Stabilized Lithium Metal Powder Coating Machine: Midterm Report

Team Number: 16

Submission Date: October 31, 2014

Submitted To: Mechanical Engineering Department

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Abstract

A formal structured plan build a Stabilized Lithium Metal Powder (SLMP) coating machine is presented in this report. By producing a project plan that outlines the methodology of techniques, requirements and specifications, a viable and efficient concept can be implemented. Using the dry method proposed, SLMP particles will be loaded on top of a copper sheet (electrode), with a loading range of ~0.5-3 mg/cm^2. The goals describe the ideal objectives and properties of uniformly coating the electrode. There are several constraints that need to be meet in order to realize our design. Supporting documentation and research shows that slurry process do not meet the requirements of this project scope. Requirements include dry-time, ease-of-use and costs, affect the future commercialization of the SLMP coating machine. The functional analysis incorporates both the mechanical and electrical design components that can be implemented and tested. Varying the funnel nozzle size and/or the mesh shape can improve the results of loading the SLMPs. Per the selection criteria safety, affordability and the ease-of-use categories will determine the optimization of our design. Further effectiveness of the design will be determined by addressing the risks and uncertainties. The methodology to implement our design is determined by a schedule of workload and resource allocation.

1 Introduction

The objective of this project is to develop a Stablized Litium Metal Powder (SLMP) coated anode electrode. In addition, the investigation of other components in Li-ion batteries and Li-ion super-capacitors will be conducted. These components include conventional carbons (e.g. graphite and hard carbon) and the high specific capacity silicon (Si) and other alloys [1]. A prototype machine that can uniformly coat SLMP on a flat battery electrode is to be developed. The stabilized lithium metal powder (Li/Li_2CO_3) is a relatively new product created by FMC. The SLMP particles are a form of lithium metal based on a core/shell concept[11]. The CO_3 reacts with the lithium metal and forms a shell layer on the surface of unexposed lithium metal[11]. According to the Safety Data Sheet for SLMP, exposure to elevated temperatures above the melting point (180.5°C/357°F) [2] can result in spontaneous ignition when it comes in contact with humid aid. The main application of this metal powder is to be used in existing lithium ion batteries. The methodology improves the capacity of the Li-ion battery by 5 to 15% [2]. Another application of the SLMP is in Li-ion super-capacitor to improve the energy density by 2-4 times [2].

In order to achieve these specifications effectively, the SLMP should be coated on the anode electrode uniformly. One specification that will be met includes, semi-automatically coating a flat battery electrode with the SLMPs. More specifically, the range for the loading of the SLMPs should be ~0.5-3 mg/cm^2. The uniformity of the coating should be expected to be better than 20% and the coating area of the electrode is variable from 5-12 cm (width) and 5-250 cm (length). The coating time process is expected to be less than ~10 minutes. The hardware for the coating machine is expected to be within a $2,000.00 budget, to furnish the machine with motor, stainless steel plates and rods for the frame.

2 Project Definition

2.1 Background research

Previous research describes a standard slurry procedure to lithiate electrodes with Stabilized Lithium Metal Power. Various documents describe methods to apply SLMP into anode electrodes. For example, one such published paper, states the process of adding the SLMP slurry by film casting using a doctor blade [10]. The slurry production process involves the mixing of the SLMP and a solvent to make a homogenous mixture. Then the slurry material is pumped into the slurry container and enters the film casting procedure. A doctor blade, which is the edge of a smooth knife, spreads the slurry onto the anode film. As shown in the figure 1 below, the slurry making process, along with an added drying time, makes the whole method long and costly. This process we are suggesting, Dry Method, would require no drying time and no slurry would produce. The SLMPs would be solely loaded onto a copper sheet to form the required electrode. The lithiated electrode could easily be activated by pressing the SLMP and breaking the particle shell[11].

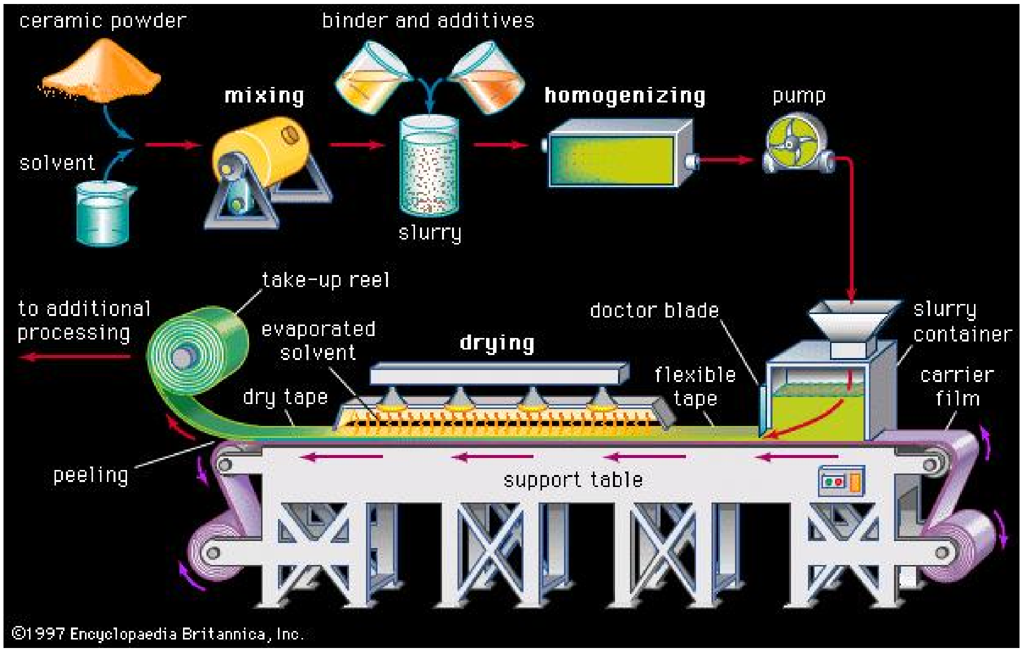


Figure 1: Doctor Blading taken from http://www.britannica.com/EBchecked/media/262/Steps-in-doctor-blading-a-tape-casting-process-employed-in

The slurry method shown above consists of a large storage container which will contain both the SLMP and a solvent that will not react with the SLMP such as Benzene. Since the SLMP is very light it is necessary to vigorously mix the solution to keep it homogenous. Which then allows for the solution to be applied to the electrode and then dried which will evaporate the unwanted solvents leaving only the SLMP coated on the electrode.

However our group decided to go with the a dry method since there are many constraints and challenges that come with a wet method like this. Some issues are that the drying time will likely take longer than the required 10 minutes, keeping to make sure the solution is homogenous may be difficult, and with our budget it seems like reasonable to try the dry method since our initial estimates show that is will be cheaper to design.

2.2 Need Statement

Group 16 is sponsored by General Capacitors, which is located in Tallahassee, FL. The sponsor is Harry Chen, the chief technology officer at General Capacitor LLC., However our main liaison and advisor is Dr. Zheng whom is their top research engineer and professor at FSU. The current project calls for group 16 to develop a coating machine. This machine will apply a uniform layer of stabilized lithium metal powder to the anode electrode of a Li-ion battery and to a Li-ion super-capacitor. This material and process application is newly developed. So group 16 is researching and developing a mechanism that can be scaled up to a production level. There are other coating machines on the marketplace, however none for this specific type of application. Due to the hazardous nature of the lithium metal powder, group 16 will develop a safe and productive way to meet our mechanisms requirements.

″A coating machine for this specific application is non existent″

2.3 Goal Statement & Objectives

Goal Statement:

“To develop an electrode with a uniform coating of stabilized lithium metal powder.”

Objectives:

- Uniformity of roughly 20%
- Ability to apply a sufficient coat onto the electrode
- Ability to apply a coat in less than 10 minutes
- Coating must be applicable to electrodes of varying sizes.
- The process must be semi-automatic

Our goal is to develop an electrode that has a uniform coating of stabilized lithium metal powder. To execute this process, our intent is to design a prototype machine that will handle the lithium metal powder safely while applying a coat of specified thickness to the surface of a metal sheet that will be later cut into an anode.

2.4 Constraints

- The budget given by General Capacitors is $2000
- The lithium powder is to cover the total surface area of the flat battery’s anode
    - The area will be varied from 5-12 cm (width) and 5-250 cm (length)
- Lithium coat must have a uniform layer of 10m with 20% fluctuation in thickness

- One coating process under 10 minutes
- The metallic lithium content of the powder needs to be at least 98%
- Working with the lithium powder must be done in a dry environment
    - AME dry room is 0.5% humidity
    - Lithium reacts explosively to H2O

A prototype machine for coating copper anodes with stabilized lithium metal powder (SLMP) will be made by May 2015. General Capacitors LLC along with AME/FSU will be providing the Senior Design group 16 with a budget of $2000. There are a couple of possible prototypes in mind, every tentative prototype, however, will must meet these constraints. Thorough research on powder metallurgy will be done to be able to understand and reproduce experimentation on the SLMP.

3 Design and Analysis:

3.1 Functional Analysis

Mechanical

We have a few choices of funnels that we will be testing to disperse the SLMP. All designs will have a similar entrance area of 300 cm by 300 cm square and similar storage volume (300x300x350 cm3). The difference is the exit shape which will either be an oval shape that is 2 cm. wide by 250 cm long or a square shape that has an exit area of 3 cm. wide by 250 cm long. We also will be testing which material would best work for our funnel and will not react or have any adverse effects on the SLMP.

The meshes that we use will also require a series of testing. This the SLMP has a very small diameter we will likely need a series of multiple meshes to control the flow rate of the powder. Possible mesh shapes are square, circular, and diamond all with a mesh range of ~(0.088-0.053mm) as seen in figure [13].

The rollers we will use to move the electrode will have a length of 250 cm. and a diameter of 8 cm while empty. However the press roller will have a smaller diameter of ~4 cm. and will have a length of 255 cm to ensure that the entire electrode is being coated and pressed to uniformity.

