Senior Design I Final Report

Team 6: Stow Away Pool Table

Team 6 Members:

Travis Jarboe - Financial
Joel Manahan - Electronics
Matthew McHugh - Ergonomics & Safety
Thomas Silva - Team Leader & Structure

Sponsors:

Beyond Innovation LLC. (Alexander York)
FAMU/FSU College of Engineering (Dr. Mike Devine)

Faculty Advisor:

Dr. Shih

Instructors:

Dr. Gupta, and Dr. Helzer

Submission Date:

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About the Team

Thomas Silva was captain for the Baja team for ASME. This leadership experience along with the technical knowledge of the Mechanical Engineering coursework allowed him to intern at Dan Foss Turbocor Compressors. Upon graduation, Thomas would like to work in the Defense industry.

Joel Manahan has had experience with prototype development on his own and hopes to continue to innovate and bring to market smart new products. Joel would like to further relationships with manufacturers to bring his own inventions to fruition but is also willing to gain experience working for innovative companies as a mechanical design engineer.

Matthew McHugh is a perfectionist, always concerned with the way things look. Whether it's the formatting of his work or the products that he is designing and developing. He strives for perfection and his experience working at Owens Corning taught him to always put safety first.

Travis Jarboe draws from his experience at the Fitness and Movement clinic at FSU as the Student Director of Finance and Accounting. He is interested in Mechanical Engineering Design after graduation and is excited to gain experience in the field right away.

Abstract

Throughout the existence of the game of pool, there have been two reoccurring issues that have caused pool table owners to have to get rid of their table: the room is needed for another purpose and the playing surface must be leveled for proper play whenever moved. The goal of this project is to design and produce a fully functional pool table that will both stow away and level at the push of a button for immediate use. This semester, computer models for the table were created and materials and parts were ordered. Some constraints were established as well: the table must be moveable by one person, and the surface must be self-leveled in under 5 minutes. Decision matrices were used to choose between stowing methods and also to select linear actuators and major electronics. A Gantt chart is presented as documentation of the team's schedule of tasks which was helpful in preparing the team to order parts and complete tasks before the end of the semester.

Acknowledgements:

Finances:

The financial provisions from Alexander York and the College of Engineering are greatly appreciated. The budget for the project this year will provide for a great end product.

Advice:

Dr. Shih has given great considerations about the overall project design and about how to go about the process of development of this product.

Dr. Gupta has been very helpful towards the understanding of the electronics involved in the leveling system of the table. He has also provided great feedback on report formatting and presentations.

Dr. Helzer has given some great feedback on our overall design and has given very helpful wording and grammar advice for report writing.

Dr. Hollis has been helpful in structural considerations especially having to do with the rotational support of the pool table as well as other connections.

The students of this 2014 Senior Design class have also been helpful in their feedback about the project and the presentations.

Table of Contents

Table of Figures

Table of Tables

1 Introduction

In order to allow the room used for a pool table to be quickly and easily repurposed without sacrificing the pool player's recreation, the pool table must be able to stow away and in order to quickly set up the table for playing, it must be able to level itself at the push of a button. The objective of this project is not only modify last year's table but to completely redesign this new table to be more functional, more economical, more easily manufactured, and more marketable overall. Alexander York, the entrepreneur/engineer who started this project last year, is sponsoring this project and the funding is provided by him along with the FSU-FAMU College of Engineering.

In this report, the desired specifications and the new design will be presented. In order to complete this new design the following steps of project planning must be completed:

- Background research of previous designs for similar problems.
- Need statement development
- Goal statement for solving the problem discussed in the need statement.
- Objectives and constraints set to achieve the Goal.
- Schedule of tasks to complete the objectives in a timely fashion.

2 Project Definition

Presented here are the parts necessary to defining this project is, the problem it solves and how it will be solved. Background research was done including the work from last year along with some other solutions used to solve similar problems. Following the Background research are the Needs statement, goal statement, objectives, constraints and specifications.

2.1 Background

The inspiration behind the design idea comes from two mechanical engineering students Alexander York and Norman Gross who graduated from the FSU/FAMU College of Engineering in 2013. Their Group 19 Senior Design project, led by Alexander York, was sponsored by Beyond Innovation LLC to design a self-leveling pool table that was also "*capable of vertically stowing itself in a discrete housing whenever additional space is needed in the area the table is kept*." [1] The team last year utilized stepper motors powering tongue jacks located on each of the four legs and a control system programmed with a stabilizing algorithm to stabilize the pool table with just the push of a button. The leveling system done by the team last year proved ineffectual as the process took too long to be considered useful. The stowing function of the table last year was to winch the table to a vertical position such that the long end would run into the ceiling of many homes. The costs of the table last year remained under the budgeted amount as shown in Table 1. Since, however the final product was not market ready, the project became available for the senior design team this year.

Table 1. Last year's final Budget Report [2].

Total spent	**$2,723**
Budget	**$3,000**
Funds remaining	**$277**

This stow-away pool table is the first of its kind so there is no opposition. There are, however other applications for leveling mechanisms such as for water vessels (Fig. 1) and space saving furniture like wall beds. Group 19's original "Self-Stabilizing Pool Table" (Fig. 2) lifts the pool table vertically until the playing surface is perpendicular to the ground and the table is fully in the housing. This product has the potential to be revolutionary because of its wide range of possibilities. It could be of great use to sports bars, hotels and homes. Basically, anywhere that can't afford to permanently sacrifice the large amount of room needed to comfortably house a pool table can benefit greatly from this design. Perhaps in the future, a more robust model with real time active leveling could be marketable to seafaring vessels but since that is a smaller market, it will not be included in the scope of the current model.

Figure 1. David Hall's self-leveling boat platform [3]

Figure 2. Group 19's original prototype [4]

2.2 Need Statement

The sponsor for our project is Alexander York, with additional funds managed by Dr. Michael Devine, Professor at the College of Engineering. This project is a continuation of Alexander's 2013-2014 Senior Design, which needs greater aesthetic value and improved functionality. The proof of concept was successful, but the product cannot be sold until the quality and aesthetics are enhanced. Additionally, the nature of the vertically stowed design posed a higher risk of serious injury to the common user, while also requiring vertical space that may not be available in households. Thus a complete redesign of the project is required.

2.3 Goal Statement & Objectives

The goal for this project is to design and produce a system to stow away a fully functional pool table, and to level it automatically when ready to use. This goal will be reached by the end of the spring 2015 semester.

Objectives for the fall semester:

- Finalize CAD model of the structural elements and translating mechanism.
- Select materials for the translating mechanism considering its structural design analysis.
- Source long-lead items.
- Design a better leveling system.
- Order the necessary parts required to begin building the table in the spring.
- Acquire the necessary software for programing the system.

2.4 Constraints

The entire concept of this design in based around making storing of the pool table quick and easy. In order to satisfy these requirements the pool table must be movable and must be ready to play on within minutes of moving it. The project as a whole must meet the customer needs specified in the original 2013-2014 project, since this product is meant to be sold to the public eventually. To guide some future decisions, here is a recollection of such needs:

1. Easy to move
2. Must be able to stow away to save space
3. Must operate at minimal noise
4. Needs to be a regulation sized table
5. Easy to use by the average person
6. Must feel no different than a regular pool table
7. System needs to be aesthetically appealing
8. System needs to be durable (long-lasting)

More specific goals have been decided on. This design must be more production friendly and thus it must be affordable from a manufacturing perspective and it must also be more marketable to the user. With this being said, the design constraints have been set as follows:

- The total cost must not exceed $11,000.
- The pool table must be movable by one person on a hard surface.
- The system must self-level in less than 5 minutes.
- The user must be able to adjust the height of the table

2.4.1 Design Specifications

As per regulation the table dimensions must follow these requirements:

- Must have a length to width ratio of 2:1
- Outside dimensions: 86 inches x 48 inches
- Playing Field: 78 inches x 39 inches
- Height Restriction: Between the range of 29 inches to 31 inches

In line with those specifications, the housing must fit our 7’ X 3.5’ table, being no more than 6 inches bigger per side, except for the width, for which we have allowed 2 ft. Considering that the slate will weigh approximately 350 lbs., the system will be kept under 700 lbs. and for a considerable factor of safety the supports should be designed to handle 1000 lbs. This weight may be reevaluated as the design evolves.

