FAMU & FSU COLLEGE OF ENGINEERING
Department of Mechanical Engineering

EML 4551C – Senior Design – Fall 2012

Final Design

Mobility Lift for European Insider Applications

Group # 19

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INTRODUCTION

Harmar Mobility currently provides mobility lift solutions for a wide range of vehicles in the United States. However, the majority of vehicles driven in Europe are much smaller and more compact than those in the United States. This prevents the lifts currently offered by Harmar from fitting into European vehicles. Our goal is to provide a solution for the individuals who transport themselves in more compact vehicles and require a mobility lift. The task is to design a lightweight interior lift to compete in the European automobile market.

Although a universal fit is ultimately the goal of this design, to achieve a suitable prototype, all design aspects were initially based on the Volkswagen Golf VI – the bestselling vehicle in Europe for the past three years [6]. All relevant dimensions for this vehicle are provided in Appendix A1. Special consideration was paid to the trunk, or hatch, dimensions of the vehicle considering that the final design will ultimately be installed in that subdivision of the car.

EXISTING TECHNOLOGY

There are only a handful of companies that currently produce mobility lifts in Europe. Of these, there are even less that have lifts for compact cars. Among those described are the B&S's Samson, AutoAdapt's Carolift 6000, and AutoChair's Olympian. Each of these mobility lifts exhibit a crane-like structure and are operated by an electric motor.

B&S's Samson lift has a lifting capacity of 115 kg, a maximum height of 100 cm and an extension of 65 cm. The height of the lift can be shortened depending upon the size of the cargo area. The lift is operated by an electric motor, and then the rotation of the lift is manual. When not in use, the lift can fold down to increase the available cargo area. Figure 1 and 2 depict the B&S Samson [5].

Figure 1 – B&S Sampson

Figure 2 – B&S Samson folded position

AutoAdapt's Carolift 6000 is designed for vehicles with a sloping or narrow rear door. It has maximum capacity of 181 kg, minimum height of 87 cm, and maximum arm length of 84 cm. The arm height and length are adjustable. This lift differs from the B&S Samson in that the rotation into the vehicle is powered, not manual. An example of the lifting action of the Carolift 6000 is shown below in Figure 3. Additionally, the lift is not capable of lying flat; however, it may be folded to the side to increase cargo capacity. A highlight feature found in smaller models includes a bendable arm as seen in Figure 4 [3].

Figure 3 – AutoAdapt Carolift 6000

Figure 4 – Bendable Arm found in product line

OVERALL PRODUCT SPECIFICATION

Since this will be a product marketed towards consumers, the final mobility lift that is developed must be tested for safety and reliability. Since safety is a number one concern, our design must include safety switches to shut off power. Our design musts pass a safety factor of 3 set by Harmar—corresponding to a static load test of 390 pounds. Additionally, the unit must perform 10,000 cycles with a load rate of 130 lbs.

CONSTRAINT

Since the target consumer for our device will be marketed more towards the disabled and senior citizens, our design must be user-friendly and easy to use. This will be achieved by the selection of a simple and user intuitive device. Simplicity will be based on a design with a limited number of complex components such as actuators and other electro-mechanic devices. On the same note, since these users are physically limited in their day to day operations, the design must also be lightweight for manual operation. This includes lifting and positioning of the different components. At the same time, however, structural strength and rigidity is not to be compromised since strict consumer safety standards are to be expected. Lastly, European products are known for their quality. These consumers then come to expect a product that meets a certain level of style. Therefore, as requested from our sponsor, the overall design must be aesthetically pleasing.

INITIAL MATERIALS SELECTION

Accounting for all the constraints above, we must balance between a proper weight and reliability factor. Plans to use high grade aircraft aluminum or steel tubing for the structure of the mobility lift were initially considered. The material chosen must have suitable mechanical properties such as tensile, compressive, and yield strength. A high fatigue limit for the endurance of the cycle test of 10,000 repetitions is also necessary to ensure the long life of the product subjected to daily use. In addition the material must be able to withstand the cold European weather. This involves analysis of materials that do not experience any ductile-to-brittle transitions over these temperatures. Moreover, the selected material should have a good machinability for production by our sponsor as well as for the completion of a prototype at the FAMU-FSU College of Engineering. Ultimately, the cost of the material will play an important role in the material selection as well.

INITIAL DESIGN CONCEPTS

DESIGN CONCEPT 1

Overview of Design Concept

The motivation behind this design concept comes from a fork lift. In the cargo area of the vehicle a track is installed, this allows for smooth movement of the lift platform in and out of the cargo area. A sample CAD drawing of this design is presented in Figure 5, below.

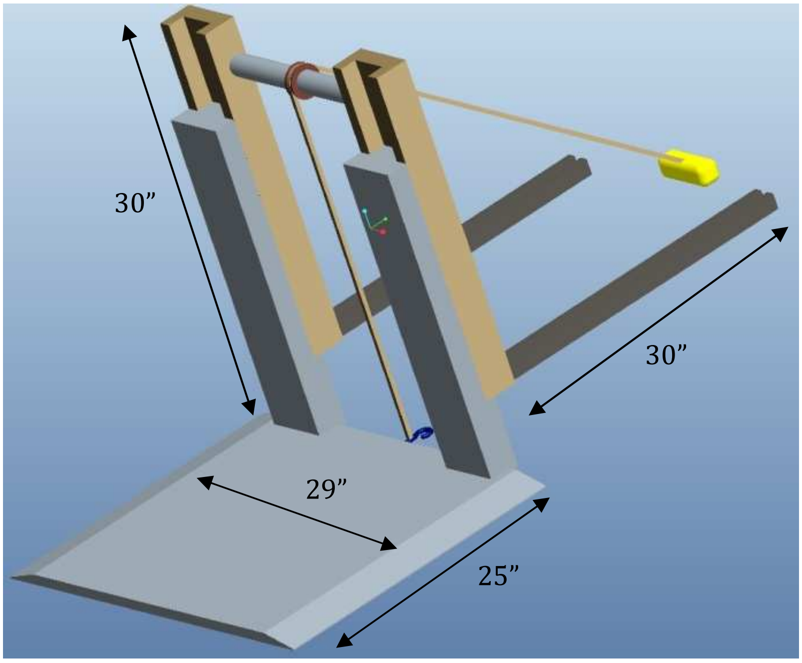


Figure 5 – Concept 1: Front Angle View

Attached to the track, by way of rollers in a c-channel, are the upright gear tracks. These gear tracks are responsible for keeping the lift platform level while raising and lowering the lift platform. The motor is attached to a strap that goes up over the roller bar, which is fixed between the upright gear tracks, and down to a hook at the base of the lift platform. This allows the employment of a single motor for lifting the platform vertically as well as moving it horizontally; therefore the design is fully automated.

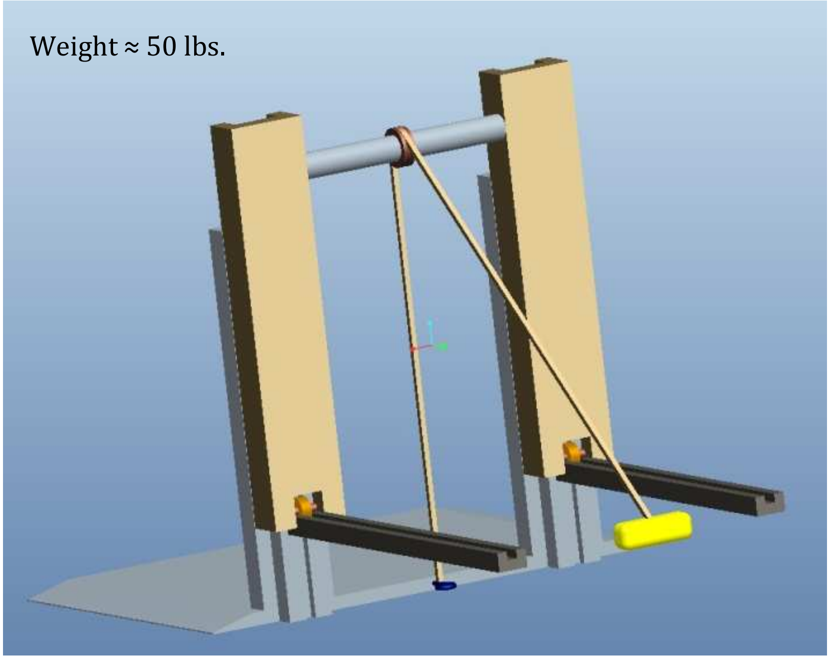


Figure 6 – Concept 1: Rear Angle View

Components and Function

Affixed to the floor in the cargo area, the track system will be the foundation of the design. The method of affixation has not yet been fully examined; however upon doing some rudimentary calculations for a single fixture, the fixture needs to be able to support a bending moment of approximately 6,230 N-m, or 1,400 lbf-ft. For this design, multiple fixtures will be employed, allowing for overcompensation of forces, as well as the safety of the component. The tracks will have a channel cut into them. This channel is where the roller that is attached to the upright gear track will move horizontally.

