68k Blade Process Handling

Senior Design Final Report – April 2012

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Abstract

Turbine Engine Component Technologies (TECT) Power manufactures a myriad of products for companies such as Boeing, G.E and Pratt and Whitney. Among them is the 68k blade, primarily used in jets and some locomotive engines. The 68k blade goes through a multi-stage process that is sometimes labor intensive due to manual material handling. The goal of this project is to focus on the ergonomic improvement and mechanical design for the processing and handling of 68K turbine blades. The mechanical design must be able to replace the need for any operator to manually lift or load a 68k forging by hand.

After coming up with a few different mechanism designs, a variable height cart and cart top were selected. These designs were chosen because they satisfied all critical customer requirements and were able to be fabricated within the project timeline. In order for this new mechanism to be effective, a redesign of the shipping containers was necessary. The new container holds the forgings in a horizontal orientation to simplify and expedite the forging extraction process in the storage area.

Once the mechanisms were built, they underwent various tests to ensure their function and durability. Some tests included stress and force calculations, others were based off ergonomic safety such as the Rapid Upper Limb Assessment and NIOSH Lifting Index. All results from analysis indicated an improvement in the new process from current methods.

Having improved the current procedure with the new process and mechanism, the design must then be implemented in two parts. The first phase is to develop the containers at a different facility and the second phase is to build and smoothly incorporate the process and mechanism at the plant. Before the procedure is put into operation performance measures must be taken.

In order to sustain the design at the facility, vital aspects of the procedure must be controlled. Assuming that the process is functional, these critical aspects encompass potential problem areas such as deviations in the process, potential mechanism failures, and safety hazards. A way to manage any changes in the process is to have employee training while maintenance and preventative measures may control potential mechanism malfunctions and safety hazards.

Introduction

TECT Power located in Thomasville, GA is a manufacturing company specializing in aerospace components. TECT Power generates profit through the engineering and manufacturing of various turbine components used throughout a wide range of applications. The primary focus of this project will be the 68k turbine blade. The manual lifting required for the handling methods to and from containers as well as milling machines is a potentially problematic process that has an increasing need for ergonomic improvement. The goal of the project is to design and develop a mechanism or process to eliminate any manual lifting of the 68k forging through the task of transporting the forgings from storage to the first milling machine in the broaching area. The 68k forging weighs approximately 45 lbs before the broaching process and when the forging is in storage. The methods used currently contain a high risk for personal injury to the worker.

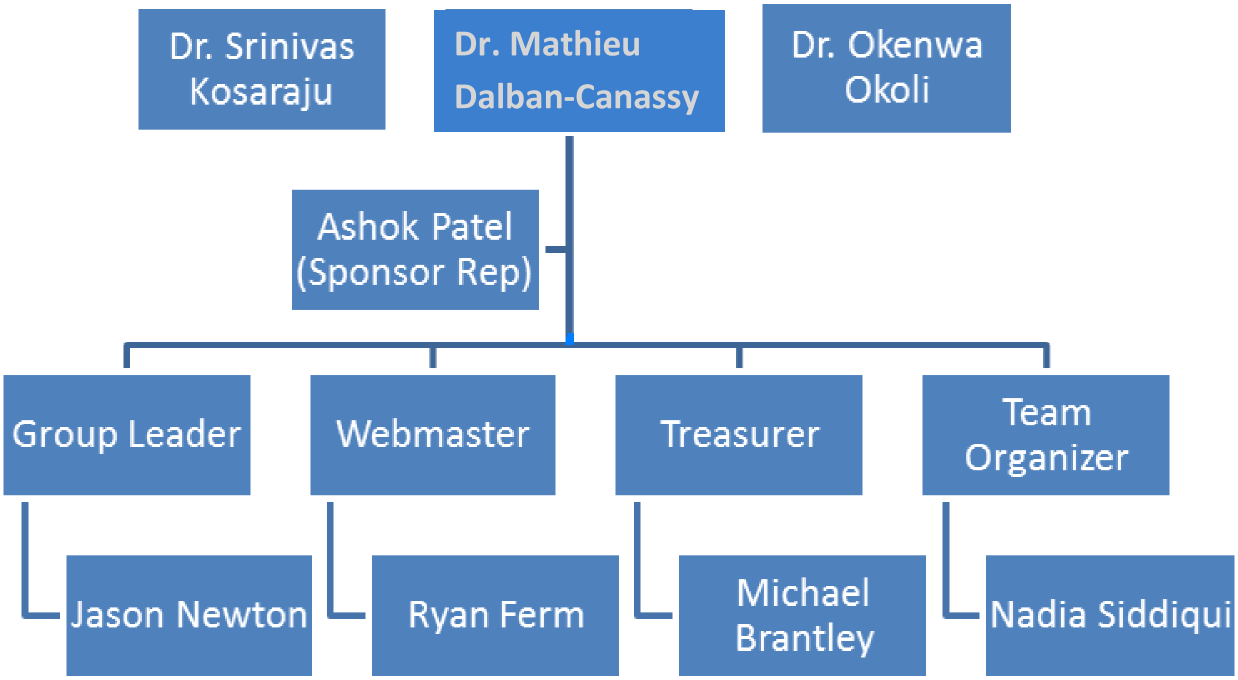


Figure 1 - Project Hierarchy and Team Organization

Team 9 Members

Jason Newton – Leader

Jason is majoring in mechanical engineering with a combination emphasis on materials and dynamics. He is scheduled to graduate with honors in spring 2012 with his B.S. degree from the FAMU-FSU College of engineering. Upon graduation, he is planning on pursuing and M.S. degree in mechanical engineering.

Nadia Siddiqui – Organizer

Nadia is originally from Miami, but was raised in Boca Raton, FL. She is majoring in industrial and manufacturing engineering; efficiency and productivity, ergonomics and materials research appeal most to her. She will graduate from the FAMU-FSU College of Engineering in spring 2012 with a Bachelor's of Science degree. She is artistic and loves to paint and draw. Her current projects include painting a mural at a local restaurant.

Michael Brantley – Treasurer

Michael is majoring in Industrial and Manufacturing Engineering from Florida State University. He is scheduled to graduate in spring 2012 with his Bachelor's Degree from FAMU-FSU College of Engineering. He started his college career at North Florida Community College in Madison during high school for the dual enrollment program. Upon graduating high school, he enrolled in Lake City Community College where he received his A.A. before being accepted to the FAMU-FSU College of Engineering.

Ryan Ferm – Webmaster

Ryan is from Clearwater, FL and is majoring in Industrial and Manufacturing Engineering. He will graduate in spring 2012 with a Bachelor's of Science degree. He has worked as an intern at Jabil Circuit Inc. for three of the previous four summers. There he focused primarily on process improvement and production scheduling.

Project Overview

The main objective of the project is to design and develop a unique solution for the transportation and receiving of the 68k forgings at TECT Power. The 68k forgings are required to be transported from the storage area to the beginning broaching machine. The travel length of the forgings from storage to the first broaching machine is approximately three hundred feet. The bulky, odd-shaped, and heavy 68k forgings can be difficult to handle and transport. This can cause a decrease in overall production efficiency. This project focused on the beginning of the process, between storage to broaching, because this is when the forging weighs the most and the risk of injury is highest.

Within the storage area, the forgings are held in a container on the floor that has 30 inch tall walls. This requires the operator to bend over at the waist to pick up a forging. The position of the operator while performing this task puts excessive strain on the operator’s lower back. When loading the first broaching machine, the operator must hold the forging in place using his own power and secure one end at a time by hand. This is very difficult to do and only a select few operators are capable of loading a 68k forging. This project attempted to make the 68k process safer and remove all heavy lifting requirements.

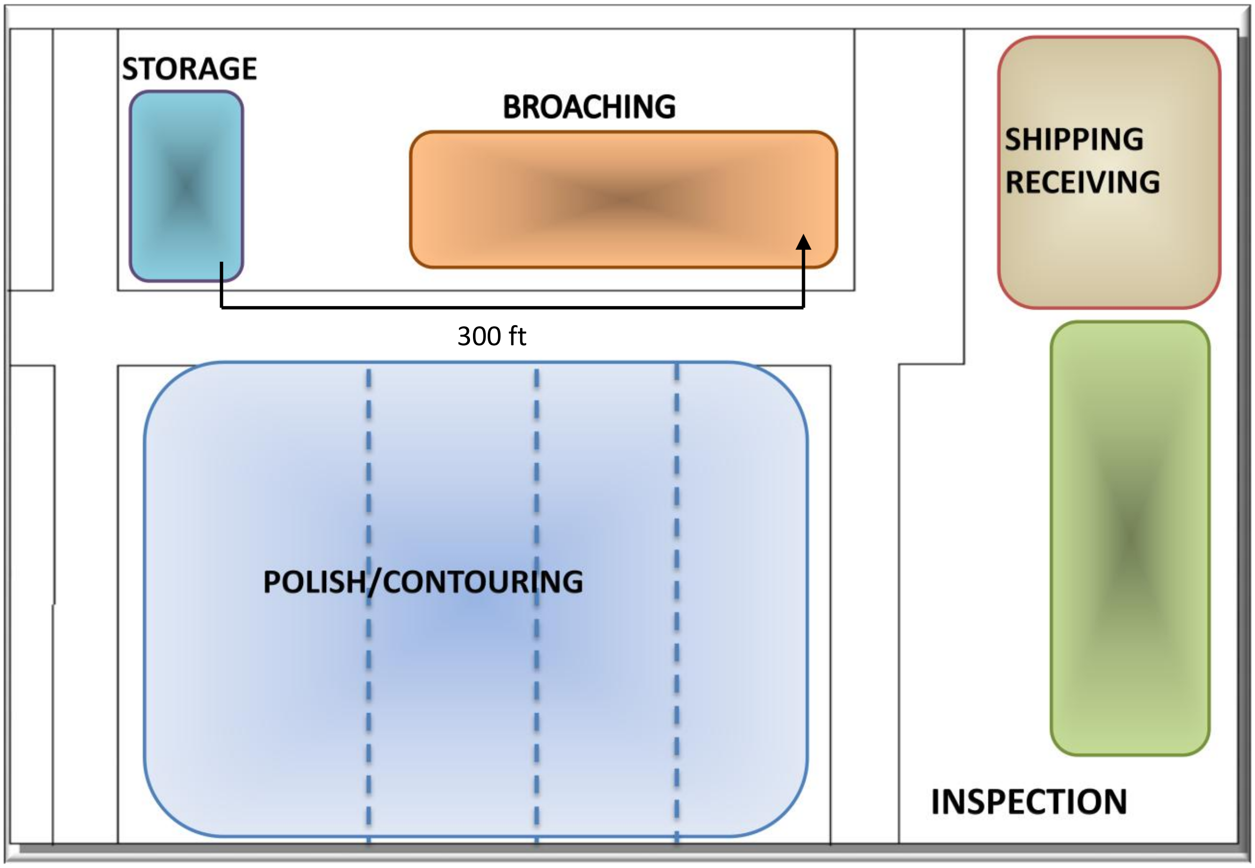


Figure 2 - Plant Layout

The main objective of the project is to reduce the risk of injury during the process and handling of the 68k forgings. The goal is to replace all manual lifting required by the operator with a mechanism that will aid the 68k process. Additionally the storage area layout and container design will be modified to better suit the new mechanism.

The mechanism must:

- Carry at least one 68k forging
- Aid in transportation, loading & unloading of 68k forging
- Be operational by any employee
- Reduce or eliminate the need for lifting
- Be an efficient alternative to current procedures
- Reduce risk of injury
- Maneuverable throughout storage and broaching areas

Current Procedures

Since TECT Power does not release pictures of their facility, a demonstration was approximated at the College of Engineering using concrete cinder blocks that weighed about 40lbs. The oil bed and milling machine were also approximated using tables of similar heights. The current procedures had been broken down into six separate steps.

1. Forgings received in unorganized container
2. Forgings placed in cluttered storage area
3. Forgings manually removed by lifting illustrated in Figure 3 (Forging Retrieval)

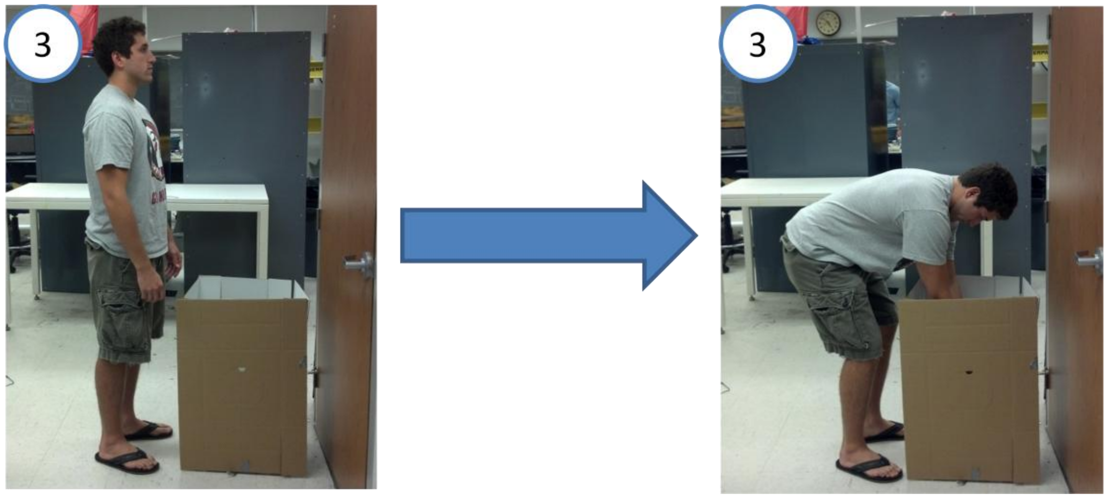


Figure 3 - Forging Retrieval

4. Forgings manually loaded onto cart for transport (depicted in Figure # (Loading Cart and Mechanism))

5. Forgings must be manually lifted from cart and placed onto milling machine (depicted in Figure 4 (Loading Cart and Mechanism))

6. The forging is then lifted out and returned to cart

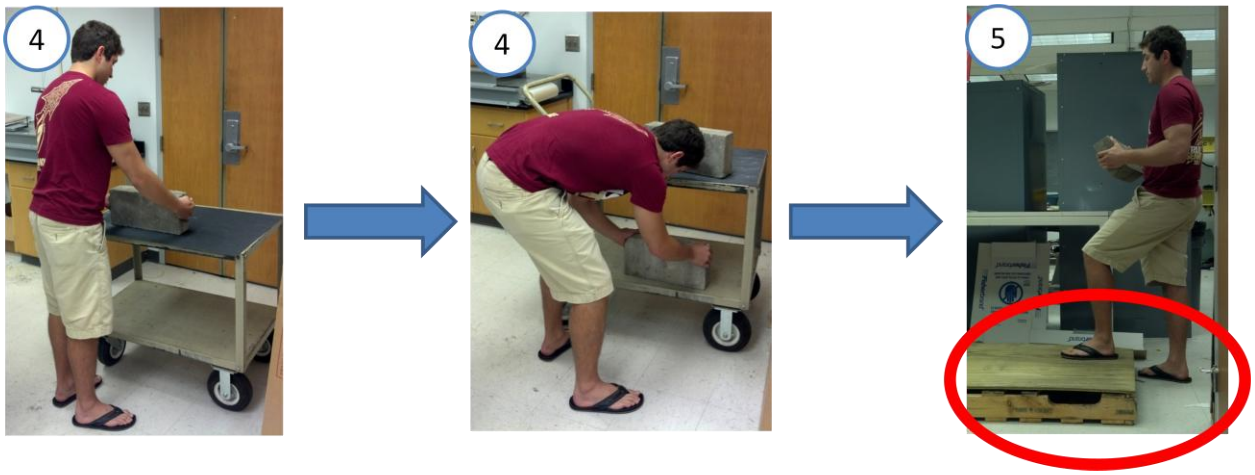


Figure 4 - Loading Cart and Mechanism

Needs Specification

TECT has requested a redesigned process that includes a mechanism that will reduce risk of injury from the 68k forging process. Currently, the 68k process is operator exclusive, where only operators of a certain strength level can handle 68k forgings. This project has developed an alternative method utilizing a mechanism to make the process safer and capable of being performed by any employee of TECT Power.

