Automated Mail Stacker

Final Design Report

ME-430 Spring 2011

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Executive Summary

The purpose of this report is to walk the reader through the design process of the Postmark Mail Stacker and to introduce the final product. This is a catch and stack device system made to work with Postmark's Letter Openers. Its purpose is to organize the opened envelopes of mixed sizes as they exit the Letter Openers in order to increase the efficiency of the machine.

This report begins with the initial stage of the design process: the background research of existing machines and technologies used for similar purposes as an envelope stacker. This research, along with the engineering specifications and the customer needs, were used in order to choose the most effective conceptual designs. The design process, all the way through to the final conceptual design, is discussed in Chapter 3. Chapter 4 provides a detailed description of the final design, including material choice, costs, safety, assembly and maintenance.

This Final Report for the Postmark Mail Stacker has been modified from the Final Design Report, which was delivered February 4, 2011. Modifications include a change of materials, the details to the design of the base, and a Manufacturing Log.

This report provides all the information required for the reader to build a mail stacker from purchasing parts to the assembly of the materials. The image below shows the solid model of the Postmark Mail Stacker Final Design.

Figure 1: Final Design for the Postmark Mail Stacker.

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Chapter 1: Introduction

This design project is a Mail Stacker for Postmark's Letter Openers and potentially for printers. In order to ensure a successful product, the first step in design was to do background research of customer needs and establish engineering specifications. This chapter discusses those tasks and results.

1.1 Problem Description

Postmark is a leading company in design and manufacture of high-speed letter openers and other mail handling equipment. They currently manufacture machines that open mixed-sized envelopes at a rate of about 30,000 envelopes per hour. Postmark is now seeking a solution for stacking the envelopes in an orderly fashion as they are sent out of the opening machine.

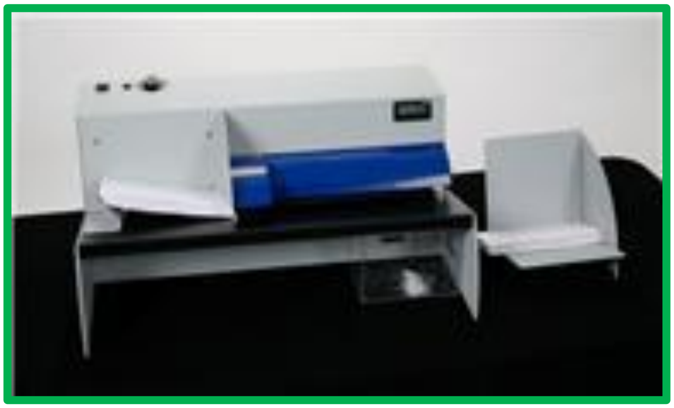

Figure 2: Postmark's 3063 Letter Opener

The efficient stacking of envelopes is an important part of mail room effectiveness. The current envelope catch that Postmark sells with their machines is small and simple, (as seen in Figure 2), but does not prevent disorder. Disorder is caused when opened envelopes come out of the machine at such a high velocity that they hit the wall of their current envelope catch and bounce in many directions. The operator must then spend time gathering the envelopes and stacking them manually which is highly inefficient.

Our team, Tyler Wetzel, Stephanie Henning, and RJ Atkinson, was the design group for this project proposed by Postmark. We worked closely with the guidance of our senior project advisor at California Polytechnic State University, Professor Sarah Harding, and our main contacts at Postmark, Chris Einerson and Morten Nielsen.

Our team designed, built, and tested a device for Postmark that will stack and organize a minimum of two feet of mixed mail being ejected from their mail opener and envelope printer. This device will eliminate the need for mail to be stacked and organized manually. It should replace Postmark's current envelope catch for small mail volume companies that own an automated mail opener. It will be fully mechanical, easy to move, small to ship, able to stack 2 feet of mail, and cost less than 150 dollars.

As described in interim reports, our group has completed the conceptual design for the mail stacker. This final report includes the process and steps taken in coming to our final concept design, as well as the plan of action executed to finish the product by June 2011.

1.2 Objectives

For this project, we proposed to design and fabricate a mixed-mail stacking device to unload and stack mail from Postmark's envelope openers and printers. Our sponsor, Postmark, designated specific design details for the stacking device. Testing of prototypes helped us to develop more design details.

The overall goal for this project was to create an easy-to-use add-on device for Postmark's existing letter-openers and envelope printers. The device will receive the opened envelopes that are exiting the opener or printer, then organize and stack them vertically in an efficient manner. This will allow for the easy removal of a large stack of opened, organized mail all at once by a single person. The stack of mail must be visible in order for personnel to know when to unload the stack of opened mail.

The specifications provided by Postmark for this model were given in order to ensure a design that will work with their existing envelope openers and printers. Using a Quality Function Deployment chart (QFD) we were able to develop a list of specifications and their importance levels. QFD translates the customer's needs and expectations into quantifiable engineering specifications. These specifications are presented in the table below along with the risks and compliance of each specification. The risk to meet each specification is indicated by an H, M, or L meaning high, medium, or low. The compliance column shows how we plan to measure compliance to the specification. The letters used are A, I, S, and T indicating analysis, inspection, similar design, and testing.

Table 1: Engineering Specifications

Spec #	Parameter Description	Requirement or Target (units)	Tolerance	Risk	Compliance
1.	Weight	15 lb	Max.	L	A, T, I
2	Simple Assembly	5 Minutes	±1.0	L	A, T, I
3	Production Cost	$150	Max	M	A
4	Height	24"-36"	±1.0	L	I
5	Works With Mixed Mail	9" x 11"	Max	M	T, S, I
6	Maneuverable	N/A	N/A	L	T
7	Letter Capacity	32000 per hr.	N/A	M	A, S, T
8	Clear Material	N/A	N/A	H	S,T

Initially this project entailed designing and fabricating two different models for the mail stacker –a simple fully mechanical model and an electronically controlled automated version. Due to time constraints the Cal Poly Post group will no longer be pursuing the electronic mail stacker. After analyzing the timeline and project details, we determined along with Postmark that rather than attempting the dual project path and finishing with two mediocre products, it would be of greater benefit to maintain focus on the smaller version to maximize product quality.

1.3 Problem Statement

Postmark currently implements a simplistic, stationary, two-sided box into which the ejected mail from their letter openers and printers collide with the sides and bounce around ending up in an unorganized heap of mixed mail. A device is needed to catch the outgoing mixed mail and stack it in at least 2 foot increments while also maintaining a consistent dual-edge line-up.

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Chapter 2: Background

In order to efficiently direct design efforts, a research of existing and patented products with similar stacking purposes was conducted. This was necessary to ensure our design could not be considered a patent infringement while giving our team a jump start on ideas for positive and negative concepts for the mail stacker. All reviews with detailed patent examples are discussed in this chapter.

2.1 Existing Products

According to the United States Postal Service, over 200 billion pieces of mail are processed each year. This number accounts for over 44% of the processed mail internationally. Over the years as this number has been steadily growing, the need for machines that can handle high capacity mail has been increasing. To get mail to its destination efficiently and on time, high-speed machines are needed to replace low-volume postal workers. Imagine how long it would take workers to manually sort 200 billion pieces of mail.

Figure 3: Example of mixed mail large businesses receive daily.

One aspect of the mail service many people overlook is the sheer volume of mail received daily by private businesses and government agencies. The average household receives only 3 pieces of mail per day, however large businesses receive thousands of pieces of mail daily. The need for consumer mail devices is growing with the rising amount of mail being sent out by banks, insurance companies, magazines, etc. This need has been ignored as many mail sorting devices are large and require capital investment that doesn't make economic sense for households and many businesses. The current focus is adopting the ideas used in large-scale and expensive post office machinery and implementing them in smaller and more affordable devices for household use and small business convenience.

In order to gain a better understanding of what sort of mail sorting devices have been used, we looked into post office machines and did a patent search on envelope stackers. In addition, our group conducted a brainstorming session to come up with current (non-mail related) stacking devices. All of the devices identified were used for ideas on what has worked and where we could improve existing designs.

Our patent search yielded no devices used to stack opened envelopes. Furthermore, there is currently no working product that is inexpensive and economically viable for businesses to purchase for their own mail stacking needs. The stacking resources have been mainly directed toward aiding high capacity post offices. These designs are discussed below.

Mass mail processing is based on two main principles, mail insertion and mail stacking. Envelope stacking by hand is considered the "bottleneck" in the mailing process. For that reason, there are currently many different designs for envelope stackers implemented in post offices worldwide. The high volume of mail being processed does present problems. For example, reliability with moving parts can be an issue that causes envelope jams. These jams not only prevent mail from being processed in an orderly fashion but they can damage the envelopes and contents. Many of the patented design descriptions we found also mentioned that applying a uniform stacking force is difficult, and that varying forces (due to springs or other mechanical devices) is a main cause of jams.

Much of the envelope stacking research has gone into developing high capacity machines for post offices. These machines are costly and involve a lot of moving parts to achieve the simple goal of stacking envelopes. There were two designs we found that attempt to solve the envelope gathering problem with a more simple approach. The first was a screw type that stacks mail by taking individual envelopes up a lead screw (Patent #US5562399). This idea is simple and has a very small foot print that is good for smaller rooms. These types of stackers are machines that are only used part of the time. The use depends on the "parent" machine's production, and thus it is best for the stacker to be compact and unobtrusive. The second simple design is a version of an envelope catch that is referred to as a "drop stacker" (Patent # US5332210). The drop stacker allows the envelopes to fall on their own into a pile. Postmark currently uses a "drop" type envelope catch with their machines. With very limited budgets and mail room space, a "smart" and simple "drop" catch design seems to be a practical idea to work off of in order to stack the envelopes.

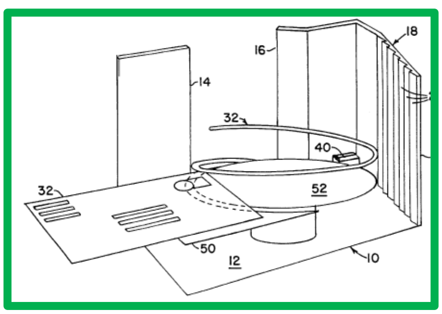

Figure 5: Automatic Mail Stacker (Screw Type), US Patent 5562399

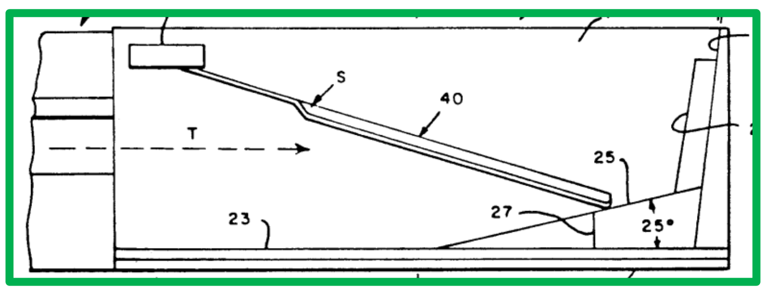

Figure 4: Variable Size Envelope Stacker (Drop Stacker), US Patent 5332210

The following is an overview of numerous patents that are in existence for products that are not mail stackers, but serve some sort of stacking purpose. This includes a table-mounted stacking device that uses a plate with constant force along the entire stacking zone to push numerous items together in an organized manner. This design requires that items be manually loaded into the stacking zone, and is not slanted for proper alignment of stacked items. Patent #US6817607

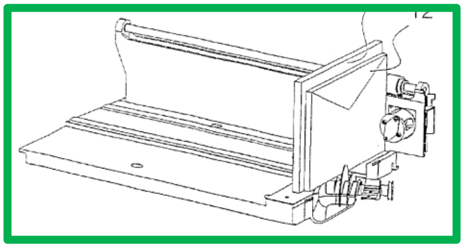

Figure 6: Stacking Device for Flat Mail Pieces Standing on Edges, US Patent 6817607

Another patent we discovered included a large table-mounted stacked mail un-loader that is meant to remove a large stack of organized mail from a standard USPS mail tray. This is done by tilting the large USPS mail tray on its side and dumping the mail stack into a catch that lowers down and allows for the removal of a large volume of mixed mail at a time. This process may become a part of our final design by being reversed and sliding the stacked mail back into the mail tray. Patent #US7713017

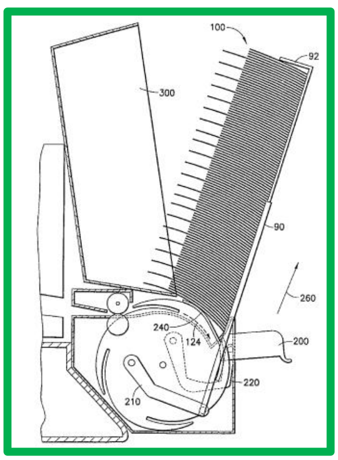

Figure 8: Method and Device for Unloading Stacked Mail Pieces, US Patent 7713017

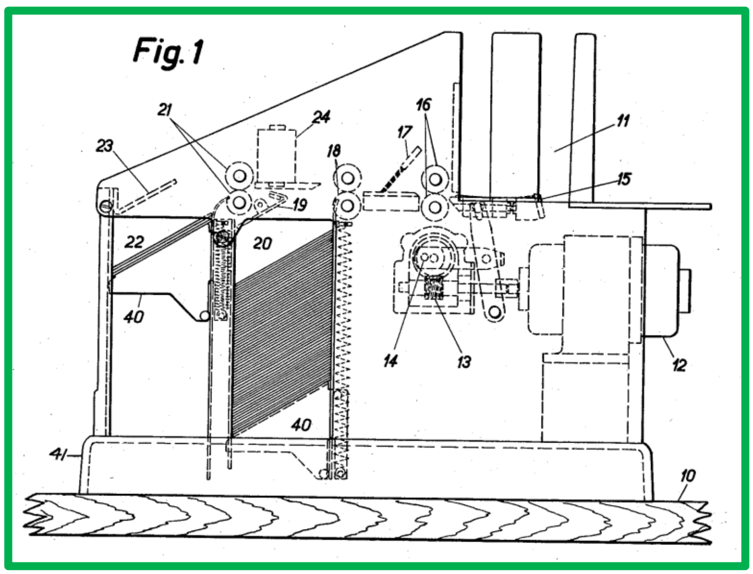

Figure 7: Card Stacking Device, US Patent 2181995

Other stacking devices include a card stacker that utilizes a series of rollers to move cards through the machine and into a ramped guide that relocates them into a shaft where they are stacked in a slanted manner by a slowing lowering platform that is moved down by a worm gear. The speed of the worm gear, which controls the moving platform to allow for more stack height, is matched to the speed of the incoming cards. However, this design isn't meant for mixed thicknesses and sizes thus it is not ideal for use on mixed thickness and size mail. Patent #US218199