Electrical

Various components of our coating machine will require power and will need to be controlled. Therefore it is important that we begin with an adequately sized power supply. We will need to power two motors that are being used to roll the electrode through the coating machine; Potential rollers that we are looking into are 80W stepper motors [9].

We have not determined if a motor will be necessary for the roller that will press the SLMP to the electrode, but once testing is completed we can also use a stepper motor such as the one that controllers the electrode roller. However we could also use a smaller DC motor [10] that will require 50 watts.

The component that will likely draw the most power is the motor(s) that will be used to vibrate the machine to create a slow for the SLMP. These motors will need to be large (~500W) since they will be moving such a large weight and will need to constantly be moving yet can be stopped at an instant when the machine is turned off. However depending on our final dispersion design we may not need motors so large to get the SLMP to flow through the funnel. By adding a series of mixers inside the machine again with simple Stepper Motors [9] that are all control as a unit will likely draw less power (i.e for 4 motors, 320 watts). However we will need to perform some testing before we can determine if this method could have the same quality as vibrating the entire machine.

In order to give the system user interface (allowing the user to turn the machine on and off and to potentially control certain functions such as coating thickness, quality, speed, etc). A MCU [11] controller will allow for complete control over the system including all switches, the display screen, the vibrating frequency, and the input/output from the motors and their sensors. The MCU we are going to use is still to be determined but we have narrowed the choices down to a select few which have many of the same qualities such as compatibility with a 12 VDC source and capable of controlling a stepper motor. The wire size needed for the MCU is 22 gauge.

Table 5: Power Requirements

	Power Needed (W)
(2) Electrode Rollers	160
Press Roller (s)	100
Vibrating Device	500
MCU/switches/display	100
Total	860 Watts
Total * 15%	989 Watts

Therefore a 1000W 12V DC Power supply would be sufficient for our design allowing some design changes and room for error without getting overloaded [12].

Figure 1. 80W Stepper Motor

Figure 2: 50W DC Motor

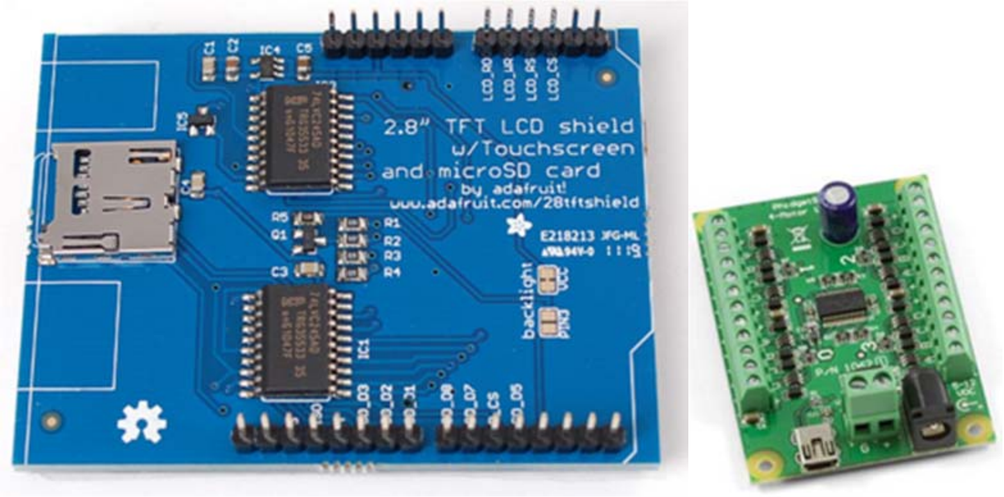


Figure 3: Arduino MCU

Figure 4: 1000W 12 VDC Power Supply

3.2 Design Concepts

3.2.1Design #1:

A copper electrode sheet will be continuously pulled by the conveyor belt. The prototype being created to coat a copper electrode sheet consists of three major parts. The first major part is a funnel dropping the SLMP onto the copper electrode sheet. The SLMP is dropped by shaking the funnel with an actuator. The funnel's nozzle is a controlled cross-section in order to evenly coat the electrode sheet, as seen in figure 8. The funnel's cross-sectional most effective shape will be determined after researching and experimentation, but on this design we will be using one with a large square outlet. The outlet of the funnel drops the SLMP through a series of meshes. The meshes are an important aspect of this design; they are what will be utilized to control the flow rate of the SLMP dropping upon the conveyor belt. This concept has a mesh combination of 3 layers of differently shaped meshes, diamonds, squares, and hexagons which can be seen in figure 9. Due to the size of the SLMP being <50 micros we have selected meshes that can allow a constant flow rate. This leads us to our decision of testing a 0.0035 - 0.0021in (0.088 - 0.053 mm) mesh range. This allows for the passage of 88-53 microns. Since we are only given that the SLMP is <50 microns it will be required to test a variety of mesh sizes to make sure no clogging will occur during the spreading of the SLMP. The next step in the coating process following the shifting of the SLMP through the meshes and drop downward is a roller that will lightly press the SLMP onto the electrode sheet to better bond it to the electrode surface. The roller design, found in figure 10, was chosen because it is typically utilized for the fast and constant pressing of sheets. Speed is the primary attribute of the roller. With the use of bearings the roller can cover a large amount of area in a given time. The roller will start with a minimum load and if need be will be loaded until the precise loading pressure is determined to ensure the SLMP sticks to the anode rather than the roller.Lastly there will be a punch, as depicted in figure 11 to cut out the desired shape out of the electrodesheet. The punch's head will be interchangeable to vary in length and width depending on what size of anode is being coated. Excess copper and lithium powder will be collected by the base, which acts both as a container and a support for the whole mechanical system. Below in figure 12, a detailed CAD drawing shows the design of base of the coating machine. This base is flat with a couple added features to smooth out the coating process. The most noticeable feature being the holes on the side of the plate. These holes will allow for excess SLMP balls to roll off and not affect the pressing of the SLMP onto the anode. Thus allowing for the coating to be uniform throughout the layer of applied SLMP. The next feature you will notice is the two rod holders at each end. These will both hold a role of the anode material, most likely copper. This will also supply the force to move the material throughout the process by using a motor on the back cylinder roller, the elevated roller.

This design's advantages are that will be affordable to construct, that it will be safe for the user to operate, and that it will be simple to operate as well as to repair. Its weakness are that it will consume more power than any of the other designs, that it is not very durable based on the types of components it is made of, and that the roller used to stick the stabilized lithium metal powder onto the electrode may be end up being a source of problems. This roller does have the possibility that it may slip. We are also unsure of how much pressure will be needed to stick the lithium onto the anode.

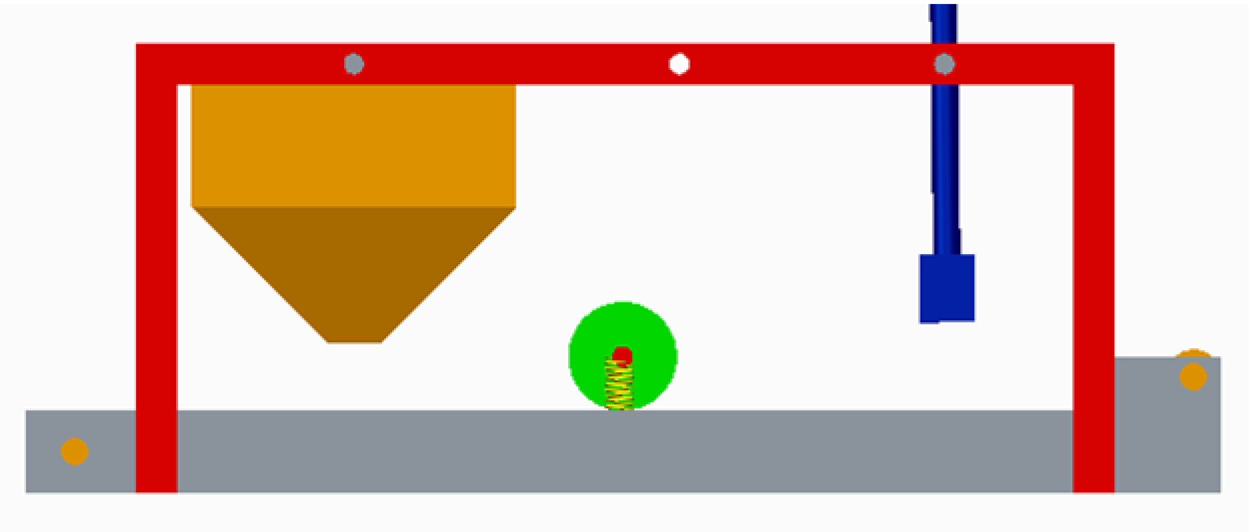


Figure 5. A CAD drawing of the full assembly of design concept #1. This is the side view.

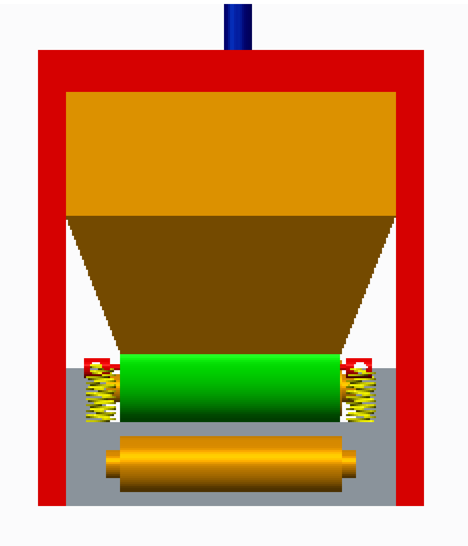


Figure 6. A CAD Drawing of the front view of design concept #1.