Critical Customer Requirements

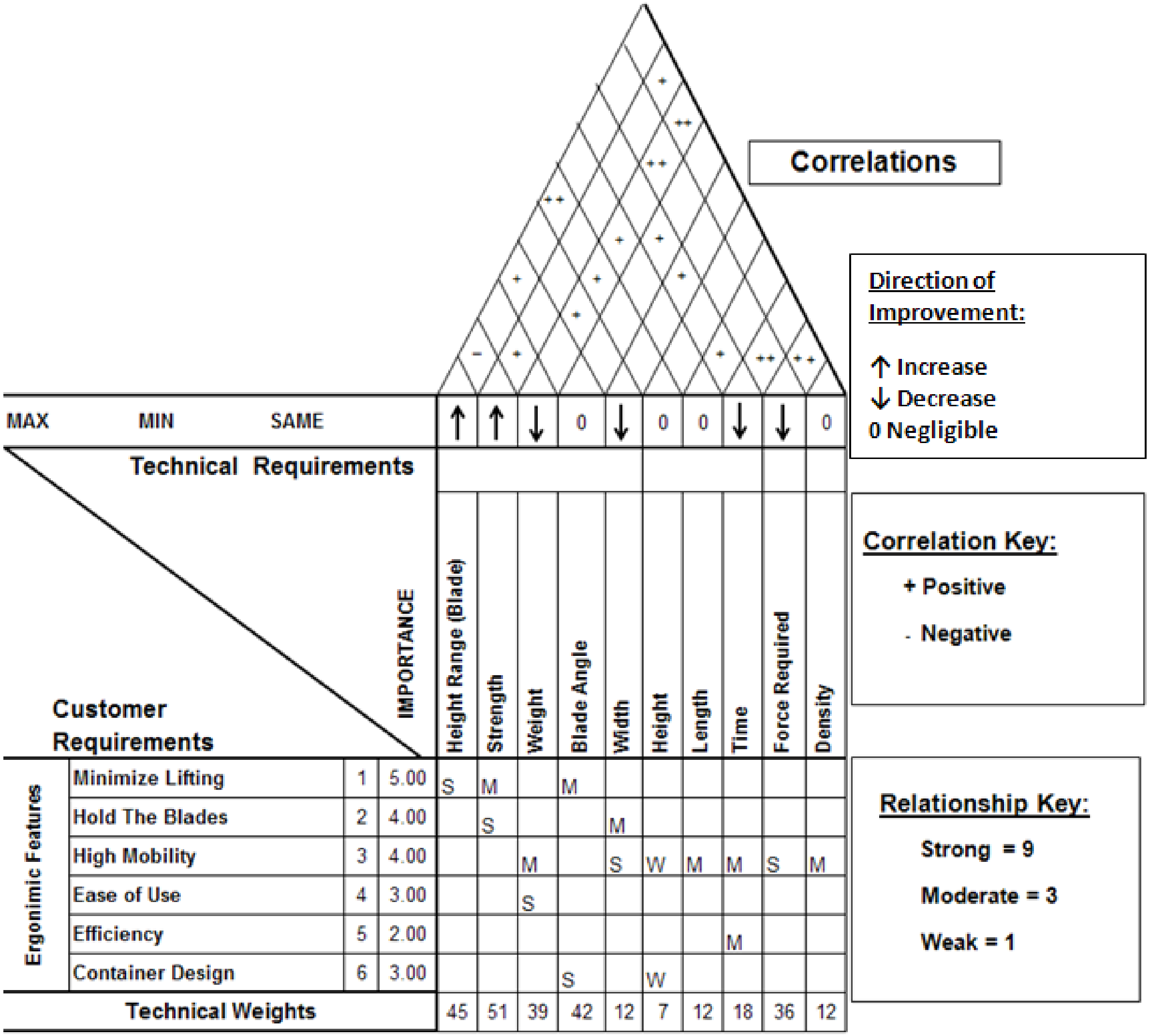
- Eliminate manual lifting
- Transport and load at least one blade
- Any employee should be capable to perform tasks
- Design safer process without significant loss of productivity

Project schedule

A project schedule was developed to manage the spring and fall semester milestones. The schedule is located in Appendix A.

House of Quality

Figure 5 depicts the house of quality used for this project. The house of quality helped to quantify the relationships between the customer requirements and technical parameters.



Customer Requirements		IMPORTANCE	Height Range (Blade)	Strength	Weight	Blade Angle	Width	Height	Length	Time	Force Required	Density
			↑	↑	↓	0	↓	0	0	↓	↓	0
Minimize Lifting	1	5.00	S	M		M						
Hold The Blades	2	4.00		S			M					
High Mobility	3	4.00			M		S	W	M	M	S	M
Ease of Use	4	3.00			S							
Efficiency	5	2.00								M		
Container Design	6	3.00				S		W				
Technical Weights			45	51	39	42	12	7	12	18	36	12

Figure 5 - House of Quality

Concept Generation

The concept generation is a way to brainstorm and create designs that would fulfill the objectives and constraints given. The redesign of this process as well as the design of a mechanical handling mechanism must adhere to the following constraints set forth by the company:

The Mechanical Design Must:

- Carry a minimum of 45lb
- Be able to extend the blade between 3-5 feet
- The device cannot exceed allowable path dimensions

The Process Redesign Must:

- Maintain or improve efficiency
- Not be operator exclusive
- Reduce time spent between machining

Preliminary Mechanism Designs

Conveyor System

The conveyor system was an intricate design for the transportation of the forgings from storage to the broaching area. The conveyor placed high overhead would be able to move each forging to the desired machine on the conveyor track. The storage area would be the initial loading point, where a forging would be loaded onto a platform capable of being lowered to a workable height for the operator and raised for the transportation of the forging to the broaching area as shown in Figure 6. The forging holder on the conveyor will be stopped at each required location and will be lowered onto a platform for easy loading and unloading. Once the machine is finished, the forging can be loaded onto the forging holder at the same location as the unloading and moved to the next machine. Advantages of the conveyor system include a decrease in walkway traffic along with assisting the operator when loading and unloading the forging to the milling machines. Cost and safety are two main disadvantages for the mechanism design. The system has high safety risks because of the heavy forgings being held at such a high height overhead. If the device is suspended overhead, there is a certain risk if failure should occur. The employees could suffer serious injury, if not death, if a forging were to fall. Also, a minor failure on the conveyor track preventing forward motion could cause the entire process to shut down until the failure is fixed. Overall, the mechanism design was not selected due to the high cost and safety hazards.

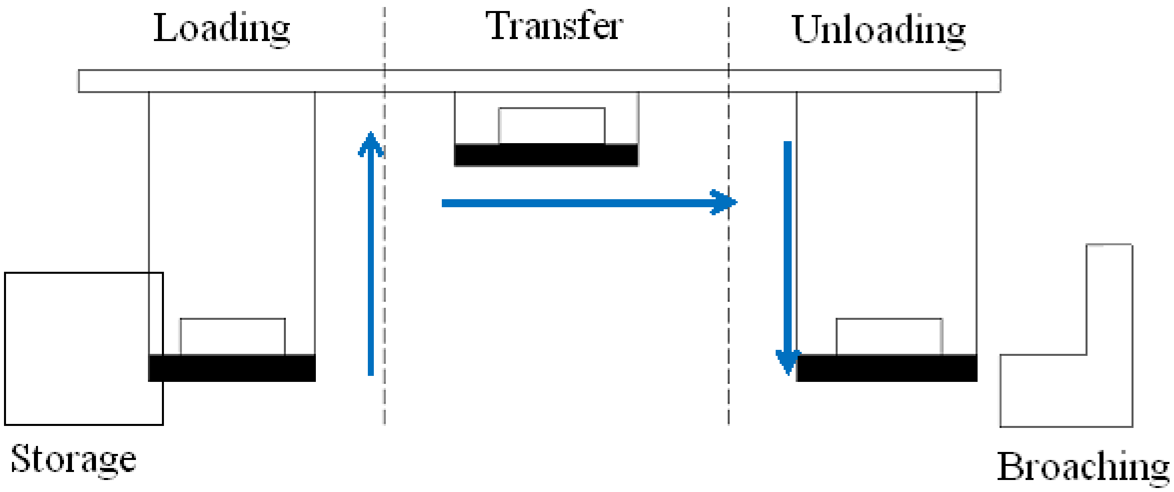


Figure 6 - Conveyor Design

Vehicle Lift

Another concept was the modification of a small industrial vehicle for the purpose of placing hoist mechanisms to the rear to provide a way of transporting the forgings. In Figure 7, a representation of the vehicle is shown with two hoist mechanisms to demonstrate the easy transportation methods used. The benefits of the mechanism include holding as many forgings as possible with the large area on the bed of the vehicle, which would decrease the number of trips from storage to the broaching area. The disadvantages include the cost and the mobility. The downside of this design involves the size constraints of the facility. The broaching area is very restrictive in its free space between machines, which may hinder movement of the vehicle. The main reason the mechanism not selected was because of the large size of the vehicle and high cost.

Figure 7 - Vehicle Mounted Lift

Barrel Cart

The barrel cart design utilizes a rotational shelf system for removal of the forgings at the same height. The design consists of a large cylinder holding approximately four to five forgings with an extender in each compartment to assist in the loading and unloading of a forging. In Figure 8, the mechanism design depicts the rotational barrel and its extending shelf system. The benefits of the barrel cart include the ability to store multiple forgings in the design when transporting from the storage area to the broaching area. Disadvantages for the barrel cart include the need for another mechanism at the milling machine to do the loading. Another disadvantage is that the operator has to manually strap in the forging when being placed in its compartment, this will add time to the process. Also, the barrel cart when fully loaded will be very heavy which causes the operator to exert a lot of force to turn the barrel rotate to the next forging. The barrel cart was not selected due to the fact that the mechanism will be heavy and hard to rotate to retrieve the forgings.

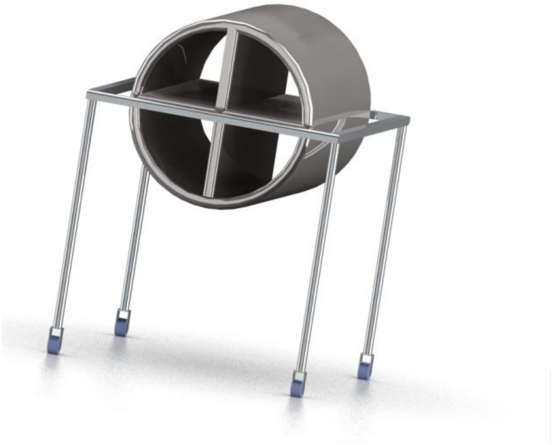


Figure 8 - Barrel Design

L Cart

The L cart design consists of a frame mounted to the oil bed with a movable platform for the loading and unloading of the forgings as seen in Figure 9. The platform is connected to the frame with linear guiderails that can be moved from the side of the cart. The L cart design shown in Figure 10 shows the ability of the guiderails vast movement, which is a key benefit when loading the fixture. The highlighted red components in the figure show the close up view of the lateral linear guides. The major disadvantage is the small lifting involved with placing the forging on the L cart platform from the cart. When using the L-cart another mechanism will be required to transport the forgings from the storage to the cart, along with being able to change heights to load the L cart. The L cart was not selected because it requires another mechanism to use and will involve some manual lifting.

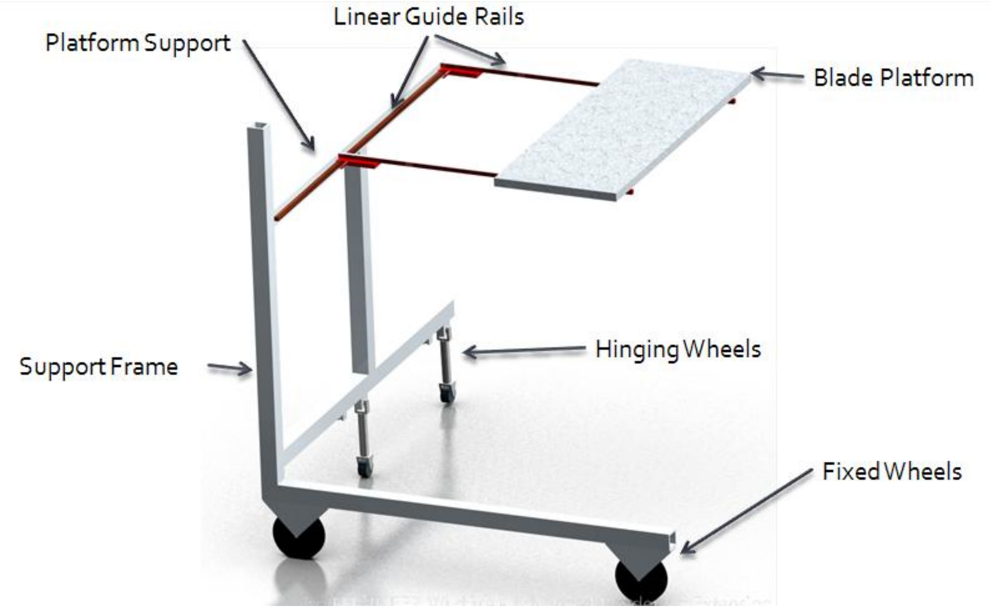


Figure 9 - L Cart Design

Figure 10 - L Cart Linear Guide Rails

Cart in Cart

The cart-in-cart design utilizes a combination of subsequent carts to achieve a desired height for the loading of the milling machine. A larger cart holds a smaller cart inside its frame, which has a variable height to help with the ease of loading the fixture. The large cart after being placed at the milling machine will have the smaller cart transport the forging up to the fixture for mounting. The other benefit is the hinging platform as shown in Figure 11 that places the forging in a vertical position for other milling machine fixtures. The mechanism can only hold one forging at a time, which will cause the operator to perform more trips to the storage. The smaller cart is set inside the larger cart which means that the smaller cart can only roll out onto oil beds that are the same heights. Another disadvantage is that the other smaller or larger oil beds will not be able to use the mechanism. The main reason why the cart-in-cart was not selected is because the mechanism can only handle one forging and can only be used on certain milling machines with the correct oil bed height.

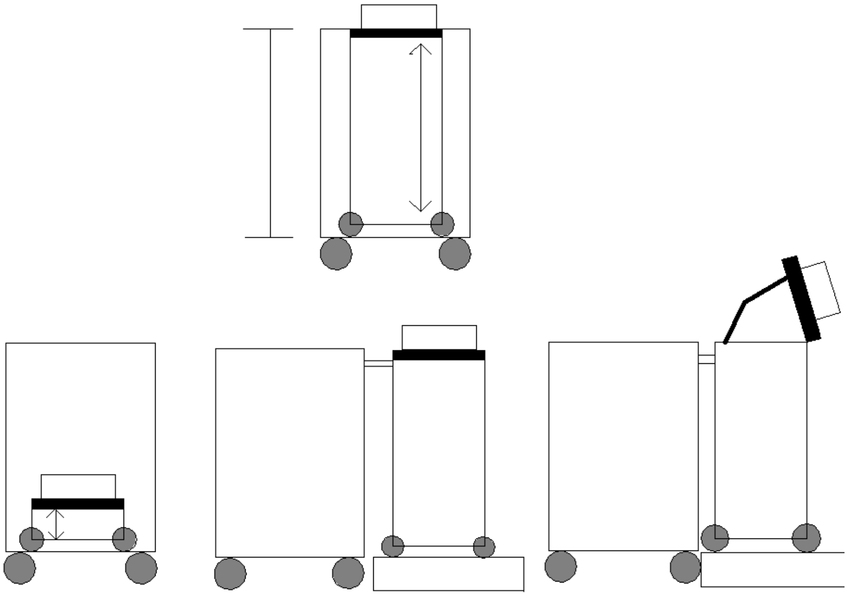


Figure 11 - Cart in Cart Capabilities

Cart top

The cart top design consists of a four forging holder attached on top of a variable height mobile cart. Each forging is kept in a separate compartment to eliminate any damage to the forging which is depicted in Figure 12. The forgings are kept in a wood tray to prevent any metal on metal contact and will be removed only after the forging is attached to the fixture in the milling machine. The process of using the cart top is very attractive because it eliminates all manual lifting. All the motions when using the cart top are sliding motions, which greatly reduce the amount of force on the body along with reducing the risk of work related injuries. The variable height cart has a foot pedal to change the height of the cart for the employee to work in a more ergonomically safe range, whereas the old procedure caused great strain on the back and waist from bending. The mobile cart will have a braking system to add stability to the process. The specific procedures for operating the cart top are below.

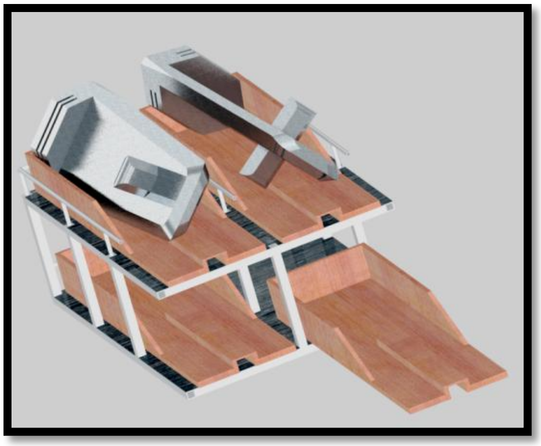


Figure 12 - Forgings in Tray on the Cart Top

Concept Generation - Container

Horizontal

One container design consists of horizontally positioned forgings separated into single sections. This design prevents nested forgings which the operator must forcibly untangle. Each forging would be removed laterally from the front of the container, which is depicted in Figure 13, and slid onto a platform.

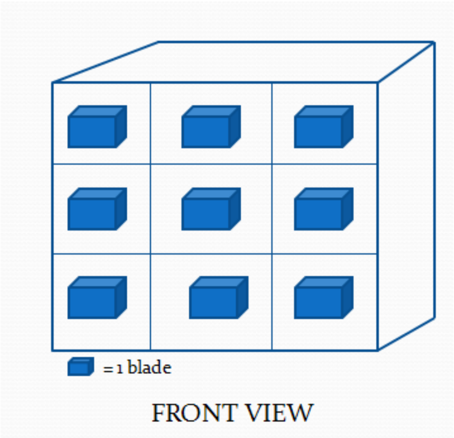


Figure 13 - Horizontal Container Design

Vertical

A container with forgings vertically positioned uses gravity instead of manual labor for forging removal. When placed atop an elevated surface, the forgings may be slid out of the bottom onto an appropriate catching device. However, the critical aspect of this design is to ensure a safe and easy release of the forging to the catching device. This concept is shown in Figure 14.