A playing card shuffling device accepts a deck of unsorted playing cards in a controlled manner and sorts them by sending them through an open section that includes 2 conical frustum wheels on either side that keep the cards from popping out of the machine when they come to an abrupt stop. Once the cards are stopped a motor spins a small wheel that grabs the underside of the cards and ejects them through a small slot where they are dispensed as a shuffled deck. Patent #US4807884

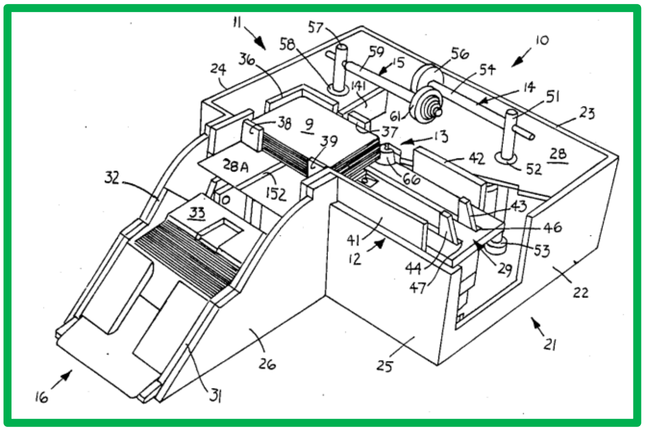

Figure 9: Card Shuffling Device, US Patent 4807884

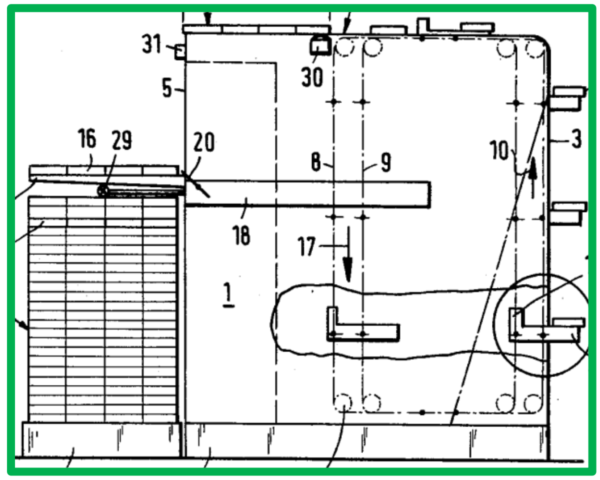

Figure 10: Stacking Device for Rod-Like or Board Shaped Goods, US Patent 4193725.

Another non-mail stacker includes a stacking device for rod-like or board shaped goods. This device uses a wheel with support arms attached in such way to keep them horizontal throughout the entire rotation. Once a board reaches the top, there are fixed stops that pick up the board as the support arm continues down in the rotation. As each board comes through the machine they slide next to each other creating a row. When the row is filled, it is moved vertically down and the current support arm drops the row into the larger stack by sliding out from underneath. Patent #US 4193725

The last interesting stacking apparatus we found was a photographic print stacking device. When photographic prints exit the cutter, they are pushed out through a conveyer system with a constant force into an upper and lower receiving device. The lower device is made so that it can continue to lower away from the top receiving element as more papers are caught. The paper slides through the devices until the front edges hit a stop. The receiving devices prevent the paper from bouncing back, leaving all of the back edges of the prints in line. Once finished the operator removes the stop and takes the stacked prints. Patent #US 4260148

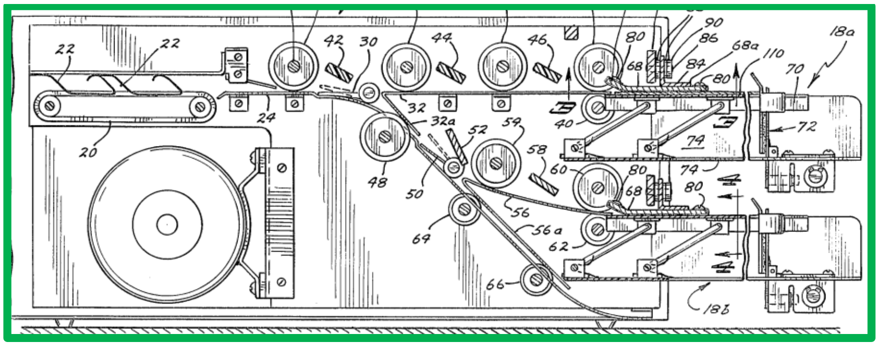

Figure 11: Photographic Print Stacking Device, US Patent 4260148

For our generation of ideas, we were able to utilize a few of the methods found in the above patents. The "drop stacker" method is one that is used in two of our top three designs because of its simplicity in stacking mixed mail. We will go further into the stacker styles we developed based off of the above patents in another section.

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Chapter 3: Design Development

In this chapter, the top three conceptual designs are discussed and evaluated to support our design team's selection of the final conceptual design for the stacker. Also discussed is the preliminary analysis used, and the considerations in the transitions from the Conceptual Design to the Final Design.

3.1 Conceptual Designs

After brainstorming sessions our group came up with many ideas for the mail stacker. These were narrowed down to the top 3 concepts based on practicality and the functions the stacker needed to accomplish. The top three models are described below.

3.1.1 Curved Path

This design was the first diverter type that we developed thinking that the main solution to the problem was changing the path of travel of the opened pieces of mail so that we could control where and how they land. To change the path of travel, we incorporated a curved plate that the edge of the ejected piece of mail follows, sending the mail downward onto the sliding catch. This helps dislodge each individual piece of mail from the normal continuous stream of envelopes, which is the root cause of the collisions leading to disarray. The elevated dropping mechanism would move down a precise increment for the corresponding amount of paper that has landed on the platform, thus no matter whether a single small envelope or a large package hits the catch, there will be enough space for the next piece of mail to land on top. The curved path also provides a downward force on all of the exiting mail pieces in order to push down the slide using a spring or friction mechanism.

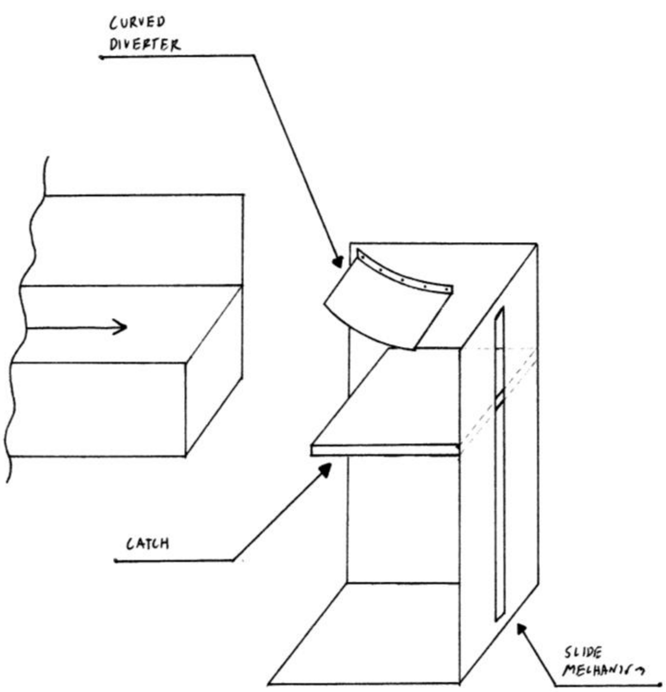

Figure 12: Curved Path Design.

Benefits:

- Free Standing
- Diverter on mail-catch stand
- Easy to access stack of mail
- Downward force holds mail

Detriments:

- Stack is in possibly unstable compression
- Curved path not adjustable
- Mail jams are more likely

3.1.2 Flip Down Box

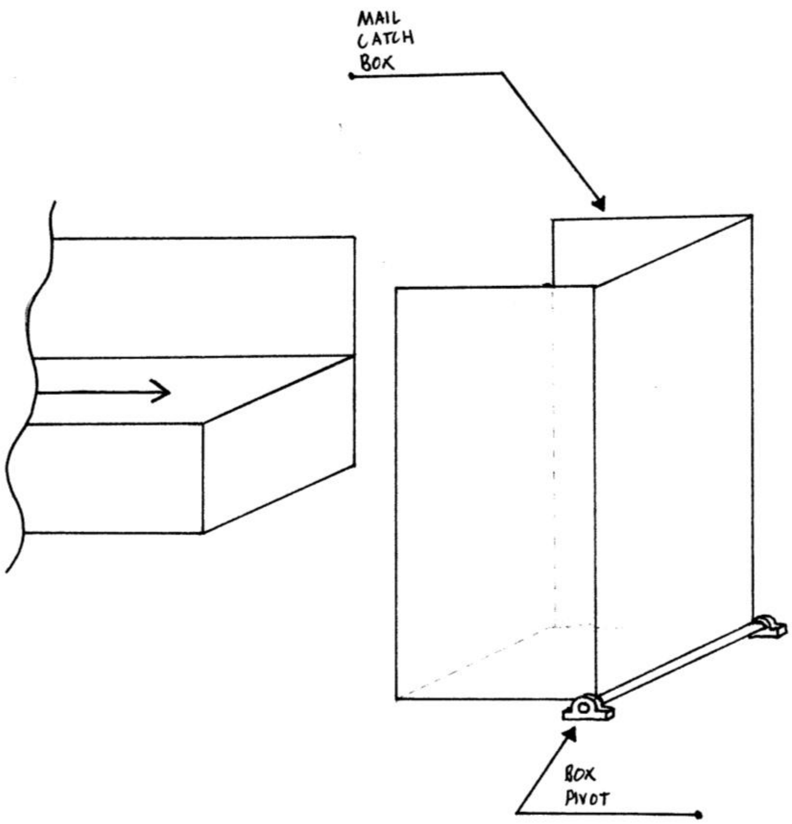

Figure 13: Flip-Down Box Design

This design was inspired by a previously existing design we found in our patent search. A stack of mail is caught in a mail catch box that is hinged at the bottom edge, which allows it to create a stack of mail from the falling envelopes. However, the stack must be organized and to do this the box is rotated to a flat position and all of the mail lines up with the sides and the bottom allowing the user to lift out the organized stack of mail. This design is the most simple with the fewest moving parts but has some downfalls in how the mail enters the catch box.

Benefits:

- Easy to use
- Few moving features
- Can be free standing on a moving base

Detriments:

- No direction control of mail
- Hard to access mail
- Stack of mail not visible

3.1.3 Diverter with Box Slide

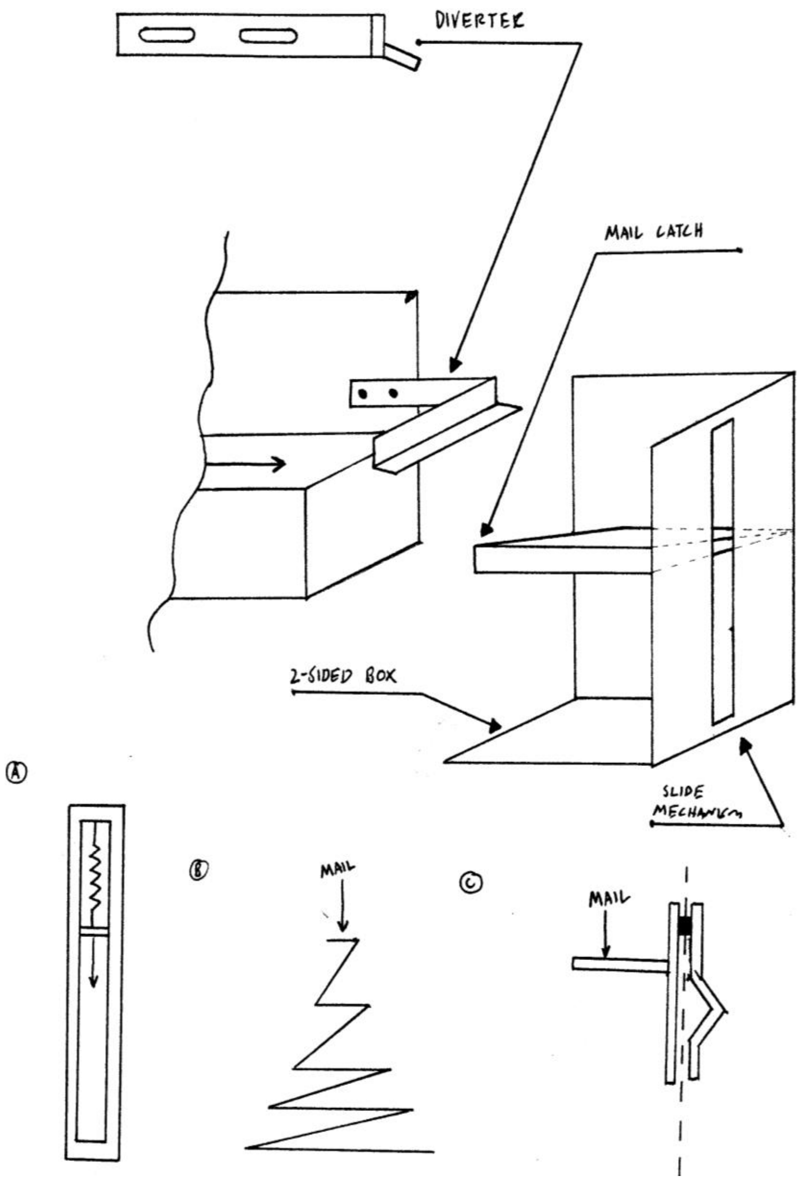

Figure 14: Diverter with Box Slide Design.