The upright gear tracks will have c-channels cut into them, which the lift platform uprights can slide in and out. Although this component has not yet been fully designed, the idea is to have at minimum one set of gears on each side of the channel, which will help to reduce the chance of abrupt sliding and allow for smooth movement vertically of the lift platform. Also, we would like to include some locking mechanism such that once the lift platform is lifted to some height it cannot go back down without unlocking the mechanism. Between the upright gear tracks is the roller bar, and in the middle of the roller bar is a pulley wheel. This pulley wheel allows the strap to be run up over the bar and out past the bumper, so as to not damage the vehicle.

The lift platform consists of two components, the uprights and the platform. The platform is the component that the mobility device will be maneuvered onto and will convey the mobility device into the vehicle. In order to allow the mobility device to drive onto it, the platform needs to be thin, yet it must be thick enough to withstand the weight of the mobility device plus a factor of safety of three. An alternative to the solid platform is to have a reinforced grate; this would cut down on the weight of the platform. The uprights will be T shaped and will have gear teeth along the T to mesh with the upright gear tracks, enabling the smooth motion previously described. A motorized wench and strap runs the entire assembly. The strap remains connected to the base of the lift platform, between the uprights. It is then run up over the pulley and roller bar, and down onto the motorized wench system.

DESIGN CONCEPT 2

Overview of Design Concept

This design concept is a product between classic and modern design. It resembles a typical insider mobility lift that is tailor fit to the European market. Since the 6th Generation Volkswagen Golf will be used as the test base to aid in the development of this product, the mobility lift dimensions are limited to 30 inches in height and 29 inches in width. This concept offers the best versatility and user-friendliness. The design has several advantages at achieving the requirements set by Harmar Mobility, Inc. For instance, it is able to fold to save space, can be rotated and swung about its center line, and the boom arm length can be extended and contracted depending on the customers need.

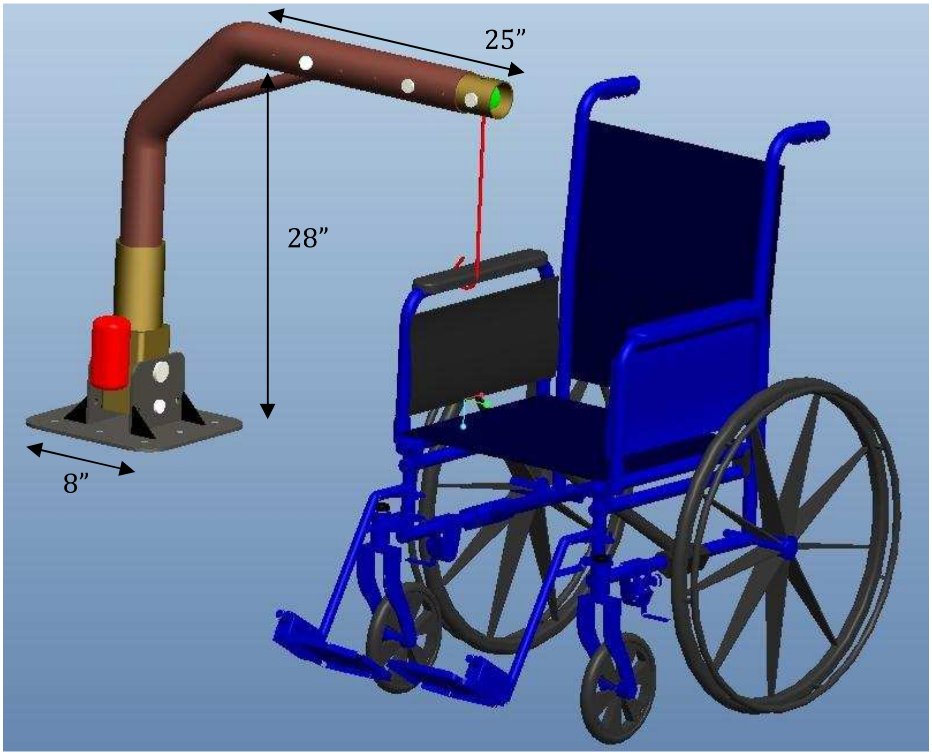


Figure 7 – Concept 2: Lift Assembly and Wheelchair (not to scale)

Components and Functions

At the foundation of the mobility lift is its base. It is mounted directly into the customer’s vehicle or testing platform. Four gusset plates are welded to the base plate to provide additional strength and assist with the welding process by creating a 90 degree angle. In addition, the user can rotate or swing the device arm from 0 degree to approximately 180 degrees about the upright center line. This design concept provides two folding options—flat at 0 degree and approximately 20 degrees depending on the user’s desire. The user can select any folding option by removing the lower pin and inserting it into one of the three pre-drilled holes at the base side.

The arm has a built-in extending and contracting mechanism, which can manually lengthen by an additional 10 inches for easier reach of larger objects. The extending arm is fit nicely into the main arm and secured to the main arm by two screws. The user can extend or contract the arm by placing the two screws at desired locations. The motor is placed inside a secure housing that is mounted directly to the lower arm. The control for this design will be accomplished with by a remote control system provided by Harmar Mobility. There will be precautionary safety switches built-in to limit the travel distance of the cable and hook system. Also, all cables, electrical wires, and pulley can be housed internally inside the arm, with a screw cap to keep it securely away from weather, dirt, and debris.

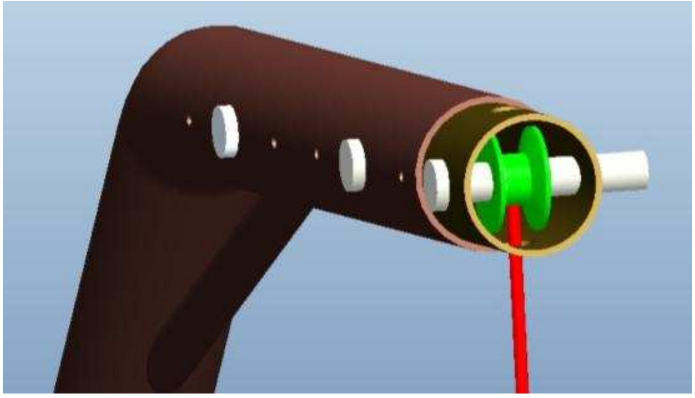


Figure 8 – Concept 2: Pulley Mechanism

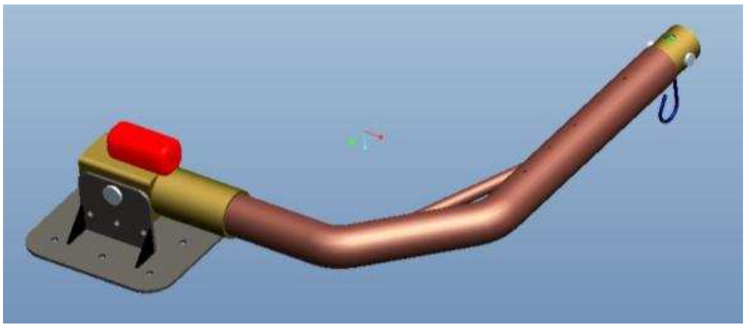


Figure 9 – Concept 2: Mobility lift at 0° Folding Position

The round pipe with a correct wall thickness was chosen over a square or t-slotted material for several reasons. One reason being to utilize the round pipe bender available at the College of Engineering machine shop in order to simplify the manufacturing process. Also, it provides a free rotation when pivoted about the center line. In addition, it is more sensible in price when compared to a t-slot structure channel. More likely than not, high grade aircraft aluminum will be used to save weight, but at this design stage no decision has been made.

Since this design is based on a typical mobility lift, it is user friendly to the physical impaired and seniors. Based on initial market analysis, older citizens prefer traditional design with modern accessories. This design concept provides the user- friendliness, ease in manufacturing and cost effectiveness. Also of importance, it satisfies all requirements out forth by Harmar Mobility.

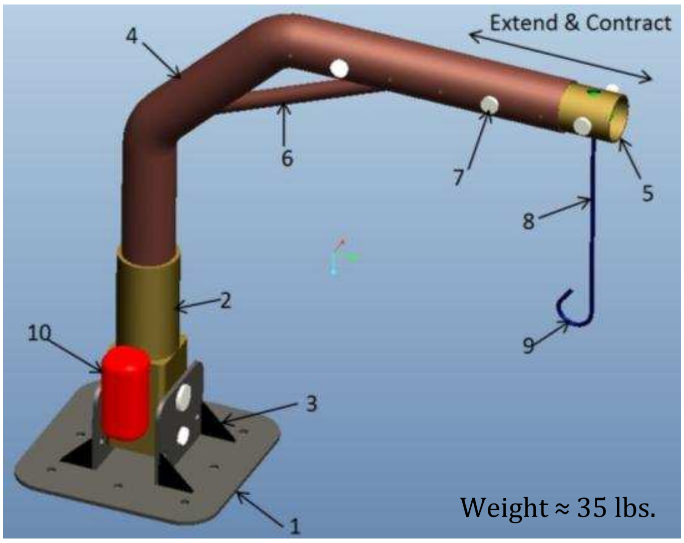


Figure 10 – Concept 2: Fully Assembly View (10 components)

DESIGN CONCEPT 3

Overview of Design Concept

In essence, this project requires the development of a specialized type of crane, or lifting mechanism. To accomplish this, a design featuring multiple advantageous aspects of various crane types was developed. First and foremost, this design concept is based primarily off of an overhead type crane system. This particular type of crane features certain properties that may be more beneficial than other types of traditional mobility lifts in the market today. For example, in industry, overhead cranes are used for their reliability and ability to lift heavy loads. Additionally, this design calls for the implementation of an extending and contracting boom similar to that of a telescoping crane. The relative compactness of a telescoping boom makes them adaptable for many mobile applications [13].