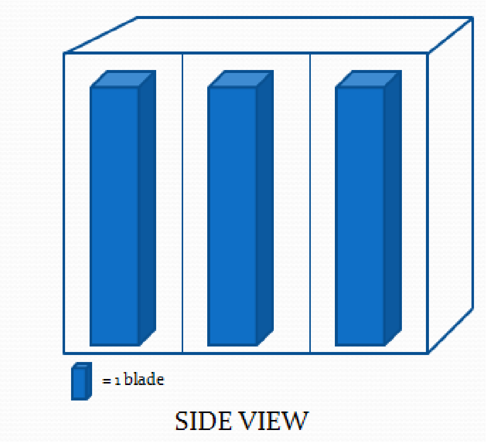


Figure 14 - Vertical Container Design

Angled

Similarly, having the forgings vertically situated at an angle uses gravity to do most of the work. One end of the forging will be mounted and wedged into a corner while the other end rests on a rigid shelf. This is visually demonstrated in Figure 15. While this method might limit the number of blades able to fit per container, it allows for a variety of retrieval methods.

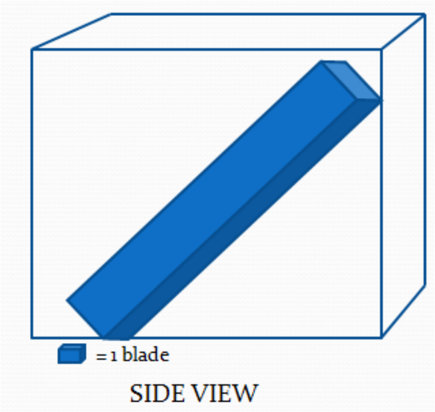


Figure 15 - Angled Container Design

Spring Container

The spring loaded container design exhibits the ability to unload each forging at the same height. Unloading the forgings at the same height will reduce the amount of bending on the employee as depicted in Figure 16. The container shaped like a rectangle with vertical columns hold forgings which sit on top of custom springs that keep the forgings at the top of the container for removal. Inside the columns, each forging will have a separator between them to prevent any damage from contact. The critical advantage of the container includes eliminating the variable height difference when unloading the forgings. As a blade is removed, the reduction in weight causes the springs to automatically raise a new forging to the proper retrieval height. Disadvantages are cost, safety, and complexity. The cost will be high because of the nonstandard springs required in each compartment of the container. Complexity of the container is a disadvantage because TECT Power utilizes these containers for frequent shipping. The unique requirements of this design could make it undesirable to manufacture in mass quantity. Another problem associated with this design arises during the shipping process. When in transit, the vibration and potential jostling could be manifested in form of blade motion due to the lack of isolation from the springs. This could potentially result in damage of the forgings and therefore an increased scrap rate.

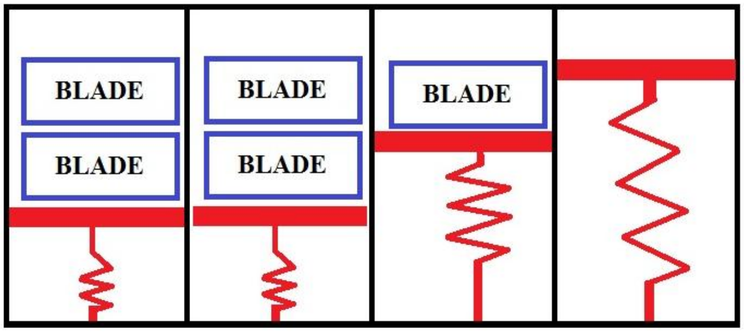


Figure 16 - Spring Loaded Container

Concept Selection

In order to compare our designs and select the ideal choice, a decision matrix was developed. The matrix rankings were based off the parameters shown in the upper chart of Figure 12. The size parameter corresponds to maneuverability of the mechanism. The force required parameter describes the amount of force necessary to utilize the cart mechanism. The force on the cart top refers to the effort needed to move a tray loaded with a blade across the cart top surface. The safety was ranked based on the combined information of the force required and the likelihood of a mechanism to cause injury (pinching, etc.). The productivity of the mechanism was determined by examining the number of forgings held as well as the time required for loading.

	Size (ft²)	Cost (USD)	Force Req. (lbf)	Loading Time (min)	Forgings Held
Concepts					
Variable Height	8	~1700	25	~2	4
L-Cart	12.5	~1900	15	~1	1
Barrel Cart	8	~1200	45	~3	4

	Maneuverability	Cost	Safety	Productivity	Total (Max 50)
Weight	0.25	0.15	0.35	0.25	1
Concepts	-	-	-	-	-
Cart Top	7	4	9	7	35
L-Cart	4	3	8	8	25
Barrel Cart	7	7	3	5	30

Figure 17 - Decision Matrix and Parameters

Cart Design

The final design as it was constructed can be seen below in Figure 18.

Figure 18 - Final Cart Design

Tray Design

The trays play an important role in the new process. Not only do they hold the forgings, but they also enable easy transferring and loading from the container to the broaching machine. In the storage area, the cart top must align with the container compartment in order to load a forging. A forging would then be loaded onto a tray and slid into the cart top. The cart is then rolled to the broaching area where the forging may be loaded onto the fixture. Since the tray elevates the end of the forging, it is easier to attach it to the fixture. Ideally, the trays should be made of Nylon for its oil resistance and strength, in addition to a lower coefficient of friction to enhance sliding. Due to budget constraints a prototype was made from plywood. Having a tray is still beneficial because it protects the forging from marring before and after the broaching process. However, the trays must be removed from the machine every time a forging is milled which may become tedious. Overall, trays were selected to allow sliding motions.

Container Design

The design of the container reflects the design of the mechanism. The table with the added height of the container is within the range of the variable height cart. The container holds eight forgings in a two level container, depicted in Figure 19. For retrieval the forgings are accessed by removing the side wall of the container. The container design improves the range of motion the employee goes through when retrieving the forgings.

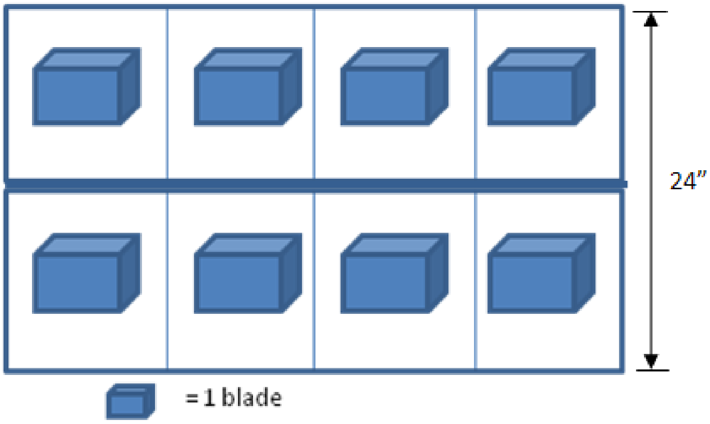


Figure 19 - Container Design Side View

Curved Conveyor

Once the cart top is loaded with forgings, the car top is brought to the broaching area where it is positioned in front of the first milling machine as shown in Figure 14. The curved conveyor, mounted to the milling machine, has rollers that the operator will use to aid in sliding the trays from the cart top to the fixture. Guardrails on the sides of the curved conveyor will prevent any dropping of the forgings which could cause major injury due to its weight. Once at the fixture, the tray will secure onto a notch, discussed below, to secure the tray into position. The tray will be removed prior to milling to prevent deterioration of the tray. Detailed procedures of the cart top and curved conveyor are stated later in the report.

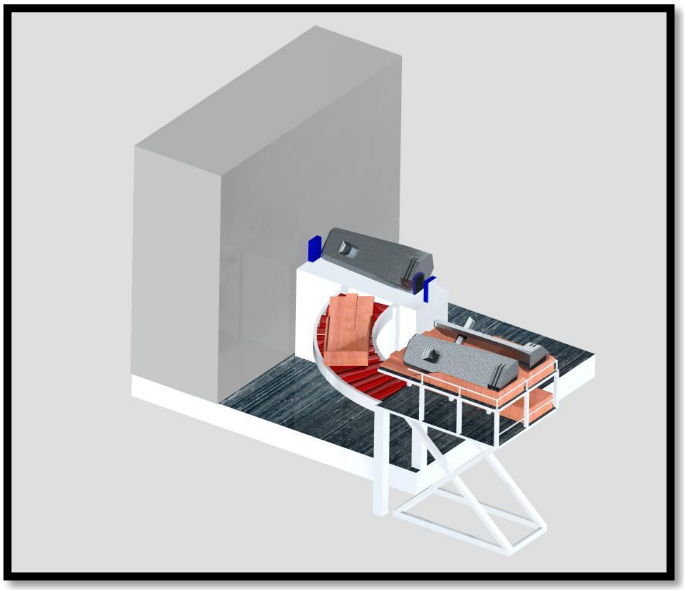


Figure 20 - Curved Conveyor on Milling Machine

Tray Pivot

During the process of loading a forging onto the milling fixture using the tray, a safety feature has been added to prevent a dropping accident by securing the tray at the fixture. As the operator slides the tray with the forging up to the mounting fixture, the tray will lock onto a notch to secure into place before the forging is mounted to the fixture as seen in Figure 21. The notch will be placed directly at the point where the forging is mounted on the fixture. The notch will catch the tray in the optimal position for mounting and prevents the tray from sliding off.

Figure 21 – Pivot Process

Storage Area

The storage area is an open space where the forgings, among other different products, are deposited after receiving. Currently, the area has designated areas depending on size, but designated section for 68k forgings overlaps into other sections and is not optimal for the storage area in general. In order to efficiently use the space for 68k forgings, an elevated roller table was proposed. Not only would this better organize assigned areas, but moving the containers would be easier. Most importantly, by elevating the proposed containers to a more convenient height the need for bending has been eliminated.

The current storage design has the forging containers place on the floor in semi-organized areas. The new design for the storage location would be to use clearly defined sections for each blade type as well as the implementation of an elevated table. The table will be placed in the 68k forging area in the storage. The elevated table, depicted in Figure 22**,** would allow for blades to be at a more manageable height allowing the mechanism design to have a smaller required height variation. When blades are received, a forklift could place the container directly onto the table to keep the forgings available for retrieval. An ideal table that TECT Power could use that would enhance the original elevated table would be an extendable table. An extendable table would be able to optimize the storage area by extending the table to fit as many containers that were located in storage. The table could also be able to shrink back when there are not as many containers.

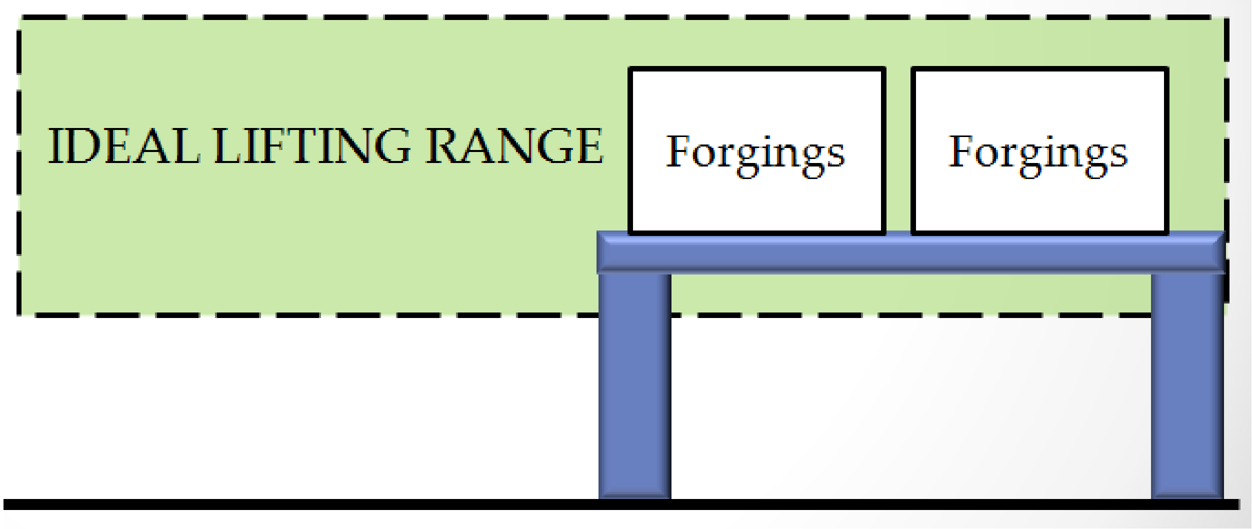


Figure 22 - Elevated Table in Storage Area

Analysis

Stress Analysis

In order to determine the mechanisms resistance to deformation and overall failure, a stress analysis was performed using Pro Engineer Mechanica. While the actual design utilizes diamond cut steel sheeting as a surface for each level, the computer generated design was constructed with a flat plate the same thickness as the steel sheeting. Each joint formed by individual parts were constrained with welded fixture. The load placed onto each surface of the cart top was 150lbf. This resulted in a factor of safety of approximately 1.7. The weight was supplied in a distributed fashion over the entire exposed surfaces of the cart. The results of this analysis can be seen in Figure 23.

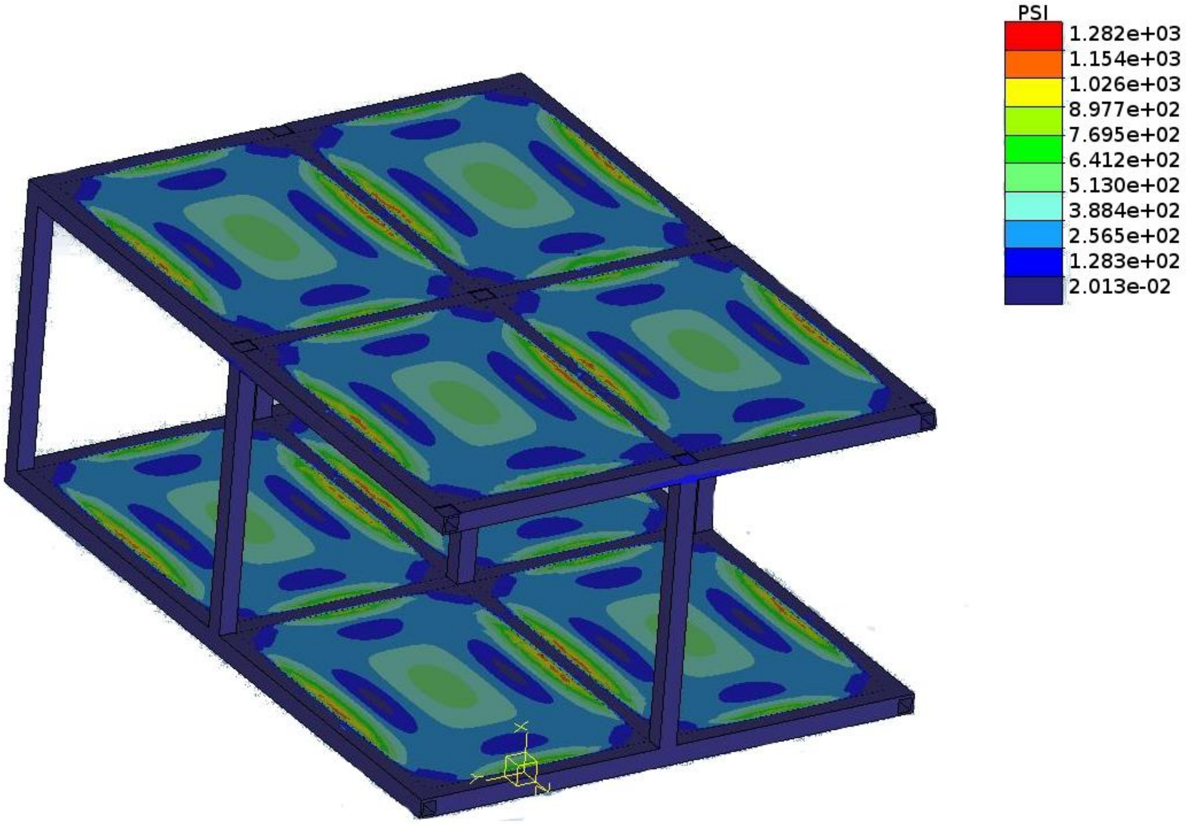


Figure 23 - Stress Analysis Results

It can be seen in the figure above that the maximum stress occurring in the design is approximately 1.3 ksi. By comparing this to the yield strength of A36 structural steel, approximately 36 ksi, it is apparent that failure will not occur even when drastically overloading the mechanism. The displacement was also estimated using the Mechanica software. The results of this test showed that the maximum displacement is approximately . This can be considered a negligible deflection.

Material Selection

When choosing the correct material for the mechanism a few requirements are to be fulfilled. The mechanism will encounter oil, heavy weight, and moisture. The material requirements will be able to make sure that the mechanism will last in this type of environment.

Material Requirements:

- Corrosion Resistance
- Moisture Resistance
- Durable
- High Strength

Cost

Cost analysis is a systematic tool for calculating the costs and advantages for a project when taking into account the different materials that could possibly be used along with the corresponding measurements for the part. A cost analysis can balance out the mechanical requirements with financial constraints. With a budget of $2000, the team was faced with either making part of the design or purchasing complete parts. Specifically, should the team purchase a mobile lift cart or purchase a premade one? The bare minimum required to construct a mobile lift cart includes a hydraulic cylinder, a frame, wheels, top sheeting and cross supports, all of which were considered from McMaster due to the short lead time. . As displayed in Table 1, it was more expensive to purchase materials in order to build a mobile cart ($2069.27) as opposed to purchasing the cart ($1437.19). Buying a mobile cart would not only be cheaper, but it will ensure the quality and reliability of the product since Mcmaster guarantees a minimum one year warranty. With the purchase of a base cart, modifications will be made to accommodate the cart top. However, the team will remain within budget or go slightly over if a cart were purchased. Therefore, the team has decided to buy.