This is another design based on diverting the constant stream of mail onto a mail catch plate. The plate is designed to position the mail into a corner of the mail catch box giving the stack a consistent dual-edge line up. There are two main pieces to this concept; the first piece is a small diverter plate that hangs off the edge of the mail opener by clamping to the flat surface and making the mail hit a small angled ledge. This causes the mail to enter the second part of the concept which is a slanted plate that slides within a two-sided box through use of a spring and friction clamps. The sliding plate follows the same pattern as the previous design and will drop down in increments calibrated for the amount of paper that lands on the platform.

Benefits:

- Dual-edged collating
- Spring or Friction-based sliding plate
- Adjustable diverter
- Free standing catch box

Detriments:

- Diverter and box not a single unit
- Not fully enclosed

3.2 Concept Selection

In order to determine which design would best meet our specifications, we used a Pugh Matrix shown in Table 2. This decision matrix allowed us to compare Postmarks existing envelope stacker, a simple three sided box as shown in Figure 15, to our top three concept designs. We chose aspects of the design to compare based on the specifications and talking to Postmark about customer needs. These characteristics were graded on a scale from "- -" to "+ +" with 0 being neutral and the rating of the existing stacker.

Figure 15: Postmark's current catch device.

Table 2: Pugh Decision Matrix of Top Three Concept Models.

	Weight Factor	Existing Catch	Curved Path	Flip-Down Box	Diverter with Box Slide
Ease of Manufacturing	2	0	0	-	-
Ease of Assembly	3	0	+	-	0
Cost	2	0	0	0	0
Weight	2	0	-	-	-
Aesthetics	2	0	+	+	+
User-interface	3	0	0	+	0
Durability	3	0	0	0	0
Stack Height	2	0	+	+	++
Noise	1	0	++	-	+
Mobility	2	0	0	-	0
Orderliness	3	0	0	+	++
Maintenance	2	0	0	0	+
Total		0	7	0	11

Utilizing the Pugh Decision Matrix above we pursued the third concept, which is the stand-alone box with separate diverter. This concept provided more compliance to the requirements, as shown above, than any of the other design concepts. Two of the most important requirements mentioned above are the total stack height and the orderliness of that stack of mail; both of these requirements scored highly with this concept model. Once a prototype was developed, we stood it up to the provided Postmark letter opener and tested both the box slide only as a diverter would only have been added if needed. This test ensured that that the mail stream is broken up into manageable pieces and the slide box accepts and stacks each piece up to two feet of mixed mail.

3.3 Supporting Preliminary Analysis

In order for this design to work, two main analyses needed to be done. These analyses include the moment that the slider carriage will need to handle and the life span of the spring.

3.3.1 Carriage Analysis

This stacker will ideally be able to stack two feet of mail. By stacking one inch of mixed mail and weighing it, we found each inch of stacked mail to weigh about one pound, giving us a final max weight of 24 pounds on the tray of the stacker. The weight of the mail will put moment on the carriage of the slider, therefore while choosing a sliding device; we needed to take into account the maximum moment force it should be able to handle.

By using the known measurements of the plate and the maximum force, we were able to calculate the moments imposed on the carriage. Two moments needed to be accounted for, one along the z-axis and the other along the y-axis which is due to the weight of the mail being off center. As we are trying to align the mail via two corners and the envelopes are of mixed sizes, the mail's center of gravity will be located toward one corner as shown in Figure 17. Figure 16 shows the moment axes imposed on the carriage.

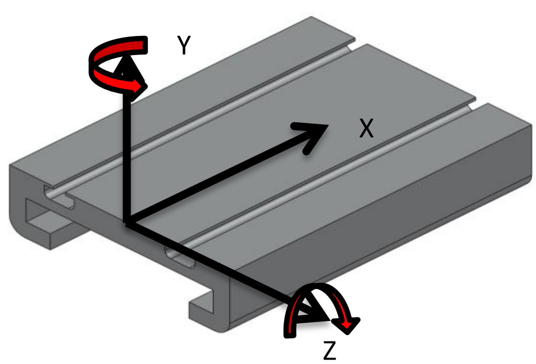

Figure 16: Directions of moments inflicted on carriage.

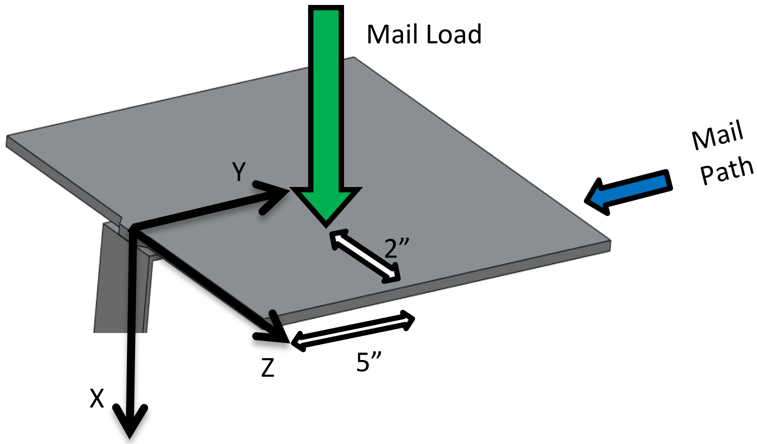

Figure 17: Center of force from weight of mail stack.

From the governing equation:

Moment = Force * Distance

The moments on the sliding carriage due to the mail load of 24 pounds were found to be as follows:

$$M_Y = 24lb * 4" = 96lb*in = \mathbf{8ft*lbs}$$

$$M_Z = 24lb * 5" = 120\ lb*in = \mathbf{10ft*lbs}$$

These maximum moment loads were then used in the final design process in order to define and select a slider and carriage system.

3.3.2 Spring Analysis

These letter openers are used in offices that receive large amounts of mail on a daily basis. Thus the spring needs not only to control the plate's vertical motion at the proper speed, but also to tolerate the number of cycles it will encounter over its design life. We estimated that a given company will receive at most 20 feet of mail per day, meaning the catcher would need to go through ten cycles daily. Because mail is not delivered on Sundays we calculated for only 6 days a week and found the following life span that the spring would need.

$$\frac{10cycles}{1Day} * \frac{6Days}{Week} * \frac{52Weeks}{1Yr} = 3{,}120\frac{Cycles}{Yr}$$

In order to ensure the life time of the stacker, the spring life cycles decided upon was 4,000 cycles per year. With this life cycle the spring should be replaced after each year, assuming it is used as often as calculated.

Chapter 4: Final Design Description

This chapter discusses our final design for the Postmark Mail Stacker including the details and specifications of each part. All manufacturer specifications for purchased parts and detailed drawings for fabricated parts of the design are included in Appendices C through N.

4.1 Overall Description

Once the conceptual design was decided upon, we were able to move on to the final design which includes the dimensions and materials. In order to confirm dimensions, a solid model of our final Postmark Mail Stacker design was made and is shown bellow.

The final design consists of two plexiglass walls for the frame of the stacker, held together by a corner L shaped bracket. A linear slide, composed of a rail and carriage, allows for the vertical motion. The slide attaches to one of the walls and holds the mail landing plate via a mount/bracket attached to the carriage as shown in the figure below. The carriage also attaches to a variable force spring located at the top of the rail. This spring controls the speed of the linear motion as the mixed mail stacks onto the plate. A swivel chair base is attached to the base of the stacker, though it is not shown in the figure ebelow. This addition allows for height adjustement and mobility of the stacker.

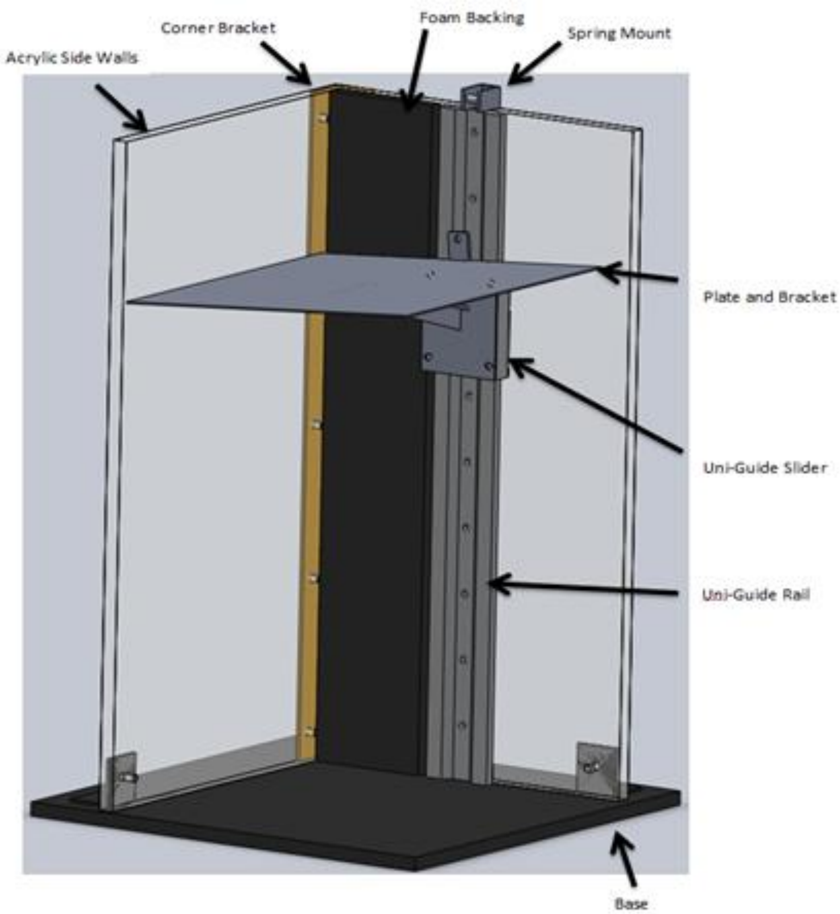

Figure 18: Solid Model of final design for mail stacker.

4.2 Detailed Design Descriptions

This section explains each component of the mail stacker. For more detailed specifications on these parts, including dimensioned drawings and manufacturer specifications, see Appendices C through N.

4.2.1 Acrylic Side Walls

In order to make the mail stacker more user friendly, the material for the sides of the box chosen was clear acrylic (plexiglass). This gives the clarity of glass while providing a structural basis to which the rest of the components can be attached. Additionally, because the device is free standing, it is important that the structure of the stacker have enough weight to withstand the loads without tipping and that the walls have substantial thickness to provide resistance to the incoming mail. For this reason we chose to go with ½" thick cast acrylic. Additionally, in order to bolt items into the plastic walls, the walls need to be thick enough to support bolts and any forces imposed onto the wall through the bolts.

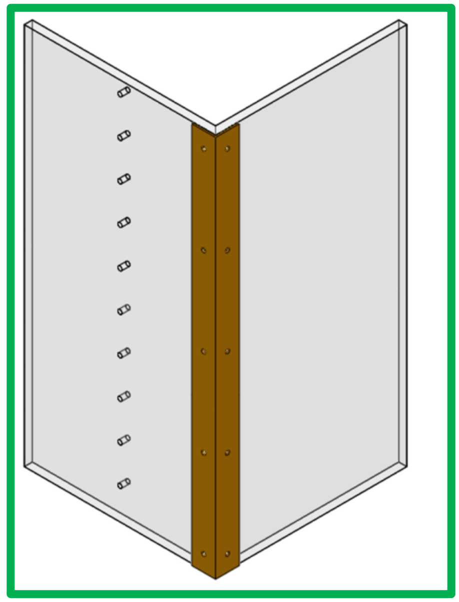

Figure 19: Side walls with corner bracket.

A main precaution when dealing with plexiglass is its tendency to crack. Threaded brass inserts will be pressed into the plastic walls to avoid cracking. The brass is softer than the acrylic and should offer some "wiggle room" when the bolts are loaded with forces.

The final dimensions for the side walls are 24" by 12" by ½". The 24 inch length was chosen by the engineering specifications because the desired stack is to be two feet high. Manufacturer specifications for the clear acrylic can be found in Appendix H.

4.2.2 Corner Bracket

The two sides of the stacker are connected using a piece of 1.5" by 1.5" by 1/8" aluminum angle. Aluminum was chosen for its light weight and cost. Details for this part can be found in Appendix N.

4.2.3 Uni-Guide Linear Slide

To save on manufacturing cost and time, a linear slide for the control of the vertical motion was chosen to be purchased. PBC Linear offers low cost products that have equivalent performance to more expensive linear motion companies. The Low Profile Uni-Guide linear slide is a robust design made out of an extruded aluminum rail and a sturdy aluminum carriage. A Frelon lined bushing, PBC Linear patented material, is a low friction sliding surface without the extra complication that comes with bearings or rollers. The railing length was chosen to be 23.5 inches, again chosen based on our engineering specifications. More manufacturer details, dimensions and specifications can be found in Appendix G.

Figure 20: Uni-Guide Linear Slide.

4.2.4 Tray and Tray Mount

The mail tray and mounting bracket was specified to be made of 18 gauge aluminum sheet metal for its light weight. The mount is bent using a sheet-metal break and angled such that when the flat tray is mounted it will be tilted towards both walls so the mail falls into the common corner. A support arm is added for durability from the mount to the far edge of the tray as shown. The mount attaches to the carriage of the linear slide via the manufacturer mounting holes. A detailed dimensioned drawing for the tray is shown in Appendix E.