Components and Functions

For this application, all designs presented are to be based on the Volkswagen Golf VI. At its core, this design features a u-shaped structure. The u-shape allows the apparatus to lift the wheelchair and then secure it within itself. Due to the light weight constraint set for the design, an aluminum alloy will most likely be used such as AL6061. However, if a more economical alternative presents itself, the material selection may be changed. This component will be drawn out from a single tube of material and will, therefore, add to the overall strength of the design. Furthermore, the simplicity in design will not only make it easier to manufacture, but also add to its user-friendliness.

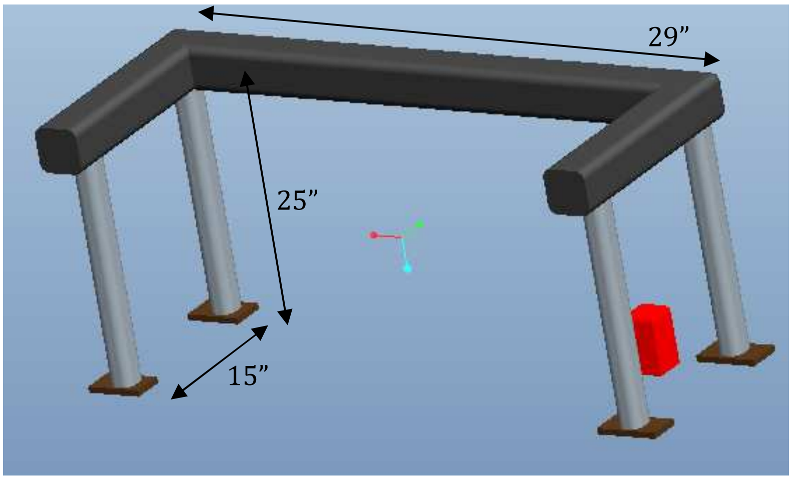


Figure 11 – Concept 3 Lift Assembly: Fully Retracted Arms

Attached are four legs that will be bolted to the floor of the automobile. Therefore, these legs are to be attached to the floor of the hatchback. The increased number of fixations to ground will ultimately help in distributing the weight of the load to be lifted. Currently, this design calls for the bolting of the legs to the floor of the automobile. This will be accomplished by a total of 16 bolts, 4 per foot. Structural analysis is to be performed to verify the required number of bolts needed for the 390 lb maximum load to be upheld. While a permanent, solid fixture adds to the overall strength of the design, some consumers may shy away from such a tradeoff. Further research into a more compromising alternative is to be explored.

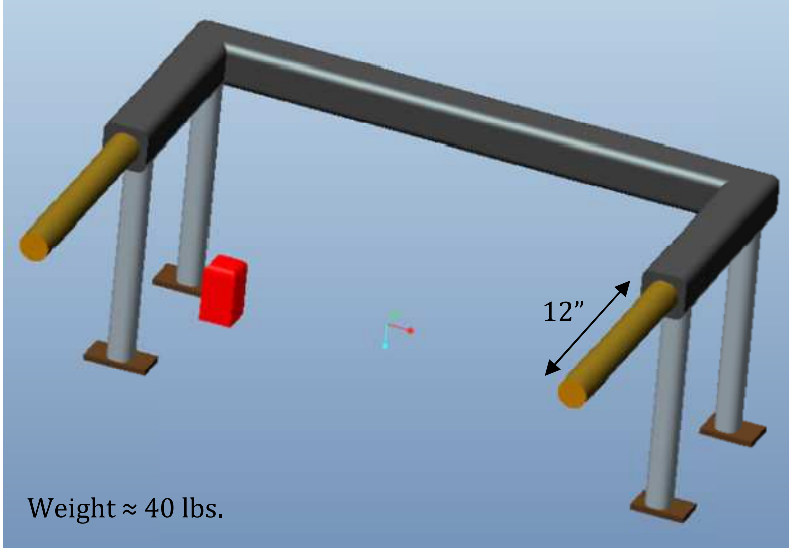


Figure 12 – Concept 3 Lift Assembly: Fully Retracted Arms

Within the structure, telescoping arms will be housed on each side. These arms will be constrained to only move forward (i.e. out of its housing) and backwards (i.e. into its housing). To achieve this, a bearing slide device will be used. Though not yet decided upon, this design may incorporate any of the following types: linear ball-bearing slides, roller bearing slides, progressive action slide. A sample drawing of a three member ball bearing slider rated at 400 – 600 lbs is shown below [4].

Within each tracks, a braided cable will run the length of the arm to be connected to the motor. The motor is to be supplied by Harmar Mobility. Therefore, proper attention will be paid to the selection of an in stock motor that will meet the demand of the design. Communication with Harmar personnel and engineers for input and advice on motor selection will be taken. Sample motor data from Harmar is shown in the Appendix. An accompanying strap and various hooks will be supplied to the consumer for attaching to the cables for lifting their load.

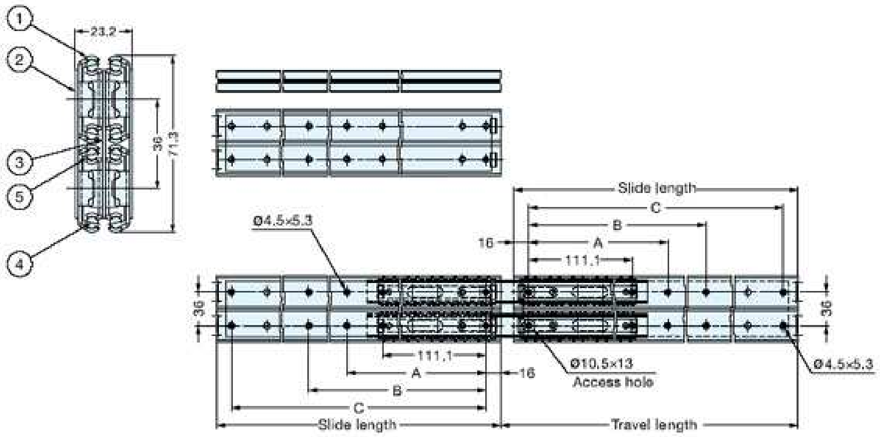


Figure 13 – Linear Bearing Slider Dimensions (mm) [4].

Lastly, an electronic mean for operating the lift will be developed in the form of a small hand control. Through discussion, Harmar has expressed their interest in using the new two-button control currently being used for their AL600 model. Harmar currently uses a PC board with a 2-button pendant (hand control) which could be used. The connection is to be wired to ensure possession with lift (i.e. will not get lost).

Overall, the design explained above is a far deviation from what is currently available in the US and Europe. This may be an advantage for Harmar as a means of distinguishing themselves from other competitors. Though different, this design is not without its advantages. Its basis from an overhead type crane directly adds to its ability to lift larger load if needed—also adding to a higher factor of safety for this particular application. Furthermore, the required custom fitting of the design for cars other than the Volkswagen Golf VI may be seen as both an advantage and a disadvantage. This includes the length of the lift to ensure the telescoping boom extends to a length suitable for lifting, as well as the height to ensure the driver's visibility is not impede for operating the vehicle.

DESIGN SELECTION

Based on the design concepts presented above a decision on which selection to continue developing must be made. To accomplish this, a decision matrix (Table 2 shown below) was employed. Each design was rated from 1 to 10. Here, a value of 1 corresponded to the lowest score possible, while 10 was the maximum. Table 1, presented below, gives the weighted criteria along with a description of each factor. As described by Harmar, cost and functionality were explained to be of great importance. Because of this, these two factors are weighted the highest—40% and 60%, respectively—and then subsections of each where expanded upon.

Table 1 – Decision Matrix Criteria

Criteria		Weight	Description
Functionality **(40%)**	User Friendliness	25%	"Will someone who requires a mobility device be able to operate the product?" This aspect touches on the amount of labor a person must put into making the lift operate. Since the majority of persons using mobility devices are limited in their mobility, the labor involved should be at a minimum.
	Appearance	15%	"Is the product aesthetically pleasing?" The sponsor from Harmar stated that they would like the lift to look nice. The reasoning behind it being that in Europe consumers are more inclined to have better appearing components installed on the vehicles.
Cost **(60%)**	Manufacturability	35%	"Will the product need many specially made parts, or can it use pre-fabricated parts?" This can also affect the cost of the product.
	Durability	25%	"Does this product stand up to normal or greater use over a term longer than 7 years?" Harmar has a 3 year transferrable warranty on all the mobility lift models, during which the mobility lift should remain in excellent working condition. Doubling the time of warranty as the test period should enable this.