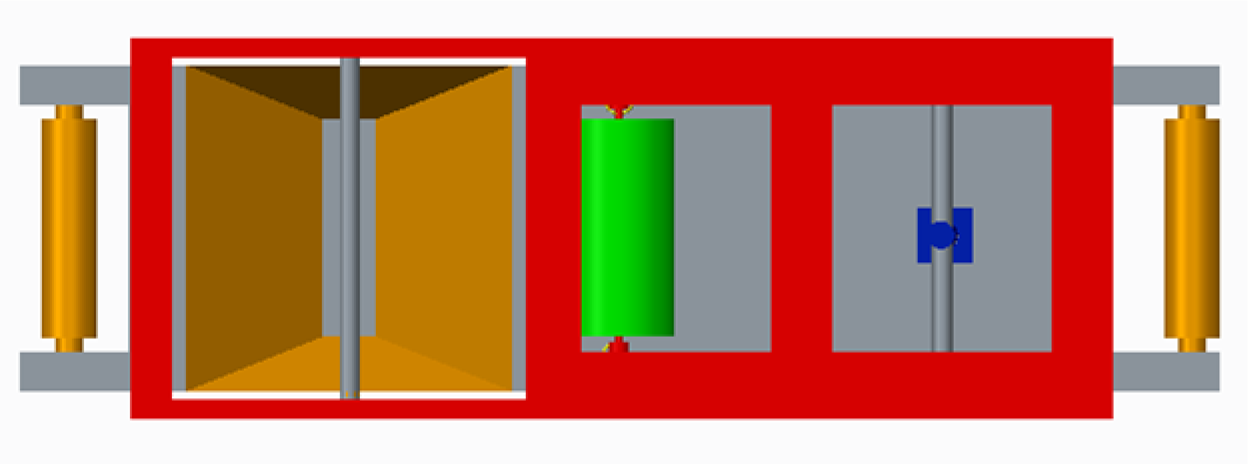


Figure 7. This is a CAD drawing of the top view of design concept #1.

Figure 8. This is a CAD drawing of the funnel shape.

Figure 9. The mesh combination that will be used in design concept #1.

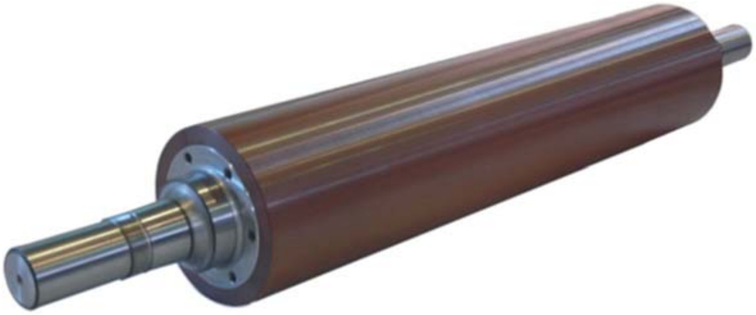


Figure 10. An illstration of the roller that will used in design concept #1.

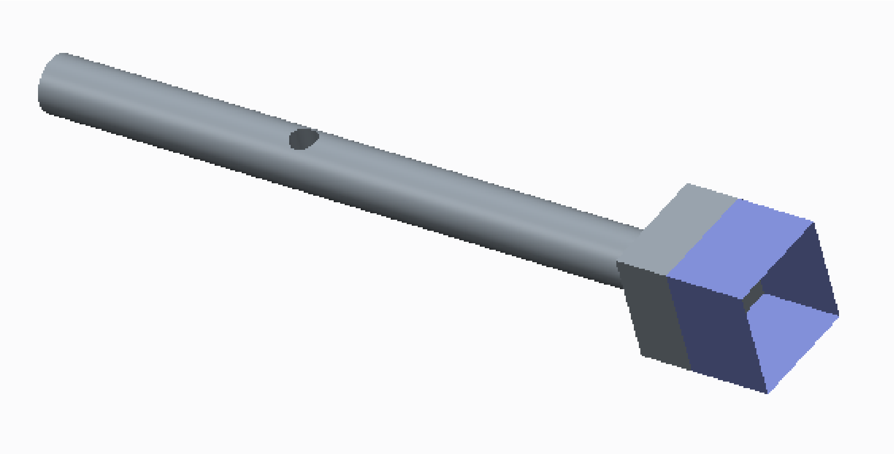


Figure 11. A CAD drawing of the puncher that will be used in design conept #1

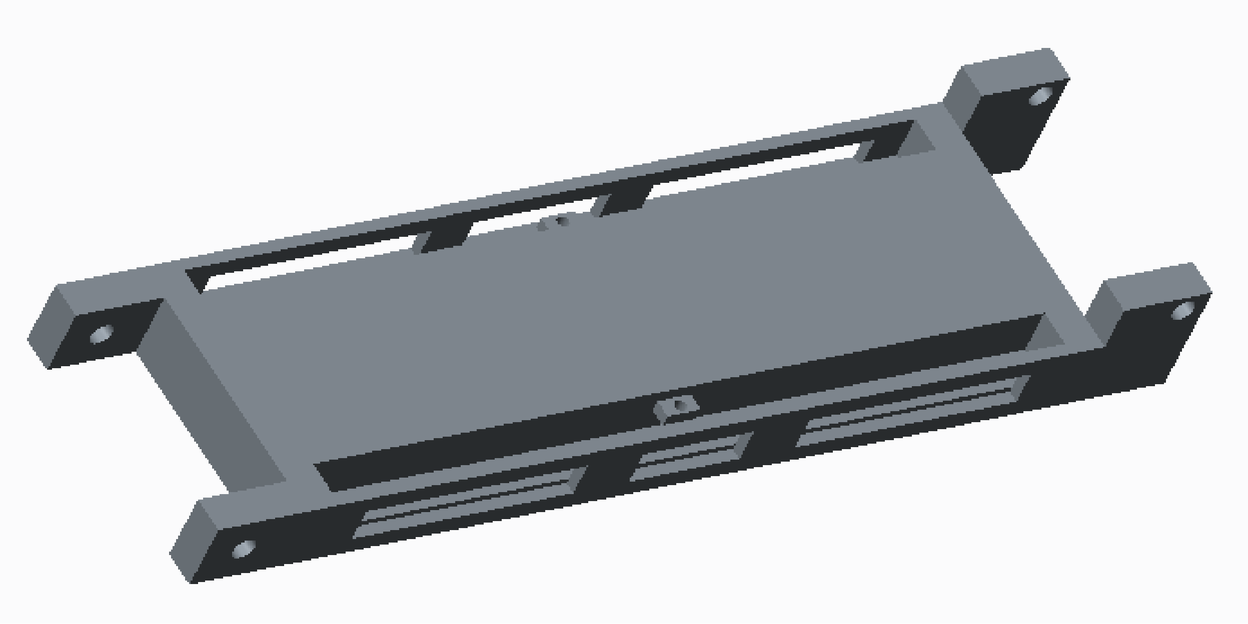


Figure 12. CAD drawing of the base of th coating machine for desing concept #1

3.2.2 Design #2:

Design 2 is a variation of the dry method for coating SLMP onto the electrode sheet, as seen in figure 13 and 14. This design still uses the three main components: funnel, roller, and punch. Instead of fixed position components design 2 uses a slider coupled with the components in order to move the components of the system. The electrode sheet would remain stationary and the components themselves would move over the electrode sheet. Only one component would be used at a time. For instance if the funnel was running then the roller and punch would be stationary at the opposite end of the funnel. The track would have gear teeth and the slider would have gears on bearings in order to move. The sliders has small motors powering the gears. The electrode sheet in design 2 is manually moved.

A long rectangular funnel is used in design 2. The funnel can be observed in appendix figure 22 and 23. Design 2's components move in a 1-D motion. The funnel needs to be wide enough for the maximum width of the electrode sheet, 12cm, thus the width of the funnel is 14cm.

The excess of the SLMP not falling onto the electrode sheet is collected and is deposited back to the SLMP reservoir. The speed of the slider mechanism will constrain what the height of the funnel opening needs to be. If the funnel system is not able to move at a certain speed then the opening of the funnel will need to be narrowed. A need of a mesh is not so relevant in a narrow opening funnel. What will be needed is a mechanism to close the funnel nozzle when SLMP flow is not needed. The funnel volume will be designed for the number of full applications of SLMP desired in a batch. For example, a full funnel may be able to coat 5 electrode sheets before needing to be refilled.

The roller and punch are both operated by similar coupling mechanisms. They are driven not only by an identical slider mechanism but also an arm coupled with the slider mechanism. The slider can be seen in the Appendix figure 25. This arm is a hydraulic arm and can be extended in order to provide the needed force onto the electrode sheet. The punch will need a more powerful hydraulic arm, making it the only difference. The SLMP is very soft and will not require much force to break its bead form. The electrode sheet is 100 µm, and is made of copper. Copper requires a much higher force in order to fracture than SLMP.

The roller's job is to break the SLMP beads and create a flat, uniform layer on top of the electrode sheet. The roller's contact with the SLMP means that some of the SLMP could stick onto the roller surface. Accumulation of SLMP on the roller surface causes irregularity of the surface and can then cause uniformity of the SLMP layer to diminish. Lubricant is be dripped on the roller while the roller is running to prevent accumulation of the SLMP. The lubricant comes from a feed through the hydraulic arm. The CAD drawing for the roller can be seen in appendix figure 24.

A sharp metal puncher is used to cut out the desired shape of the electrode. The punch is made from steel and is detachable from the hydraulic arm. The punch mechanism exerts the most force than either the funnel mechanism or roller mechanism. The strength of the track and base are constrained to the maximum force required to punch out an electrode from the electrode sheet. By using a punch, production of the electrodes is faster and more efficient than cutting by hand. The CAD drawing of the punch can be seen in appendix figure 26.

This design safe at a distance. Its components are moving constantly and rapidly, until a process is done and a new electrode sheet is introduced. The design is open and exposed; this means a person close to the machine could be covered with SLMP if not careful. Human fingers will need to avoid the roller and especially the punch. Many parts are needed to build design #2, which drastically increases the cost of the system. The more parts also means more possibilities of a component breaking driving the maintenance cost higher. Repairs will take longer the more parts there are to a system. The system will be automated and only the movement of the electrode sheet is manual, making design #2 easy to use. Most of the prototype machine will be aluminum and steel. Metal has a high wear coefficient, components will last for many cycles. Power consumption is high for this machine; every component has a small motor. Pumps for the hydraulic arms and lubrication feed all require electrical power. The prototype machine can be easily moved between work sites. Every component can be removed from the system's body for storage or workstation changes. The powder dispersion will be satisfactory; the 1-D motion of the funnel will decrease jerks and irregularities. The gear system in the track can be a fine as needed to increase uniform powder dispersion.