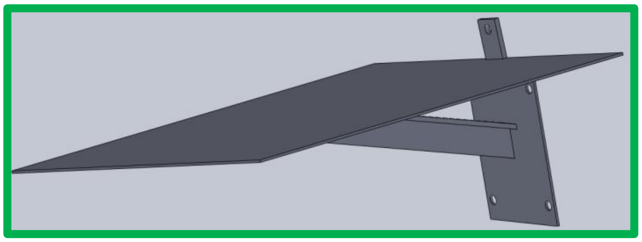
Figure 21: Envelope tray and tray mount.

4.2.5 Variable Force Spring

Vulcan Spring, a custom spring manufacturer, will make a variable force spring for our project. Since the load on the tray will vary from 1 pound (the tray and mount weight alone) up to 25 pounds (tray, mount, and 24 inches of mail weight) the force of the spring needs to vary so the tray displacement remains variable. A torsional spring was chosen to prevent the wasted space of the un-stretched length of a conventional spring. The spring will be mounted on a roller at the top of the device as shown in Figure 18. As the mail is loaded onto the tray the spring will unwind maintaining a steady displacement. Once the mail is unloaded by the user, the spring will wind back up and the tray will be ready for the next load. The spring is expected to go through approximately 3,200 cycles/year and Vulcan can design springs with 4,000-50,000 cycle lifespans. The determining factor for spring life is the outside diameter of the spring, smaller outside diameter results in fewer life cycles. The range in outside diameters is from 2 to 7 inches. Vulcan Spring sent us a sample kit of springs in order for us to test which spring would work best for our purposes. The spring we have chosen has an OD of 2 ¼" and width of ¼". Manufacturer details are shown in Appendix I.


Figure 22: Typical variable force springs from Vulcan Spring.

4.2.6 Spring Mount

The spring mount is made out of 3/16" 6061 aluminum plate. It is bolted to the back of one of the acrylic side walls in line with the carriage using two ¼" button socket-cap screws. Two arms reach over the top of the acrylic wall in order to hold the spring directly over the carriage and plate as shown in Figure 23. A carriage bolt is placed between the ½" opening in the two arms and holds acts as a support for the spring.

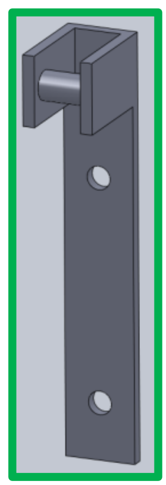
Figure 23: Spring Mount

4.2.7 Base

The base is a 15" x 15" wooden sheet with 2 aluminum angle pieces bolted in place to hold the entire unit steady during operation. These pieces are bolted down to the wood permanently and then bolted using the outside holes in the acrylic with 2 more ¼" button socket-cap screws as shown in Figure 24. The wooden base is then fastened down to the adjustable air chamber swivel base that has wheels and enables the unit's mobility.

Figure 24: Swivel Chair Base.

4.3 Materials and Cost Analysis

Two different cost analyses needed to be taken into consideration, the cost to make our prototype and the estimated cost of mass purchasing and production. Both cost analyses are broken down into bill of material tables.

The bill of materials listed below represents the per-unit cost of each mail stacker. This incorporates the prices of only the hardware that is used on each stacker at the lowest price for bulk orders that we researched. The total price of this table will be the total production cost of each stacker using the designated materials at the designated quantity. As shown in the table, the total cost will be near our goal of $150.

Table 3: Bill of Materials for the per-unit cost of each mail stacker when produced in bulk.

Part Number	Description	Quantity	Material	Dimensions	Cost Per Stacker
PMST001	Side Walls	2	Acrylic Plexiglass	12" x 24" x ½ "	$50.91
PMST002	Corner Bracket	1	Aluminum	1 ½ " x 24" x 1/8"	$4.77
PMST003	Uni-Guide Rail	1	Aluminum	594 mm Length	$33.77
PMST004	Uni-Guide Carriage	1	Aluminum	100 mm x 73 mm	$34.55
PMST005	Variable Force Spring	1	Steel	2 ¼" OD x ¼" W	$20.00
PMST006	Spring Mount	1	Aluminum	NA	$10.00
PMST007	Plate Mount	1	Aluminum	9" x 3"	$2.00
PMST008	Plate	1	Aluminum	12" x 12"	$3.00
PMST009	Flat Socket-Cap Screws	12	Stainless Steel	1/4"-20 x 5/8"	$1.80
PMST010	Button Socket-Cap Screws	5	Stainless Steel	1/4"-20 x 5/8"	$0.65
PMST011	Press-Fit Threaded Inserts	17	Brass	1/4"-20 x 5/8"	$6.32
PMST012	Countersunk Washers	12	Steel	1/4"	$0.80
				Total Price:	**$168.57**

The next bill of materials listed below incorporates the total cost of our prototype. The quantity of each part shows how many of each part we were required to buy, and the total cost of that bulk order. These two tables represent the difference in single-unit production versus volume production. Buying in bulk quantities and using all of the parts purchased will reduce the per-unit cost of the final product.

Table 4: Bill of Materials for prototype of mail stacker.

Part Number	Description	Quantity	Material	Dimensions	Spent
PMST001	Side Walls	2	Acrylic Plexiglass	12" x 24" x 1/2"	$71.91
PMST002	Corner Bracket	1	Aluminum	1.5" x 120" x 1/8"	$11.93
PMST003	Uni-Guide Rail	1	Aluminum	594 mm Length	$33.77
PMST004	Uni-Guide Carriage	1	Aluminum	100 mm x 73 mm	$34.55
PMST005	Variable Force Spring	1	Steel	2 ¼" OD x ¼" W	$20.00
PMST006	Spring Mount	1	Aluminum	NA	$30.00
PMST007	Plate Bracket	1	Aluminum	9" x 3"	$36.00
PMST008	Plate	1	Aluminum	12" x 12"	$100.00
PMST009	Flat Socket-Cap Screws	50	Stainless Steel	1/4"-20 x 5/8"	$7.49
PMST010	Button Socket-Cap Screws	50	Stainless Steel	1/4"-20 x 5/8"	$6.64
PMST011	Press-Fit Threaded Inserts	25	Brass	1/4"-20 x 1/2"	$9.30
PMST012	Countersunk Washers	100	Stainless Steel	1/4"	$6.95
PMST009.1	Corrected Flat Screws	8	Steel	1/4"-20 x 3/4"	$2.85
Drill Bit	Plas Drill Bit	1	Tool Steel	5/16"	$9.18
PMST013	Gas cylinder swivel base	1	Composite	N/A	$50.00
				Total Price:	**$430.57**

4.4 Safety Considerations

The purpose of the mail stacker design is to stack the envelopes while requiring little or no operator input. The only operator actions required should be placing the mail stacker in the specified location adjacent to the letter opener, and removing the mail once the letters have been stacked. We have considered the safety of this design in numerous ways, including preventing pinch points or sharp edges. Additionally, we have minimized the number of moving parts, and made the entire system easily moveable no matter the weight of the mail loaded onto it.

Our design incorporates the vertical motion of a large, spring-loaded plate aligned inside a two sided box. Because there is a rail and carriage system attached to one of the walls, the tray will not be creating the desired seal that is acquired between the tray and the wall without the railing. This gap needed to be taken into consideration to ensure that the operator's fingers would not get pinched in between the plate and the wall. For that reason, the plate is designed at a specified distance from the track-wall, leaving clearance to allow an operator's fingers to pass through without getting jammed or cut. The non-track wall will not have a gap large enough to catch or pinch any appendage and will be mostly blocked by the incoming mail. The outside edges of the aluminum catch tray will be lined with protective plastic liners meant to cover sharp edges. These are all solutions for potential problem areas that will experience high operator interaction during the use of the mail stacker.

The main moving components include the aluminum catch tray, the Uni-Guide sliding carriage, and the spring that will be constantly extending and retracting as the tray lowers and rises with the carriage. The carriage itself does not provide a hazard since it remains tucked underneath the large aluminum tray. The operator will be protected from the plate using the previously mentioned methods and the spring will be tucked away in the channel of the Uni-Guide rail so that it does not impede the mail in any way or come into contact with the operator.

Chapter 5: Manufacturing

In this section we will go through the steps taken in order to build the mail stacker. These explanations can be followed in order to construct further stackers. Additionally included are step by step directions in order for the user to assemble the stacker once they have received the unit.

5. 1 Manufacturing Log

Acrylic Box Sides

The 2-sided box is made up of two 12 by 24 inch sheets of ½ inch acrylic. These pieces come pre-cut from the manufacturer. If in the future full-size sheets of plastic are ordered, the pieces can be easily cut using a table saw with a right angle guide. The two pieces of acrylic are joined at a right angle using a piece of 1.5 by 1.5 by ⅛ inch aluminum angle and ¼-20 machine screws. Since acrylic is very brittle, it is important to not thread the fasteners into the acrylic as it can crack easily and does not hold much of a load. To solve this issue, we used threaded brass inserts that are knurled. Using a 5/16 inch Plas-Drill drill bit, the initial holes are drilled for the inserts. These holes are a little undersized and in order to prevent cracking the acrylic when pressing the inserts. Drill the holes out to a letter P which is the perfect fit. A quick grip clamp is used to press the inserts in and the aluminum is fastened to the plastic to complete the two sided box. Drilling all of the holes, adding in the press fits and then putting together the walls took 50 minutes for the prototype. An estimated mass production time for this process would be 30 minutes.

Mail Tray and Carriage Mount

The mail tray is the surface upon which the exiting mail will land. Along with the carriage mount the tray will move along the linear slide surface. The tray that will hold the exiting mail is made out of 18 gauge aluminum sheet metal. Aluminum is necessary to obtain the low weight requirements of the torsional spring used in this design. The tray is cut to design dimensions using a stomp shear. Using a bead roller, the x is rolled into the surface of the tray to provide a rigid structure while keeping weight down. To attach to the linear slide carriage, a small piece of the same aluminum sheet is cut and bent on a finger break into the angle requirements that will help align the mail on the common corner. One issue is that though the top may be ridged, it will still flex where the carriage mount is bent at a near 90 degree angle. A small length of 3/4in aluminum angle was cut with sheet metal shears to act as a gusset under the tray. In the prototype the gusset, tray, and carriage mount are joined by TIG welding small tack welds, this process can be streamlined in production by using a spot welder. The process took nearly 2 hours to complete for the prototype. We estimate that it would only take 40 minutes in mass production.

Spring Mount

Using the sheet of 3/16 inch aluminum, the spring mount piece was cut. The mount is attached to the stacking device through one of the holes that holds the linear slide. A longer ¼-20 bolt and a locking nut are used on this hole to ensure a secure mounting point. The linear slide hole was used because the aluminum of the slide offers more support than just fastening the spring mount to the acrylic. The spring is held in the mount by wrapping around an extra-long carriage bolt with a milled shaft in the center that locks in place and allows the spring to rotate freely and unravel.

Rolling/Height Adjustment Base Manufacturing Log

It is important that the device be easy to maneuver around the mailroom and be able to adjust to different counter heights. This was achieved by using a standard office chair base. Although this is not an ideal solution as it is hard to ship and heavier than it needs to be, the chair base is rugged, readily available, and can roll and change heights. A pneumatic cylinder quickly raises the base with 6 inches of stroke. A small piece of ¾ inch plywood was cut to 14" by 14" so that there is ample room to mount the stacker. Using the same 1.5 inch aluminum angle that was used to connect the two sides of the acrylic box, the stacker was bolted to the base with the same ¼" x 20 fasteners. This process took 30 minutes for the prototype and has an estimated time in mass production of 15 minutes.

5.2 User Assembly

For shipping purposes, when the user receives the stacker, they will have to assemble it. We have designed the stacker so that assembly should require minimal tools and no more than ten minutes. The steps that the user will take in order to assemble the stacker are listed below:

1. Bolt together the two plexi-glass sides using the provided corner bracket, button-head bolts and washers. The corner holes have the press-fit threaded inserts mounted in the plexi-glass. Align the edges of the side walls and use the holes to attach to the bracket.
2. Securely tighten each of the corner bolts until snug.
3. Attach the Uni-Guide rail to the inside of the plexiglass wall. One of the walls has holes running down the center which should be used to attach the rail to the wall with pan-head bolts. Each pan-head bolt should thread in from the inside (the recessed channel in the rail) through the provided washers and into each of the threaded inserts in the plexiglass.
4. Securely tighten down each of the bolts until snug.
5. Attach spring mount to the outside of the plexiglass wall enclosure overhanging the inside. The mount will be on the same wall as the Uni-Guide rail.
6. Slide the variable force spring onto the spring mount with the leading edge coming off the top toward the inside of the box.
7. Bolt the tray to the Uni-Guide slider using the supplied screws in the designated bolt pattern.
8. Slide the entire assembly onto the Uni-Guide rail attached to the inside of the plexiglass enclosure.
9. Attach the free end of the spring to the carriage directly below where the spring is mounted using one screw.
10. Place entire assembly onto the wooden base and place bolts through the angle-aluminum pieces and through the plexi-glass side walls securely locking the stacker in place.
11. Fasten the wooden base to the rolling mount.
12. Place the entire assembly in front of mail opener or envelope printer at the specified distance and allow mail to stack up.

5.3 Maintenance and Repair

One part in particular of the mail stacker assembly experiences more wear and tear than any other. This is the variable force spring. Consequently, this piece will wear out and may need to be replaced on a yearly basis depending on usage. The spring mount is designed to be easily removable for replacement.

