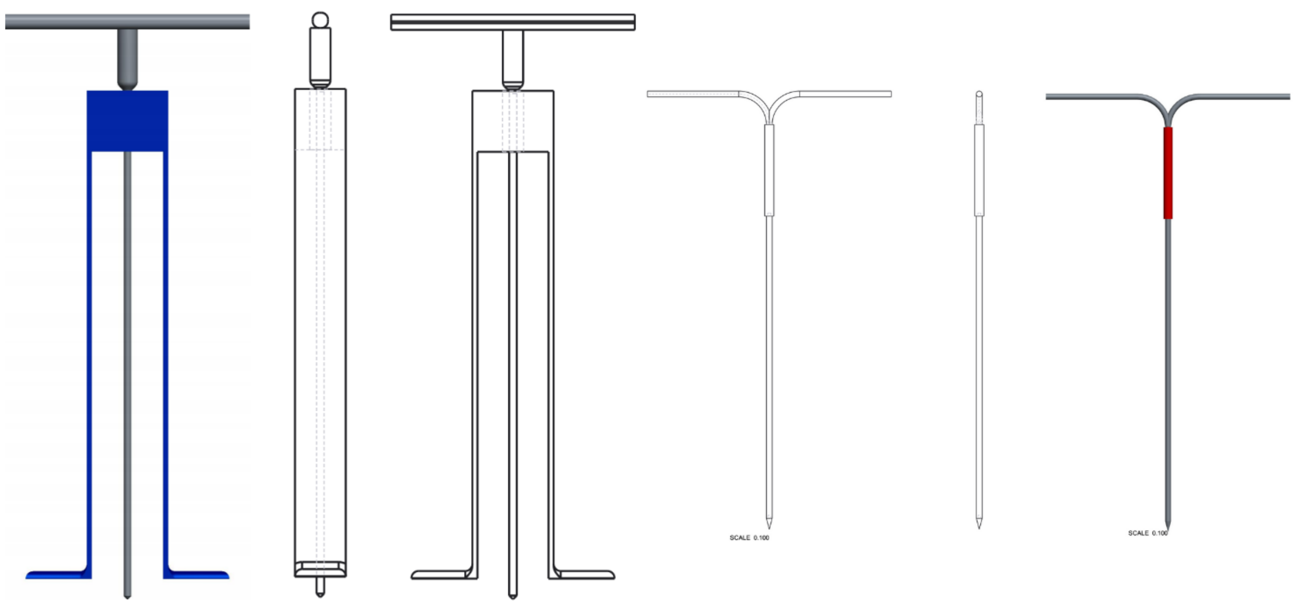

Figure 13. Mechanical Design B

Mechanical Design B is very similar to design A in the fact that is uses two load cells in a friction sleeve. The main and very important difference between these two models is the actual location of the load cells. In design A the cells are at the bottom of the shaft and have a direct impact with the soil. In design B the load cells are at the top of the shaft. This makes it much easier to keep the load cells weather resistant and it enables a larger sized load cell without having a large shaft diameter. Testing will have to be done with material choices to ensure the load from the bottom of the shaft can accurately be transferred to the load cells at the top of the shaft. Another modification to this design is the housing shown in blue. Since the model is to be wireless and battery operated, it would make sense to have a separate housing from the actual shaft itself. This will make for a lighter moving T-bar and easier use in the field. It will also keep the electrical equipment from getting damaged from repetitive compressive loads.