The decision matrix was then completed based of the aforementioned criteria explained in Table 1. The results of this selection can be seen in Table 2. From here, it is evident that Design 2 will be the selected concept to move forward with. This concept proved to be the best choice given the inputs required of the design and will be expanded upon for further improvements and analysis.

Table 2 – Decision Matrix

		Weight	Concept A	Concept B	Concept C
Functionality (40%)	*User Friendly*	*0.25*	3	9	7
	Appearance	*0.15*	4	5	7
Cost (60%)	*Manufacturability*	*0.35*	2	8	4
	Durability	*0.25*	5	6	7
Total		*1.00*	3.30	7.30	5.95

In the end, Design 1 proved to be too bulky for the application at hand. Additionally, after speaking with our sponsor, all parties felt that this design was impractical for small applications. That is to say, Design 1 would lend itself more to the lifting of very heavy 200+ lb power wheelchairs found in the market today. Of course, this goes beyond the scope of this project and was therefore rejected. Lastly, the size of Design 1 would also limit the available choice of vehicles for installment. As noted in Figures 5 and 6, Design 1 proved to be the largest in terms of overall dimensions and weight (≈ 50 lbs).

On that same note, Design 3 was relatively close to becoming the design of choice (5.95 design evaluation). However, it was ultimately concluded that this design proved to be more complex than what was needed for small scale applications. Although, most design criteria fell within range of the constraints, Design 3 was ultimately abandoned in favor of Design 12. The following text will describe the finalization, improvement, and analysis of Design 2.

FINAL DESIGN

IMPROVEMENTS FROM INITIAL DESIGN

The final design is based on the original concept of Design 2 with the addition of more degrees of freedom. Additionally, the development of a universal base that can be mounted in many type of vehicle—including one with a spare tire—was added. Alterations to the round tubing found throughout the initial design were replaced with square tubing. This change was made in order to utilize the standard stock material that is already available at Harmar Mobility production facilities. Furthermore, the change to square tubing was made to eliminate the need of a tube bending machine; a change that will ultimately lower the manufacturing cost. The rigid neck was replaced by an adjustable neck that is able to give users a greater range of motion when lifting larger and differing sizes of wheelchairs. Lastly, the motor was relocated to the side of the base and is mounted securely inside a plastic molding housing. An initial assembly of the new design is given in Figure 14, below.

Figure 14 – Final Design (Assembled)

DETAIL OF DESIGN

The final design of this mobility lift concept includes many unique features, such as a telescoping arm. Figure 15 shows a more detailed assembly of the final design, as well as significant dimensions. To position the telescoping arm, the user must remove and place the two arm-pins in their desired location in the pre-drilled holes along the length of the outer arm. Another added feature is the adjustable height of the upright, or boom, that will allow users to lift any taller or larger objects within its operating weight. The height is adjusted through the use of a collar, help in place by a set screw. The set screw must be unscrews and the collar may be reset to any position along the length of the boom. Additionally, the neck pith is also adjustable via the adjustable pins placed at a desired orientation on the angle plate (blue). Two angle plates are mounted on both side of the hoisting arm, from which, the screws will enter on one side and exit through the other.

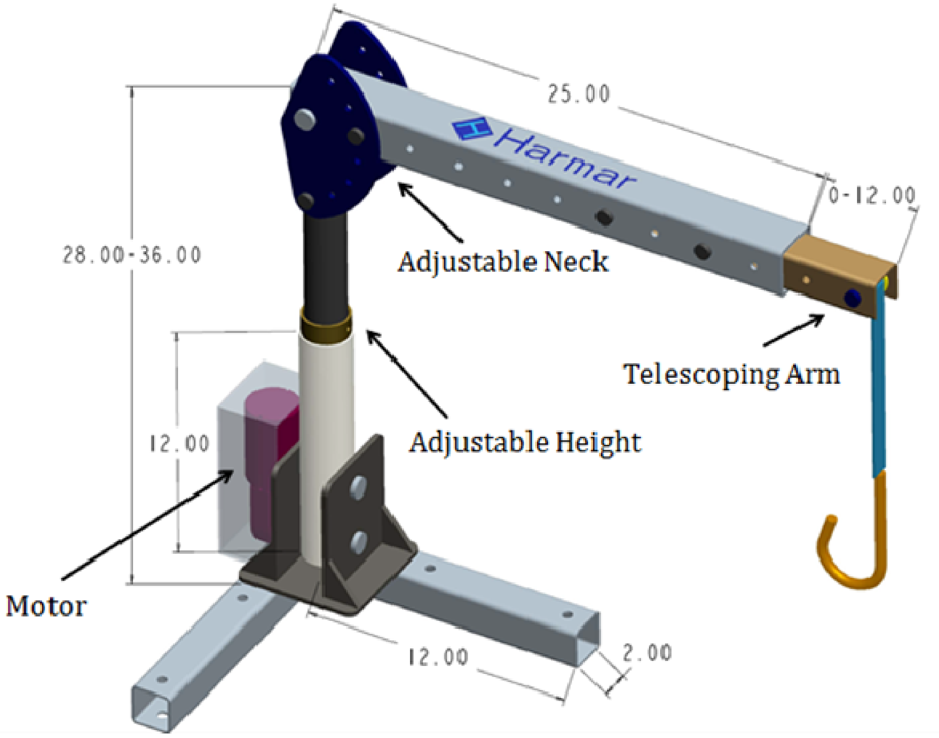


Figure 15 – Detail Assembly with Dimensions

One of the factors considered competitive in the European mobility lift market — also listed as a constraint for our design— is the ability for a design to be compact and have a folding option since European cars are smaller than American cars. In order to maximize cargo space and not obstruct the rear viewing space for divers, a full fold-down option was also expanded on from the initial design. Figure 16 below shows the implementation of this feature on our final design.

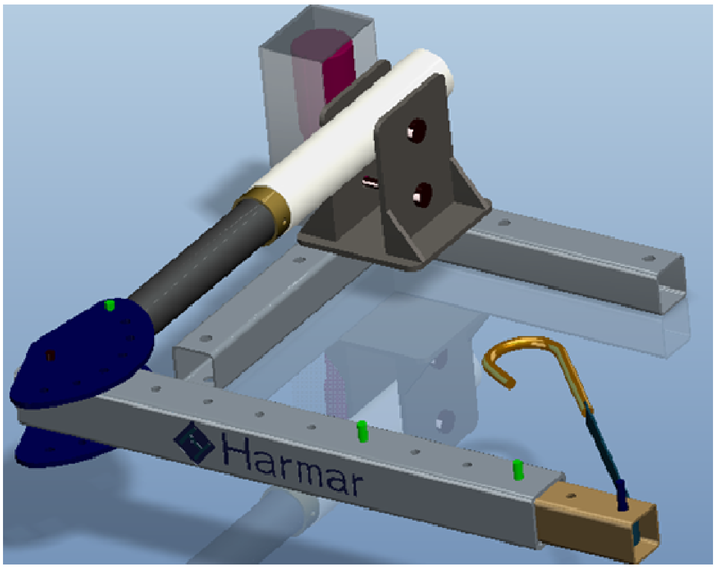


Figure 16 – Full Fold-Down Option

Lastly, since Harmar Mobility is providing customers with a limited warranty, our design must operate smoothly and trouble free in any reasonable weather and under any condition. Therefore, the pulley and roller system is protected internally inside of the extending arm. Although not shown in Figure 17, a plastic cap will be installed on the front-face opening of the extending arm to hide and protect these components from consumers and users.

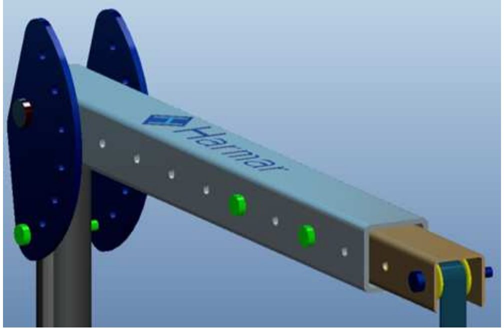


Figure 17 – Hoisting Pulley-Roller System

COMPONENTS

Motor and Electrical System

In order to standardize the manufacturing process and minimize the research and development cost for this project, Harmar Mobility is providing a DC motor (50 volt). Conveniently, this motor already comes coupled with a gearbox. An example of the aforementioned motor can be seen below in Figure 18. (Please refer to Appendix B1 for more technical specifications provided by Harmar Mobility, Inc.).

Figure 18 – Driver Motor

As seen from Table 1, the selected motor is available with three gear ratio options. It is important to note that, at this point in time, Harmar Mobility, Inc. has yet to determine which exact motor option (and therefore gear ratio) is to be used for this specific application.

Table 3 – Motor Parameters

Motor Model – KSV 4030

Gear Box	Aluminum
Speed (RPM)	15 – 260
Torque (Nm) [Max]	5
Starting Torque (NM) [Max]	45
Ratio	1:37.5 | 1:75 | 1:89
Optional Encoder	70 – 100
Optional Self-Locking	Yes

As per the Gantt chart for Team 19, power and control systems will be the subject the Spring 2013 semester design analysis. Because of this, the fact that this characteristic is still unknown has little detrimental implications on the design process at this point in time. I necessary, for all subsequent calculations, a gear ratio of 1:75 will be assumed. However, when notified by Harmar, this ratio may be changed and all subsequent analysis will be recalculated.