2.4.2 Performance Specifications

Expectations of performance of the table when used by consumers include instrumentation output requirements (operation range, accuracy, and resolution), display features, detection capability (for setting the height of the table), data transmission, and power and time efficiency. Following the successful readings of the inclinometers used last year, the angle range of ±10º will be sufficient again. Since these inclinometers have a resolution of 200 mV per degree of inclination, a reading of 2 mV will yield a measurement approximately equivalent to 0.0125” for the long span of the table. The leveling system must finish its task in less than 5 minutes. This means that the players will not be made to wait more than that after the table has been set horizontally. The system will have a graphic user interface so that the player knows when the leveling system is working, and when it is finished.

3 Design and Analysis

Here are presented the changes being made to the previous project and solutions to the various project needs in both form and function. The final choice from the solutions are based on the following functional analysis, keeping in mind the desires of the sponsors of the project.

3.1 Functional Analysis

One of the biggest changes that is being made to the original prototype that was created last year is that instead of rotating the table about its latitudinal axis, it will be rotated about its central longitudinal axis. When the pool table is ready to be stowed-away, the user will be able to attach it to the stow-away component and manually rotate it 90º so that the playing surface is perpendicular to the ground and facing away from the housing. Once it is in the stow-away position, the user will then push it into the housing were it can be hidden. This change will improve the practicality and effectiveness of the design. Extensive research into this change has been conducted by the team before making the decision to pursue this design alteration.

The issue with having the pool table rotated about its latitudinal axis is that it requires a structure at least 8 ft. tall to house the table. This makes the design impractical because it would be too tall to fit in most normal rooms especially when the goal of the design is to reduce the amount of space that the pool takes up. Rotating the pool table about its longitudinal axis and storing it would only require a structure about 5 ft. tall. Granted the structure will still have to be 8 ft. wide rather than tall, this method of storage will be easier to install and operate than the former one.
By having the axis of rotation pass through the center of gravity of the pool table, all net forces and moments on the pool table will be minimized when it is supported by the stow-away mechanism. This requires very little applied force in order to rotate the table 90º for space saving storage. The stow-away mechanism will also need to feature assisted rotating components that will allow the user to slowly and safely rotate the pool table to its stow-away position in a controlled manner. If the system doesn't have this feature it would make the stow-away process extremely dangerous because of the immense weight of the pool table. Various methods of assistance are being researched. These methods include using counterweights, hydraulics or torsional springs. Once testing is complete with both physical models and computer analysis, a decision will be made on which method to use.

3.2 Initial Design Concepts

These three designs are the results of initial brain storming and considerable follow up. In the end, the decision matrix does not rate one design significantly above another. Thus the final choice for Design # 1 to be pursued came from the sponsor, Alex York, who seemed set on a housing which would completely hide the pool table.

3.2.1 Design #1

This system has two main components: a pool table, and a housing. The project is consequently divided into those two as subsystems, where the former integrates the leveling components, and the latter handling the stowing mechanism. The table's legs have deployable caster wheels so that it can be moved close to the housing when ready to be stowed. The legs also integrate a power screw that serves as the mechanisms that raises and lowers the table to respond to the leveling system's demands. Lastly, when the table is using the stowing mechanism as support the legs cease to act as vertical support, which allows the user to fold the legs in. With the legs folded, the profile of the table can be reduced to approximately 12 inches.

The housing contains a sideways-laid scissor-style mechanism that extends outward to a position that matches the neutral longitudinal axis of the table; the table is then pin secured to the scissor. Before collapsing the scissor (effectively bringing the table into the housing), the table must be rotated 90 degrees. Two potential problems have been identified. The first is that the calculations of the location of the neutral axis require homogeneous material assumptions, which could lead to the table not being properly balanced when suspended. Such scenario would require post assembly rebalancing of the table. If the addition of counterweights do not suffice, a torsional spring or other force assistance might be needed to accomplish effortless rotation of the table. The second potential problem would be the scissors not staying in the open or closed position without the user holding it, which would mean that the opening or closing of the scissor would require a considerable force input. The backup plan that we will develop consists of a linear actuator to aid in the in/out movement of the table. Figure 3 shows the table stowing process where the table is first pushed toward the housing until the pivot points of the table are aligned with those of the stowing mechanism. Once the table and housing are secured together through pin connections, the table's legs retract and fold inward, effectively reducing the cross sectional area of the table. The table is then rotated 90 degrees and pushed into the housing.