Mechanical Design C & D

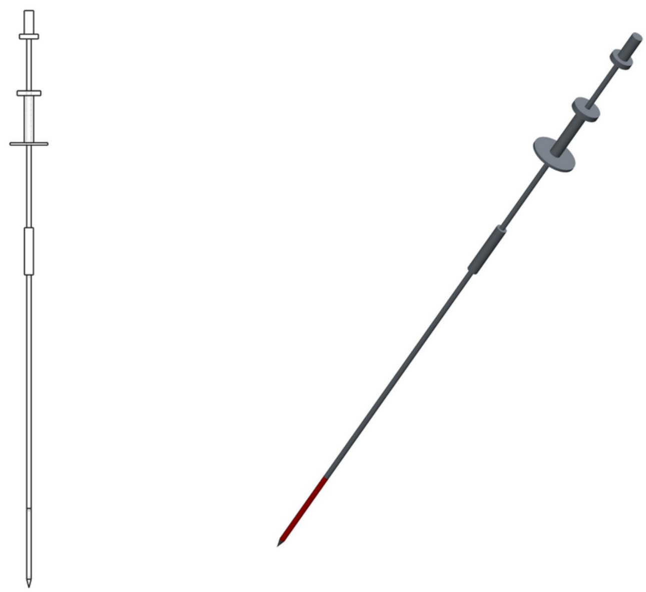

Figure 14. Mechanical Design C & D

Mechanical design c and d utilize the drop weight as its main form of applied load, this applied standard load allows for consistent data applied to the top strain gauge. For both designs the strain gauge method will be explored, the top compartment will receive the load applied from the drop weight and as the force is transferred through the rod the secondary load cell will be placed directly above the penetration cone allowing for less forces to be lost from the transfer of the force from the ground. The difference between both designs lies in the actual placement of the strain gauges and the housing of the strain gauges that will be receiving the impact force. For design C the strain gauges will be set up in a vertical orientation along a material specimen that will experience a deformation in the horizontal direction much like the diagram shows above in section 3.1 and for design D the strain gauges will be set up in a horizontal orientation and the load applied will create a deflection of the material specimen in the vertical direction. Both of these concepts will be explored more deeply for sensitivity levels and accurate transfer of the applied load.