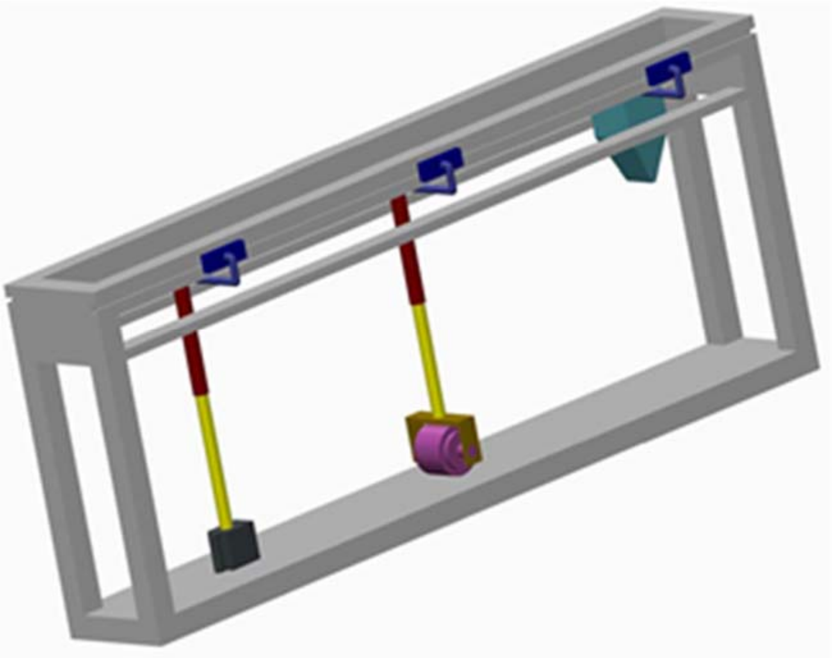


Figure 13. CAD Drawing of Assembly design #2: Coating SLMP by translating components

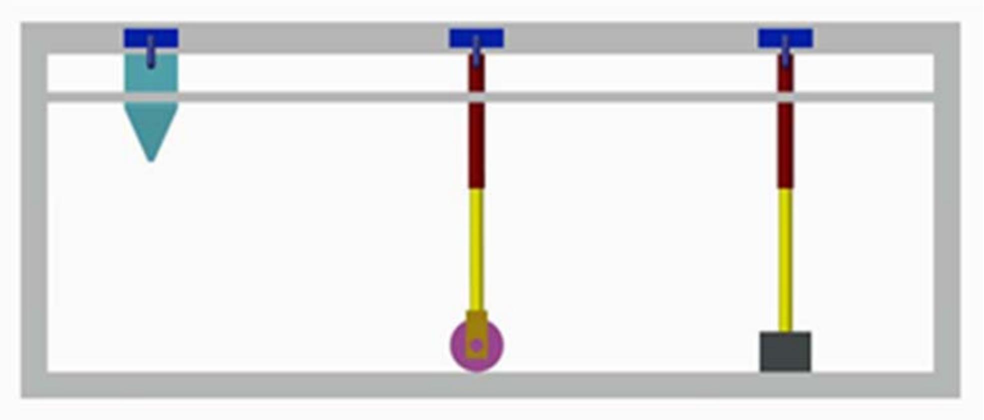


Figure 14. CAD drawing of Side view of Assembly of Design #2

3.2.3 Design #3

This design forgoes complexity and is a simple funnel, drop, and roll system. The funnel is similar to the other designs' funnels however this one is fed onto a ramp at a 45-degree angle with the horizontal in order to add to the feeding process. The ramp includes edges along the sides to prevent SLMP from slipping off the side. The reasoning behind the ramp is hopefully it could improve the consistency of the drop rate of SLMP. While the SLMP is dropping, a conveyor belt will be moving the electrode at a constant speed into the roller and out the other end. This roller is to be a full roller, ideally with a pressure sensor/actuator to allowing for negligible pressure on the lithium powder to avoid sticking. The internal structure of the machine is held by horizontal rods of quarter inch diameter. Such a simple structural support was chosen due to its simplicity to interchange and replace internal parts. If, for some reason, down the line we decide to remove the ramp, it is a simple matter of pushing out those associated support rods and perhaps lowering the hopper. As one can see, there is no punching device in the back of the case, which is fairly empty. For this design, the user of the machine would have to manually punch the electrode after coating. The reason the case is not consequently shortened is that the extra length provides some balance to aid in the offset mass caused by the funnel and leaves more room for future additions.

The funnel shape and mesh size are key aspects to this design that will drastically affect the flow rate of the SLMP and, consequently, how evenly the SLMP is coated onto the electrode. For convenience the funnel is shown as a square funnel for the time being. The final shape of the funnel and the specifics of the mesh layer are to be experimentally determined and then retrofitted to the pre-existing design.

Overall, one can see that this is a very minimalistic or simple approach. There’s a lot of room in the case yet, which leaves room for further customization in the future. The advantages of this design are it is inexpensive, easy to make, and further customizable. The disadvantages of this design is that it requires more manual input than the rest of the designs and will likely not be as consistent in the coating process.

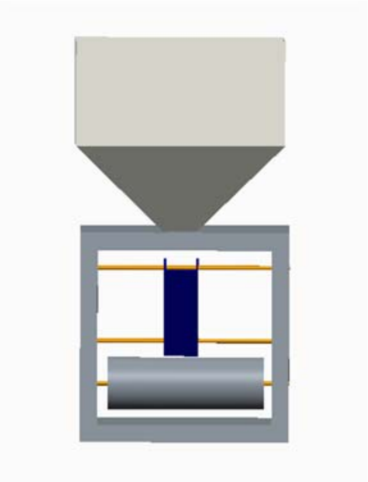


Figure 15. A CAD drawing of the front view of design concept #3.

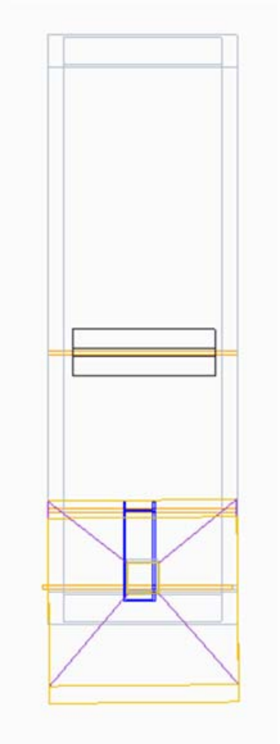


Figure 16. A CAD drawing of the top view of design concept #3.

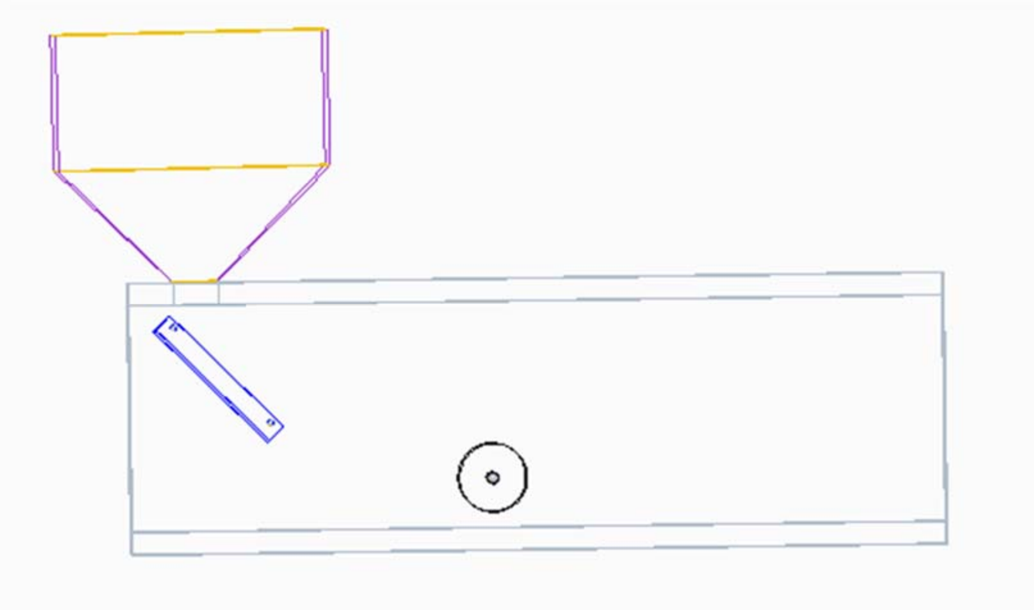


Figure 17. A CAD drawing of the side view of design concept #3.

3.3 Evaluation of designs

Based on the layout, various components, strengths, and weakness of each design as discussed above in section 3.2, the design concepts will be given a score of 1-10(10 being the best) in eight different selection criteria. The score is then multiplied by a weight factor determined by the relevance of the selection criteria defined. The design with the best overall weighted total will then be selected as our optimum design. Below in table 2, are the results of our decision matrix comparing our concepts.

Table 6. Decision Martix used to make a design concept selection. Score is 1-10, 10 being the best. The weight score will determine the best design.

			Design Concepts		
		Weight	Design 1	Design 2	Design 3
Selection Criteria	Safety	20%	8	6	7
	Affordability	20%	8	6	10
	Ease to use	10%	8	7	6
	Ease of repair	10%	8	5	9
	Durability	10%	6	7	5
	Power consumption	5%	6	5	7
	Portability	5%	7	7	4
	Powder Dispersion	20%	8	8	6
Total			59	51	54
Weighted Total			7.65	6.5	7.15

3.3.1 Criteria, Method

The selection criteria used to determine the optimum design is divided into eight categories: safety, affordability, ease to use, ease to repair, durability, power consumption, portability, and powder dispersion. These eight criteria are subdivided further into major and minor categories. Each category highlights a specific need in the system's design that will be crucial to a successful concept.