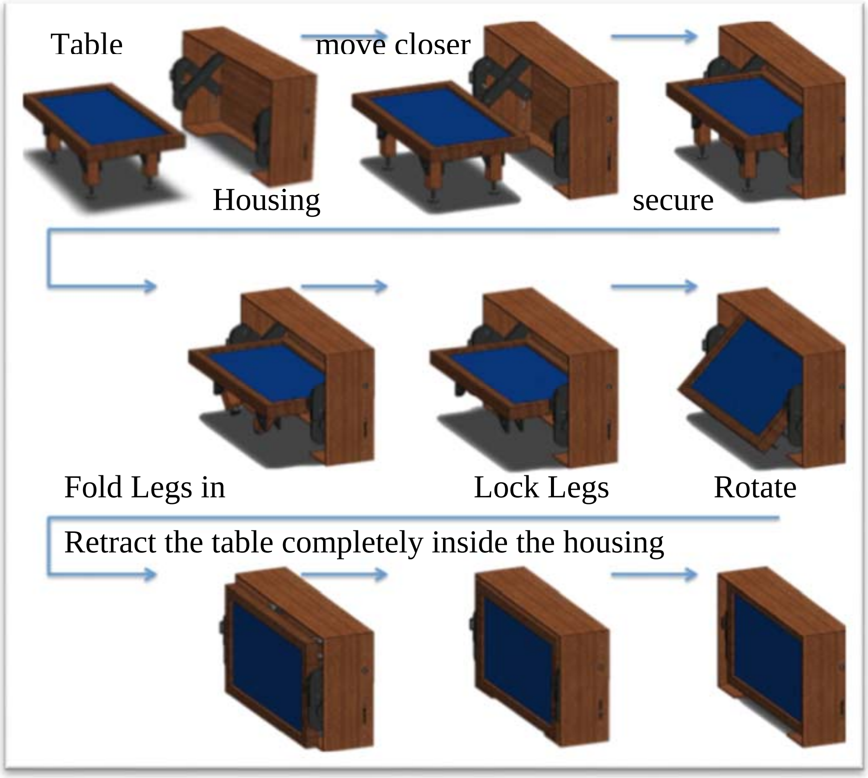


Figure 3. Stowing process of Design #1

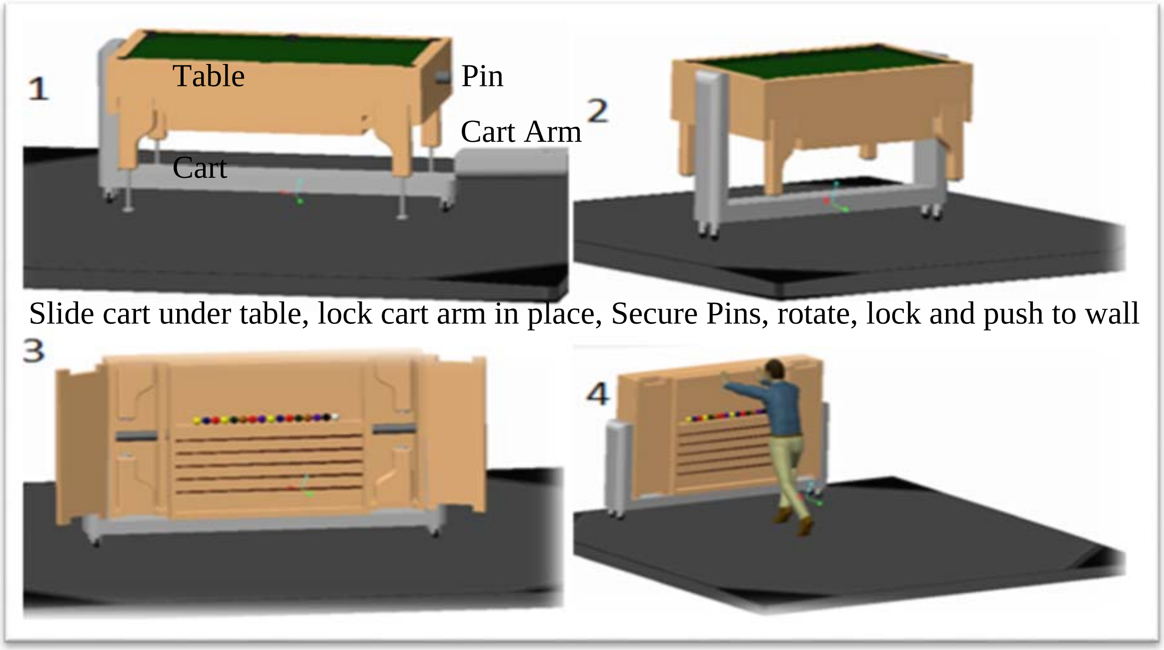


Figure 4. Four step process of design #2

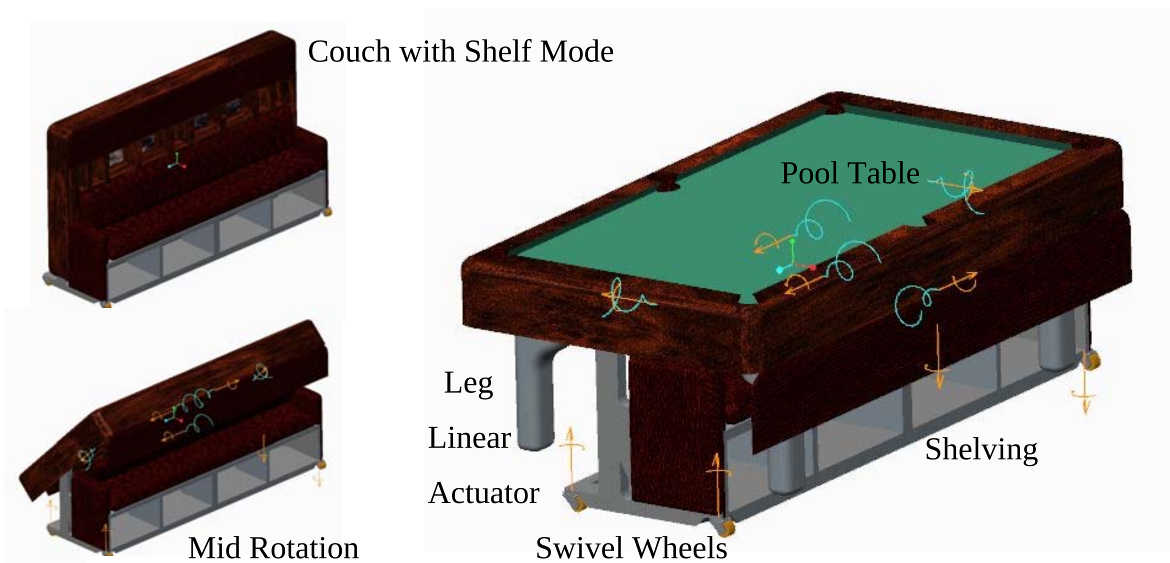
3.2.2 Design #2

Design #2 features a removable U-shaped cart that attaches to pins extruding from the pool table or alternatively pins on the U-cart may be inserted into slots in the sides of the table. Figure 4 illustrates the steps of the stow-away process for this design. The cart can be kept out of the way while the pool table is in use. Once it is time to stow-away the pool table, the cart is wheeled out and one end of the upright arms can be adjusted through the use of a hinge joint to allow the cart to be rolled under the pool table. Once it is time to stow-away the pool table, the cart is wheeled out and one end of the upright arms can be adjusted through the use of a hinge joint to allow the cart to be rolled under the pool table. Once the cart is under the table with the uprights at opposite ends, the hinged upright is swung back into its original position where it is connected to the pin on that side. Once both arms are secured in their upright positions and on the pins, the legs of the pool table are retracted completely into the table so that the full weight of the pool table is supported by the cart. The table can then be manually rotated 90° so that the playing surface is perpendicular with the ground. The legs of the pool table will also be connected with pins so that they can fold into compartments under the pool table. These compartments will have doors that open to place the legs in and conceal them along with racks to place the cues and balls when they are not in use. This design would reduce the footprint of the table by 71% after stowing away the table and the wheeled cart allows for the pool table to be easily movable. The lightweight cart allows for quick and easy storage of the pool table. However, due to the fact the cart is so slim and lightweight, it has potential to create a hazardous situation while being moved. The pool table is extremely heavy and when in the stow-away position, it could easily become unbalanced and fall over. Also, this design lacks the room for motors or hydraulic systems to comfortably fit and assist with the rotating portion of the stow-away process. In order to allow adequate space to house these components, the percentage of footprint reduction must be sacrificed.

3.2.3 Design #3

Design #3 transforms from a bench and shelf combo to a pool table. Figure 5 illustrates these forms and the transition between them. The rotation of the table may be handled easily by hand and the same for the legs that fold down. The front legs may be folded out at any time as they do not interfere with the bench at any time. The back legs, however, must be folded down after the table is rotated enough for them to come out. Once the legs are locked in place the user simply pushes a button for the system of linear actuators to extend to the floor and level the pool table. When converting the table back into its bench-shelf combo mode, the user pushes a button to retract the feet of the linear actuators, folds up the legs and then rotates the table to its vertical position. The wide base and weight of the bench on the side opposite the slate when the pool table is rotated up adds stability to the system while it is being moved. One could even sit on the seat while pushing the bench-shelf combo to the desired location. The underside of the bench would also likely feature a system of easy to pull out drawers, the hardware for which would add more weight.

With this design, the whole system may be kept as one whole piece or the bench may be removed while the table stands on its own, providing some seating on the side. Though the base of the bench/shelf might be larger than the other designs, the space taken up is made useful with the shelf-bench combo reducing the need to bring in more seating for the room now being used as something other than a billiard room.



Rotate the shelf down to reveal the table, lock the legs out and push “Level”

Figure 5. Computer model showing the reversible positions of Design #3

3.3 Evaluation of Initial Designs

Following is described the process that was gone through to decide on a design to pursue further. This included using a decision matrix, rating each design according to the criteria set forth by the sponsor. Also weighing heavily in the design selection was further input from Alex York, one of the sponsors necessitating a housing which would fully hide the pool table.

3.3.1 Criteria, Method

After speaking with the sponsor about possible design ideas for the stow-away component of the pool table various criteria were created and weighed in accordance with their importance to the design constraints. Each team member filled out an individual decision matrix by giving each design a score from 1 to 3 for each criteria. A score of 1 means the design meets the criteria poorly and 3 means the design meets the criteria sufficiently. The top priorities for criteria were safety, footprint reduction and visual appeal. Safety was weighed so heavily because this will be a very heavy apparatus; when moving something so heavy, all the necessary precautions must be taken. Footprint reduction is basically a measure of how effective our design is, since the goal statement was to “reduce the footprint of the pool table” this is a vital aspect for the design. Visual appeal is important because we are placing emphasis on the marketability of the product. This pool table must catch the customers’ eye and be something that they would be proud to have in their house. The product must be sleek, all nuts and bolts must be out of sight, and there shouldn’t be any unnecessary parts extruding from the table.