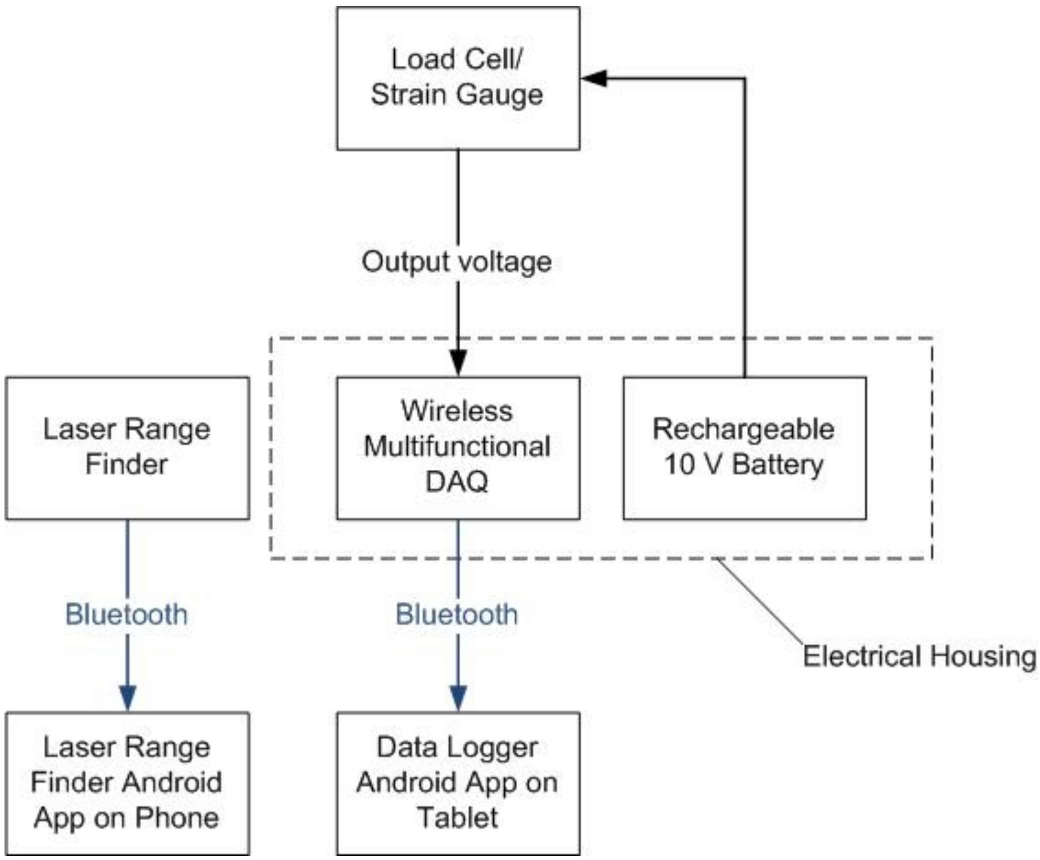

Figure 15. Electrical Block Diagram

The above block diagram is the Wireless DAQ design. The load cells or strain gauges will be powered by a 10 V rechargeable battery that can be replaced in the field if the battery dies. The wireless DAQ is powered by two rechargeable AA batteries and will directly record the output voltage of the load cells or strain gauges. The battery and wireless DAQ will be placed in an electrical housing to protect from the elements of nature such as water, dirt, etc. The wireless DAQ will then send the data via Bluetooth to an Android tablet running an application (app) to be developed by the team. The app will display real time results and store the data for further analysis.

The laser range finder also runs on two AA batteries, and will record the depth that the penetrometer travels into the soil. This data is sent through Bluetooth to an Android cell phone running an app created by Vertek. Once the phone is paired with the laser range finder, it will notify the user that a measurement is recorded, and when it is ready for the next measurement to be taken with a "beep" sound. The data is displayed on the app and generates a soil profile to be saved for further analysis.