Table 1 - Cost Comparisons

	Make Cart ($)	**Buy Cart ($)**
Cart	2069.27	1437.19
Total Design	2364.14	2270.74

The different options for the mobile carts are shown below in Table 2. The few carts that McMaster offered varied by its foot pedal pump to inches raised. The cart needs to have a good ratio to make sure that the operator doesn't waste time when using the mechanism in the process. The cart chosen had a ratio of 1 pump to 1.25 inches. The cheapest option isn't the correct solution because the operator needs to raise the height by a reasonable amount of time. The cheapest option with the good pump ratio was selected.

Table 2 - Options for Mobile Carts

Cart Option [Supports]	Option 1	Option 2	Option 3
Cart 1 [3]	**1642.3**	**1611.97**	**1632.49**
Cart 2 [3]	**2131.4**	**2101.07**	**2121.59**
Cart 3 [3]	**2094.79**	**2064.46**	**2084.98**
Cart 4 [3]	**1415.07**	**1384.74**	**1405.26**

Force

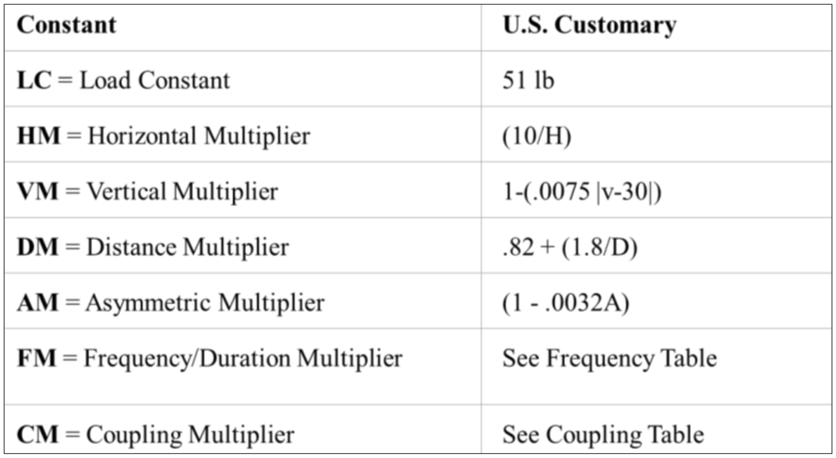
The baseline force exhibited to slide a forging was calculated theoretically and experimentally. Since the materials at TECT were unknown, the coefficients of friction were assumed to be 0.25. With a load of 45lb it was found that theoretically it takes approximately 11.25lbs to slide a 68k forging. Using the plywood tray prototype and the coated steel cart top, it was experimentally found that the coefficient of friction was approximately 0.5. The force required to slide a forging of 45lbs resting on a tray of approximately 5lbs was 25 lbs.

NIOSH

The National Institute for Occupational Safety and Health lifting equation is used to find the recommended weight limit for a load of a manual lifting process. For example, the current weight of the load at TECT power is approximately 45lbs.

To calculate the recommended weight limit for the current process at TECT, factors such as frequency of lifts, and various distances are needed. In addition, the origin, where the object is lifted from, and destination, where the object is placed are considered. The NIOSH lifting equation for the recommended weight limit is seen in below. Table 3 illustrates the parameters used for the lifting equation.

Table 3 - Lifting Equation Parameters



Constant	U.S. Customary
LC = Load Constant	51 lb
HM = Horizontal Multiplier	(10/H)
VM = Vertical Multiplier	1-(.0075 |v-30|)
DM = Distance Multiplier	.82 + (1.8/D)
AM = Asymmetric Multiplier	(1 - .0032A)
FM = Frequency/Duration Multiplier	See Frequency Table
CM = Coupling Multiplier	See Coupling Table

It was determined that the recommended weight limit at the origin was 13.38 lbs and 16.31 lbs at the destination for lifting one forging during the process. Both limits are well below the current weight of the forging. The purpose of the NIOSH lifting equation is to rank the alternatives, not give absolute risks. By calculating the lifting indexes at both origin and destination, the higher alternative must be chosen to account for the worst case scenario. The indexes are based on a scale on one to three. A lifting Index of 1.00 or less is acceptable, greater than 1.00 up to 3.00 Indicates Need for Task and/or Administrative Change and a lifting Index of Greater than 3.00 Unacceptably Hazardous - Engineering Changes Required.

Where LW is the actual load weight and RWL is the recommended weight limit.

The Lifting Index (LI) interpretation is as follows:

- LI < 1 corresponds to a low risk situation
- 1 < LI < 3 is associated with a moderate level of risk and should be redesigned
- LI > 3 depicts a significant risk to the individuals and should be redesigned

The lifting index for the origin was 3.36 and the destination lifting index was 2.76, the higher of the two selected. The index at the origin is greater than three and justifies that a redesign is necessary.

These calculations are based on lifting only one forging; however the process at TECT requires multiple forgings to be lifted. To account for the additional lifting the multi-task lifting index is calculated resulting in 3.73 which indicates that cumulatively the process is more hazardous. The new process will effectively remove lifting, eliminating the associated risks and the ability to use the NIOSH lifting equation. Therefore a different quantifying tool must be used to analyze the new process.

Psychophysical

Since the new process eliminates manual lifting, the NIOSH equation is no longer an applicable analysis tool. Instead, the Liberty Mutual Tables were used to determine whether or not the new process is an acceptable alternative.

The Liberty Mutual Tables, as seen in Appendix B, were compiled using psychophysical methodology, a type of analysis based on self-imposed limits of pushing, pulling, and carrying along with anthropometric characteristics. It has been shown to be very accurate in predicting the human capabilities of different tasks.

For this new proposed procedure, operators will retrieve and deposit the forging from the storage area to the broaching area using a combination of pushing and pulling actions.

From the tables, it was found that the maximum allowable push and pull force for 75 percent of the female population was 59lbs with a sustained force of 42lbs, and 57lbs and a sustained force of 35lb respectively.

Based on the experimental calculations a force of approximately 25lbs is required to initially slide one forging. This is well within the allowable range. To initially push or pull a cart carrying four forgings, assuming a load of 500lbs and no wheels on the cart, a force of approximately 75lbs was needed. This number will be lower after including wheels and a realistic load.

Since the calculations are within the ranges, and since manual lifting has been eliminated this design is a significant improvement.

RULA

The Rapid Upper Limb Assessment worksheet considers upper body movements and quantifies the risk of an operation for the worker. Limbs assessed include wrist, arm, neck and trunk, and are evaluated based range of motion. For example, a trunk that bends at 60 degrees will have a higher total score than a trunk that bends 10 degrees.

The RULA is based on a scale of one to seven where a score of one relates no risk and a score of seven relates high risk, shown in Table 4.

Table 4 - RULA Score Interpretation

RULA score	Interpretation
1-2	The person is working in the best posture with no risk of injury from their work posture.
3-4	The person is working in a posture that could present some risk of injury from their work posture, and this score most likely is the result of one part of the body being in a deviated and awkward position, so this should be investigated and corrected.
5-6	The person is working in a poor posture with a risk of injury from their work posture, and the reasons for this need to be investigated and changed in the near future to prevent an injury
7+	The person is working in the worst posture with an immediate risk of injury from their work posture, and the reasons for this need to be investigated and changed immediately to prevent an injury

The current process at TECT involves manually lifting and received a score of seven

With the new process in place and lifting eliminated, theoretically the RULA score will be a three.

New Process

New Design Procedure includes a nine step process.

1. Cart aligned with front of container in storage area
2. Forging can be slid from container to tray
3. Repeat until cart is full
4. Travel from storage to broaching area
5. Place cart in front of conveyor (depicted in Figure 24)

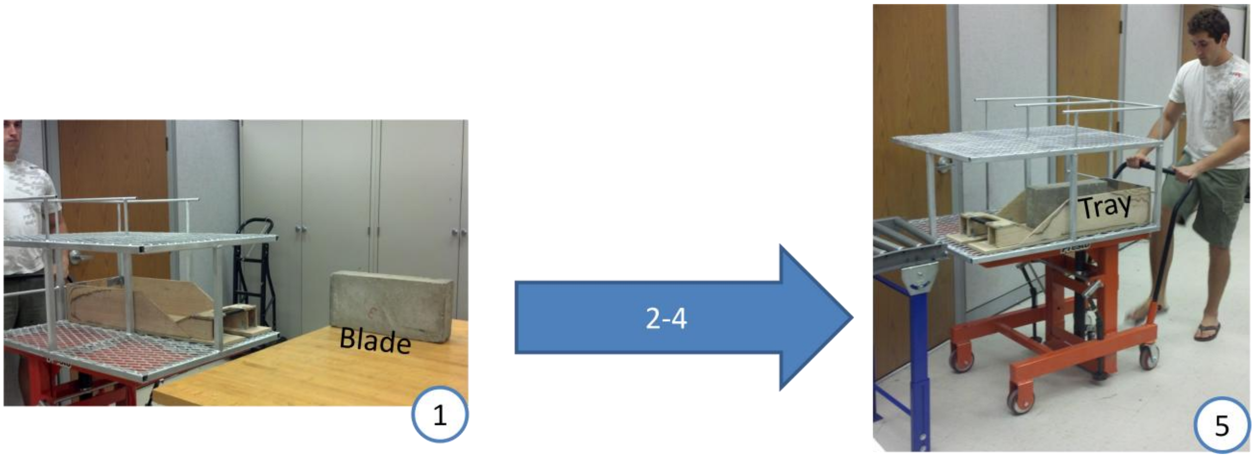


Figure 24 - Steps 1-5

6. Slide tray along conveyor to mounting area
7. Mount blade and remove tray
8. Once milling complete, replace tray and remove forging (illustrated in Figure 25)

9. Place forging into cart and remove new forging

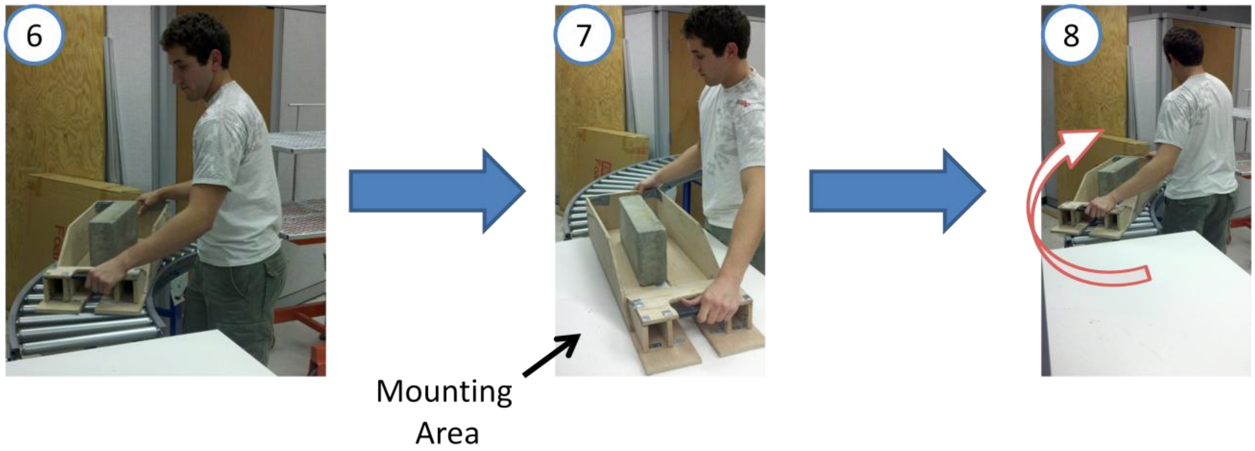


Figure 25 - Steps 6-8

Bill of Materials

The bill of materials included is a list of the materials required for the product being manufactured. The list in Table 5 shows the exact list of parts needed to build the cart top and curved conveyor. The list includes all of the required materials needed for manufacturing. The final amount became $2552.74 which is over our initial budget of $2,000. The extra money required was approved by the Mechanical Department.

Line	Quantity	Product	Description	Unit Price	Total Price
1	1 Each	5825K77	1-3/8" Dia Steel Roller Conveyor 90 Degree Curve, 3" Roller Spacing, 18" O'all Width (Same as 5825K777)	$160.53	$160.53
2	3 Each	5833K413	Bolt-on Conveyor Stand for 18" O'all Conveyor Width, 31"-37" H Adjustment	$44.78	$134.34
3	1 Each	24485T22	Easy Access Foot-Operated Mobile Lift Table 2000# Capacity, 30" - 48" Table Height	$1437.19	$1437.19
4	8 Each	6527K31	Low-Carbon Steel Square Tube 1" X 1", .120" Wall Thickness, 6' Length	$24.14	$193.12
5	1 Each	9302T47	Expanded Metal Sheet (1008 Carbon Steel) Flattened, .110" O'all Thickness, 4' X 8'	$97.11	$97.11
6	1 Each	9017K14	Low-Carbon Steel 90 Degree Angle 3/16" Thick, 1" Leg Length, 6' Length	$15.00	$15.00
7	1 Pack	91251A587	Black-Oxide Alloy Steel Socket Head Cap Screw 5/16"-18 Thread, 1-1/2" Length, Packs of 50	$11.80	$11.80
8	1 Pack	95462A030	Zinc-Plated Grade 5 Steel Hex Nut 5/16"-18 Thread Size, 1/2" Width, 17/64" Height, Packs of 100	$5.40	$5.40
9	1 Pack	96582A321	Black Luster Coated Steel Type A USS Washer 5/16" Screw Size, 7/8" OD, .06"-.11" Thick, Packs of 10	$10.20	$10.20
10	1 Each	8974K711	Multipurpose Aluminum (Alloy 6061) 2" Diameter X 1' Length (Same as 8974K71)	$21.81	$21.81
11	1 Each	1125T35	Marine-Grade Plywood 1/2" Thick, 36" X 48"	$64.00	$64.00
12	1 Each	8968K29	Galvanized Low-Carbon Steel 90 Degree Angle Perforated, 2-1/4" X 1-1/2" Legs, 5/64" Thk, 6' L (Same as 8968K27)	$20.43	$20.43
13	3 Each	89955K56	4130 Alloy Steel Aircraft-Grade Round Tube .500" OD, .083" Wall Thickness, 6' Length	$33.27	$99.81
				Subtotal	**$2270.74**
			Shipping		**282**
				Total	**2552.74**

Table 5 - Project Cost

Maintenance

To prevent potential malfunctions of the mechanism certain components must be functional, namely the foot pedal and bolts that attach the cart top to the cart. They can be seen in Figure 26 below, which depicts the variable height cart. With a foot pedal malfunction, the cart will not be able to vary its height consequently voiding the entire process. Additionally, if the foot pedal fails, the cart top will drop to its minimum height damaging anything in its path. It is essential to keep that area clear to prevent any harm. Therefore, inspecting the foot pedal is a critical aspect. Additionally, since the cart top is connected to the mobile cart by industrial bolts, they must be maintained as well.

Figure 26 - Variable Height Cart

Maintenance of the mechanism is necessary to avoid malfunction. To assess the potential areas of malfunction, weekly inspections should be required. The mandatory inspections should be recorded for company information. The entire cart will be inspected with emphasis on critical components which are listed below.

Inspection points:

- Check floor lock for positive locking operation
- Check all nuts and bolts for proper tightness
- Check structure for abrasives, dirt, and oil caked contaminants
- Check structural frames for damage and cracked welds
- Clean and inspect guides and guide wheels
- Clean and inspect all welds
- Clean and inspect lifting chains
- Test floor lock for holding ability
- Check for hydraulic leaks
- Check hydraulic fluid with the platform fully lowered

For the process to work, maintenance of the mobile cart will be required at least once a month. The few tasks mandatory for maintenance are listed below.

- Tighten the bolts (the cart top to the mobile cart)
- Clean the foot pedal
- Oil the foot pedal
- Lubricate brake chain with a rust inhibitive lubricant
- Lubricate wheel axles, kingpins, and bearings

Conclusion

The main objective of the project was to reduce the risk of injury during the process and handling of the 68k forgings. The goal was to replace all manual lifting required by the operator with a mechanism that will aid the 68k process. Additionally the storage area layout and container design will be modified to better suit the new mechanism.

A mechanism design was created to eliminate manual lifting from the process. The mechanism concept consisted of two main devices. The devices were a variable height cart with a cart top for transportation and a curved conveyor for loading/unloading of the milling machine. Supplementary designs included a horizontally oriented forging container with removable walls, and a more organized storage area, with a designated table for the said containers.

While developing these devices, stress and displacement analysis was conducted using Pro-Engineer Mechanica to ensure that the mechanisms did not fail. Besides being structurally sound, this design selection completely eliminated manually lifting from the process; moreover, it had ergonomic and cost justification. Using the Rapid Upper Limb Assessment (RULA) worksheet and the Liberty Mutual Tables it was determined that this process had more ergonomic benefit than the current methods at TECT. The RULA score was drastically reduced from the worst score possible to a more acceptable one. In addition, the cost of manufacturing this design was actually cheaper than any other option the group had considered. Over the course of a school year, the team was able to complete the project to the best of their ability.