Manufacturability and design simplicity are related but they are not the same. The manufacturability of a design describes the ease and timeliness of which the product could be reproduced for sale. Design simplicity takes into account the difficulty to create a working physical prototype of the design. Each design will require extensive calculations, simulations and testing. Once the design has been successfully created, in order to manufacture it, all that is needed is the dimensions and specifications for the components so a design may be easily manufactured but complex to design. The team is willing to contribute the necessary time and effort in order to design the best product possible so simplicity was weighed lightly.

One requirement the sponsor, Alex York, stressed was the familiarity of the product. He wants it to look and feel like a traditional, high-end pool table rather than a tacky attempt at appearing futuristic. He strongly believes that the familiarity of the table will improve its marketability so he wants to spare no expense in satisfying this criteria. With a budget of $11,000, there will be plenty of resources available for testing, researching and developing. In order to satisfy the sponsor’s request, familiarity was placed among the criteria. Cost was placed on the list of criteria because it is always important to consider although it will not be a large constraint for our design.

3.3.2 Selection of Design to pursue

The scores for the individual decision matrices were averaged together for each design to get the team average stow-away design decision matrix seen in Table 3. The final scores were very close but Design 1 came out slightly on top and also involves the housing desired by the sponsor Alex York. Design 1 will be the designated prototype although this is subject to change as unforeseen circumstances arise. As the testing and prototyping process begins the design matrix may be revisited, to add new criteria, rescore the designs or even create another design concept or merge concepts.

Table 2: Team Rounded Average Stow-away Design Decision Matrix

	Decision Criteria							
	Safety	**Low Cost**	**Ease of Manufacture**	**Visual Appeal**	**Familiarity**	**Design Simplicity**	**Footprint Reduction**	**Total**
Weights	3	2	2	3	2	1	3	**16-48**
Design 1	3	2	2	3	3	2	1	**37**
Design 2	2	3	3	1	3	3	2	**36**
Design 3	2	2	2	2	2	3	3	**36**

3.4 Leveling System Design

This section is devoted to the parts of the design pertaining only to the leveling system and does not include how those components will attach to the table frame.

3.4.1 Mechanical Components

Five possible choices were selected for the jack that will raise and lower the pool table. Three of these choices were industrial grade linear actuators, one was a trailer track that would be modified to stabilize the pool table and the last option was to design and build a power screw from scratch. For the selection process of which jack to use, a team average decision matrix was used. Each team member filled out an individual decision matrix and the scores were averaged together to get the team average jack decision matrix seen in Table 3. The criteria that was weighed the heaviest in this decision matrix was the ease of implementation in the pool table. One of the main constraints for this design is that the pool table must have the look and feel of a traditional pool table so the jacks must be easily concealed in the pool table so that the user can't see them. In order to do this, the jacks must be compact so they can easily fit in the table's legs without any parts protruding. Low cost and high quality also were large criteria because the table must be easy to manufacture and sell. The costumer is going to want a high quality product for the lowest price possible.

Table 3 Team Average Jack Decision Matrix

	Low Cost	**Easy Implementation**	**No Wasted parts**	**Size**	**No Wasted Power**	**Higher Quality**	**Total**
Weights	**4**	**5**	**2**	**3**	**2**	**4**	**20**

Modified Trailer Jack	2	2	1	1	1	1	**29**
EBay Linear Actuator	3	2	2	2	2	2	**44**
Joyce Linear Actuator	2	2	2	2	2	2	**40**
Expensive Linear Actuator	1	2	2	2	2	2	**36**
Custom Build Power Screw	1	1	1	2	2	1	**25**

The modified trailer jack option received a low score because the modifications required to make it suitable would be too costly and it wouldn't ensure a safe design. Although building a power screw from scratch would allow us to design the jack to fit the exact requirements needed, it would expensive and difficult to implement in our design. Out of the three industrial grade linear actuators, The EBay actuator received the highest score mainly because of its low cost and it ended up being the highest scoring option, it will be used as the jack in the leveling mechanism. This choice is subject to change if there are unexpected issues with this linear actuator or another one is found that better satisfies the criteria. Figure 2 shows an image of the Joyce linear actuator model number MA1527B1130.

Figure 6. Joyce Linear Actuator MA1527B1130 [5]

3.4.2 Electrical Components

After selecting the linear actuators, the circuit boards could then be selected. The Microprocessor to be utilized is the Pololu OrangutanX2 with its dual motor controller. It was chosen for its capabilities to handle the higher amperage drawn by the linear actuators. It comes fully assembled and includes programmability with many libraries for simplifying the coding process and also has the required number of I/O ports for use with the sensors and controlling a second dual motor driver. The same dual motor controller as with the X2 was also chosen for a total of four controllers to be linked to the four linear actuators. Beyond those two major components the following electrical components were also chosen:

- 22 gauge wiring for circuit connections
- 16 gauge wiring for connecting to the 12 V power source and the actuators
- AC to 12 V DC converter for the required power supply to the actuators
- 5 V 1A regulator for power supply to the microprocessor

3.4.3 Programming Logic and controller design

In order for the pool table to be self-leveling with just the push of a button, the motor controller must be programmed with detailed logic. This logic will allow it to use the signal from the inclinometer to move the inclinometers either up or down to bring the table within the tolerable angle range that is considered level enough for a proper game of pool. The controller must be programmed to power all four actuators simultaneously in order to make the leveling process as quick as possible. When the table is being leveled, the actuators must be rotating at variable speeds in order to allow both axes to be leveled at the same time. The two short edges of the pool table were named the breaking edge and racking edge for the purpose of naming each actuator in the program logic. Figure 7 illustrates the nomenclature for the motors located in each leg along with the two axes of incline angle measurement.

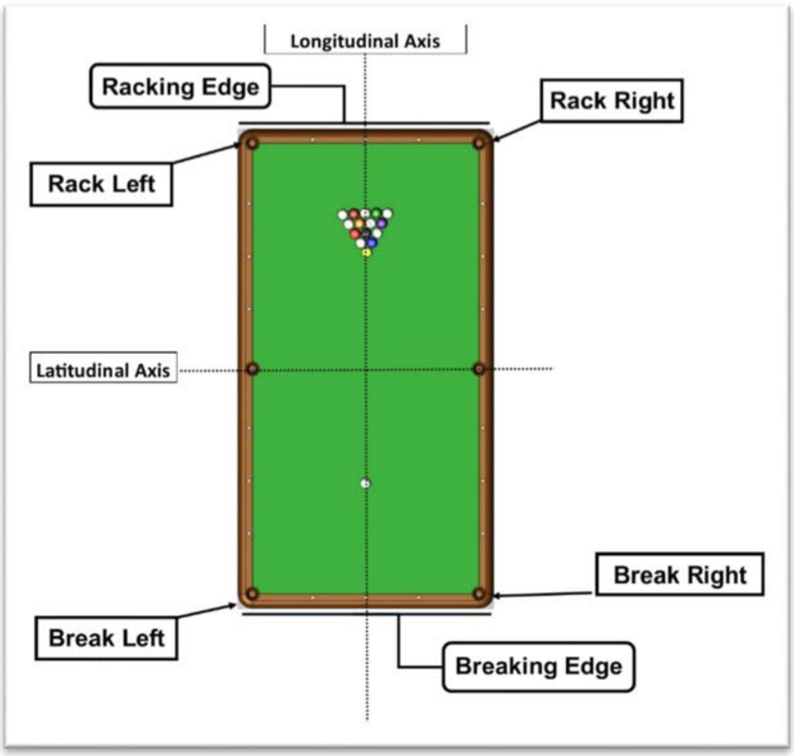


Figure 7. Table conventional nomenclature

For the leveling process, the controller will first check the direction and magnitude of the incline if any exists. The controller will then set the motor driver of each actuator to a suitable speed and direction for the correct adjustment. If the breaking edge is higher than the racking edge, then the break left and break right motors will lower that side while the rack right and rack left actuators will raise the racking side in order to level the longitudinal axis. The speeds vary for each actuator. For example if the left side is higher than the right side, then the break left and rack left motors will spin at slower speeds then the break right and rack right motors. This will allow for the right side to raise in comparison to the left side and the latitudinal axis will eventually become level. A detailed leveling logic diagram illustrating what each motor would do in any possible situation can be found in Appendix A.