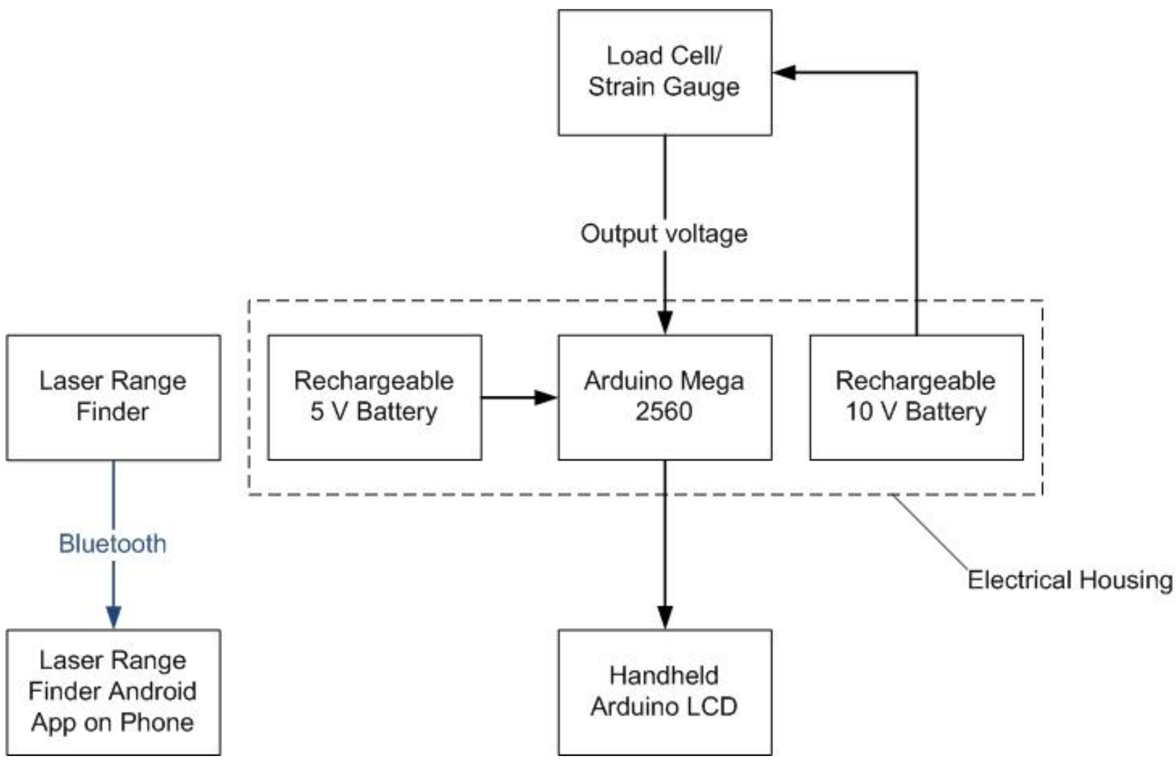

Figure 16. Electrical Block Diagram for Arduino Design

The block diagram above is the Arduino design. This design replaces the wireless DAQ with an Arduino Mega 2560 microcontroller board to record the output voltage of the load cells or strain gauges. An extra 5 V rechargeable battery will be added into the electrical housing to supply power to the Arduino board. The data is viewed by directly connecting an Arduino LCD screen to the Arduino board. The laser range finder will operate the same way as previously mentioned in the Wireless DAQ design.

3.3 Evaluation of Designs

		Portability		Ease of Use		Weight		Measurability		Durability		Cost		Total
	Weight (%)	0.30		0.25		0.15		0.15		0.10		0.05		1.00
Designs	**A**	Score	Total	Score	Total	Score	Total	Score	Total	Score	Total	Score	Total	4.95
		4	1.2	6	1.5	2	0.3	8	1.2	5	0.5	5	0.25	
	B	Score	Total	Score	Total	Score	Total	Score	Total	Score	Total	Score	Total	5.7
		5	1.5	6	1.5	7	1.05	5	0.75	6	0.6	6	0.3	
	C	Score	Total	Score	Total	Score	Total	Score	Total	Score	Total	Score	Total	6.25
		5	1.5	8	2	8	1.2	6	0.9	3	0.3	7	0.35	
	D	Score	Total	Score	Total	Score	Total	Score	Total	Score	Total	Score	Total	6.65
		5	1.5	8	2	8	1.2	6	0.9	7	0.7	7	0.35	

Figure 17. Design Decision Matrix

		Portable/Wireless		Cost		Ease of Use		Durability		Total
	Weight (%)	0.35		0.10		0.40		0.15		1.00
Designs	**Wireless DAQ**	Score	Total	Score	Total	Score	Total	Score	Total	8.65
		8	2.80	2	2.0	7	2.80	7	1.05	
	Arduino	Score	Total	Score	Total	Score	Total	Score	Total	5.30
		5	1.75	8	0.80	5	2.00	5	0.75	

Figure 18. Electrical Decision Matrix

3.3.1 Criteria

The Mechanical design criteria for the selection of a final design consists of six main categories based on the project objectives and goals developed earlier. The six categories, in order of descending weight, are: portability, ease of use, weight, measurability, durability, and cost.

- **Portability:** Portability is the top priority when designing the penetrometer. The device will be used continuously for 8-9 hours, and the user will be moving across the work site to test multiple areas. If the device cannot be transported easily, it is of no use. It should not take more than two people to transport the device, and the device should not have to be transported as many separate parts.
- **Ease of Use:** The device must be able to be operated by 1-2 people while in the field. The setup, use, and breakdown of the penetrometer must be simple and quick to allow for more time to test holes at the work site with little to no complications.
- **Weight:** The weight of the mechanism must be light enough to be carried to and from the work site, and transported across the work site continuously. The goal is to construct a device that weighs no more than 50 pounds.
- **Measurability:** The purpose of using this device over the current method is to remove any bias that may come from the user of the penetrometer. Therefore, the device must deliver reliable data and results.
- **Durability:** The mechanism must be extremely durable because the user will not be able to make any major repairs in the field. The shaft, friction cone tip, and handle should not crack or fracture at any time during use.
- **Cost:** The cost is of the lowest weight because our sponsor has made clear that the top priority is to construct a feasible prototype. While we are taken our given budget into heavy consideration, our sponsor has informed us that if we do need more funding to purchase materials of a higher quality, he will be willing to consider increasing the budget.