Safety is one of three major categories. Our project revolves around the use of stabilized lithium metal powder, as mentioned above in section 1 and 2.1. Lithium is an extremely reactive and flammable element that must be handled with the utmost care and attention. Our designs must ensure that that the lithium will not be exposed to humidity or to anything that may cause it to ignite. Our concept must always guarantee the user's wellbeing. Safety has a weight factor of 20%.

Affordability is another major category. Since each project is allocated a specific budget at the beginning of our team assignments, it is necessary to be realistic with each concept. Some ideas will incorporate unique and intrinsic components that require manual labor and a significant amount of money. Although innovation and original design is important and favored, if the concept is out of reach, the concept remains only an idea. Our budget must be able to cover any expense, such as raw materials, payment for labor for machined components, various meshes, funnels, rollers, wires, and a number of electrical components. Affordability will be a major factor in whether a design can be constructed, this criteria has a weight factor of 20%.

Ease to use is how simple a design is to operate for a user. This criterion has a weight factor of 10%. Although ease to use is not what a design is focused on, it is still an important part to be taken into consideration in the selection process. Although we are currently making a prototype machine if we wish for our mechanism is to be used in a fabrication line, its ease of use is a factor that will be needed and expected.

Ease of repair is the category that ranks a design's maintainability. Whether or not a design uses standard parts that can be purchased in bulk for maintenance or if the part has to special order to be fabricated. The weight factor for ease of repair is 10%.

Durability is directly related to the precedent category ease of repair. This category ranks a concept's cyclic life, thus its weight factor is 10%. Our customer expects a machine that will function for a reasonable period of time before any issues arise. Our concepts must be well thought out to ensure that it will function properly each cycle as well as a certain cycle life.

Power consumption is a necessary criterion to know how much power will be needed to sustain our prototype machine's operations. Each design has different components that will rely on certain electrical devices that will need power to run. This category clearly shows which designs will require more power supplies, thus essentially cost more to operate. This criteria has a weight factor of 5%.

Portability is another minor category. This ranks the design's ability to be moved as well as its relative weight. A design's portability is not crucial in the prototype stage, but if the design is to be mass-produced it can be an issue. Portability has a weight factor of 5% as of current, but in subsequent stages of fabrication this may change.

The last selection criteria is powder dispersion, this is the third major category. Our project is centered on the ability of our mechanism producing a layer of stabilized lithium metal powder onto an anode. The ability of a design to disperse this lithium metal powder is critical to our goal. If a design is unable to disperse an acceptable amount of lithium then the design is essential deemed a failed design. This criteria has a weight factor of 20%.

3.3.2 Selection of optimum ones

Table 7. This table shows the ranking of each design with their weighted totals.

Concept Selection		
Design Concept	Ranking	Weighted Total
Design #1	1st	7.65
Design #2	3rd	6.5
Design #3	2nd	7.15

Based on the result from the decision matrix in table 3, the optimum selection was determined to be design #1. It was scored an eight in safety, this is based on the fact that this design was sized to be operated within a hood or dry room to ensure user safety. Also the base design in this specific concept captured excess SLMP particles so that the user will not have to clean the mechanism, there will be an easy remove of material. In the criteria of affordability the design received a score of eight. The overall cost of this design has been estimated to be within our general budget thus can be considered as our optimum choice in terms of affordability. For the criterion of ease to use, the design was given a score of eight. It will be directly controlled using the MCU controller, discussed in section 3.1, that will allow for any input necessary to operate the machine. In terms of ease of repair, the design received a score of eight. The part that are necessary to construct this mechanism are all standard parts that can be store bought and are available at a number of locations. This directly correlates to the scored given for durability, six. Although this mechanism uses standard part it is not indestructible, meshes can be easily broken an motor can burnout after being in operation for such long periods of time. This design was determined to have a score of six in power consumption due to the number of motors and electrical components that will be necessary to power the machine. For portability this design received a seven. It is sized to be used under a hood thus it is relatively compact and will be easy to transport. In the final criterion, powder dispersion, the design scored eight. The weight total of the design was determined to be 59.

This design scored highly in the selection criteria of: safety, affordability, ease to use, ease of repair, and powder dispersion. Although it did not score as well in durability, power consumption, and portability, we determined that this design concept was the most reasonable selection. It is an economical design that will keep the user safe during the coating process. The fact that it has a large projected use of power is outweighed by the fact that it is simple to operate and quick to repair outweigh its repair that means that it can be fixed quickly without any major damage to operation timelines.

3.3.3 Risks and Uncertainty

Each design concept has specific risks and uncertainty attached to them, but they are aspects of the design that must be studied. Our system must aim to work through all of the risks and uncertainties that may arise in a safe and effective manner. The optimum design choice was determined to be design # 1.

The main uncertainty with this design will be its ability to effectively create a layer of uniform thickness lithium metal powder onto the anode. We need the layer to be the same thickness throughout to reach our customer’s needs. Another uncertainty is whether or not the roller will apply enough pressure on the lithium powder dispensed to properly stick it to the anode. It is possible that during the coating process the roller may accumulate lithium metal powder onto its surface thus not properly stick the powder on the anode. A risk of this design is that the roller, due to bearing friction and roller surface to lithium powder friction could heat the roller and could cause the SLMP coated electrode to ignite.

To minimize the risks associated with direct contact of the stabilized lithium metal powder, we will require that the prototype machine only be operated within a dry room, that the user take a safety training course, and that at anytime the user is handling the lithium they are wearing the appropriate clothing, gloves, and eyewear.

This design also has several electrical components working simultaneously alongside the mechanical. We must consider that these electrical components may short circuit thus a trip system will be installed on the fuses. Another risk of this design is that if an electrical fire occurs we must be able to stop operations and close off the lithium metal powder dispenser. To avoid this there will be an emergency stop button will be installed. This emergency stop button will automatically stop operations and seal off the lithium from the rest of the mechanism to attempt to minimize the damage and spread of the fire. If the power supply to the system is ever cut, the mechanism will stop at whatever point in the process it was currently at and the lithium supply will stop. Once the power is restored the system will ask for a user password and then will ask whether to continue on the stopped operation or to return to the start position.

4 Methodology

The design process and construction of the prototype machine will require a vast amount of research, manufacturing, construction, testing, and analysis. This overall process with take a significant amount of time and as such will need to broken down into tasks and mile stones. Our schedule breakdown can be found below in section 4.1 along with figures and tables with further explanation.

Another portion of our project that will need to planned out and scheduled will be programming of certain components and user interfaces. Our prototype machine will have a programmable logic controller that will be utilized to allow a user to input the desired values.

4.1 Schedule

To properly develop a prototype machine that will uniformly coat an electrode with stabilized lithium metal powder a strict schedule must be adhered to. Below in figure 18 and 19 is a breakdown of all of the tasks and milestones required to fulfill our goal. Many of the tasks will be dependent on precedent work, while others will grow upon one another from this point forward. Typically major tasks will be given a 7-day period for completion. For Milestones the time period can range from a 14-day to 30-day period. The time limit assigned is based on the amount of research, analysis, and labor that we as a team have deemed necessary for each task.