The only other moving part of this design is the Uni-Guide linear slide. This part comes with a manufacturer Frelon ceramic coating on the mated parts of the carriage and rail to provide an extremely durable surface and extremely low wear. For that reason, maintenance should not be required. However the stacker has been designed to ensure that the slider can be easily unbolted and replaced if necessary.

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Chapter 6: Design Verification Plan

In order to ensure that the mail stacker design meets all of the specifications, a series of lists have been created along with a design verification plan and report (DVPR) check list used to document the testing phase.

6.1 Test Descriptions

1. **Spring Max Stretch Length:** The desired amount of stacked mail is 2 feet. Therefore, in order for our design to work, the spring needs to stretch down 2 feet with the tray as envelopes are loaded in. For this test we put the spring on the spring mount and ensured that it could reach the full distance down to the bottom of the catch without damage to the spring.
2. **Spring Constant Test:** This test was done to ensure the spring maintains the same speed as the letters load onto the tray by running the letters through the opener and watching the speeds.
3. **Plate Loads:** The tray of the stacker must hold large amounts of weight while it is held by one end only. This test was done to ensure no amount of weight that the stacker will see can bend the tray. By loading weights from 1 to 50 pounds onto the tray, we intended to ensure the tray's stability and durability.
4. **Slider Speed (Friction):** As loads are placed onto the tray, a moment force is imposed on the slider carriage. This moment can create more friction or potentially bind the carriage to the slider. We loaded from 1 to 50 pounds onto the tray and watched the reaction of the carriage to ensure no binding.
5. **Stacker Frame Stability:** When the envelopes enter into the stacker, they will be hitting the side wall then dropping down, meaning that the frame needs to be able to withstand continuous impacts of different forces. This test was conducted by running a variety of mixed mail through the letter opener and watching to make sure that the stand does not move as the mail hits the wall.
6. **Noise:** Noise is a large annoyance in a quiet office environment. This test was conducted using a decibel meter to test the noise level as the letters hit the plexiglass. The noise should stay below 50dB as that is typical office noise level.
7. **Mail Alignment:** The purpose of this stacker is to organize and stack the opened envelopes in a neat manner. We ran a large variety of mixed mail through the opener and into the stacker in order to ensure that this stacker can stack the mail with two aligned edges.

6.2 Design Verification Plan and Report (DVPR)

Table 5: Design Verification, Plan and Report.

ME428/ME481 DVP&R Format												
Report Date: 1/13/2010		Sponsor: Postmark						Component/Assembly		REPORTING ENGINEER: CP Post		
TEST PLAN									TEST REPORT			
Item No	Test Description	Acceptance Criteria	Test Responsibilit	Test Stage	SAMPLES Quantity	SAMPLES Type	TIMING Start date	TIMING Finish date	TEST RESULTS Test Result	TEST RESULTS Quantity Pass	TEST RESULTS Quantity Fail	NOTES
1	Spring Max Stretch Length: load tray with letters to see how far spring will stretch	18-24"	Tyler	PV	20	B	5/29/11	5/29/11	20"	20	0	Spring reached full length.
2	Spring Constant Test: Run letters through opener and into stacker to ensure lowering speed matches opener speeds.	match opener speed	Tyler	PV	20	B	5/29/11	5/29/11	Correct Sprng	20	0	
3	Plate Loads: Put weights on try until device tips	170Nm	Tyler	PV	1	A	5/29/11	5/29/11	26 pounds of mail	1	0	No Tipping With Maximum Load of Mail
4	Slider Speed (Friction): load tray with mail and see if slider lowers without binding	match opener speed	Tyler	PV	1	C	5/29/11	5/29/11	Speeds Matched	1	0	
5	Stacker Frame Stability: run letters through opener and ensure catch doesn't move.	0 displacement	Tyler	PV	1	C	5/29/11	5/29/11	0	1	0	Stacker did not roll or spin when active.
6	Noise: test noise of letters when hitting walls	50 dB	Tyler	PV	1	C	5/29/11	5/29/11	N/A	1	0	Couldn't record stacker sound levels since opener was louder.
7	Mail Alignment: ensure mail lands in an organized matter after running through opener.	2 aligned edges	Tyler	PV	1	C	5/29/11	5/29/11	±0.25" Misalligned	1	0	

Chapter 7: Plan of Action

This chapter explains how our group planned the design and fabrication of a quality prototype for Postmark's Mail Stacker by the design deadline of June 2011.

7.1 Design Approach

Our design process began with an analysis of the requirements list provided by Postmark. From that point, we developed design specifications for this product to ensure all of the requirements would be fulfilled for the end-user. A team-management plan was then developed, and can be found in section 7.3 of this report. The team management plan delegates the important parts of the project to each group member in a manner that ensures we can bring all parts together into one complete design by the due date.

With the plan completed, we began our brainstorming idea-generation techniques. We were able to populate a list of possible solutions for how to stack the envelopes in the container, as well as spring and slider designs to allow the plate holding the mail to lower as more envelopes enter. The list was evaluated for the pros and cons of each design, and we then narrowed the considerations to the top three designs that best met our product and customer needs. Using a Pugh Matrix, the top three concepts were ranked on how well they fulfilled each specification to give us a final conceptual design.

Once the conceptual design was established, the process of creating a final design began. An analysis of the proposed stacker was done in order to design a spring that works effectively with the weight and speed of the envelopes. The next phase was to begin determining the dimensions and materials which was done by creating a solid model and following the specifications given by Postmark.

Before any materials were purchased, a thorough research was done to ensure that the most cost-effective materials were selected. Much analysis was conducted to determine which materials will work best to reduce noise, cushion impact, and provide a smooth surface for envelopes to slide on. As agreed with Postmark, after their approval, the materials were purchased personally by one of the group members and the receipts were submitted to Postmark's office for reimbursement.

In order to ensure ample time for building and testing, a manufacturing plan was created with dates of when parts should be purchased and assembled. This manufacturing plan is presented below in Section 7.2. At the fabricating stage of the design process, we utilized university equipment to build the chosen best design and develop a final prototype. Once the working prototype was finalized, we performed test runs using Postmark's specified letter-opener and analyzed the prototype feedback to ensure it met all customer needs and the design specifications agreed upon with Postmark. The testing was started in early April to guarantee enough time to go back and redesign any specific components. For example, during the testing phase we went through many different springs which ranged in sizes from 5" to 1" in diameter, and 1" to .25" in thickness. Because the size of the springs tested differed so much, the spring mount design had to be changed three times, meaning three different mounts were built for different testing purposes. By Thursday June 2nd, the final product will be completed and delivered to Postmark.

7.2 Manufacturing Plan

Below is a schedule our team followed in order to keep us on track with the manufacturing phase.

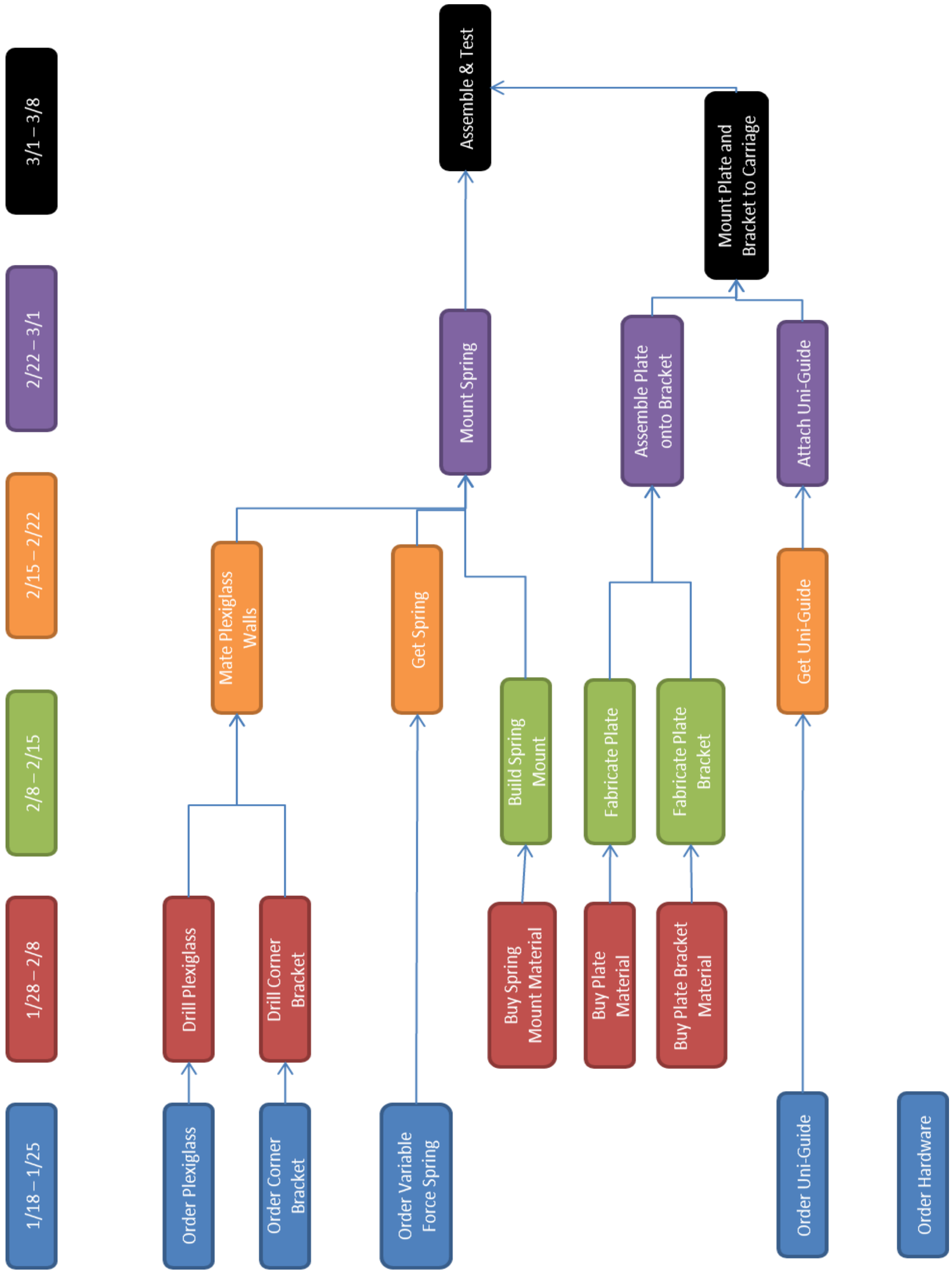

Figure 25: Manufacturing Plan

7.3 Project Management Plan

As there were many tasks required to complete this project, the responsibilities were divided among each team member in order to work efficiently. The responsibilities were divided as follows:

RJ Atkinson

RJ was responsible for sponsor communications including setting up meeting times and keeping e-mail and telephone dialogue with Postmark. He also ran the testing plans by coordinating with Postmark to set up a testing area with one of their automated letter openers and our prototypes. During the analysis stage of the design process, he teamed up with Stephanie on coordinating our calculations and solid modeling.

Stephanie Henning

Stephanie handed the documentation of project progress. This included keeping up-to-date information on where we were at all times in our design process and making sure that we are on schedule with due dates and meetings. She also lead the organization and creation of the various design reports as well as the weekly reports.

Tyler Wetzel

Tyler was in charge of much of the fabrication aspect of the design including materials gathering and prototype fabrication. He additionally worked closely with both RJ and Stephanie in the idea generation phase in order to create an easy-to-use product as well as in the analysis phase when calculating information on user-interface, cost, and ease of use.

Our group worked together effectively covering all of the required tasks by due dates listed below. These tasks included:

- Project Proposal 10/19/10
- Concept Model 11/9/10
- Concept Design Report 12/3/10
- Critical Design Review 2/1/11
- Final Design Report 2/4/11
- Senior Project Expo 6/2/11

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Chapter 8: Conclusion and Recommendations

The nature of this design allows for many possibilities for increasing mobility and adjustability with a computer-chair-style wheel system that will mount to an attachable base support on the plexiglass.

After ordering all of the required materials for our prototype build, we began to analyze the ways to decrease the production cost. We found that scaling down the size or quality of certain parameters could help lower the cost and weight of this design drastically. Recommendations for cost purposes are reducing the wall thickness of the plexiglass or even making the walls out of less expensive materials that would provide the stability needed while reducing the cost. This would have the most significant effect on lowering costs; however other modifications could be made such as moving from stainless steel hardware to steel and using a smaller base than the current one from a chair. The chair base serves the purpose needed. However it is very heavy and expensive. The cost of shipping that extra weight should be taken into consideration as the chair base is built for much larger loads. We believe a smaller and lighter base would work well and be more cost effective for the Postmark Mail Stacker.

As for improvements to the performance of the mail stacker, we believe that the slider should be changed from the Uni-guide Linear Slide to a Low Profile Redi-Rail Linear Guide. As shown in the carriage analysis, section 3.31, the load from the envelopes will twist the plate, putting a sideways moment on the slider carriage. The Redi-Rail uses a system composed of rollers which we believe will work better with the loads being place onto the tray and carriage as opposed to a rail and frictionless carriage. The downside of the Redi-Rail is that the cost is higher; however it is light weight and in the end should improve the movement of the tray as the mail stacks. These options are for future consideration and would, of course, require compromise on numerous specified preferences provided at the beginning of the project by Postmark.

This report has described in detail the final design for the Postmark Mail Stacker. Once the conceptual design was decided upon, we were quickly able to move into the details of material selection and dimensioning. Many factors were taken into consideration for this design phase. Cost was a key factor, as were safety, reliability, maintenance, and functionality. All of these were discussed thoroughly in the above sections. Two separate Bills of Materials with complete costs were incorporated into this report. One gave the parts and costs of the prototype our group is working on, the other is a researched estimate of how much it would cost to produce each mail stacker when built in mass production. These bills give full details including dimensions and quantities of each part. Also described are the tests that needed to be performed and the timeline for the assembly and testing of the machine. Full details of the manufacturing process with time it took to build each part have also been given for convenience of reproducing a stacker.