Future Work

After the completion of this project, it must then be implemented at TECT’s Thomasville facility. Mostly, this includes training operators to become accustomed to the procedural changes. This training should emphasize critical aspects such as brake usage, and alignment of the cart top with the forging container as well as the roller conveyor. Additionally, employees should be aware of the maintenance required of the variable height cart. Fortunately, the variable height cart was purchased from McMaster and comes with a five year warranty should frequent inspections not suffice. In order to save time, TECT should have the CAD of the containers sent to an injection molding company on the commencement of training employees. By implementing both training and fabrication of the containers simultaneously, a smoother launch of the new design may be achieved.

Since TECT plans to continue this project in the future, more work may be accomplished. Primarily, instead of having a mechanism that works only with the first broaching machine TECT wishes to develop a process that integrates all the machines in the broaching area. Currently, the height range of the improved design may include the second milling machine which requires the forging to be mounted vertically. However, a method for manipulating the forgings for all types of mountings in the broaching area is preferred.

Although TECT requested that the mechanism carries at least one forging, the improved design has a capacity of up to four forgings. Future teams may wish to increase this number to reduce trips to the storage area.

Aside from mechanism improvements, future work may involve improvement of the forging tray. As discussed, the prototype tray is made from plywood but ideally should be made from a polymer capable of injection molding, namely Nylon. However, more research may be complied to advise TECT on the different materials to decrease the current coefficient of friction. Not only can the material be improved, but the function of the tray as well. A tray that is not only functional, but can follow a forging throughout all its processes in the broaching area is immense motivation for the next TECT team.

Acknowledgments

Ashok Patel

Dr. Chiang Shih

Dr. Srinivas Kosaraju

Dr. Mathieu Dalban-Canassy

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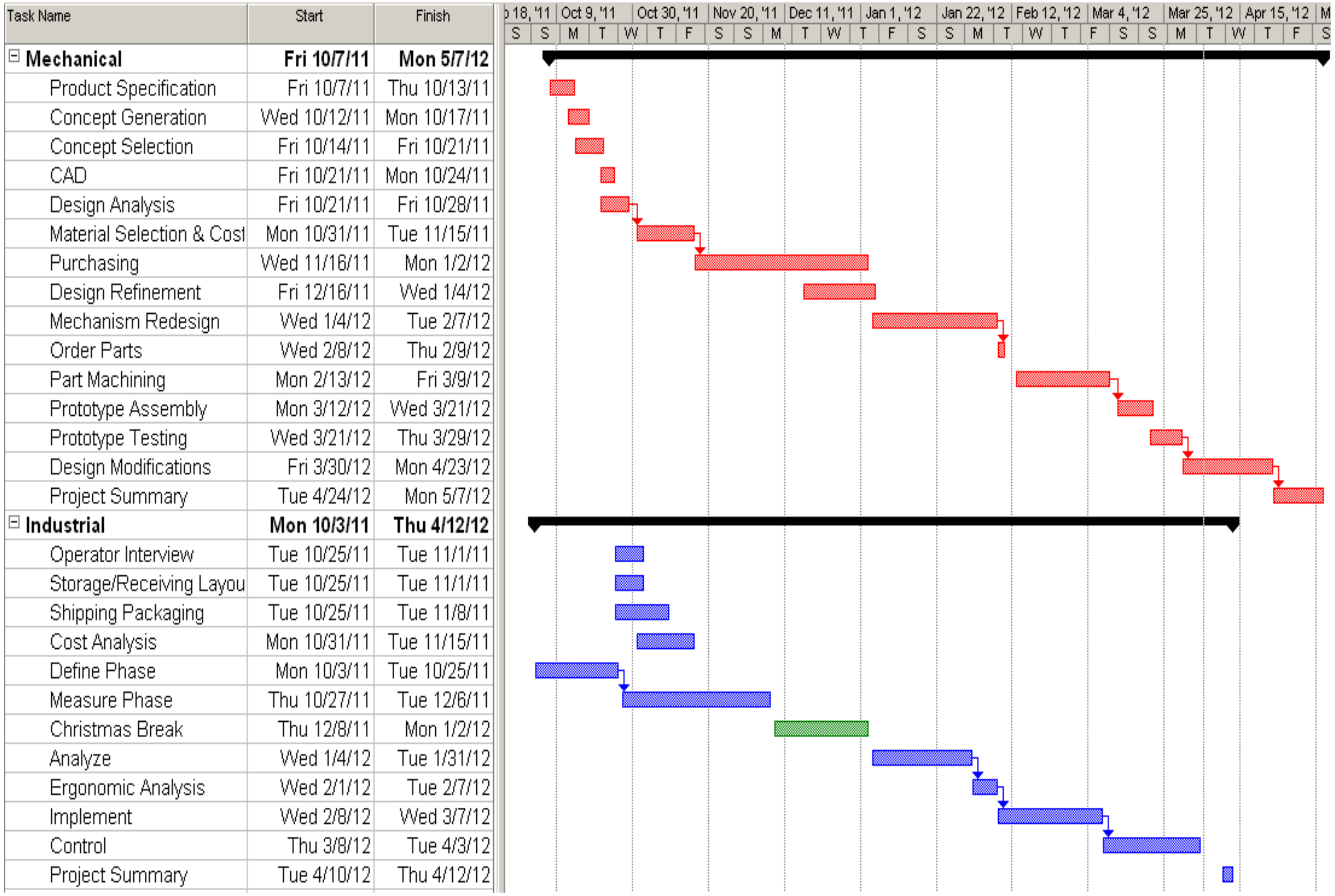
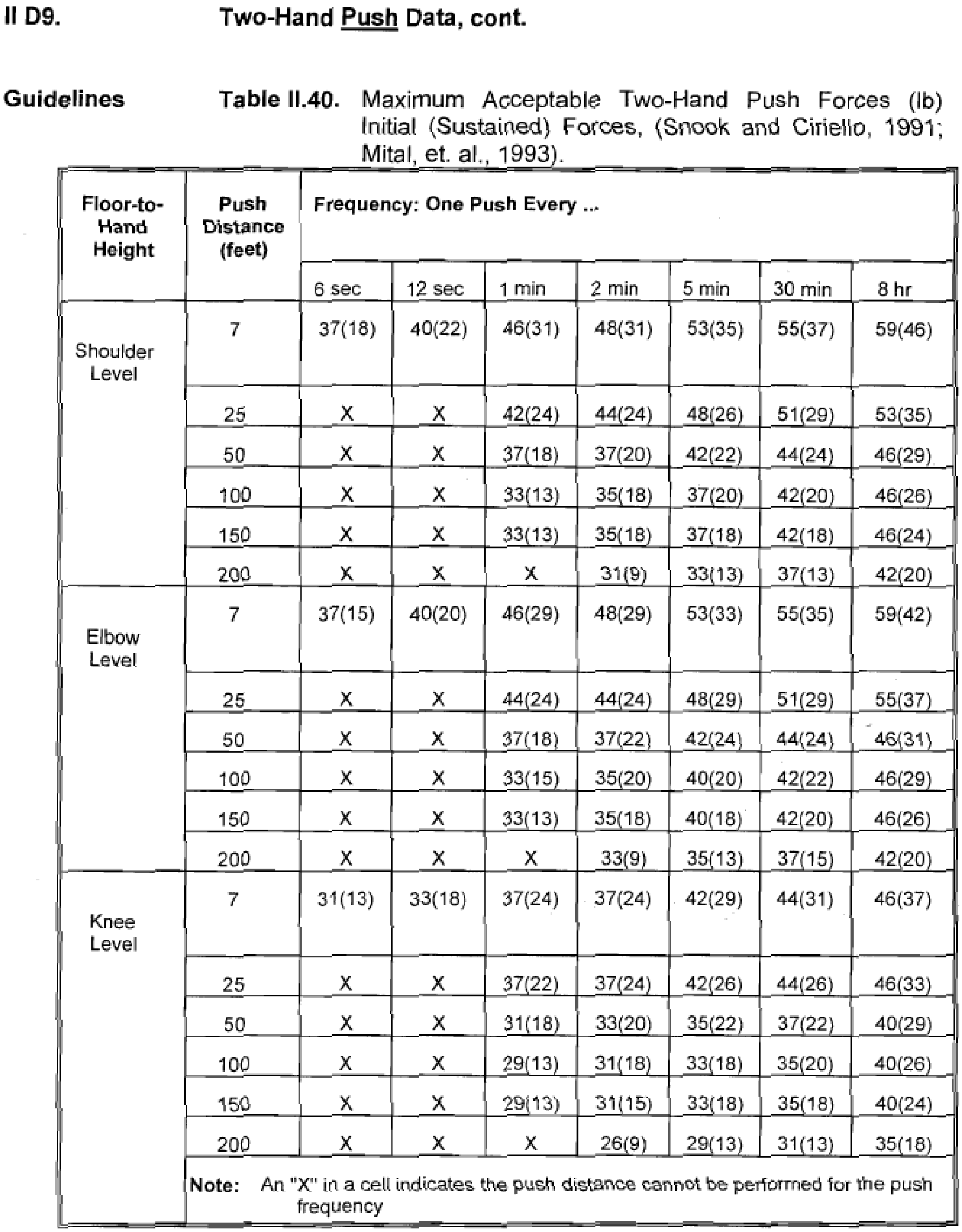
Appendix A – Project Schedule



Task Name	Start	Finish
Mechanical	**Fri 10/7/11**	**Mon 5/7/12**
Product Specification	Fri 10/7/11	Thu 10/13/11
Concept Generation	Wed 10/12/11	Mon 10/17/11
Concept Selection	Fri 10/14/11	Fri 10/21/11
CAD	Fri 10/21/11	Mon 10/24/11
Design Analysis	Fri 10/21/11	Fri 10/28/11
Material Selection & Cost	Mon 10/31/11	Tue 11/15/11
Purchasing	Wed 11/16/11	Mon 1/2/12
Design Refinement	Fri 12/16/11	Wed 1/4/12
Mechanism Redesign	Wed 1/4/12	Tue 2/7/12
Order Parts	Wed 2/8/12	Thu 2/9/12
Part Machining	Mon 2/13/12	Fri 3/9/12
Prototype Assembly	Mon 3/12/12	Wed 3/21/12
Prototype Testing	Wed 3/21/12	Thu 3/29/12
Design Modifications	Fri 3/30/12	Mon 4/23/12
Project Summary	Tue 4/24/12	Mon 5/7/12
Industrial	**Mon 10/3/11**	**Thu 4/12/12**
Operator Interview	Tue 10/25/11	Tue 11/1/11
Storage/Receiving Layou	Tue 10/25/11	Tue 11/1/11
Shipping Packaging	Tue 10/25/11	Tue 11/8/11
Cost Analysis	Mon 10/31/11	Tue 11/15/11
Define Phase	Mon 10/3/11	Tue 10/25/11
Measure Phase	Thu 10/27/11	Tue 12/6/11
Christmas Break	Thu 12/8/11	Mon 1/2/12
Analyze	Wed 1/4/12	Tue 1/31/12
Ergonomic Analysis	Wed 2/1/12	Tue 2/7/12
Implement	Wed 2/8/12	Wed 3/7/12
Control	Thu 3/8/12	Tue 4/3/12
Project Summary	Tue 4/10/12	Thu 4/12/12

Appendix B – Liberty Mutual Tables



II D9. **Two-Hand Push Data, cont.**

Guidelines **Table II.40.** Maximum Acceptable Two-Hand Push Forces (lb) Initial (Sustained) Forces, (Snook and Ciriello, 1991; Mital, et. al., 1993).

Floor-to-Hand Height	Push Distance (feet)	Frequency: One Push Every ...						
		6 sec	12 sec	1 min	2 min	5 min	30 min	8 hr
Shoulder Level	7	37(18)	40(22)	46(31)	48(31)	53(35)	55(37)	59(46)
	25	X	X	42(24)	44(24)	48(26)	51(29)	53(35)
	50	X	X	37(18)	37(20)	42(22)	44(24)	46(29)
	100	X	X	33(13)	35(18)	37(20)	42(20)	46(26)
	150	X	X	33(13)	35(18)	37(18)	42(18)	46(24)
	200	X	X	X	31(9)	33(13)	37(13)	42(20)
Elbow Level	7	37(15)	40(20)	46(29)	48(29)	53(33)	55(35)	59(42)
	25	X	X	44(24)	44(24)	48(29)	51(29)	55(37)
	50	X	X	37(18)	37(22)	42(24)	44(24)	46(31)
	100	X	X	33(15)	35(20)	40(20)	42(22)	46(29)
	150	X	X	33(13)	35(18)	40(18)	42(20)	46(26)
	200	X	X	X	33(9)	35(13)	37(15)	42(20)
Knee Level	7	31(13)	33(18)	37(24)	37(24)	42(29)	44(31)	46(37)
	25	X	X	37(22)	37(24)	42(26)	44(26)	46(33)
	50	X	X	31(18)	33(20)	35(22)	37(22)	40(29)
	100	X	X	29(13)	31(18)	33(18)	35(20)	40(26)
	150	X	X	29(13)	31(15)	33(18)	35(18)	40(24)
	200	X	X	X	26(9)	29(13)	31(13)	35(18)

Note: An "X" in a cell indicates the push distance cannot be performed for the push frequency

II D10. Two-Hand Pull Data, cont.

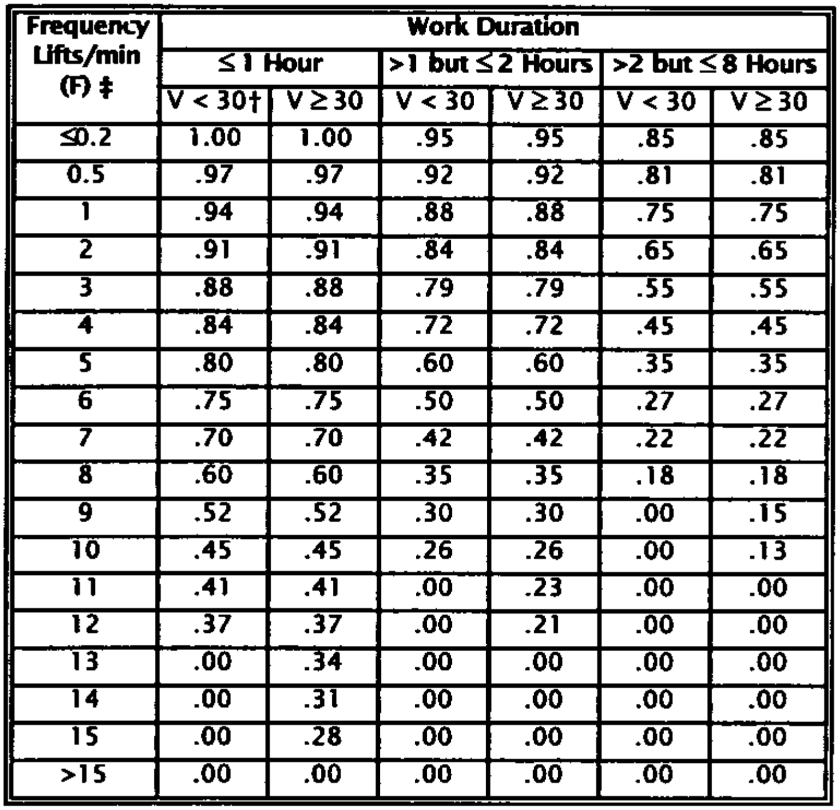
Guidelines **Table II.41.** Maximum Acceptable Two-Hand Pull Forces (lb) Initial (Sustained) Forces, (Snook and Ciriello, 1991; Mital, et. al., 1993)

Floor-to-Hand Height	Pull Distance (feet)	Frequency: One Pull Every...						
		6 sec	12 sec	1 min	2 min	5 min	30 min	8 hr
Shoulder Level	7	35(15)	42(22)	44(29)	46(31)	53(33)	55(35)	57(44)
	25	X	X	42(26)	42(26)	46(29)	48(31)	53(40)
	50	X	X	35(20)	35(22)	40(24)	42(26)	44(33)
	100	X	X	31(15)	35(20)	37(22)	40(22)	44(31)
	150	X	X	31(13)	35(20)	37(20)	40(20)	44(26)
	200	X	X	X	31(13)	33(15)	35(15)	40(22)
Elbow Level	7	35(15)	42(22)	46(29)	48(29)	55(33)	57(35)	59(42)
	25	X	X	42(24)	44(26)	48(29)	51(31)	55(37)
	50	X	X	37(20)	37(22)	42(24)	44(26)	46(31)
	100	X	X	33(15)	35(20)	40(20)	42(22)	46(29)
	150	X	X	33(13)	35(18)	40(20)	42(20)	46(26)
	200	X	X	X	33(11)	35(15)	37(15)	42(20)
Knee Level	7	37(13)	44(20)	48(26)	51(26)	57(29)	59(31)	62(40)
	25	X	X	44(24)	46(24)	51(26)	53(29)	57(35)
	50	X	X	37(18)	40(20)	44(22)	46(24)	48(29)
	100	X	X	35(13)	37(18)	40(20)	44(20)	48(26)
	150	X	X	35(13)	37(18)	40(18)	44(18)	48(24)
	200	X	X	X	33(11)	35(13)	40(13)	44(20)

Note: An "X" in a cell indicates the pull distance cannot be performed for the pull frequency

Appendix C – NIOSH

Table 5
Frequency Multiplier Table (FM)



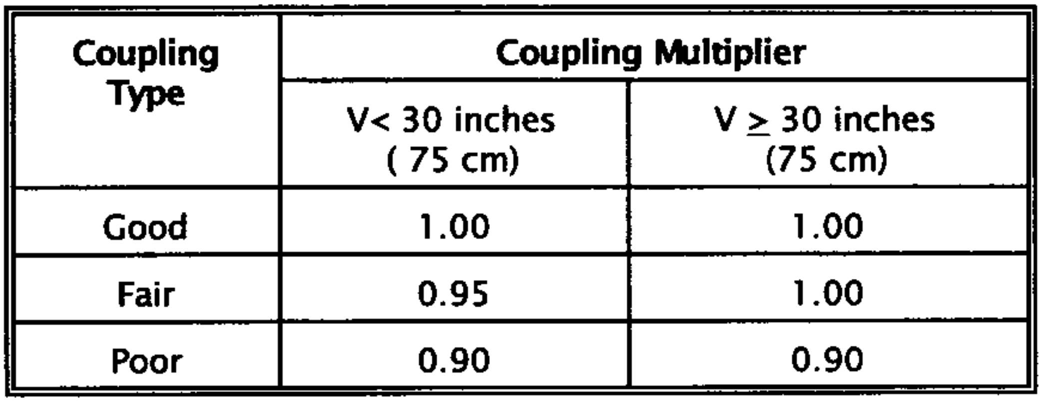
Frequency Lifts/min (F) ‡	Work Duration					
	≤ 1 Hour		>1 but ≤ 2 Hours		>2 but ≤ 8 Hours	
	V < 30†	V ≥ 30	V < 30	V ≥ 30	V < 30	V ≥ 30
≤0.2	1.00	1.00	.95	.95	.85	.85
0.5	.97	.97	.92	.92	.81	.81
1	.94	.94	.88	.88	.75	.75
2	.91	.91	.84	.84	.65	.65
3	.88	.88	.79	.79	.55	.55
4	.84	.84	.72	.72	.45	.45
5	.80	.80	.60	.60	.35	.35
6	.75	.75	.50	.50	.27	.27
7	.70	.70	.42	.42	.22	.22
8	.60	.60	.35	.35	.18	.18
9	.52	.52	.30	.30	.00	.15
10	.45	.45	.26	.26	.00	.13
11	.41	.41	.00	.23	.00	.00
12	.37	.37	.00	.21	.00	.00
13	.00	.34	.00	.00	.00	.00
14	.00	.31	.00	.00	.00	.00
15	.00	.28	.00	.00	.00	.00
>15	.00	.00	.00	.00	.00	.00

†Values of V are in inches. ‡For lifting less frequently than once per 5 minutes, set F = .2 lifts/minute.