Control System

Similar to the motor selection, Harmar Mobility is also providing the control system and all the necessary wiring harnesses. Previously, no decision had been made as to whether or not a wired or wireless control was to be used. Examples of both devices are shown in Figures 19 and 20, respectively.

After communication Harmar, both involved parties felt a wireless control was beyond the scope of this design. In order to maintain an economical advantage over any possible competitors, a wired control was chosen.

Figure 19 – Harmar handheld wireless controller

Figure 20 – Harmar wired control

MATERIAL SELECTION REVISITED

After finializing the design process, analysis then had to be made to determine if the proposed concept was viable in terms of strength and robustness of design. To make this analysis, the material selection had to be re-evaluated in order to input the correct values and properties into a computer simulation. Ultimately, a bulk material was chosen that was readily avaialble (as noted previously). This material was then found to be ASTM A500 Grade B welded structural steel tubing. Relevant material properties for this steel is presented in Table 4, below.

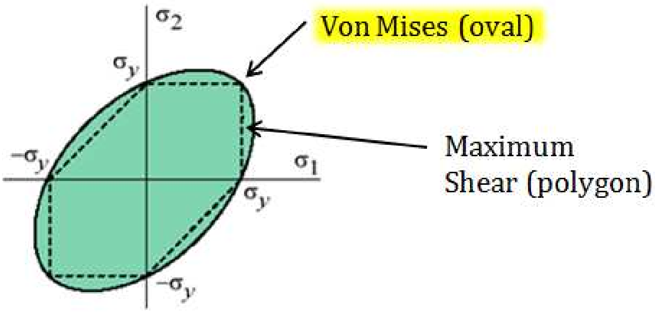
Table 4 – Selected Material Properties

Density	7850 $\frac{kg}{m^3}$
Young's Modulus	200 GPa
Yield Strength	415 MPa
Tensile Strength	725 MPa
Poisson's Ratio	0.33

FEM ANALYSIS

After a proper material was selected, the design was imported into computer software programs to begin finite element analysis. These programs included Mechanica, a subset application of PTC Creo Elements/Pro® as well as COMSOL Multiphysics®. Both software programs are available for use at all computer stations throughout the FAMU-FSU College of Engineering.

In performing the FEM analysis, the design was subjected to the maximum static load set forth by Harmar, roughly 390 lbs. This value corresponded to a safety factor of roughly 3x expected operating conditions. Additionally, stress analysis was tested against the Von Mises yield criterion. A visual explanation of this theory can be seen in Figure 21, below. Simply stated, this theory states that failure occurs when a stress value is encountered that equals or exceeds the von Mises boundary.



$$\frac{1}{2}[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2] \leq \sigma_y^2$$

Figure 21 – von Mises Yield Theory

General Assembly

A general assembly was constructed in COMSOL with the hope of finding any potential stress concentrations that would lead to yeilding, or failure. A mesh of the assembly is given in Figure 22. This mesh consisted of 16,555 number of elements, which this team feels is a fair compromise between memory and processing limitations of the hardware, as well as provide sufficient resolution for the analyis.

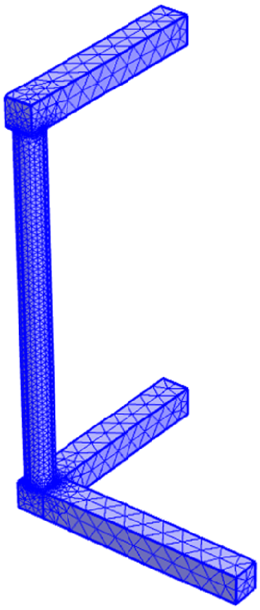


Figure 22 – Assembly Mesh

The output from the processed analysis is given in Figure 23. Again, it is important to reiterate that this analysis was conducted for a maximum static load of 390 lbs, or a factor of safety of 3. From Figure 23, we see two significant stress concentrations. These include a stress of 126.24 MPa—the highest stress experienced—occurring at the connection of the base with the boom and a 107.22 MPa stress occurring at the connection of the hoisting arm with the boom. Recalling Table 4 which shows a yield strength of 415 MPa, we come to the conclusion that the selected material is more than adequate in withstanding this load. Additionally, as Figure 23 shows, some deflection is to be expected to the subjection of this load. Through COMSOL, a maximum deflection of 0.135 in. was found to occur to this corresponding 390 lb static load.

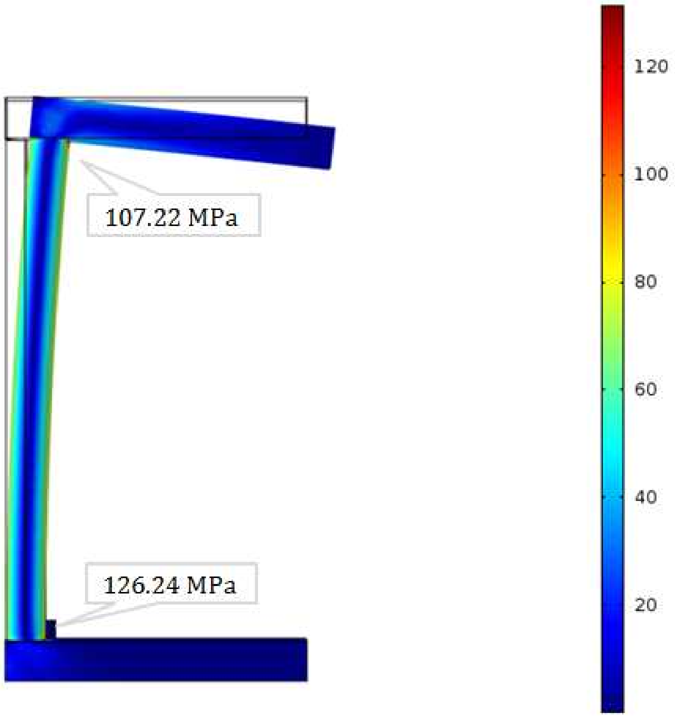


Figure 23 – COMSOL FEM Output

Additional views of this output are shown in Figures 24 and 25, respectively. From both figures we see that the entire boom experience some type of stress throughout its length. However, once again, we find no expectation of failure from these stresses. (For future goals and work, please see the relevant section below.)

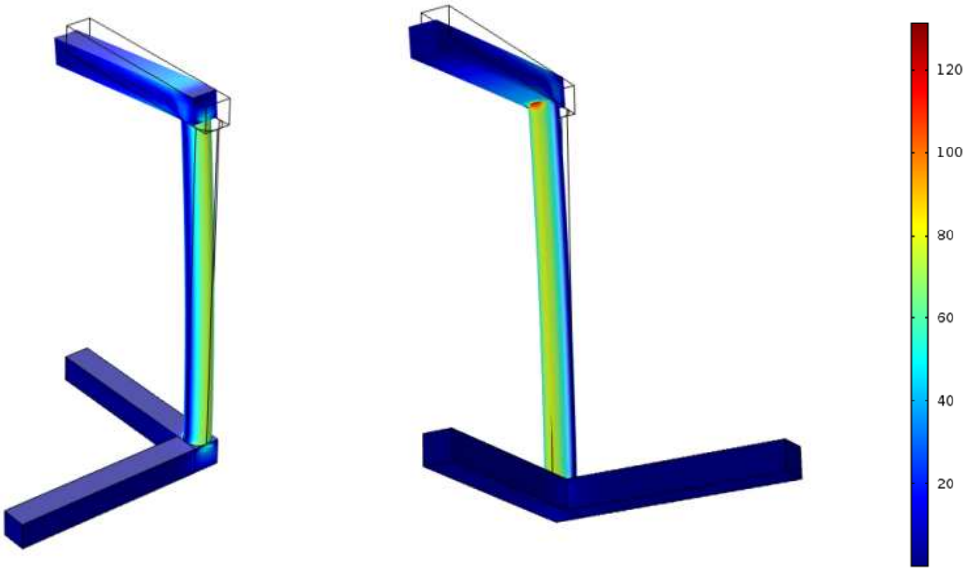


Figure 24 – FEM Assembly Additional Views

Individual Components

Similar to analysis of the entire assembly, individual components that this team felt were critical to the overall assembly were subjected to the same analysis. These components could not be made into the general assembly analysis for reasons stated previously. That is to say, the memory and processing limitations of the hardware were not capable of supporting such a complex design. However, stress analysis for these parts was conducted in PTC Creo’s Mechanica. Figures 25-28 shows the corresponding stress analysis for these components. It is important to note that the output for these components is given in ksi. The corresponding yield strength is the 60.19 ksi.

Figure 25 shows the base subjected to the 390 lb load at a angle of 45°. This angle was thought to be the expected worst case scenario that would likely be experienced by a user (A load corresponding to 0° or 90° was felt to be illogical). From the figure we see stress concentrations occurring at the sharp junctions of the gusset plate. This is to be expected, however, we still find that the no error occurs.