The Electrical design criteria for the selection of a final design consists of five main categories based on the project objectives and goals developed earlier. The five categories, in order of descending weight, are: ease of use, portability/wireless, durability, and cost.

- **Ease of Use:** The application developed to display real-time results on an android device must be able to display results without any configuration by the user.

- **Portability/Wireless:** The connection between the android device and the data acquisition must not impede efficient work in the field because the users need to be able to move from hole to hole with ease during an 8 hour period. It is imperative that the user can carry all of the equipment with very few wires so that the user does not have to spend time or energy untangling wires.
- **Durability:** The android device and the data acquisition must be able to withstand typical weather conditions and possible contact to dirt. The user should not have to worry about the data acquisition or android device failing because of typical weather conditions in Florida.
- **Cost:** The price of the data acquisition system and the android device should not exceed the amount of money that the sponsor is willing to spend.

3.3.2 Selection of Optimum Ones

Using the design matrix with the chosen criteria, the best design concept is design D, which utilizes strain gauges mounted vertically on the penetration shaft. This design had the highest score, or tied for the highest score, in five out of the six categories. It scored low in the measurability section, but we will look into ways to improve the reliability of the data gathered when using this design. Design D tied with design C, which is the alternative strain gauge design, on five out of the six categories because there were only a few minor differences between the two designs. The major difference was the alignment of the strain gauges within the penetration shaft; the alignment is the cause of the drastic difference between the scores of the two designs in the durability section. When the strain gauges are loaded vertically on the shaft, they are able to withstand a greater load. When all the criteria are combined, design D had the highest score, making it the best choice for our final mechanical design concept.

The Wireless DAQ design won in all of the categories except for price. Price did not have a significant weight because the DAQ is only $200, and the Arduino is only $45. The DAQ won in the Portable/Wireless category because the design transmits the data wirelessly. The Arduino board design has a LCD screen hooked up to the Arduino board, plus an extra battery source to operate the board. Both designs have great resources and information on how to operate them, but the advantage goes to the Wireless DAQ design because there are templates to apps to begin measurements immediately. The DAQ seems more durable since it is enclosed in a manufactured case, while the Arduino board is open with no extra protection. The Arduino LCD screen may also not be very durable as well since a type of enclosure will have to be made to protect the screen. This will also require unnecessary time and funds to make or purchase an enclosure for the LCD screen. For all of these reasons, the decision matrix was created and determined that the Wireless DAQ design is the best fit for this project.

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.

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 10/31/14	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

Table 1. Assigned Task List

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, and must have low power consumption. 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. With these specifications, the team has implemented a design matrix to successfully choose the design of the penetrometer. Criteria for design included portability, ease of use, weight, measurability, durability, and cost. Using the design matrix with the chosen criteria, the best design concept is design D, which utilizes strain gauges mounted vertically on the penetration shaft. This design had the highest score, or tied for the highest score, in five out of the six categories. It scored low in the measurability section, but we will look into ways to improve the reliability of the data gathered when using this design. The Wireless DAQ design won in all of the categories except for price. Price did not have a significant weight because the DAQ is only $200, and the Arduino is only $45. The DAQ won in the Portable/Wireless category because the design transmits the data wirelessly. Both designs have great resources and information on how to operate them, but the advantage goes to the Wireless DAQ design because there are templates to apps to begin measurements immediately. The DAQ seems more durable since it is enclosed in a manufactured case, while the Arduino board is open with no extra protection.

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. 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.

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>.