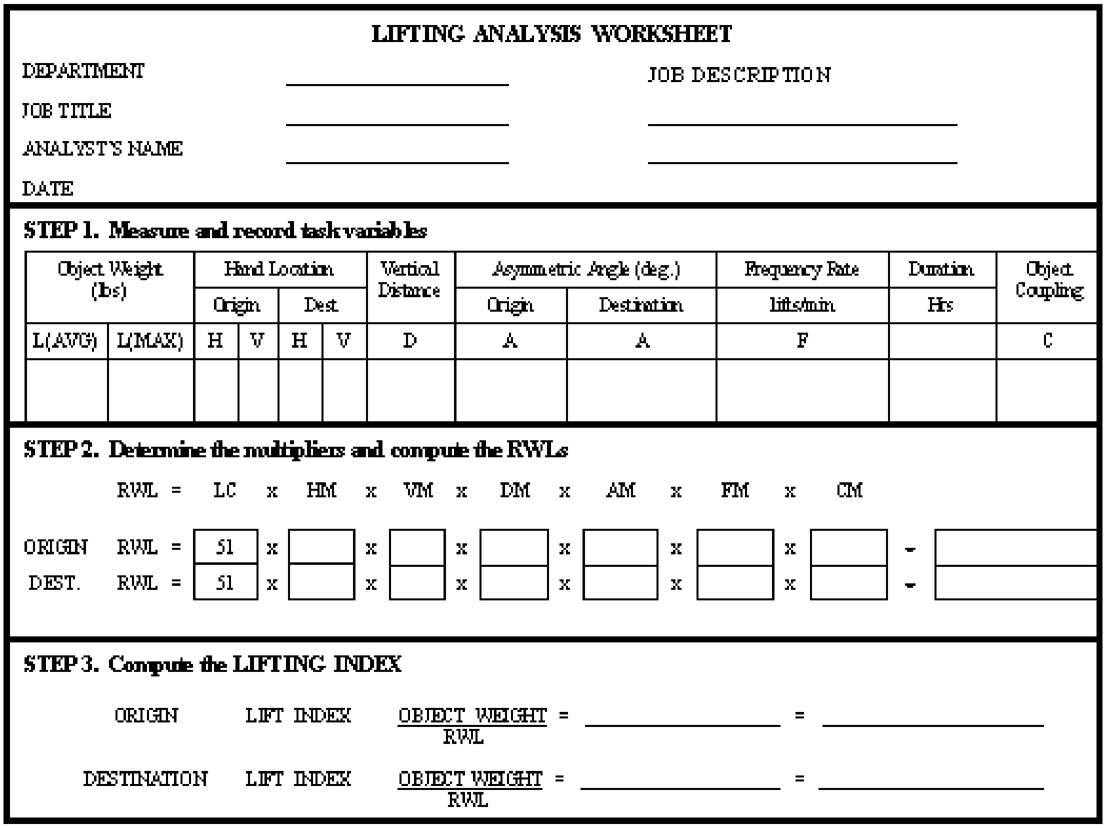
Table 6
Hand-to-Container Coupling Classification

GOOD	FAIR	POOR
1. For containers of optimal design, such as some boxes, crates, etc., a "Good" hand-to-object coupling would be defined as handles or hand-hold cut-outs of optimal design [see notes 1 to 3 below].	1. For containers of optimal design, a "Fair" hand-to-object coupling would be defined as handles or hand-hold cut-outs of less than optimal design [see notes 1 to 4 below].	1. Containers of less than optimal design or loose parts or irregular objects that are bulky, hard to handle, or have sharp edges [see note 5 below].
2. For loose parts or irregular objects, which are not usually containerized, such as castings, stock, and supply materials, a "Good" hand-to-object coupling would be defined as a comfortable grip in which the hand can be easily wrapped around the object [see note 6 below].	2. For containers of optimal design with no handles or hand-hold cut-outs or for loose parts or irregular objects, a "Fair" hand-to-object coupling is defined as a grip in which the hand can be flexed about 90 degrees [see note 4 below].	2. Lifting non-rigid bags (i.e., bags that sag in the middle).

Table 7
Coupling Multiplier



Coupling Type	Coupling Multiplier	
	V< 30 inches (75 cm)	V ≥ 30 inches (75 cm)
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90



LIFTING ANALYSIS WORKSHEET

DEPARTMENT ____________________ JOB DESCRIPTION

JOB TITLE ____________________ ____________________________

ANALYST'S NAME ____________________ ____________________________

DATE

STEP 1. Measure and record task variables

Object Weight (lbs)		Hand Location				Vertical Distance	Asymmetric Angle (deg.)		Frequency Rate	Duration	Object Coupling
		Origin		Dest			Origin	Destination	lifts/min	Hrs	
L(AVG)	L(MAX)	H	V	H	V	D	A	A	F		C

STEP 2. Determine the multipliers and compute the RWLs

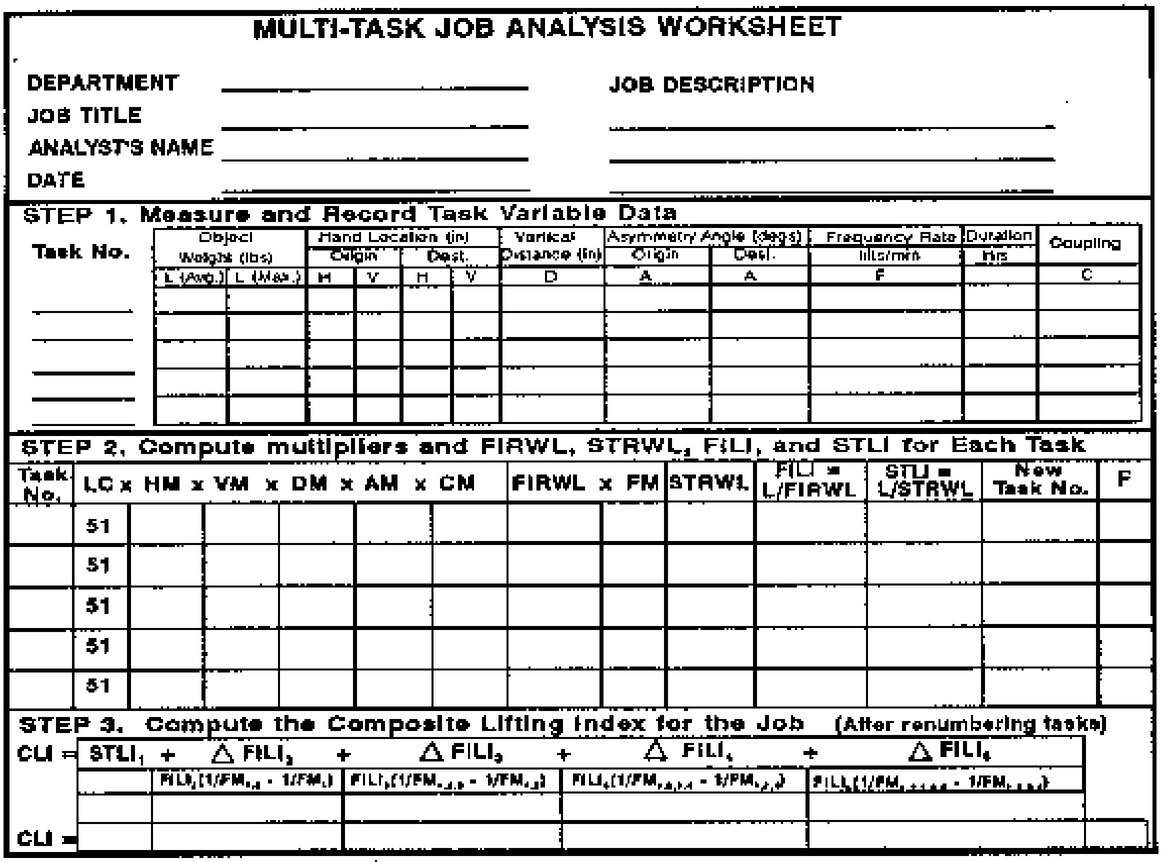
RWL = LC x HM x VM x DM x AM x FM x CM

ORIGIN	RWL =	51	x	☐	x	☐	x	☐	x	☐	x	☐	x	☐	-	☐
DEST.	RWL =	51	x	☐	x	☐	x	☐	x	☐	x	☐	x	☐	-	☐

STEP 3. Compute the LIFTING INDEX

ORIGIN LIFT INDEX $\frac{\text{OBJECT WEIGHT}}{\text{RWL}}$ = ____________________ = ____________________

DESTINATION LIFT INDEX $\frac{\text{OBJECT WEIGHT}}{\text{RWL}}$ = ____________________ = ____________________



MULTI-TASK JOB ANALYSIS WORKSHEET

DEPARTMENT ____________ JOB DESCRIPTION

JOB TITLE ____________

ANALYST'S NAME ____________

DATE ____________

STEP 1. Measure and Record Task Variable Data

Task No.	Object Weight (lbs)		Hand Location (in)				Vertical Distance (in)	Asymmetry Angle (degs)		Frequency Rate lifts/min	Duration Hrs	Coupling
			Origin		Dest.			Origin	Dest.			
	L (Avg.)	L (Max.)	H	V	H	V	D	A	A	F		C

STEP 2. Compute multipliers and FIRWL, STRWL, FILI, and STLI for Each Task

Task No.	LC x	HM x	VM x	DM x	AM x	CM	FIRWL x	FM	STRWL	FILI = L/FIRWL	STLI = L/STRWL	New Task No.	F
	51												
	51												
	51												
	51												
	51												

STEP 3. Compute the Composite Lifting Index for the Job (After renumbering tasks)

CLI =	$STLI_1$ +	$\Delta FILI_2$ +	$\Delta FILI_3$ +	$\Delta FILI_4$ +	$\Delta FILI_5$
		$FILI_2(1/FM_{1,2} - 1/FM_1)$	$FILI_3(1/FM_{1,2,3} - 1/FM_{1,2})$	$FILI_4(1/FM_{1,2,3,4} - 1/FM_{1,2,3})$	$FILI_5(1/FM_{1,2,3,4,5} - 1/FM_{1,2,3,4})$
CLI =					

Figure 4: MULTI-TASK JOB ANALYSIS WORKSHEET

Appendix D - Technical Drawings

It should be noted that all drawings are depicted using inches as the scale measurement

PART #	PART NAME	QTY
1	FRAME SIDE	4
2	FRAME CROSS	6
3	FRAME CONNECTOR	4
4	RISER	7
5	LOWER SHEETING	1
6	UPPER SHEETING	1
7	GUARDRAIL LOWER	2
8	GUARDRAIL RISER	6
9	GAURDRAIL UPPER SIDE	3
10	GUARDRAIL UPPER BACK	2

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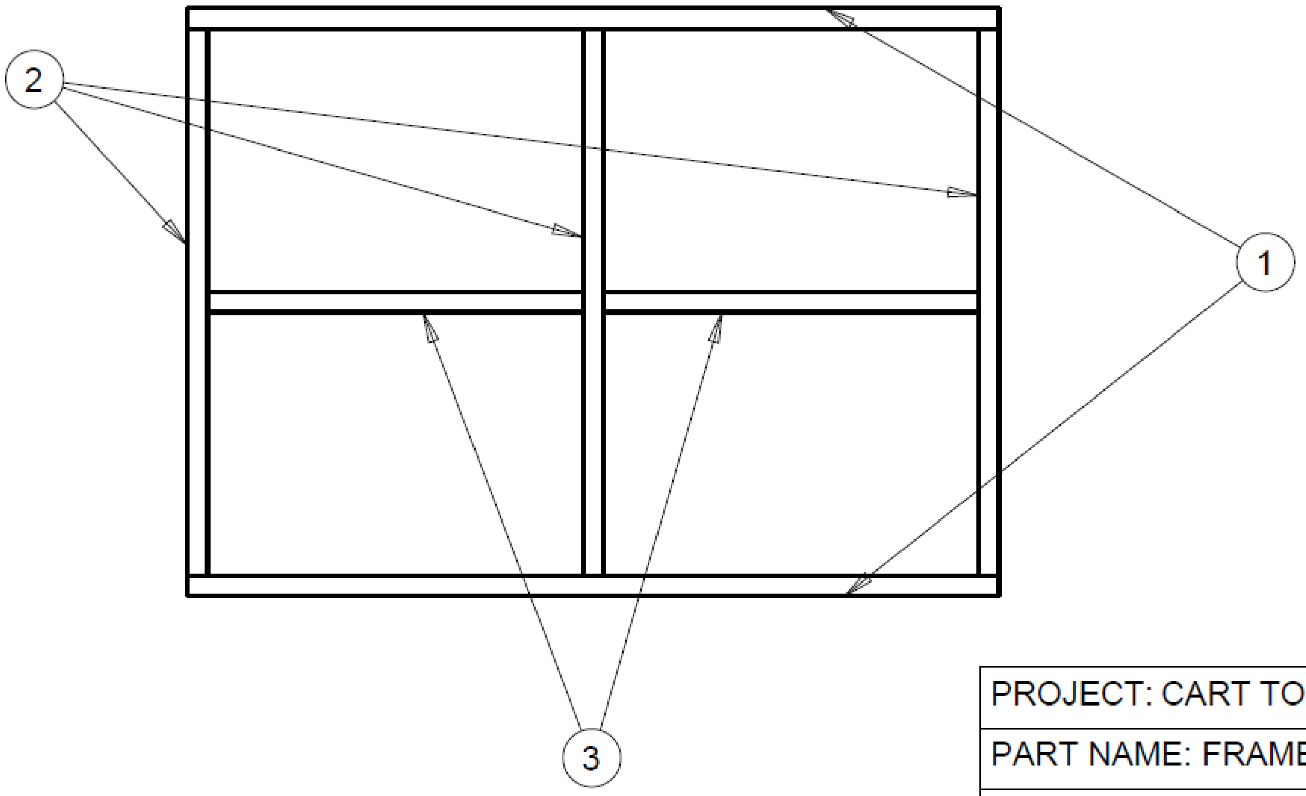
COE