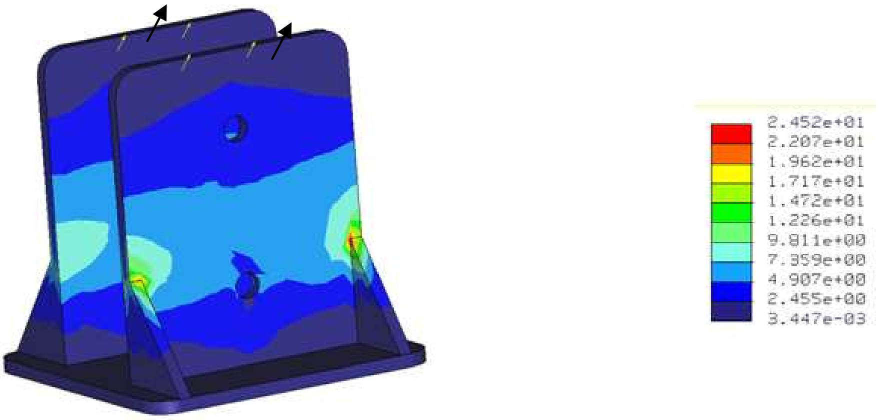


Figure 25 – FEM for Base

Similarly, Figure 26 shows the outer arm subjected to the maximum static load occurring at the furthest point of the face of the outer arm. From the figure we some stress concentrated around the pin hole connecting the arm to the rest of the body. These stresses, however, prove to be insignificant.

Figure 26 – FEM for Arm

The pins found throughout the body of the assembly were also analyzed for failure. Figure 27 shows a pin that would connect the outer arm (Figure 26) to the assembly. This pin was subjected to a load at two position corresponding to the surfaces where the pin would interact with the arm. This distributed load was oriented at 0°, the presumed worst case scenario. Once again, we find no yielding to be expected.

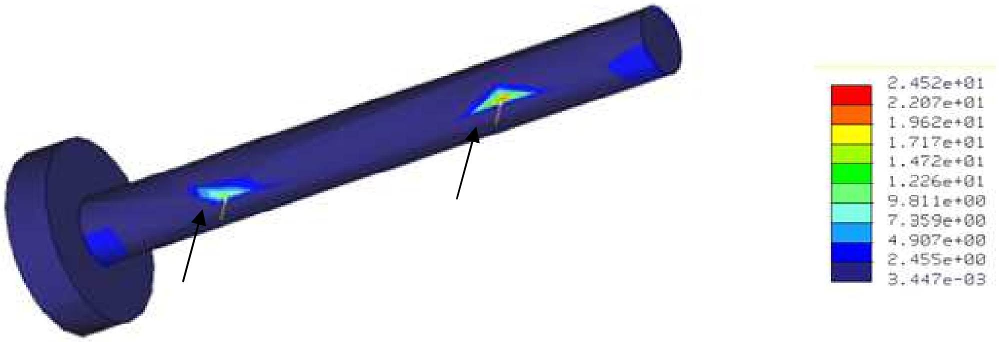


Figure 27 – FEM for Pin

Lastly, the angled plate was analyzed in a similar fashion. Figure 28 shows the output of the simulation. Here, the angle plate was subjected to a load at the position corresponding to the surfaces where the pin (Figure 27) would interact with the component. This distributed load was oriented at 0°, the presumed worst case scenario. The lower pin hole shows the stress reactions to this load. Once again, we find no yielding to be expected.

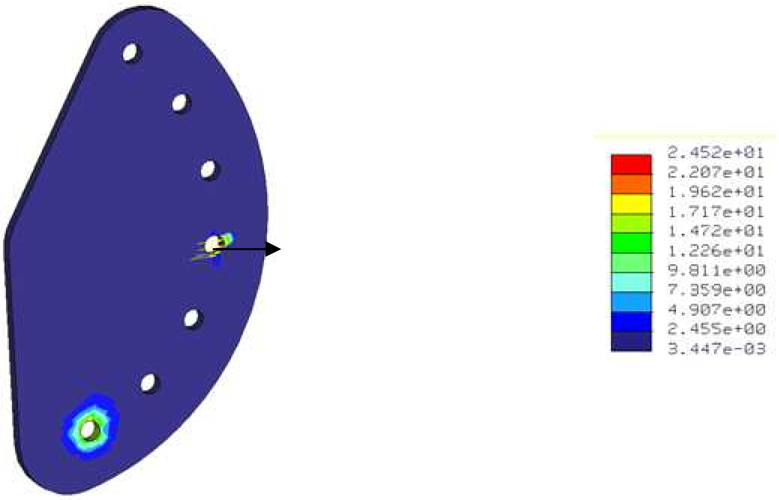


Figure 28 – FEM for Angle Plate

ENVIRONMENTAL AND SAFETY ASPECTS

Since this will be a product marketed towards consumers, the final mobility lift that is developed must be tested for safety and reliability. Since safety is the number one factor, our design must include a safety which can cut off power to the device. Our design musts also pass a factor of safety of 3, which is set by Harmar, and corresponds to a static load test of 390 pounds. Additionally, the unit must perform 10,000 cycles with a load rate of 130 pounds.

Since the motor and control system is being supplied by Harmar Mobility, the safety power shut off being used is the one currently being utilized on all the lifts currently offered by Harmar mobility. Upon speaking with our sponsor, he informed us that they have not yet had any safety issues with the current motor and controls.

As for testing the testing the loading of the unit, prior to building, computer based Finite Element Analysis will be done on the entire assembly. When it passes the Finite Element Analysis, and has been build, the plan it to test it much like Harmar Mobility's manufacturing plant does. The first will be to lift the static test load of 390 pounds. Once that has been completed, we will connect the controls to a computer which will run a program, supplied by Harmar Mobility, that will make the mobility lift operate every three minutes. This will be done a total of 10,000 times to ensure it will not fail due to fatigue.

The environmental impact of our design is no more than any other mobility lift device. It is comprised mainly of steel parts, which is a large contributor of CO2 emissions into our atmosphere, mostly due to the coal being used to heat the blast furnaces (Iron and Steel Emissions). Initially the design was to be comprised of aluminum, however our budget did not allow for such high priced materials. One other environmental concern would be the use of the automobile battery as the power source for the lift. This may cause the battery to drain quicker, causing the need to replace the battery sooner. This would have been a problem about 15 years ago, before the disposal of lead-acid batteries was prohibited, however lead battery recycling has reached approximately 97% in the United States (Lead-Acid Battery Recycling).

COST ANALYSIS

Table 5 below provides a detailed cost estimation based on McMaster Carr supplier for components. The materials, motor, and miscellaneous components such as nuts and bolts are based on current market price and shipping costs. From the table, we see that the motor is the most expensive item next to the overall cost of materials. For machining cost, we used an online cost estimation calculator based on the machinability of our design. We currently are assuming a labor cost is zero for the cost estimation. This is because, we feel, the designing and building of the initial prototype is expected to be significant and would otherwise skew the overall cost estimation. The total for the design and prototype for this product is approximate at about $430.00. This fits well into our $500.00 assigned budget. In addition Harmar Mobility will provide any materials and necessary hardware to build a working prototype for this mobility lift that cannot be found or made by ourselves.

Table 5 – Detailed Cost Estimation

Square Tubing 2 X 2 X 11 GA	$30.36
Round Tubing 2-1/2" SCH 80	$22.58
Round Tubing 1-1/2" SCH80	$30.48
A36 Steel Plate 3/16” thick	$9.65
A36 Steel Plate 1/4” thick	$25.72
Nylon Sleeve	$4.95
Lift Sling	$38.95
Swivel J Hook with Bolt	$5.60
Heavy Duty Nylon Pulley	$8.90
Plastic Molded Motor Housing	$11.95
Ankarsrum KSV 4030 motor	$135.00
Nuts and Bolts	$20.97
Machining Cost	$85.50
Labor	$00.00
Total Prototype Cost	**$430.61**

GOALS AND FUTURE WORK

Our future goals are shown—but not limited to:

While the details of the spring semester are not yet nailed down, we do have a few goals and deadlines in mind.