3.5 Table Design

3.5.1 Framing

The frame of this pool table, illustrated in figure 8, is much different than the typical pool table. This pool table's frame will be constructed with steel tubing as compared to wood. By using steel tubing, the weight of the frame will be greatly reduced due to the fact that much more wood would be needed to provide the same amount of rigid support required for making the table safe. It is estimated that the frame being constructed will be under 100 pounds. The use of the steel frame also provides a rigid support that transfers all of the torsional forces created when rotating the table into the stow-away position. This concept is very important because if the frame didn't absorb the forces, the slate would, which could potentially result in the slate cracking. In addition to its main purpose of providing good support, the frame also allows for a secure and easy assembly of the rail subassembly which is discussed in the next section.

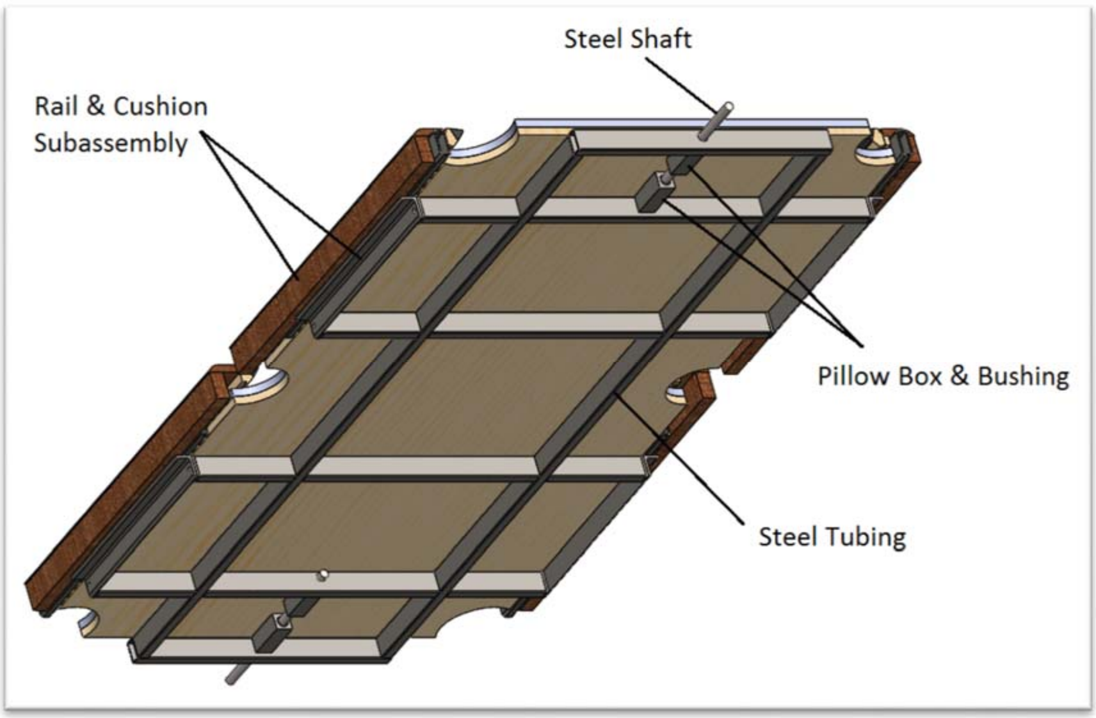


Figure 8: Detailed Frame & Pool Table

3.5.2 Rails & Cushions

The rail & cushion design (shown in figure 9) focuses on several important features required for the pool table to be functional. The most important part of this design is the concept that the rail system actually attaches to the frame itself, and provides all-around support for the slate. The purpose of this extra slate support is for when the pool table is rotated into the stow-away position. This design secures the slate from falling out of place using the smaller angle beam that is hidden under the sub-rail and welded onto the steel tubing (See the close up in figure 10), providing both safety for the consumer as well as prevention of the slate breaking in the instance that it did fall.

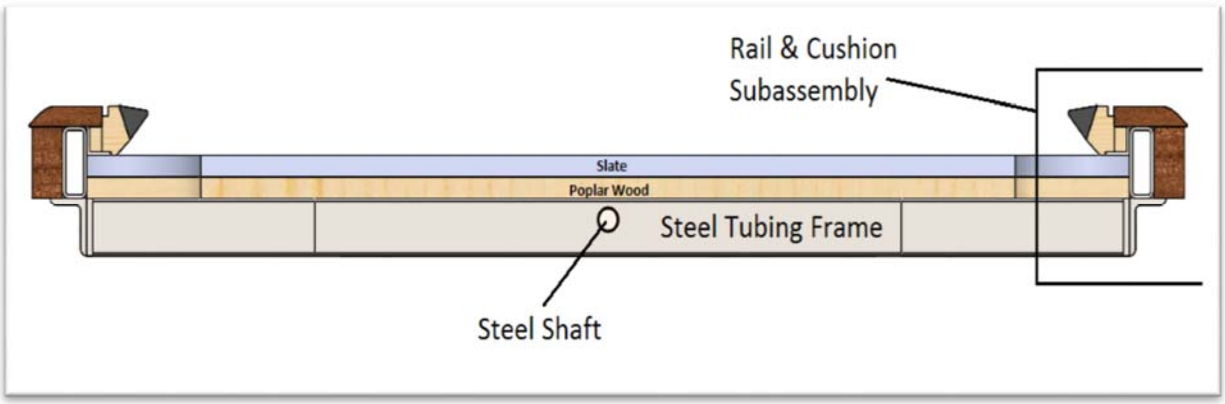


Figure 9: Table and Rail/Cushion Cross Section

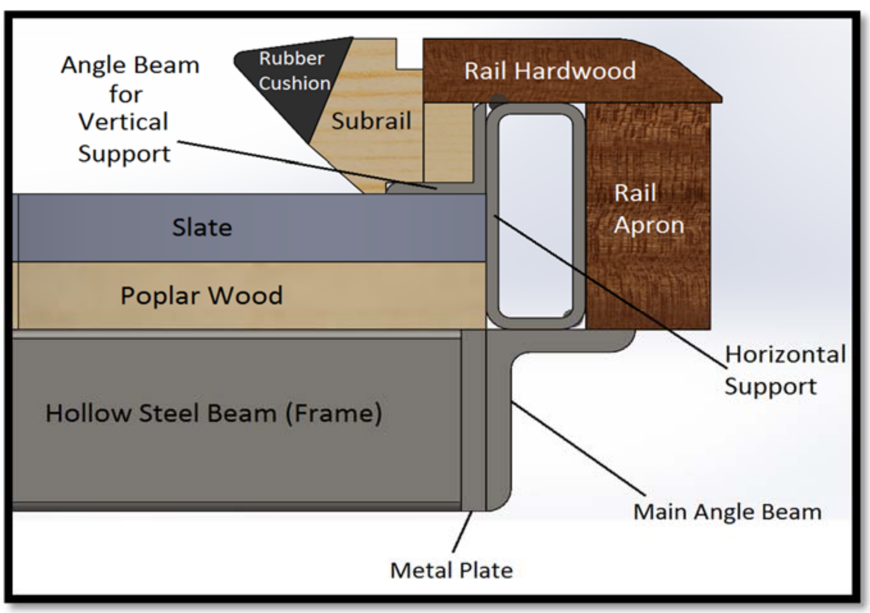


Figure 10: Rail & Cushion Subassembly

Once the assembly is done. However, one may wonder, how does the slate get set in place if it's secured in all directions? This brings up the concept that the entire rail subassembly will be able to detach from the frame itself. There will be bolts that attach the rail subassembly to the frame through the main angle beam and metal plate. This concept also allows for the rails to be easily replaced in case they are damaged in any way. The metal components of the rail subassembly will all be permanently attached to each other, while the wooden components will be secured using a bolt that goes through the rail apron, steel tubing, and small angle beam into the sub-rail. Note that the rail hardwood and the rail apron will be permanently and adhesively attached.