PROJECT: CART TOP	
PART NAME: BOM	
DATE: 3/5/2012	
DRWN BY:JASON NEWTON	
REV: 0	SHT#: 1 of 1
PART #: SP12-BOM	



QTY: 2

PROJECT: CART TOP
PART NAME: FRAME ASMBLY
DATE: 3/5/2012
DRWN BY:JASON NEWTON
REV: 0 SHT#: 1 of 2
PART #: SP12-ASMB-1

JOINTS WELDED

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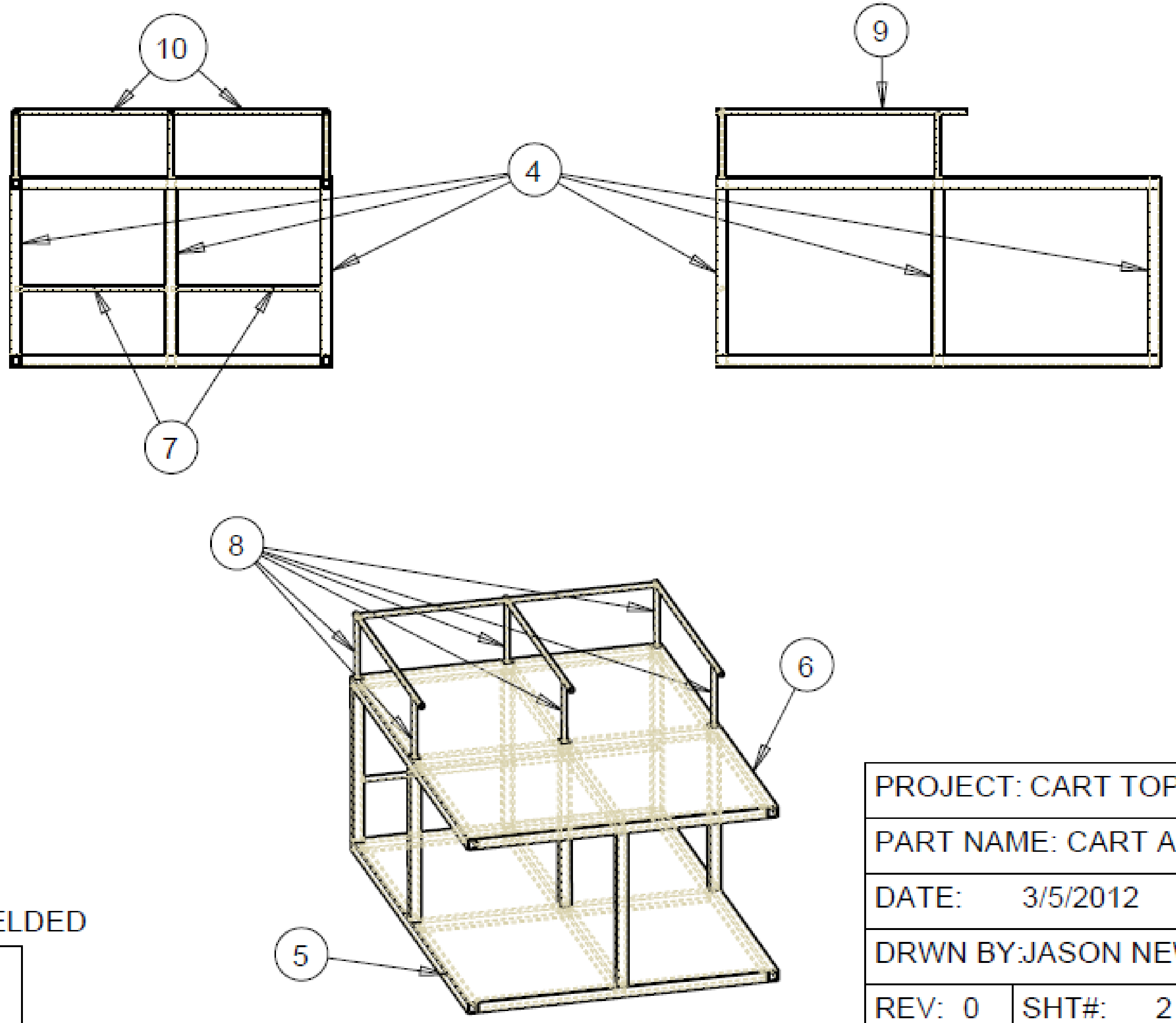
SCALE 0.125