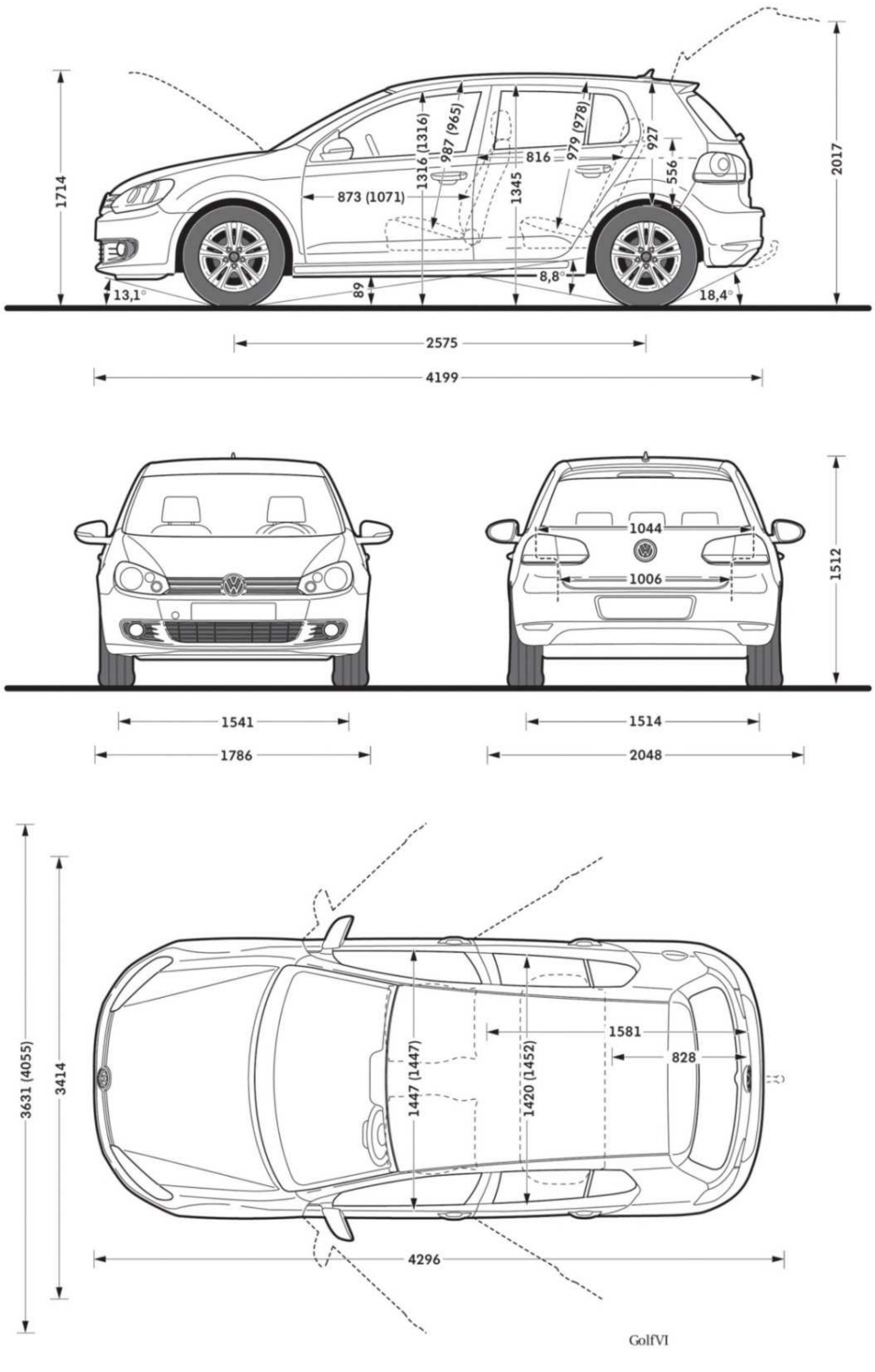
- Develop more in-depth model for simulated analysis
- Complete CAD drawings packets by second week of February 2013
- Visit Harmar Mobility, Inc. during the build process
- Finish prototype by second week of March 2013 (spring break)
- Prototype testing and analysis (may take up to a month to complete)
- Provide Harmar Mobility with a unique and profitable product

WORKS CITED

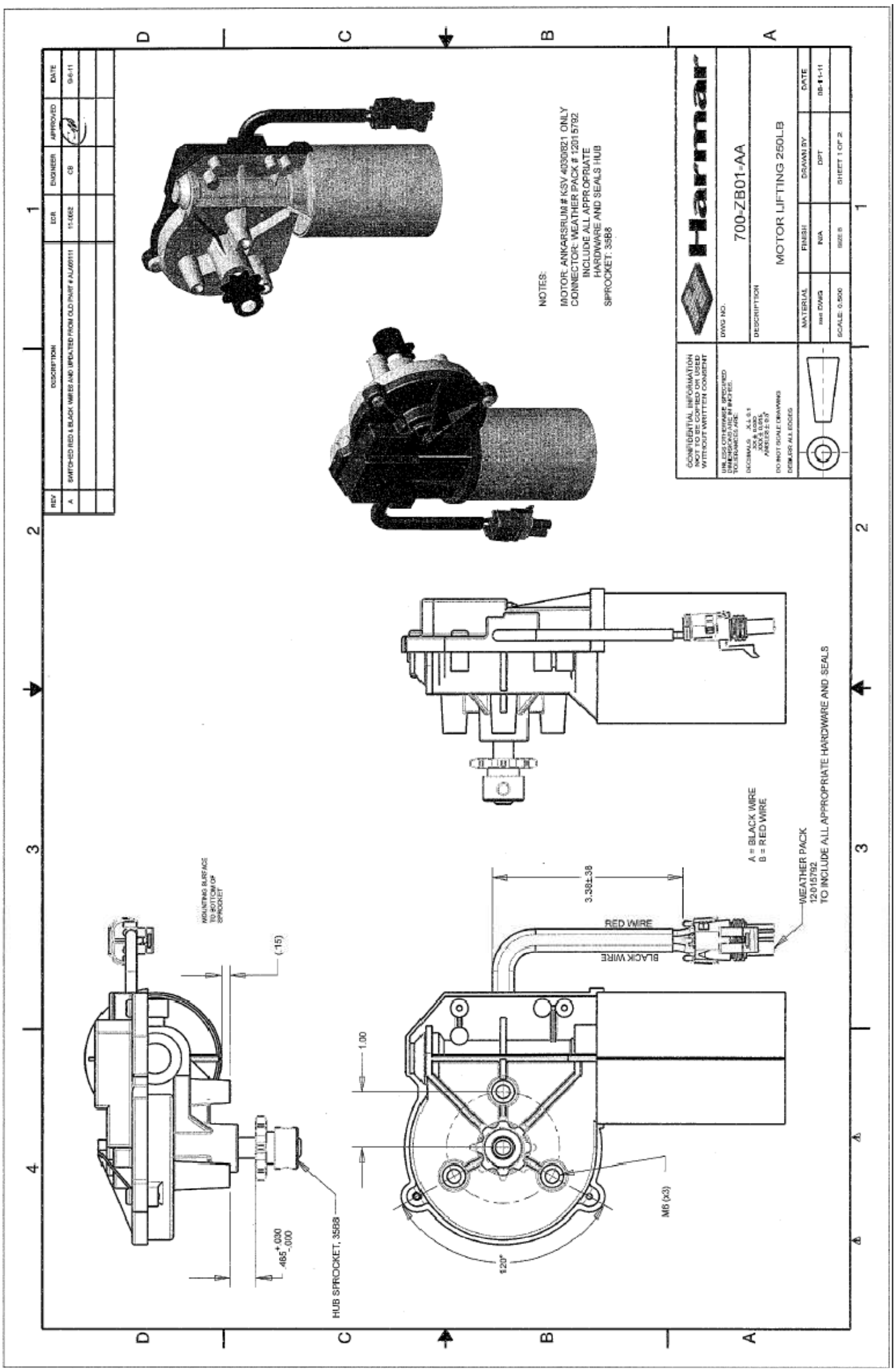
1. AL055 Economy Inside Lift
   http://www.harmar.com/products/23
2. Ankarsrum Motors AB DC Motors
   http://www.ankarsrum.com/website1/1.0.1.0/16/DC-motors_web08.pdf
3. AutoAdapt Carolift Brochure
   http://www.autoadapt.com/produkter/PDF/Carolift-6000-6900/Carolift-6000-6900_EN.pdf
4. Ball Bearing Three Member Slide
   http://sugatsune.com/products/ProductDetails.cfm?CATID=13&SUBCATID=3&PRODUCTID=ESR-10
5. B&S Wheelchair Hoists Brochure
   http://www.onbeperktinbeweging.nl/documents/Engels-Kofferbakliften.pdf
6. European Bestselling Cars
   http://bestsellingcarsblog.com/2012/03/03/europe-full-year-2011-top-318-all-models-ranking-now-available
7. Harmar Lift Systems Brochure
   http://www.harmar.com/system/brochures/9/original/2012_Harmar_Micro_Lift_System.pdf
8. Harmar AL055 Installation Guide
   http://www.youtube.com/watch?v=3FRcDZatqPI
9. Legend Lat Pull-down Machine 905
   http://www.fitnessgiant.com/lat905.html#.UIWbkaPheRU
10. McMaster-Carr Supplies
    http://www.mcmaster.com/
11. Project Alliancing: A Relational Contracting Mechanism for Dynamic Projects
    http://www.leanconstruction.org/lcj/V2_N1/LCJ_05_005.pdf
12. PTC Creo Mechanism Dynamics Extension
    http://www.ptc.com/product/creo/mechanism-dynamics-extension
13. Types of Cranes
    http://norman-spencer.com/assets/files/programs/cranes/Types_of_Cranes.pdf
14. Wheelchair CAD Drawing
    http://grabcad.com/library/wheelchair--1