Another design feature to note is the poplar wood layer that is below the slate. This layer of wood allows for the table cloth to be stapled into place as compared to being adhesively attached to the slate. This provides an easier method of replacing the table cloth, which is one of the most likely parts of the pool table to get ruined, whether it is from spills or rips from sharp objects.

4 Procurement

The item procurement stage begins with sourcing and ordering of the items. The sourcing process is complete and the ordering process has almost been completed. Once an item was sourced and selected, a purchase order table was created. This table included the product name, item number, company name, unit price, any additional costs, desired quantity and total cost for the order. This table was sent to Jon Cloos who was responsible for reviewing the order and approving it. He then would send it to Cindy Stewart who responsible for making the payment for the order. Once the payment was made, she would then send a confirmation to the Financial Advisor: Travis Jarboe. The Master Purchase Order Table for all purchases that have been made to this date can be found in Appendix C. In order to minimize shipping and handling costs, all items that were sourced from the same company were ordered together. To this date, the only orders that have been delivered and received by the team is the first order of the Orangutan X2 and the VNH2SP30-E motor driver.

5 Future Work

5.1.1 Leveling System

Now that all of the components for the leveling mechanism have been ordered, the next step in the design of the leveling system is to begin writing the code for the program of the motor controllers. The Orangutan X2 motor controller is simple to use and comes “pre-programmed” with preset libraries to implement in the code. These libraries have already been downloaded so now they can be examined to see if they will be useful at all in the leveling program. Once that is finished, functions will be developed that relate the output of the inclinometer to the speed of the motors in the linear actuators. These functions will take into account the pre-determined tolerances, the sensitivity of the inclinometers, the resolution of the motor controller, the size of the motors, and the pitch of the power screws in the linear actuators. Along with developing the program, the mounting of the leveling system components onto the pool table will be designed. This will be designed in a fashion that allows the components to be concealed in order to give the table the desired traditional look.

By the time that the program and system mounting is developed, most of the parts that have been ordered should be delivered and the testing process can begin. During the testing process, each part will be tested individually before being implemented in the design. This will allow for any possible problems to be detected easily before the design is built. Once the parts are tested, they will be individually implemented into the leveling system design. Testing on the system will continuously be conducted as each part is included to ensure that the parts work effectively in the design. Once the entire system is put together, it will be mounted onto the table and more testing will proceed. Every possible scenario will be repeatedly tested under any possible circumstance in order to ensure that the leveling system is both safe and effective.

5.1.2 Table and Housing Design

On the mechanical side of things, the next step for the project focuses on beginning the assembly process for the frame and rails. Even though the building of the frame will take a long time and careful machining, it is still important that there is time set aside for designing the foldable legs for the table and the housing unit in which the entire assembly will be stored. The design of the foldable legs must be rugged because it incorporates the linear actuators used in the leveling system, which requires great stability and support. The legs also still need to be aesthetically pleasing, so the design also requires the integration of wood covering to provide a traditional look. The housing unit is an extremely important part of the final project being that the main focus of the project is for the table to be stowed away. This housing assembly needs to be able to support the entire weight of the table and all of its components. The two main concerns regarding the housing are the strength and stability of the internal mechanical components providing the aforementioned support, as well as the aesthetically pleasing outer look of the assembly. Due to the importance of those two factors, much of the housing design has been postponed to the spring semester.

6 Methodology

The methodology for the completion of this project involves the following

- Team brainstorming
- Team organization
- Individual research and computer modeling
- Budgeting
- Workplace set up at TCC
- Acquisition of tools, supplies, parts and materials

After the total design is complete, the building process will commence and the team will work together through the issues and obstacles to a final product. Throughout all of these steps the team will be meeting up regularly and constantly be updating strategy and plans. The designing process will be starting with the completion of the product specifications report and the finalization of the planning process. Although the official start of the build will occur next semester, the most integral part, the slate was received from the sponsor before the 30th of October, which will allowed the team to take real dimensions and draw the system around it.

6.1 Schedule

To help plan out the project for this semester, a Gantt chart provided in Appendix B have both been created. These will allow the team to stay on schedule and proceed with the design process in a detailed and organized fashion.

6.2 Resource Allocation

The projected resource allocation hours are presented in Table 4 and each task can be easily traced back to a subsystem or the person ultimately responsible for its execution. The team meets regularly to brainstorm on all aspects of the project. Great suggestions come even when the subject is somewhat trivial. Each member is leading a subsystem: Jarboe handles financial and procurement aspects, Manahan is in charge of the leveling subsystem, McHugh takes care of assembling the components that increase esthetic value, and Silva develops the table frame and stowing mechanism. To successfully put together the system as a whole, the team has agreed to personally devote their undivided time and attention to their respective subsystems before dedicating efforts to other tasks.

6.3 Communications

The group has done well communicating throughout the semester. The main form of communication has been through the use of Facebook messenger, where a group chat was created. The group can access the group chat through their phones, tablets, and/or computers. The communication of ideas and design concepts has also been very good and has led to good teamwork. No group member is being singled out or left out and the group meets several times throughout the week to communicate new ideas and make decisions for the project.

Table 4: Resource Allocation Hours

Category	Task	Lead	Time
Design Selection & Prototyping	Brainstorm Possible Designs	**All**	**2 hours**
	Sponsor Meeting	**All**	**1 hour**
	Create CAD Prototypes	**Travis Jarboe, Joel Manahan & Thomas Silva**	**2 hours eacl**
	Decision Matrix	**Thomas Silva**	**1 hour**
Website Development	Initial Website Design	**Joel Manahan**	**2 hours**
	*Continually Update Website	**Joel Manahan**	**20 min/wee**
Functional Analysis	Pool Table Force Analysis	**Travis Jarboe & Matthew McHugh**	**5 hours**
	Housing Force Analysis	**Matthew McHugh & Thomas Silva**	**5 hours**
	Ergonomics and Structure Integration	**Travis Jarboe & Thomas Silva**	**5 hours**
	*Design Analysis	**Matthew McHugh & Thomas Silva**	**2 hours/wee**
Acquisition of Parts	*Material Research	**Matthew McHugh & Thomas Silva**	**3 hours/wee**
	*Electronics Research	**Joel Manahan**	**3 hours/wee**
	Budgeting	**Travis Jarboe**	**5 hours**
	Team/Sponsor Decision Meeting	**All**	**1 hour**
	Create Bill of Materials	**Matthew McHugh**	**1 hour**
	Order Parts/Machines	**Thomas Silva**	**1 hour**
Coding	Develop Leveling Algorithm	**Joel Manahan**	**5 weeks**
	Implement Motor Controls Code	**Joel Manahan**	**3 days**
	Integrate IR Range Sensor Code	**Joel Manahan**	**3 days**
	Integrate Inclinometer Code	**Joel Manahan**	**3 days**

***Ongoing Tasks**

7 Risk and Reliability Analysis

While designing the pool table, several topics have come up pertaining to possible risks that we need to assess and prevent. While safety is without a doubt the most important of these potential risks, there is also risk associated with the quality of the final product and its success in the pool table market. Some of the risks/reliability issues that have been addressed and some possible solutions are listed in the sub-sections below:

7.1 Safety Concerns

- Pins supporting pool table in stow away position
  - Material & component selection
  - Factor of safety
- Design of fold-up legs
  - Design lift method to avoid the need to get under the table
  - Mechanical assistance
  - Locking mechanisms
- Stability of legs
- Spinning of heavy table when on pins during process of rotating the table into stow-away position.
  - Limiting degrees of freedom of rotation
  - Locking mechanisms
  - Mechanical assistance

7.2 Mechanical Assistance

- Lifting of pool table foldable legs
  - Crank/Screw system
- Rotation of pool table into stow away position
  - Torsional springs
- Movability of pool table from playing area to housing unit
  - Wheel/cart system
- Retraction of the pool table into housing unit
  - Linear actuators

7.3 Maintenance of Pool Table

- Ease and possibility of replacing pool table rails/cushions
  - Placement of screws for accessibility
  - Design of how parts fit together for ease of assembly/disassembly
- Ease and possibility of replacing pool table slate
  - Frame construction allows for easy assembly/disassembly
- Accessibility of linear actuator components for maintenance/replacement
- Table Cloth Replacement
  - Poplar wood layer is being placed under slate so that the table cloth can be stapled to the slate as compared to being adhesively attached.
    - This allows for an easier and cleaner removal
- Striving for lubrication free mechanisms

8 Environmental & Safety Issues and Ethics

The Occupational Safety and Health Administration (OSHA) was created once congress enacted the Occupational Safety and Health Act of 1970. OSHA's mission is to help employers and employees reduce on the job injuries, illnesses and deaths. Being that this project is one of the entrepreneurial senior design project, the pool table being made and the way it is being made will comply to the applicable OSHA regulations in order to protect the potential company, product, and customers. These regulations apply to topics such as the materials being used for the pool table as well as the warning stickers available for items such as the infrared sensors used in the mechatronics system.

9 Conclusion

With abundant information from last year's project, and with a team member who had direct involvement in its development, our Senior Design project has the potential to greatly improve on specific features developed previously. The objectives and Gantt chart for the Fall semester were laid out to function as a guide that the team must adhere to. By the end of the first half of the project, the team accomplished the three objectives stated initially: the structural elements and the translating mechanism were modeled in 3D, the materials for the stowing arms were selected, and long-lead items were procured. To reduce risk of injury and assembly failure, the mechanics subsystem was designed for the structural elements to provide vertical and lateral support for the slate, accounting for scenarios where the table is incorrectly rotated to an upside-down position. The stowing arms were modified to contact the ground directly at all times, per suggestion of advisors and sponsor; the non-cantilever setup further reduces risk and injury liability. The electronics subsystem made strides to procure all hardware in anticipation of the programming and integration that follows the Fall semester.

Team 6 made improvements in the area of communication by creating two files that complement the Gantt chart. The first file is a Master Task List where all electronic components get individually spec'd, integrated, and purchased by the principal team member along with a secondary member reviewing and approving each step as a form of verification. The mechanics and structural components part of the Master Task List follow a similar format, with the steps for each component being: Draw and integrate, Source, and Purchase. The second file is a simple Journal of Events that clearly documents every event so that the team can keep track of all progress and communications. The Journal is also meant to document all pertinent information in case the project is taken over by a new team again in the future.

Both subsystems laid out expectations of work to be done the following semester. The electronics will be coded and tested as separate modules before gradually being integrated to the system as a whole. Similarly, the mechanical components will be assembled early next semester, considering the concept of modularity to minimize the impact of individual components' changes on the rest of the system.

References

[1]Gross, Norman, and Alexander York. "Deliverables 2014 Final Report." *2013/2014 Senior Design Team19*. Beyond Innovation, LLC, n.d. Web. 26 Sept. 2014. <http://eng.fsu.edu/me/senior_design/2014/team19/deliverable.html>.

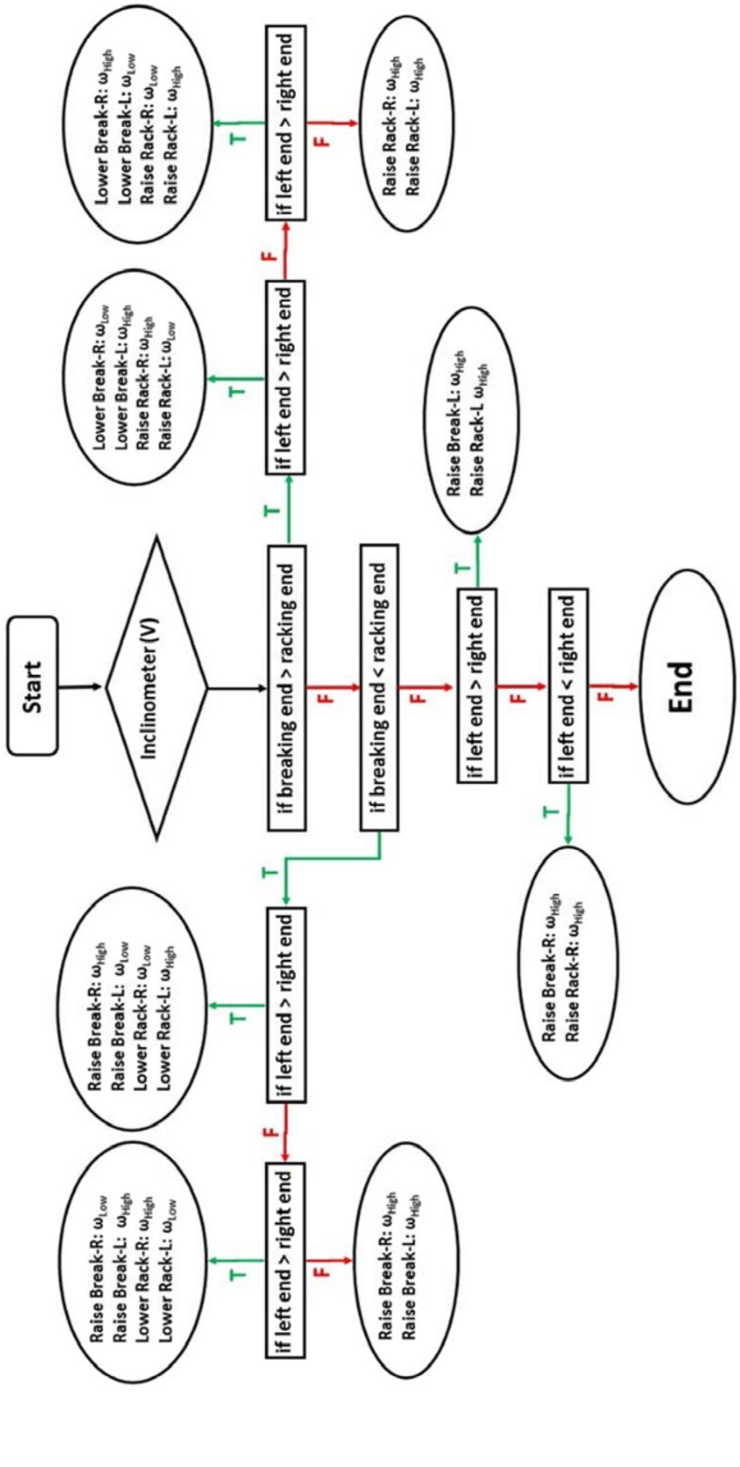
[2]Gross, Norman, and Alexander York. "Deliverables 2014 Final Report." *2013/2014 Senior Design Team19*. Beyond Innovation, LLC, n.d. Web. 26 Sept. 2014. <http://eng.fsu.edu/me/senior_design/2014/team19/deliverable.html>.

[3]Vescia, Paolo. "Velodyne Inventor Builds Self-leveling Boats." *Widgets RSS*. San Francisco Business Times, 15 Apr. 2014. Web. 26 Sept. 2014. <http://www.bizjournals.com/sanfrancisco/gallery/22511>.