After all testing was finished we were able to finalize all of the specifications which are stated in the Bill of Materials of the working Mail Stacker. The final stacker was presented on Thursday June 2nd to Postmark and the Mechanical Engineering Department at the Mechanical Engineering Senior Project Expo. The stacker along with this report will be delivered to Postmark as a guide to build and produce the Mechanical Stacker as a Postmark Product.

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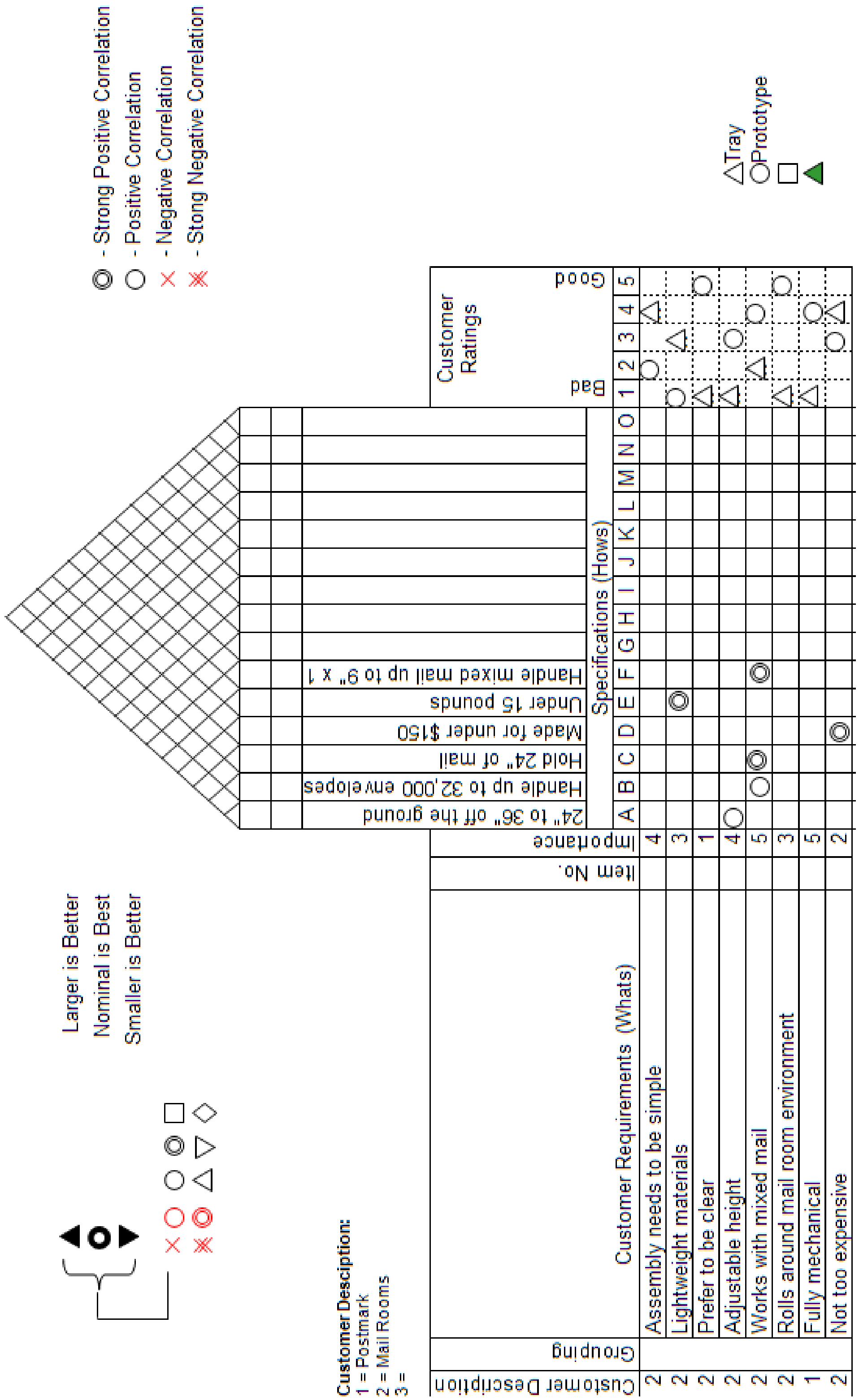
Appendices

Appendix A	Quality Function Deployment Chart
Appendix B	Gantt Chart (Timeline)
Appendix C	Detailed Drawing of Two Sided Box Frame
Appendix D	Detailed Drawing of Two Sided Box with Bolt Placements
Appendix E	Detailed Drawing of Tray
Appendix F	Detailed Drawing of Corner Bracket
Appendix G	Low Profile Uni-Guide Slide Manufacturer Specifications
Appendix H	Professional Plastics' Specifications for Plexiglass Walls
Appendix I	Vulcan Spring Information
Appendix J	Manufacturer Details of Button Screws
Appendix K	Manufacturer Details of Countersunk Washers
Appendix L	Manufacturer Details of Flat Head Screws
Appendix M	Manufacturer Details of Press Fits
Appendix N	Manufacturer Details of L Shaped Bracket

Appendix A

QFD



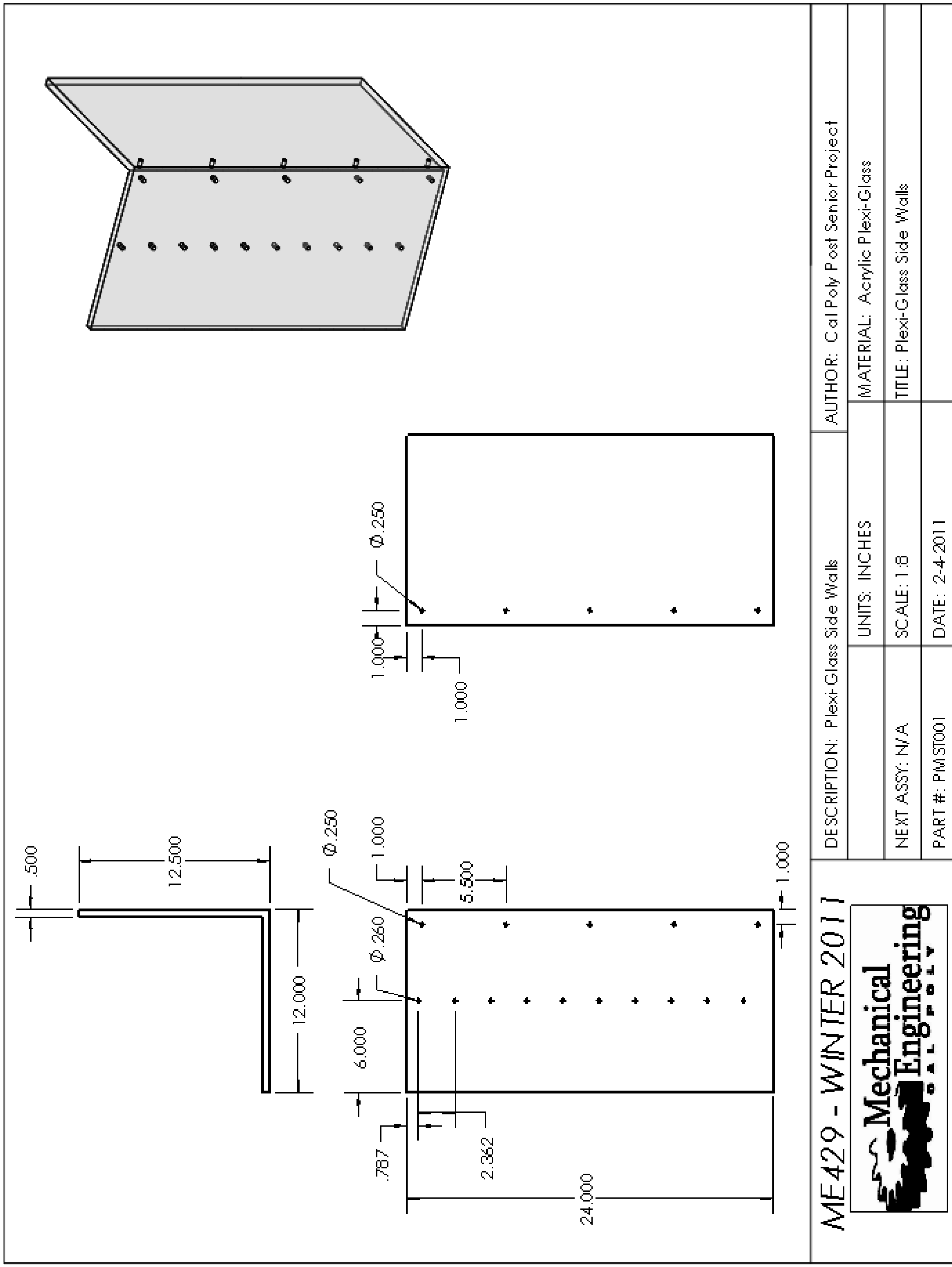
Appendix B

Gant Chart

WBS	Task Name	Duration	Start	Finish	Predecessors
1	**Design and Planning**	**49 days**	**Mon 9/27/10**	**Fri 12/3/10**	
1.1	Meet With Sponsor and Find Specifications	1 day	Mon 9/27/10	Mon 9/27/10	
1.2	Research	10 days	Mon 9/27/10	Fri 10/8/10	
1.3	Team Contract	0 days	Thu 10/7/10	Thu 10/7/10	
1.4	Project Requirements Document	9 days	Thu 10/7/10	Tue 10/19/10	4
1.5	Project Proposal Due	0 days	Tue 10/19/10	Tue 10/19/10	5
1.6	**Concept Generation**	**15 days**	**Wed 10/20/10**	**Tue 11/9/10**	**6**
1.6.1	Idea Selection	7 days	Wed 10/20/10	Thu 10/28/10	
1.6.2	Compile Top Designs	3 days	Fri 10/29/10	Tue 11/2/10	8
1.6.3	Conceptual Modeling	5 days	Wed 11/3/10	Tue 11/9/10	9
1.6.4	Concept Model Due	0 days	Tue 11/9/10	Tue 11/9/10	10
1.7	Gantt Charts and Timeline Development	3 days	Tue 11/2/10	Thu 11/4/10	
1.8	**Conceptual Design Report**	**17 days**	**Wed 11/10/10**	**Fri 12/3/10**	
1.8.1	Work on it	12 days	Wed 11/10/10	Thu 11/25/10	
1.8.2	In-Class Report Presentation	0 days	Thu 11/25/10	Thu 11/25/10	14
1.8.3	Finalize Report with Peer Edits	5 days	Fri 11/26/10	Thu 12/2/10	15
1.8.4	Submit Report to Sponsor	0 days	Fri 12/3/10	Fri 12/3/10	
2	**Build Preparation**	**40 days**	**Wed 1/12/11**	**Tue 3/8/11**	
2.1	**Analysis and Bill of Materials**	**40 days**	**Wed 1/12/11**	**Tue 3/8/11**	
2.1.1	Develop Test Plans	5 days	Wed 1/12/11	Tue 1/18/11	
2.1.2	Obtain Materials	16 days	Tue 2/15/11	Tue 3/8/11	20
2.2	Student Presentation	0 days	Thu 1/20/11	Thu 1/20/11	
2.3	Finalize Design Report	8 days	Thu 1/20/11	Mon 1/31/11	22
2.4	Submit Design Report	0 days	Tue 2/1/11	Tue 2/1/11	
2.5	Ethics Presentation Development	11 days	Tue 2/1/11	Tue 2/15/11	24
2.6	Project Update Memo	15 days	Wed 2/16/11	Tue 3/8/11	25
2.7	Project Update Memo to Sponsor Due	0 days	Tue 3/8/11	Tue 3/8/11	
3	**Build, Test, Get Out**	**49 days**	**Mon 3/28/11**	**Fri 6/3/11**	
3.1	Manufacture and Test Review	0 days	Mon 3/28/11	Mon 3/28/11	
3.2	Gather Materials into Workspace	6 days	Mon 3/28/11	Mon 4/4/11	
3.3	Fabrication	6 days	Tue 4/5/11	Tue 4/12/11	30
3.4	Assembly	6 days	Wed 4/13/11	Wed 4/20/11	31
3.5	Testing	6 days	Thu 4/21/11	Thu 4/28/11	32
3.6	Fabrication Again	6 days	Fri 4/29/11	Fri 5/6/11	33
3.7	Check in with Sponsor	0 days	Fri 5/6/11	Fri 5/6/11	34
3.8	Hardware Demo	0 days	Mon 5/9/11	Mon 5/9/11	
3.9	Finalize Product and Report	18 days	Mon 5/9/11	Wed 6/1/11	36
3.10	Senior Design Expo… Product	0 days	Thu 6/2/11	Thu 6/2/11	
3.11	Senior Design Expo… Report	0 days	Fri 6/3/11	Fri 6/3/11	