JOINTS WELDED

FSU-FAMU
COE

PROJECT: CART TOP

PART NAME: CART ASMBLY

DATE: 3/5/2012

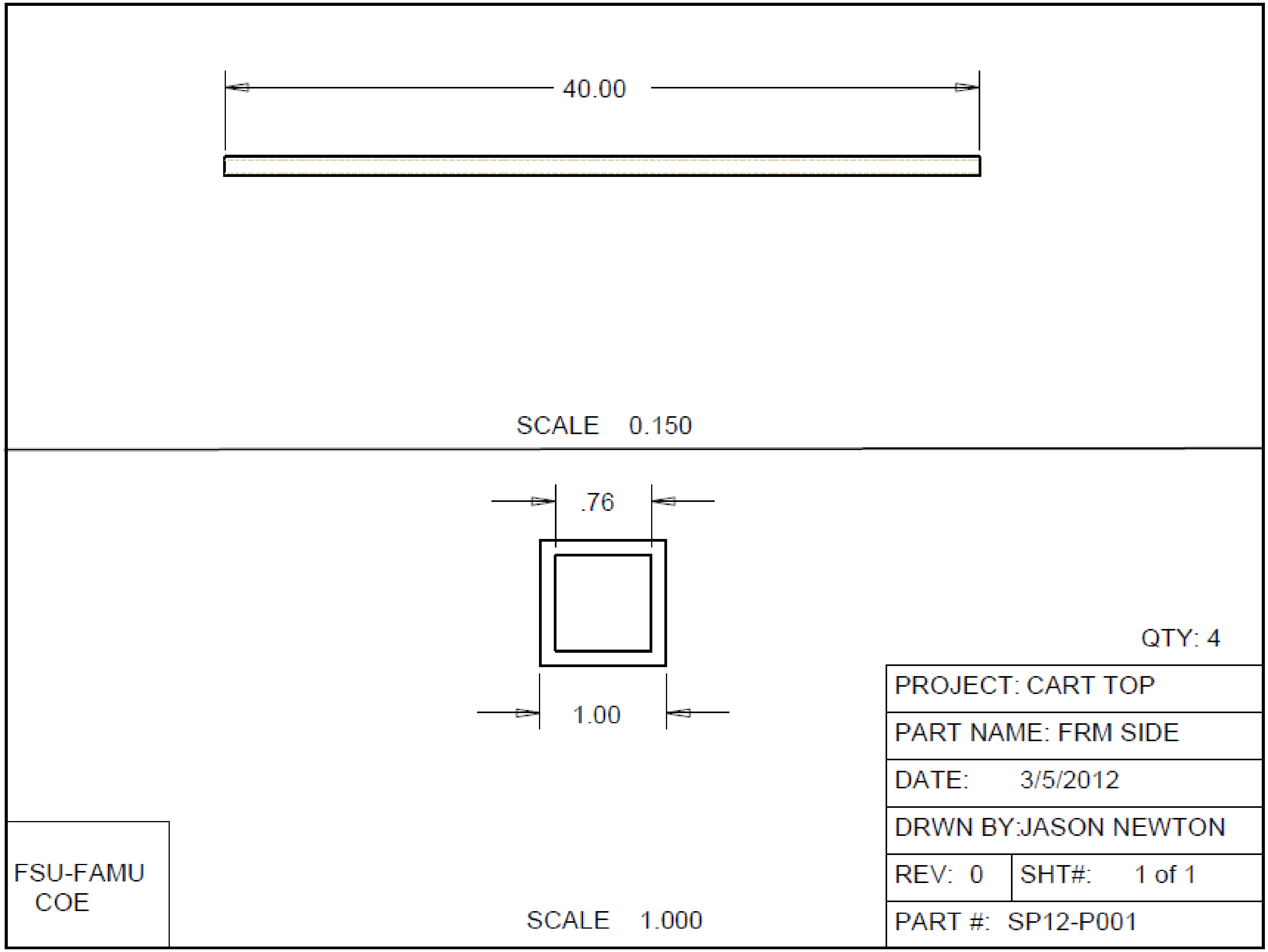
DRWN BY:JASON NEWTON

REV: 0

SHT#: 2 of 2

PART #: SP12-ASMB-1

SCALE 0.075



QTY: 4

PROJECT: CART TOP

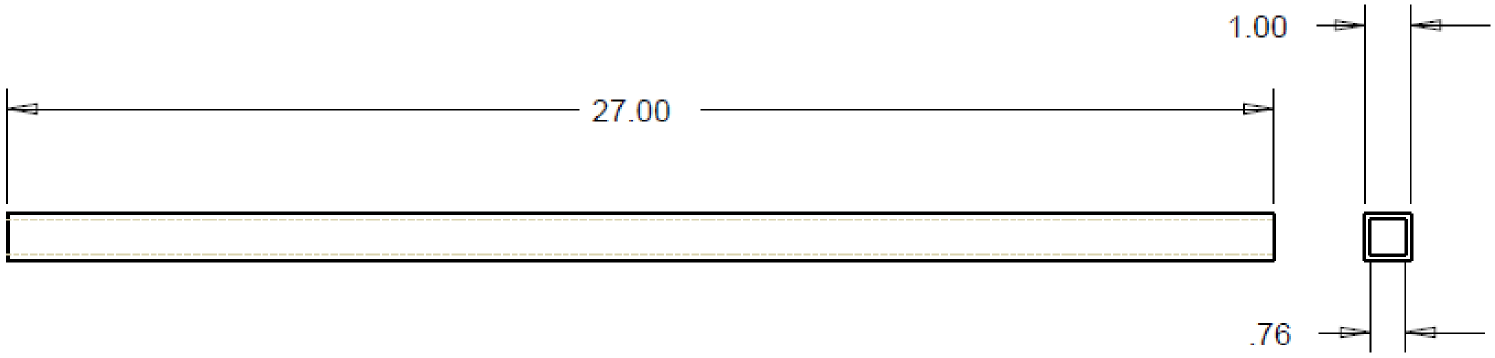
PART NAME: FRM SIDE

DATE: 3/5/2012

DRWN BY:JASON NEWTON

REV: 0 SHT#: 1 of 1

PART #: SP12-P001



QTY: 6

PROJECT: CART TOP

PART NAME: FRM CRSS

DATE: 3/5/2012

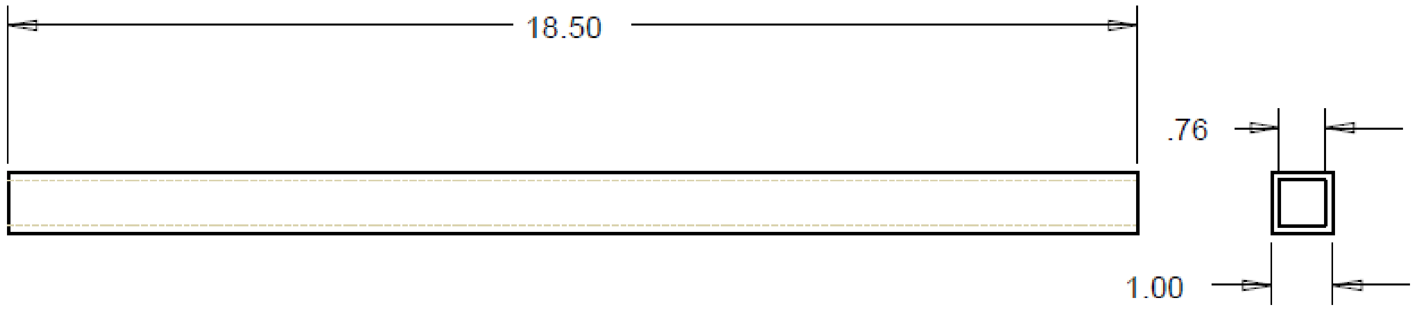
DRWN BY:JASON NEWTON

REV: 0 | SHT#: 1 of 1

PART #: SP12-P002

SCALE 0.300

FSU-FAMU
COE

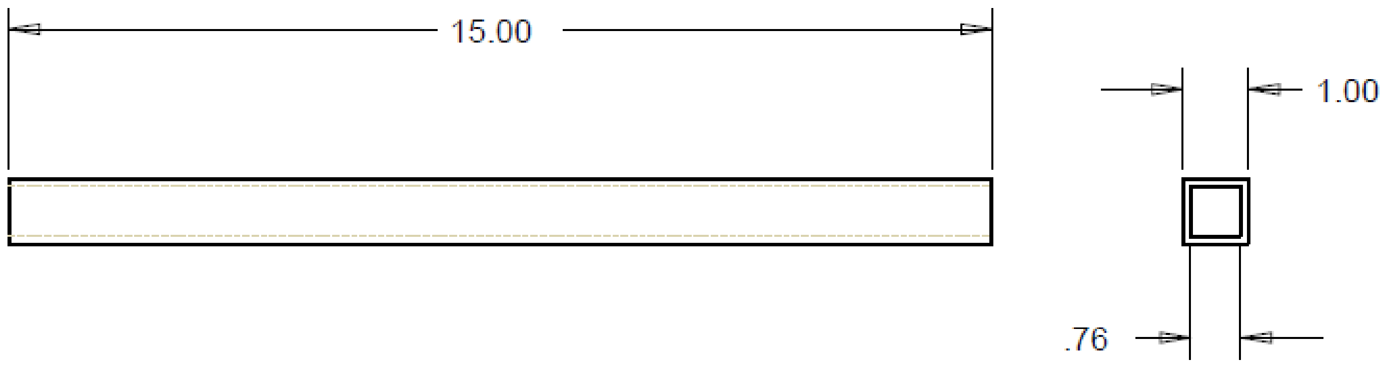


QTY: 4

PROJECT: CART TOP	
PART NAME: FRM CNCT	
DATE: 3/5/2012	
DRWN BY:JASON NEWTON	
REV: 0	SHT#: 1 of 1
PART #: SP12-P003	

FSU-FAMU
COE

SCALE 0.400

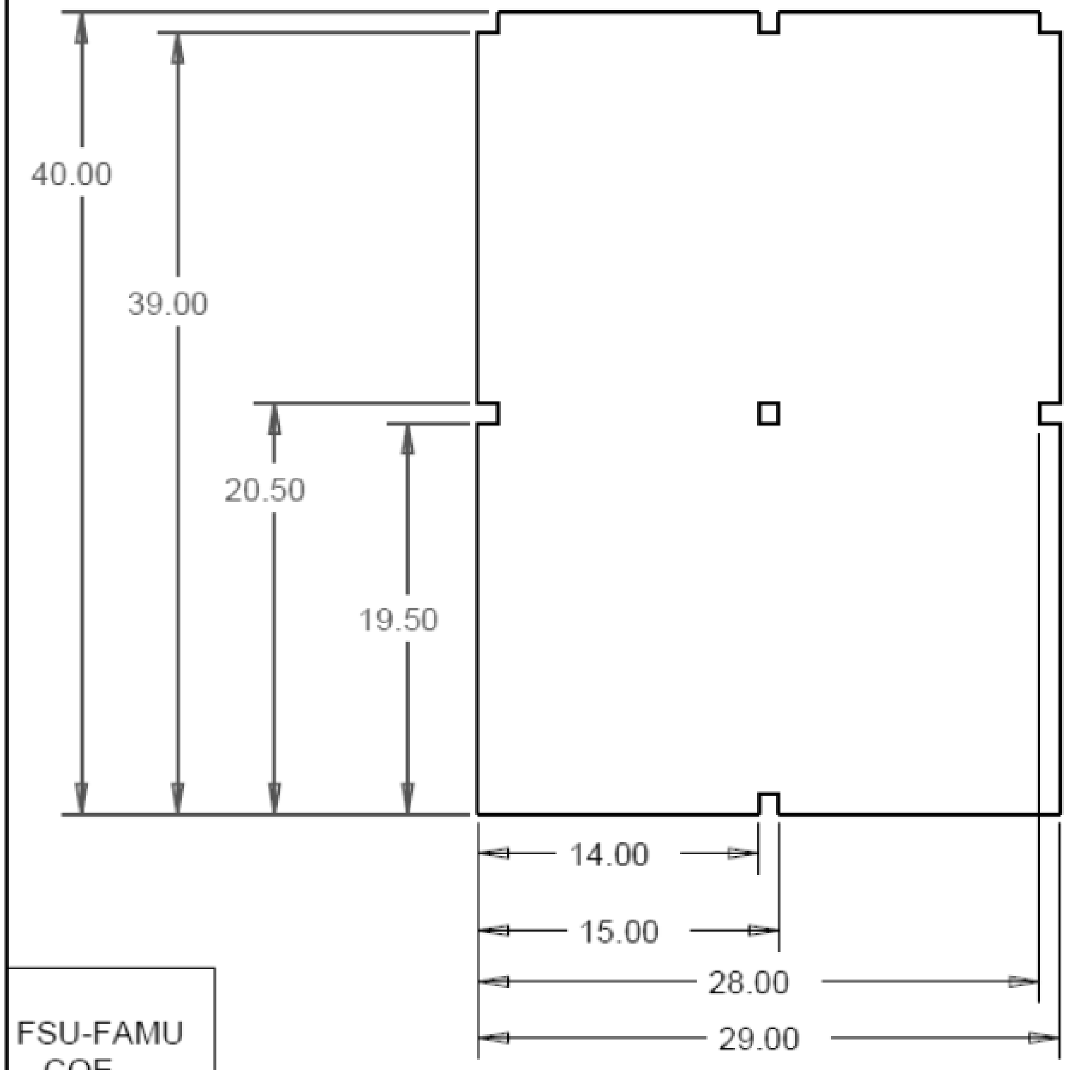


QTY: 7

PROJECT: CART TOP	
PART NAME: RISER	
DATE: 3/5/2012	
DRWN BY:JASON NEWTON	
REV: 0	SHT#: 1 of 1
PART #: SP12-P004	

SCALE 0.400

FSU-FAMU
COE

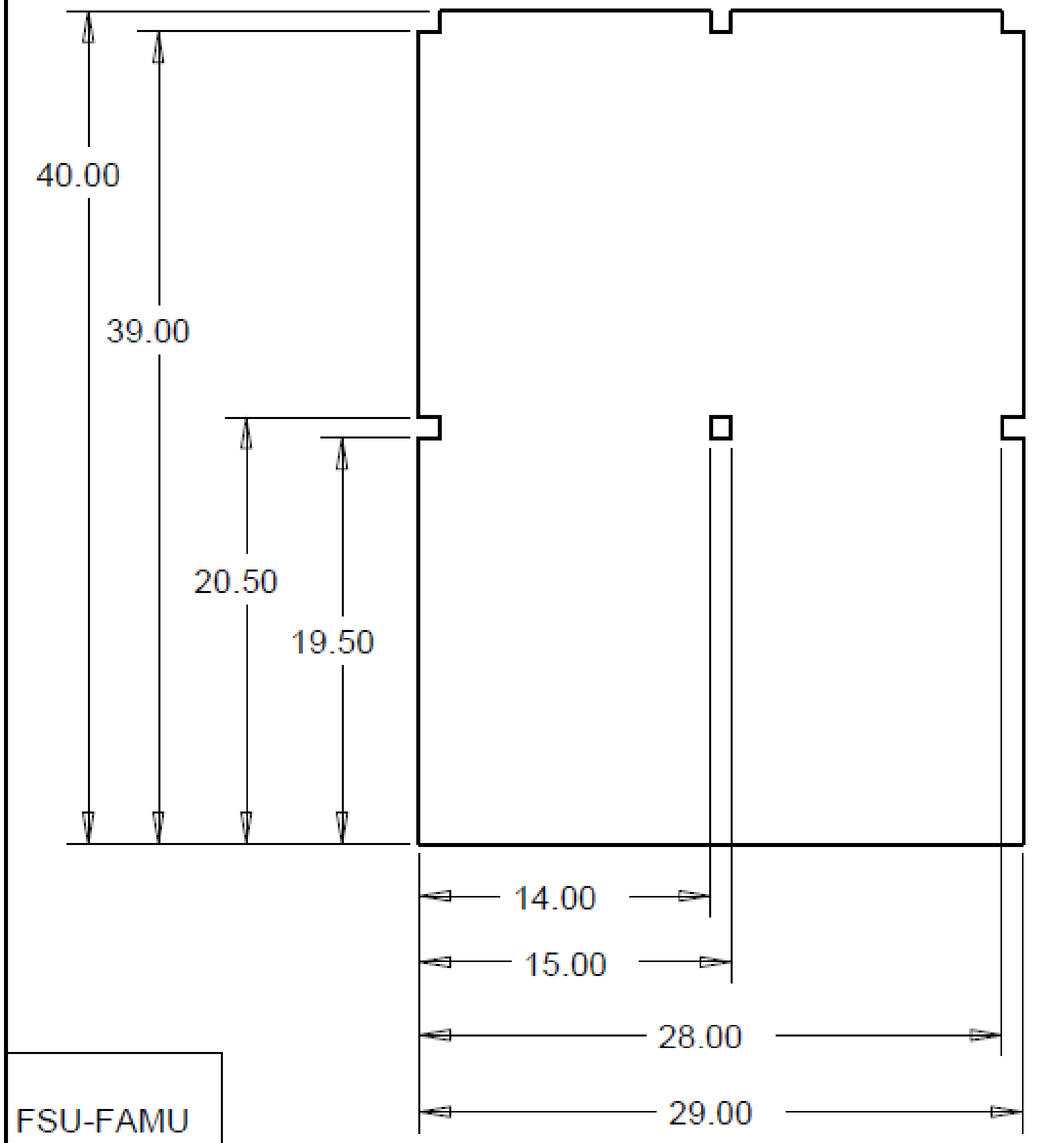


SCALE 0.125

QTY: 1

PROJECT: CART TOP
PART NAME: LWR SHT
DATE: 3/5/2012
DRWN BY:JASON NEWTON
REV: 0
SHT#: 1 of 1
PART #: SP12-P005

FSU-FAMU
COE

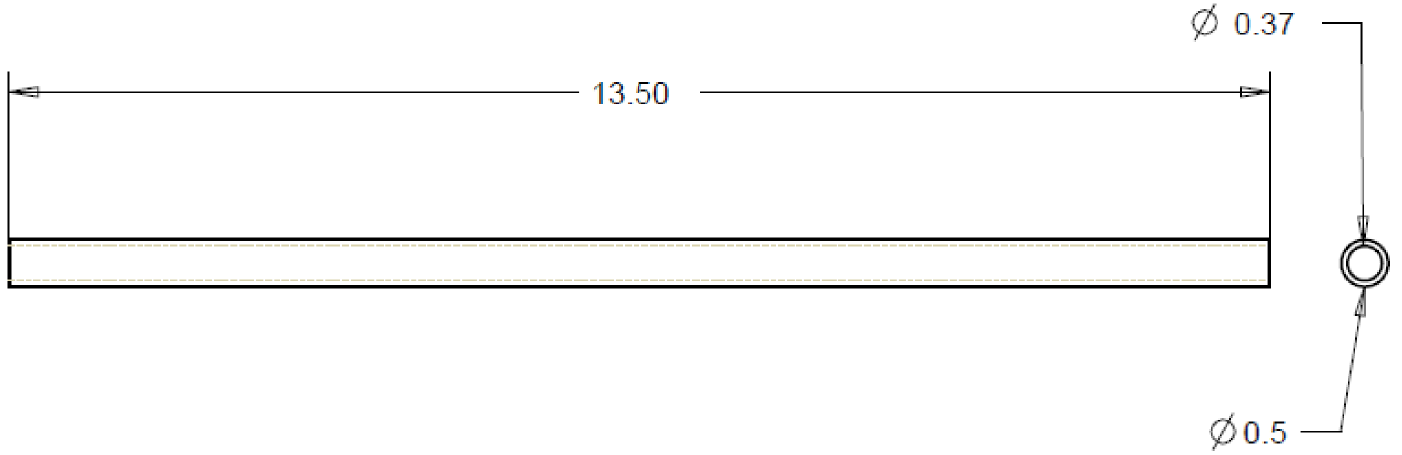


SCALE 0.125

FSU-FAMU
COE

QTY: 1

PROJECT: CART TOP	
PART NAME: UPR SHT	
DATE: 3/5/2012	
DRWN BY:JASON NEWTON	
REV: 0	SHT#: 1 of 1
PART #: SP12-P006	

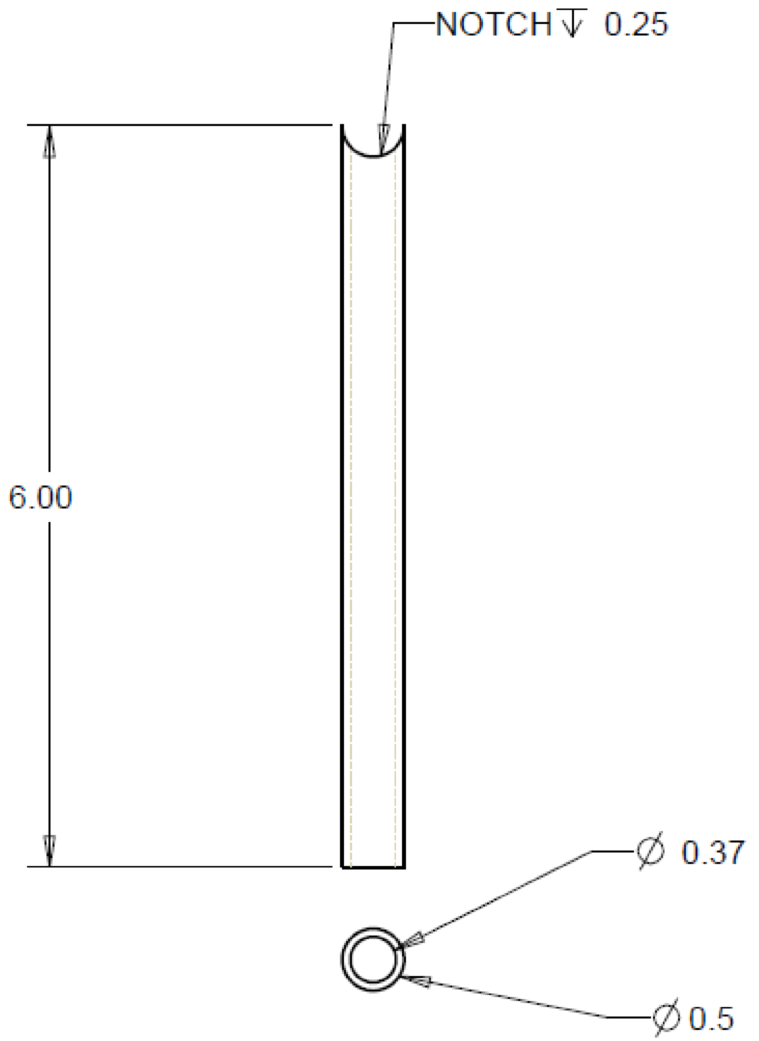


QTY: 2

PROJECT: CART TOP	
PART NAME: GRD LWR	
DATE: 3/5/2012	
DRWN BY:JASON NEWTON	
REV: 0	SHT#: 1 of 1
PART #: SP12-P007	

SCALE 0.600

FSU-FAMU
COE

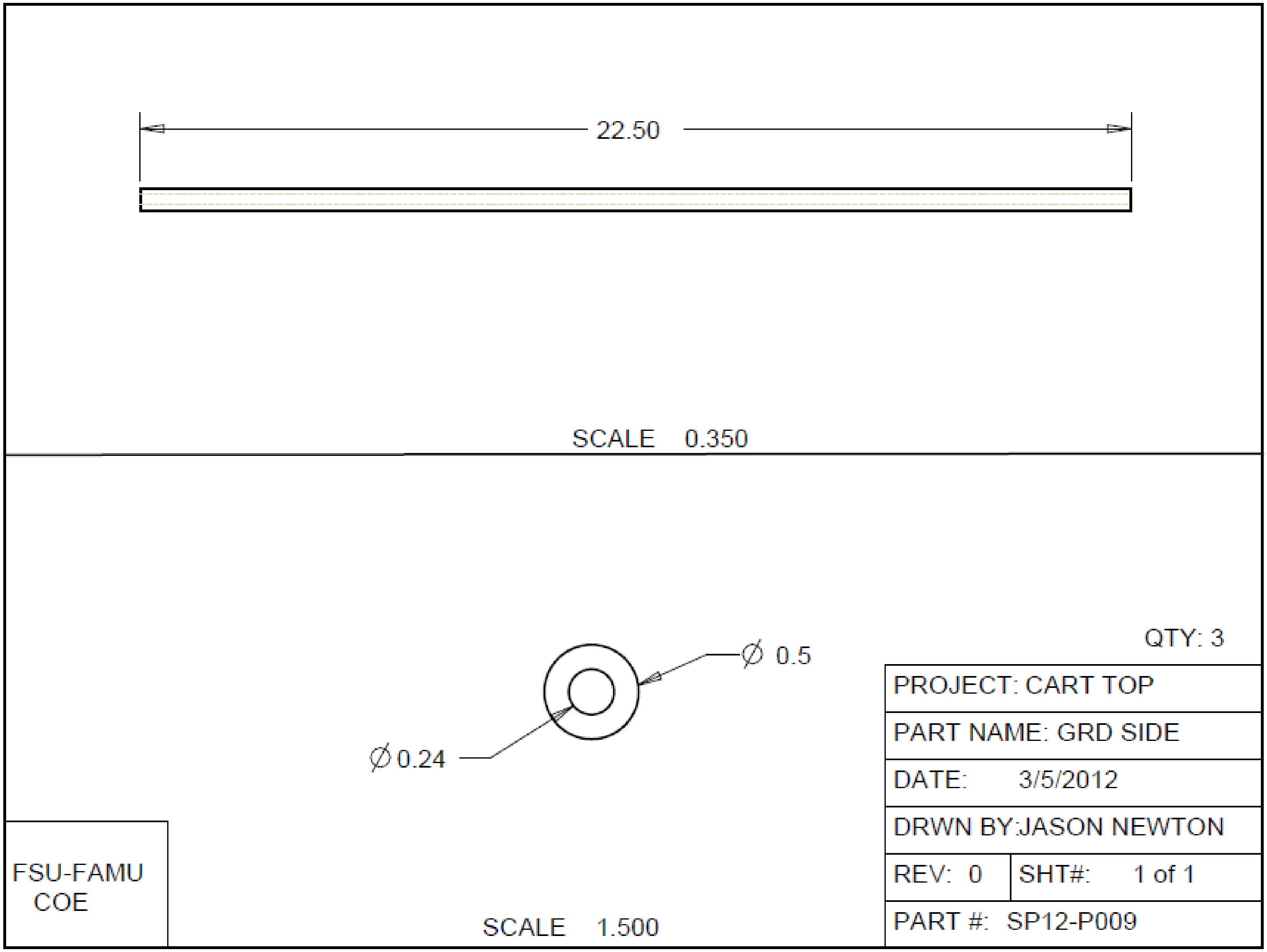


SCALE 0.750

QTY: 6

PROJECT: CART TOP	
PART NAME: GRD RISE	
DATE: 3/5/2012	
DRWN BY:JASON NEWTON	
REV: 0	SHT#: 1 of 1
PART #: SP12-P008	

FSU-FAMU
COE



QTY: 3

PROJECT: CART TOP

PART NAME: GRD SIDE

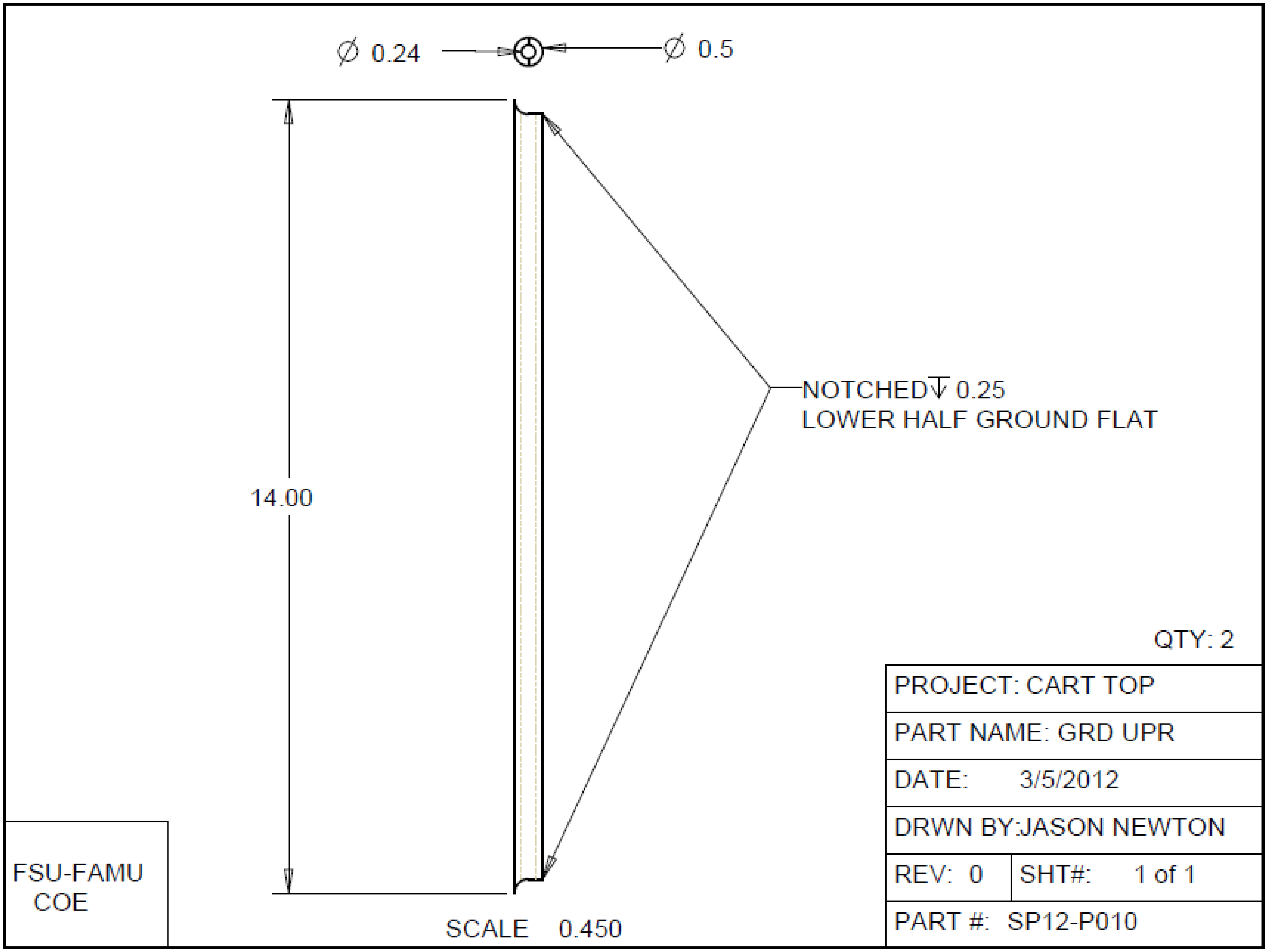
DATE: 3/5/2012

DRWN BY:JASON NEWTON

REV: 0 | SHT#: 1 of 1

PART #: SP12-P009

FSU-FAMU
COE



QTY: 2

PROJECT: CART TOP	
PART NAME: GRD UPR	
DATE: 3/5/2012	
DRWN BY:JASON NEWTON	
REV: 0	SHT#: 1 of 1
PART #: SP12-P010	

FSU-FAMU
COE