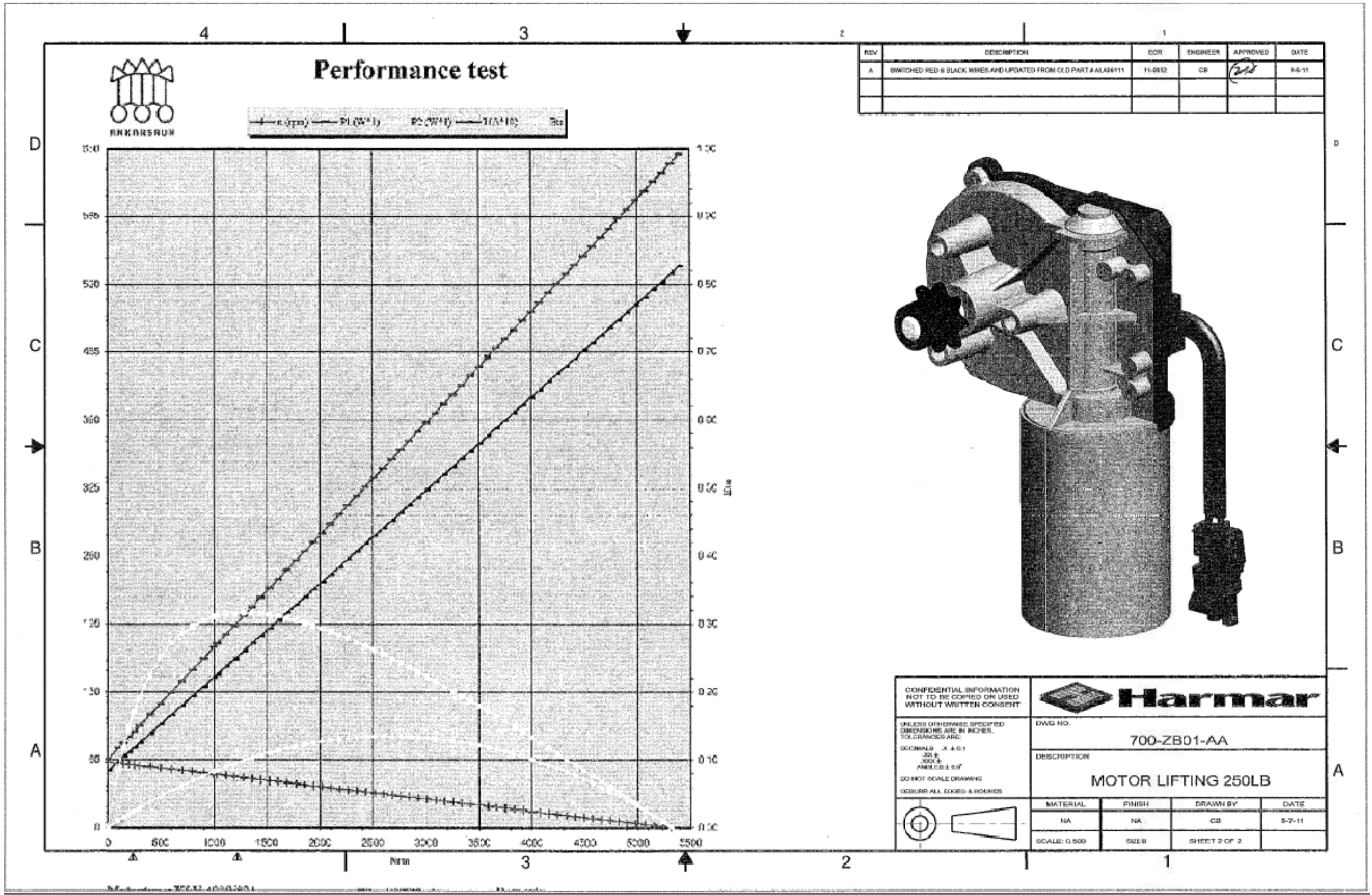
APPENDIX

A1 - VOLKSWAGEN GOLF VI DIMENSIONS

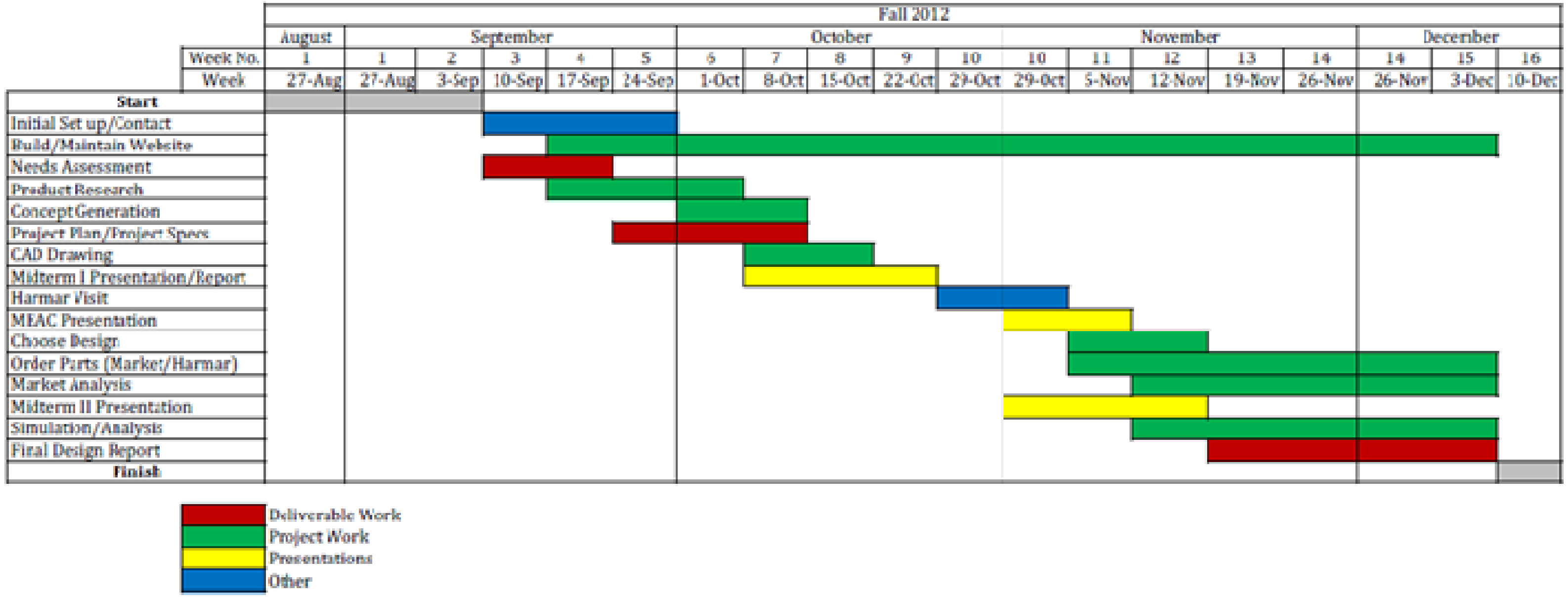


B1 - MOTOR SPECIFICATIONS




Performance test
n (rpm)
P1 (W*1)
P2 (W*1)
I (A*10)
Eta
0
65
130
195
260
325
390
455
520
585
650
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
Nm
REV
DESCRIPTION
ECR
ENGINEER
APPROVED
DATE
A
SWITCHED RED & BLACK WIRES AND UPDATED FROM OLD PART # AILA06111
11-0052
CB
9-6-11
CONFIDENTIAL INFORMATION NOT TO BE COPIED OR USED WITHOUT WRITTEN CONSENT
Harmar
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE:
DECIMALS .X ± 0.1
.XX ±
.XXX ±
ANGLES ± 0.0°
DO NOT SCALE DRAWING
DEBURR ALL EDGES & ROUNDS
DWG NO.
700-ZB01-AA
DESCRIPTION
MOTOR LIFTING 250LB
MATERIAL
NA
FINISH
NA
DRAWN BY
CB
DATE
9-7-11
SCALE: 0.500
SIZE B
SHEET 2 OF 2
A
B
C
D
1
2
3
4

C1 – FALL GANTT CHART



	Fall 2012																		
	August	September					October					November					December		
Week No.	1	1	2	3	4	5	6	7	8	9	10	10	11	12	13	14	14	15	16
Week	27-Aug	27-Aug	3-Sep	10-Sep	17-Sep	24-Sep	1-Oct	8-Oct	15-Oct	22-Oct	29-Oct	29-Oct	5-Nov	12-Nov	19-Nov	26-Nov	26-Nov	3-Dec	10-Dec
Start	▨	▨	▨																
Initial Set up/Contact				🟦	🟦	🟦													
Build/Maintain Website					🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	
Needs Assessment				🟥	🟥														
Product Research					🟩	🟩	🟩												
Concept Generation							🟩	🟩											
Project Plan/Project Specs						🟥	🟥	🟥											
CAD Drawing								🟩	🟩										
Midterm I Presentation/Report								🟨	🟨	🟨									
Harmar Visit											🟦	🟦							
MEAC Presentation												🟨	🟨						
Choose Design													🟩	🟩					
Order Parts (Market/Harmar)													🟩	🟩	🟩	🟩	🟩	🟩	
Market Analysis														🟩	🟩	🟩	🟩	🟩	
Midterm II Presentation												🟨	🟨	🟨					
Simulation/Analysis														🟩	🟩	🟩	🟩	🟩	
Final Design Report															🟥	🟥	🟥	🟥	
Finish																			▨

🟥	Deliverable Work
🟩	Project Work
🟨	Presentations
🟦	Other