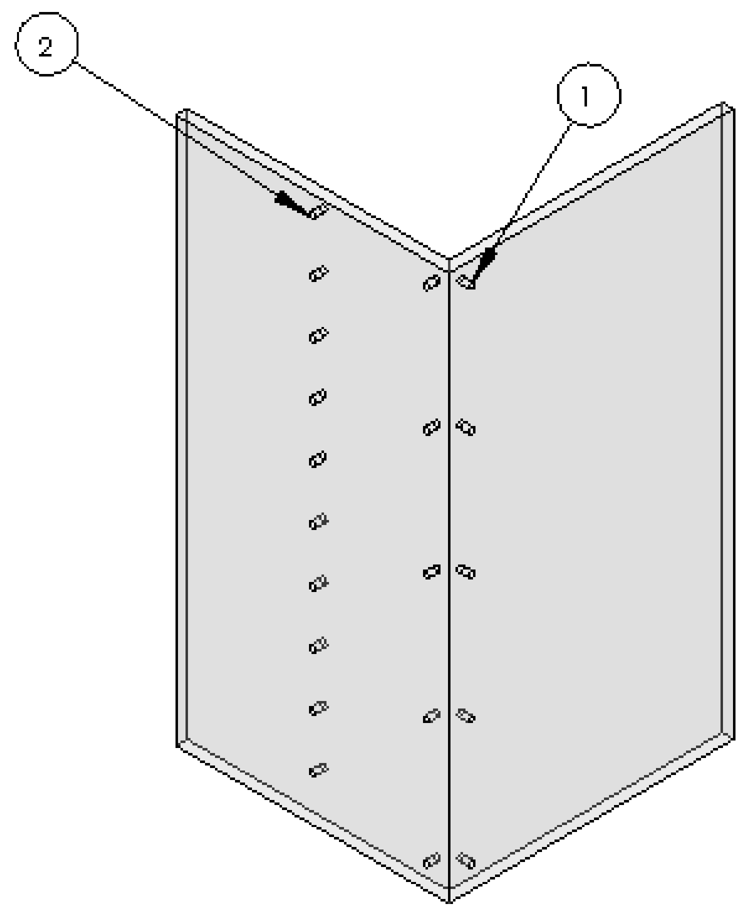
Appendix C

Two-Sided Box Frame



Appendix D

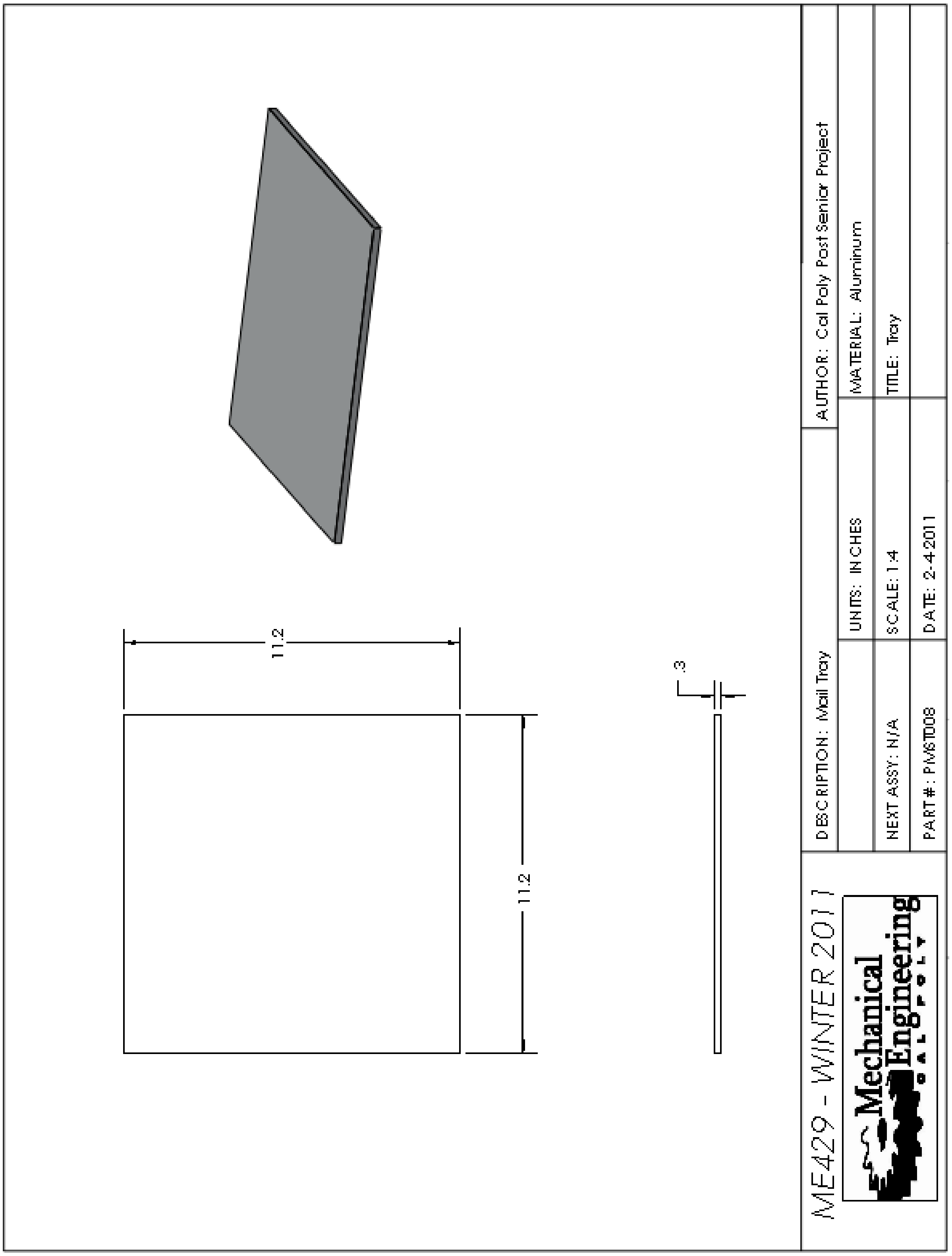
Bolt Placement



1	Flat head bolt through washer and into threaded insert	1/4"-20 x 3/4"
2	Button head bolt through Uni-Guide rail and into threaded insert	1/4"-20 X 3/4"

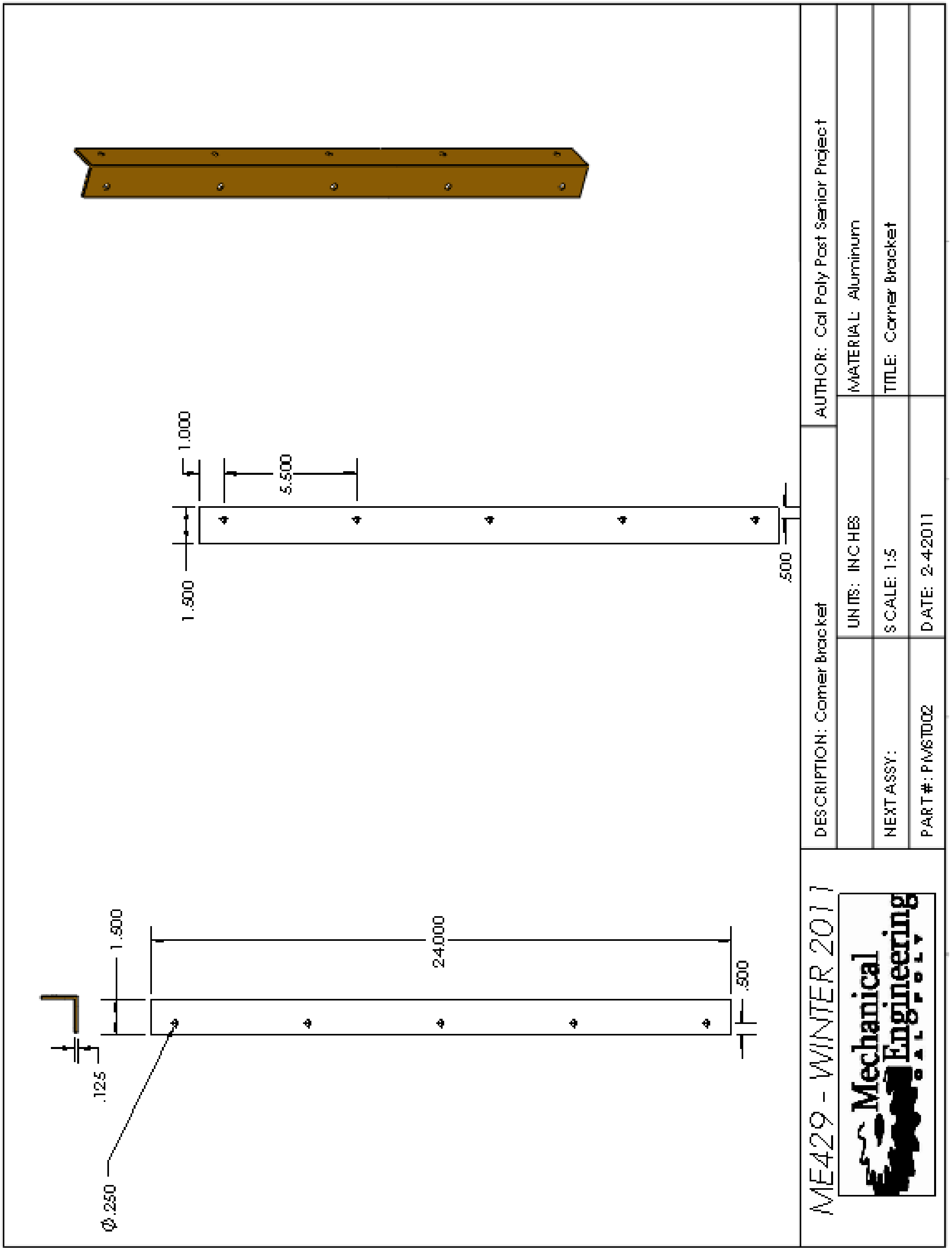
Appendix E

Tray



Appendix F

Corner Bracket

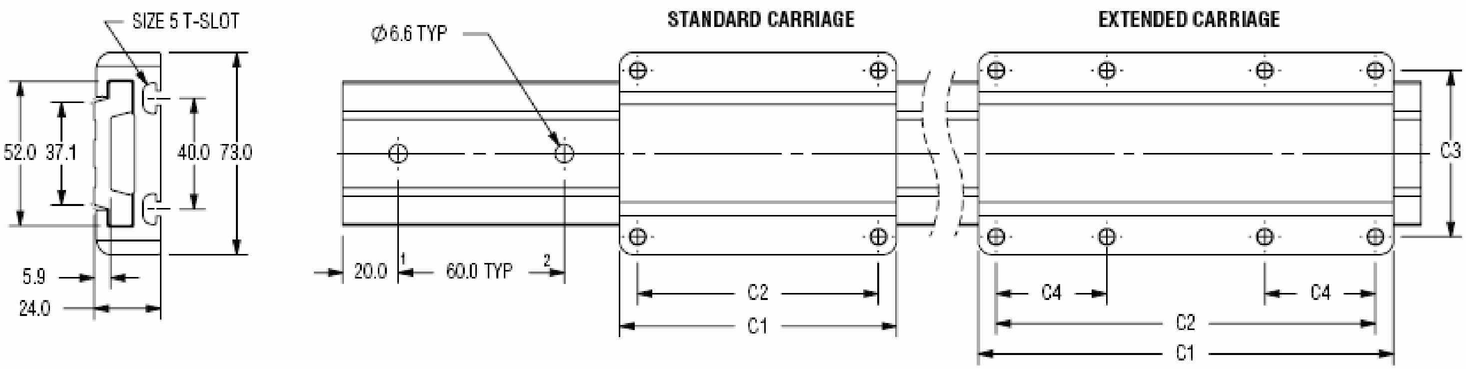


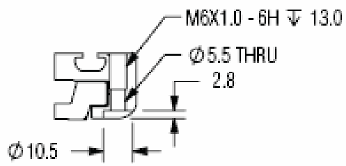
Appendix G

Uni-Guide Slide

UTGST-005

DIMENSIONAL INFORMATION





MATERIALS

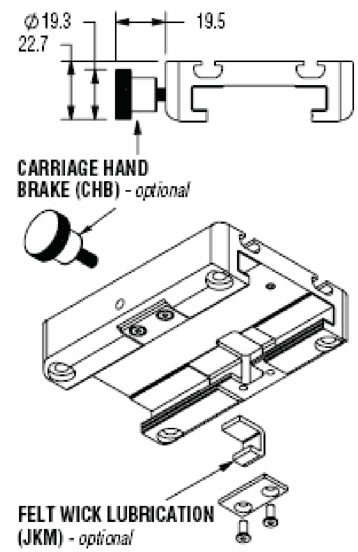
Anodized aluminum rails and carriage plate

Working Temperatures: -400°F/+400°F
-240°C/+204°C

Coefficient of Friction: 0.1 - 0.2

Frelon® GOLD, J or W liner available

CARRIAGE ACCESSORIES



CARRIAGE PART#	RADIAL	AXIAL	AXIAL	ROLL	PITCH	YAW	STANDARD CARRIAGE (MM)				
	F_Y (N)	F_Z (N)	F_Z (N) Inverted	Mx (N-m)	My (N-m)	Mz (N-m)	C1	C2	C3	C4	lbs. (kg)
UGA040C-0x1xxx	4900	8200	2700	120	170	170	100	87	60	N/A	.504 (0.23)
							EXTENDED CARRIAGE				
UGA040C-1x1xxx	5700	6600	2700	120	290	290	150	137	60	40	.750 (0.34)
UGA040C-2x1xxx	6100	4900	2700	120	290	290	200	187	60	60	1.014 (0.46)