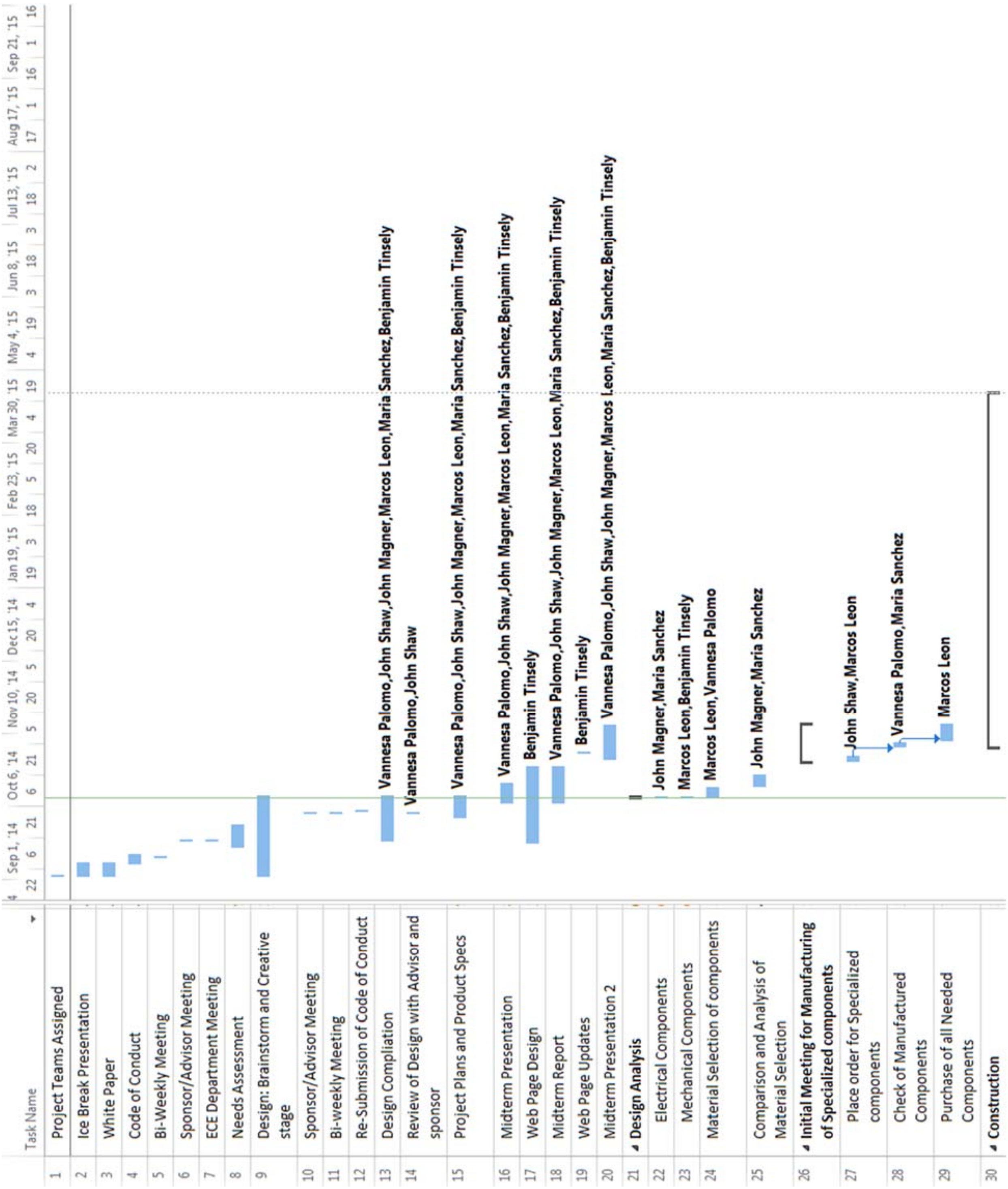


Figure 18. Page 1 of the Gantt chart schedule created using microsoft project

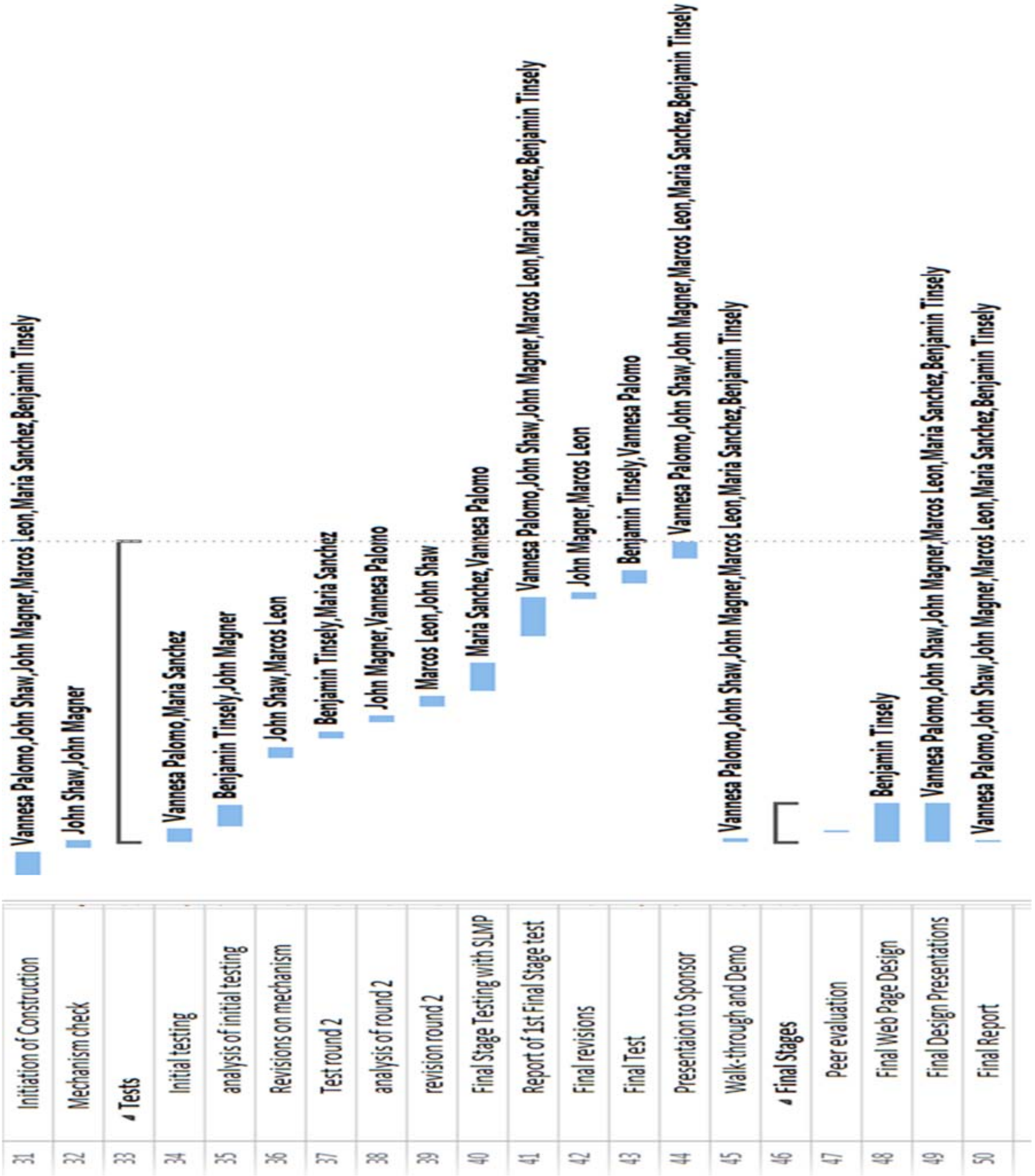
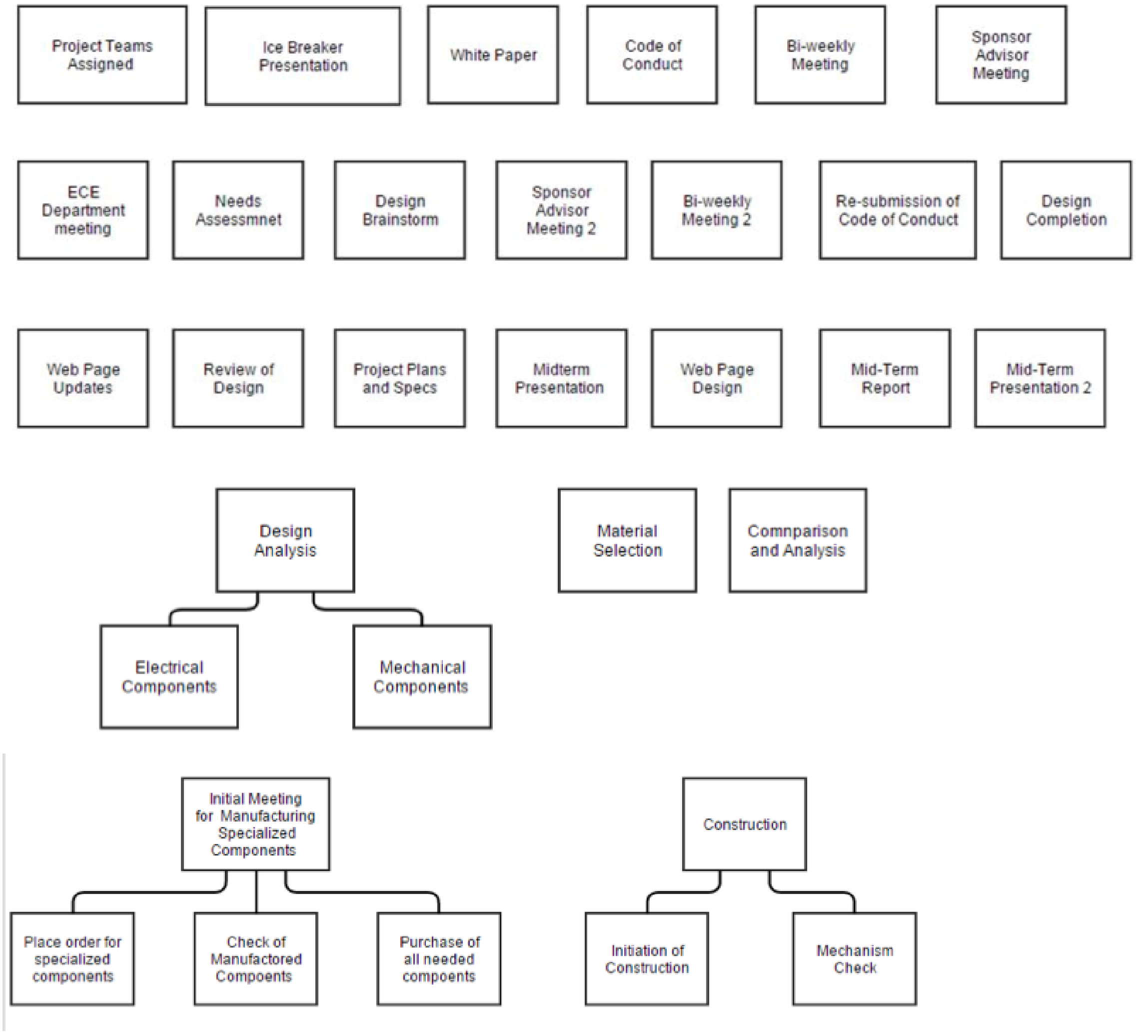


Figure 19. Page 2 of Gantt chart schedule created using microsoft project

The work breakdown structure, WBS, found below in Figure 20, is an organizational chart that breakdown the tasks from the Gantt Chart into a hierarchy structure. This structure clearly shows the dependency of specific tasks on one another, as well as some that are independent of one another. It will be used to help our team understand what tasks will have to be closely related to others and what will be affected by prior work.