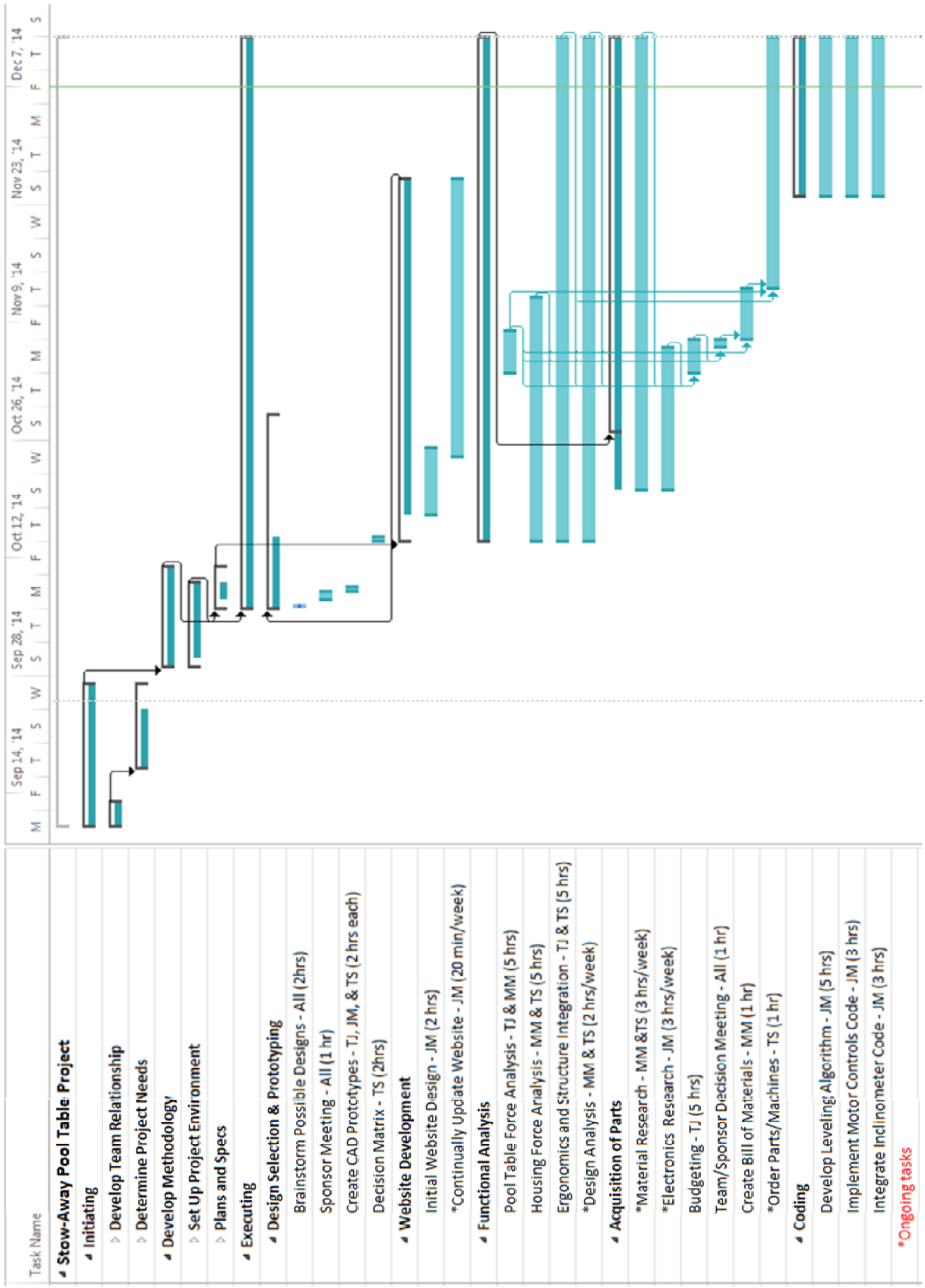
[4]Gross, Norman, and Alexander York. "Deliverables 2014 Fall Midterm Report." *2013/2014 Senior Design Team19*. Beyond Innovation, LLC, n.d. Web. 26 Sept. 2014. <http://eng.fsu.edu/me/senior_design/2014/team19/image_21.html>.

[5]157.1. "JOY-1811 Actuator Brochure." *Ø13 MA1527/MA3507 (12 VDC)* (n.d.): 4. Web.

Appendix A: Program Logic



Appendix B: Gantt Chart



Appendix C: Bill of Purchased Materials

Company	Order Date	Item	Part Number	Unit Cost	Quantity	Additional Costs	Total Cost
Adafruit	11/30/2014	Hook-up Wire Spool Set - 22AWG Solid Core - 6 x 25 ft	1311	$ 15.95	1	$ -	$ 15.95
Superbright LEDs	11/30/2014	16 AWG Four Conductor Power Wire	WP16-4	$ 0.59	50	$ -	$ 29.50
	11/30/2014	22-16 AWG Grey 3M Wire Nut	WN-2216	$ 0.09	50	$ -	$ 4.50
Robot Shop	11/30/2014	Sharp GP2Y0A02YK0F IR Range Sensor - 20 cm to 150 cm	RB-Dem-02	$ 14.59	1	$ -	$ 14.59
eBay: intl-trading	11/30/2014	Heavy Duty 6" 330lbs Pound Max Lift 12Volt DC Linear Actuator&Mounting Brackets	N/A	$ 65.54	4	$ -	$ 262.16
Muellers	12/4/2014	Replacement 7' Valley Coin-Op Rails Set of 6	36-237	$ 149.95	1	$ -	$ 149.95
Online Metals	12/4/2014	Mild Steel A513 Hot Rolled Rectangle Tube 1"x2"x0.12" Cut to: 24"	N/A	$ 13.03	15	$ 19.50	$ 214.95
	12/4/2014	Mild Steel A513 Hot Rolled Rectangle Tube 1"x2"x0.12" Cut to: 84"	N/A	$ 34.21	2	$ -	$ 68.42
	12/4/2014	Mild Steel A513 Hot Rolled Rectangle Tube 1"x2.5"x0.12" Cut to: 36"	N/A	$ 27.00	6	$ 6.00	$ 168.00
	12/4/2014	Mild Steel A569/ASTM A1011 Hot Rolled Sheet 0.125" (11ga.) Cut to: 12"x12"	N/A	$ 10.25	1	$ -	$ 10.25
Metals Depot	12/4/2014	2" x 1-1/2" x 1/4" Steel Angle A-36 Steel Angle Size: 2 Ft.	A1211214	$ 10.80	6	$ -	$ 64.80
	12/4/2014	1/4" x 1" Hot Rolled A-36 Steel Flat Size: 2 Ft.	F2141	$ 2.84	2	$ -	$ 5.68
	12/4/2014	1" x 1" x 1/8" Steel Angle A-36 Steel Angle Size: 2 Ft.	A11118	$ 2.64	6	$ -	$ 15.84
Lowes	12/4/2014	Kiln-Dried Poplar Board (Common: 1-in x 12-in x 48-in; Actual: 0.75-in x 11.25-in x 48-in)	Item #: 1105 Model #: 0118	$ 21.58	8	$ -	$ 172.64
Polulu	11/28/2014	Orangutan X2 Motor Controller	738	$ 149.00	1	$ -	$ 149.00
	11/28/2014	Dual VNH2SP30 Motor Driver Carrier MD03A	708	$ 59.95	1	$ -	$ 59.95
	12/4/2014	Wall Power Adapter: 12VDC, 5A, 5.5×2.1mm Barrel Jack, Center-Positive	1468	$ 18.95	1	$ -	$ 18.95
	12/4/2014	Pololu 5V, 1A Step-Down Voltage Regulator D24V10F5	2831	$ 7.49	1	$ -	$ 7.49
	12/4/2014	DC Power Adapter Barrel Jack	1139	$ 0.85	1	$ -	$ 0.85
	12/4/2014	400-Point Breadboard	351	$ 3.75	1	$ -	$ 3.75
		Total Cost (Before Shipping & Handling Fees)					**$1,437.22**