1 N=0.2248 lbf   1 N-m = 0.7376 ft.-lbs.

Appendix H

Professional Plastics
The Global Leader in High Performance Plastics

TYPICAL PROPERTIES of CAST ACRYLIC		
ASTM or UL test	**Property**	**Acrylic**
PHYSICAL		
D792	Density (lb/in³) (g/cm³)	0.043 1.18
D570	Water Absorption, 24 hrs (%)	0.3
MECHANICAL		
D638	Tensile Strength (psi)	8,000 - 11,000
D638	Tensile Modulus (psi)	350,000 - 500,000
D638	Tensile Elongation at Break (%)	2
D790	Flexural Strength (psi)	12,000 - 17,000
D790	Flexural Modulus (psi)	350,000 - 500,000
D695	Compressive Strength (psi)	11,000 - 19,000
D695	Compressive Modulus (psi)	-
D785	Hardness, Rockwell	M80 - M100
D256	IZOD Notched Impact (ft-lb/in)	0.3
THERMAL		
D696	Coefficient of Linear Thermal Expansion (x 10^{-5} in./in./°F)	5 - 9
D648	Heat Deflection Temp (°F / °C) at 264 psi	150-210 / 65-100
D3418	Melting Temp (°F / °C)	- / -
-	Max Operating Temp (°F / °C)	150-200 / 65-93
C177	Thermal Conductivity (BTU-in/ft²-hr-°F) (x 10^{-4} cal/cm-sec-°C)	3.9 1.2
UL94	Flammability Rating	-
ELECTRICAL		
D149	Dielectric Strength (V/mil) short time, 1/8" thick	400
D150	Dielectric Constant at 60 Hz	4.0
D150	Dissipation Factor at 60 Hz	0.05
OPTICAL		
-	Light Transmission, minimum (%)	92
-	Refractive Index	1.48-1.50

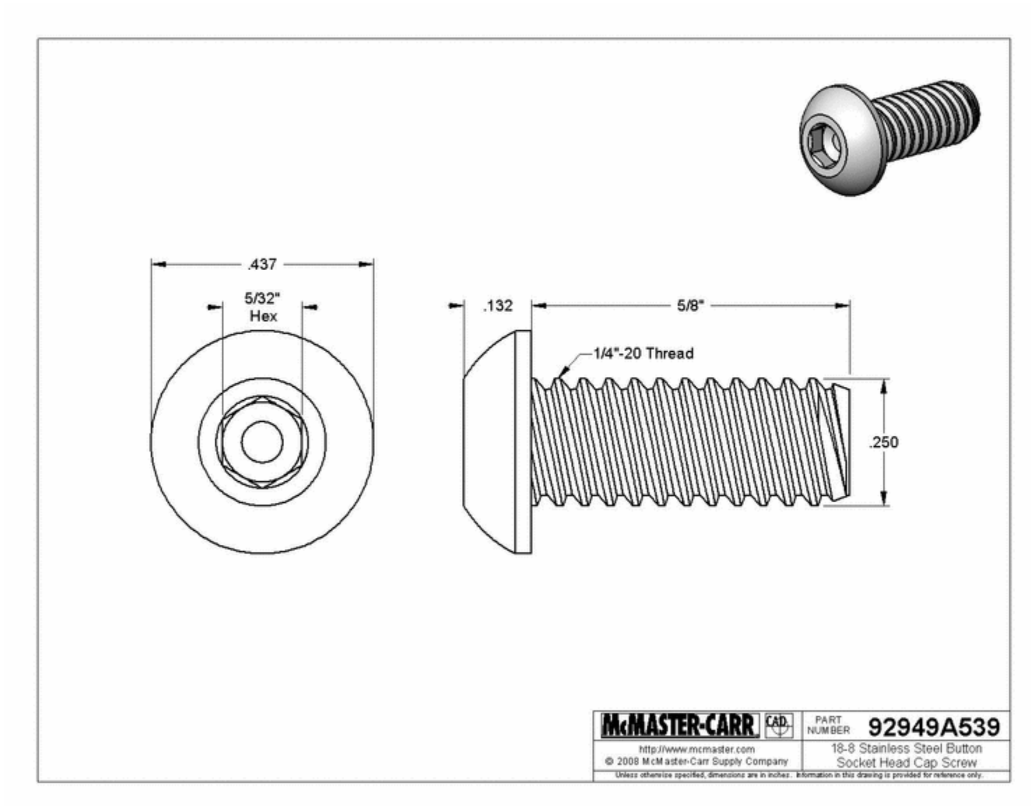
NOTE: The information contained herein are typical values intended for reference and comparison purposes only. They should NOT be used as a basis for design specifications or quality control. Contact us for manufacturers' complete material property datasheets.
All values at 73°F (23°C) unless otherwise noted.

Appendix I

Vulcan Spring

Appendix J

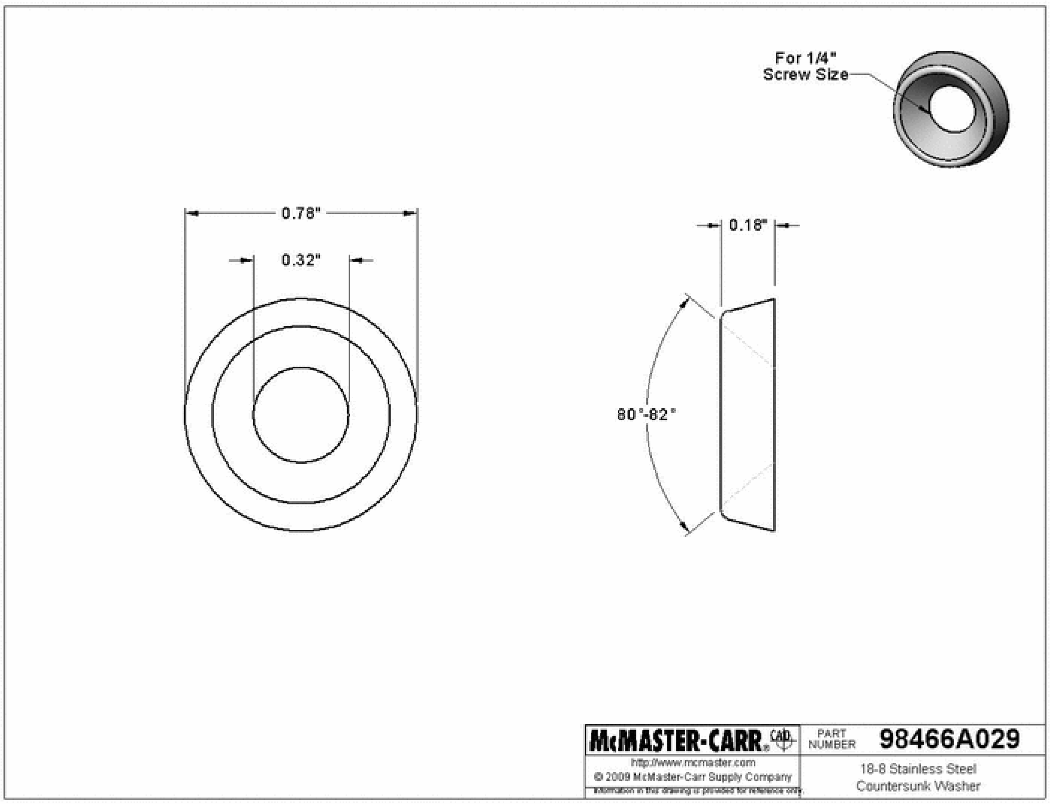
Button Screws



Head Style	Button
Material Type	Stainless Steel
Finish	Plain
Class	Not Rated
Stainless Steel Type	18-8 Stainless Steel
Drive Style	Hex Socket
Inch Thread Size	1/4"-20
Length	5/8"
Thread Length	Fully Threaded
Thread Direction	Right Handed
Tip Type	Plain
Self-Locking Method	None
Screw Quantity	Individual Screw
Hex Size	5/32"
Head Diameter	.437"
Head Height	.132"
Rockwell Hardness	Minimum B70
Minimum Tensile Strength	70,000 psi
Thread Fit	Class 3A
Specifications Met	Not Rated

Appendix K

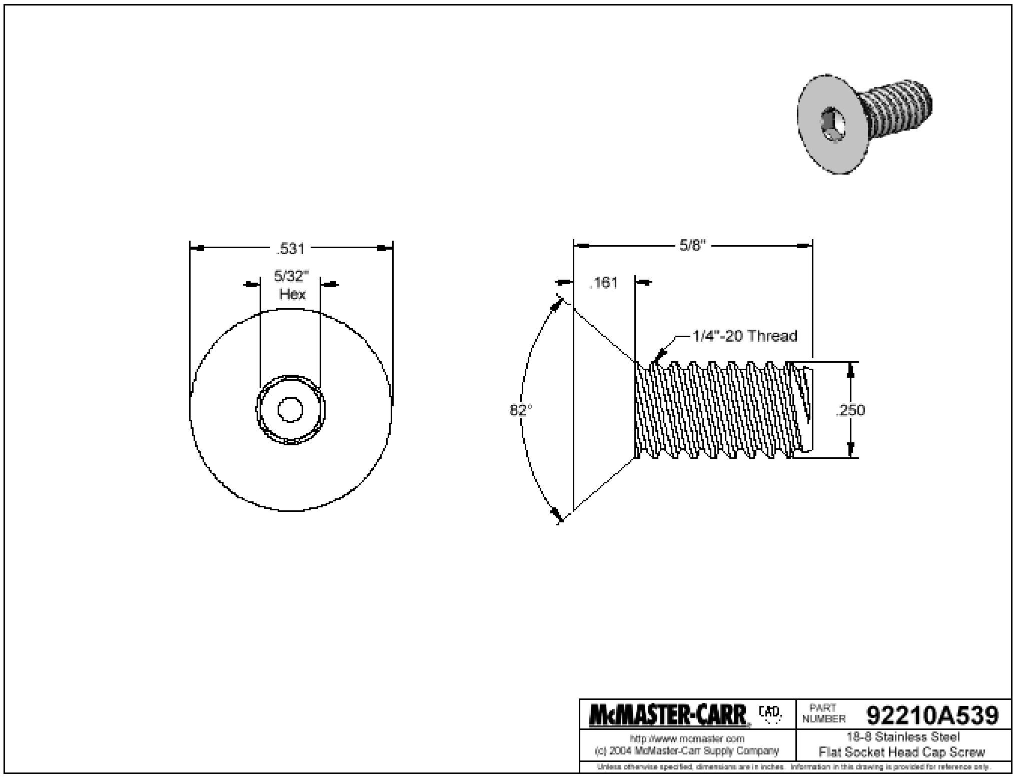
Countersunk Washers



Shape	Finishing
For Screw Size	1/4"
Material Type	Stainless Steel
Finish	Plain
Stainless Steel Type	18-8 Stainless Steel
Countersunk Shape	Countersunk
Inside Diameter	.32"
Outside Diameter	.78"
Finishing Type	Countersunk
Height	.18"
Application	Finishing Washer
Rockwell Hardness	Not Rated
Specifications Met	Not Rated
Note	Use with standard 80°-82° flat and oval countersunk-head screws.
Shape	Finishing
For Screw Size	1/4"
Material Type	Stainless Steel
Finish	Plain
Stainless Steel Type	18-8 Stainless Steel
Countersunk Shape	Countersunk

Appendix L

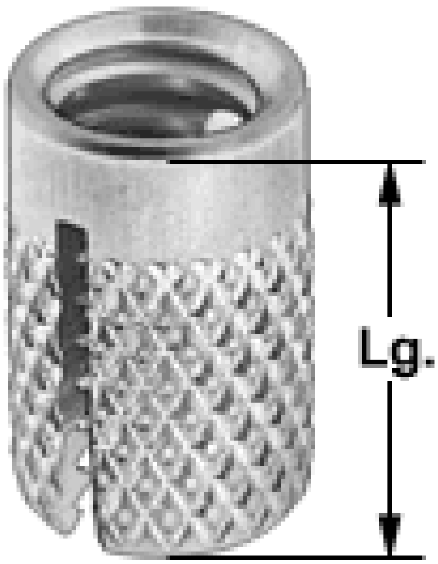
Flat Head Screws



Head Style	Flat
Material Type	Stainless Steel
Finish	Plain
Class	Not Rated
Stainless Steel Type	18-8 Stainless Steel
Drive Style	Hex Socket
Inch Thread Size	1/4"-20
Length	5/8"
Thread Length	Fully Threaded
Thread Direction	Right Handed
Tip Type	Plain
Self-Locking Method	None
Screw Quantity	Individual Screw
Hex Size	5/32"
Head Diameter	.531"
Head Height	.161"
Undercut Head	No
Head Angle	82°

Appendix M

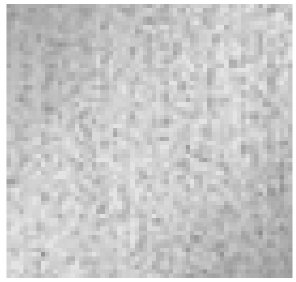
Press-Fits

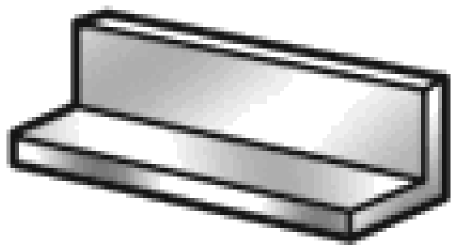


Type	Press-Fit
Press-Fit Type	Knurled
Knurled Style	Diamond Without Flange
For Use With	Plastic
Application	Create New Threads
Material	Brass
Brass Type	Alloy 360
Finish/Coating	Plain
Threaded Type	Right-Hand Threaded
System of Measurement	Inch
Internal Thread Size	1/4"-20
Internal Thread Fit	2B
Insert Length	.500" (1/2")
Drill Size	5/16"
Rockwell Hardness	B78
Minimum Tensile Strength	18,000 psi

Appendix N

L Shaped Bracket





Material	Ultra-Corrosion-Resistant Architectural Aluminum (Alloy 6063)
Shape	90° Angles
Finish/Coating	Unpolished (Mill)
Angle Corner Type	Square
Tolerance	Standard
Thickness	1/8"
Thickness Tolerance	±.007"
Length	8'
Length Tolerance	±1"
Leg Length	1-1/2" x 1-1/2"
Leg Length Tolerance	±.014"
Straightness Tolerance	.0125" per foot
Test Report	Without Test Report
Temper	T5
Hardness	55-60 Brinell
Yield Strength	15,000 to 21,000 psi
Temperature Range	-320° to +212° F
Specifications Met	American Society for Testing and Materials (ASTM)
ASTM Specification	ASTM B221