7 Appendix

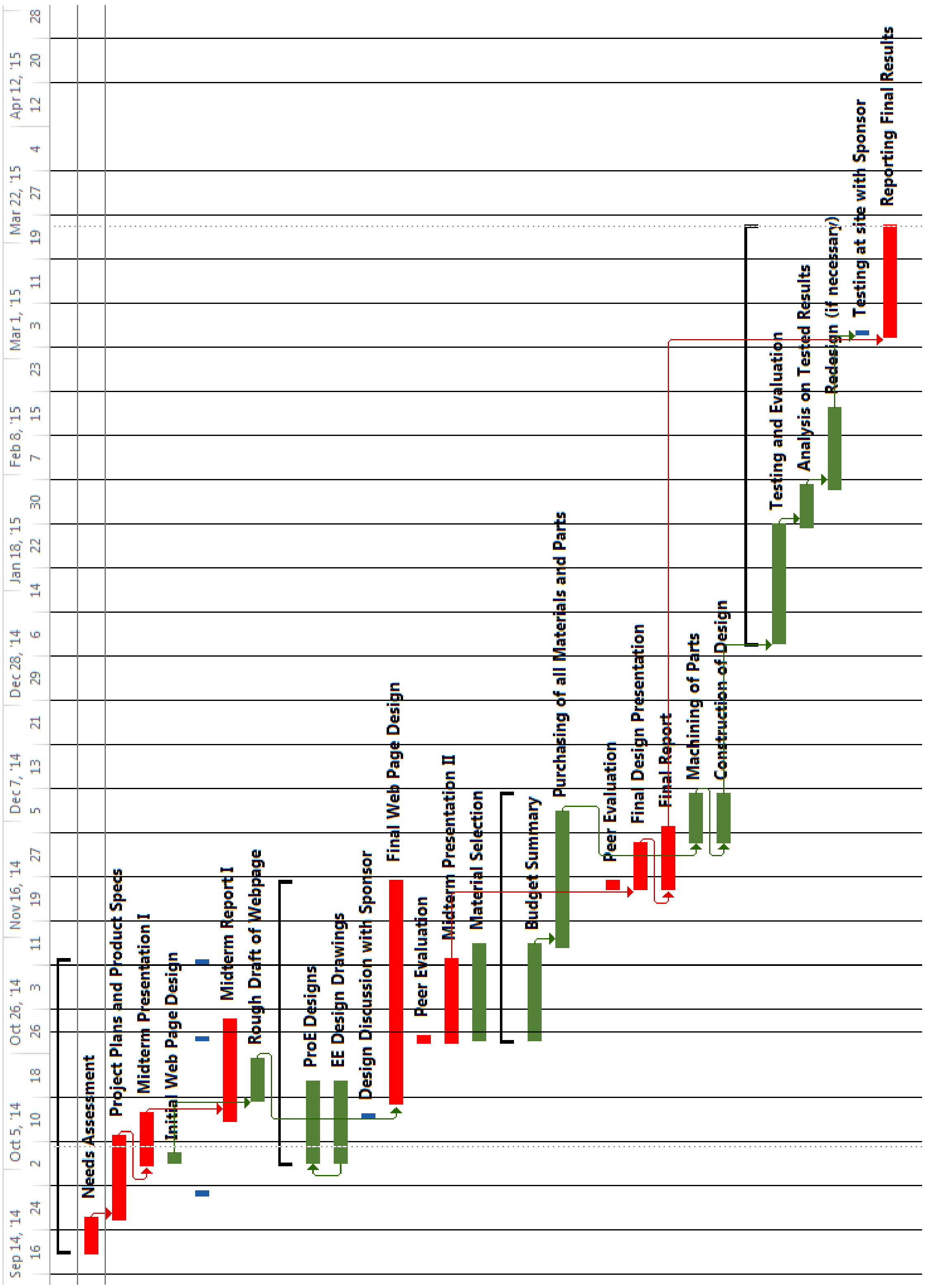

Figure 19. Gantt Chart for Team 18