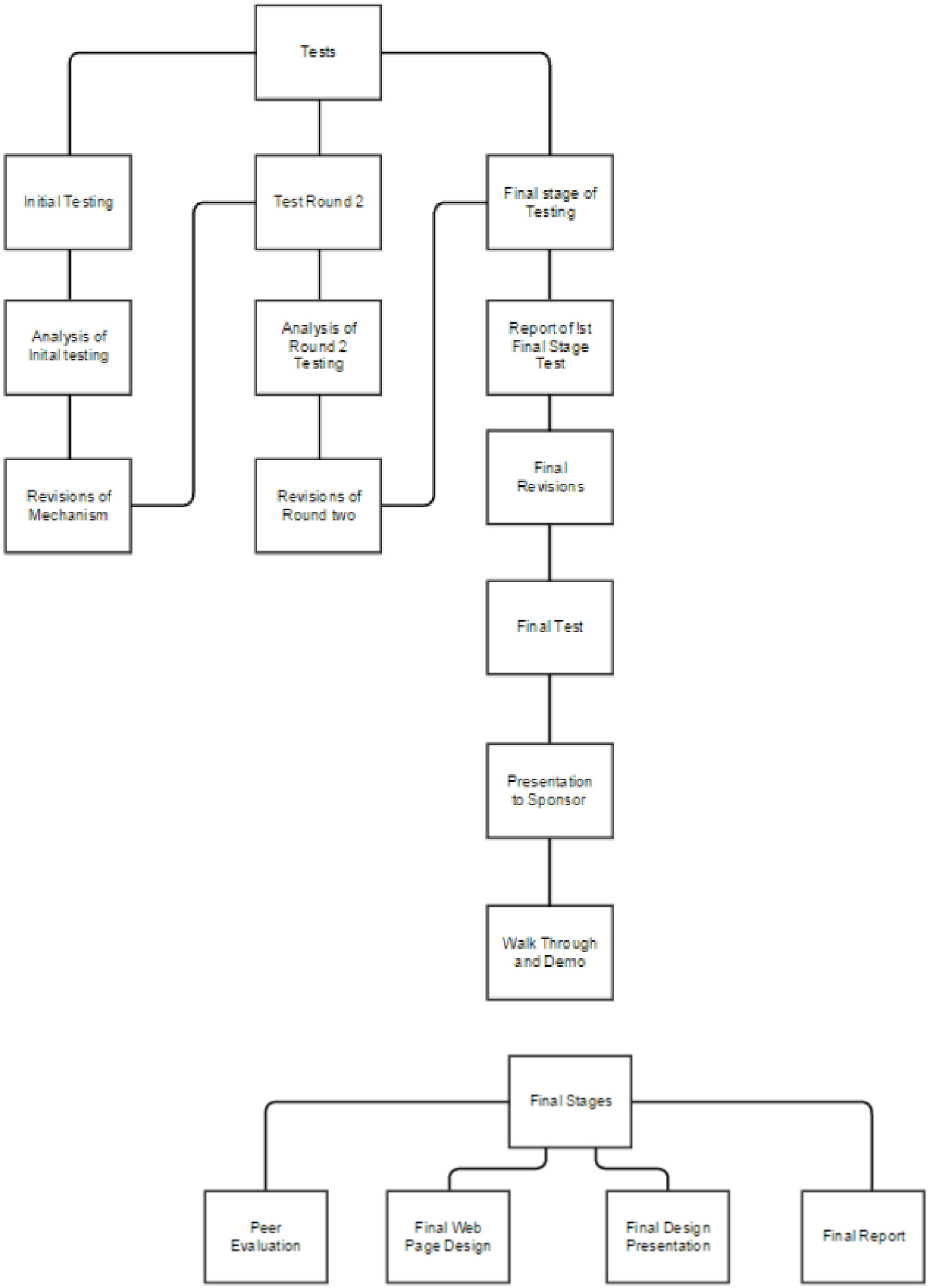


Figure 20. The work breakdown structure depicts all major task and milestones and the hierarchy between them.

4.2 Resource Allocation

Resource Allocation has been divided amongst the team equally. Each member will be required to put in a minimum of 1,000 hours of work into this project. These hours are divided throughout the year as to minimize the burden on the team. Each team member will have time to rest in between assigned tasks to be fair and to ensure efficiency and productivity. The detailed division of labor can be found below in table 4.

Table 8. Shows the Resource Allocation of all tasks/milestones of the project. It shows which members are responsible for what tasks as well as the amount of time allotted for each task.

		Team Members					
Task/ Milestone	Hours/Days Need to Complete	Marcos Leon	John Magner	Vannesa Palomo	Maria Sanchez	John Shaw	Benjamin Tinsley
Design Compliation	16 Days	X	X	X	X	X	X
Review of Design with Advisor and sponsor	1 day			X		X	
Project Plans and Product Specs	9 days	X	X	X	X	X	X
Midterm Presentation	8 days	X			X	X	
Web Page Design	27 days						X
Midterm Report	13 days	X	X	X	X	X	X
Midterm Presentation 2	13 days		X	X			X
Design Analysis- Electrical Components	3 days		X		X		
Design Analysis- Mechanical Components	3 days					X	X
Material Selection of components	3 days	X		X			
Comparison and Analysis of Material Selection	4 days		X		X		
Place order for Specialized components	3 days	X				X	
Check of Manufactured Components	2.875 days			X	X		
Purchase of all Needed Components	8.5 days	X					
Initiation of Construction	10 days	X	X	X	X	X	X
Mechanism check	4 days		X			X	

	Initial testing	5 days			X	X		
	Analysis of initial testing	7 days		X				X
	Revisions on mechanism	3.875 days	X				X	
	Test round 2	3.875 days				X		X
	Analysis of round 2	3.875 days		X	X			
	Revision round 2	3.875 days	X				X	
	Final Stage Testing with SLMP	10.875 days			X	X		
	Report of 1st Final Stage test	14 days	X	X	X	X	X	X
	Final revisions	4 days	X	X				
	Final Test	5 days			X			X
	Presentation to Sponsor	7 days	X	X	X	X	X	X
	Walk-through and Demo	2 days	X	X	X	X	X	X
	Peer evaluation	1 day	X	X	X	X	X	X
	Final Web Page Design	14 days						X
	Final Design Presentations	14 days	X	X	X	X	X	X
	Final Report	14 days	X	X	X	X	X	X
Number of tasks to Complete			17	17	18	17	17	17
Total Amount Time Spent on Task/Milestone			1,096 Hours	1,077 Hours	1,139 Hours	1,107.4 Hours	1,020.4 Hours	1,215 Hours

5 Conclusion

The proposed method shows a promising design that meets the requirements for application of SLMP to anodes used in lithium ion batteries. The semi-automatic coating SLMP onto a flat battery electrode can be achieved by effectively addressing the specifications. Uniformity of the SLMP layer will be met by applying a variation of different nozzle sizes and mesh shapes. By addressing both the mechanical and the electrical components (rollers, motor, microcontrollers, etc.) of the design, the design is further validated. The lithiated electrode will be easily activated by using the “press” to break the SLMP particle shells. As no drying time will be required and the SLMP material will remain unprocessed (no slurry) the design process will be time efficient, to the required ~10 min coating time. The suggested design provides a new method that compensates for the shortcomings of previous standards used in industry. Future work could include finalizing the design specifications to move onto design implementation and testing. Testing phase would start with the individual components to acquire preliminary data on flow rates of the material through the funnels.

6 References

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[11] B. Xiang, L. Wang, G. Liu, A.M. Minor, J. Electrochem. Soc. 160 (2013) A415**e**A419.

7 Appendix

Design #2 components:

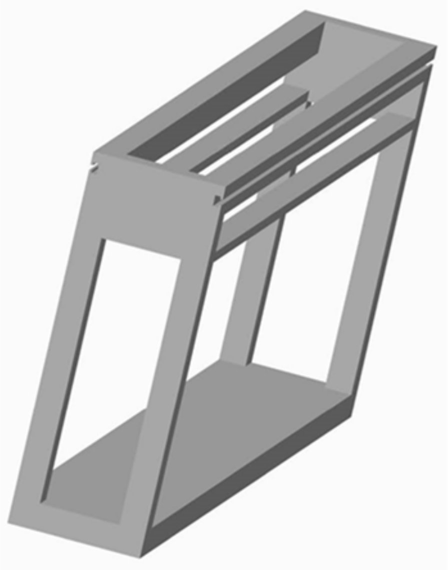


Figure 21

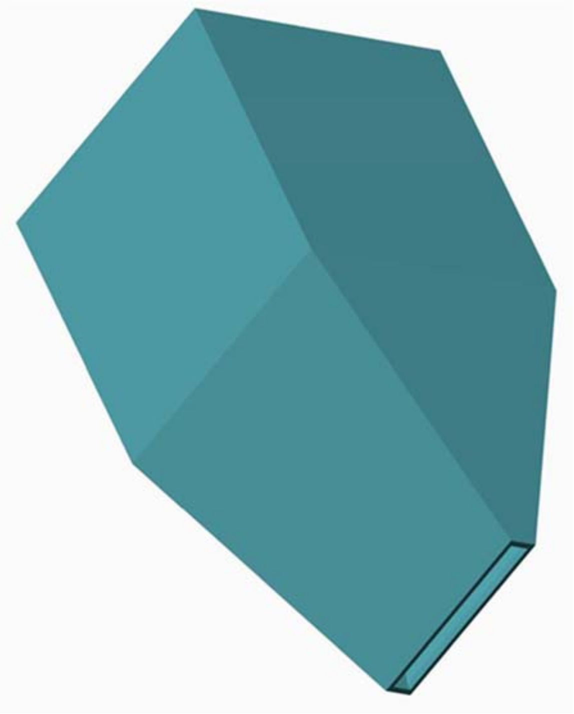


Figure 22

Figure 23

Figure 24

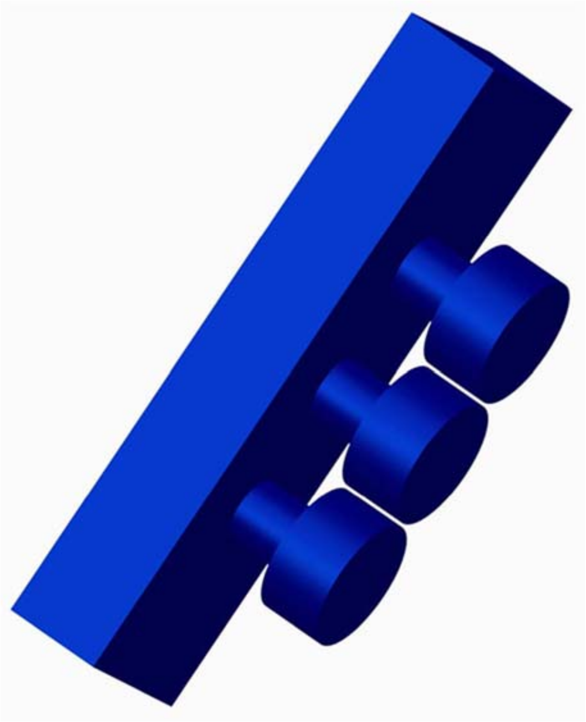


Figure 25

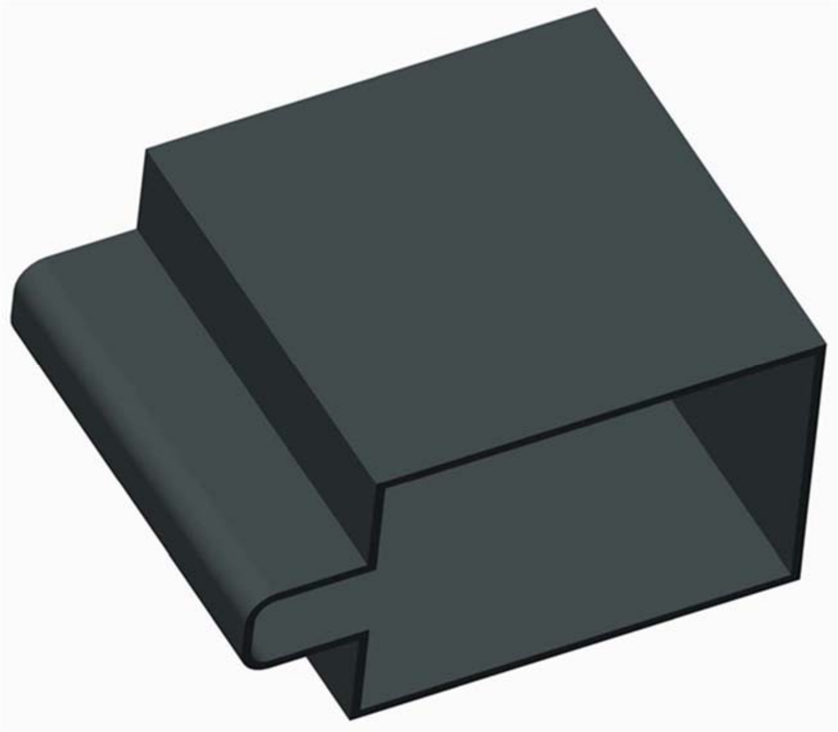
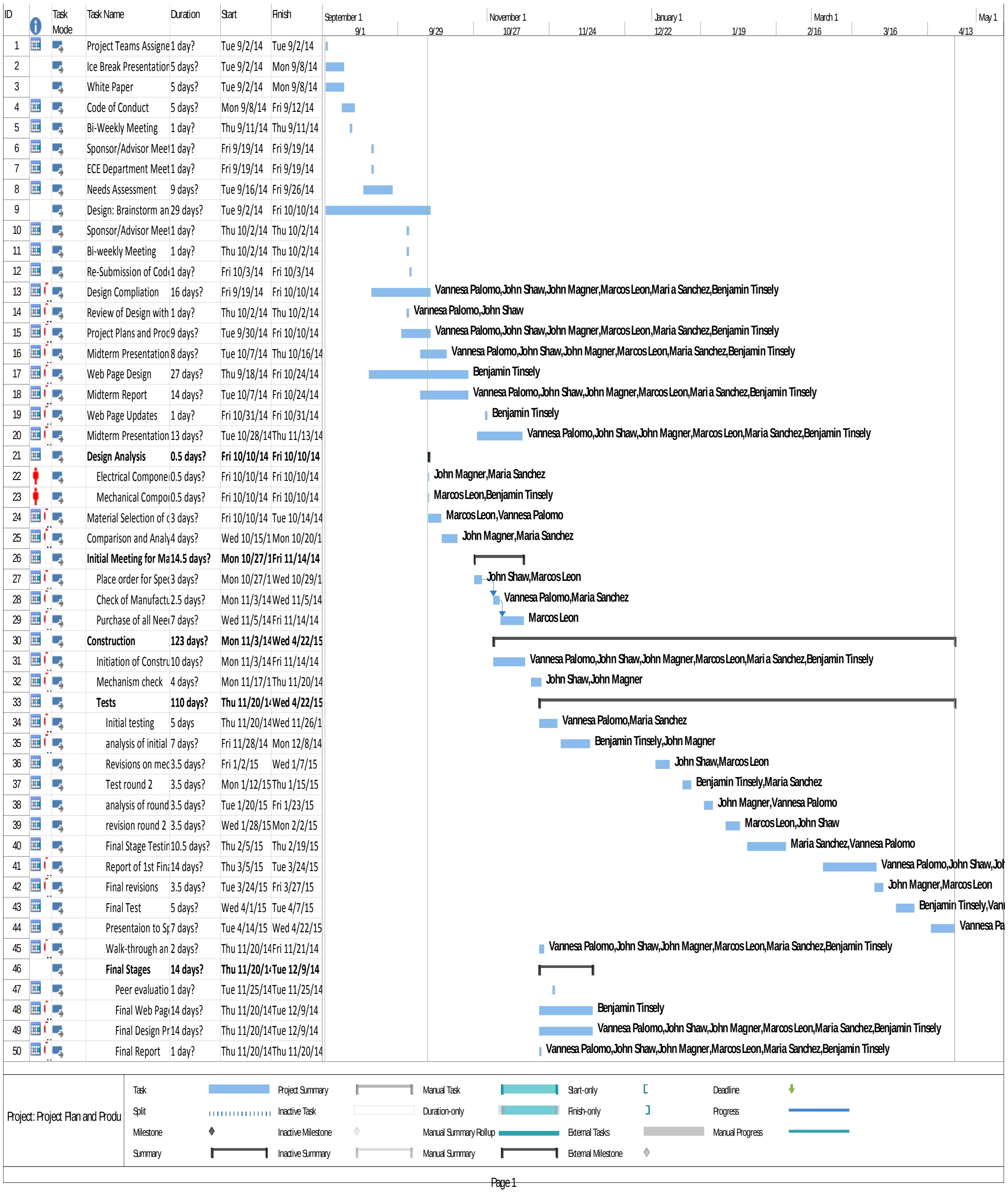


Figure 26



ID	Task Name	Duration	Start	Finish
1	Project Teams Assigne	1 day?	Tue 9/2/14	Tue 9/2/14
2	Ice Break Presentation	5 days?	Tue 9/2/14	Mon 9/8/14
3	White Paper	5 days?	Tue 9/2/14	Mon 9/8/14
4	Code of Conduct	5 days?	Mon 9/8/14	Fri 9/12/14
5	Bi-Weekly Meeting	1 day?	Thu 9/11/14	Thu 9/11/14
6	Sponsor/Advisor Meet	1 day?	Fri 9/19/14	Fri 9/19/14
7	ECE Department Meet	1 day?	Fri 9/19/14	Fri 9/19/14
8	Needs Assessment	9 days?	Tue 9/16/14	Fri 9/26/14
9	Design: Brainstorm an	29 days?	Tue 9/2/14	Fri 10/10/14
10	Sponsor/Advisor Meet	1 day?	Thu 10/2/14	Thu 10/2/14
11	Bi-weekly Meeting	1 day?	Thu 10/2/14	Thu 10/2/14
12	Re-Submission of Code	1 day?	Fri 10/3/14	Fri 10/3/14
13	Design Compliation	16 days?	Fri 9/19/14	Fri 10/10/14
14	Review of Design with	1 day?	Thu 10/2/14	Thu 10/2/14
15	Project Plans and Proc	9 days?	Tue 9/30/14	Fri 10/10/14
16	Midterm Presentation	8 days?	Tue 10/7/14	Thu 10/16/14
17	Web Page Design	27 days?	Thu 9/18/14	Fri 10/24/14
18	Midterm Report	14 days?	Tue 10/7/14	Fri 10/24/14
19	Web Page Updates	1 day?	Fri 10/31/14	Fri 10/31/14
20	Midterm Presentation	13 days?	Tue 10/28/14	Thu 11/13/14
21	**Design Analysis**	**0.5 days?**	**Fri 10/10/14**	**Fri 10/10/14**
22	Electrical Compone	0.5 days?	Fri 10/10/14	Fri 10/10/14
23	Mechanical Compo	0.5 days?	Fri 10/10/14	Fri 10/10/14
24	Material Selection of c	3 days?	Fri 10/10/14	Tue 10/14/14
25	Comparison and Analy	4 days?	Wed 10/15/1	Mon 10/20/1
26	**Initial Meeting for Ma**	**14.5 days?**	**Mon 10/27/1**	**Fri 11/14/14**
27	Place order for Spec	3 days?	Mon 10/27/1	Wed 10/29/1
28	Check of Manufactu	2.5 days?	Mon 11/3/14	Wed 11/5/14
29	Purchase of all Nee	7 days?	Wed 11/5/14	Fri 11/14/14
30	**Construction**	**123 days?**	**Mon 11/3/14**	**Wed 4/22/15**
31	Initiation of Constru	10 days?	Mon 11/3/14	Fri 11/14/14
32	Mechanism check	4 days?	Mon 11/17/1	Thu 11/20/14
33	**Tests**	**110 days?**	**Thu 11/20/1**	**Wed 4/22/15**
34	Initial testing	5 days	Thu 11/20/14	Wed 11/26/1
35	analysis of initial	7 days?	Fri 11/28/14	Mon 12/8/14
36	Revisions on mec	3.5 days?	Fri 1/2/15	Wed 1/7/15
37	Test round 2	3.5 days?	Mon 1/12/15	Thu 1/15/15
38	analysis of round	3.5 days?	Tue 1/20/15	Fri 1/23/15
39	revision round 2	3.5 days?	Wed 1/28/15	Mon 2/2/15
40	Final Stage Testin	10.5 days?	Thu 2/5/15	Thu 2/19/15
41	Report of 1st Fina	14 days?	Thu 3/5/15	Tue 3/24/15
42	Final revisions	3.5 days?	Tue 3/24/15	Fri 3/27/15
43	Final Test	5 days?	Wed 4/1/15	Tue 4/7/15
44	Presentaion to Sp	7 days?	Tue 4/14/15	Wed 4/22/15
45	Walk-through an	2 days?	Thu 11/20/14	Fri 11/21/14
46	**Final Stages**	**14 days?**	**Thu 11/20/1**	**Tue 12/9/14**
47	Peer evaluatio	1 day?	Tue 11/25/14	Tue 11/25/14
48	Final Web Pag	14 days?	Thu 11/20/14	Tue 12/9/14
49	Final Design Pr	14 days?	Thu 11/20/14	Tue 12/9/14
50	Final Report	1 day?	Thu 11/20/14	Thu 11/20/14